PROTECTED AREAS AND CLIMATE CHANGE IN CANADA

CHALLENGES AND OPPORTUNITIES FOR ADAPTATION

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CONSEIL CANADIEN DES AIRES ÉCOLOGIQUES
CCEA
CANADIAN COUNCIL ON ECOLOGICAL AREAS

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Protected Areas and Climate Change in Canada: Challenges and Opportunities for Adaptation

Christopher J. Lemieux [1], Thomas J. Beechey [2], Daniel J. Scott [1] and Paul A. Gray [3]
[1] Faculty of Environment, University of Waterloo
[2] Canadian Council on Ecological Areas
[3] Ontario Ministry of Natural Resources

For further information, please contact:

Christopher J. Lemieux
Canada-U.S. Fulbright Scholar
Centre for Applied Sciences in Ontario Protected Areas (CASIOPA)
Faculty of Environment, University of Waterloo
Waterloo, Ontario, Canada, N2L 3G1
Phone: (519) 888-4567 ext. 32072, E-Mail: cjlemieux@uwaterloo.ca

Canadian Council on Ecological Areas (CCEA)
Secretariat: c/o Canadian Wildlife Service, Environment Canada
3rd floor, 351 St. Joseph Boulevard
Gatineau, Québec, Canada
K1A 0H3

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Front Cover: The shrinking of pack ice attributed to climate change is reducing habitat for Polar Bear (*Ursus maritimus*) in and around protected areas and throughout much of their range. Polar Bear mother and cub, west coast of Hudson Bay. (Photo Credit: RobertMcCaw.com)

Back Cover: Satellite image of North America illustrating the largest Canadian protected areas. (Image and Data Sources: ESRI Canada, and Conservation Areas Reporting and Tracking System 2010)

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CCEA Mission

The Canadian Council on Ecological Areas (CCEA) is an independent national organization constituted in 1982 to encourage and to facilitate the selection, protection and stewardship of a comprehensive network of protected areas in Canada. In 1995, the CCEA became a registered charitable organization. The Council draws its following and support from First Nations and Inuit peoples, federal, provincial and territorial government agencies, non-governmental organizations, universities, industry and private citizens concerned with protected areas.

The goal of the CCEA is to facilitate and to assist Canadians with the establishment, management and use of a comprehensive viable network of protected areas that represents the diversity of terrestrial, marine and other aquatic ecosystems in Canada.

To this end, the work of the CCEA is centred on the following activities:

1) Promoting the value of protected areas for conserving biodiversity and for helping to sustain ecosystems and species for the environmental, social and economic well being of all Canadians.

2) Providing scientific advice and guidance on the design of a nation-wide network of protected areas incorporating both terrestrial and aquatic ecosystems and the selection of areas to complete it.

3) Advancing sound ecological and science-based stewardship practices for protected areas including the management, restoration and use of them for conservation, science, education and heritage appreciation.

4) Monitoring, reporting and disseminating information on initiatives and progress regarding the establishment, conservation, management and use of protected areas in Canada.

5) Assisting in determining the administrative and institutional arrangements for the securement, protection, management and use of protected areas.

6) Communicating and working with regional, national and international interests toward the achievement of Council's goals and objectives.

7) Conducting other such work and activities as may be necessary to support these aims.

For more information, visit the CCEA website at www.ccea.org

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Foreword

The protected areas movement is barely a heartbeat in geological time. Yet in human terms, and despite its comparative youth and humble beginnings, it has been a long journey—one often fraught by major challenges and contentious debate. First established to preserve scenic wonders and tourist attractions, in recent years the rationale for protected areas has matured to become a cornerstone of biodiversity conservation and ecological sustainability, as well as an important barometer of world ecosystem health and the human condition.

Climate change has sufficiently begun to impact critical, once relatively stable climate regimes to now garner worldwide attention as the most serious environmental concern of the 21st century. Both the Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report (AR4)* and Canada's national synthesis on climate change, *From Impacts to Adaptation: Canada in a Changing Climate 2007*, have clearly substantiated that climate change induced by human-generated greenhouse gas emissions is now implicated in a myriad of coincident impacts: perturbations in regional temperature regimes and precipitation patterns; severe weather events; sea level rises; changes in ecosystem structure and function; and, projected extinctions of species (IPCC, 2007a; Lemmen *et al.*, 2008). In ecological terms, the anticipated shifting of biomes and species distributions—consequences less commonly visible than impacts on human settlements and livelihoods—may well be the most disruptive long-term impacts. As fixed assets established to conserve samples of ecosystems and species, protected areas worldwide are vulnerable to the shifting ecological matrix induced by climate change.

Over the past decade, as science has confirmed the realities of climate change, protected areas have become a focus of concern. The World Conservation Union's (IUCN) World Commission on Protected Areas (WCPA) has taken up the charge, and member states are beginning to respond with various initiatives to address the impacts of climate change on protected areas. Canada, a world leader in the protected areas movement, has made some progress in recognizing and documenting the issue, with work initiated in some agencies to begin dealing with climate change. However, national climate change response strategies have not addressed the role that protected areas can play in mitigation, adaptation, and in protecting and enhancing the livelihoods of Canadians. As the recent IUCN WCPA-led report entitled *Natural Solutions: Protected Areas Helping People Cope with Climate Change* emphasized, protected areas are uniquely positioned to support national climate change mitigation and adaptation strategies as they benefit from existing policies, laws, and institutions that govern their management and on-the-ground capacities and expertise (Dudley *et al*., 2010). Indeed, the many climate change mitigation and adaptation solutions currently lauded by scientists and politicians around the world can already be found within the rich confines of protected areas. More substantive efforts to mitigate the impacts of climate change on protected areas and to adapt planning and management efforts geared mainly to once more stable conditions clearly require more concerted attention, collaboration, and comprehensive action within Canada and internationally.

Federal, provincial, territorial, and some non-governmental conservation efforts have embraced the principles of 'eco-regional planning', 'ecological representation', and 'ecological integrity' as cornerstones for selecting, planning, and managing protected areas. The Canadian Council on Ecological Areas (CCEA) has as its mission the goal *"to facilitate and to assist Canadians with the establishment and management of a comprehensive network of protected areas representative of Canada's terrestrial and aquatic ecological diversity."* (CCEA, 2009a) The implications of climate change on the realization of this widely adopted vision now necessitate broad-based review, thoughtful consideration and consultation regarding the projected impacts of climate change on protected areas, and possible ways to address them.

To that end, this report seeks to fulfill six objectives:

1) To provide an overview of global and Canadian climate change issues and impacts and their implications for protected areas in Canada;

2) To set the international context with a review of lead efforts in jurisdictions with advanced initiatives and adaptation strategies for protected areas;

3) To summarize the results of a survey to report issues, needs and constraints facing protected areas agencies and organizations across Canada;

4) To report case work on selected jurisdictional activities and initiatives in Canada, currently underway or planned, that are directly relevant to protected areas;

5) To offer provisional thinking on issues, remedial strategies and adaptation regarding critical aspects of policy, planning and management for protected areas; and,

6) To provoke a call to action for protected areas agencies in Canada to develop a coordinated approach to climate change adaptation.

The current absence of a globally binding agreement on climate change, in addition to the likelihood that Earth is committed to some degree of climate change despite future greenhouse gas emission reductions, means that climate change *adaptation* will be increasingly necessary in certain regions and for certain socio-economic and environmental systems in Canada. Adaptation involves making adjustments in our decisions, activities and thinking because of observed or expected changes in climate, in order to moderate harm or take advantage of new opportunities (IPCC, 2007b; Lemmen *et al*., 2008). Adaptation is a necessary complement to the reduction of greenhouse gas emissions in addressing climate change (IPCC, 2007b; Lemmen *et al*., 2008). In this the United Nations *International Year of Biodiversity*, the authors hope that this report will help to ignite deeper consideration and action on protected areas in Canada as a key part of the larger worldwide agenda on climate change adaptation and mitigation.

Christopher J. Lemieux
Canada-U.S. Fulbright Scholar
Department of Geography and Environmental Management and Centre for Applied Sciences in Ontario Protected Areas (CASIOPA), Faculty of Environment, University of Waterloo, Waterloo, Ontario, Canada

Thomas J. Beechey
Principal, Nature Matters and Associate Director, Canadian Council on Ecological Areas, Cambridge, Ontario, Canada

Daniel J. Scott
Canada Research Chair in Global Change and Tourism, Department of Geography, University of Waterloo, Waterloo, Ontario, Canada

Paul A. Gray
Climate Change Program, Applied Research and Development Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario, Canada

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Acronyms

2C1F	Two Countries/One Forest (Deux Pay/Une Forêt)
A2A	Algonquin to Adirondacks Conservation Association
AHTEG	Ad Hoc Technical Group for Biodiversity and Climate Change (of CBD)
AR4	Fourth Assessment Report (of IPCC)
BCPARF	B.C. Protected Areas Research Forum
CARTS	Conservation Areas Reporting and Tracking System (formerly CCAD)
CASIOPA	Centre for Applied Sciences in Ontario Protected Areas (formerly PRFO)
CBD	Convention on Biological Diversity
CBI	Canadian Boreal Initiative
CCAD	Canadian Conservation Areas Database (currently CARTS)
CCEA	Canadian Council on Ecological Areas
CCME	Canadian Council of Ministers of the Environment
CCSP	Climate Change Science Program (of Government of U.S.)
CEC	Commission on Environmental Cooperation
CFL	Compact Fluorescent Light
CFP	Climate Friendly Parks (of U.S. NPS)
CLIP	Climate Leadership in Parks (of U.S. NPS)
CPC	Canadian Parks Council
COP	Conference of the Parties (of CBD and UNFCCC)
CPAWS	Canadian Parks and Wilderness Society
CSFF	Colin Stewart Forest Forum
ECO	Environmental Commissioner's Office (of Ontario)
ELC	Ecological Land Classification
ENGO	Environmental Non-government Organization
ENPAA	English National Parks Authority Association (of Government of U.K.)
EPA	Environmental Protection Agency (of Government of U.S.)
ESA	Environmentally Sensitive Area
ESRI	Environmental Systems Research Institute, Inc.
EU	European Union
FHIO	Federal House in Order Initiative (of Government of Canada)
FPPC	Federal Provincial Parks Council (currently Canadian Parks Council)
FWS	Fish and Wildlife Service (of Government of U.S.)
GAO	Government Accountability Office (of Government of U.S.)
GCM	Global Climate Model
GHG	Greenhouse Gases
GNWT	Government of the Northwest Territories
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LEED	Leadership in Energy and Environmental Design
LULUCF	Land Use, Land-Use Change and Forestry (of the UNFCCC)
MAB	Man and Biosphere Reserve (of UNESCO)
MBS	Migratory Bird Sanctuary (of Environment Canada)
MNR	Ministry of Natural Resources (of Government of Ontario)
MPB	Mountain Pine Beetle
NACPS	Natural Area Conservation Plans (of NCC)
NCC	Nature Conservancy of Canada
NEP	Niagara Escarpment Plan
NHS	National Historic Site
NMCA	National Marine Conservation Area (of Parks Canada)
NPS	National Parks Service (of Government of U.S.)

NRS	National Reserve System (of Government of Australia)
NWA	National Wildlife Area (of Environment Canada)
OAGC	Office of the Auditor General of Canada
OP-CCAWG	Ontario Parks-Climate Change Adaptation Working Group
PACC	Protected Areas and Climate Change
PAS	Protected Areas Strategy (of GWNT)
PCIC	Pacific Climate Impacts Consortium (of University of Victoria)
PPARFM	Parks and Protected Areas Research Forum of Manitoba
PRFO	Parks Research Forum of Ontario (currently CASIOPA)
RAN	Saskatchewan's Representative Areas Network
REDD	Collaborative Program on Reducing Emissions from Deforestation and Degradation in Developing Countries (of UN)
RMR	Required Migration Rate
SARA	Species at Risk Act (of Canada)
SNAP	Scenarios Network for Alaska Planning (of University of Alaska, Fairbanks)
SRES	Special Report on Emissions Scenarios (of IPCC)
TEK	Traditional Ecological Knowledge
TNC	The Nature Conservancy (of U.S.)
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USGS	United States Geological Survey (of Government of U.S.)
WCPA	World Commission on Protected Areas (of IUCN)
WCMC	World Conservation Monitoring Centre
WDPA	World Database on Protected Areas
WCS	Wildlife Conservation Society
WNBR	World Network of Biosphere Reserves
WWF	World Wildlife Fund for Nature
Y2Y	Yellowstone to Yukon Conservation Initiative

Dedicated to all Canadians in the United Nations *International Year of Biodiversity*, this report calls for adaptive approaches with concerted efforts to mitigate the environmental impacts of climate change on Canada's protected areas and biodiversity.

2010 International Year of Biodiversity

Introduction and Study Context

Canada's vast network of northern protected areas includes many spectacular areas, such as Prince Leopold Island Migratory Bird Sanctuary in Nunavut, that have been established to protect internationally significant landscapes, biotic communities and species that may now be vulnerable to climate change. (Photo Credit: Canadian Wildlife Service, Environment Canada)

The Canadian Conservation Imperative

Canada is a vast geographic area housing a remarkable array of terrestrial, marine and freshwater ecosystems, biotic communities, and species. South to north it spans Carolinian, Transitional, Boreal, and Arctic regions; east to west it embraces Atlantic, Great Lakes St. Lawrence, Prairie, Cordilleran and Pacific coastal ecosystems. Over the past one hundred years, protected areas have emerged as a central component of collective efforts to conserve this living legacy and enhance broader ecological sustainability. With protected areas now comprising nearly 10% of the nation, these designations are a highly significant asset serving many regional, national and international conservation objectives. Together, Canada's protected areas represent a spectacular range of ecosystems, biotic communities, and species.

Climate change is now recognized as a global stressor already affecting ecosystems and species in many ways. Owing to the size and diversity of Canadian ecosystems and the protected areas already established to represent them, climate change may present itself as a spectral disorder across this unique Canadian mosaic. For protected areas and biodiversity, climate change poses both negative and positive impacts. Whereas the biodiversity represented in northern protected areas may be subject to range contractions, extirpations, and negative functional changes, some biotic communities and native species represented in southern protected areas may actually benefit from climate change.

The Canadian conservation imperative extends beyond the protected areas envelope to embrace the more global dimensions of climate change affecting the wider social, environmental, and economic dimensions of ecosystem integrity and human welfare. At the same time that many protected areas are threatened by climate change, these very areas are critical in efforts to mitigate the wider global impacts of climate change. The extensive contributions of protected areas to Canada's globally important conservation efforts clearly signifies the importance of formulating proactive adaptation strategies that aim to mitigate the negative impacts of climate change and better position protected areas agencies to take advantage of associated benefits.

While acknowledging the broader context for protected areas and climate change, this report focuses on those situations where climate change impacts may jeopardize the goals and objectives for protected areas resulting in negative impacts on species and ecosystems targeted for conservation. Drawing on the extensive literature, the views and experiences of many Canadian practitioners, and wider international efforts, this report provides a national synthesis on the topic for conservation professionals and decision-makers engaged in establishing and managing protected areas in Canada.

An Overview of Protected Areas in Canada

Canada has a long tradition of establishing and managing protected areas and it is internationally recognized as a leader in the stewardship of protected areas and natural assets. The 1992 *Statement of Commitment to Complete Canada's Network of Protected Areas* catalyzed an impressive growth in protected areas across the country throughout the 1990s (FPPC, 2000). *The Canadian Biodiversity Strategy* (CBS) (Government of Canada, 1995), developed jointly by federal, provincial, and territorial governments and released in 1996 in response to the United Nations (UN) *Convention on Biological Diversity* (CBD), highlights the importance of Canada's natural assets and sets out a range of strategic directions for the conservation and sustainable use of Canada's natural capital. Protected areas are considered a key strategic asset in Canada's international efforts to meet its obligations under the *Convention*.

Types of protected areas in place across the country include national and provincial parks, migratory bird sanctuaries, national wildlife areas, wilderness areas, conservation areas, ecological reserves, marine conservation areas, and many other designations. The specific design criteria, management objectives, and levels of protection offered by each of these categories differ by jurisdiction. For example, many protected areas agencies apply the principle of 'representation' to both terrestrial and marine natural regions (i.e., ensuring that the diversity of natural features within each natural region is represented within the protected area system as a whole). Other criteria include the following: the conservation and protection of wildlife and wildlife habitat; the maintenance of unique and productive ecosystems/habitats; the retention of critical habitat for endangered or threatened species; and, responding to initiatives of local indigenous communities. Protected areas agencies are also increasingly recognizing the importance of maintaining key ecological processes and functions (e.g., natural processes such as fire) and enhancing connectivity within and between protected areas.

As of 2010, Canada's terrestrial protected areas number more than 4,850 spanning 101.2 million hectares (ha) and representing 9.92% of Canada's total land base (Figures 1 and 2). Approximately 0.12% of Canada's oceans are protected as well. Although some terrestrial protected areas on Canada's coasts have marine components, the establishment of specific marine protected areas (e.g., National Marine Conservation Areas by Parks Canada Agency and Marine Protected Areas by Fisheries and Oceans Canada) is a more recent initiative. A number of jurisdictions are also beginning to incorporate the conservation of freshwater systems into their protected areas planning. However, no reporting system designed to provide data and information on the amount of freshwater habitat contained within Canada's protected areas currently exists.

Canada's remote northern protected areas are typically large and of territorial, national, and international significance (e.g., Canada's largest protected area, Queen Maud Gulf Migratory Bird Sanctuary, is also a RAMSAR site that encompasses 61,765 km^2 of Arctic tundra and marshes). Generally, the parks and other protected areas in the 'Settled South', many of which protect representative, unique, and endangered ecosystems, are typically much smaller than those in the North. For examples, Point Pelee National Park, covering 15 km^2 in southwestern Ontario, protects many species-at-risk representative of the Carolinian Zone, and Canada's smallest protected area, the Christie Islet Bird Sanctuary in British Columbia, encompasses only 30 m^2. Between these extremes, Canadian agencies protect a variety of small to large sites across central northern ecosystems.

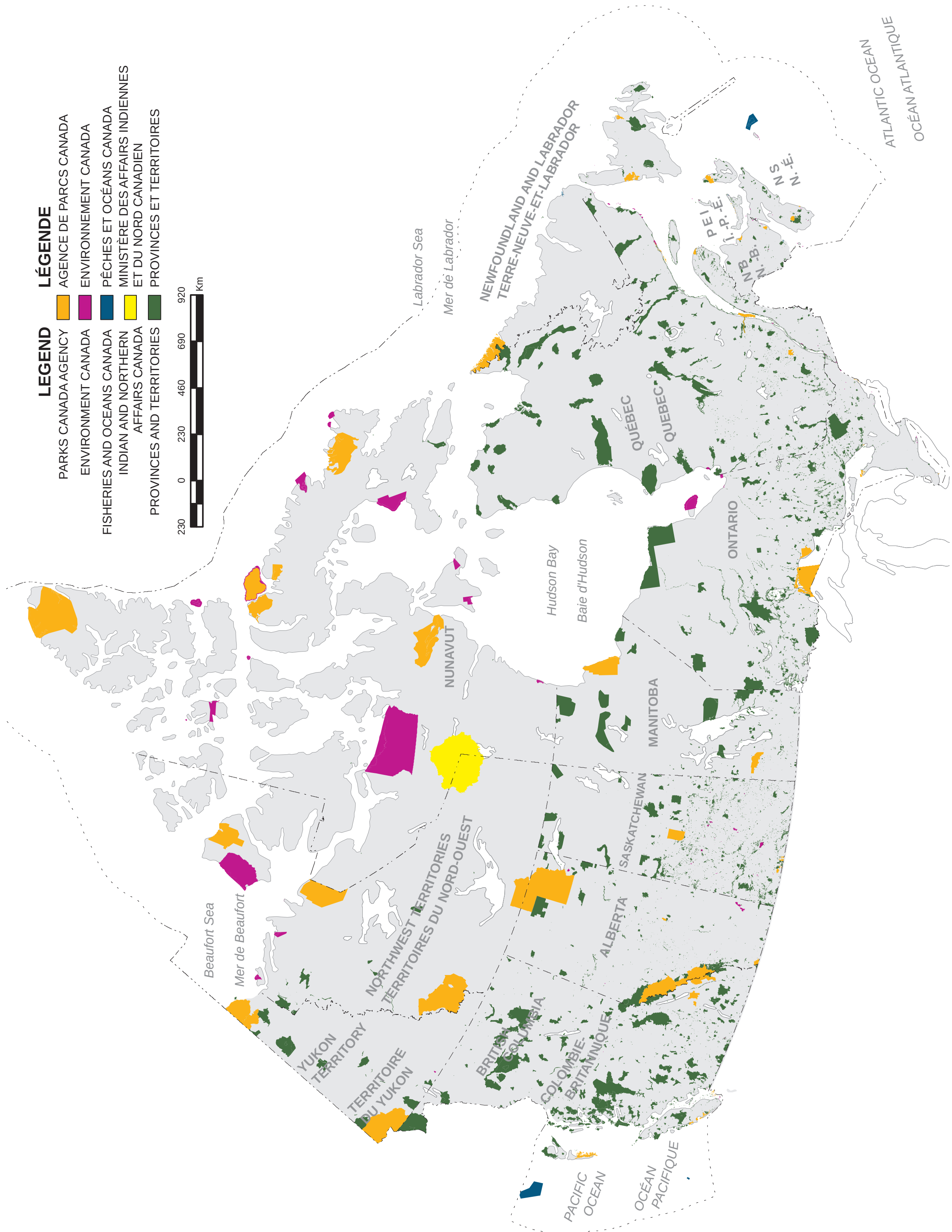


Figure 1: Canada's protected areas include a wide range of designations comprising 9.92% of the area of the country. Small sites are not conspicuous for southern Ontario and other southern settled regions due to limitations of scale (Source: CARTS, Environment Canada, 2010).

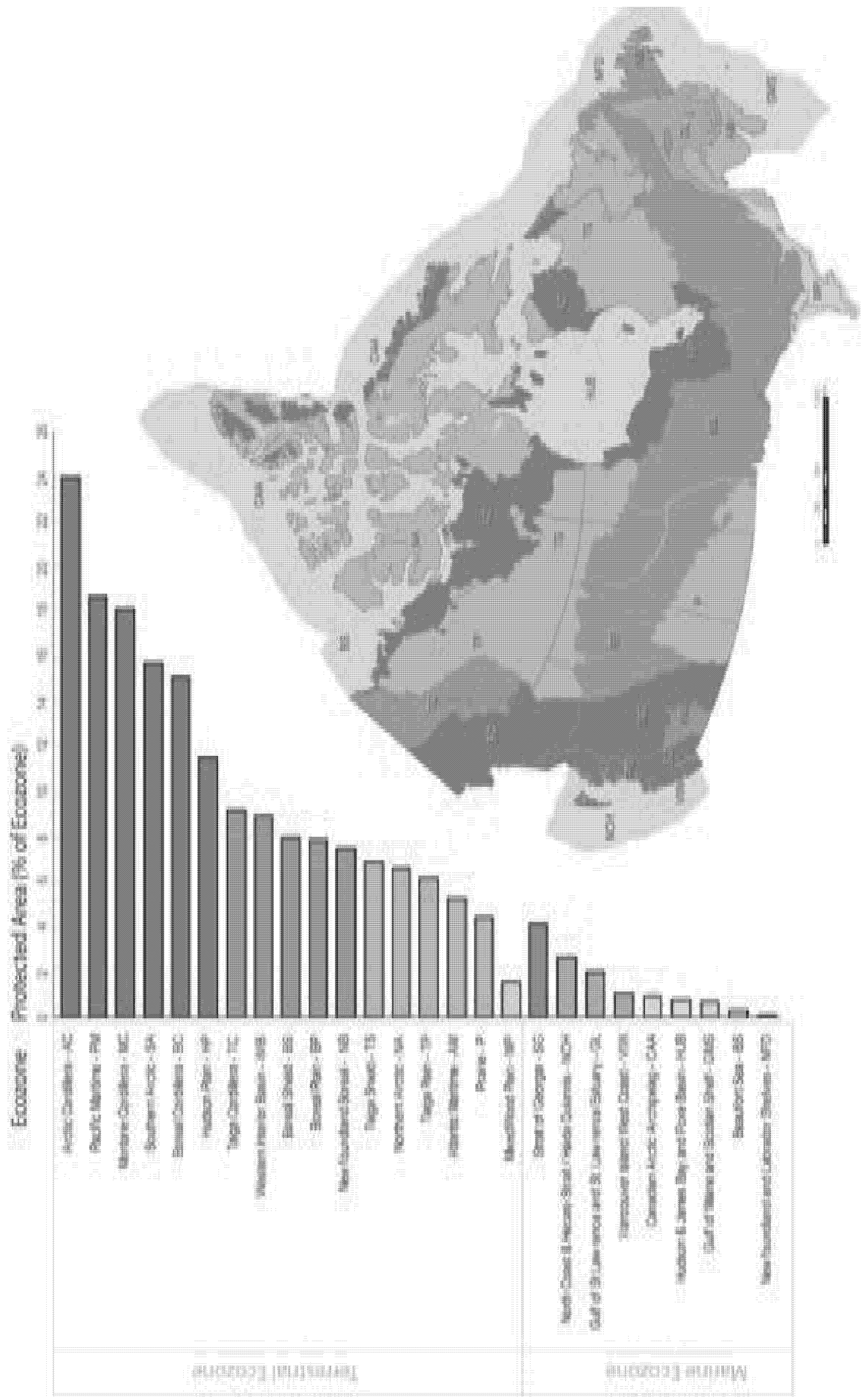


Figure 2: Percentage (%) of Ecozone allocated to terrestrial protected areas in Canada covered by Categories I through VI of the IUCN classification for protected areas. (Source: CARTS, Environment Canada, 2010).

Nature conservation is a shared responsibility in Canada. All governments—federal, provincial, and territorial—sponsor legislation, policies, and programs to delineate, establish, and manage protected areas. Regional and local governments across Canada have increasingly begun to incorporate protected ecosystems, such as 'Environmentally Sensitive Areas' (ESAs), into official plans and growth strategies. Aboriginal governments and land claims organizations play an increasingly significant role in protected area establishment and management. Involvement of Aboriginal communities is significant and increasingly a driving force behind protected areas establishment, particularly in the northern territories where the negotiation of comprehensive land claim settlements provide a formal mechanism for collaboration and co-management. Citizens also play a vital role in conservation efforts through contributions to private land trusts and non-governmental organizations, and by embracing and living according to values that support the care and protection of natural places.

Currently, federal departments such as Parks Canada Agency and Environment Canada manage approximately 50% of the total area encompassed by Canadian protected areas, while provincial and territorial governments manage most of the remainder together with many privately owned natural areas. The federal government has traditionally played a greater role in the management of marine ecosystems, with Fisheries and Oceans Canada, Parks Canada Agency, and Environment Canada administering almost 90% of the total area contained in all marine protected areas established to date.

Canadian progress toward the CBD 2010 target of *"significantly reducing the rate of biodiversity loss"* is mixed, with significant progress in some areas, and limited progress in others. Despite significant additions to Canada's networks of protected areas (with total area protected more than doubling since 1990), research suggests that current conservation targets (e.g., 12% protection of a given natural region) are inadequate for the long-term persistence of biodiversity (Scott *et al.*, 2001; Rodrigues *et al*., 2004; Wiersma *et al.*, 2005; Beazley *et al.,* 2005). Degradation, fragmentation, land conversion, and shifts in the composition and structure of many ecosystems are also adding synergistic pressures on biodiversity and protected areas systems in general.

Climate change is a key emerging issue for agencies and organizations responsible for the care of parks and other protected areas under the CBD. The impacts of changing climate are already evident in every region of Canada (Lemmen *et al.*, 2008). Some of the reported impacts include changes in the geographic distribution, migratory pathways, and abundance of species; changes in the timing of reproduction of species; changes in phenology (e.g., onset, end, and length of growing season); changes in the geographical occurrence and magnitude of pest outbreaks; changes in inter-specific interactions; and widespread aquatic responses to increasing temperatures in both freshwater and marine ecosystems (Lemmen *et al*., 2008). Climate change will exacerbate many current climate threats, and present new risks and opportunities, with significant implications for ecosystems and biodiversity conservation in Canada.

According to Canada's most recent report under the CBD (September, 2009), only minimal progress has been made with respect to Goal 7 (*"7A Address challenges to biodiversity from pollution"* and *"7B Address challenges to biodiversity from climate change"*). The report states that the Rating of Trends of Indicators with respect to addressing challenges to biodiversity to climate change (e.g., Target 7.1: *"Maintain and enhance resilience of the components of biodiversity to adapt to climate change"*) is either poorly understood or getting worse due to recent climate change-induced impacts on species and ecosystems (Government of Canada, 2009).

While the impacts of climate change pose a number of challenges for managers, parks and other protected areas can also play an important role in adapting to the effects of climate change and in working toward achieving objectives outlined in both international and national conservation agreements, policies, and plans. For example, protected areas: 1) serve to maintain or strengthen ecological resilience, including the provision of habitat for plants and animals; 2) play an important role in maintaining and renewing essential ecosystem services such as clean air and clean water; and, 3) in some cases, provide protection against the physical impacts of extreme weather events and other climate-related impacts. As such, they provide what the International Union for Conservation of Nature (IUCN) has termed *"nature infrastructure"* to help ecosystems adapt to the impacts of climate change.

In summary, across Canada protected areas have assumed an important role in efforts to conserve biodiversity and to enhance ecological sustainability within and beyond formally designated sites. Adaptation measures that focus on reducing vulnerability to both current and future climate represent a logical first step that delivers benefits regardless of the rate of future climate changes (Lemmen *et al.*, 2008). The provision of ecological goods and services that derive from these areas presents a compelling rationale for insuring that adaptation efforts carefully consider mitigation measures for protected areas. Moreover, the fact that system planning for protected areas is being increasingly integrated with more comprehensive land-use planning in Canada may proffer well for specific action on climate change adaptation for protected areas within the context of broader landscape planning and management.

The International Context for Protected Areas and Climate Change Adaptation

The UN Convention on Biological Diversity and Climate Change

The United Nations (UN) *Convention on Biological Diversity* (CBD, 1992) is an international treaty that was adopted at the Earth Summit in Rio de Janeiro in 1992. The *Convention* has three main goals: 1) conservation of biological diversity; 2) sustainable use of its components; and, 3) fair and equitable sharing of benefits arising from genetic resources. In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development.

The frequency of major international events and activities related to climate change, biodiversity conservation, and protected areas with specific attention paid to the UN *Convention on Biological Diversity* (CBD) and the International Union for Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA) has increased over the last decade (Figure 3). The UN CBD first recognized climate change as a threat to biodiversity at its fifth meeting of the Conference of the Parties (COP)[1] (Nairobi, 2000,decisions V/3 and V/4). In response to a request issuing from the CBD, the Intergovernmental Panel on Climate Change (IPCC) prepared a technical report entitled *IPCC Special Report on Climate Change and Biodiversity* in 2002 (IPCC, 2002). The report examined the known and potential impacts of climate change on biodiversity conservation and concluded that *"The placement and management of reserves and protected areas will need to take into account potential climate change if the reserve systems are to continue to achieve their full potential."* (IPCC, 2002: 41)

The IPCC report also emphasized that expanded partnerships will be needed between international bodies and their respective agreements [e.g., the CBD and the *United Nations Framework Convention on Climate Change* (UNFCCC)] in order to effectively deal with climate change and biodiversity-related issues. For example, the objective of the UNFCCC refers to the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent *"dangerous"* anthropogenic interference with the climate system, and further states that such a level should be achieved within a time frame sufficient to allow ecosystems to *adapt naturally* to climate change (UNFCCC Article 2). Concurrently, one of the goals adopted under the CBD is to "*Address challenges to biodiversity from climate change"* (decision VII/30/Goal 7) and, with specific reference to protected areas, to *"Integrate climate change adaptation measures in protected area planning, management strategies, and in the design of protected area systems."* (Decision VII/28/Goal 1.4.5.) In general, the aim of such partnerships would be to ensure that the conventions optimize chances for achieving or maintaining some level of prescribed ecological integrity and to promote synergies under the common objective of sustainable development, in order to avoid duplication of efforts, strengthen joint efforts, and use available resources more efficiently.

At the most recent COP of the CBD (COP 9, Bonn, 2008), Parties were:

1) Encouraged to enhance research on and awareness of the role that protected areas and the connectivity of networks of protected areas play in addressing climate change (decision IX/18A/23);

2) Invited to explore funding opportunities for protected area design, establishment and effective management in the context of efforts to address climate change (decision IX/18B/3h); and,

[1] All decisions related to the CBD Conference of the Parties can be accessed at: http://www.cbd.int/convention/cops.shtml

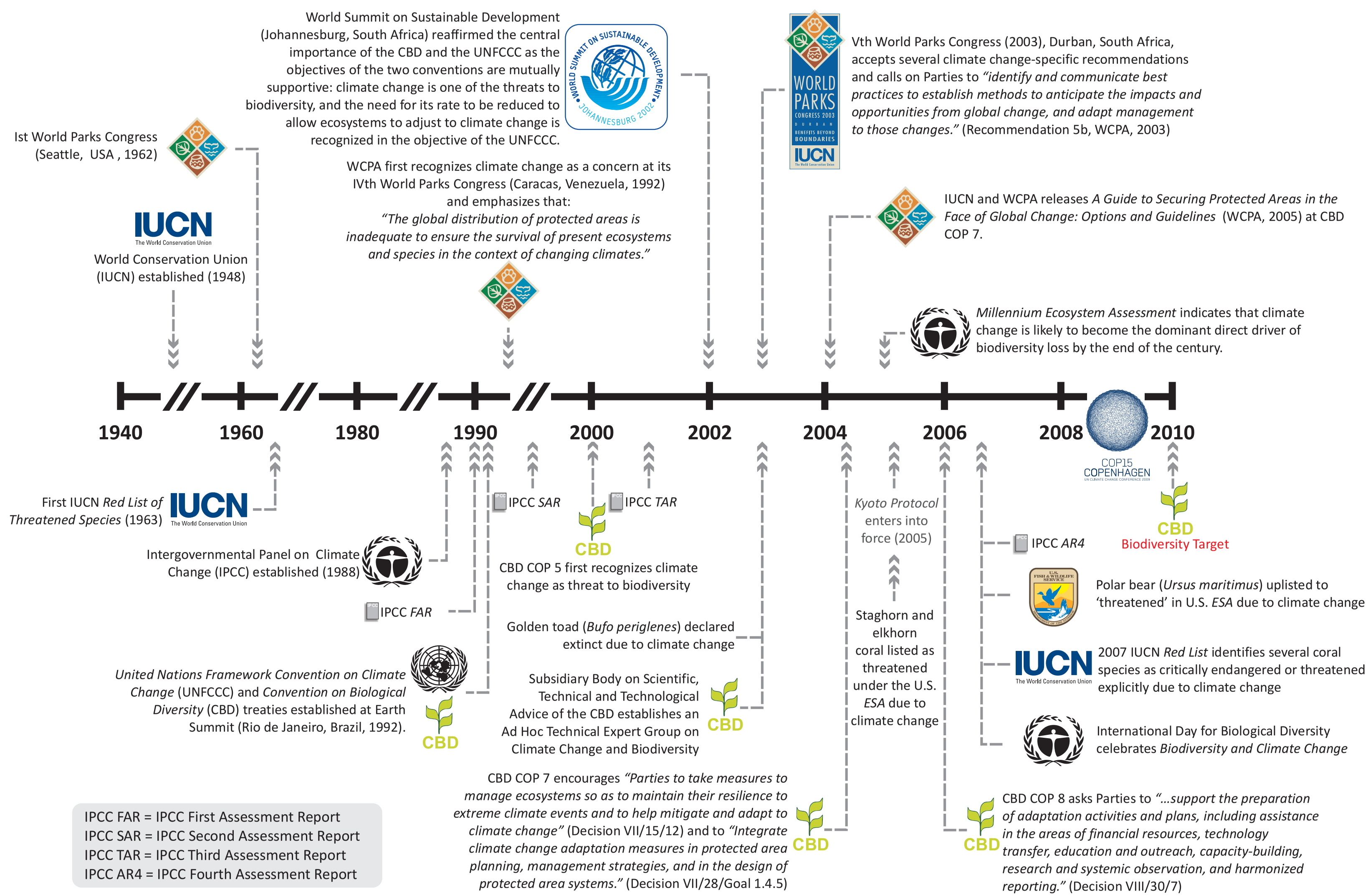


Figure 3: Timeline of major international events and activities related to climate change, biodiversity and protected areas (adapted from: Lemieux, 2008).

3) Urged to support projects that demonstrate the role that protected areas play in addressing climate change (decision IX/18B/6e).

To a great extent, the UN CBD's involvement in climate change initiatives has largely been an outcome of its work that has focused on achieving the COP 2010 Biodiversity Target: *"to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth."* In order to achieve this target, the COP was requested, *inter-alia*, to ensure that *"At least 10% of each of the ecological regions is effectively conserved"* (including marine and coastal biodiversity, inland waters, mountain biodiversity, dry and sub-humid lands biodiversity and island biodiversity) (COP 8, Goal 1, Target 1.1) and to *"Maintain and enhance resilience of the components of biodiversity to adapt to climate change."* (COP 8, Goal 7, Target 7.1) The COP established this target in 2002. It was later endorsed by the World Summit on Sustainable Development (2002) and the UN General Assembly, and was subsequently incorporated as a new target under the Millennium Development Goals (2006) (COP 6 decision VI/6, COP 7 VII/30, and COP 8 VIII/18).

The IUCN World Commission on Protected Areas

The International Union for Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA) first recognized climate change as a 'theoretical concern' over 15 years ago at its IVth World Congress on National Parks and Protected Areas (Caracas, 1992) (McNeely, 1992). At the Congress, it was concluded that *"The global distribution of protected areas is inadequate to ensure the survival of present ecosystems and species in the context of changing climates"* (conclusion b), a position that is often reflected in the scientific literature today. More recently, the position of the IUCN and the WCPA has evolved from one that has traditionally focused on the 'theoretical concerns' of climate change to one that now recognizes climate change as a major and measurable threat to protected areas worldwide. The UN and the IUCN have implemented a program of work on climate change, with emphasis on policy development.

Climate change was a prominent issue at the 2003 World Parks Congress in Durban, South Africa and at the 2008 World Conservation Congress in Barcelona, Spain. At the Vth World Parks Congress, delegates agreed to Recommendation 05 (*"Climate Change and Protected Areas"*) that emphasized the need to protect biodiversity in the face of climate change with a two-fold response: firstly, through the mitigation of climate change by stabilizing greenhouse gas (GHG) concentrations (a task largely outside of the purview and capabilities of protected areas); and, secondly, by the institution of new conservation strategies, including the establishment of new protected areas that are specifically designed to be resilient to climate change-related impacts (WCPA, 2003). The statement also recommended *"Governments, and protected area managers and planners, include concepts of resilience and adaptive management of protected areas to mitigate the impacts of climate change, including designing and managing protected area networks flexibly to accommodate adaptations to change."* (WCPA, 2003: Recommendation 9)

For the first time in its history, the 2007 IUCN *Red List of Threatened Species*[2] identified several ocean corals [Floreana coral (*Tubastraea floreana*), Wellington's solitary coral (*Rhizopsammia wellingtoni*) and Galapagos coral (*Polycyathus isabela*)] as either "critically endangered" or "vulnerable to extinction" specifically due to climate change. The IUCN also has recently acknowledged that the status of the polar bear (*Ursus maritimus*), which is currently listed as "vulnerable", may have to be uplisted in the "very near future" to "critical" due to the rapid reduction of the extent of sea ice occurring in the Arctic and other climate change-related impacts (IUCN, 2007). In fact, the U.S. Department of the Interior recently uplisted the polar bear as "threatened" on its federal *Endangered Species Act* in part due to climate change-related impacts (USDI, 2008).

At the 2008 IUCN World Conservation Congress in Barcelona, Spain, a number of resolutions about the role of protected areas in managing for climate change were passed, including:

- **Resolution 4.075 (3b)** which called on Parties to *"explicitly consider the role that ecological connectivity and systems of protected areas can play in mitigation and adaptation to climate change for biodiversity, ecosystem services and*

[2]The IUCN *Red List of Threatened Species* (also known as the IUCN *Red List* or *Red Data List*), created in 1963, is the world's most comprehensive inventory of the global conservation status of plant and animal species (IUCN, 2007). The IUCN is the world's main authority on the conservation status of species.

livelihoods, and to ensure that climate funds are invested in building and effectively managing protected area systems to maintain their functions in the face of climate change"; and,

- **Resolution 4.076 (3b)** *"to incorporate in their national plans and strategies approaches that acknowledge the role that biodiversity, ecosystems and protected area systems can play in climate change mitigation and adaptation."* (IUCN, 2008a and 2008b)

Overall, the UN CBD and the IUCN recognize the critical and complex relationships between and among biodiversity, protected areas, and climate change. To date, a number of international efforts have advanced the biodiversity, protected areas, and climate change discourse through various conferences and congresses, communication products (e.g., technical reports and media releases), recommendations, and policy statements. Moreover, these efforts have motivated agencies and organizations into action and encouraged capacity-building. On the other hand, these international programs have had minimal influence on generating national-level responses, perhaps in part because of a lack of the practical guidance that enables jurisdictions to design and implement adaptation programs. In addition, the scale of the discourse (largely global) that these international organizations have used to address climate change, biodiversity, and protected areas issues has not matched the scale of the solutions needed by protected areas planners, managers, and policy-makers working at sub-national, provincial/territorial, municipal, or site-specific scales. Given the local nature of impacts and the management implications associated with climate change, and the lack of engagement of many agencies and stakeholders whose participation is essential in this regard, the scale of these international deliberations has had limited influence on practical decision-making related to proactive, planned adaptations.

Beyond Canada, there has been some progress on formulating adaptation strategies for protected areas and climate change in a number of jurisdictions. A number of countries have embarked on work to assess the implications of climate change on their protected areas, and some have initiated work to develop mitigation strategies. The review of such experiences is useful to gauge the state of current efforts elsewhere and to assess strategies and measures that may be applicable to Canada. Select jurisdictional responses to climate change can be found in **Annex 1.**

Protected Areas and Climate Change in Canada

Prairie communities dominated by native, deep-rooted grasses and herbaceous plants, such as those in Grasslands National Park in Saskatchewan, may have more inherent resilience and adaptive capacity than other ecosystems to withstand enhanced droughty conditions projected to result from climate change for some parts of the midwest prairie region of Canada. (Photo Credit: A. Cornellier, courtesy Parks Canada Agency)

Recent Climate Change

Earth's climate has changed, is changing, and will continue to change. It is primarily fuelled by energy (heat) from the Sun and created by interactions between the atmosphere, oceans and lakes, ice, land, and organisms (IPCC, 2007b). Climate is 'average weather' described statistically as the mean and variability of temperature, precipitation, and wind. Both paleo-climatic temperature data reconstructions and modern instrument-based observations indicate that climate change occurs on all time scales, from day-to-day (e.g., extreme events), to inter-annual (e.g., year-to-year), and to the geological (e.g., millions of years and longer). In fact, episodic rapid (or 'abrupt') changes in climate have been detected throughout the paleo-record. For example, an abrupt climate shift out of the Younger Dryas event (approximately 15,000 years BP) was characterized by a regional warming in Greenland of about 8°C in less than a decade (Alley *et al.*, 2003).

The Earth's climate changes in response to natural events (e.g., sunspots and solar fluctuation, volcanoes and the Earth's orbital wobble) and human activities such as the combination of fossil fuel combustion and land clearing that increase the amount of greenhouse gas (GHG) in the atmosphere (IPCC, 2007a). Carbon dioxide (CO_2) and other naturally occurring gases help to regulate the Earth's climate by capturing heat energy and acting as an insulating blanket. This blanket keeps the Earth's surface temperature 33°C warmer than it would otherwise be (i.e., +14°C instead of -18°C) and supports liquid water that is essential for life on Earth (IPCC, 2007b). Although GHGs increased with the development of agriculture, the industrial revolution that began around 1750 marked the beginning of the period during which truly significant amounts of CO_2 have been added to the atmosphere.

Atmospheric CO_2 has increased 31% since pre-industrial times, the result of burning fossil fuels (coal, oil, and gas), converting forests to non-forested conditions (this is deforestation, which contrasts with sustainable forest management), and draining wetlands (IPCC, 2007b). The increased concentrations of GHGs keep more heat energy in the lower atmosphere, which increases temperature and changes precipitation and wind patterns (IPCC, 2007b). Since the energy reaching the Earth from the Sun has remained roughly constant since 1978, most scientists conclude that most of the observed temperature change is due to GHG emissions from human activity (IPCC, 2007b; National Academies, 2009).

The Intergovernmental Panel on Climate Change (IPCC) recently estimated that global average temperature has increased about 0.76°C over the past 100 years (1896 to 2005) and the rate of warming has greatly accelerated since the 1950s (Mann *et al.*, 2003; Mann and Jones, 2003; Mann, 2007; IPCC, 2007a; Hou *et al.,* 2007). Eleven of 12 years, between 1995 and 2006, ranked among the 12 warmest years in the instrument-based record of global surface temperature (since 1850).

Annual temperatures have been increasing across Canada as well. Over the last 62 years, temperatures have increased 1.4°C (Environment Canada, 2010a) (Figure 4). Seven of 12 years (between 1995 and 2006) ranked among the 12 warmest years in the instrument-based record, with 1998 (+2.5°C) edging out 2006 (+2.4°C) as the warmest year on record. Conversely, 1972 was the coolest year on record since 1948 with a decrease in the average annual temperature of 1.8°C.

The warming trend across Canada has not been geographically or seasonally uniform (Table 1). For example, the Mackenzie District (Northwest Territories) experienced the largest warming trend of 2.1°C and the Atlantic region experienced the smallest warming trend of 0.3°C over the 61-year period of record. With the exception of the springs of 2002 and 2004, seasonal temperatures have remained above or near normal for more than 11 years.

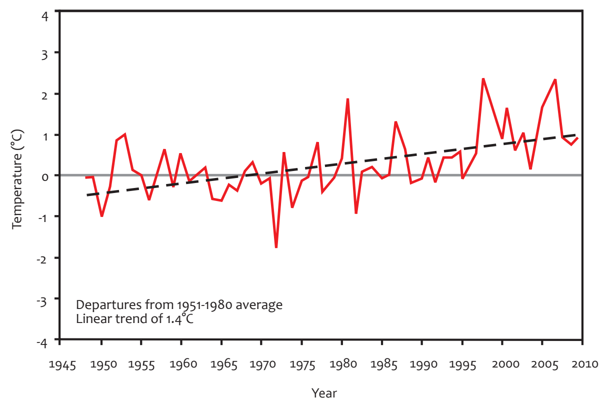


Figure 4: Annual national temperature departures and long-term trend, 1948-2009 (Environment Canada, 2010a).

Similarly, precipitation has been greater than normal across all seasons (Environment Canada, 2010a). Only once (2001) in the last 35 years were national precipitation levels significantly below normal, the rest of the period has been very close to normal or above normal. The driest year was 1956 (-7.3%) and the wettest was 2005 (+13.4%) (Environment Canada, 2010a) (Figure 5).

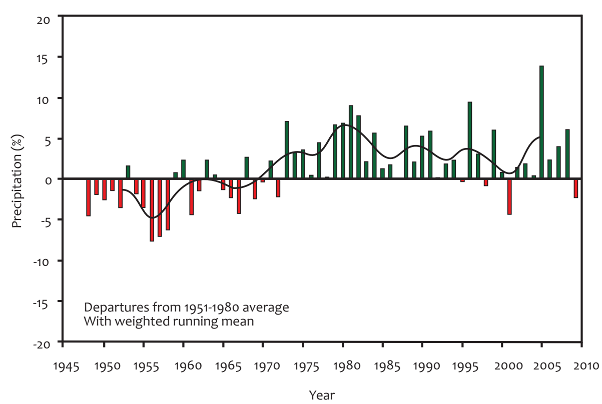


Figure 5: Annual national precipitation departures with running mean, 1948-2009 (Environment Canada, 2010a).

Future Climate Change

The IPCC (2007a) has estimated that the pace of climate change is "very likely" (>90% probability) to accelerate with continued GHG emissions, with the best estimate that globally averaged surface temperatures will rise by between 1.8° and 4.0°C by the end of the 21st century. Even if atmospheric concentrations of GHGs were stabilized at current levels, the Earth would continue to warm as a result

Table 1: Annual temperature trend, extremes and current season ranking, 1948 - 2008 (61 Years) (Environment Canada, 2009).

Region	Trend (°C)	Coolest		Warmest	
		Year	(°C)	Year	(°C)
Atlantic Canada	+0.3	1972	-1.4	1999	2
Great Lakes / St. Lawrence Lowlands	+0.6	1978	-1	1998	2.3
Northeastern Forest	+0.8	1972	-1.9	2006	2.3
Northwestern Forest	+1.7	1950	-2.1	1987	3
Prairies	+1.4	1950	-2.1	1987	3.1
South British Columbia Mountains	+1.5	1955	-1.8	1998	2
Pacific Coast	+1.1	1955	-1.2	1958	1.6
North British Columbia Mountains/Yukon	+2	1972	-2.1	2005	2.8
Mackenzie District	+2.1	1982	-1.5	1998	3.9
Arctic Tundra	+1.6	1972	-2.4	2006	3.4
Arctic Mountains and Fiords	+1.2	1972	-1.9	2006	2.3
Canada	+1.3	1972	-1.8	1998	2.5

of past GHG emissions and feedbacks in the global climate system. Several recent studies have indicated that temperatures will exceed 2°C average global warming by 2100 (Hansen *et al.*, 2007; Anderson and Bows, 2008; Parry *et al.*, 2009; Meinshausen *et al.*, 2009; Rogelj *et al.*, 2009). This level of warming is considered by many scientists and over 100 nations (IPCC, 2007a) including the G8 nations (National Academies, 2009) to represent *"dangerous interference with the climate system"* as outlined in the *United Nations Framework Convention on Climate Change* (UNFCCC).

"Climate change will continue for many decades, and even centuries, regardless of the success of global initiatives to reduce greenhouse gas emissions..." (Lemmen *et al.*, 2008: 4)

Climatologists have projected the range of potential change in Canada's climate using different climate models and scenarios of anthropogenic GHG emissions. For example, over 100 general circulation model/scenario experiments compiled by the Pacific Climate Impacts Consortium (PCIC, 2009) (Figure 6) project annual mean temperature increases of 3.1 to 10.6°C by the 2080s over Canada's terrestrial ecosystems, which is about double the projected global average temperature change (PCIC, 2009). The 100 experiments project mean annual precipitation changes ranging from -0.2 to +8.7% for the 2020s, +0.3 to 16.7% for the 2050s, and +2.5 to 19.2% for

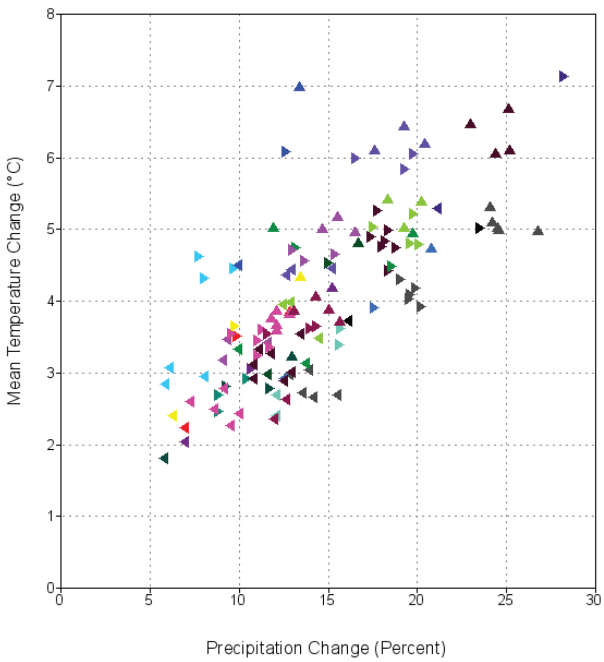


Figure 6: Mean temperature change vs. precipitation change projections for Canada [Special Report on Emissions Scenarios (SRES) AR4 scenarios, 2080s] (PCIC, 2009). Regional scenarios can be accessed at: http://pacificclimate.org/tools

the 2080s. It is important to note that these changes are not expected to be uniform across the country, and that temperature-controlled evaporation rates will increase and create a water deficit in many areas. Maps illustrating the difference between the baseline annual mean temperature (1971-2000) and annual mean temperature projections for the 2080s for Canada and U.S. terrestrial protected areas are included in **Annex 2**.

Modern and Future Species and Ecosystem Response to Climate Change

Terrestrial Species and Ecosystems

Temperature increases that have occurred over the last 50 years are impacting the distribution and abundance of life on Earth as we know it (e.g., Parmesan, 1996; Parmesan *et al.*, 1999; Hughes, 2000; McCarty, 2001; Thomas *et al.*, 2001; IPCC, 2001, 2007b; Walther *et al.*, 2002; McLaughlin *et al.*, 2002; Parmesan and Yohe, 2003; Root *et al.*, 2003; Parmesan and Galbraith, 2004, Menzel *et al.*, 2006; Walther *et al.*, 2005; Bradshaw and Holapzfel, 2006; Parmesan, 2007; IPCC, 2007b). Alarmingly, climate change has already been attributed to several species extinctions (Pounds *et al.*, 1999; McLaughlin *et al.*, 2002; Thomas *et al.*, 2006), which will be exacerbated in the future as temperatures continue to rise and as precipitation and wind patterns change (Thomas *et al.*, 2004; Schwartz *et al.*, 2006; IPCC, 2007b).

Parmesan and Yohe (2003) projected climate change-related ecological impacts by conducting meta-analyses using more than 30 studies evaluating over 1,700 species from a variety of taxa (e.g., insects, vertebrates, and plants). Despite the very different levels of detail, design, and scale, the analyses revealed that more than half of the plant species demonstrated changes in their phenology and/or their distribution. The changes reported were not random but were systematically in the direction expected from regional changes in the climate. On average, northern hemispheric geographic range boundaries moved 6.1 km northward per decade. Quantitative analyses of phenological responses gave estimates of advancement of 2.3 days per decade across all species.

As a further indicator of ecological impacts attributed to climate change, the authors found that 279 (or 82%) of the species included in their analyses exhibited "sign-switches" (i.e., boundaries shifting northward in warm decades and southward in cool decades) and the authors concluded that no other factor (other than climate) could be responsible for such changes. Parmesan and Yohe (2003) also emphasized that the unexpectedly strong response of a high number of species across multiple scales is outweighing other potentially counteractive global change forces, such as habitat loss.

A parallel can be drawn from the results of Root *et al.* (2003) who found that more than 80% of the 1,468 species included in their analysis were responding to climate change in the direction expected on the basis of known physiological constraints. The average shift in spring phenology (such as breeding or blooming) for temperate-zone species was 5.1 ± 0.1 days per decade earlier (Root *et al.*, 2003). These trends are greater than the results obtained by Walther *et al.* (2002) who found earlier leaf unfolding in both the United Kingdom (1.4 to 3.1 days per decade earlier) and North America (1.2 to 2.0 days per decade earlier).

A number of meta-analyses also suggest that Canadian species and ecosystems are responding to recent climate change. Some of the reported impacts include the following: changes in the geographic distribution, migratory pathways, and abundance of species; changes in the timing of reproduction of species; changes in phenology (e.g., onset, end, and length of growing season); changes in the geographical occurrence and magnitude of pest outbreaks; changes in inter-specific interactions; and, widespread aquatic responses to increasing temperatures in both arctic and boreal lakes (see Figure 7 and **Annex 3**).

Future climates likely will be significantly different from current climates, which will contribute to change in the composition, structure, and function of the Earth's ecosystems. Correlative 'climatic envelope' methods have been applied to species modelling to project the future impacts of climate change on terrestrial ecosystems and species. Studies consistently suggest that there will be major shifts in species and significant changes to ecosystems. At the global scale, Malcolm *et al.* (2002a) project that more than 80% of the Earth's ecoregions could experience extinctions as a result of climate change. Northern ecoregions in Canada, Russia, and Asia are especially vulnerable—seven ecoregions within these areas showed 70% or more change in at least one vegetation model [Ural Mountains Taiga (Russia); Canadian Low Arctic Tundra; Altai-Sayan Montane Forests (Russia/ Mongolia); Muskwa/Slave Lake Boreal Forests (Canada); Kamchatka Taiga and Grasslands (Russia); Canadian Boreal Taiga, and Southwestern Australia Forests and Scrub]. Moreover, average required migration rates (RMRs) (i.e., the rates at which species would need to move to successfully keep up with climate change) were unusually high, especially in Canada, often exceeding 1,000 m/year^{-1}. Rates of change of this magnitude would be about 10 times faster than the rapid migrations during the last post-glacial period. Given that this is unlikely to happen, many species could fail to re-establish and disappear.

> *"Although examples of persistence through repeated periods of unfavorable climate are documented in the fossil record, the record of extirpations and extinctions suggests that limits to adaptation are greatest during periods of rapid climate change, such as that predicted for the future."* (Davis and Shaw, 2001: 678)

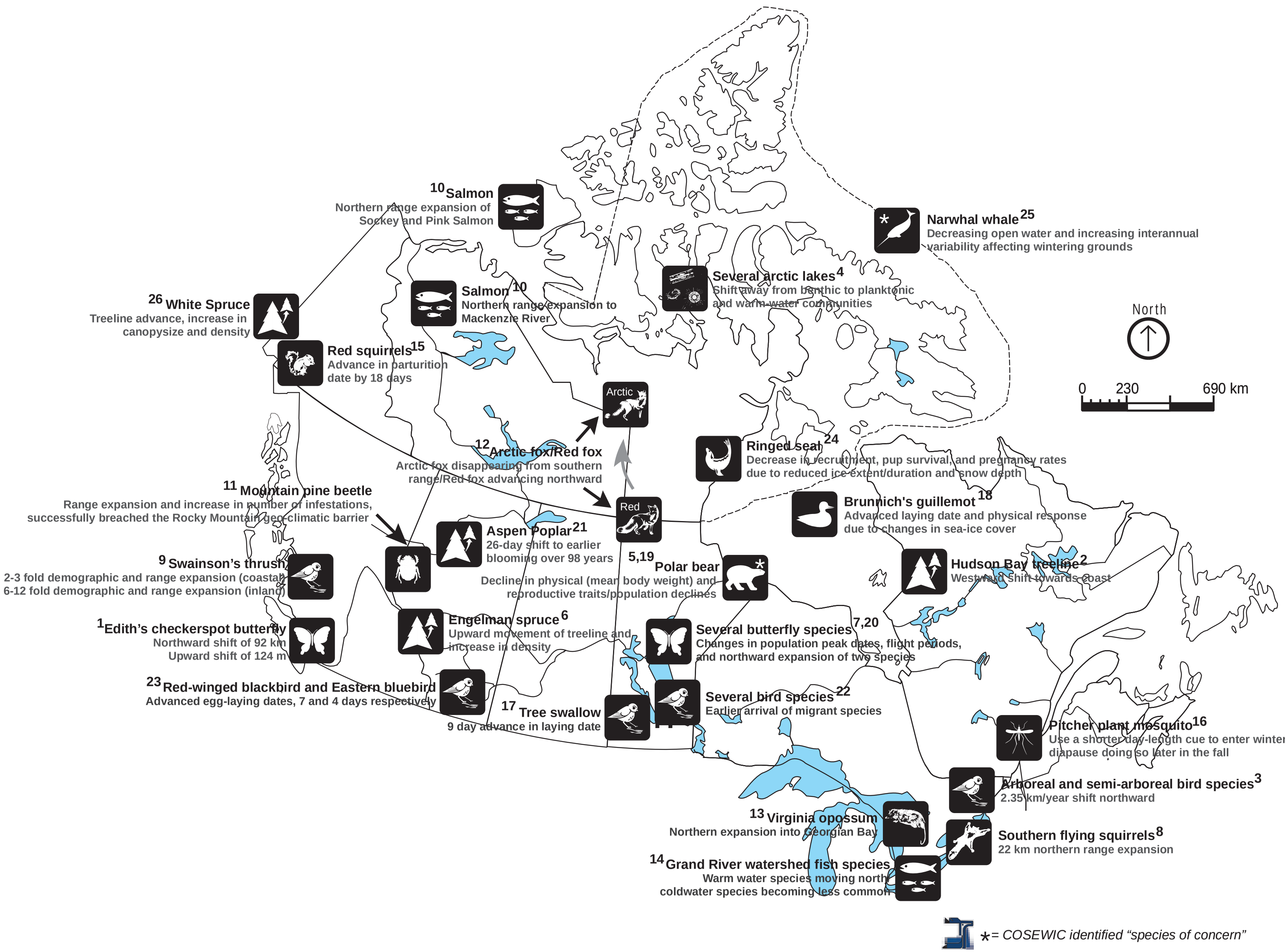
> *"...Anthropogenic climate warming at least ranks alongside other recognized threats to biodiversity... it is likely to be the greatest threat in many if not most regions."* (Thomas *et al.*, 2004: 147)

Both national (e.g., Rizzo and Wiken, 1992; Lenihan and Neilson, 1995; McKenney *et al.*, 2007a, 2007b) and provincial-level [e.g., British Columbia, Hogg and Hurdle (1995); Hamann and Wang (2005); Saskatchewan, Henderson *et al.* (2002); Ontario, Malcolm *et al.* (2004); Goldblum and Rigg (2005)] bioclimatic envelope modelling studies show the possibility of strong latitudinal and altitudinal effects, with the greatest changes occurring at high latitudes (e.g., Arctic ecosystems) and altitudes (e.g., the Rocky Mountains and the Mackenzie Mountains) and relatively less change in temperate areas.

Over the next century, the traditional bioclimatic envelope of species may shift as much as 300 to 700 km north (Rizzo and Wiken, 1992; McKenney *et al.*, 2007a, 2007b). Substantial reductions in the extent of northern species' bioclimatic envelopes and the expansion of more southerly bioclimatic envelopes are consistently projected (Rizzo and Wiken, 1992; Lenihan and Neilson, 1995; Malcolm *et al.*, 2002a, 2002b; Malcolm *et al.*, 2004; McKenney *et al.*, 2007a, 2007b). For example, even with a major shift into the current distribution of taiga and tundra bioclimatic envelopes, substantial losses in geographical extent are consistently projected for species that comprise Canada's boreal forest. Some projections estimate that the extent of the boreal forest bioclimatic envelope could be reduced by as much as 50%, with more southern areas being replaced by temperate bioclimatic envelopes (Rizzo and Wiken, 1992; Malcolm *et al.*, 2002a; Gray, 2005).

More recent species-specific climate change modelling analyses for Ontario suggest that the bioclimatic envelope for many forest species could expand or contract in geographical extent, be displaced, or increase or decrease in dominance depending on their location. For example, the range of dominant species currently associated with the northwest section of the Ontario boreal shield ecosystem, such as black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*), are expected to contract in geographical extent and decline in their relative dominance (Malcolm *et al.*, 2004). Conversely, species

Figure 7: Examples of recent terrestrial, marine and freshwater species and ecosystem responses to climate change across Canada (see Annex 3 for more detailed information including sources).



such as red maple (*Acer rubrum*), mixed poplar (*Populus*) and birch (*Betula*), currently characteristic of the southern part of the Ontario boreal shield ecosystem, are projected to expand their ranges into the northwest and increase in relative dominance (Malcolm *et al.*, 2004). Species that are more common to the southern Lake Simcoe–Rideau Region Ecoregion, including sugar maple (*Acer saccharum*), red oak (*Quercus rubra*), white pine (*Pinus strobus*), black ash (*Fraxinus nigra*), eastern white cedar (*Thuja occidentalis*) and red maple are projected to expand their geographical range into the southern section of the Ontario boreal shield ecosystem (Malcolm *et al.*, 2004).

Interestingly, Malcolm *et al.* (2004) and McKenney *et al.* (2007a and 2007b) found that the bioclimatic envelope for a number of tree species currently not found in Canada could appear under the projected warmer climate of the late 21st century. Both conservative (i.e., a climate resulting from significantly reduced GHG emissions) and extreme (e.g., a climate resulting from high GHG emission levels) climate change scenarios alike projected the northward migration of the bioclimatic envelope for several species currently restricted to the U.S. into the Lake Simcoe-Rideau region, including black hickory (*Carya texana*) and shortleaf pine (*Pinus echinata*) (Malcolm *et al.*, 2004). These scenarios also project the northward movement of the bioclimatic envelope of osage orange (*Maclura pomifera*) and post oak (*Quercus stellata*) into the Carolinian ecosystems of southwestern Ontario (Malcolm *et al.*, 2004). Assuming that suitable conditions exist to allow for the successful migration of these southern species (i.e., seed dispersal and establishment), these are the first studies to suggest that climate change may result in an increased number of tree species in Canada. Bioclimatic envelope modelling results for select species across Canada can be found in **Annex 4** (see also McKenney *et al.*, 2007a and 2007b).

> *" As a result of climate change, many areas in the Western Hemisphere will likely experience a significant reorganization of their vertebrate fauna over the coming century…. Change of the magnitude we predict for many regions in the Western Hemisphere, even when it includes the addition of new species to a region, is likely to profoundly alter local ecology and ecosystem functioning."* (Lawler *et al.*, 2009: 595)

Assessing the potential effects of future-climate simulations on the geographic ranges of 2,954 species of birds, mammals, and amphibians in the Western Hemisphere, Lawler *et al.* (2009) found that 80% of the climate projections based on a relatively low GHG emissions scenario result in the local loss of at least 10% of the vertebrate fauna over much of North and South America. The largest changes in fauna are projected for the Canadian tundra, Central America, and the Andes Mountains where, assuming no dispersal constraints, specific areas are likely to experience over 90% turnover. The authors concluded that faunal distributions in the future will bear little resemblance to those of today. In a Canadian context, while range extensions may result in the introduction of new species in southern regions, this novelty does not compensate for range contractions and species loss likely to be prevalent across northern regions.

A number of studies also suggest increased frequency and severity of forest fire outbreaks resulting from climate change over the next century and beyond. Flannigan and Van Wagner (1991) project a 40 to 50% increase in area burned in the Canadian boreal region under a climate resulting from a doubling of CO_2 levels from pre-industrial to contemporary times (e.g., an increase from 280 to 560 ppm). A more recent analysis suggests that the total area burned in Canada could increase between 74 and 118% by the end of this century under a tripled CO_2 scenario (Flannigan *et al.*, 2005). Using a Global Climate Model (GCM) driven fire model provided by Stocks *et al.* (1998) to project future forest fire intensity in Ontario's provincial parks, Lemieux *et al.* (2007) found declines in the low forest fire severity rankings and significant increases in high and extreme forest fire severity rankings by the 2050s and 2090s. The authors noted that during the 1980 to 1989 baseline period, only 3% of Ontario's provincial parks were classified within the extreme fire severity ranking. By the 2050s this potential condition increased to 10%, and by the 2090s extreme fire severity is projected to expand into nearly 21% of all provincial parks. Such projections suggest that Canada's fire-adapted forests could potentially undergo rapid ecological change resulting from increased forest fire activity.

Temperature is a major variable limiting the geographical ranges, over-wintering success, population growth rates and dispersal and migration of insect pests and disease. For example, climate change will affect the distribution and the intensity of infestation of insect pests and disease, such as mountain pine beetle (*Dendroctonus ponderosae*) and spruce budworm (*Choristoneura fumiferana*). The spruce budworm is projected to become more damaging in northern parts of the boreal and less damaging in southern parts of boreal Ontario (Candau *et al.*, 2007). Assessing the potential for additional range expansion by mountain pine beetle under continued climate change, Carroll *et al.* (2006) discovered that most of the western and central regions of Canada (north of the prairies) could become climatically optimal (i.e., high or extreme climatic suitability) for mountain pine beetle by 2041-2070.

Evidence from virtually all meta-analyses completed to date indicate that climate change will negatively impact many species in ecosystems throughout the world. For example, by examining over 1,100 animal and plants species from sample regions covering some 20% of the Earth's terrestrial surface, Thomas *et al.* (2004) estimated that between 15 to 37% (depending on the climate change scenario used and the migration capacity of the species) could be *"committed to extinction"* by 2050. Similarly, Malcolm *et al.* (2006) suggest that 39 to 43% of biota in 'biodiversity hot spots' could face extinction under a $2xCO_2$ climate (representing the potential loss of some 56,000 endemic plant species and 3,700 endemic vertebrate species).

> *"The synergism of rapid temperature rise and other stresses, in particular habitat destruction, could easily disrupt the connectedness among species and lead to a reformulation of species communities, reflecting differential changes in species, and to numerous extirpations and possibly extinctions."* (Root *et al.*, 2003: 57)

The IPCC (2007b) estimated that approximately 20 to 30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C. According to Pounds and Puschendorf (2004) and others (e.g., Opdam and Wascher, 2004), estimates of species extinction may be optimistic when the synergistic effects of habitat fragmentation, habitat destruction, and climate change on the landscape are considered.

Marine and Freshwater Species and Ecosystems

Although the focus of less discussion and scientific discourse, marine and freshwater ecosystems are as vulnerable to climate change as terrestrial ecosystems. The direct effects of climate change on water temperature, water levels, and ice cover are likely to have profound influences on both marine and freshwater species and on the composition, structure, and function of coastal wetland areas (Poff *et al.*, 2002). Predicted increases in water temperature in response to climate change will alter thermal habitat and induce both range expansions in warm-water species and range contractions in cold-water species (Magnuson *et al.*, 1997). Moreover, because precipitation primarily determines the hydrological regimes of freshwater ecosystems, any considerable change in the amount and timing of precipitation is likely to have direct and indirect effects on freshwater ecosystems. For example, a decline in precipitation, water levels, and low flow in rivers could negatively affect spawning, nursery and feeding grounds of fish species in shallow regions (Schindler *et al.*, 1996). Climate change is also likely to further stress sensitive coastal wetlands, which are already adversely affected by a variety of other human impacts, such as altered flow regimes and deterioration of water quality (Poff *et al.*, 2002). Wetland protected areas, such as Canada's 37 sites established as Wetlands of International Importance under the *RAMSAR Convention*, often provide critical habitat for many species that are poorly adapted for other environmental conditions and/or are at risk due to incompatible surrounding land-use development activities such as agriculture and urban and industrial land-use.

In Canada, the fingerprints of climate change on freshwater systems are starting to appear in the Great Lakes, causing discernible changes to water temperatures, ice cover, and declines in water levels. Jones *et al.* (2006) found increasing summer water temperatures and decreasing winter length in western Lake Erie. Similarly, Austin and Colman (2007) observed increasing summer water temperatures in Lake Superior between 1979 and 2006, coupled with a decrease in winter ice cover. A recent report by the International Joint Commission (IJC, 2009) found that lake levels in Lake Huron and Lake Michigan have fallen about a quarter metre relative to Lake Erie since the early 1960s, with 40 to 74% of the reduction due to recent changes in precipitation patterns and temperatures.

Sharma *et al.* (2007) assembled a database of summer surface-water temperatures for over 13,000 lakes across Canada and projected surface-water temperatures suitable for smallmouth bass (*Micropterus dolomieu*) under climate change scenarios. The authors found that water temperatures in the majority of Canada are projected to increase by 5 to 10°C and northern regions could experience temperatures 10 to 18°C warmer than current. As a result, climate change has the potential to greatly influence smallmouth bass distribution by increasing the amount of thermal habitat available to the warm water species over thousands of kms. The authors concluded that the majority of the lakes in Canada could potentially contain suitable thermal habitat to sustain smallmouth bass populations by 2100. Conversely, Minns *et al.* (2009) project that temperature increases in Ontario lakes could reduce lake trout (*Salvelinus namaycush*) habitat by about 30%, with steep declines (up to 60%) in the south and east only partly offset by increases (>30%) in the northwest.

Climate change will also exacerbate the significance and complexity of the impacts of alien species in Canada's marine and freshwater ecosystems. The carp (*Cyprinus carpio*), zebra mussel (*Dreissena polymorpha*), curly-leaf pondweed (*Potamogeton crispus*) and Eurasion milfoil (*Myriophyllum spicatum*) exemplify the damage that can be caused by alien species in freshwater ecosystems. Climate change may exacerbate their impact, particularly if they are evolved to thrive in warmer climates.

Climate-induced changes to freshwater biodiversity could be especially rapid, being comparable to, or even exceeding, those estimated for terrestrial ecosystems (Heino *et al.*, 2009). According to Heino *et al.* (2009), this projected rate of decline is due to the fact that fresh water ecosystems support disproportionate levels of biodiversity compared to their spatial coverage (e.g., despite the fact that fresh waters constitute only 0.01% of the world's water and cover only 0.8% of the Earths surface area, they support at least 100,000 species or about 6% of the 1.8 million described species on Earth). Compared to terrestrial ecosystems, it has been suggested that aquatic ecosystems have a limited ability to adapt to climate change and reducing the likelihood of significant impacts to these systems will depend on human activities that reduce other sources of ecosystem stress and enhance adaptive capacity (Poff *et al.*, 2002).

Overall, the lack of information and knowledge on marine and freshwater biodiversity and climate change impacts across Canada makes interpretations for protected areas policy, planning and management difficult at this time.

Changes to Other Protected Areas Assets

Climate change has potentially important implications for recreation and tourism opportunities in parks and other protected areas because visitor use is strongly correlated to climate. Climate influences the physical resources (e.g., water levels, snow cover, and wildlife species) that provide the foundation for outdoor recreation (e.g., boating, cross-country skiing, bird-watching), defines when specific activities can take place (e.g., beach use, swimming), and influences the level of visitor satisfaction (Jones and Scott, 2006a and 2006b). Canada's national and provincial parks, for example, are major resources for nature-based tourism and any changes in the length and quality of recreation seasons induced by climate change will have considerable implications for park visitation, revenue, and management requirements.

Two recent analyses indicate that Canada's protected areas could experience an increase in visitors under climate change due to a lengthened and improved warm-weather tourism season (Jones and Scott, 2006a and 2006b). For example, Jones and Scott (2006a) found that overall visitation levels to Canadian parks could increase 6 to 8% in the 2020s, 9 to 29% in the 2050s and between 10 and 41% in the 2080s, with the largest increases in visitation occurring during the spring and fall months as climatic conditions conducive to warm-weather recreation activities persist for longer periods of time (Figure 8).

Some of the most significant increases in visitation are projected for national parks located in more northerly locations, such as Pukaskwa in Ontario (2020s: +12.2 to 22.6%; 2050s: +14.2 to 40.2%; 2080s: +16.4 to 58.8%) and Prince Albert in Saskatchewan (2020s: +6.7 to 14.6%; 2050s: +10.4 to 35.7%; 2080s: +11.7 to 55.1%). Similar results were projected for Ontario's provincial parks (Jones and Scott, 2006b) where visitation could potentially increase between 11 and 27% system wide in the 2020s and between 15 and 56% in the 2050s. In the 2080s, the number of people visiting Ontario's provincial parks was projected to increase between 19 and 82% (Jones and Scott, 2006b). This is especially true for high northern and mountainous landscapes where ice and snow-based assets like glaciers and associated wild life are central attractions.

Climate indirectly affects nature-based tourism by impacting the physical resources that define the nature and quality of natural environments on which mountain tourism depends (i.e. climate-induced biophysical change). Despite the findings of Jones and Scott (2006b), which revealed potential increases in visitation resulting from climate change, any changes in the natural characteristics of environments could also *negatively influence* tourism by reducing the perceived attractiveness of a region's parks (Scott *et al.*, 2007).

A recent study by Scott *et al.* (2007) explored how climate-induced environmental change could also indirectly affect visitation at Waterton Lakes National Park for the 2020s, 2050s, and 2080s. The environmental change scenarios for the 2020s and 2050s were found to have minimal influence on visitation. However, the environmental change scenario for the 2080s (under the warmest climate change conditions) was found to have a negative effect on visitation, as 19% of respondents indicated that they would not visit the park and 37% stated that they would visit the park less often. A key finding of the study was the contrast between the climate-visitation model and the visitor survey with regard to the impact of climate change late in the 21st century. While the climate-visitation model projected the direct impact of a changed climate would increase visitation to the park (+11% to 60%—2080s), the survey found that the indirect impact of climate-induced environmental change in the park might reduce visitation, with 56% of respondents indicating that they would no longer come to the park or would visit less often if the environmental changes under the warmest scenario (2080s) were realized.

Changes in the seasonal visitation rates will be an important issue for protected area managers in Canada because there are significant implications for user-fee collection, environmental operations, and staffing needs (Scott and Lemieux, 2007). Protected areas agencies would benefit economically from increased visitors; however, an increase in visitors during the peak tourism period will place extra stress on park assets (Scott and Lemieux, 2007). Moreover, understanding the behavior of 'future tourists' under changing climatic and environmental conditions is important to understanding potential visitor trends at protected areas. It is likely that management strategies to mitigate the impacts of additional visitors will be needed in the short-term to offset ecological degradation and reduce potential conflicts among park users (Jones and Scott, 2006a).

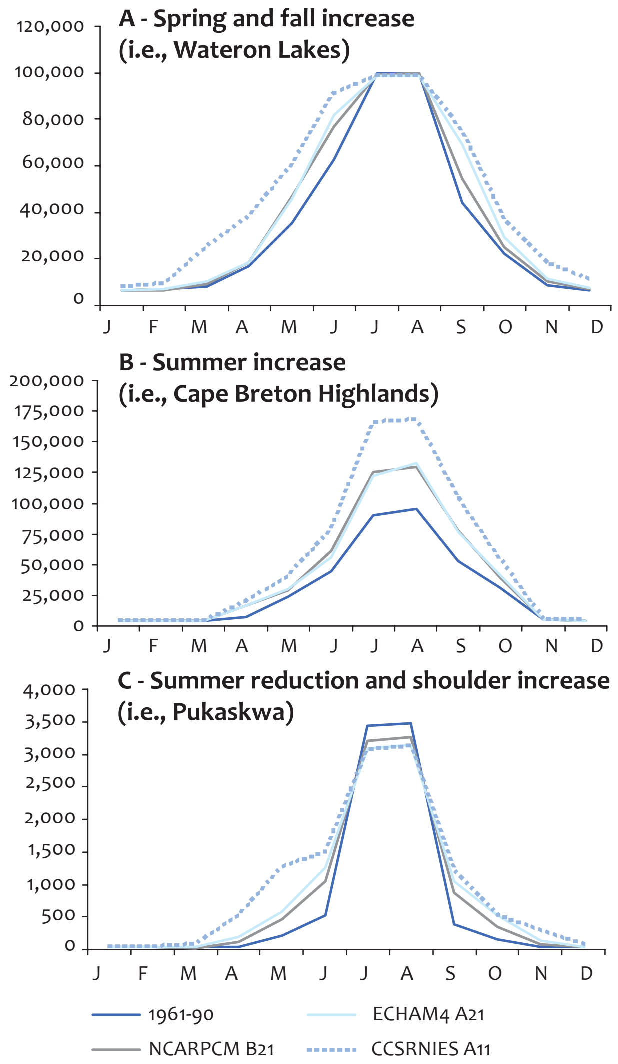
The Conservation Challenge in Canada

More than 4,850 terrestrial protected areas encompassing more than 100 million km^2 have been established in Canada. This represents an area equal to nearly 10% of the country's total land mass (Environment Canada, 2010b). The extent of protected areas in Canada varies significantly between different ecological regions of the country—ranging from 22.6% of the Arctic Cordillera Ecozone, to 7.4% of the Boreal Shield Ecozone, to only 0.4% of the Mixed wood Plain Ecozone (Great Lakes – St. Lawrence Valley).

Currently, Canada's *National Parks System Plan* (Parks Canada, 1997) and nearly all provincially/territorially-based system plans have adopted some form of ecoregional or biogeoclimatic classification framework as a primary system-planning tool for their terrestrial protected areas system. For example, as of 2006, 46 national parks had been established to represent 25 'natural regions' in Canada (Environment Canada, 2006). Overall, 41% of Canada's terrestrial ecoregions have what is currently considered to be "moderate" or "high" representation of protected areas (Environment Canada, 2006). However, only British Columbia has fulfilled the 1992 *Statement of Commitment* to complete a network of protected areas representative of Canada's land-based natural regions (Environment Canada, 2006).

Implications for Protected Areas Policy, Planning and Management

Climate change is a threat to the long-term existence of many species in protected areas and has significant implications to the planning and management programs (i.e., ecoregion representation) established to care for natural assets within the existing climate 'envelope'. Consequently, existing commitments inscribed in protected areas systems and individual park management plans may be difficult to attain in a rapidly changing climate.



Lines represent observed (1961-1990 average) and projected changes (2050s) in the seasonal pattern of visitation to national parks using three GCMs.

*Parks projected to experience each pattern:

A: spring/fall increase (Banff, Jasper, Kouchibouguac, La Mauricie, Mt. Revelstoke/Glacier, Point Pelee, Prince Albert and Waterton Lakes*);

B: summer increase (Cape Breton Highlands*, Kootenay, Pacific Rim, Prince Edward Island, Terra Nova and Yoho);

C: summer reduction (Pukaskwa*).

*=Illustrated in figure.

Figure 8: Projected changes in the seasonal pattern of national park visitation (2050s)* (Jones and Scott, 2006a: 11).

There has been a growing discussion in the scientific literature on the implications of climate change for protected areas in Canada (e.g., Scott and Suffling, 2000; Scott *et al.*, 2002; Scott and Lemieux, 2005; Welch, 2005; Lemieux and Scott, 2005; Jones and Scott, 2006a, 2006b; Scott and Lemieux, 2007). However, agency-specific studies have been limited to Ontario (Jones and Scott, 2006b; Lemieux *et al.*, 2007) and Saskatchewan (Henderson *et al.*, 2002; Vandall *et al.*, 2006). These studies have focused on the implications of changing species distributions combined with the fixed nature of protected areas and on the implications of climate change for park-based tourism and recreation. For example, Lemieux and Scott (2005) projected that between 37 and 48% of Canada's protected areas could experience a change in terrestrial biome type under doubled atmospheric CO_2 conditions. More recently, scientists and managers have begun to address the issue of climate change 'adaptation' (e.g., Scott and Lemieux, 2005; Welch, 2005; Vandall *et al.*, 2006; Lemieux *et al.*, 2008).

Scott and Lemieux (2005) and Lemieux *et al.* (2007) identified a number of potential climate change-induced policy and management issues requiring attention by the Canadian protected areas community in the 21st century that are listed in Table 2.

The implications of climate change for both marine and freshwater protected areas have been explored in the literature in only a rudimentary way and significant knowledge gaps remain (see Jessen and Patton, 2008 for example). One of the primary objectives of many protected areas in Canada is to provide ecologically

Table 2: Potential climate change and protected areas policy, planning and management issues in Canada.

Protected Areas Establishment and Design
• All or part of future novel species' habitat may not be represented in the existing suite of protected areas. • Intervening landscapes and waterscapes between formally protected areas may be critically important to achieving protection commitments. • Boundaries for protected areas may require adjustment to help achieve protection commitments. • Management plans and conservation targets for protected areas will require revision.
Protected Areas Habitat and New/Invasive Species
• Some protected area habitat may become unsuitable for existing species (e.g., species unable to acclimatize to changing climatic and ecological conditions). • Some protected area habitat may become suitable for new/invading species (i.e., species currently occupying niches in more southerly located ecosystems). • The bioclimatic envelopes of invasive species may extend northward and emerge as a pervasive management issue in protected areas. • Current definitions of non-native/exotic species may require revision.
Ecological Disturbances
• Many ecosystems, such as the boreal forest, depend on disturbances through fire and pest outbreaks to renew and maintain ecological integrity. Ecologically, increased frequency and scale of disturbances such as fire may result in increased distribution and dominance of early successional ecosystems characterized by fire-adapted species, such as white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), jack pine and black spruce within protected areas. • Forest fire management plans may require preparation or revision to promote the use of fire to re-establish or maintain ecological representation and address increased fire severity in some locations. • Natural asset managers may find it increasingly difficult to achieve a balance between protecting socio-economic values (such as forestry interests), protecting representative natural values, promoting the use of fire in restoring and maintaining ecosystem health, and managing pest outbreaks (e.g., spruce budworm and mountain pine beetle) in a rapidly changing climate.

Table 2: Cont'd

Recreation and Tourism Assets
• The availability of some recreational opportunities may decline in some areas (e.g., cross-country skiing) while other/new recreational opportunities may increase/emerge (e.g., climatic suitability for camping in shoulder seasons).
• A range of management issues could be affected, such as user-fee collection, environmental operations (e.g., increased fire bans and beach closures) and staffing needs (i.e., to take advantage of an extended operating period).
• Visitor management plans may need to be revised (e.g., how to manage for potentially large increases in visitation due to extended and improved warm-tourism season?).
• Environmental change within parks (e.g., loss of glaciers, changes to flora and fauna) may affect visitor experiences in parks and park visitation.

sustainable outdoor recreation opportunities and encourage associated economic benefits (see *Ontario's Provincial Parks and Conservation Reserves Act* and *Alberta's Provincial Parks Act*, for examples). Changes in fish species distribution and abundance in lakes and streams would certainly change sport-fishing activities in protected areas that permit such activities. As lake and river waters warm, cool and cold water fish habitat will disappear and habitat for warm water fish species will increase. This will influence not only where and when people choose to fish, but possibly the types of fish available to anglers (see Hunt and Moore, 2006). Moreover, changes in the duration and extent of ice cover could increase risk to outdoor enthusiasts who depend on the ice for travel and/or pursue ice fishing as a recreational activity.

Network approaches to the planning of marine and freshwater protected areas systems are in their infancy in Canada. The historical and current approach to establishing such areas has proceeded on a site-by-site basis with no consideration of functional linkages. These things said, the relative youth of marine and freshwater protected areas system planning in Canada might work to the advantage of the agencies and organizations responsible for their establishment and management. For example, the recent federal *Marine Protected Areas Strategy* (Fisheries and Oceans Canada, 2005) explicitly recognizes the utility of the precautionary principle, integrated management, adaptive management, and an ecosystem approach to ensure responsibility, the best use of available information, and the consideration of linkages among key ecosystem components when identifying, planning and managing marine protected areas. Moreover, principles for incorporating climate change adaptation into marine protected area site and system planning have been developed to help guide current and future federal, provincial and territorial marine and freshwater conservation initiatives (e.g., Hoffman, 2003; Hannah and Hansen, 2005; Dudley *et al.*, 2005). Such science-based information and guidance was not as fully available when Canada's system of terrestrial protected areas more than doubled over the past 20 years.

> *"We cannot... fulfill our duties as stewards of the Earth's last natural ecosystems if we plan and manage for a world that no longer exists."*
> (WCPA, 2004: xv)

In summary, computer model projections suggest that climate change likely will cause significant ecological impacts across Canada, including shifts in species and changes in structure and function in terrestrial, marine, and freshwater ecosystems alike. Owing to Canada's diverse ecological make-up, the effects of climate change will vary from region to region, with consequential and sometimes unique impacts on protected areas. So too, the response of protected areas will vary in a regional context, with implications for the values that they were designated to conserve and the goods and services that they currently provide.

The Canadian Protected Areas and Climate Change Survey

Patterns of seasonal stopovers and residency of protected areas by migratory birds and other wildlife, and the visitation patterns of Nature enthusiasts who come to view them in renowned places like Point Pelee National Park in Ontario, may be altered by climate change. (Photo Credit: B. Morin, courtesy Parks Canada Agency)

Survey Context and Purpose

A central role of the Canadian Council on Ecological Areas (CCEA) involves the coordination of efforts to design, plan, and manage protected areas. Climate change has been recognized as an issue of high priority within the CCEA's past and current *Business Plans* (CCEA, 2004; 2009b), and its importance has been further highlighted by Canadian protected areas agencies participating in a recent CCEA Northern Protected Areas (NPA) Survey (Wiersma *et al.*, 2006).

Understanding how protected areas agencies view climate change (both independent of and with respect to adaptation) is an important precursor for CCEA to assist in developing tools, techniques and strategies for adaptation. Pielke (1998) and Vedwan and Rhoades (2001) stressed that the way in which decision-makers perceive climate change is a significant factor influencing the management options to be adopted. Moreover, there is an urgent need identified in the literature for ongoing, rigorous 'accounting' of climate change adaptation to assist natural asset managers in their efforts to establish new programs (Thompson *et al.*, 2006).

In response to these needs, and with the endorsement of the North American Chapter of the International Union for Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA), the University of Waterloo and the CCEA initiated a collaborative Protected Areas and Climate Change (PACC) Survey in 2007, and updated in 2009, to assess the state of current efforts on climate change adaptation by Canadian protected areas agencies and organizations.

This section presents the results of the PACC Survey, which was designed to address three objectives:

1) To identify what climate change impacts are currently perceived to be affecting and/or are anticipated to affect protected areas across Canada;

2) To evaluate the perceived importance of climate change relative to other protected areas management issues within Canadian jurisdictions; and,

3) To determine what policy, planning and management responses (i.e., adaptations) have been developed or are being considered by protected areas agencies and organizations across Canada.

The results of the PACC Survey will enhance the CCEA's efforts to assist with the design, development and management of the Canadian protected areas network with specific reference to studies focused on adaptation (e.g., Scott and Lemieux, 2005, Lemieux *et al.*, 2007, Welch, 2005, Vandall *et al.*, 2006). The survey responses provide an important overview of the state of awareness, understanding, and initiatives developed in response to climate change in protected areas in Canada, and a measure of the current capacity (as self-evaluated) of agencies to respond to climate change issues. The results also help to determine further steps that need to be taken as part of a coordinated response to climate change adaptation in Canada. The survey questionnaire is included in **Annex 5**.

Sampling Methods and Participants

Survey participants were selected mainly from government agencies and environmental non-governmental organizations (ENGOs) that plan, establish, and/or manage protected areas in Canada. The survey sample was selected to represent the full spectrum of agencies and organizations operating at varying geographical and jurisdictional scales across Canada (n=35) (Table 3). Collectively, agencies included in the survey are responsible for at least 4,850 protected areas or about 99% of Canada's entire protected areas network both in terms of the total number of protected areas and the total area protected.

The survey was forwarded to CCEA jurisdictional representatives and senior staff within ENGOs (e.g., directors, managers and coordinators) who either completed the questionnaire themselves (sometimes in co-operation with other staff) or forwarded the survey onto appropriate personnel. Staff working in principal federal departments (n=4) and provincial/territorial ministries/departments (n=13) engaged in protected areas planning and management were included in the survey as well. In addition, a small sample of other agencies that operate at smaller jurisdictional scales, such as municipalities and conservation authorities, were included (n=5). A sampling of First Nations and ENGOs that plan and establish protected areas independently or provide important research, capacity-building, and/or outreach functions within the Canadian protected areas community were also surveyed (n=13).

Survey Results

Perceptions of Climate Risk and Vulnerability

All agencies and organizations considered climate change to be an important management issue for protected areas now (91%) or in the very near future (i.e., 2020s) (100%). Further, 71.4% of the agencies surveyed either strongly agreed or somewhat agreed with the statement that *"climate change will substantially alter protected area policy and planning over the next 10 years."* When asked the same question, but in the context of the next 25 years, virtually all respondents (94%) 'strongly agreed' or 'somewhat agreed' with the statement.

Although climate change was identified as an issue affecting the management of protected areas now, respondents ranked a number of other forces and factors ahead of the impacts of climate change (Table 4). However, when asked the same question in the context of 25 years from now, 60% of the agencies ranked climate change as an issue of greater importance than currently perceived. Climate change ranked as the second most important management issue for protected areas agencies 25 years from now, ranking only behind external threats and human land-use patterns.

With respect to the range of climate change impacts expected to occur within protected areas, respondents indicated that the most important impacts will be on watersheds (including wetlands, water quality and

Table 3: Summary of respondents who participated in the Canadian Protected Areas and Climate Change (PACC) survey (* = CCEA affiliate agency).

Federal Government (n=4)

- Environment Canada, Canadian Wildlife Service*
- Parks Canada Agency*
- Canadian Heritage Rivers (Parks Canada Agency)*
- Department of Fisheries and Oceans, Marine Protected Areas*

Provincial Government (n=13)

- Government of Alberta, Alberta Community Development, Parks and Protected Areas*
- Government of British Columbia, British Columbia Ministry of Environment*
- Government of Manitoba, Manitoba Conservation*
- Government of New Brunswick, Department of Natural Resources*
- Government of Newfoundland and Labrador, Department of Environment and Conservation, Parks and Protected Areas Division*
- Government of Nova Scotia, Environment and Labour, Protected Areas Branch*
- Government of Nunavut, Department of Environment, Nunavut Parks and Special Places*
- Government of Ontario, Ontario Ministry of Natural Resources (MNR), Ontario Parks*
- Government of Prince Edward Island, Forests, Fish and Wildlife Division, Department of Environment, Energy and Forestry*
- Govournement du Québec, Ministère du Développement durable de l'Environnement et des Parcs*
- Government of Saskatchewan, Saskatchewan Environment*
- Government of Yukon, Yukon Environment, Parks Branch*
- Government of Northwest Territories, Department of Industry, Tourism and Investment, Tourism and Parks Division*

Environmental Non-governmental Organizations (ENGOs) (n=13)

- Canadian Boreal Initiative (CBI)
- Canadian Biosphere Reserves Association (CBRA)
- Clayquot Biosphere Trust
- Deh Cho Land Use Plan
- Long Point Biosphere Reserve
- Nature Canada
- Nature Conservancy of Canada
- Wildlife Habitat Canada (WHC)
- World Wildlife Fund (WWF) Canada
- Carolinian Canada Coalition (CCC)
- Ontario Nature
- Yellowstone to Yukon (Y2Y)
- Canadian Parks and Wilderness Society (CPAWS)

Other (n=5)

- Federation of Canadian Municipalities
- Conservation Ontario (including Toronto and Region Conservation Authority and Credit Valley Conservation Authority)
- Niagara Escarpment Commission (NEC)

Table 4: Current and future perceived importance of climate change relative to other protected areas management issues by Canadian protected areas agencies (based on median of rankings, 1-10, by respondents).

Perceived Importance				Management Issue
Now		Future		
Rank	Median	Rank	Median	
1	3	1 (n/c)	2	External Threats (e.g., surrounding land-use, habitat fragmentation)
10	8	T-2 (+8)	4	Climate Change
2	3.5	T-2 (n/c)	4	Human Land-use Patterns (e.g., roads, population density)
T-4	5	T-4 (n/c)	5	Wildlife Management (e.g., species richness, population dynamics, trophic structure)
3	4.5	T-4 (-1)	5	Rare/Endangered Species Management
T-4	5	T-6 (-2)	6	Water Quality/Air Quality
7	6	T-6 (+1)	6	Exotic Species (e.g., animal and plant)
T-8	7	8 (n/c)	7	Disturbance Frequencies (e.g., fire, insects, floods)
T-4	5	T-9 (-5)	8	Visitor Stresses (e.g., public facilities, interpretation centres)
T-8	7	T-9 (-1)	8	Contamination/Pollution

T= tie in ranking; value in parentheses indicates increase/decline in ranking
n/c = no change in ranking

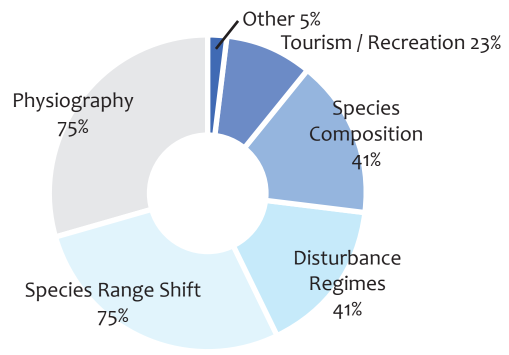
quantity), wildlife and vegetation, with 89% of the agencies surveyed identifying climate change impacts on these features as either 'very important' or 'important'. Impacts of climate change on both policy and management for protected areas also ranked high, with 80% and 74% of respondents identifying impacts on these functions as either 'very important' or 'important' respectively. Conversely, respondents took the position that the least important climate change-related impacts on protected areas will be those associated with revenues (with over a quarter assessing this issue to be 'unimportant' and 31% assessing it to be 'slightly important'), operations and development (i.e., infrastructure), and interpretation programs (with 37% agencies assessing these issues to be 'unimportant' or 'slightly important').

Climate Change Impacts, Adaptation and Information Needs

Interestingly, 73% of survey respondents indicated that protected areas within their agency's jurisdiction were currently affected by climate change-related impacts. For example, respondents for all provincial/territorial jurisdictions and all federal departments indicated that at least one climate change-related impact was occurring within their protected areas. The remaining respondents (27%) indicated that they were 'not sure' whether or not protected areas within their jurisdiction were experiencing climate change-related impacts.

Figure 9 illustrates the range of impacts attributed to climate change that have been reported to be occurring within Canada's protected areas network. Species range shifts and changes in physiography (e.g., shoreline erosion and glacial retreat) were reported to be the most common climate change-related impacts occurring within Canada's protected areas with nearly 75% of respondents reporting such impacts. Changes in species composition (i.e., the character of the vegetation within a protected area) and changes in disturbance regimes (e.g., forest fire frequency and pest/disease outbreaks) were also reported to be occurring within protected areas by nearly half of the respondents (41%). Examples of 'other' reported climate change impacts included sea level rise within Migratory Bird Sanctuaries (MBSs) and National Wildlife Areas (NWAs) managed by Environment Canada. For example, over the past century sea level has risen approximately 32 cm in the Atlantic region (Parks, 2006), 4 cm in Vancouver,

Figure 9: The range of climate change impacts reported to be occurring within Canada's protected areas network (by % of respondents reporting impact type).



8 cm in Victoria, and 12 cm in Prince Rupert, British Columbia (B.C. Ministry of Water, Land and Air Protection, 2002).

Despite agency perceptions of the importance of climate change over the next 25 years, and a range of climate change impacts reportedly already occurring within Canadian protected areas, the majority of respondents (83%) indicated that their agency had not completed a comprehensive assessment of the potential impacts and implications of climate change for their respective policy, planning and management functions. This suggests that jurisdictional and agency-specific climate change impacts and implications for protected areas are largely unknown in Canada. Ontario Parks (Lemieux *et al.*, 2007), Saskatchewan Parks (Henderson *et al.*, 2003; Vandall *et al.*, 2006) and New Brunswick's Department of Tourism and Parks (no external publication available) are the only provinces (or territories) known to have undertaken a climate change vulnerability assessment of protected areas and, with the exception of the World Wildlife Fund (WWF, 2003), none of the other 12 ENGOs (92%) participating in the survey have completed such an assessment. Parks Canada Agency is the only federal department to have completed a climate change scoping report (Scott and Suffling, 2000). No assessments have been completed for species-at-risk or for MBSs and NWAs [which include 144 sites protecting over 14 million ha, equating to nearly half of the total area protected by Parks Canada Agency (Environment Canada, 2006)].

These results reflect the limited scientific information available to protected areas agencies and the scarcity of resources that agencies have to devote to the

Table 5: Types of additional information Canadian protected natural areas agencies would like to have on various climate change-related issues (by percent of total number of responses).

Research Theme	Much More Information	Some More Information	No More Information
Information on climate or atmospheric processes	12%	59%	29%
Errors and problems in computer modelling of the climate system	6%	50%	44%
Detecting climate change (e.g., temperature trends)	29%	44%	27%
Ecological consequences of climate change	79%	21%	0%
Impacts of climate change on physiography	41%	50%	9%
Impacts of climate change on visitation (tourism and recreation)	35%	41%	24%
Implications of climate change for planning, policy and management	56%	38%	6%
Strategies for climate change adaptation	71%	23%	6%
Strategies for effective communication of climate change issues	50%	44%	6%

climate change issue. Table 5 illustrates the levels of additional information that agencies would like to have on various climate change-related issues. Generally speaking, agencies did not want 'more information' on issues associated with atmospheric processes and climate modelling or on errors in and challenges with the climate system. Agencies expressed interest in information about the ecological consequences of climate change (all agencies and organizations noted that they would like 'much more information' or 'some more information' on the issue) and the implications of climate change for policy, planning and management strategies (with 94% of agencies noting that they would like 'much more information' or 'some more information' on the issue). A large majority (94%) of the respondents indicated that they wanted 'much more information' or 'some more information' on strategies for managerial response (adaptation) to climate change impacts, and strategies for effective communication of climate change issues, respectively.

Of all respondents, only Parks Canada Agency, Ontario Parks, Government of Saskatchewan, Government of British Columbia, and the WWF acknowledged having a budget allocated specifically to respond to the challenges of climate change. Nearly half of the agencies surveyed (46%) noted that they do not have an individual within their agency responsible for climate change-related issues (including legislation, policy, research, planning, management, and research and monitoring) and, for the agencies that do, climate change was perceived to be more of a future issue and thus a lower current priority.

As Figure 10 illustrates, little response is currently being undertaken or being considered by most protected areas agencies to deal with climate change-

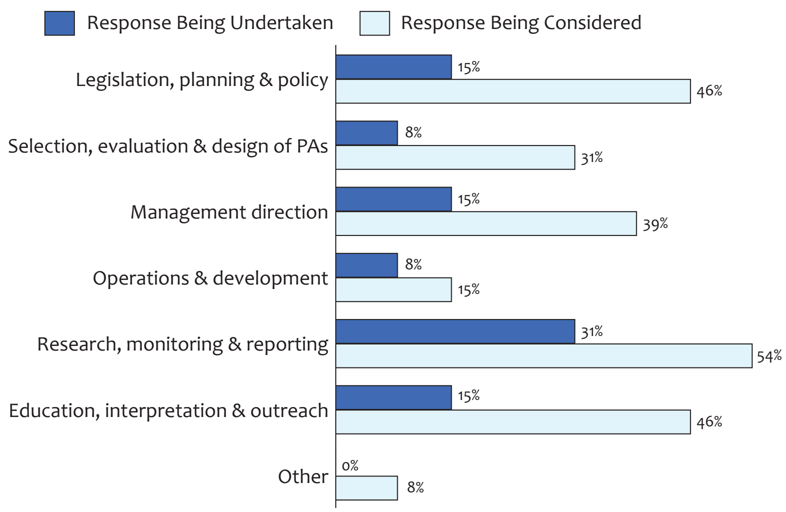


Figure 10: Climate change responses being undertaken or being considered by Canadian protected areas agencies (by major program area, percentages have been rounded).

related issues. Moreover, despite the important role that protected areas could play in climate change detection, monitoring and research and in facilitating species adaptation, only half of the agencies reported that the magnitude and extent of climate-change related impacts in their protected areas are being investigated. While 97% of the agencies surveyed 'strongly agreed' or 'somewhat agreed' with the statement that *"climate change detecting and monitoring should be a priority for protected area agencies"*, less than one-third reported that they specifically monitor for climate change impacts.

Five agencies and organizations (14%) have developed indicators for the long-term monitoring of climate change, although the extent of monitoring activities appears to be limited to solitary impacts, such as glacial retreat or single-species monitoring. Of the agencies involved in climate change research, much of the work has been conducted outside of their respective departments/agencies (Figure 11).

Finally, despite the leading role that protected areas could play in educating the public about climate change, demonstrating its impacts, and providing examples of adaptation, only six agencies (17%) have incorporated climate change into public education, interpretation and outreach programs. Importantly, however, a number of agencies, including Parks Canada Agency and Ontario Parks, have included climate change information on their websites and interactive posters aimed at youth, and some have begun incorporating climate change into park interpretation programs.

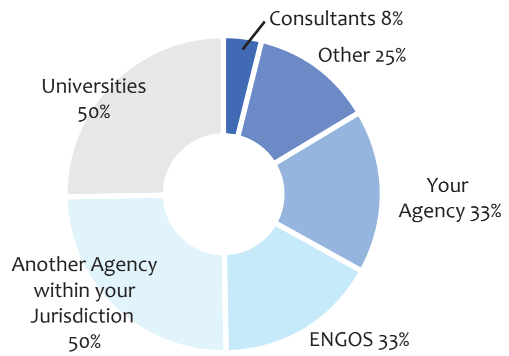


Figure 11: Climate change-related research being conducted in Canada's protected areas by 'researcher type' (respondents could select more than one category).

Capacity Issues Related to Climate Change Adaptation

Despite the limited response to date, it's apparent that Canadian protected areas agencies want to move forward on this issue. Over two-thirds of the agencies strongly 'disagreed' or 'somewhat disagreed' with the statement that *"there are too many uncertainties regarding climate change to develop adaptation strategies for protected areas"* and nearly two-thirds indicated that formal climate change discussions have taken place within their agency. Most of these discussions have occurred through various awareness and capacity-building initiatives, including workshops and other expert meetings. Nevertheless, protected areas agencies appear uncertain about how to proceed: 91% of the agencies reported that they currently *do not* have the capacity necessary to effectively respond to climate change. It comes as little surprise, therefore, that 83% of the agencies surveyed do not have a climate change policy or adaptation strategy specifically pertaining to protected areas or biodiversity conservation, or a climate change mitigation strategy (i.e., in-house plan to reduce greenhouse gas emissions). Moreover, of the 29 agencies currently without a climate change policy or adaptation strategy directly related to protected areas, only four (11%) stated they were currently in the process of developing one.

The lack of information on climate change and species-at-risk in Canada is of particular concern. Many of the species currently classified as 'at-risk' may be among the most vulnerable to climate change and least capable of adapting naturally given their typically small populations, limited suitable habitat, and exposure to external stressors. A screening level assessment of the impacts of climate change on endangered species in Canada determined that climate change might have a potential overall negative influence on more than half of all endangered species in Canada (Lundy, 2009). While relatively few species were projected to respond in an overall positive or neutral manner to climate change, a large portion of endangered species were classified as having insufficient information to generate a decision on the net influence of climate change. These results demonstrate the need for greater research and monitoring on climate change and consideration of the implications for species-at-risk management and policy. For example, Canada's *Species at Risk Act* (SARA) does not explicitly address the issue of climate change. Furthermore, limitations exist in SARA's time-sensitive definition of wildlife species eligible for protection in Canada and in the interpretation of SARA's mandates in the context of anthropogenically driven climate change.

Capacity constraints at the provincial/territorial and federal levels appear to be similar. All but one province/territory stated that they did not have the capacity to respond to climate change. This was rather alarming considering that the provinces and territories are responsible for over 95% of Canada's protected areas (encompassing about 50% of total ha protected). Common reasons included lack of staff and financial resources and inadequate internal scientific capacity to deal with climate change. Such findings are consistent with other sectors (e.g., agriculture, water and forestry) that are also challenged to mainstream climate change into current policy, planning, and management frameworks (e.g., Ogden and Innes, 2009).

These findings are also consistent with the national and provincial/territorial audits and assessments of protected areas programs, such as: *the Canadian Protected Areas Status Report* 2000-2005 (Environment Canada, 2006); the 2008 *March Status Report of the Commissioner of the Environment and Sustainable Development* (OAGC, 2008a); *Doing Less with Less: How Shortfalls in Budget, Staffing and In-house Expertise are Hampering the Effectiveness of MOE and MNR* (ECO, 2007); and the *Ontario Parks Program Audit* (AGO, 2002 and 2004). Consistent with the PACC survey findings, all of these independent reviews have raised concerns about the capacity of protected areas agencies to properly fulfill their mandates, which are diversifying and growing in complexity.

The Government of Canada's *Budget 2007* mandated dramatic cuts to several Environment Canada programs, including the Environmental Monitoring and Assessment Network (EMAN) (-50%), the Migratory Bird Sanctuary program (-50%) and the National Wildlife Areas program (-100%). Similarly, the Ontario Ministry of Natural Resources' (MNR) total operating budget has decreased by 35% since 1992 (ECO, 2007). These reductions in staffing levels and operating budgets have reduced capacity in management planning, enforcement, and ecological monitoring (AGO, 2002; ECO, 2007; OAGC, 2008a and 2008b). As the *Canadian Protected Areas Status Report* (2000-2005) concluded, such cutbacks are impacting the management effectiveness of protected areas agencies across Canada, and agencies are finding it increasingly difficult to implement actions identified in management plans, maintain and monitor the ecological integrity of their networks, and report systematically on the state of their protected areas and species-at-risk (Environment Canada, 2006; OAGC, 2008a and 2008b). With further financial constraints anticipated in many jurisdictions, the availability of funding for climate change is not likely to improve substantially in the short-term.

Case Studies on Protected Areas and Climate Change Adaptation in Canada

Despite limited resources reported in most jurisdictions, it is encouraging to see a number of efforts underway that contribute (albeit in many cases indirectly) to adapting to and mitigating some impacts attributed to climate change. Examples of beneficial actions include: increasing the number/density of protected areas; ensuring the inclusion of still unrepresented ecosystems and habitats; establishing large protected areas and focusing on connectivity to help facilitate movements of plants and animals; completing biodiversity inventories; undertaking ecological restoration initiatives; completing carbon valuation analyses and reducing carbon emissions in field operations; initiating trans-boundary collaboration; and, conducting climate change research, education and outreach activities including the application of agency websites to inform the public about protected areas and climate change issues. Although not tailored specifically to climate change, all of these efforts can help to mitigate climate change impacts and facilitate (albeit to an unknown extent) climate change adaptation over the 21st century and beyond. Moreover, Canada's protected areas managers and practitioners have ample local knowledge and technical expertise that will certainly facilitate adaptation both within specific protected areas and more broadly across networks of sites. The key will be to take these approaches and enhance and adapt them on the basis of new knowledge in order to explicitly and proactively increase the overall 'resiliency' of 'the system' to climate change impacts.

A number of Canadian jurisdictions have initiated adaptation initiatives in support of program development and implementation; some are working on specific adaptation strategies. As the peer-reviewed literature in this area is scarce, we have drawn on the grey literature, PACC Survey responses, and personal communications with key protected areas personnel to provide some examples of climate change initiatives sponsored by Canadian protected areas agencies. The PACC Survey revealed that Parks Canada Agency and Canadian Wildlife Service are taking proactive approaches to climate change and adaptation at the federal level and, in many respects, Parks Canada Agency is taking the global lead on the issue. At a provincial and territorial level, Ontario Parks, B.C. Parks, the Government of Newfoundland and Labrador, the Government of Yukon, and the Government of the Northwest Territories (GNWT) have all made significant progress in determining known and potential impacts of climate change on their protected areas systems and, in some cases, have begun identifying, evaluating and implementing adaptation practices. A number of Canadian-based ENGOs, including the Nature Conservancy of Canada (NCC) and the World Wildlife Fund (WWF) have also been proactively engaged in climate change research, communications and outreach, and have advanced science-based conservation approaches which have significant climate change adaptation value. In addition, a number of trans-boundary initiatives, including the Canadian Boreal Initiative (CBI) (CBI, 2009), the Algonquin to Adirondack (A2A) Conservation Initiative (A2A, 2009), the Yellowstone to Yukon (Y2Y) Conservation Initiative (Y2Y, 2009), and Two Countries/One Forest (Deux Pay/Une Forêt) (2C1F) (2C1F, 2009) have also begun to explore the implications of climate change for protected areas within their respective regions.

Although the following accounts are not fully inclusive of the range of activities currently underway across Canada, they are illustrative of the variety of initiatives currently being pursued. Combined with the PACC Survey results, these accounts help to reveal the state of existing efforts to cope with climate change issues affecting protected areas in different jurisdictions and different ecological regions of the country.

PACC Case Study 1: Parks Canada Agency

As the federal agency responsible for the protection and presentation of nationally significant examples of Canada's natural and cultural heritage, Parks Canada Agency currently manages 42 national parks, 3 national marine conservation areas, and 166 national historic sites. These areas protect over 30 million ha of land (approximately 3% of Canada's total land mass) and 1.9 million ha of marine and freshwater environments. Parks Canada Agency is informing the development of the federal government's climate change adaptation and mitigation strategies by bringing focus to the role that well-connected, well-managed networks of parks and other protected areas play in enhancing the adaptive capacity of ecosystems, biodiversity, and people to climate change (i.e., ecosystem-based adaptation). It is evaluating potential synergies between actions that contribute to climate change adaptation (e.g., park establishment, restoration, and landscape connectivity) and climate change mitigation (i.e., carbon storage and sequestration) and it has taken steps to reduce its own greenhouse gas emissions.

Ecosystem-based Adaptation

Parks Canada continues to take a range of actions that enhance Canada's capacity to adapt to climate change:

1) The establishment of new national parks and other protected heritage areas, particularly in vulnerable northern regions;

2) The effective management of its network of national parks and other protected areas; and,

3) Local, regional, and national partnerships.

Since 2006, Parks Canada Agency, in collaboration with Aboriginal communities, and other partners and stakeholders, has added more than 3 million ha to its protected heritage areas network. Highlights include:

- A six-fold expansion of Nahanni National Park Reserve to over 3 million ha thereby securing important ecosystem values including most of the watershed of the South Nahanni River, and lands of great cultural value to area First Nations;

- The creation of the 1 million ha Lake Superior National Marine Conservation Area - the largest freshwater protected area in the world;

- The permanent protection of Saoyú – Æehdacho National Historic Site - a more than 500,000 ha Aboriginal cultural landscape in the Northwest Territories of great importance to the Sahtu people; and,

In addition, more than 4 million ha of land and water in Canada's North have been newly protected as an interim step to the eventual creation of two more national parks. Efforts to establish new protected heritage areas continue in accordance with system plans.

Many national parks now address climate change in their management plans, and risk assessments and impact reduction measures have been conducted at several national historic sites. Below are highlights of recent achievements in management practices that contribute to enhancing Canada's adaptive capacity.

Ecological Restoration

Restoration of ecosystems can be a cost-effective ecosystem-based adaptation strategy (CBD, 2009). In 2007, Canada's federal, provincial and territorial parks and protected areas ministers agreed to *Principles and Guidelines for Ecological Restoration in Canada's Protected Natural Areas* (Parks Canada Agency and the Canadian Parks Council, 2008). These guidelines are being implemented in active management and restoration programs that aim to re-establish healthy and resilient natural ecosystems (Parks Canada, 2008 and 2009a).

Cultural Resource Management

Sound conservation practices reduce the vulnerability and increase the resilience of cultural resources to impacts from a range of stressors, including climate change. Parks Canada Agency's *Cultural Resources Management Policy* and the *Standards and Guidelines for the Conservation of Historic Places in Canada* guide the application of best practice management. In 2008, a study was initiated to assess current knowledge on the effects of climate change on the Agency's cultural resources, providing an important baseline and identifying climate change indicators to assist in maintaining the value of significant cultural resources into the future.

Research and Monitoring

In the early 2000s, Parks Canada commissioned an assessment of climate change impacts on Canada's National Parks, and compiled climate scenarios for each park (Scott and Suffling, 2000; Scott, 2003). Parks Canada also supported research on the impact of climate change on nature-based tourism (Jones and Scott, 2006a). Most recent studies have focused on local and regional impacts and adaptation options, for example:

- Sea level rise and storm surges at Kouchibouguac National Park;
- Garry oak ecosystem of Gulf Islands National Park Reserve;
- Permafrost changes at Wapusk National Park;
- Glacier extent at Glacier National Park;
- Sea level and coastal erosion at Fortress of Louisbourg National Historic Site; and,
- The impact of climate change on the defensive wall of Prince of Wales Fort NHS.

In March 2009, Parks Canada Agency launched a monitoring program to measure, assess and report on indicators of ecological integrity in national parks, including the effects of climate change. Monitoring, in combination with research and modelling, will play an important role in developing proactive approaches to dealing with the effects of climate change on park ecosystems, particularly in Canada's North. As a distributed monitoring network based in terrestrial and marine protected areas, Parks Canada Agency's ecological monitoring program can also form the basis for understanding impacts of climate change on the broader land and seascape, informing land-use planning, marine planning, environmental assessment, and other processes important for sustainable development.

Partnerships

Parks Canada has developed strong relationships with Aboriginal people, particularly in the North, to cooperatively manage Canada's protected heritage areas. These relationships can support community adaptation to the impacts of climate change on traditional resource harvesting and other cultural practices, as well as by diversifying economies through job creation.

Parks Canada is engaged in a variety of partnerships with other federal agencies, such as Environment Canada and Natural Resources Canada, and with provincial and territorial parks agencies through the Canadian Parks Council (CPC), to facilitate understanding and information sharing related to climate change adaptation. The Agency is also a partner in the Ouranos Consortium to model climate change impacts on biodiversity in Québec.

Engaging Canadians

Parks Canada hosts approximately 22 million person-visits per year and has a mandate for public outreach education. Thus it plays an important role in helping Canadians and international visitors understand the value of protected heritage areas in enhancing Canada's resilience and capacity to adapt to climate change. By sharing information about impacts and adaptation measures in these areas through visitor experience and public outreach education programs, it also helps to create awareness and long-term support for Canada's climate change adaptation and mitigation efforts.

Synergies with Mitigation

While maintaining a focus on the role of national parks and other protected areas in contributing to climate change adaptation, Parks Canada Agency is also examining how its park establishment and management efforts, particularly ecological restoration, can contribute to enhanced carbon storage and sequestration. Its internal efforts to reduce greenhouse gas emissions from its operations have already been successful; 2007/2008 emissions were about 10.5% lower than 1998/1999 emissions (Ferland, 2008) (Figure 12) – well below the Agency's target of 5.2%.

Based on a search of scientific and government publications, park agency websites, and consultation with park experts, to our knowledge no other national park agency has adopted formal emission reduction targets, let alone achieved them. In this respect, Parks Canada Agency is demonstrating international leadership among protected areas organizations on GHG mitigation from its operations (Keenleyside, 2009).

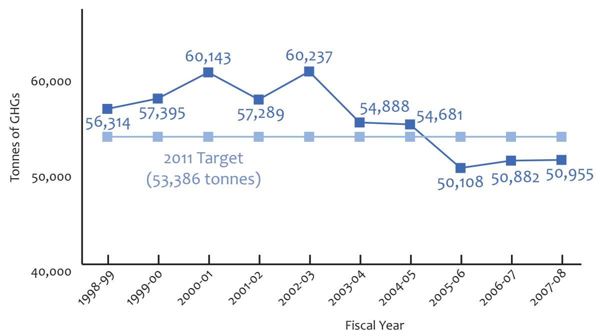


Figure 12: Parks Canada Agency greenhouse gas emissions over the past decade (1998/1999 to 2007/2008) (Ferland, 2008).

PACC Case Study 2: Canadian Wildlife Service

Environment Canada assumes responsibility for the federal interests in wildlife conservation through the Canadian Wildlife Service (CWS). As part of this mandate, CWS administers Canada's second largest network of protected areas comprised of National Wildlife Areas (NWAs) and Migratory Bird Sanctuaries (MBSs). Altogether the system includes 143 areas with a total area of 11,892, 533 ha. Beyond this federal system of protected areas, CWS also has interests in other provincial, territorial, and non-governmental protected areas that contribute to the federal mandate for species and habitat conservation.

CWS has embarked upon some initial work to assess the implications of climate change on the distribution of species and habitats that have an important bearing on the role of protected areas in their conservation. Currently four initiatives are underway to assess the impacts of climate change on protected areas. In concert with CCEA, one of these involves a pilot study drawing on Conservation Areas Reporting and Tracking System (CARTS) data to project implications for species representation in national, provincial and territorial protected areas under various climate change scenarios. The three other studies are in-house assessments largely aimed at furnishing information primarily geared to protected areas central to the interests of CWS (Lindsay, 2009). The four initiatives in more detail include:

1) Gap analysis of species representation in Canada's protected areas network, according to current species distributions and distributions predicted under climate change scenarios.

2) Investigation of consequences of climate change for CWS protected areas network. Examples include:
    - Large scale (continental, national, regional) species/biome shift modelling;
    - Climate change and conservation objectives vulnerability assessments;
    - Consequences of climate change for network planning; and,
    - Prioritizing climate change adaptations options.

3) Vulnerability assessments of individual protected areas. Examples include:
    - Consequences of climate change for species of conservation concern (e.g., migratory birds, species-at-risk) and rare/unique habitats;
    - Potential climate change impacts on species and ecosystem processes and structures;
    - Potential climate change impacts on permafrost and consequences for local hydrological regimes;
    - Potential impacts of sea level rise on shorebird coastal staging/feeding areas; and,
    - Potential shifts in marine resources such as forage fish populations; and,

4) Inclusion of climate change indicators in the selection of candidate protected areas in Northwest Territories.

PACC Case Study 3: Nature Conservancy of Canada

The Nature Conservancy of Canada (NCC) utilizes a science-based approach for its efforts on planning, securing and managing natural areas across Canada. Priorities for the conservation of natural areas are drawn from 'Conservation Blueprints', which present biodiversity portfolios of landscapes, communities and species for natural regions across southern Canada (e.g., Riley *et al.*, 2007; Henson and Brodribb, 2005; Wichert *et al.*, 2005). *Natural Area Conservation Plans* (NACPs) are then developed for priority areas identified in the Blueprints, setting out a vision, goals and objectives for specific natural areas along with a prescription of conservation actions for the securement and stewardship of biodiversity features and processes targeted for conservation. The potential impacts of climate change are considered on a case-by-case basis in developing and implementing NACPs.

Although the planning areas of NACPs vary in size, they tend to be landscape scale units that are dynamic in nature and enable shifts in species, community composition and structure. Climate change is one factor that may be considered in the selection and the design of these areas, and one of the threats considered in developing management regimes for sites secured by NCC through these plans. For example, in Atlantic Canada, potential sea level changes attributed to climate change are considered in sites housing coastal environments and communities, and special conservation measures may be necessary to conserve targeted species, such as piping plover (*Charadrius melodus melodus*) or the Gulf of St. Lawrence beach pinweed (*Lechea maritima* var. *subcylindica*). Similarly, the control of invasive species, such as reed grass (*Phragmites communis*)—the spread of which may be enhanced by water level changes induced by climate change—may be targeted for specific management efforts. Elsewhere, in Ontario and western Canada, management regimes for prescribed burns in prairie and savannah ecosystems may be custom-tailored to combat invasive species favoured by climate change. These and other planning and management needs are carefully determined on a site-specific basis taking into account the nature of the threat and the ability to mitigate any impacts that may be detrimental to ecosystems and species targeted for conservation.

In recent years, NCC has developed a robust approach toward the stewardship of secured lands and Conservancy staff have acquired a great deal of experience and expertise on ecological restoration. Stewardship efforts have involved the development and application of innovative techniques so that adaptive management has become a hallmark of the Conservancy's core stewardship culture. Although not yet fully engaged on adaptation efforts to confront climate change, NCC's flexibility and innovative approaches position it well to introduce and apply specific measures and actions as needs are identified. In addition to the foregoing measures, NCC staff are currently assessing the contribution that the +2 million acres of lands secured to date by the Nature Conservancy across Canada is making to carbon sequestration (Kraus, 2009).

PACC Case Study 4: Yukon Territory

Protected areas have been recognized as 'natural laboratories' for studying climate change impacts. Qikiqtaruk (Herschel Island) Territorial Park and Kusawa Territorial Park have become focal points for climate change research in Yukon Territory. These parks have experienced a number of climate change related impacts, including coastal erosion, permafrost and vegetation changes, bird and wildlife population changes [e.g., declines in black guillemot (*Cepphus grylle*) populations associated with changes in sea ice], and slope instability and landslides in recreational areas. As a result, these parks have gained national and international attention for the dramatic climate change impacts that are occurring in Yukon and have also become focal points for educating the public on climate change impacts (Downie, 2009).

PACC Case Study 5: Northwest Territories

The NWT *Protected Areas Strategy* (PAS) of Northwest Territories (NWT) is a community-guided planning process to protect culturally and ecologically important areas in the NWT by using both traditional knowledge and western science (Government of the Northwest Territories, 1999). The NWT PAS Science Team has made some preliminary efforts to determine how to incorporate climate change as a factor in protected area planning, both in terms of what data are available and useful and in terms of making the information relevant to communities.

In 2006, the NWT PAS Science Team commissioned the Nature Conservancy to complete a biome shift analysis. Output of a dynamic global vegetation modelling project was analyzed, combining the raw modelled vegetation zones into biomes, re-projecting the raw geographic data into equal-area projection for spatial analysis, and determining areas of projected biome change for the period 1990-2100 (Gonzalez *et al.*, 2005). These analyses employed a general circulation model, an emissions scenario, and a global vegetation model. The spatial resolution of the output was 50 km, which was interesting from a regional perspective, but too coarse to be useful for protected areas planning.

Currently, the PAS Science Team is working with the University of Alaska Fairbanks Scenarios Network for Alaska Planning (SNAP) program to identify the best-performing subset of global climate models for northwest Canada and to produce performance-weighted, downscaled climate data. These data will then be available to the PAS and others for a wide range of analyses.

Additionally, in 2008 the Government of the Northwest Territories released the NWT *Climate Change Impacts and Adaptations Report* and it is developing a *Climate Change Adaptation Plan* for NWT. Establishing parks and protected areas has been identified as an important way to minimize the impacts of climate change on the biodiversity of NWT. For more information on the NWT *Protected Areas Strategy*, please visit: http://www.nwtpas.ca/.

PACC Case Study 6: B.C. Parks

B.C. Parks has been actively addressing climate change concerns and implementing adaptive measures aimed at enhancing the overall resilience of the protected areas system to potential climate change impacts. Examples of such measures include: climate change-integrated system planning; the establishment of large protected areas; focusing on connectivity; and, education, interpretation and outreach activities. The *Protected Areas Strategy* (Government of British Columbia, 1993) that called for representation across the province guided B.C.'s dramatic increase in protected areas from 6% in 1990 to more than 14% in 2008. As a result, B.C. currently has a system that is well distributed across the geographical and ecological breadth of the province. An analysis of future predicted climate envelopes revealed that B.C.'s current protected areas system would continue to represent the province's climates, latitudes and elevations as the climate shifts.

An analysis of the size of the parks in the B.C. system indicates that it includes 10 park complexes greater than 270,000 ha. Six of these parks are entirely within the province and four include some areas in adjacent jurisdictions (Yukon, Alaska, Washington, Montana, and Alberta). These areas make up about 60% of B.C.'s protected areas. B.C. is also conducting an analysis of connectivity at a coarse scale to help to identify areas that are strategically important to connectivity under changing climatic conditions.

B.C. Parks' ecosystem restoration program has primarily focused on restoring fire-dependent ecosystems. The program serves the dual purpose of restoring resilience to forested ecosystems and managing fuel loads. Two long-term (20-year) management plans include climate change pilot projects that will be assessed for wider application (Mt. Robson Park and Mt. Assiniboine Park).

B.C.'s *Protected Areas Strategy* includes a goal to conserve marine ecosystems. Climate change planning has identified marine shorelines as particularly susceptible to change. B.C. Parks is conducting research on factors that contribute to shoreline resilience, relationships between physical and biological processes, and protected areas concepts of representation, viability and connectivity.

Finally, B.C. Parks has developed a page for its parks website that outlines how climate change affects protected areas and what the agency is doing to address it. Information has been supplied to interpreters to help them create programs for the public that include information on climate change (Morrison, 2009).

PACC Case Study 7: Nova Scotia

The Government of Nova Scotia's Protected Areas Branch is engaged in a systems planning process in support of its legislated goal to have 12% of the province designated as protected area by 2015. The initial stage of this process—a science-based evaluation of priority areas for protection —was undertaken in co-operation with the Colin Stewart Forest Forum (CSFF). The CSFF consists of representatives of the province's four largest forestry companies and several leading ENGOs, with technical assistance from the provincial Departments of Environment and Natural Resources. The CSFF's goal was to develop a mutually agreeable proposal toward the completion of the protected areas network, which mitigated associated wood supply and cost impacts for the forestry industry. The proposal was presented to the provincial government in late 2009 and forms a major science and policy contribution to the 12%-by-2015 planning and consultation process.

The 12%-by-2015 goal, while not adopted specifically because of climate change, will take the province from the current level of 8.6% with the following results: increasing the number and density of protected areas, and thereby helping to maintain some level of connectivity through more 'stepping stones'; establishing more large nodes; and, potentially creating several corridors oriented mostly along rivers, which may have value under changing climatic and ecological conditions.

The CSFF has identified the narrow, low-lying Isthmus of Chignecto as a priority area for protection. This candidate site would incorporate some of the highest ground in Nova Scotia and connect it to the rest of North America and, as such, it has high climate change adaptation value. The CSFF has also considered the value of low-lying coastal bogs as the possible locales for future new salt marshes in its site selection process (MacKinnon, 2010).

PACC Case Study 8: Ontario Parks

Among the Canadian provinces and territories, Ontario Parks is taking a leading role with respect to climate change adaptation and mitigation. At the 'corporate' level, adaptations have tended to concentrate on scenario formulation, risk and vulnerability assessments, capacity-building, and awareness campaigns. The Ontario Ministry of Natural Resource (MNR)'s Climate Change Program has played an important supporting role through the provision of research, information dissemination, public education, and financial assistance and/or participation in workshops and conferences.

MNR staff and partners have completed 300+ reports, publications, posters, and extension products that address a variety of issues relating to the management of natural assets in a rapidly changing climate including natural heritage areas like parks. In addition, the MNR established a Climate Change Research Report Series in 2005 and at the time of printing this series had published more than 13 reports (e.g., Wotton *et al.*, 2005; Boivin *et al.*, 2005; Colombo *et al.*, 2005; Hunt and Moore, 2006; Colombo *et al.*, 2007; Lemieux *et al.*, 2007; Carter *et al.*, 2007; Browne and Hunt, 2007; Varrin *et al.*, 2007; Colombo, 2008; Candau and Fleming, 2008; Minns *et al.*, 2009, McKenney *et al.*, 2010; and Hasnain *et al.*, 2010) and nine Climate Change Information Notes (Warner *et al.*, 2003; Colombo, 2006; Obbard *et al.*, 2006; Colombo *et al.*, 2006; Jackson, 2007; Bird and Boysen, 2007; Trumpickas *et al.*, 2008; Gleeson and La Croix-McDougall, 2009; Gleeson *et al.*, 2009).

A scoping report to explore potential impacts and implications of climate change for Ontario Parks' policy, planning and management frameworks was completed in 2007 (Lemieux *et al.*, 2007). Managers, planners, and decision-makers from head office have participated in several capacity-building initiatives as well, such as the Centre for Applied Sciences in Ontario Protected Areas (CASIOPA) (formerly the Parks Research Forum of Ontario, PRFO) State of the Art Workshop on Climate Change and Protected Areas (Beveridge *et al.*, 2005). The aim of this workshop was to help foster climate change understanding and define critical impacts and adaptation issues confronting protected areas managers.

Within respective park regions (Ontario Parks is organized according to six administrative regions), a variety of adaptation actions have been undertaken. Although not all of these actions were specifically taken in response to climate change, they contribute to reducing greenhouse gases and adapting to a changing climate. Examples of adaptations to programs classified as 'Operations and Development' include increased operations in the fall to accommodate increased visitation, alternative vehicle solutions, energy conservation initiatives, and retrofitting existing buildings to reduce greenhouse gas emissions and energy costs. There also has been increased monitoring of climate change-related impacts—four regions are now specifically monitoring for region- or park-specific climate change impacts (Northeast, Northwest, Central and Algonquin) and staff at two provincial parks (Algonquin and Rondeau) recently installed weather stations for climate monitoring purposes. Table 6 summarizes recent climate change initiatives undertaken by Ontario Parks.

Table 6: Ontario Parks' actions to-date on climate change (information prepared by Ontario Parks).

Strategic Initiatives
• The Ontario Parks *Go for Green Strategy* was prepared to outline specific strategies for Ontario Parks to 'green' its operations. The strategy complements the broader government initiative, *Go Green, Ontario's Action Plan on Climate Change*, and addresses specific actions related to capital, operations, and program development and marketing.
Policy
• Climate change adaptation will be considered in the development of the new planning manual and in the review of policies and procedures.

Table 6: Cont'd

Selection and Design of Protected Areas
• The selection and design of the protected areas system is based on representing the full range of Ontario's biodiversity natural heritage. As ecosystems move and change in response to climate change, some representative features may be lost from the fixed boundaries of protected areas. Adjustments may be needed in the selection and design criteria that are currently used to better allow species and ecosystems to migrate in response to climate change. Work is continuing on the 'Far North' initiative, which as aimed at protecting 50% of the province north of 50.
• Also in collaboration with the University of Waterloo, Ontario Parks in partnership with the broader MNR and with funding from Natural Resources Canada, have designed and conducted a series of Delphi surveys to identify and evaluate potential climate change adaptation options (Lemieux *et al.*, 2008). The seven-step adaptation framework is outlined on page 71 of this report.
• A series of *State of the Protected Areas Reports* are in preparation that will include a component on climate change. The reports are based on an ecological monitoring framework with criteria and indicators. In addition to the climate change component, the report will include other measures related to climate change, such as fire, insect infestations and invasive species.
• Weather stations have been installed in two parks and climate change considerations, such as temperature, water level and flow monitoring, is beginning to be incorporated into some park monitoring strategies.
Management Direction
• Currently, few plans or statements explicitly consider climate change adaptation. The development of additional guidance and technical support is likely to be needed in order to address climate change adaptation in management planning in future.
Research and Monitoring
• Ontario Parks has been working in collaboration with the University of Waterloo to investigate the implications of climate change on the protected areas system and to develop adaptation options. A state of the art workshop was hosted by the Parks Research Forum of Ontario (PRFO) for Ontario Parks staff and partners in support of the study in 2005. Workshop proceedings are documented in the PRFO publication *Climate Change and Ontario's Parks* (Beveridge *et al.*, 2005). Preliminary results of the study are presented in the report, *Climate Change and Ontario's Provincial Parks: Towards an Adaptation Strategy* (Lemieux *et al.*, 2007). The report includes potential implications of climate change for the protected areas system and program based on a literature review and modelling of likely changes in vegetative biomes.

Table 6: Cont'd

Natural Heritage Education
• An award winning poster series, *'Hop to It'*, was developed for use in park interpretive programs and schools. Climate change is featured in one of the posters. • A climate change module, based on the '*Hop to It*' series, is available on the Ontario Parks 'Campsite 24' educational website for students and teachers (see http://www.campsite24.ca). • Climate change has been incorporated into natural heritage education at many parks since 2007. A climate change backpack toolkit was provided to Natural Heritage Education (NHE) leaders at the NHE conference in 2008 to assist with climate change programming. • The '*Park Once Challenge*' has been promoted at several parks to encourage campers to park their vehicles during their visit and get around on foot or bicycle. • The 2008 Natural Heritage Education Conference included training on climate change.
Operations and Development
• Alternative vehicles are being utilized in several operating parks to reduce vehicle emissions. These include hybrids and other types of vehicles such as gators, electric cars and bicycles instead of pickup trucks. • All facets of Leadership in Energy and Environmental Design (LEED) for building design are being explored for new buildings or retrofits in provincial parks and implemented as appropriate. These include considerations such as: solar water heating and solar power; energy-saving technology such as Compact Fluorescent Light (CFL) bulbs; water saving efforts such as low-flow shower heads; instantaneous water heaters instead of 60-gallon hot water tanks; right sizing facilities for the specific site and purpose; and recycling materials. • Some parks are increasing operations in the fall to accommodate increased visitation.

Moving Forward on Climate Change Adaptation

New governance models with First Nations, such as that being advanced for the Taku River Tlingit First Nation in the Pacific Northwest, can serve to preserve traditional homelands and Aboriginal cultures in extensive wilderness settings that help to mitigate the impacts of climate change. (Photo Credit: Brian Evans, courtesy Round River Conservation Studies)

Setting the Framework

It has been estimated that species are currently in the 'first-order' of ecological response to this modern climate change episode (i.e., adjusting phenotypes and minor adjustments in geographic ranges) (Barnosky *et al.*, 2003). However, a growing number of researchers contend that if the climate envelopes in which species and ecosystems have adapted over the past several interglacial periods rapidly disappear, widespread extinctions may result. Although there is much uncertainty about the timing, extent, and manner in which ecosystems and other protected area assets (e.g., recreational opportunities) might respond to evolving climatic conditions, it is critically important that management agencies identify, assess, and implement adaptation options that could reduce the vulnerability of Canada's protected areas (and their constituent biodiversity) to climate change. Adaptive capacity in the protected areas sector, however, is largely determined by factors other than climate change, including access to financial and other resources, human capital, and political will, and it is important to understand how such external factors influence an agency's ability to adapt.

Perhaps as a result of these additional challenges, there have been a limited number of publications that address climate change adaptation options specifically for protected areas (Halpin, 1997; Hannah *et al.*, 2002; Welch, 2005; Scott and Lemieux, 2005; Huntley, 2007; Dunlop and Brown, 2008; and more recently West *et al.*, 2009 and Baron *et al.*, 2009 are the exceptions). Table 7 summarizes this literature in a portfolio of adaptation options available to conservation professionals and protected area managers. This protected area adaptation portfolio is organized into four main areas: system planning and policy; management; research and monitoring; and, capacity-building, awareness and corporate culture and function. To evaluate the scientific and pragmatic merits of each adaptation option is beyond the scope of this report (the desirability and feasibility of many of these adaptation options are discussed in Lemieux *et al.*, 2008); however, some important points about the state of adaptation discussions for protected areas are proffered in the following sub-sections.

Table 7: Climate change adaptation portfolio for protected areas agencies (originally compiled by Scott and Lemieux, 2005 and updated using Lemieux *et al.,* 2008; West *et al.*, 2009 and Baron *et al.*, 2009).

System Planning and Policy
• Expand the protected areas network where possible and enlarge protected areas where appropriate. • Improve natural resource planning and management to focus on preserving and restoring ecosystem functionality and processes across regional landscapes. • Select redundant reserves. • Select new protected areas on ecotones. • Select new protected areas in close proximity to existing reserves. • Improve connectivity and protected areas systems. • Continually assess protected areas legislation and regulation in relation to past, anticipated or observed impacts of climate change. • Maintain representation. • Identify refugia, i.e., environments that are less affected by climate change than other areas. • Identify heterogeneous areas.
Management (including active, adaptive ecosystem management)
• Include adaptation to climate change in the management objectives and strategies of protected areas. • Implement adaptive ecosystem-based management. • Enhance the resiliency of protected areas to allow for the management of ecosystems, their processes and services, in addition to ‘valued’ species. • Manage for change when ecosystem resiliency has been breached. • Minimize external stresses to facilitate autonomous adaptation. • Eliminate non-climatic *in-situ* threats. • Create and restore buffer zones around protected areas. • Implement *ex-situ* conservation and translocation strategies if appropriate. • Increase management of the landscape matrix for conservation. • Mimic natural disturbance regimes where appropriate. • Revise protected area objectives to reflect dynamic biogeography. • Prevent or reverse the establishment of invasive non-native species that threaten native species or impede current ecosystem function. • Systematically broaden and integrate management plans as much as possible. • Consider triage approaches to mitigation.

Table 7: Cont'd

Research and Monitoring • Make resources available to aid research on the impacts of past (e.g., paleo-ecological change) and future climate change (e.g., projected species composition changes). • Utilize parks as long-term integrated monitoring sites for climate change (e.g., monitoring of species, especially those at-risk or extinction-prone). • Identify specific 'values' at risk to climate change. • Conduct regional modelling of biodiversity response to climate change. • Incorporate climate change impacts in protected areas 'state-of-the-environment' reporting. • Implement science-based management will be necessary because past experience may not serve as a guide for novel future conditions.
Capacity-building, Awareness and Corporate Culture and Function • Strengthen professional training and research capacity of protected area staff with regards to climate change. • Capacity-building and awareness should proceed with the goal of securing public acceptance for climate change adaptation. • Partnerships/collaboration with greater (regional) park ecosystems stakeholders to respond to the need for climate change adaptations. • Improved collaboration/stewardship from local to international scales. • Make resources available for investing in active, adaptive management. • Develop precautionary approaches (such as disaster preparedness and recovery systems) through forecasting, early warning and rapid response measures, where appropriate. • Consider implementing human resource management policies that actively manage for uncertainty, e.g., 'safe-to-fail' policies. • Develop a culture of trust between public servants and their public to facilitate acceptability of climate change-related policies and management decisions.

While some recommendations identified in the scientific literature may be of immediate benefit to conservation-oriented governments or organizations, others have been criticized as being so far removed from the realities in which protected area managers work that they are largely irrelevant to practice (Lemieux *et al.*, 2008). Welch (2005) similarly concluded that the limited protected area-climate change literature provides little guidance to the managers of already established protected areas. It is only recently that the desirability and feasibility of adaptation options have begun to be explored within the institutional realities of jurisdictions and agencies (see Lemieux *et al.*, 2008 for a case study on Ontario Parks and Ogden and Innes, 2009 for a discussion in the Canadian forestry sector, for examples).

The scientific literature on climate change adaptation overwhelmingly suggests that adapting *now* (i.e., mainstreaming climate change into policy, planning and management program functions) will be more effective than adapting later (i.e., more cost-effective and efficient in reducing the potential for irreversible impacts, such as species extinction). Notwithstanding the need to act sooner rather than later, protected area planners, managers and decision-makers remain unsure as to how to go about adapting in an effective and efficient manner.

In addition, there remains a significant gap between the perceived importance of climate change and the capacity (i.e., funding, staff expertise, etc.) of protected areas agencies and organizations to respond to the challenges of rapid climate change. The ability of protected areas agencies across Canada is currently constrained by insufficient flexibility in policy and political will, as well as limited access to necessary financial resources and human capital.

The challenge for protected areas planners, managers and decision-makers in the short-term, therefore, will be to create and maintain an 'enabling environment' that encourages staff and partners to adapt to the emerging threats and to take advantage of the opportunities associated with climate change when they emerge.

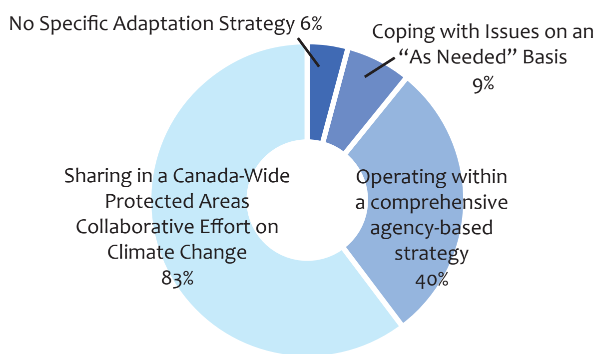
There is an evident lack of strategic response in the policy, system planning and management programs of various jurisdictions. No strategy (or action plan) specific to any protected areas agency has been developed to help with decision-making at the regional or park levels. This lack of response in most of the policy, planning and management functions gives the impression that many jurisdictions may be unprepared to deal effectively with the more widespread and complex impacts that are anticipated as the climate continues to change throughout the 21st century.

While constraints such as limited financial resources, limited capacity, and lack of understanding of real or anticipated climate change impacts need to be reduced, an immediate concern for protected areas agencies is the further strengthening and development of relational professional networks at all scales. Climate change education, capacity-building, and information dissemination has largely occurred through external conferences (i.e., 'piggy-backing') rather than through formally established networks. Moreover, only about one-half of the agencies participating in the PACC survey are actively involved in climate change dialogue and capacity-building initiatives (e.g., staff participation in workshops and conferences and staff training, etc.), which suggests that adaptive capacity will remain low for the foreseeable future. Recognizing complementary strengths and weaknesses between and among agencies will be critical in any collaborative effort to address climate change. Collaboration could be enhanced through the establishment of professional networks. Examining and communicating the potential role and contribution of protected areas in helping communities to mitigate and adapt to climate change are also important research and policy avenues that have not been explored in any meaningful way.

Given the multi-scale and cross-jurisdictional nature of climate change impacts, independent top-down approaches will not suffice in the long-term. Protected areas planners and managers will need to exchange practical experience and share lessons-learned on the strategic and tactical aspects of climate change adaptation; analyze the specific challenges of adapting protected areas management to climate change in the trans-boundary context; and, exemplify how trans-boundary cooperation can be incorporated into climate change adaptation strategies: from the assessments vulnerability, potential impacts (both positive and negative), and to the selection of compatible and mutually beneficially responses.

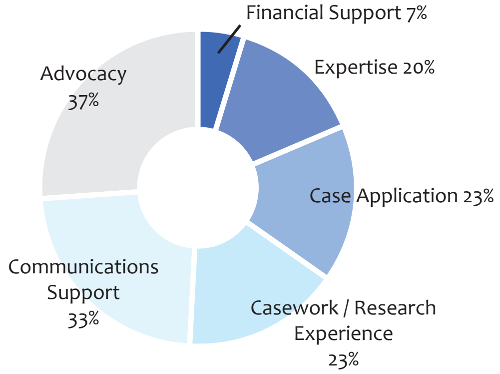
A more integrated and collaborative approach will be needed if protected areas agencies are to address effectively the climate change issue. Nearly all protected areas agencies participating in the PACC survey (86%) noted that they would be willing to participate in either a nation-wide working group or workshop on climate change and protected areas. Furthermore, 83% held the position that a nation-wide collaborative effort on climate change would be a suitable approach to adaptation (Figure 13).

Figure 13: Protected areas agencies selected preferences from among suggested approaches to climate change adaptation (by % of respondents; agencies could select more than one option).



Communicating about the impacts of climate change and associated agency management responses is one of the most important responses and fortunately there appears to be adequate capacity to communicate climate change messages to staff, members of specific associations and groups, and to the general public. A third of the PACC respondents indicated that they would be prepared to provide advocacy and communications support to a national working group or national workshop (Figure 14). On the other hand, few agencies are in a position to provide financial resources or human assets (i.e., scientific expertise).

Figure 14: Resources protected areas agencies would be willing to provide for a climate change and protected areas working group or a nation-wide conference on the topic (respondents could select more than one option).



Pursuing Measures for Adaptation

By and large, agencies across Canada employ similar approaches to the selection, protection, management, and use of protected areas. Indeed, conventional views of protected areas are increasingly recognizing that the entire range of protected areas designations is necessary to fully complete a comprehensive system of sites that represent the spectrum of natural diversity and fulfill the many associated objectives for biodiversity conservation (e.g., Dudley, 2008; Gray *et al.*, 2009). With these fundamentals in mind, and taking into consideration the PACC survey results coupled with the models, case studies, and other experiences presented within this report, this section discusses some of the core principles that require consideration in efforts to advance adaptation measures for protected areas.

The Role of Protected Areas

The Global Mission

Protected areas are viewed as the most common and effective response to ecosystem degradation, including biodiversity loss, and are called for under the United Nations (UN) *Convention on Biological Diversity* (CBD) (Article 8) and the *Canadian Biodiversity Strategy* (Government of Canada, 1995). In line with this international recognition, Canadian protected areas have traditionally served many objectives, generally including:

1) The permanent protection of representative ecosystems, biodiversity, and other significant elements of natural and cultural heritage;

2) The retention of representative and unique ecological areas to provide opportunities for scientific research, monitoring and training;

3) The provision of educational and learning opportunities for people to increase their knowledge and appreciation of Canada's natural and cultural heritage;

4) The provision of opportunities for nature-based tourism, outdoor recreation and passive enjoyment; and,

5) The delivery of critical ecological functions and services that contribute to broader ecosystem health and socio-economic objectives.

Although forecasts for climate change project serious environmental impacts with consequential affects on protected areas, in all likelihood these five pillars will persist as an over-arching framework for agencies charged to establish protected areas in Canada and other jurisdictions.

Ecological Goods and Services

Protected areas could become increasingly viable under emerging payments for environmental services schemes, such as through carbon sequestration and 'biodiversity banking' (often referred to as 'biodiversity credits'). Data from the UNEP-WCMC suggests that there are already 312 Gt of carbon stored in the world's protected areas network, or 15% of the world's terrestrial carbon stock (UNEP-WCMC, 2008). Given that many protected areas provide complete protection of forests, grasslands, wetlands, rivers, and lakes, biodiversity credits and ecosystem service credits could be assessed, valued, accrued, and integrated into the 'mainstream economy'. And while there remain significant barriers to mainstreaming ecological and biological values into the traditional economy, ongoing and growing experience with the concept of carbon credits and the results of numerous studies that examine techniques to value ecological goods and services hold promise for a robust marketplace that accounts for the full range of natural assets that are protected in natural heritage areas and on intervening landscapes and waterscapes (e.g., Costanza *et al.*, 1997; Wilson, 2008; Anielski and Wilson, 2003).

The potential for inclusion of carbon credits and other natural asset values could potentially offer additional criteria by which protected areas are valued, established, restored, or connected. Recent experiences with regulatory regimes, such as wetland and conservation banking in the United States, tradeable forest conservation obligations in Brazil, and habitat compensation requirements in Australia, Canada and the European Union, have been supplemented by growing interest in the potential of voluntary biodiversity offsets (IUCN, 2004). When defining offsets, the ecological value of the offset site in the landscape context and its potential contribution to landscape connectivity and buffer zones are considered (Van Teffelen *et al.*, 2006; Business and Biodiversity Offsets Programme, 2009). The identification of areas to offset estimated impacts consider a number of priorities, including ecological corridors or areas contributing to important ecological processes (Araújo, 2009a). Such considerations certainly have climate change adaptation value in the greater landscape context. While no studies to date on biodiversity offsetting have incorporated climate change explicitly, the role of offsets in providing permeable landscapes between protected areas requires further investigation.

> *"Sufficient evidence now exists to indicate that early implementation of new protected areas is likely to substantially reduce the threat climate change poses to biodiversity."* (Hannah, 2008: 201)

Ecological Representation

The Foundation Construct

Systematic planning for protected areas was introduced as a planning tool in the mid-20th century and rapidly evolved in response to recommendations by the International Union for Conservation of Nature (IUCN) (Dasmann, 1972, 1973) and other organizations to establish a network of 'representative' samples of the world's ecosystems. In Canada, 'system planning' efforts emerged in the 1960s and 70s in response to global efforts to adopt more methodical approaches for the selection of parks and other protected areas. The Natural Regions framework adopted by Parks Canada during that period was often regarded as a flagship example of this movement, and it provided an example for other jurisdictions.

Shortly after its establishment in 1982, the Canadian Council on Ecological Areas (CCEA) developed an interest in advancing a national framework for protected areas. CCEA adopted the ecozone framework for Canada (Wiken *et al.*, 1996) as the basis to partition the country into pre-defined ecological regions, with the aim of creating a system of protected areas that would represent the ecological diversity of the various regions. Work commissioned by CCEA explored approaches to defining 'representation' and concluded that efforts should adopt an 'enduring features' approach. This approach focused on characterizing ecosystems and environments on the basis of 'stable' landform attributes, such as physiographic features, geomorphology, topography and soil types, that controlled key ecological determinants (Petersen and Petersen, 1991). Accordingly, the ecozones and ecoregions coupled with the concept of representation provided the basis for the national framework for protected areas (Gauthier, 1992; Gauthier *et al.*, 1995). Adoption of the ecozone framework in CCEA's initial registry of protected areas (Gray and Rubec, 1989) and subsequent databases including the Canadian Conservation Areas Database (CCAD) and the current Conservation Areas Reporting and Tracking System (CARTS) provide a uniform approach for targeting and reporting progress on the creation of protected areas across Canada.

Accelerated Progress

Federal and provincial/territorial system planning, primarily focusing on representing samples of Canada's ecoregions and biodiversity, increased dramatically in the early 1990s with the launch of the World Wildlife Fund's (WWF) Endangered Spaces Campaign (WWF, 1990). The campaign was designed to encourage federal, provincial/territorial agencies to achieve a protected areas target of 12% by establishing new parks and other types of protected areas. The signing of the *Statement of Commitment* by Canadian Parks Ministers in 1992 obligated jurisdictions to complete Canada's networks of protected areas (FPPC, 2000). Although they did not achieve the 12% target, Canadian jurisdictions did significantly increase the area protected during the period of the campaign (WWF, 2000; Nelson, 2003), and since then, additional significant progress in establishing and managing natural heritage areas has been achieved in some jurisdictions. This increase in the number of protected areas will assist Canadian jurisdictions in their effort to maintain healthy, complex, and resilient ecosystems during a time of rapid climate change.

WWF was largely influenced by the CCEA approach in its campaign, and through the 1990s most jurisdictions embraced approaches modelled after the CCEA framework. In addition, 'representation' has been adopted as a management objective in many jurisdictions around the world. System planning approaches are called for under Article 8 of the *Convention on Biological Diversity* and are regarded as the most effective means to improve the probability of substantial progress in conservation. They also promote integrated approaches to linking conservation with other land-use planning exercises.

Variations on the Theme

A variety of natural assets and approaches have been adopted to define ecological representation at many different scales. These schemes continue to provide for the basic design and establishment of protected areas across Canada. System planning utilizing representation approaches based entirely or even partially on biotic elements may turn out to be the most vulnerable to climate change because the distribution and abundance of species and ecosystem boundaries are largely determined by climate. By comparison, system planning focused on physiographic representation may be equally vulnerable from a biotic standpoint, but at least this approach captures a range of 'stable' representative abiotic conditions such as geological and surficial substrates which will persist as more durable 'baseline values' of protected areas. Comprehensive, physiographically-based representation schemes should manifest more resilience as shifting species and biotic communities may have greater opportunity to re-colonize sites in new protected areas similar to those lost to invading climate regimes in their place of origin. Given the stable platform that physiographically-based representation schemes have been designed to provide, this approach remains fundamentally sound as a core design construct for protected areas systems.

In some jurisdictions representation is enshrined in legislation (e.g., Parks Canada Agency's *National Parks Act* and *Ontario Parks' Provincial Parks and Conservation Reserves Act*). As of 2009, 46 national parks represent 25 of the 39 'natural regions' delineated by Parks Canada Agency. Parks Canada Agency has also committed to establishing a network of National Marine Conservation Areas (NMCAs) that will protect and conserve for all time marine areas that represent the full range of Canada's Atlantic, Arctic and Pacific oceans, and the Great Lakes. In order to achieve a nationally representative system, the marine environment has been subdivided into 29 distinct geographic units or 'marine regions' based on oceanographic and biological characteristics with the aim of protecting a representative sample of each region within the NMCA system (Parks Canada, 1997). Currently, two NMCAs have been established in Canada (Saguenay-St. Lawrence Marine Park in Québec and Fathom Five National Marine Park in Georgian Bay in Ontario) and planning for a third NMCA, the Lake Superior NMCA in Ontario, is nearing completion. System planning aimed at completing a representative system of NMCAs in Canada is in its infancy. Efforts of the Marine Task Force to focus attention and expertise on planning and managing marine protected areas is a timely step to augment marine conservation efforts.

Implications of Climate Change

Canada's current systems of terrestrial, freshwater and marine protected areas are essentially fixed assemblages of lands and waters that represent a wide array of ecosystems and biotic communities and provide habitats for many species. Historically, these approaches to conservation have not accounted for potential climate-induced shifts in ecosystem composition, structure, and function. Mainstreaming concepts such as 'resiliency' of 'ecosystem processes' into protected areas policy, planning and management programs will enhance the robustness of institutional decisions to protect selected areas. Such change will require that institutions adopt new approaches to decision-making and governance. For example, protected areas planners and managers would have to expand their definition of 'desirable ecosystem states' often inscribed in management plans (with attention now frequently paid to native species housed within a given park or protected area), to accept maintaining ecological processes (i.e., trophic complexity) as an important goal in addition to species identity or ecological pattern.

Reconciling the fundamental principles of protected areas likely will challenge jurisdictions in many new ways, with 'ecological representation' being one of the foremost challenges. This is an area where critical dialogue, supported with the best science perspectives and information will be necessary to shape consensus views on adaptation. Work on large scale biome shift scenarios coupled with more detailed modelling and assessments of predicted consequences on specific ecoregions and their contained protected areas is necessary to provide new insights and inform appropriate actions on legislation, policy, planning, and management.

Ecological Integrity

The Functional Imperative

Much like ecological representation, 'ecological integrity' is an important underlying principle in designing and managing protected areas. The concept embodies functional ecological conditions and processes that are essential for the maintenance of species, biotic communities, and other natural features targeted for conservation within protected areas. So while ecological representation is primarily concerned with ecosystem form and structure, ecological integrity is more focused on the retention of ecological processes and functions that are necessary to sustain a desired assemblage of natural features, particular ecological conditions, or natural systems. The concept was acknowledged as a national design construct for protected areas by the CCEA in its national framework for developing a nationwide system of ecological areas (Gauthier *et al.*, 1992).

A few agencies, notably Parks Canada Agency and Ontario Parks, employ 'ecological integrity' as the primary management goal of their respective protected areas systems. For example, Ontario's *Provincial Parks and Conservation Reserves Act* states that the *"Maintenance of ecological integrity shall be the first priority and the restoration of ecological integrity shall be considered"* in all aspects of the planning and management of Ontario's system of provincial parks and conservation reserves (Government of Ontario, 2007: Section 3.1). Parks Canada Agency defined ecological integrity in the *National Parks Act* (Clause 2) (18) as, *"...a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes."* Furthermore, *"Ecosystems are inherently dynamic and change does not necessarily mean a loss of integrity. A system with integrity may exist in several states, but the change occurs within acceptable limits"* (their emphasis) (Parks Canada, 1997: 19).

A number of components of this definition have implications for climate change adaptation. For example, the focus on species persistence and supporting ecological processes emphasize the inherent dynamism of ecosystems and the associated importance of monitoring in a rapidly changing climate. However, the magnitude of climate change and associated changes in disturbance regimes are likely to accelerate ecosystem change beyond what science has observed to be the 'natural range' in some regions. The compounded perturbations resulting from climate change (e.g., vegetation change, altered disturbance regimes, invasive species, and increased frequency of extreme weather events) is also likely to heighten the occurrence of 'ecological surprises' and non-linear responses by ecosystems. Consequently, it remains uncertain how ecosystem change *"within acceptable limits"* will be interpreted by Parks Canada Agency managers (or practitioners in other jurisdictions) within the context of climate change (Scott *et al.*, 2002; Lemieux and Scott, in preparation).

Moreover, a common assumption of what is considered to be 'successful conservation' has traditionally been achieved by isolating protected areas from the processes that threaten their existence, and to support continued protection of current ecological communities and species housed within the boundaries of specific protected areas. The definition of ecological integrity, in contrast, supports the greater ecosystem approach to management where protection of processes that facilitate ecosystem adaptation to climate change often extend beyond the boundaries of individual protected areas (i.e., onto non-park lands). Accordingly, the concept of ecological integrity, including what exactly constitutes 'acceptable rates of change' and species 'characteristic of a natural region', should be redefined to account for climate change impacts.

Assisted Migration and Conservation Triage

In a changing climate, the utility of prescribed burning, species re-introduction, species translocation (i.e., assisted migration), and other management tools and techniques will need to be addressed. For example, there are a number of ethical and biological issues associated with assisted migration. The translocation of species-at-risk to more suitable habitat, a strategy which is commonly proposed in the literature (e.g., McLachlan *et al.*, 2007; Hugh-Guldberg *et al.*, 2008), could be interpreted as inconsistent with maintaining ecological integrity if the species in question is not native to the destination region and could have a negative impact on other native species. Agencies will need to decide whether to manage protected areas in a manner that forestalls undesirable impacts of ecosystem change, or using an approach that facilitates ecosystem change 'naturally' or through active adaptive measures such as species translocation or restoration to anticipated future conditions. Moreover, protected areas managers will need to begin thinking about the ethical implications and obligations to species—a 'hands-off' or 'non-interventionist' approach may not be a tenable approach if a highly valued species (such as a species-at-risk or charismatic mega-fauna) is unable to adapt naturally to climate change-related impacts.

The rate and magnitude of climate change projected for the 21st century is likely to exceed many of the thresholds to which current species assemblages have become adapted, regardless of such management interventions. As such, it is conceivable that not all species will be able to persist despite the best conservation efforts. As such, 'conservation triage' may emerge to be a critical tool in the prioritization and selection of which species to assist. The allocation of scarce resources to assist certain species (and not others) will have considerable ethical implications, and despite the burgeoning literature on climate change and biodiversity conservation over the past 20 years, debate and discussion over core questions such as *"Which species will be saved?"* (i.e., use limited resources to avoid trying to save one species at the expense of several others?) and *"Is it acceptable to let a species go extinct in a national park?"* have not occurred.

Ecological Restoration

The goals of ecological restoration within protected areas, which are often aimed at re-establishing or maintaining native vegetation types (e.g., prescribed burning activities for prairie and savannah restoration), may also need re-assessment. The usefulness and viability of using historical ecosystem conditions as baseline reference points or targets must be evaluated in light of the fact that restoring these historic ecosystems may be more difficult, if not impossible, in the novel biophysical conditions of the future (e.g., Harris *et al.*, 2006; Hobbs and Cramer, 2008; Dunwiddie *et al.*, 2009). In addition, such activities may prove to be an inefficient use of (limited) resources by protected areas agencies in relation to other priorities. More consideration and debate needs to be directed at the implications of climate change for restoration practices both within protected areas and in the broader landscape.

Protected Areas Design

Design for Ecological Integrity

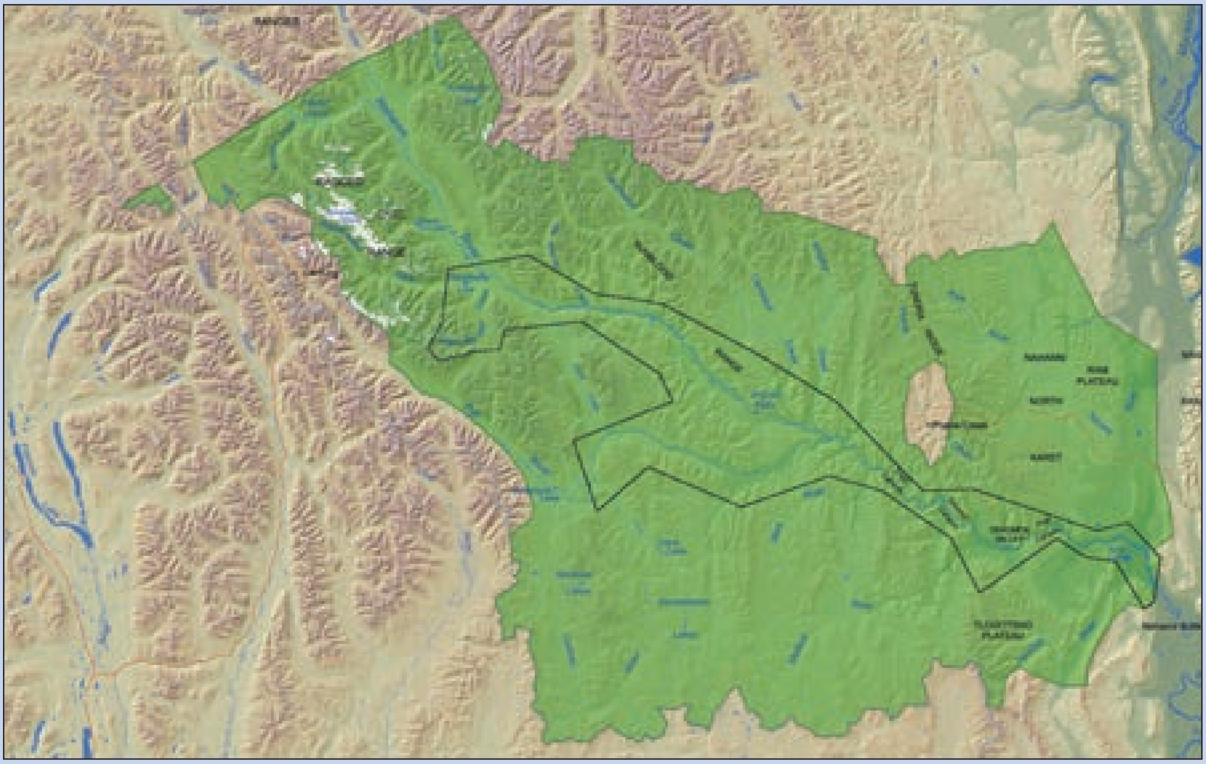
Standards for the design of protected areas vary across Canada and are dependent upon the legislated mandates and policies governing the establishment, protection, and use of these areas. In support of protecting biodiversity in a rapidly changing climate, protected areas design should be focused on maintaining and where possible enhancing ecological integrity, complexity, and resiliency. As noted above, integrity is a state or condition to which natural asset managers can aspire. An area with high integrity and (eco) system complexity (measured in terms of composition, structure, and function) is more likely to retain the same or similar function in a rapidly changing climate.

Design for Complexity and Resiliency

Given that potential future climates may be significant forcing agents, the probability of achieving or maintaining ecological integrity, will in large measure depend on how well agencies and organizations protect the complexity and resilience of the ecosystems in natural heritage areas (and in many cases ecosystems outside of and adjacent to these natural heritage areas). For example, on 9 June 2009, the Canadian Government and the Dehcho First Nations, announced legislation that increased the area of Nahanni National Park Reserve by more than six times. The new protected area will cover approximately 30,000 km^2, including 91% of the Greater Nahanni ecosystem in the Dehcho region and most of the South Nahanni River watershed (Box 1). The large expansion to Nahanni will help buffer the park from incompatible land-uses, and will significantly increase the potential for species housed within the park, including grizzly bear (*Ursus arctos*), woodland caribou (*Rangifer tarandus caribou*), and Dall sheep (*Ovis dalli*), to adapt to climate change.

Box 1: Nahanni National Park Reserve Expansion

In June 2009, the Government of Canada introduced legislation that enlarged the protected area of the South Nahanni and its tributaries (area delineated by the black boundary line within the larger green polygon) to some 30,000 km^2. Nahanni National Park Reserve will become the third largest national park in Canada, covering an area almost the size of Vancouver Island. In expanding the park reserve, the park will become more resilient to climate change impacts.



For more information, please visit: http://www.pc.gc.ca/pn-np/nt/nahanni/ne/ne2_e.asp

Source: Parks Canada Agency (2009b)

An ecologically resilient ecosystem can absorb (climate-induced) disturbance, reorganize while undergoing change, and retain the same or similar function in a rapidly changing climate (Walker *et al.*, 2004). Many of the actions associated with a commitment to maintain ecological integrity will help natural asset managers optimize ecosystem health by maintaining and protecting ecological complexity and resiliency. And while change to ecosystem composition, structure, and function is inevitable in a rapidly changing climate, enhanced protection will result in resilient ecosystems that better buffer the impacts, provide habitat for native species for longer periods of time, and provide healthy, evolving systems that will provide habitat for new combinations of species capable of adapting to the new climate envelope. Once ecosystem resiliency is breached, protected areas managers will need to begin *"managing for change"* (West *et al.*, 2009). Managing for change means helping people understand and cope with the transformation of an ecosystem to a new state.

Design Across Multiple-Scales

There are small to large ecosystems operating according to fast and slow ecological processes (inclusive of composition, structure, and function) (Holling, 1992), and guidelines designed to maintain ecological processes at different scales will help guide the selection of new protected areas and should enhance the integrity of existing protected areas. A key management strategy for protected area design in a changing climate, therefore, should be to define, delineate, and protect entire ecosystems either directly in the protected area and/or indirectly through cooperative management in the context of a 'greater ecosystem approach to management'. Guidelines for protected area boundary delineation and protection will assist managers prepare for the uncertainties of climate change in the 21st century.

The establishment of large protected areas is an important hedging strategy against climate change, especially where such areas straddle several ecological regions and contain a wide range of habitat types. The CCEA recently issued guidelines for selecting and designing northern protected areas in order to encourage the creation of additional large sites across the North while opportunities remain to do so (Wiersma *et al.*, 2006). The conclusions of this report favour the creation of large areas and networks of sites to meet the specific challenges posed by the conservation of wide-ranging northern species and ecosystems including a rapidly changing climate. Overall, substantial networks of protected areas that encompass a range of different habitat types and physical characteristics are more likely to be more resilient to climate changes (Noss, 2001; Huntley, 2007; Dunlop and Brown, 2008; Araújo, 2009a).

The 'greater ecosystem approach' such as the one embraced by the Man and the Biosphere (MAB) program back in the early 1970s provides for a zoning system to strictly protect core areas, and to manage human use in buffer areas and transition areas. Biosphere reserves are intended to fulfill three complementary and mutually reinforcing functions:

1) Conservation (e.g., legal protected areas which form the core of the biosphere reserve);

2) Development (e.g., ecologically sustainable development within buffer and transition zones); and,

3) Logistical needs (e.g., support for research, monitoring, education, and information exchange related to conservation and development within core, transition, and development zones).

A more recent example includes the National Capital Commission Greenbelt, which is organized according to zones designed to preserve an area (Core Natural Area), protect or buffer the core natural area (Natural Area Buffer), link core and buffer areas (Natural Area Link), and manage human use (Cultivated Landscape, Rural Landscape, Buildable Site, and Infrastructure Corridor) (National Capital Commission, 1996). Unlike 'traditional' types of protected areas, Biosphere Reserves and the National Capital Commission Greenbelt exemplify programs designed to protect core areas while simultaneously allowing people to pursue prescribed activities in the other zones. The overall intent for the management of the National Capital Commission properties, Biosphere Reserves, and a number of other types of Canadian designations is consistent with many of the criteria developed for Category V protected areas by the IUCN (see Dudley, 2008; Gray *et al.*, 2009; Phillips, 2002; Swinnerton and Buggey, 2004). These criteria recognize a holistic, ecologically-oriented approach to management (including important terrestrial 'greenway' and aquatic 'blueway' linkages over large areas) (Gray *et al.*, 2009) that would help buffer the impacts of climate change in many situations.

Smaller protected areas are also important to help fulfill representation needs, especially in highly developed regions where most endangered and endemic species in Canada are located and where opportunities to establish large protected areas are limited. Smaller areas may also provide provisional habitat for shifting species under a changing climate (Riley and Mohr, 1994; Beechey *et al.*, 2000; Pollock-Ellwand *et al.*, 2000; Environment Canada, 2005).

Design for Redundancy

Replication, or redundancy, is an important hedging strategy and acts as a form of insurance against the unpredictable nature of climate change and ecological responses (West *et al.*, 2009). For example, redundancy can be incorporated into protected areas system planning approaches to ensure that representation is maintained within the overall protected areas system, despite potential losses in individual protected areas. As West *et al.* (2009) emphasized, most replication strategies also serve as representation strategies (since no two populations or ecosystems can ever be truly identical), and conversely, most representation strategies provide some form of replication.

Other Design Innovations

Ensuring the persistence of species and habitats under climate change could also be enhanced with existing and new approaches to management. The creation of new types of protected areas including temporary designations such as 'Evolutionary Baseline' class parks, and adaptive protection designations and strategies on the intervening landscapes and waterscapes between formally protected areas deserve consideration. As well, stewardship activities aimed at restoring habitat and/or facilitating connectivity, continued conservation incentives on private lands, biodiversity offsets, and assisted migration are techniques in need of further review and testing (see previous discussion on pages 47-51). The establishment of new protected areas 'classes', such as 'Evolutionary Baseline' class parks for example, would permit natural evolution, which could be used to research, monitor, and report on ecosystem change. In addition to expanding the density and size of core (i.e., permanently protected) parks and protected areas and establishing new classes, 'temporally defined protected areas' (i.e., transient or 'floating' protected areas and/or temporal corridors), based on forecast habitat availability for key vegetation and wildlife species under climate change, may provide fundamental linkages needed to facilitate species response and migration between core protected areas. Dynamic protected areas may also better integrate protected areas within the management of the greater landscape and provide the flexibility needed to protect species-at-risk, endemic species, and critical wildlife habitat outside core protected areas without excessively compromising other resource allocations and land-use planning initiatives.

Protected Area Systems and Networks

Management Classification

There are now over 100,000 protected areas worldwide, covering 13.9% of the Earth's land surface (WDPA, 2010). These areas represent one of the most significant human resource use allocations on the planet (Chape *et al.*, 2005). Despite the growth in global agreements on nature conservation and the establishment of protected areas, the protected area designations used by countries are not necessarily directly comparable because of different legislative and governance regimes. One thousand (1,000) different terms are known to be used around the world to designate protected areas (Chape *et al.*, 2005). Canada compares favourably to worldwide performance, having more than 4,850 areas with a combined area of 933,930 km^2, representing 9.92% of its total area. Here, too, there is a myriad of terms that make it difficult to complete a comprehensive tally of all types of protected areas. Canada is home to over 200 categories of protected areas that are managed by various government agencies and private and non-governmental organizations. The degree of protection afforded to these areas varies widely and they assume many different forms and functions [see Paleczny *et al.* (2000) and Gray *et al.* (2009) for reviews on Ontario]. The *Canadian Guidebook for the Application of IUCN Protected Area Categories*, recently issued by CCEA (2008), aims to assist practitioners in efforts to classify and report on the many different types of protected areas in Canada in order to track progress and to facilitate comparisons in both ecoregional and jurisdictional contexts.

Standard practice in many jurisdictions now recognizes the idea of protected area networks comprised of different types of protected areas serving multiple objectives (i.e., IUCN Classifications I-V) (Box 2). As noted, most Canadian jurisdictions, and a number of non-governmental organizations such as the Nature Conservancy of Canada (NCC), have adopted some form of system planning approach to complete their networks of protected areas. However, the climate change adaptation issue is one that extends beyond any single province and/or managing agency or organization, and even Canada, necessitating a continental response to enhance the overall effectiveness of 'the system' to climate change impacts. The various systems of protected areas in Canada will need to be functioning in tandem and nested within a common strategy to build a comprehensive continental network of nodes, linkages, and connectivity.

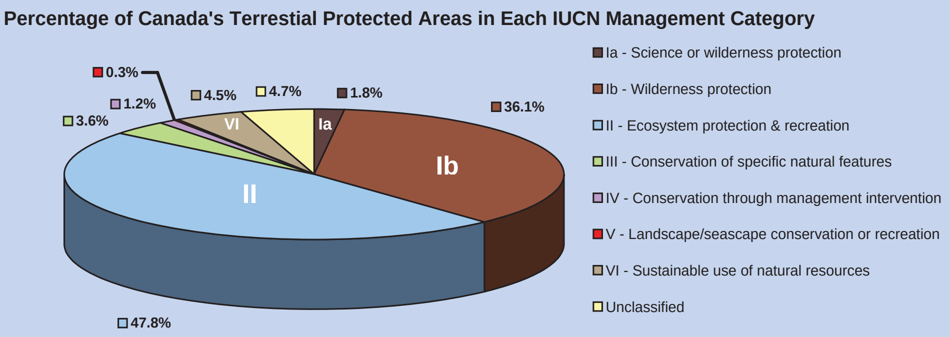
While the focus on classifying protected areas in Canada has concentrated on IUCN categories I-IV, there are precedents to utilize all six categories. IUCN categories V and VI have been applied to classify some federal lands and some areas in Alberta, Québec, and Newfoundland and Labrador (CARTS, 2010). Saskatchewan's Representative Areas Network (RAN), initiated in 1997 to conserve representative and unique examples of the province's diverse landscapes, has completed a comprehensive tally of all protected

Box 2: Management classification of Canada's terrestrial protected areas (IUCN Categories)

Globally and within Canada, protected areas are classified according to a series of six management categories, depending upon their management objectives. These categories, developed by the International Union for Conservation of Nature (IUCN), are summarized as follows:

- *Category Ia* - Protected area managed mainly for science or wilderness protection.
- *Category Ib* - Protected area managed mainly for wilderness protection.
- *Category II* - Protected area managed mainly for ecosystem protection and recreation.
- *Category III* - Protected area managed mainly for conservation of specific natural features.
- *Category IV* - Protected area managed mainly for conservation through management intervention.
- *Category V* - Protected area managed mainly for landscape/seascape conservation or recreation.
- *Category VI* - Protected area managed mainly for the sustainable use of natural resources.

Over the past few years, protected areas agencies have begun to review and re-assess their various protected areas using guidelines issued by the CCEA, in order to help to ensure national consistency in the application of the IUCN categories for the classification of Canada's protected areas. This is a work in progress; protected areas agencies continue to work with the CCEA to further refine and ensure consistency in the evaluation and reporting of these categories for Canada's protected areas.



Source: Environment Canada (2006)

areas in Saskatchewan that meet the IUCN definition of a protected area. The RAN assessment includes both protected areas on Crown lands in the public domain as well as securely protected private lands held by non-governmental organizations and private landowners. Since being initiated in 1997, the total area protected has grown from just under 3 million to more than 7 million ha, with an eventual target of 7.8 million ha (Saskatchewan Environment, 2005; CARTS, 2010). As the application of categories V and VI are better understood and more widely applied across Canada, their universal adoption will broaden the Canadian protected areas network and add to building a more comprehensive system of sites.

Ecosystem-based Management

In the last two decades some basic changes have been made in approaches to national parks and protected areas in North America and elsewhere. It has been recognized that, in addition to the establishment of protected areas, the future of much of the biosphere will depend on managing large areas using an integrated approach that embraces human populations and activity in ensuring the continuing productivity of the ecosystems within which they live. Ecosystem-based management seeks to organize human use of ecosystems in order to strike a balance between benefiting from the natural resources available from an ecosystem's components and processes, while maintaining an ecosystem's ability to provide these at a sustainable level. This concept was endorsed at the fifth Conference of the Parties to the *Convention on Biological Diversity* (CBD) (COP 5 in Nairobi, Kenya; May 2000/Decision V/6) as the primary framework for action under the *Convention*. According to the CBD, the approach to ecosystem-based management is that: *"Ecosystem and natural habitats management seeks to meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned. Important within this process is the setting of explicit goals and practices, regularly updated in the light of the results of monitoring and research activities."* (CBD, 1992)

Since climate change is a much bigger issue than simply parks and protected areas, there is a need to address conservation on a more holistic level. It will also be important to address climate change and changing ecological representation and protection needs on non-park lands. Ecosystem-based management contains the guiding and operational principles that inherently contain substantial climate change adaptation value at different spatial scales ranging from specific protected areas to extensive ecological systems and land/waterscapes.

A central premise of ecosystem-based management is that the structure and functional integrity of the system needs to be maintained. Ecosystem-based management also recognizes the dynamic nature of ecosystem boundaries (i.e., legal or administrative boundaries should not be established in such a way that cut across the major functional linkages of an ecosystem), focuses on maintaining biodiversity (and the importance of monitoring ecosystem change especially with respect to endemic species), and recognizes the inevitable change of species and ecosystems (and the associated human uses). Moreover, ecosystem-based management recognizes people as part of the ecosystem, the need for knowledge-based adaptive management, the utility of the precautionary principle given uncertainty (which is especially relevant given the uncertainties associated with climate change), and the need for multi-sectoral collaboration (Pirot *et al.*, 2000). Protected areas can contribute to ecosystem-based adaptation across a spectrum of adaptation challenges, and particularly at a local level, using community-based approaches to address climate change impacts (Dudley *et al.*, 2010). Indeed, institutionalizing ecosystem-based management may be the most effective climate change adaptation tool available to conservation practitioners.

One approach for dealing with large ecosystem boundaries and trans-boundary issues is through bioregional planning, as endorsed by the IUCN World Commission on Protected Areas (WCPA). Through this approach boundaries are adopted at the landscape scale. Within a bioregion there are three basic elements:

1) Core areas that contain wild, undomesticated plant and animal communities, and the habitat or site requirements needed for their long-term survival (often housed within formal protected areas);

2) Buffer zones adjacent to the core areas where human communities manage land and resources in such a way as to minimize negative impacts on core areas; and,

3) Corridors that link core areas and buffer zones in a way that allows for plant and animal migrations, such as those brought about by changes in climate.

Canada's protected areas 'network diversity' incorporates wide ranging features and critical ecological functions such as drainage, groundwater recharge, air purification, connectivity, and wildlife corridors, which represent significant characteristics vital to the viability of protected areas in an era of climate change. A large amount of research has been done on the importance of linkages and connectivity under current climatic regimes, much of which is relevant in a climate change context (see Peters and Darling, 1985; Hunter *et al.*, 1988; Bennet, 1998; Shafer, 1999; Margules and Pressey, 2000 for examples). Interestingly, earlier thinking on the application of island biogeography and formative ideas of nature reserve design (e.g., Wilson and Willis, 1975; Diamond, 1975) remain highly relevant in current and future considerations regarding the design of protected areas networks. Box 3 presents a number of principles important to the design of protected areas networks that are conducive to climate change adaptation.

Box 3: Principles for designing protected areas networks conducive to climate change adaptation

- Adopt ecoregional perspective
- Emphasize physiographic diversity
- Maximize species and community diversity
- Utilize representation approaches
- Ensure ecological integrity
- Design for multiple scales
- Incorporate redundancy and replication
- Plan for species persistence
- Ensure landscape permeability
- Retain/enhance linkages and corridors
- Incorporate range of reserve sizes
- Give priority to large areas
- Design for reserve clusters
- Minimize management intervention where possible

Box 4: Climate Change and the Yellowstone to Yukon Conservation Initiative (Y2Y)

Y2Y is analyzing the way climate change could affect the region, and factoring these understandings into grizzly bear, avian and aquatic conservation strategies. These strategies address the pressures of climate change on animal and plant species by:

- Conserving large areas of connected landscapes, and thereby providing plants and animals with the ability to move to more habitable locations or occupy a new niche in their traditional territory;
- Offering linked, north-south habitat zones that offer safe wildlife migrations;
- Providing various elevations that allow both plant and animal species to ascend to higher ground;
- Maintaining an 'around the mountain' element, allowing plants to drift to other slope aspects in order to survive; and,
- Sustaining as many native plant species as possible in order to reduce the invasion of exotic species.

Source: Y2Y (2009)

International and Regional Initiatives

There are many examples of protected areas systems and networks, and various initiatives that have adopted the appropriate bioregional scales with which the protected areas and climate change issue can be addressed more effectively. Examples of well-known international initiatives include the Yellowstone to Yukon Conservation Initiative (Y2Y) (Y2Y, 2009) (Box 4) the Algonquin to Adirondack Conservation Initiative (A2A) (A2A, 2009), and Two Countries/One Forest (Deux Pay/Une Forêt) (2C1F) (Trombulak *et al.*, 2007; 2C1F, 2009). At provincial and a regional intra-provincial scale, the *Niagara Escarpment Plan* (NEP) (Niagara Escarpment Commission, 2009) and the *Oak Ridges Moraine Conservation Plan* (Government of Ontario, 2002) in Ontario, are good examples of legislatively based, landscape-scale initiatives that integrate multiple protected areas and other conservation lands managed by many jurisdictions. At the foundation of such initiatives are core protected areas, buffer zones, and corridors nested within bioregions where resident communities, landowners, and resource users live and work. These initiatives are aimed at meeting regional and local needs, maintaining or restoring ecosystem integrity, and conserving biodiversity, simultaneously. In one respect, these large-scale initiatives have adopted the idea of protecting conservation gradients employed so successfully in MAB reserves.

The traditional pattern of protected area design and distribution throughout Canada mimics in part the network design principles underlying regional initiatives such as those alluded to above. Although there are relatively few protected areas in the far North, those that exist are generally large and usually embedded in working landscapes still dominated by native species and natural ecosystems. In the mid-North, networks are characterized by a larger number of protected areas of more varied sizes, sometimes occurring as clusters and often connected by protected riparian corridors in still quite natural settings. In contrast, southern regions tend to have higher numbers of protected areas that are small in size relative to more northern regions. Although highly developed and fragmented, protected areas networks in many of the southern regions still exhibit a fair degree of ecological integrity as sites are often clustered and buffered by sympathetic land-use zoning to soften ecological edges and enhance landscape permeability. Building on this pattern, efforts going forward offer hope for protected areas and biodiversity conservation in an era of climate change.

Canada has an unprecedented opportunity to protect natural values that are of regional, national and global significance. In particular, it is one of the few remaining countries in the world that maintains large, relatively unfragmented ecosystems, such as the Boreal forest and Arctic, which still contain large scale functioning natural processes. The Canadian Boreal Initiative (CBI), a national convener for conservation in Canada's Boreal forest, is working with governments, conservation organizations, First Nations, industry and other interested parties to protect at least 50% of the Boreal in a network of large interconnected protected areas (Box 5).

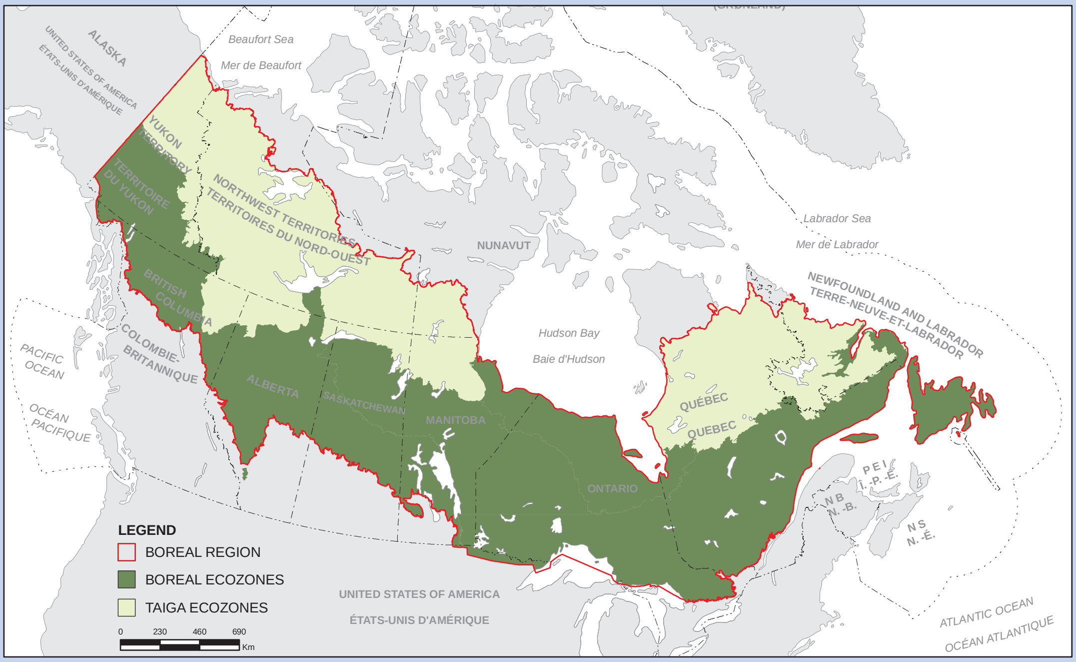
The *Boreal Forest Conservation Framework*, developed by the Boreal Leadership Council, and endorsed by over 1,500 scientists worldwide, 25 First Nations, and industries that have an interest in the Boreal, aims to "*Maintain ecological processes which account for the overall health of the Boreal Forest across the full spectrum of human uses*" and *"Maintain intact areas to minimize fragmentation wherever possible.*" (CBI, 2007) The realization of such an ambitious conservation goal, the *Framework* acknowledges, will only happen if it is integrated into consensus-based decision-making prior to land-use decisions or industrial development. The *Framework* also explicitly states that it is committed to protecting old growth forests and ensuring ecological resiliency so *"Boreal species can adapt to natural disturbances and climate change"* (CBI, 2007). Old growth forests may turn out to be important refugia for some species as they have been shown to have greater inertia to climate change than newly-established forests (Noss, 2001; WWF, 2003). The *Framework* also supports the use of policy tools such as interim land deferrals and conservation offsets to facilitate voluntary stewardship by industry. If implemented successfully and according to its *Framework*, the CBI would provide a global model for sustainable development with conservation at the core.

Integration of Protected Areas into Regional Land-Use Planning

Interestingly, the paradigm shift in land-use planning over the past two decades in Canada is quite in harmony with best practices for ecosystem-based planning and

Box 5: Conserving Canada's Boreal Forest

Canada's boreal region covers 58.5% of the country's land mass and represents 30% of the world's total boreal forest. The Canadian Boreal Initiative (CBI) brings together diverse partners, including government, industry, conservation groups, major retailers, financial institutions, scientists, and First Nation groups, to create new solutions for boreal forest conservation. The CBI's goal is to protect at least half of Canada's boreal, with the rest under sustainable development, while respecting Aboriginal rights. The Government of Ontario has committed to the protection of more than 50% of its Far North boreal region, an area of approximately 22 million ha (McGuinty, 2008). Manitoba and Ontario have also signed a Memorandum of Understanding respecting a Manitoba/Ontario Interprovincial Wilderness Area. It encompasses over 940,000 ha of boreal forest and provides significant habitat for species-at-risk such as woodland caribou (*Rangifer tarandus caribou*), bald eagle (*Haliaeetus leucocephalus*), and wolverine (*Gulo gulo*). Protecting such vast areas would ensure the boreal landscape continues to fight the effects of global climate change by maintaining its capacity to absorb and store carbon from the air.



Source: CBI (2009)

management, and it may help to facilitate further adjustments to accommodate necessary adaptation to climate change. The validation of protected areas as legitimate core allocations in land-use plans in most provinces and territories has enhanced their standing with the general public and in resource development sectors. The Peel Watershed Planning Commission *Recommended Land Use Plan* in Yukon Territory is a landmark regional planning effort in Canada that will help ensure wilderness characteristics, wildlife and their habitat, cultural resources, and waters are maintained in an era characterized by rapid climate change while also managing resource use (Box 6).

The application of zoning systems and conservation gradients comprised of core protected areas with softer, complementary conservation designations, together with the recognition of the importance of ecological sustainability in functional ecological systems, is a major step in thinking that can help to advance adaptation for climate change. On the social side, the degree to which these plans have drawn together once staunchly competitive sectors could also prove valuable in furthering movement

Box 6: Peel Watershed Planning Commission Recommended Land Use Plan

The Peel watershed is a vast unpopulated area in northeastern Yukon highly valued for wilderness recreation, big game outfitting, mineral and oil and gas potential, tourism, and ecological integrity. It also has significant cultural, heritage, and economic value for the three Yukon First Nations with overlapping traditional territories including: the Na-cho Nyak Dun, Tr'ondëk Hwëch'in, and Vuntut Gwitchin. Also overlapping the Peel Watershed Planning Region are the primary and secondary use areas of the Teetł'it Gwich'in. The social, economic and environmental values, together with very few roads and little industrial development in the region, make this area unique at territorial, national, and even global levels.

The *Recommended Peel Regional Watershed Land Use Plan* was produced by the Peel Watershed Planning Commission as part of the implementation of Chapter 11 of the Final Agreements for Nacho Nyak Dun, Tr'ondëk Hwëch'in and Vuntut Gwitchin First Nations. An important aspect of the *Plan* is the incorporation of sustainable development, and the recognition that renewable and non-renewable land-uses should be accommodated only if consistent with sustaining ecosystems and social systems.

The protected areas and conservation opportunities in the Peel Region, which are significant at a national and global scale, are unparalleled. The *Plan* makes a direct connection between climate change and the need for protected areas that represent large intact ecosystems (section 4.3.1.6). The *Plan* states that: *"A land use plan cannot manage climate-change effects. It is vital to consider and account for any climate change using both scientific investigation and traditional and local knowledge/observations. While there will always be some uncertainty, it is important to use the fullest information to manage risks and adapt to climate and other landscape change. The Plan considers and accounts for potential climate-change effects by recommending a higher level of conservation. Setting aside large intact ecosystems is a good way to help ecological values to persist in the face of climate change. This strategy was an important consideration in the zoning of the Land Management Units (Section 4.2) and other recommendations in this Plan."*

Source: *Peel Watershed Planning Commission (2010)*

Overall, the *Recommended Plan* is a landmark regional planning effort in Canada that will help to ensure that wilderness characteristics, wildlife and their habitat, cultural resources, and waters are maintained in an era characterized by climate change while also managing resource use.

For more information, please visit:
http://www.peel.planyukon.ca/

on collaboration, co-operation and partnerships necessary to deal with climate change.

Protected Areas Management

Management Perspectives

Similar to protected areas around the world, many protected areas in Canada were established with the intent of protecting highly valued individual species and/or species associations and their habitats in perpetuity. Indeed, the representation construct, when applied solely to conserve species and biotic communities, often falls into this 'era' or feature management stream. In these cases, the primary goal of management planning for protected areas is often geared to ensure that there is a clearly defined direction for the maintenance of targeted species and/or communities. Where necessary, management regimes may prescribe active intervention including the restoration of ecological integrity to achieve this primary goal and guide appropriate use of these areas. Active management techniques, such as the use of prescribed burns, ecosystem restoration, and the eradication of alien and invasive species, are often used to improve or maintain the ecological integrity of a given protected area. Systems level work and network modelling can inform decisions on refining the design and management of existing protected areas to better reflect climate change needs for such areas.

In contrast to those protected areas that are managed to perpetuate specific conditions, features or species, many jurisdictions also have protected areas that are established where the goal is to let the forces of nature prevail. Such sites tend to include larger areas, including extensive segments of national parks, and various 'wilderness' and 'wildlands' designations in provincial networks of parks and other protected areas. The *laissez-faire* management regimes adopted for these areas are often geared to permitting free rein of natural processes to allow for processes such as natural succession and evolutionary change. Often, protected areas are managed in this fashion in their entirety; in other cases, large tracts may be zoned where 'evolutionary' management is the prescribed approach. Although the protection and management of such areas may be easier to reconcile under climate change scenarios, it will still be important to recognize that biome shifts and natural perturbations will likely accelerate changes in the structure and function of these areas. Since a primary objective of such sites is often to retain ecological baselines, determinations will need to be made whether this goal takes precedence over intervention to mitigate radical change.

Disturbance Regimes

Many ecosystems, such as those found in the Boreal forest, depend on natural patterns of fire and pest outbreaks for renewal and maintenance of ecological integrity, and these factors may emerge to be more important agents of change than increased temperature and precipitation levels alone. Ecologically, the increased distribution and frequency of disturbances may result in increased distribution and dominance of early successional ecosystems dominated by fire-adapted species. Wildfire management plans may require revision (to utilize them to re-establish or maintain current ecological representation or facilitate adaptation), and natural resource managers may find it increasingly difficult to achieve a balance between protecting socio-economic values (such as forestry interests), protecting representative natural values (such as rare or endangered species and ecosystems), promoting the use of fire in restoring and maintaining ecosystem health, managing for carbon, and managing pest outbreaks (e.g., spruce budworm and mountain pine beetle) under climate change. Where protected areas are embedded in such dynamic landscapes, managers will be confronted with the same range of choices and decisions regarding the need and the approaches for active intervention.

Non-native Species

Invasive species may expand their biogeoclimatic envelopes northward and emerge to be a more pervasive management issue in protected areas located in the newly expanded ranges of these species. Invasive plant species threaten native and managed ecosystems worldwide and are increasingly expensive to control (e.g., Pimentel *et al.*, 2000; Colautti, 2006). Climate change is expected to further expand the risk of plant invasion through ecosystem disturbance and enhanced competitiveness due to elevated CO_2 (Thuiller *et al.*, 2005, 2007). For example, there is recent evidence demonstrating that non-native species, and invasive species in particular, have been better able to respond to recent climate change compared to native species by adjusting their flowering time in the eastern U.S. (Willis *et al.*, 2010). Climate change has likely played, and will continue to play, an important role in facilitating non-native species naturalization and invasion at the community level. However, climate change may also reduce invasive plant competitiveness if conditions become climatically unsuitable, creating opportunities for restoration in areas currently dominated by intractable invasive species (Bradley *et al.*, 2009).

Ecological Restoration

Ecological restoration can play three major important roles under climate change:

1) It can be employed to reconnect fragmented ecosystems allowing animals and plants to migrate in response to such change;

2) It can help to capture carbon through the restoration of forests, peat-forming wetlands, and other ecosystems that act as carbon sinks (see previous discussion); and,

3) Restoration can also provide for artificial translocation or assisted migration (e.g., such as by planting future-adapted species).

When opportunities for ecological restoration arise, the major crux for protected areas managers will be to assess the usefulness of historical ecosystem conditions as targets, and new references may have to be set against the likelihood that restoring these historic ecosystems is unlikely to be easy, or even possible, in the changed biophysical conditions of the future (Harris *et al.*, 2006).

More consideration and debate needs to be directed at defining the implications of climate change for restoration practices within protected areas and then determining how restoration options relate to protected areas policy, planning and management under new climate change scenarios. Although the arrival of a new species may be identified as a negative outcome of climate change and a negative impact on a protected area, it can also be interpreted as successful autonomous adaptation by a species to anthropogenic climate change thereby adding further complexity to species management decisions (Scott and Lemieux, 2005). Further to this point, the *Canadian Species at Risk Act* defines a “wildlife species” as a species “native” to Canada and one that has been present in Canada for at least 50 years (Government of Canada, 2003). A literal interpretation of this definition indicates that a species classified as endangered in the U.S. that naturally expands its range into Canada under changing climate would not qualify for protection as a species-at-risk under the Canadian *Species at Risk Act* (Scott and Lemieux, 2005). As Bradley *et al.* (2009: 1519) emphasized, the uncertainties associated with changes to invasive species, as well as the unknown make-up of viable future vegetation, *“...highlight a pressing need for integrated modelling, monitoring, and experimental work to better address the ecological consequences of climate change.”* Another important dilemma for conservation practitioners will be whether to intervene when such changes or opportunities arise, or whether to adopt a ‘hands-off’ approach and let nature take its course.

On a positive note, protected areas agencies have acquired considerable experience in developing and applying restoration techniques for the management of biotic communities and species. In itself, this effort has often required experimentation, trial and error, modification and adaptation. Thus, many agencies operate with a management culture that is conducive to confronting the accelerated adaptation efforts likely to be necessitated by climate change. Guidelines recently developed by the CPC in collaboration with Parks Canada Agency offer guidance on restoration work that has become common practice in many parks and other protected areas (Parks Canada Agency and Canadian Parks Council, 2008). To the extent that these efforts embrace conservation science and invoke broad-based expert input and public consultation, they have established some of the key underpinnings that will be helpful in moving forward on shaping adaptive measures for climate change. For certain, management of protected areas will assume great importance since the network of areas across Canada is so vast, with so many protected areas already established.

Management and Governance

A decade ago, Scott and Suffling (2000) recognized four management regimes under a changed climate that will need to be considered by protected areas managers at different times and under different management contexts:

1) *Static Management*: continue to manage and protect current ecological communities within

existing protected area boundaries using established goals;

2) *Passive Management*: recognize the ecological response to climate change and allow evolutionary processes to take place unhindered;

3) *Adaptive Management*: maximize the capacity of species and ecological communities to adapt to climate change through active management (e.g., fire suppression, species translocation, invasive species suppression); and,

4) *Hybrid Management*: some combination of the above.

As the authors noted, to pursue *Static Management* (static in the sense of prolonging the *status quo*) against unfolding processes would be unsustainable. *Passive Management* advocates will argue that ecosystems inherently accommodate to climate change, and that they should be allowed to adapt without human interference. This approach would depart from the current scientifically based management to preserve a *status quo* or to restore a former state. Canadians would probably be unwilling to accept the casualties of this *laissez faire* approach and, where valued or symbolic species decline rapidly, a powerful interventionist lobby is sure to emerge. *Adaptive Management,* or some form of hybrid management within an ecosystem-based approach, may be the only recourse for protected areas agencies during an era of climate change.

The role of alternative government regimes and the potential for promoting new voluntary commitments may also need further consideration by protected areas managers. Innovative governance mechanisms for protected areas, in particular co-managed protected areas (with First Nations and Inuit communities, for example) and community-conserved areas, could emerge as legitimate, efficient and effective governance options to facilitate protected areas management under changing climatic and ecological conditions (see Eagles, 2008 for a review of various governance models for protected areas). From another perspective, it may prove necessary to consider a single management plan for a cluster of protected areas rather than individual sites, since the former approach would require considerations of scale that could better accommodate the impacts of climate change on individual sites and clusters of areas. Indeed, the same ecosystem frameworks used for the initial selection of sites may prove to be appropriate envelopes for more strategic approaches to management planning.

Across Canada, protected area management programs grow more sophisticated with time. For the most part, management policies are clearly articulated and applied in the development and approval of management plans. While most plans do not yet address climate change, many do employ ecological integrity and restoration as fundamental concepts, which will require a progressive and flexible approach to decision-making in the 21st century.

Operational Considerations

Visitor Planning and Management

As previously described, climate change also has potentially important implications for recreation and tourism that are an important goal of many protected areas and often inscribed within legislation and individual park management plans. Visitation to Canada's protected areas is strongly influenced by climate. Climate influences the physical resources (e.g., water levels, snow cover and wildlife species) that provide the foundation for outdoor recreation (e.g., boating, cross-country skiing, bird watching), defines when specific activities can take place (e.g., beach use, swimming), and influences the level of visitor satisfaction (Jones and Scott, 2006a and 2006b). Canada's national and provincial parks are major resources for nature-based tourism and any changes in the length and quality of recreation seasons induced by climate change would have considerable implications for park visitation, revenue and management.

Generally speaking, warm-weather outdoor recreation activities within protected areas (e.g., camping and pubic use of beaches) are projected to benefit from climate change (i.e., longer operating seasons), but winter recreation (e.g., cross-country skiing and snowshoeing) would be negatively impacted (Jones and Scott, 2006a). More visitors would result in higher revenues generated from entrance fees and other tourism-related services for protected areas agencies across Canada. Park communities would also benefit from higher visitation if opportunities to increase visitation can be accomplished in a safe and sustainable manner and the integrity of natural environments, on which nature-based tourism depends, can be maintained. However, there are many uncertainties associated with future visitation to parks and protected areas which require further investigation, including demographic changes in population, international travel, socio-political and economic conditions, and changes in the routines and habits of visitors (e.g., park visitation is highly influenced by institutional holidays and 'routine vacations' at certain and predictable times of the year). Changes in the seasonal timing of increases in visitation will influence a range of protected areas management issues, including user-fee collection, environmental operations, and staffing needs.

Various operational aspects of parks and other protected areas, that are managed to accommodate visitation, provide opportunities for climate change mitigation and adaptation. The reduction of intensive CO_2 generating management efforts, such as retaining manicured settings, using motorized vehicles, reducing electrical consumption and other conservation measures are not only demonstrative of responsible actions to curb energy use and CO_2 production, but can make real contributions to abatement. This may be the easiest area for protected areas agencies to exercise and demonstrate adaptation, and indeed it is an area where some agencies such as Parks Canada Agency and Ontario Parks have taken a lead.

Aboriginal Interests in Protected Areas

Many northern protected areas are planned and managed to preserve the cultures of Inuit and First Nations (Box 7). Protected areas frequently permit traditional hunting, fishing and trapping. Where these are primary goals affecting the long-term sustainability of Aboriginal communities, dramatic change could prompt discussion and debate on intervention management in otherwise natural areas in order to maintain or contribute to the livelihood of Aboriginal peoples. Recent impacts of climate change combined with traditional ecological knowledge (TEK) are already revealing issues likely to escalate as climate change progresses. Such issues may necessitate the review and changing of current policies for some northern protected areas. Given the critical importance of many northern protected areas to Inuit and First Nations, it is vitally important that they be centrally involved in consultation and decision-making regarding the planning, management and operations of existing protected areas as well as exercises to identify, select and design candidate sites for future protection.

Education and Awareness

A Window of Opportunity

As previously noted, parks and protected areas are among the largest visitor attractions in Canada and many protected areas have a legislative mandate to provide visitors with educational experiences. For example, Canada's national parks and Ontario's provincial parks attract more than 10 million visitors per year, respectively, with economic benefits extending far beyond park boundaries (Ontario Parks, 2005; Parks Canada Agency, 2009c). Ontario Parks estimates that provincial parks generate annual gross provincial economic impacts of $344.5 million and provide 6,261 person-years of employment (Ontario Parks, 2005). Many operating parks across Canada have visitor services programs including interpretative talks and literature on natural history.

Parks and protected areas represent an important vehicle to inform and to educate the public on challenges and threats imposed by climate change in and beyond protected areas, and on the various mechanisms and tools available to mitigate the causes and the impacts of climate change. Given their conservation focus, the protected areas sector should be 'leading by example' and should be used to educate the public (e.g., through interpretation programs) about climate change impacts and the implications of these impacts for park features (e.g., species, habitats and ecosystems). Parks and other protected areas could be effective windows for building public support on climate change initiatives both within parks and broader society.

A number of Canadian protected areas agencies currently provide information on climate change via websites (e.g., Parks Canada Agency, B.C. Parks, and Ontario Parks), and a few individual parks have begun to incorporate climate change into interpretative programs. The U.S. National Parks Service (NPS) has initiated aggressive education and interpretative programming on climate change in its parks, which provides a useful model upon which Canadian protected area jurisdictions can build and enhance their own programs. For example, the NPS has developed an online climate change resource centre that focuses on three themes: 'Learn', 'Act', and

Box 7: Innovations in conservation in Canada's Pacific Northwest, the Great Bear Rainforest and the Taku River Tlingit Conservation Projects

Over the past two decades, the Northwest Pacific coastal region of Canada has been a hub of conservation innovation and activity. In particular, the region features flagship projects on protected areas and sustainable development that engage multiple stakeholders notably First Nations, government agencies, non-governmental organizations and industry in the design and implementation of large scale conservation projects. The Round River Conservation Studies group has been an innovator, a catalyst, and a facilitator in several of these initiatives.

The Great Bear Rainforest project, first initiated in the early 1990s, is an emerging success story that is reconciling the creation of new protected areas within a larger cultural and industrial matrix where land-use and resource development are being modified to soften their ecological footprint. The Round River Conservation Studies group, initially in collaboration with the Big House Society of the Heiltsuk First Nation and the Raincoast Conservation Society, has been instrumental in providing solid, science-based planning utilizing GIS-based analysis and assessment to integrate Traditional Ecological Knowledge (TEK) with Western scientific values and approaches. Prompted by many stakeholders, including ForestEthics, Greenpeace and Sierra Club B.C., the planning culminated in the announcement by the Government of British Columbia on March 31, 2009 to protect one third of the 6.4 million ha core area, complementing Haida Gwai, a number of provincial parks, and modified resource management in the region. Principle breakthroughs have been the application of GIS analysis, extensive collaboration across multiple sectors, and new governance paradigms that broaden responsibility and accountability among multiple partners. Ongoing collaboration with the Heiltsuk First Nation is developing new leaders in the community to carry on with preserving their homeland in a sustainable manner.

Areas protected from logging and Ecosystem based Management operating areas in the Great Bear Rainforest (Great Bear Rainforest, 2009).

Box 7: Cont'd

The Taku Tlingit River Conservation Project showcases similar innovations in efforts to protect the traditional homelands and wilderness values of the Taku Tlingit First Nation. Altogether, the territory comprises more than three million ha of wilderness dominated by the Taku River watershed. Once again, the key has been the application of science-based planning coupled with GIS applications to identify, document and map key values for conservation. The resulting plan provides a solid basis for the First Nation in negotiating land-use settlements and subsequent conservation and management efforts aimed at sustaining their way of life. Drawing on extensive community consultation and GIS applications, the new plan sets out a vision for a network of protected lands called 'Tlatsini' (meaning "places that make us strong"), which is intended to protect 'khustiyxh'- the Tlingit land-based way of life.

Ongoing efforts are helping the First Nation leaders to strengthen their abilities for joint governance of the territory in collaboration with the Government of British Columbia. The non-profit Taku Atlen Conservancy is exploring opportunities to develop joint ventures for ecotourism in the Taku watershed.

For more information, please visit: www.roundriver.org and www.savethegreatbear.org.

'Share'. This toolkit, developed by the NPS with the U.S. Environmental Protection Agency, and the U.S. Federal Wildlife Service, provides information on climate change and its potential impacts on wildlife, national parks, and wildlife refuges. The website also includes introductory materials, brochures on climate change impacts (e.g., climate change and cold water fish, climate change and birds, and climate change and public lands) and climate change case studies within specific ecoregions (e.g., Great Lakes and Upper Midwest, Western Mountain and Plains) (NPS, 2008). This is the most advanced web-based information source on protected areas and climate change available worldwide. Overall, parks and protected areas contain an untapped potential to educate visitors on impacts and institutional responses to climate change. They could also be used to encourage personal responsibility by providing visitors with climate change ideas and conservation-oriented activities that they can act on themselves to help to reduce greenhouse gas emissions.

Research, Science and Monitoring

Quantity and Quality of Science-based Information for Decision-making

Successful conservation outcomes depend on effective management of protected areas and conservation practitioners must choose from a range of alternative actions, including inaction (see discussion above). Pyke *et al.* (2007) recently emphasized that most support resources for climate-related decisions are currently limited by the quantity and quality of available information. Recent studies in the protected areas sector have similarly shown that practitioners have insufficient scientific knowledge and, consequently, primarily use 'experience' to assess their management decisions (Cook *et al.*, 2009). Given the relatively recent emergence of the climate change issue, one can only assume that most protected areas managers, not only in Canada but also globally, are inadequately experienced to deal with climate change. Moreover, past experience may not serve as a guide for management decisions in novel future conditions (Baron *et al.*, 2009). Therefore, lack of experience and scientific evidence to support decision-making in parks and protected areas potentially could compromise outcomes and jeopardize the investment made in protected areas for conservation.

Protected Areas as Benchmarks of Change

Canada's protected areas could provide significant points of reference to support monitoring of climate change on landscapes and waterscapes. The relatively undisturbed nature of national parks and other protected areas landscapes make them a valuable resource for climate change monitoring programs. Many protected areas agencies have monitoring programs in place to track and report on the activities affecting the health of protected areas through 'state-of–the-parks' reporting. Examples of robust programs already in place include those of Parks Canada Agency, Ontario Parks, B.C. Parks, and Alberta Parks.

Data collection is an important function of ecosystem-based management to provide a baseline in time to detect change. Climate stations in Canada's protected areas networks could be upgraded to include the collection of weather data (in the long-term, climate data) in conjunction with biodiversity data. National standards and protocols on ecological monitoring and assessment will be essential and the recent loss of Environment Canada's Ecological Monitoring and Assessment Network (EMAN) is an unfortunate set- back. In future, it will be important for agencies to assess climate change impacts in state-of-the-park reporting to evaluate the effectiveness of the current plans and help to identify the magnitude of adjustments that may be required to meet objectives. It is also important to include measures that are relevant to monitoring climate change, such as species composition, trophic diversity, ice/shore phenology, and those related to indicator species that are more sensitive to climate-related changes (e.g., species sensitive to changes in water levels and temperature and those at the southern and northern limits of their ranges).

There are two dimensions to science and research as they relate to protected areas and climate change: 1) applied science and research aimed at improving efforts to plan and manage protected areas; and, 2) more wide ranging scientific enquiry and study associated with the broader understanding of ecosystem function, species diversity, and genetic diversity. Research in the former dimension is needed on aspects such as: protected areas systems design; remediation and ecological restoration; predictive modelling for climate change and the design of protected areas; new paradigms and models for protected areas in an era of climate change; and, species persistence and future 'hotspot' identification. Research is also needed generally on the science and research functions of protected areas under emerging climate regimes (e.g., time/trend studies, species adaptation, alien and invasive species management, demonstration areas, etc.).

Some of the key questions about climate change in protected areas that transcend both the natural and social sciences are listed in Box 8. One or more workshops (perhaps a combination of a national session and/or regional caucuses) could be used to explore these questions and begin the development of a national strategy on climate change and protected areas.

Providing a better understanding of global environmental change through research activities in biosphere reserves is an explicit priority of UNESCO-MAB (the Man and Biosphere Program sponsored by the United Nations Educational, Scientific and Cultural Organization). In line with this goal, the potential use of biosphere reserves in mitigating and adapting to climate change impacts was recently recognized within the *2008 Madrid Declaration on the UNESCO MAB Programme and the World Network of Biosphere Reserves* (WNBR). The *Madrid Declaration* called upon UNESCO Member States, including Canada, to *"Capitalize upon the potential for action of biosphere reserves to address new challenges such as… climate change, biodiversity and sustainable development; and, in particular, as places for investments and innovation to mitigate and adapt to climate change…"* (UNESCO-MAB, 2008) As of 2010, 15 MAB sites are designated in Canada (examples include Waterton Lakes in Alberta, Mont St. Hilaire in Québec, Frontenac Arch in Ontario, and Clayoquot Sound in British Columbia). There is merit in applying biosphere reserve design techniques to existing designations or use them in the creation of new areas to help mitigate the impacts of climate change.

Adaptive Management

Given the significant uncertainties associated with climate change, there is an urgent need to reduce the knowledge gaps related to potential impacts in the protected areas sector, some of which are anticipated to be substantial as early as the 2020s. Adaptive management favours learning processes that help us optimize social organization and function and guide human behaviour in ecosystems during a period of rapid climate change. Given the importance of human behavior and preferences in determining conservation outcomes and the increasingly important role of multi-use public and private lands in conservation practice (Heller and Zavaleta, 2009), more research is needed on the social dimensions of climate change adaptation, in addition to the ecological aspects of climate change. A constant influx of new information about climate and ecosytem function will help practitioners and stakeholders make rational decisions related to climate change and conservation. Accordingly, an important aspect of any such enquiry is the need to document and report case studies on various adaptive approaches and techniques initiated to deal with climate change so that knowledge and experiences are shared among practitioners.

Box 8: Key questions with respect to protected areas, biodiversity and climate change

Policy, Planning and Management

- What are the implications of climate change for international conservation laws? What statutory requirements are necessary for adaptation?
- How can management goals be achieved in light of a changing climate?
- How can climate change be integrated into management plans?
- What is the potential role of an integrated freshwater, marine and terrestrial approach to protected areas planning and climate change adaptation?
- What are the implications of climate change for different IUCN protected areas categories? How can IUCN management categories be used to facilitate adaptation and mitigation efforts?
- How can different natural resource management policies within and between jurisdictions and agencies be aligned to facilitate mitigation and adaptation activities?
- Can a generic climate change adaptation decision framework be developed for managers operating at the site level? What options/tools are currently available or required?
- What are the opportunities and barriers with respect to climate change adaptation?
- What are the top priorities for protected area adaptation programs?
- How can agencies manage for the uncertainty associated with climate change?

Operations and Development

- What can protected areas agencies and organizations do 'in- house' to reduce GHG emissions (e.g., within buildings and offices, alternative vehicle solutions, energy conservation initiatives, etc.)?
- What adaptations are required to address changes in water levels in protected areas?
- What adaptations are required to help manage the impacts of new invasive species that migrate into protected areas boundaries?
- What adaptations to visitor infrastructure and services are required to reduce risks to visitors?
- How can protected areas jurisdictions take advantage of new recreation and leisure opportunities provided by climate change? What current recreation and leisure activities, programs and infrastructure are vulnerable to climate change impacts?

Science, Research and Monitoring

- What performance measures should be used to monitor impacts and management effectiveness with respect to climate change in State-of-the-Park reporting?
- What are the ecological research and monitoring priorities, needs and thresholds required to inform and trigger management decisions?
- What ecosystems and species will be negatively affected by climate change? What ecosystems and species will benefit?
- How can resiliency be increased to offset potential negative impacts of climate change?
- What is the long-term vision for ecological integrity in a rapidly changing climate?
- What are the synergies between climate change mitigation activities and biodiversity conservation?

Education, Interpretation and Outreach

- How do program managers engage and educate visitors and the general public on climate change impacts and adaptation?
- Is it advantageous to develop a generic suite of messages about climate change impacts and adaptation for use by all or many Canadian agencies and organizations?

Corporate Culture and Function

- How can funding be secured to support ecological integrity and climate change-related research?

Box 8: Cont'd

- How can agencies increase the awareness of the climate change issue within their own jurisdictions?
- How can human capital within protected areas agencies be enhanced?

Society and Culture

- How will climate change impacts within protected areas affect nearby communities (e.g., in terms of ecosystem services provided by protected areas)?
- How can protected areas help local communities adapt to climate change?
- How can society help facilitate mitigation and adaptation activities within and around protected areas?
- What are the societal forces that will influence mitigation and adaptation activities within and around protected areas?
- How can traditional ecological knowledge (TEK), local knoweldge, and scientific knowledge be used to help facilitate adaptive management?
- How will climate change-induced ecological change impact traditional use of protected areas?

Forging Common Pathways to Adaptation

Conservation strategies can be developed at various scales and with different time frames—from global to local, and from short-term to long-term. Owing to the spatial extent and ecological diversity of protected areas across Canada, climate change poses a range of issues, many of which will exhibit unique regional and local expressions. Accordingly, adaptation responses and mitigation measures for protected areas necessarily must be spatially and temporally flexible to accommodate potentially rapid and novel changes in ecosystem structure and function at various scales.

There is no single 'correct' approach to confronting climate change in protected areas, including efforts to develop broad-based adaptation strategies. Various approaches have strengths and weaknesses, and the success of any will depend on many considerations such as threat, scale, mandate, resourcing, information and expertise. Beyond satisfying local and regional needs, agencies responsible for protected areas will have to work collaboratively in order to maintain a comprehensive network of federal, provincial, territorial, and privately owned protected areas that is resilient to climate change.

Enhanced Inter-Jurisdictional and Stakeholder Collaboration

Climate change adaptation in the protected areas sector can only progress by means of a more integrated approach within government and institutions, among sectors, and between a complex overlay of ecological and jurisdictional scales, from the international to the local. Ecosystems do not adhere to political boundaries and inter-agency collaboration will be increasingly important. Networks will need to be established for adaptation strategies at the policy-making, implementation, and reporting levels. A logical next step, therefore, would be for the Canadian protected areas community to establish a climate change working group and/or to hold a national conference on issues associated with climate change, biodiversity conservation and protected areas. Since the institutional ramifications of climate change extend beyond the operational boundaries of government agencies, the CCEA is structured strategically to facilitate the development and implementation of comprehensive support mechanisms that will improve the capacity of cross-jurisdictional collaboration to adapt to climate change. In fact, many respondents to the PACC survey specifically indicated that they would be interested in working with the CCEA in this regard.

As ecosystems and their species increasingly respond to climate change impacts, agencies will need to develop better partnerships with counterparts within provinces and territories, between provinces and territories, and with the United States and Mexico. A tri-national workshop between Canada, the United States and Mexico will be needed to discuss research needs and to prioritize adaptation options on a continental scale. A strategic visioning exercise on the role of protected areas in an era of climate change, in addition to the ethical and moral facets associated with different management options, is also required. Considering limited financial resources for active management, and the uncertain external effects and externalities associated with various management decisions (e.g., the possible migration of non-target species, such as invasive species and pests resulting from connectivity conservation measures), costs, benefits, and trade-offs will need to be carefully considered and examined (see Hodgson *et al.*, 2009). Such a forum might be convened through the tri-lateral Commission on Environmental Cooperation (CEC), in which CCEA and other Canadian conservation organizations have participated in on previous conservation initiatives.

At the same time that national and hemispheric perspectives are critical for dealing with over-arching issues, regional enquiries would be valuable to pursue implications and mitigation measures for more local situations. As climate change scenarios will vary in different ecosystems, such as marine versus terrestrial, prairie ecoregions versus boreal forest, and wetlands versus arid environments, regional conferences and workshops could explore specific issues and needs facing protected areas in such ecologically defined settings. Such 'regional caucuses' could share information and collaborate on common needs. Such a 'bottom-up' approach would strengthen the regional dialogue and networking to magnify scarce resources and expertise. Forums such as the Centre for Applied Sciences in Ontario's Protected Areas (CASIOPA), the Parks and Protected Areas Research Forum of Manitoba (PPARFM), and the B.C. Parks and Protected Areas Research Forum (BCPARF) are well positioned to lead regional enquiries into protected areas and climate change.

Interdisciplinary Expertise

Given the implications and complexity of climate change, it is apparent that a wide range of expertise will be required to develop adaptation strategies and actions for protected areas. Beyond the collaborative forums suggested in the previous section, there are many tools for tapping into the interdisciplinary expertise of conservation experts, including practitioners and scientists. One example is the use of Policy Delphi panels. Policy Delphi panels, like the ones used by Ontario Parks to identify and evaluate climate change adaptation options (see Lemieux *et al.*, 2008), provide respondents with the opportunity to present innovative and sometimes controversial ideas anonymously to the panel in order to elicit objective and frank input on contentious issues or viewpoints (i.e., without fear of repercussions to either the panelist proposing the idea or to the panelist supporting it). This is particularly important in the protected areas sector because some adaptations proposed in the scientific literature will require fundamental changes in the way protected areas agencies plan and manage ecological areas and may be highly controversial within some agencies. The advantages associated with the Policy Delphi approach include balancing the influence of dominant individuals, eliminating irrelevant and biased communication, and reducing group pressure for conformity (i.e., minimized influence of power relationships). In the Ontario study, this worked toward meeting the objectives of the research and clearly overcame the weaknesses implicit in relying on a single expert, a 'one-shot' group average, or facilitated workshop discussion (Box 9).

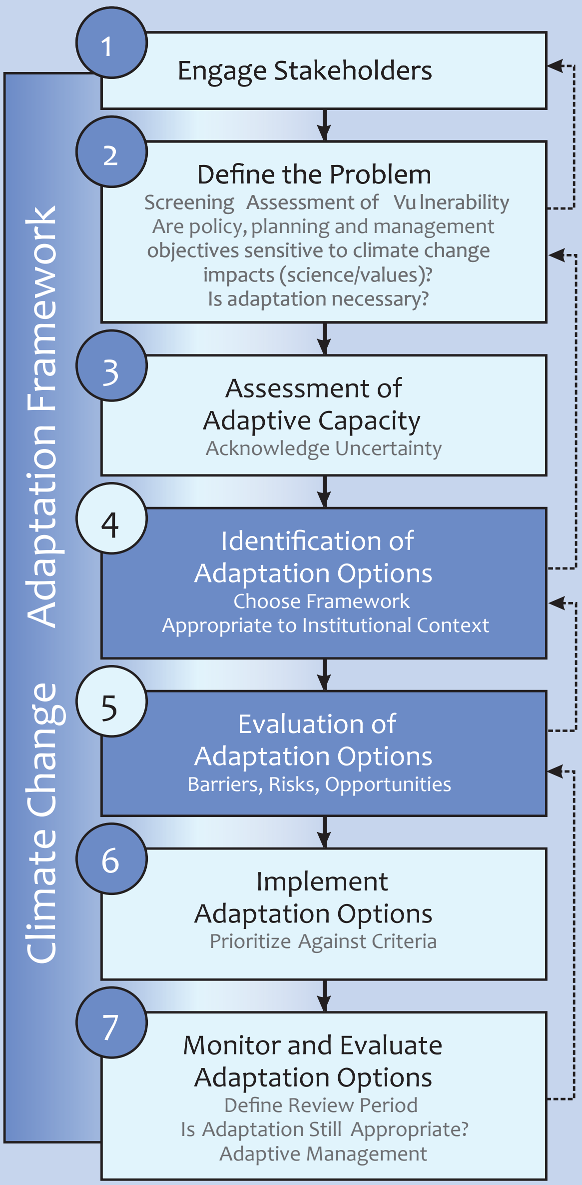
'Scenario Planning', 'Polarity Management' and 'Mediated Systems Modelling' are other emerging tools that could be used by agencies and organizations to identify and adapt to a variety of possible futures under climate change. 'Scenario Planning' consists of using contrasting scenarios to explore the uncertainty surrounding the future consequences of a decision and to increase the resilience of decisions to surprise(s) (Peterson *et al.*, 2003). The U.S. NPS is currently utilizing Scenario Planning in its efforts to increase its ability to design and implement management plans that will be effective under future uncertain climate change conditions. Similarly, 'Mediated Systems Modelling' facilitates the integration of expert information and stakeholder' participation in a dynamic framework to address complex problems. This process allows policy-makers and other stakeholders to see the consequences of their decisions in the face of significant uncertainty (van de Belt, 2004).

Principles to Guide Climate Change Adaptation

Traditional approaches to protected areas, together with the guiding principles of ecological representation and ecological integrity, have played, and will continue to play, an important role in protected areas planning,

Box 9: The climate change adaptation framework developed by Lemieux *et al.* (2007 and 2008) to examine climate change adaptation within Ontario Parks

The University of Waterloo, Ontario Parks, and the MNR initiated a collaborative study on climate change and Ontario's protected areas in 2004. The seven-step adaptation framework outlined below has guided Ontario Parks' adaptation actions to date and could be adopted by other jurisdictions in tailoring their own adaptation actions and strategy. The process was informed by climate change adaptation initiatives in other sectors (UNEP, 1998; UNDP, 2004; USAID, 2007; UNEP, 2008) and should not be used as a linear process. Instead, it should be used as an iterative cycle of problem definition, adaptation implementation, and evaluation of outcomes. Full results of the study can be found in the report entitled *Changing Climate, Challenging Choices: Ontario Parks and Climate Change Adaptation* (Lemieux *et al.*, 2008).



Step 1 Engage Stakeholders: Stakeholder engagement was initiated in 2004 at a Parks Research Forum of Ontario (PRFO) State-of-the-Art Workshop on Climate Change (Beveridge *et al.,* 2005). The aim of the workshop was to explore the evidence for climate change, the uncertainties involved, the implications for Ontario Parks' properties, and the measures that might be taken to adapt to changing conditions. The workshop was primarily intended for park managers and other staff to gain state-of-the-art knowledge on climate change as it relates to their current responsibilities, and to determine whether or not capacity existed within the organization to adequately address the issue **(Step 3: Assessment of Adaptive Capacity)**.

Step 2 Define the Problem: Problem definition focused on identifying policy, planning and management sensitivities to climate change (via literature reviews and climate-envelope modelling) to help Ontario Parks understand the risks associated with climate change. The results of the scoping assessment were published in Lemieux and Scott (2005) and Lemieux *et al.* (2007) and provided Ontario Parks with a preliminary assessment of risks of climate change to assets in protected areas (e.g., biodiversity, tourism and recreation) and a forecast of implications of climate change for protected areas policy, planning, and management.

Step 4 Identify Adaptation Options: Option identification can be focused on compiling both preparatory and participatory climate change adaptation activities. Preparatory activities began with the identification of adaptation actions, strategies, and policies in place to address current

Box 9: Cont'd

climate-related risks. Participatory activities included use of a Policy Delphi to engage key experts in an effort to identify alternative management practices, policies and technologies that may help Ontario Parks better cope with the anticipated impacts of climate change. Academic, federal government, private and ENGO experts were engaged during the Policy Delphi and encouraged to share information and experience, and to identify potential gaps that may have resulted from an 'Ontario Parks only' generated adaptation portfolio. In total, 165 adaptation options were identified for Ontario Parks major program areas by the Policy Delphi panel.

Step 5 Evaluate Adaptation Options and Select a Course of Action: The adaptation portfolio identified by the expert panel in Step 4 was evaluated and ranked according to the perceived level of desirability, feasibility and implementation time-frame of specific options. To further evaluate the recommended climate change adaptation options for their 'real-world applicability' and to systematically prioritize them for consideration in climate change adaptation strategies for Ontario's protected areas, an Ontario Parks Climate Change Adaptation Working Group (OP-CCAWG) was established. The OP-CCAWG consisted of 13 policy-makers and decision-makers representing the various program areas of Ontario Parks. The purpose of the OP-CCAWG was to evaluate the climate change adaptation options that were assessed to be 'Very Desirable' and/or 'Desirable' by at least 90% of the expert panel participating in the second round Policy Delphi survey.

Steps 6 and 7 Implement Adaptations and Monitor and Evaluate Adaptations: These two steps focus on implementation, monitoring, and reporting (i.e., adaptive management) of adaptation options,which fall under the mandate of Ontario Parks and MNR.

management and operations under changing climate regimes. However, these approaches and principles will need to be re-evaluated and enhanced if the primary role of protected areas systems (e.g., the persistent representation of species) is to be achieved in an era of rapid climate change. While current system-wide goals are likely to remain as valid as ever, decisions to maintain existing protected areas and create new areas in a rapidly changing climate will require adaptive approaches to management that draw upon evolving management tools and techniques.

Based on the review and discussions presented within this report, and on syntheses conducted in Canada by Scott and Lemieux (2005), Welch (2005), Lemieux *et al.* (2008) and others internationally (e.g., Huntley, 2007; Baron *et al.*, 2009; West *et al.*, 2009), there are a number of key principles essential to any climate change adaptation strategy designed for the protected areas sector. Many of these principles already underpin the best protected areas programs in Canada and are proven cornerstones that can also be used to effectively address climate change adaptation.

Adopt a Science Base

Policies for protected areas should embrace a science-based, adaptive management approach to better deal with potential climate change impacts (i.e., acknowledgement of the dynamic nature of ecosystems and increased flexibility to better manage uncertainty). Adaptive management embraces the uncertainty associated with climate and ecological change and it provides the means for managers to design actions that specifically test uncertainties about ecosystem dynamics and outcomes of proposed interventions (Baron *et al.*, 2009). It can also be used to adjust and refine management based on new knowledge (Walters and Holling, 1990). Policies and targets should not only address elements of biodiversity pattern, but should also include the spatial and temporal aspects of natural processes, including population sizes, movements, metapopulation dynamics, disturbance regimes, ecological refugia, and adjustments to climate change. As past experience may not serve as a guide for novel future conditions, science-based adaptive management will be necessary (Baron *et al.*, 2009).

Plan for Multiple Scales

The entire array of protected areas regardless of size and jurisdictional authority will be important to effectively adapt to climate change. The scales at which climate change impacts become apparent 'on-the-ground' will dictate the appropriate scales at which management strategies should be developed and the adaptation approach pursued. Protected areas should be part of networks of ecological areas within which biodiversity can survive, move, and be appreciated. Protected areas agencies should promote the importance of regional ecosystems characterized by connectivity and permeable landscapes for wildlife movement. The integration of protected areas design, selection, planning and management with multi-sectoral land-use plans can only benefit discussion and decisions on climate change adaptation within and around protected areas.

Work across Boundaries

Because climate change will affect ecosystems, watersheds, migratory species, and other trans-boundary natural systems and processes, inter-jurisdictional planning and management is important. Improved collaboration and stewardship from local to international scales will be required. Protected areas agencies and organizations need to consult with their counterparts and other land resource users in adjacent provinces and states to help anticipate, plan, and synergize cross-jurisdictional objectives to anticipate the 'loss and gain' of species, communities and processes, and to ensure the retention of ecoregional representation and ecological integrity.

Innovate Novel Approaches

Climate change adaptation requires implementation of a range of measures, from short- to long-term and from precautionary and proactive to reactive. While information on ecology and nature conservation will always be essential, greater examination of the human dimensions (e.g., social aspects) of climate change is also required. There is a need to integrate ecology with other disciplines and approaches that explicitly address the roles of institutions, policy, politics and people in climate change decision-making and integrated conservation strategies for climate change adaptation. Integrating scientific knowledge with socially robust or context-sensitive knowledge will better address the needs of society and users (e.g., practitioners) and better inform action at the science-policy-practice interface.

Establish New Partnerships

Protected areas agencies and organizations should work in co-operation with other organizations outside of protected area boundaries to help reduce the impacts of climate change through approaches such as protected areas system design, ecological restoration, and compatible land-uses adjacent to and surrounding protected areas. Protected areas organizations should also explore the potential of volunteer monitoring programs (e.g., NGOs, 'Friends Of' groups, local schools, park users, etc.) to detect and monitor climate change impacts and to document the effect of conservation actions.

Research and Monitor Effects

Research and monitoring are imperative to understand the impact of past and future climate change and to identify values-at-risk. Protected areas should be promoted as potential long-term monitoring sites. Agencies should work toward ensuring that appropriate climate change information is available for all aspects of protected areas management. An integrated and collaborative monitoring strategy to detect and monitor trends and impacts, especially for climate-sensitive species, extinction prone species, and management target species, should be established and implemented at a broad ecoregional/ multi-jurisdictional level. Such a monitoring program should also be used to document and assess the success or failure of remedial actions and to gauge the effectiveness of management actions via 'state-of-the-park' reporting.

Utilize Adaptive Management

Principles of 'adaptive management' and 'ecosystem-based management' should be incorporated into all aspects of management (e.g., preparing and implementing resource management plans and their subset of interventions) and planning directions (strategic/corporate, systems planning, site level management plans) of protected areas agencies. Adaptive management is likely to be an effective method for implementation, given uncertainty in both climate change impacts and the effectiveness of response strategies. Tracking progress toward goals, through research and monitoring, and evaluating the effectiveness of strategies and actions provide the feedback protected areas agencies need to adjust goals, priorities and strategies, and establish new directions.

Build Expertise and Capacity

There remains an important gap between the perceived salience of climate change and the capacity (i.e., funding, staff expertise, etc.) of protected areas agencies to adapt. Internal capacity-building for continued climate change adaptation will be required. Professional training and research capacity of protected areas staff with regards to climate change will need to be strengthened. Capacity-building and awareness should proceed with the goal of securing public acceptance for climate change adaptation. Resources for investing in active, adaptive management will be needed.

Lead Mission by Example

Protected areas agencies should lead by example in public interpretation and education activities. Protected areas should be used to educate the public (e.g., through interpretation activities) about climate change impacts and the implications of these impacts for protected features (e.g., species, habitats, ecoregions, physiography, etc.), and to build public support on climate change initiatives. Parks and other protected areas should be used to inform the public about climate change efforts to mitigate and adapt to it. The reduction of greenhouse gases within all aspects of park operations should be a priority of protected areas agencies.

Communicate Change

Climate change presents significant and complex ecological, social, and economic challenges and opportunities to protected areas agencies and organizations in Canada. Accordingly, agencies and organizations will be responsible for communicating these challenges and opportunities to an increasingly diverse and concerned public audience. Parks and other forms of protected areas offer the potential to educate millions of visitors annually on climate change impacts and their implications for natural assets, and they provide the opportunity to enhance understanding of associated managerial responses. Communication strategies will need to be scientifically-based and carefully developed and coordinated across agencies to ensure robust, clear, and consistent messaging. Communication efforts should address identified local problems and needs (i.e., be 'place-based'), as well as regional, national and international issues, in order to connect visitors and nearby communities to climate change issues. Further research on climate change communication will allow protected areas agencies and organizations to determine communication barriers and effective strategies and technologies (e.g., social media technologies) that can be used to communicate protected areas and climate change-related issues to park visitors and the wider Canadian public.

Ensure Public Accountability

Effective governance and public accountability are fundamental in all policy areas and they are especially crucial functions of complex and long-term issues like climate change. Accountability with respect to climate change needs to be institutionalized within protected areas agencies and organizations at all scales. Given the now widely recognized importance of protected areas in providing a wide range of ecological goods and services, both within and beyond their boundaries, it is increasingly important that these areas continue to be protected and managed to the highest standards. Regular reporting on the state of these areas is an effective way to strengthen public accountability that is essential to gauge the degree to which conservation efforts are successful.

Be Comprehensive in Scope

In summary, future efforts on protected areas in Canada and beyond will need to adopt a comprehensive outlook on the design, protection and stewardship of viable networks of sites. Principles such as ecological integrity and landscape conservation will have to become universal touchstones for developing viable networks that are robust and resilient to accommodate ecological change. Seamless transitions between protected areas and surrounding conservation-minded land-uses will help to better provide for the movement and migration of species and biotic communities. Such an adjustment will require similar cultural flexibility in the acceptance of such a comprehensive architecture with policy, legislation and governance finely tuned to respond to changing needs.

Report Summary and Concluding Remarks

Although protected areas on their own cannot guarantee the survival of large apex predators, such as Polar Bear (*Ursus maritimus*), large areas remain important cornerstones of range-wide efforts to conserve such species through comprehensive strategies for wildlife conservation, ecological sustainability and climate change mitigation. (Photo Credit: RobertMcCaw.com)

Report Summary

Over the past two decades, Canada's image as a world leader in parks and protected areas has been substantially reinforced by a surge of interest and strengthened commitment. Remarkable progress in the creation of new protected areas has generated more than a twofold increase in the total area protected, which now exceeds the combined area of Germany and France. In the process, protected areas have gained legitimacy as a prominent land-use highly relevant in efforts to conserve biodiversity and enhance ecological sustainability. The integration of systems planning for protected areas with more comprehensive land-use planning exercises underscores the maturity of the protected areas movement.

This report is the first major synthesis and review regarding climate change mitigation and adaptation for protected areas in Canada. With nearly 10% of the country housed within protected areas—a virtual storehouse of biodiversity and other ecological goods and services—the need to protect and sustain this extensive heritage estate represents an environmental and social imperative in Canada's longstanding tradition of conservation. While the report highlights many of the issues and threats posed by climate change, it also identifies many opportunities to develop adaptive strategies and mitigation measures to confront the challenge. So while the prospect of accelerated climate change may be daunting, there is room for optimism based upon Canada's international commitments to protected areas and biodiversity conservation.

The Climate Change Context

Among the many challenges confronting protected areas agencies and organizations, climate change has emerged in recent years as a topic of considerable global concern. The impacts of changing climate are already evident in every region of Canada. Some of the reported impacts include changes in the geographic distribution, migratory pathways and abundance of species, changes in the timing of reproduction of species, changes in phenology (e.g., onset, end, and length of growing season), changes in the geographical occurrence and magnitude of pest outbreaks, changes in inter-specific interactions, and widespread aquatic responses to increasing temperatures in both freshwater and marine ecosystems. Climate change will exacerbate many current climate threats, and present new risks and opportunities, with significant implications for ecosystems and biodiversity conservation in Canada and indeed globally.

Summary of Key Points:

- Global temperature has increased about 0.76°C over the past 100 years (1896 to 2005) and the rate of warming has greatly accelerated since the 1950s.
- In Canada, temperature has increased 1.4°C, about double the global increase over the past 62 years.
- Only once in the last 35 years (2001) was Canada's annual precipitation level significantly below normal.
- Global temperatures are projected to increase by 1.1 to 6.4°C over the next 100 years, with land areas warming more than the oceans, and with high latitudes (including Canada) warming more than lower latitudes (e.g., the tropics).
- In Canada, annual mean temperature increases of 3.1 to 10.6°C are projected for the 2080s.
- Earth likely will experience some climate change regardless of aggressive emissions reductions.
- The warming that has occurred over the last 50 years has had a discernible impact on biodiversity now, and it has been implicated in a number of species extinctions.
- Modelling analyses for Canada suggest that many species will extend or reduce their distribution depending on their location and ability to adapt.
- Virtually all meta-analyses to date suggest that climate change will have predominantly negative consequences on biodiversity if adequate climate change mitigation and adaptation measures are not put in place.

The Conservation Challenge in Canada

Federal, provincial and territorial efforts to establish and manage protected areas in Canada have embraced the principles of 'eco-regional planning', 'ecological representation' and 'ecological integrity' as cornerstones in policy and planning for protected areas. The implications of climate change on these principles and approaches now necessitate broad-based review, thoughtful consideration and consultation regarding the projected impacts of climate change on protected areas, and possible ways to address them.

Canada, a world leader in the protected areas movement, has made some progress in recognizing and documenting threats and opportunities, with work initiated in some agencies to begin dealing with climate change. However, national, provincial and territorial response strategies have essentially not addressed the role that protected areas can play in climate change mitigation, adaptation, and in protecting the livelihoods of Canadians.

Summary of Key Points:

- Earth's networks of protected areas have largely been designed to protect specific natural features, species and communities *in-situ*, not taking into account the major shifts in ecosystem composition, structure, and function that could be induced by climate change.
- Climate change poses a new threat to long-term persistence of biodiversity and complicates the planning and management practices (i.e., ecoregion representation) that have been developed within the 'envelope' of current climate and ecosystem distribution.
- Current protected area habitats may become suitable for new species (i.e., species currently occupying niches in more southerly located ecosystems).
- Some recreational opportunities may decline (e.g., cross-country skiing) while others may increase and new ones may be introduced.
- Active management plans, such as those for restoration, invasive species, species re-introductions, forest fire management, and prescribed burns may require revision.

The Protected Areas and Climate Change (PACC) Survey

Understanding how protected areas agencies view climate change (both independent of and with respect to adaptation) is an important precursor to any attempt at developing tools, techniques and strategies for adaptation. Moreover, there is an urgent need identified in the literature for ongoing, rigorous 'accounting' of climate change adaptation to assist natural asset managers in their efforts to establish new programs. In response to these needs, the University of Waterloo and the CCEA initiated a collaborative Protected Areas and Climate Change (PACC) Survey in 2007, and updated in 2009, to assess the state of current efforts on climate change adaptation employed by Canadian protected areas agencies and organizations.

The PACC Survey was designed to address three objectives:

1) To identify what climate change impacts are currently perceived to be affecting and/or are anticipated to affect protected areas across Canada;

2) To evaluate the perceived importance of climate change relative to other protected areas management issues within Canadian jurisdictions; and,

3) To determine what policy, planning and management responses (i.e., adaptations) have been developed or are being considered by protected areas agencies across Canada.

Summary of Key Findings:

- 100% of survey respondents believed that climate change is an important management issue for protected areas in the very near future (2020s).
- 73% of survey respondents indicated that protected areas within their agency's jurisdiction were currently affected by climate change-related impacts.
- 27% of survey respondents indicated that they were *not sure* whether or not protected areas within their jurisdiction were experiencing climate change-related impacts.
- 94% strongly agreed or somewhat agreed with the statement that *"climate change will substantially alter protected areas policy and planning over the next 25 years"*.
- Species range shifts and changes in physiography (e.g., shoreline erosion and glacial retreat) were the most commonly reported climate change-related impacts occurring within Canada's protected areas with nearly 75% of respondents reporting such impacts.
- No agencies surveyed currently have a climate change adaptation strategy or action plan in effect.
- There is a lack of information on the implications of climate change for species-at-risk in Canada.
- Agencies expressed a need for more information on the ecological consequences of climate change and the implications of climate change for policy, planning and management strategies.
- A large majority (94%) of the respondents indicated that they wanted 'much more information' or 'some more information' on strategies for managerial response (adaptation) to climate change impacts and strategies for effective communication of climate change issues respectively.
- Over two-thirds of the agencies strongly disagreed or somewhat disagreed with the statement that *"there are too many uncertainties regarding climate change to develop adaptation strategies for protected areas".*
- While the PACC Survey did reveal a strong motivation by protected areas agencies and organizations to move forward on climate change adaptation, most acknowledged that they are uncertain about how to proceed.
- 91% of agencies took the position that they currently *do not* have the capacity necessary to deal with climate change issues.
- The PACC Survey revealed a clear disconnect between the perceived salience of the possible impacts of climate change on protected areas and a lack of available resources to address the issue (e.g., specifically, there is a shortage of financial resources, staffing, and scientific expertise).
- Case studies on current Canadian initiatives relevant to protected areas and climate change revealed wide-ranging activities across the country, but no unified comprehensive approach to climate change.

Moving Forward on Climate Change Adaptation

Traditional approaches to protected areas, together with the guiding principles of 'ecoregional representation' and 'ecological integrity', have played and will continue to play an important role in protected areas planning, management and operations in the future. However, these approaches and principles may need to be refined and enhanced if the primary roles of protected areas systems are to be achieved in an era of climate change. While current system-wide goals are likely to remain as valid as ever, more careful consideration will have to be assigned to individual protected areas since climate change impacts may be highly variable depending upon the nature of the environments, ecosystems and species housed in specific areas.

While the impacts of climate change pose a number of challenges for managers, protected areas can also play a vital role in adapting to the effects of climate change and in working toward achieving objectives outlined in both international and national conservation agreements, policies and plans. For example, they can increase ecological resilience, provide protection against the physical impacts of extreme weather events and other climate change impacts, and help species and communities adapt to changing conditions. Clearly, however, there remains an important gap between the perceived importance of climate change and the capacity (i.e., funding, staff expertise, etc.) of protected areas agencies and organizations to respond. The ability of protected areas agencies across Canada is currently constrained by a lack of flexible policy and political will as well as insufficient financial resources and human capital.

Summary of Key Points:

- Significant progress has been made in understanding the potential impacts and implications of climate change for biodiversity conservation in terms of policy, planning and management for Canada's protected areas. However, many jurisdictions have not been engaged in any substantial dialogue on climate change and adaptation.
- Ensuring the persistence of species and habitats under climate change will not only require adjustments and changes to the extent of protected areas, and changes in the way they are managed, but it will also require new and innovative conservation approaches.
- The following approaches may assist enhancing the permeability of the greater landscape and facilitating the dispersal of species in an era of climate change:
    - New protected areas 'classes' (including consideration of dynamic reserves);
    - Off-site protected areas establishment (either temporary or permanent);
    - Stewardship activities aimed at restoring habitat and/or facilitating connectivity;
    - Conservation incentives on private lands;
    - Biodiversity 'offsets';
    - Ecosystem and species redundancy; and,
    - Assisted migration in the unprotected matrix.
- Reconciling foundation principles, such as 'ecological representation' and 'ecological integrity' may well comprise challenging dilemmas for protected area practitioners.
- Valuing current carbon stock and sequestration potential as part of an adaptation policy is yet to be explored in Canada and the trade-offs and long-term implications are largely uncertain. Despite these current limitations, the potential inclusion of carbon management in any post-*Kyoto* agreements could potentially offer an additional criterion by which protected areas are established, restored, connected, and thus weighted and valued.
- Given their conservation focus, the protected areas sector should be 'leading by example'. Protected areas should be used to educate the public (e.g., through interpretation activities) about climate change impacts and the implications of these impacts on conserving ecosystems and natural features (e.g., species, habitats, ecoregions, physiography, etc.).
- Protected areas could provide important opportunities to strengthen public understanding and support on climate change initiatives both within specific areas and more broadly in other sectors.
- The relatively undisturbed nature of national park landscapes and many other categories of protected areas make them a valuable resource for climate change research and monitoring purposes.

Principles to Guide Climate Change Adaptation

A number of key principles essential to any climate change adaptation strategy within the protected areas sector are identified below. Many of these principles already underpin the best protected area programs in Canada and are proven cornerstones that can also be used to effectively address climate change adaptation.

Summary of Key Principles to Guide Climate Change Adaptation:

- Adopt a Science Base
- Plan for Multiple Scales
- Work across Boundaries
- Innovate Novel Approaches
- Establish New Partnerships
- Research and Monitor Effects
- Utilize Adaptive Management
- Build Expertise and Capacity
- Lead Mission by Example
- Communicate Change
- Ensure Public Accountability
- Be Comprehensive in Scope

Challenges and Opportunities for Climate Change Adaptation

In many respects, jurisdictions are not starting from 'ground zero' in responding to the climate change issue. Despite the fact that most jurisdictions still need to incorporate provisions for climate change into the policy, system planning, management and operations of protected areas across Canada, many have made indirect progress that is beneficial for climate change adaptation.

Examples of beneficial actions include:

- Increasing the number/density of protected areas;
- Ensuring the inclusion of still unrepresented ecosystems and habitats;
- Establishing large protected areas and focusing on connectivity to help facilitate movements of plants and animals;
- Completing biodiversity inventories;
- Undertaking ecological restoration initiatives;
- Completing carbon valuation analyses and reducing carbon emissions in field operations;
- Initiating trans-boundary collaboration; and,
- Conducting climate change research, education and outreach activities.

Although not all are tailored specifically to climate change, all of these efforts can help to mitigate climate change impacts and facilitate climate change adaptation over the 21st century and beyond. Moreover, Canada's protected areas managers and practitioners have ample local knowledge and technical expertise that will certainly facilitate adaptation both within and beyond protected areas. The fact that system planning for protected areas is being increasingly integrated with more comprehensive land-use planning in Canada may proffer well for specific action on climate change adaptation for protected areas within the context of broader landscape planning and management.

Summary of Key Points:

- Some level of human-induced climate change will be realized in the 21st century. As a result, climate change adaptation is a *necessary* policy strategy.
- There is generally insufficient information on the best places to safeguard or enhance biodiversity in an era of climate change and there has been little direct investigation into the practicality (including costs) of adaptation in protected areas.
- Incremental adaptation within Canada's protected areas agencies is occurring to some extent, but independent and regardless of a coordinated national approach.
- With limited information and resources at their disposal, it is re-assuring that a number of Canadian protected areas agencies have progressed as much as they have on climate change adaptation.
- Adaptation efforts have been constrained by other more immediate priorities and a general lack of clear roles and responsibilities among national, regional and local mandates.
- Accountability is unclear which inhibits maintaining commitment with respect to climate change.
- There is an over-riding need for more resources to build capacity for effective management within protected areas institutions.
- It is to be hoped that extreme events, such as species extinctions, are not required to raise the consciousness of climate change *vis-à-vis* policy-making for protected areas in order to legitimize conservation action.
- Given the relatively undisturbed state of many ecosystems and substantial opportunities for integrated regional land-use and conservation

planning, Canada has an unprecedented opportunity to protect natural values that are of regional, national and global significance in an era of climate change.
- The relative youth of marine and freshwater protected areas system planning in Canada might work to the advantage of the agencies and organizations responsible for their establishment and management. Principles for incorporating climate change adaptation into marine protected area site and system planning have been developed and can be considered by protected areas managers to help guide current and future federal, provincial and territorial marine and freshwater conservation initiatives. Such science-based information and guidance was not so readily available when Canada's system of terrestrial protected areas more than doubled over the past 20 years.

Concluding Remarks

Both the UN Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report* (AR4) (IPCC, 2007b) and Canada's national synthesis on climate change, *From Impacts to Adaptation: Canada's Changing Climate in 2007* (Lemmen *et al.*, 2008), have indicated that despite efforts to reduce greenhouse gas emissions, some level of human-induced change will be realized in the 21st century. Indeed, studies by Hughes (2000), Parmesan and Yohe (2003), CCME (2003), Root *et al.* (2003), the IPCC (2007a), and Lemmen *et al.* (2008) report that a number of species are already responding to climate change. The recent IPCC Working Group II report stressed that *"The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances, and other global change drivers [and] the magnitude and timing of impacts will vary with the amount and timing of climate change and, in some cases, the capacity to adapt."* (IPCC, 2007a: 7-8)

"Although… natural resource managers already have many tools that can be used to address climate-change effects, managers will likely need to apply these tools in novel and innovative ways to meet the unprecedented challenges posed by climate change." (Mawdsley *et al.*, 2009: 1080)

The impacts of climate change may effectively alter the traditional 'rules' of biodiversity conservation in Canada and may have far-reaching consequences for those agencies and organizations that manage them (Scott and Lemieux, 2005). Although many adaptation options are available to protected areas managers, uncertainty about the magnitude and timing of climate change, delayed ecosystem responses, and a lack of adequate resources and capacity has discouraged their adoption. While the U.S., Australia, the U.K., and Canada appear to be forerunners on climate change adaptation in protected areas, it is difficult to identify exemplary approaches as little implementation of adaptation has taken place to date. All protected areas agencies around the world appear to be struggling with adaptation at the resource and decision-making levels.

Correspondingly, there is generally insufficient information on the best places to safeguard or enhance biodiversity in an era of climate change and there has been little direct investigation into the practicality (including costs) of adaptation in protected areas. Indeed, the task of 'operationalizing' climate change adaptation in protected areas has just begun and 'mainstreaming' climate change into protected area management at all scales remains a task for the future. Strong stakeholder participation in adaptation research is recommended in many jurisdictions to ensure that the adaptation process is transparent and successful. While shifts such as climate change and a changing society present new challenges and opportunities for protected areas managers, a strong foundation has been established upon which to build in the years to come. The fundamentals of protected areas in mitigating and adapting to climate change should not be overlooked. Many facets of modern approaches to planning and managing protected areas in recent years have relevant application to addressing climate change (e.g., network-based approaches, including core areas, connecting linkages and buffers). The dramatic expansion of the Canadian protected areas network over the past two decades has created a substantial foundation with some inherent resiliency to climate change and provides a solid foundation that can be built upon. The contemporary efforts, based on approaches to capture representative nodes of physiographic and biological diversity, provide a hedge against uncertainty and the necessary acceleration of mitigative actions. Moreover, Canada has an unprecedented opportunity to protect natural values that are of regional, national and global significance. In particular, it is one of the few remaining countries in the world that maintains large, relatively unfragmented ecosystems, such as the Boreal forest and Arctic region, which still contain large scale functioning natural processes.

With limited resources at their disposal, it is encouraging that many protected areas agencies have progressed as much as they have on climate change adaptation. However, adaptation within Canada's protected areas jurisdictions is occurring independent from and regardless of a coordinated national approach. The results of the PACC Survey and the findings of independent audits on the management effectiveness of protected areas agencies indicate that there is an over-riding need for more resources to build capacity for effective management within protected areas institutions. Indeed, independent audits of a number of parks agencies across Canada and in the U.S. have consistently revealed that these agencies do not have the capacity to manage for ecological integrity nor climate change (AGO, 2002; ECO, 2007; OAGC, 2008a and 2008b; GAO, 2009). As Lord Nicholas Stern emphasized in a recent IUCN WCPA-led report on climate change and protected areas, *"Without the investment made in protected areas systems worldwide, the situation would be even worse."* (Dudley *et al.*, 2010: 3)

> *"Protected areas are an essential part of the global response to climate change. They are helping address the cause of climate change by reducing greenhouse gas emissions. They are helping society cope with climate change impacts by maintaining essential services upon which people depend. Without them, the challenges would be even greater, and their strengthening will yield one of the most powerful natural solutions to the climate crisis."* (Dudley *et al.*, 2010: 7)

Adaptation measures that focus on reducing vulnerability to both current and future climate represent a logical first step that delivers benefits regardless of the rate of future climate changes (Lemmen *et al.*, 2008). Increasing the number and size of protected areas, minimizing internal and external threats (such as habitat fragmentation and reducing the prevalence of invasive species), and restoring ecological integrity both within and surrounding protected areas are examples of precautionary and proactive adaptation measures that focus on reducing vulnerability to both current and future climate and would undoubtedly enhance the resiliency of species and ecosystems to climate change impacts. Such proactive approaches would encourage conservation planning that is relevant both today and in the future.

> *"The failure to make significant progress on adaptation efforts exposes Canadians' social and economic well-being to risk... Taking steps now to adapt to a changing climate can help protect Canadians and their assets and reduce the potential economic, social, and environmental costs."* (OAGC, 2006: 23)

Overall, however, protected areas institutions are currently not adequately prepared to mitigate impacts nor take advantage of the benefits and opportunities that may be provided by climate change. Professional training and research capacity with regards to climate change will have to be strengthened within protected areas institutions. Adaptation efforts have been constrained by other more immediate priorities and a general lack of clear roles and responsibilities among federal, provincial, territorial and local agencies. Moreover, the unclear accountability regarding the development of climate change adaptation strategies for protected areas further inhibits action. Clarifying roles and responsibilities would undoubtedly help to encourage adaptation.

We hope that the information in this report provides a foundation for ongoing dialogue on the development and implementation of strategies and approaches for adaptation to curb the projected impacts of climate change on protected areas and to better position agencies to take advantage of associated benefits. Hopefully, the increased awareness and understanding of the implications of climate change on protected areas and biodiversity will lead to more concerted conservation action. Ultimately, whatever is done about climate change will be, in the end, a value judgement. Protected areas agencies will have to decide how much uncertainty that they are willing to confront and the degree of change necessary to precipitate conservation action. All of these issues, together with the collective resolve of all jurisdictions to combat them, will determine how climate change adaptation processes are likely to unfold within Canadian protected areas agencies.

This report seeks to address many of the common issues and needs associated with climate change that are confronting agencies and organizations responsible for protected areas throughout Canada. The ideas and thinking on moving forward with a strategy for climate change adaptation are surely provisional and intended to provoke further consideration. The fact that climate change is such a pervasive force does present some challenges and some opportunities. All protected areas agencies and all protected areas across Canada (and indeed, North America and globally) do need to confront the many common issues and challenges posed by climate change. The choice is for individual agencies and organizations to 'go it alone', or for the protected areas sector to unite and to pool resources for the mutual benefit of all parties. A common forum with a mandate to consult, deliberate and formulate an over-arching strategy for climate change adaptation seems like the most reasonable and most efficient first-step to confront such a wide-sweeping issue. Such a forum could embody 'regional caucuses' to assess variations in regional issues and needs thereby providing both a 'top-down' and 'bottom-up' perspectives and input into the process.

We call on all levels of Government to begin mainstreaming protected areas systems into broader climate change mitigation and adaptation strategies to ensure effective management of protected areas, since a comprehensive approach is the best way to help protected areas endure climate change and keep them working effectively for present and future generations of Canadians.

Annotated Plates

The impacts of climate change on marine ecosystems may affect large predatory marine mammals such as the distinctive Orca or Killer Whale (*Orcinus orca*), which inhabits the coastal waters of Pacific Rim National Park and other protected areas on the West coast, through impacts on the structure and function of lower food chains which may affect prey species. (Photo Credit: F. Mercier, courtesy Parks Canada Agency)

Together with photographs elsewhere in this report, this travelogue presents a portfolio of images mostly from protected areas in Canada, that illustrates existing or projected impacts attributed to climate change together with principles and actions that may help to mitigate site-specific threats. While decidedly northern in perspective, situations are also featured from southern Canada where protected areas and biodiversity are also implicated by climate change.

The certainty of climate change and its impact on species, ecosystems and protected areas may be subdued by its insidious and incremental nature and its frequently localized expression. However, taken together, over time, the impacts of climate change are cumulative and they will increasingly precipitate the need for adaptive management in order to achieve conservation goals and objectives for protected areas and biodiversity conservation.

This portfolio was motivated by the review of projected climate change impacts on National Parks conducted by Scott and Suffling (2002). Many of the negative impacts that were chronicled by them regrettably seem to be coming to fruition. The survey in this annex provides a visual dimension to their earlier documentation and forecast, and is broadened here beyond National Parks to emphasize and display the global nature of climate change and its potential impacts on all categories of protected areas.

Correspondents who assisted in searching out and providing photographs for this portfolio are listed in the Acknowledgements.

For the lay person and scientist alike, receding glaciers and the shrinking polar ice cap, which are contributing to sea level rise and associated impacts on terrestrial, freshwater and marine ecosystems and species, have become the most demonstrative marquee for climate change. Kaskuwuksh Glacier and Ice field, Kluane National Park, Yukon. (Photo Credit: J. Butterill, courtesy of Parks Canada Agency)

A panoramic vista on Ellesmere Island illustrating accelerated seasonal snowmelt with orphan glacial lobes, subsidence of tundra meadows, and abraded mountain slopes and scree sites which are becoming more prevalent as Arctic conditions retreat in response to ongoing global warming. Quttinirpaaq National Park, Ellesmere Island. (Photo Credit: J. Gould)

The melting and retreat of permafrost will have a number of impacts including the release of carbon dioxide and methane gas, subsidence of landforms, and altered patterns of dehydrated and paludified sites, with consequential changes to the distribution, structure and function of Arctic ecosystems and species. Quttinirpaaq National Park, Ellesmere Island. (Photo Credit: J. Gould)

Prominent mounds with ice cores, known as 'Pingos', in permafrost regions of Canada's far North, such as this striking example near Erly Lake in Tuktut Nogait National Park in Northwest Territories, are a signature landform of the Arctic now threatened under persistent warming of northern climates. (Photo Credit: I.K. MacNeil, courtesy Parks Canada Agency)

Migratory species, such as Barren Ground Caribou (*Rangifer tarandus groenlandicus*) in Vuntut National Park in Yukon, may be disrupted in both their summer and winter ranges, as well as along corridors that are critical for their annual migrations as a result of changing ecological conditions attributed to climate change. (Photo Credit: W. Lynch, courtesy Parks Canada Agency)

Alpine ecosystems and their associated biota, such as Mountain Goat (*Oreamnos americanus*) on Sheep Mountain in Kluane National Park in Yukon, may be subject to the effects of climate change resulting from habitat dislocation arising from northerly and altitudinal shifts of regional climatic patterns. (Photo Credit: W. Lynch, courtesy, Parks Canada Agency)

The legendary and ancient lineage of Musk Ox (*Ovibus moschatus*), known as 'Oomingmak' to Inuit people, may be vulnerable to the progression of climate change which may impact its tundra and barren habitats in protected areas and surrounding regions. Aulavik National Park, Northwest Territories. (Photo Credit: W. Lynch, courtesy Parks Canada Agency)

Intricate community patterns and soil catenas associated with estuaries and river deltas, such as this complex system in the Nisutlin River Delta National Wildlife Area in Yukon, may be dramatically altered by sea level changes with consequential impacts on transient and nesting migratory birds and other species. (Photo Credit: J. Hawking, courtesy Canadian Wildlife Service)

Protected areas and their surrounding matrix encompassing forested ecosystems, wetlands, lakes and rivers throughout Canada's vast Boreal forest region will be subject to a range of climate change impacts projected under biome shift scenarios. Projet de parc Natashquan-Aquanus-Kenamu, North Shore of St. Lawrence Gulf, Québec. (Photo Credit: J. Gagnon, Service des parcs, ministère du Développement durable, de l'Environment des Parcs)

Exposed summits of the Otish Mountains with tundra-like vegetation in the Réserve de biodiversité projetée Albanel-Témiscamié-Otish in central Québec. These 'alpine' summits could be invaded by forests with climate change, putting these southerly alpine communities and plants at risk. (Photo Credit: J. Gagnon, Service des parcs, ministère du Développement durable, de l'Environment at des Parcs)

The amelioration of winters resulting from climate change, as projected to occur in some ecoregions of Canada, may favour the outbreak and spread of diseases and pests in some regions and some protected areas, such as Spruce Budworm (*Choristoneura fumiferana*) in Cathedral Park in British Columbia. (Photo Credit: T. Stevens, courtesy B.C. Parks)

Fire regimes and forest fires, such as this one in Stein Valley, Niaqua'pamux Heritage Park in British Columbia, which are an important factor governing the regional ecology and protected area ecosystems in boreal and cordilleran regions, may be enhanced by climate change here and in other regions of Canada. (Photo Credit: B.C. Parks Staff, courtesy B.C. Parks)

Tidal pools and their associated marine life in some littoral ecosystems around Canada's vast coastline, such as this one on Botanical Beach in Juan de Fuca Park in British Columbia, may be affected by rising sea levels resulting from the addition of water from the melting ice cap and the expansion of warmer oceans being attributed to climate change. (Photo Credit: G. Ross, courtesy B.C. Parks)

Lake Pingualuit, nestled in the heart of the Pingualuit Crater in Parc national des Pingualuit in Québec, is nearly perfectly circular and boasts water so clear that it has practically no equal on Earth. Climate change may accelerate surrounding erosion and eutrophication of this unique ecosystem. (Photo Credit: S. Cossette, Service des parcs, ministère du Développement durable, de l'Environment et des Parcs)

Specialized wetlands already stressed in southern regions, notably bogs and fens that are restricted to colder-than-normal sites, may be adversely affected by drier and warmer conditions that could accelerate succession and displace relict communities and their many unique populations of northern plants. Wylde Lake Bog, Luther Marsh Conservation Area, Ontario. (Photo Credit: T. Beechey)

Dry grassland ecosystems with localized saline lakes in British Columbia's southern interior, such as this segment in the Okanagan-Shuswap Heritage Grasslands, feature a tolerant biota and communities with rare flora and fauna that may present some novel scenarios for biodiversity conservation precipitated by climate change. (Photo Credit: T. Ennis, Nature Conservancy of Canada)

Comprehensive wetland conservation in and around protected areas can help to mitigate potential climate change stresses on amphibians, such as Spring Peeper (*Pseudacris crucifer*) and many other species of frogs and salamanders which are already being threatened by habitat loss and pollution throughout much of their range. (Photo Credit: RobertMcCaw.com)

Increases in sea level anticipated to result from climate change may affect draw-down zones in brackish and freshwater marshes, such as these at Tusket River in Nova Scotia, that could impact species such as Parker's Pipewort (*Eriocaulon parkeri*) that are now restricted to narrow inter-tidal zones in Atlantic Canada. (Photo Credit: S. Blaney, Nature Conservancy of Canada)

Eastern Lilaeopsis (*Lilaeopsis chinense*), an herbaceous plant of inter-tidal zones listed as a 'species of special concern' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), is confined to local estuaries in Nova Scotia that are vulnerable to rising sea levels projected for the Atlantic region. Tusket River Nature Reserve, Nova Scotia. (Photo Credit: S. Blaney, Nature Conservancy of Canada)

Giant Swallowtail (*Papilio cresphontes*), one of Canada's more charismatic butterflies, and Aromatic Sumac (*Rhus aromatica*), a fragrant southern shrub, are two of many southern species with ranges that may be extended due to the influence of global warming which could augment the dispersal and distribution of southern species in some regions. Fish Point Provincial Nature Reserve, Ontario. (Photo Credit: T. Beechey)

Although climate change may drastically alter the character and ecological composition of some protected areas, existing areas, such as Lowel Glacier and the Alsek River in Kluane National Park in Yukon, will continue to protect important segments of Canada's ecosystems and biodiversity for scientific study and heritage appreciation. (Photo Credit: W. Lynch, courtesy Parks Canada Agency)

Representative protected areas capturing the entire altitudinal gradient from tablelands through foothills to alpine peaks, such as the landscape around Waterton Lakes National Park in Alberta and other protected areas in the Canadian Rockies, are better designed to accommodate ecological shifts than situations representing only portions of such gradients. (Photo Credit: Bob Lee, Nature Conservancy of Canada)

The Niagara Escarpment in Ontario, with its southern two thirds protected by the *Niagara Escarpment Plan* and designated as a World Biosphere Reserve, forms a striking 1000+ km sinuous corridor that features an impressive network of protected areas and conservation lands conducive to plant and animal migration. Cup and Saucer Trail, Manitoulin Island. (Photo Credit: P. Kor, Ontario Parks)

Cavern Lake Canyon Provincial Nature Reserve in Ontario, and associated protected areas along Lake Superior's northern coast feature colder-than-normal microclimates that may continue to provide important refugia for northern plants vulnerable to climate change, just as they have sustained significant arctic-alpine flora since the last de-glaciation. (Photo Credit: T. Beechey)

Protected riparian corridors in all ecoregions across Canada will continue to play important roles in helping to retain ecological linkages that are necessary for the movement and conservation of biotic communities, plants and animals affected by climate change. Main River, Canadian Heritage River, Newfoundland. (Photo Credit: S. French, Department of Environment and Conservation, Government of Newfoundland and Labrador)

Despite the fact that ecosystems, flora and fauna on coastal islands and in marine environments, such as those in Desolation Sound Marine Park in British Columbia, may be influenced by climate change, protected areas in these systems will remain important to assist the migration of plants and animals and sustain biodiversity conservation. (Photo Credit: J. Underhill, courtesy B.C. Parks)

Although mobility and the wide range distribution of many birds may confer some adaptative advantages to adjust to ecological shifts, many species such as Nashville Warbler (*Vermifora ruficapilla*) still have specific habitats and niches that may be more or less vulnerable to sequential or non-linear changes in biotic communities arising from climate change. (Photo Credit: RobertMcCaw.com)

With the expected rises in sea level, dune complexes protected within the Île-de-l'Est Wildlife Refuge at the Magdalen Islands, Gulf of St. Lawrence in Québec, may be subjected to erosion and may eventually be destroyed. Unique populations of several rare plants including St. Lawrence endemics and coastal species may be lost. (Photo Credit: J. Gagnon, Service des parcs, ministère du Développement durable, de l'Environment et des Parcs)

Low-lying islands in protected areas, such as Sable Island Provincial Nature in Lake of the Woods in Ontario, may be vulnerable to lake level fluctuations induced by climate change. In such environments, coastal erosion and the loss of sandy shorelines could degrade or destroy habitat for species-at-risk, such as the endangered Piping Plover (*Charadrius melodus*). (Photo Credit: P. Kor, Ontario Parks)

With standardized indicators and protocols, such as those previously fostered by the Environmental Monitoring and Assessment Network (EMAN), protected areas across of Canada could play important roles in monitoring environmental conditions associated with the progression of climate change and its impact on species and ecosystems. Turner Glacier, Auyuittuq National Park, Nunavut. (Photo Credit: G. Klassen, courtesy Parks Canada Agency)

The traditional role of protected areas to serve as natural laboratories for biophysical, ecological and wild life research and training could assume added importance in helping scientists to understand and develop adaptive responses for ecosystems and species impacted by climate change. Overlook at the entrance to Auyuittuq National Park from Pangnirtung, Nunavut. (Photo Credit: J. Poitevin, courtesy Parks Canada Agency)

Eroded stacks of sedimentary bedrock, called 'Hoodoos', these in Sirmilik National Park in Nunavut, are testimony of prehistoric geological and erosional processes that have witnessed changing climate regimes in Canada's far North over past millenia. Near Low Point, Bylot Island, Sirmilik National Park. (Photo Credit: M. McComb, courtesy Parks Canada Agency)

Glossary

Adaptation
Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaptation, including anticipatory, autonomous and planned adaptation (IPCC, 2007c).

Adaptive capacity
The whole of capabilities, resources and institutions of a country, region, community or group to implement effective adaptation measures (IPCC, 2007d).

Alien species
Species of plants, animals, and microorganisms introduced by human actions outside their natural past or present distribution (Parks Canada Agency and Canadian Parks Council, 2008).

Biodiversity
Biodiversity, or "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 1992).

Biodiversity offsets
Biodiversity offsets are conservation activities intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects (IUCN, 2004).

Capacity building
In the context of adaptation to climate change, capacity building is developing the technical skills and institutional capabilities of stakeholders to enable their participation in all aspects of adaptation to, and research on, climate change (IPCC, 2007c).

Carbon sequestration
Carbon sequestration is a biochemical process by which atmospheric carbon is absorbed by living organisms, including trees, soil micro-organisms, and crops, and involving the storage of carbon in soils, with the potential to reduce atmospheric carbon dioxide levels (Dudley *et al.*, 2010).

Community structure
The characteristic features or appearance of a community with respect to the density, horizontal stratification, and frequency distribution of species-populations, and the sizes and life forms of the organisms that comprise those communities (Parks Canada Agency and Canadian Parks Council, 2008).

Ecological integrity
A condition that is determined to be characteristic of (a park's) natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological components, rates of change and supporting processes (Parks Canada Agency and Canadian Parks Council, 2008).

Ecological restoration
The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Parks Canada Agency and Canadian Parks Council, 2008).

Ecosystem
The interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales (IPCC, 2007c).

Ecosystem approach (ecosystem-based management)
The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It applies appropriate scientific methodologies focused on the essential structure, processes, functions and interactions among organisms and their environment, and recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. It is refers to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (IPCC, 2007c)

Ecosystem function/ecosystem process
The dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment (Parks Canada Agency and Canadian Parks Council, 2008).

Ecosystem services
Ecological processes or functions having monetary or non-monetary value to individuals or society at large. There are 1) supporting services, such as productivity or biodiversity maintenance; 2) provisioning services, such as food, fibre or fish; 3) regulating services, such as climate regulation or carbon sequestration; and 4) cultural services, such as tourism or spiritual and aesthetic appreciation (IPCC, 2007c).

Ecotone
Transition area between adjacent ecological communities (e.g. between forests and grasslands) (IPCC, 2007c).

Ecoregions
Ecological Land Classification (ELC) systems are used to classify and describe ecosystems at many scales. From the most general to detailed, Canadian ecosystem scales are classified as Ecozones, Ecoprovinces, Ecoregions, and Ecodistricts. Ecoregions are subdivisions of Ecoprovinces, which are characterized by regional ecological factors. There are 194 ecoregions in Canada (Environment Canada, 2010b).

Ecozones
Ecological Land Classification (ELC) systems are used to classify and describe ecosystems at many scales. From the most general to detailed, Canadian ecosystem scales are classified as Ecozones, Ecoprovinces, Ecoregions, and Ecodistricts. Ecozones are the most general level. Canada is subdivided into 15 terrestrial ecozones, 11 of which are forest ecozones (Environment Canada, 2010).

Extirpation
The disappearance of a species from part of its range; local extinction (IPCC, 2007c).

Greenhouse gas (GHG)
Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, by the atmosphere itself and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. In addition, there are human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances (IPCC, 2007d).

(climate change) Impacts
The adverse and beneficial effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (IPCC, 2007c).

Institutions
Rules and norms that guide how people within societies live, work and interact. Formal institutions are codified rules, such as the constitution, organized markets or property rights. Informal institutions are rules governed by social or behavioural norms of a family, community or society (The Resilience Alliance, 2007).

Invasive species
Those harmful species whose introduction or spread threatens the environment, the economy, or society, including human health. Invasive species may be native or alien in origin (Parks Canada Agency and Canadian Parks Council, 2008).

Mainstreaming
In the context of adaptation, mainstreaming refers to the integration of adaptation considerations (or climate risks) such that they become part of policies, programs and operations at all levels of decision-making. The goal is to make the adaptation process a component of existing decision-making and planning frameworks (UNDP, 2004).

Matrix
A landscape consists of three main components: a matrix, patches, and corridors. The matrix, the dominant component in the landscape, is the most extensive and connected landscape type, and it plays the dominant role in landscape functioning. If we try to manage a habitat without considering the matrix, we will likely fail to provide what species need in that area (Ingegnoli, 2002).

Mitigation
Technological change and substitution that reduces resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse

gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007c).

Native species
Organisms that occur naturally in a particular area instead of being introduced, directly or indirectly, by human activity (Parks Canada Agency and Canadian Parks Council, 2008).

'No regrets' policy/measure
A policy or measure that would generate net social and/or economic benefits irrespective of whether or not climate change occurs (IPCC, 2007c).

Phenology
The study of natural phenomena that recur periodically (e.g. development stages, migration) and their relation to climate and seasonal changes (IPCC, 2007c).

Protected areas
Protected areas are a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008). There are six IUCN Protected Areas categories into which various protected areas may fall.

Resilience
The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change (IPCC, 2007c).

Risk
A combination of the likelihood (probability of occurrence) and the consequences of an adverse event (e.g. climate-related hazard) (UNDP, 2004).

SRES Scenarios
The storylines and associated population, GDP and emissions scenarios associated with the Special Report on Emissions Scenarios (SRES), and the resulting climate change and sea-level rise scenarios. Four families of socio-economic scenario (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns, and global versus regional development patterns (IPCC, 2007c). For more information on SRES, refer to **Annex 2**.

Stakeholder
A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy (IPCC, 2007c).

Tools (for adaptation)
Methodologies, guidelines and processes that enable stakeholders to assess the implications of climate change impacts and relevant adaptation options in the context of their operating environment. Tools may occur in a variety of formats and have diverse applications: crosscutting or multidisciplinary (e.g. climate models, scenario-building methods, stakeholder analysis, decision-support tools, decision-analytical tools) to specific sectoral applications (e.g. crop or vegetation models, methods for coastal-zone vulnerability assessment) (Lemmen *et al.*, 2008).

Traditional (ecological) knowledge
A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Berkes *et al.*, 2000).

Uncertainty
An expression of the degree to which a value is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts) (IPCC, 2007c).

Vulnerability
Vulnerability is the susceptibility to be harmed. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007c).

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Ultimately, the actions of this generation to confront climate change and to counter the environmental impacts of global warming may well determine the future course for protected areas and biodiversity conservation in Canada and beyond.

Annexes

The creation of Yellowstone National Park with its free-ranging American Bison (*Bison bison*), coupled with early efforts to establish other parks like Banff National Park and Algonquin Provincial Park in Canada, are cornerstones in the protected areas movement that now faces challenges posed by climate change. The pervasive nature of global warming compels conservation professionals worldwide to confront the impacts of climate change on protected areas and biodiversity. (Photo Credit: Mike Beechey, milesfromnowhereimages.com)

Annex 1: Selected International Jurisdictional Responses to Climate Change

While the volume of adaptation research has increased significantly in the last five years, response by the protected area disciplines is lagging. It may be because of the complexity and uncertainty of managing protected areas in a rapidly changing climate (Scott and Lemieux 2005). Unlike other managed resource systems (e.g., water, agriculture, fisheries), there are no past exposures or climate change analogues to learn from at the systems planning or protected area management levels. Furthermore, the management objectives for protected areas have very long time horizons (e.g., 22nd century and beyond), and fewer adaptation options exist for protected areas than for lands and waters that are actively and extensively manipulated or managed for a variety of other human uses.

Based on the extent of the academic literature and reports sponsored by agencies and organizations, and on the frequency and duration of other activities such as conferences and workshops, the United States (e.g., NPS, 2006a; Baron *et al.*, 2009; West *et al.*, 2009; Joyce *et al.*, 2009; Griffith *et al.*, 2009; U.S. Fish and Wildlife Service, 2009; Mawdsley *et al.*, 2009), Australia (Dunlop and Brown, 2008), the European Union (e.g., Araújo, 2009a and 2009b), Canada (Scott and Suffling, 2000; Scott *et al.*, 2002; Scott and Lemieux, 2005; Lemieux and Scott, 2005; Welch, 2005; Scott and Lemieux, 2007; Pearson and Burton, 2009) and the U.K. (e.g., Huntley, 2007; ENPAA, 2008) are leading in capacity-building initiatives pertaining specifically to protected areas and climate change adaptation (including mitigation). For example, a number of empirical studies examine the potential and known impacts, as well as policy, planning and management implications of climate change for protected areas. In the last 2-3 years, there has been an increase in studies that explore adaptation options. What follows is a brief description of various responses to climate change emanating from the above listed jurisdictions.

United States Federal Initiatives in Parks and Other Protected Areas

The Climate Change Science Program (CCSP) specifically addresses climate change research in the U.S. The goals of this program are to develop scientific knowledge of the climate system, causes of changes in the system, and the effects of such changes on ecosystems, society, and the economy--all in order to determine how best to apply that knowledge in decision-making. Climate change research conducted across 13 U.S. government departments and agencies is coordinated through the CCSP. The U.S. National Parks Service (NPS), Fish and Wildlife Service (FWS), and the Geological Survey (USGS) have been actively engaged in research on the implications of climate change for ecosystems and species and the identification of adaptation options.

The CCSP is responsible for providing the best science-based knowledge possible to inform management of the risks and opportunities associated with changes in the climate and related environmental systems. To support its mission, the CCSP has commissioned 21 “synthesis and assessment products” (SAPs) to advance decision-making on climate change-related issues by providing current evaluations of climate change science and identifying priorities for research, observation, and decision-support.

In 2008, the CCSP released the report entitled *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources* (CCSP, 2008). The report explored potential adaptation options that could be used by natural resource managers within the context of the legislative and administrative mandates of the six systems examined: National Forests, National Parks, National Wildlife Refuges, Wild and Scenic Rivers, National Estuaries, and Marine Protected Areas. The report synthesized climate change research with the experience of on-the-ground ecosystem and resource managers to suggest adaptation options that consist of: 1) adjustments to current practices to ensure their effectiveness given climate change interactions with “traditional stressors”; and, 2) creation of new practices. The level of confidence in each of the adaptation approaches were evaluated by the authors based on their experience and assessment of the peer-reviewed literature on climate change impacts, current management techniques, and ecological responses. The report was written by a team of 61 scientists and managers and represents the largest review to date of management adaptations to climate change.

The NPS has primarily concentrated on education and outreach of climate change impacts and on reducing greenhouse gas emissions through the 'Climate Friendly Parks' (CFP) program. As part of this program, the NPS has also implemented a program to educate park staff on climate change issues, in addition to training for presenting this information to park visitors in 11 national parks (Baron *et al.*, 2009). The NPS has published several resource bulletins summarizing the potential consequences of climate change in national parks (NPS, 2006a), including impacts on melting glaciers (NPS, 2006b) and mountain streams (NPS, 2006c). The NPS has developed an online climate change resource centre that focuses on three themes: "Learn", "Act" and "Share". The "Learn" theme focuses on climate change science and impacts, and provides external links to websites associated with the Intergovernmental Panel on Climate Change (IPCC), the USGS and the U.S. Environmental Protection Agency (EPA). The "Act" theme focuses on inventorying and mitigating greenhouse gas emissions especially by national parks operations and national park visitors. The "Share" theme focuses on increasing visitors' awareness of climate change and its impacts and provides them with tools to address (i.e., mitigation) their individual greenhouse gas contribution.

The CFP, a collaboration of the NPS and EPA, provides national parks with management tools and resources to address climate change mitigation. CFPs, of which there are currently 15, earn their distinction by achieving several 'milestones', including: developing a baseline inventory using the Climate Leadership in Parks (CLIP) Tool; setting an emissions reduction target and defining a comprehensive set of planned climate-friendly actions (e.g., using energy-efficient products, using bio-diesel in park vehicles, etc.); and helping to educate the public with environmental outreach programs.

The U.S. Fish and Wildlife Service's proposed *Strategic Plan* for climate change sets out a foundation for the agency's role in the Department of the Interior's national efforts to conserve fish and wildlife in a rapidly changing climate. This plan will establish a framework within which the Service and its employees will work with the larger conservation community to safeguard fish, wildlife and their habitats in the face of accelerating climate change. The plan calls for the most advanced efforts to climate change adaptation by any conservation agency internationally. For example, the proposed climate change action plan, an appendix to the Strategic Plan, outlines specific actions that the Service will take during the next five years to implement the Strategic Plan (Box 1).

Box 1: Goals and actions of the U.S. Fish and Wildlife Service with respect to climate change adaptation, mitigation and engagement

Adaptation

Goal 1 – We will develop and apply capacity for biological planning and conservation design to drive conservation at broad landscape scales. Proposed actions include:

- Develop a National Fish and Wildlife *Adaptation Strategy*;
- Access regional climate science and modelling expertise through regional climate science partnerships;
- Develop Landscape Conservation Cooperatives to acquire biological planning and conservation design expertise;
- Conduct species and habitat vulnerability assessments;
- Incorporate climate change into all Service activities and decisions;
- Provide requested support to State and Tribal Managers to address climate change issues that affect the Service's Trust Resources;
- Evaluate laws, regulations and policies to identify barriers to and opportunities for successful implementation of climate change actions.

Box 1: Cont'd

Goal 2 – We will plan and deliver landscape conservation that supports climate change adaptations by fish, wildlife, plants and habitats of ecological and societal significance. Proposed actions include:

- Implement National Fish and Wildlife *Adaptation Strategy* as the Service's long-term adaptive response to climate change;
- Take conservation action for climate vulnerable species;
- Promote habitat connectivity and integrity;
- Identify and fill priority freshwater needs;
- Manage genetic resources;
- Reduce susceptibility to diseases, pathogens and pests;
- Conserve coastal and marine resources;
- Address Fish and Wildlife needs in renewable energy development;
- Reduce non-climate change ecosystem stressors;
- Foster international coordination for landscape conservation.

Goal 3 – We will develop monitoring and research partnerships that will provide complete and objective information to plan, deliver, evaluate and improve actions that help fish and wildlife adapt to accelerating climate change. Proposed actions include:

- Develop a National Biological Inventory and Monitoring (I&M) Partnership;
- Promote physical science and remote sensing monitoring programs;
- Develop research and monitoring capability for use in landscape conservation;
- Further develop collaborative research partnerships.

Mitigation

Goal 4 – We will achieve carbon neutrality by 2020. Proposed actions include:

- Reduce the carbon footprint of the Service's facilities, vehicles, work force and operations;
- Reduce the Service's land management carbon footprint;
- Offset the remaining carbon balance.

Goal 5 – We will build capacity to understand, apply and share biological carbon sequestration science and work with partners to sequester atmospheric GHGs in strategic locations. Proposed actions include:

- Develop biological carbon sequestration expertise;
- Develop standards, guidelines and best management practices for biological carbon sequestration;
- Integrate biological carbon sequestration activities into landscape conservation approaches;
- Facilitate biological carbon sequestration internationally;
- Facilitate biological carbon sequestration research;
- Evaluate geological carbon sequestration.

Engagement

Goal 6 – We will engage Service employees, our public and private partners, our key constituencies and stakeholders, and everyday citizens in a new era of collaborative conservation to seek solutions to the impacts of climate change and other 21st century stressors to fish, wildlife and habitats. Proposed actions include:

- Provide Service employees with climate change information, education and training;
- Share climate change information, education and training opportunities with external audiences;
- Forge alliances and create forums on climate change to exchange information and knowledge and to influence policy internationally.

For more information, please visit: http://www.fws.gov/home/climatechange/strategic_plan.html

Source: U.S. Fish and Wildlife Service (2009)

Parks and Protected Areas Cared for by the Government of Australia (Parks Victoria)

Like other jurisdictions, the Australian Government's activity in climate change adaptation activities is relatively recent (i.e., since 2007). A number of initiatives and research projects have been/are currently focused on assessing the vulnerability of Australia's biodiversity to climate change. In March 2008, the Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts released *Implications of Climate Change for Australia's National Reserve System: a Preliminary Assessment* (Dunlop and Brown, 2008), which addresses the potential future impacts of climate change on Australia's system of formally protected conservation areas, the National Reserve System (NRS), and the implications of these impacts on the development and management of the reserve system. The report describes actions that can be implemented immediately or during the next 5-10 years, and information and research needs for these management implications (Box 2).

Box 2: Recommended actions to address climate change in Australia's National Reserves System (NRS)

1. Understand how biodiversity will respond to climate change and the implications for conservation. To effectively address climate change, the management, policy, research and general communities need a good and broad understanding of the possible changes to species and ecosystems, and the implications of those changes for conservation and the NRS. One immediate implication is the need to revise the core objective of conservation to accommodate ongoing changes in biodiversity – "manage the change to minimize the loss". Implementation of this objective will require community debate (to inform trade-offs) and better information about change. Coordinated observation and formal monitoring programs can identify what types of change are actually occurring; further research (including improved methods) is needed for assessing likely future changes on a bioregional basis. Key uncertainties include the importance of changes in distributions and abundances, interactions between species, changes in ecosystem processes, the dynamics of changes, changing threats (especially new species, altered fire regimes, land use change and altered hydrology) and the role of habitat and landscape diversity in mediating changes.

2. Protect more habitat and more diverse habitat. Protecting habitat is probably the best way to conserve species under climate change. While the species and ecosystems in any one area will change over time, the greater the total area of habitat available, and the more diverse that habitat, the greater the number of ecosystems and species that will be able to survive. The bioregional framework used in the NRS is therefore very well suited for building a robust reserve system, and it will be much more effective under climate change than systems that mainly target endangered species and communities. However, at present the effectiveness of the NRS is limited as habitat in many regions is very poorly represented. Further habitat protection through the NRS and other conservation programs is a priority in these regions and in regions that are identified as likely to experience the most significant ecological changes. Protection of additional habitat may also be required for some species that are particularly vulnerable.

3. Manage habitat to reduce threats. Management of protected areas and other areas of native habitat will be required to reduce the impact of known and anticipated threats to biodiversity. In addition, active management will be required in some situations to facilitate natural adaptation processes, and in other situations to maintain habitat that is suitable for species that have been identified as particularly vulnerable to climate change. Policies and guidelines about managing protected areas may need to be revised to accommodate changing conservation objectives under climate change.

4. Manage landscape-scale issues. Many important ecological processes occur at scales larger than that of individual protected areas. Additional protection may be warranted for areas that act as fire or climate

Box 2: Cont'd

refuges for species within a broader region. Connectivity of habitat at various scales can be important for facilitating the movement of different species, which may increase their viability and ability to respond to climate variability and change. Connectivity may also facilitate the spread of fire and movement of species that might have negative impacts on other species; hence it may be beneficial to protect isolated as well as well-connected habitat areas, and to assess the risks and benefits before increasing the connectivity of habitat. Some threats, including new species, land use change and altered landscape hydrology, may be best addressed at broad-scales via the coordinated efforts of a variety of conservation programs.

For more information, please visit: http://www.environment.gov.au/parks/nrs/index.html

Source: Dunlop and Brown (2008: 16-17)

There is no indication that the adaptation options outlined in the report have been acted upon at various scales and whether these documents provide the guidance required by protected area managers to make climate change-integrated decisions. Moreover, it has been suggested that while climate change is on the agenda of Australian protected areas agencies, biodiversity protection programs are generally under-funded and there are more immediate management priorities, such as invasive species, tourism and indigenous populations within parks (Figgis, 2008).

Parks and Protected Areas Cared for by Federal Agencies in the United Kingdom

The United Kingdom's (U.K.) National Parks Authorities (NPAs) have sponsored climate change adaptation and mitigation programs for a number of years. Similar to the U.S. National Parks Service, adaptation activities have been focused on vulnerability assessments, including a review of climate change implications for U.K. conservation policy (U.K. Climate Impacts Programme, 2000; Hossell *et al.*, 2003) while mitigation activities have been focused on reducing GHG emissions within and around national parks as part of a multi-sectoral national response to climate change.

National Parks programs in the United Kingdom and other European Union (E.U.) countries differ from many other national parks programs around the world because socio-economic objectives are pursued in conjunction with a commitment to preservation and conservation. As a result, Many E.U. countries have implemented integrated approaches to addressing climate change that accounts for ecological, social, cultural, and economic values. Hossell *et al.* (2003) recommended three types of management strategies for protected areas under climate change, including:

1) Preservation (implying a high degree of intervention in ensuring species survival and in excluding undesirable species from invading locations or habitats);

2) Dynamic solutions (working in the direction of climatic changes and include, *inter alia*, the translocation of species, habitat creation and the recognition of new species associations within habitat types); and,

3) *Laissez-faire* (acknowledges that the magnitude of climate change will overwhelm any effort to protect the species or habitat type).

Few policy statements have been completed to date. One exception is a policy position statement issued by the English National Park Authorities Association (ENPAA) in November 2006 (Box 3). This statement emphasizes the need to for agencies to protect the special qualities of the National Parks from the effects of climate change and to sponsor work to design and implement adaptive management strategies and programs where possible (ENPAA, 2006). Moreover, the collective goal of ENPAA with respect to climate change is to move toward 'carbon neutrality' (ENPAA, 2006). As part of this goal, the National Park Authorities (in keeping with the programs sponsored by the variety of government agencies) are committed to attaining carbon neutrality by 2012 through reductions of greenhouse gas emissions, reductions in their own operations, working with farmers and landowners to maintain healthy peat landscapes

Box 3: English National Park Authorities Association (ENPAA) position statement on climate change

Climate Change represents a serious threat and challenge to the special qualities of England's National Parks and their communities and our environment more generally. We believe urgent action is needed to reduce emissions, to adapt to those changes in our climate that are inevitable, and to raise awareness amongst residents, visitors and decision makers of the effects of climate change on these special areas. The National Park Authorities of England are committed to do their bit and becoming carbon neutral, as part of a wider coordinated response to climate change.

Sustainable Land Management

- National Park Authorities will champion and actively support work to prevent further carbon dioxide emissions by maintaining and, where needed, restoring peatlands, fens, moors and woodlands.
- National Park Authorities will actively support appropriate land management techniques that help absorb more carbon from the atmosphere.
- National Park Authorities, alongside partners such as Natural England and the Environment Agency, will work with farmers to help them adapt their farming methods to reduce emissions.

Low Carbon Rural Communities

- As planning authorities, we will continue to use our planning powers to safeguard natural resources, promote appropriate renewable energy and energy efficiency measures and shape future development within National Parks.
- Our vision is to move from isolated demonstration projects to a situation where renewable energy and energy efficiency is the norm in remote rural areas.
- Exemplars in Climate Change Adaptation on a landscape scale.
- National Park Authorities will work to increase understanding of how climate change, and society's response to it, will affect National Parks.
- National Park Authorities will continue to work to protect and develop resilient habitat networks that allow natural environment adaptation, providing ecological links both within National Parks and across the wider countryside.
- National Park Authorities will ensure that we maintain good public access across National Parks by repairing eroded footpaths and bridleways and flood- proofing bridges.

Communicating Climate Change

- We will promote understanding of the mitigation and adaptation work that is taking place or is planned in National Parks.
- We will use our education service to inform young people about the issues around climate change and explain the value of National Parks now and in the future.
- We will engage with our visitors on energy efficiency measures, promote sustainable transport options and local food, and explore how the transition to a low carbon society could happen.
- National Park Authorities will continue to engage people through offering excellent volunteering activities.

For more information, please visit: http://www.enpaa.org.uk/climate_change_statement

Source: ENPAA (2006 and 2009)

and soils, and through peatland restoration activities (ENPAA, 2008).

The ENPAA has made important progress in the development and implementation of climate change adaptation and mitigation activities, especially as it pertains to education and outreach and in working with landowners within and around National Parks to become carbon neutral by 2012. The ENPAA has also been working to identify and restore areas (with landowners) to enhance ecosystem connectivity on a landscape scale, and its planning policy statement provides general management direction on this aspect for the ENPAA with respect to climate change. However, it is largely unknown if these activities are providing sufficient information to plan for and manage the effects of climate change on the federal national resources that it manages, with the exception of carbon management.

The European Union Parks and Protected Areas Programs

The E.U. has sponsored the completion of significant research on past, current, and future projected impacts of climate change on biodiversity (e.g., Huntley, 2007). These reports provide a number of recommendations toward the development of recommendations and adaptation strategies for conserving biodiversity. Several countries and European bodies are starting to develop strategies for adaptation to climate change. However, similar to Canada, such strategies tend to focus on the technological, structural, and socio-economic developments, and linkages between biodiversity and protected areas are often overlooked (Araújo, 2009a).

Araújo (2009a) provided a useful overview of a number of general approaches for the mitigation of climate change impacts on biodiversity, including strategies for management of protected areas (e.g., increasing available habitat), management of protected area networks (e.g., enhancing diversity and resiliency), and off-protected areas management (e.g., conservation on private lands). The report also reviews European initiatives that are already in place for mitigating climate change impacts on biodiversity (e.g., *Bern Convention*) and provides a prospective discussion of required actions for the future. While the report found that protected areas are likely to act as buffers against climate change, better than expected by chance, the Natura 2000 network is more vulnerable and no more effective in retaining climate conditions for species than the surrounding landscape matrix (Araújo, 2009b). The report concluded that a paradigm shift in protected areas planning and management is needed to address the all-encompassing impacts of climate change. Effective conservation in European protected areas will require the identification and management of stationary refugia, or range retention areas, displaced refugia, and areas of high connectivity within a proactive and flexible management framework (Araújo, 2009a).

Conclusions

Overall, with the increasing strength of climate change science and observed ecosystem impacts, protected areas agencies around the world have increasingly begun to explore the implications for their policies and management practices. Summaries of anticipated ecological impacts are found in many jurisdictions and a number of workshops dedicated to responses by protected areas agencies have occurred in recent years. Generally, there is consensus that current policies are inadequate to cope with the challenges presented by even moderate climate change scenarios for the 21st century. Protected areas agencies are still largely focused on developing a comprehensive understanding of the impacts of climate change and are only in the very preliminary stages of developing strategic responses. To date, there has been little progress on the development of policy for protected areas and climate change.

Annex 2: Annual Mean Temperature Change Projections for Canadian and United States Protected Areas

The figures presented within this Annex were produced with data provided by Dan McKenney, Natural Resources Canada. For more information, please visit: http://cfs.nrcan.gc.ca/subsite/glfc-climate .

About the A2 and B2 Storylines and Scenario Families

Interested readers should consult the *IPCC Special Report on Emissions Scenarios* for further information and references noted in the description below.

IPCC Special Report on Emissions Scenarios:
http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/

A2 Storyline and Scenario Family

Compared to the A1 storyline it is characterized by lower trade flows, relatively slow capital stock turnover, and slower technological change. The A2 world "consolidates" into a series of economic regions. Self-reliance in terms of resources and less emphasis on economic, social, and cultural interactions between regions are characteristic for this future. Economic growth is uneven and the income gap between now-industrialized and developing parts of the world does not narrow, unlike in the A1 and B1 scenario families.

The A2 world has less international co-operation than the A1 or B1 worlds. People, ideas, and capital are less mobile so that technology diffuses more slowly than in the other scenario families. International disparities in productivity, and hence income per capita, are largely maintained or increased in absolute terms. With the emphasis on family and community life, fertility rates decline relatively slowly, which makes the A2 population the largest among the storylines (15 billion by 2100). Global average per capita income in A2 is low relative to other storylines (especially A1 and B1), reaching about US$7200 per capita by 2050 and US$16,000 in 2100. By 2100 the global GDP reaches about US$250 trillion. Technological change in the A2 scenario world is also more heterogeneous than that in A1. It is more rapid than average in some regions and slower in others, as industry adjusts to local resource endowments, culture, and education levels. Regions with abundant energy and mineral resources evolve more resource-intensive economies, while those poor in resources place a very high priority on minimizing import dependence through technological innovation to improve resource efficiency and make use of substitute inputs. The fuel mix in different regions is determined primarily by resource availability. High-income but resource-poor regions shift toward advanced post-fossil technologies (renewables or nuclear), while low-income resource-rich regions generally rely on older fossil technologies. Final energy intensities in A2 decline with a pace of 0.5 to 0.7% per year.

In the A2 world, social and political structures diversify; some regions move toward stronger welfare systems and reduced income inequality, while others move toward "leaner" government and more heterogeneous income distributions. With substantial food requirements, agricultural productivity in the A2 world is one of the main focal areas for innovation and research, development, and deployment efforts, and environmental concerns. Initial high levels of soil erosion and water pollution are eventually eased through the local development of more sustainable high-yield agriculture. Although attention is given to potential local and regional environmental damage, it is not uniform across regions. Global environmental concerns are relatively weak, although attempts are made to bring regional and local pollution under control and to maintain environmental amenities.

B2 Storyline and Scenario Family

The B2 world is one of increased concern for environmental and social sustainability compared to the A2 storyline. Increasingly, government policies and business strategies at all levels are influenced by environmentally aware citizens, with a trend toward local self-reliance and stronger communities. International institutions decline in importance, with a shift toward local and regional decision-making structures and institutions. Human welfare, equality, and environmental protection all have high priority, and they are addressed through community-based social solutions in addition to technical solutions, although implementation rates vary across regions.

Like the other scenario families, the B2 scenario family includes futures that can be seen as positive or negative. While the B2 storyline is basically neutral, Kinsman (1990) in his "Caring Autonomy" scenario clearly paints a positive world with emphasis on decentralized governments and strong interpersonal relationships. In the "New Civics" scenario by Wilkerson (1995), values are only shared within small competing groups, which results in a decentralized world of tribes, clans, families, networks, and gangs. The IIASA-WEC "Middle Course" scenario (Nakicenovic *et al*., 1998), with slow removal of trade barriers, may also be grouped in this family. On the positive side, this storyline appears to be consistent with current institutional frameworks in the world and with the current technology dynamics. On the negative side is the relatively slow rate of development in general, but particularly in the currently developing parts of the world.

Education and welfare programs are pursued widely, which reduces mortality and, to a lesser extent, fertility. The population reaches about 10 billion people by 2100, consistent with both the UN and IIASA median projections. Income per capita grows at an intermediate rate to reach about US$12,000 by 2050. By 2100 the global economy might expand to reach some US$250 trillion. International income differences decrease, although not as rapidly as in storylines of higher global convergence. Local inequity is reduced considerably through the development of stronger community-support networks.

Generally, high educational levels promote both development and environmental protection. Indeed, environmental protection is one of the few truly international common priorities that remain in B2. However, strategies to address global environmental challenges are not of a central priority and are thus less successful compared to local and regional environmental response strategies. The governments have difficulty designing and implementing agreements that combine global environmental protection, even when this could be associated with mutual economic benefits.

The B2 storyline presents a particularly favorable climate for community initiative and social innovation, especially in view of the high educational levels. Technological frontiers are pushed less than they are in A1 and B1, and innovations are also regionally more heterogeneous. Globally, investment in energy research and development continues its current declining trend (EIA, 1997, 1999), and mechanisms for international diffusion of technology and know-how remain weaker than in scenarios A1 and B1 (but higher than in A2). Some regions with rapid economic development and limited natural resources place particular emphasis on technology development and bilateral co-operation. Technical change is therefore uneven. The energy intensity of GDP declines at about 1% per year, in line with the average historical experience since 1800.

Land-use management becomes better integrated at the local level in the B2 world. Urban and transport infrastructure is a particular focus of community innovation, and it contributes to a low level of car dependence and less urban sprawl. An emphasis on food self-reliance contributes to a shift in dietary patterns toward local products, with relatively low meat consumption in countries with high population densities.

Energy systems differ from region to region, depending on the availability of natural resources. The need to use energy and other resources more efficiently spurs the development of less carbon-intensive technology in some regions. Environment policy co-operation at the regional level leads to success in the management of some trans-boundary environmental problems, such as acidification caused by sulfur dioxide (SO_2), especially to sustain regional self-reliance in agricultural production. Regional co-operation also results in lower emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs), which reduce the incidence of elevated tropospheric ozone levels. Although globally the energy system remains predominantly hydrocarbon-based to 2100, a gradual transition occurs away from the current share of fossil resources in world energy supply, with a corresponding reduction in carbon intensity.

The following maps illustrate three scenarios for North America that depict the implications of shifts in regional climate envelopes based on the above storylines and scenarios. The backdrop of protected areas > 10,000 ha plotted on the maps clearly reveal significant implications of the A2 and B2 scenarios for protected areas in Canada and the U.S.

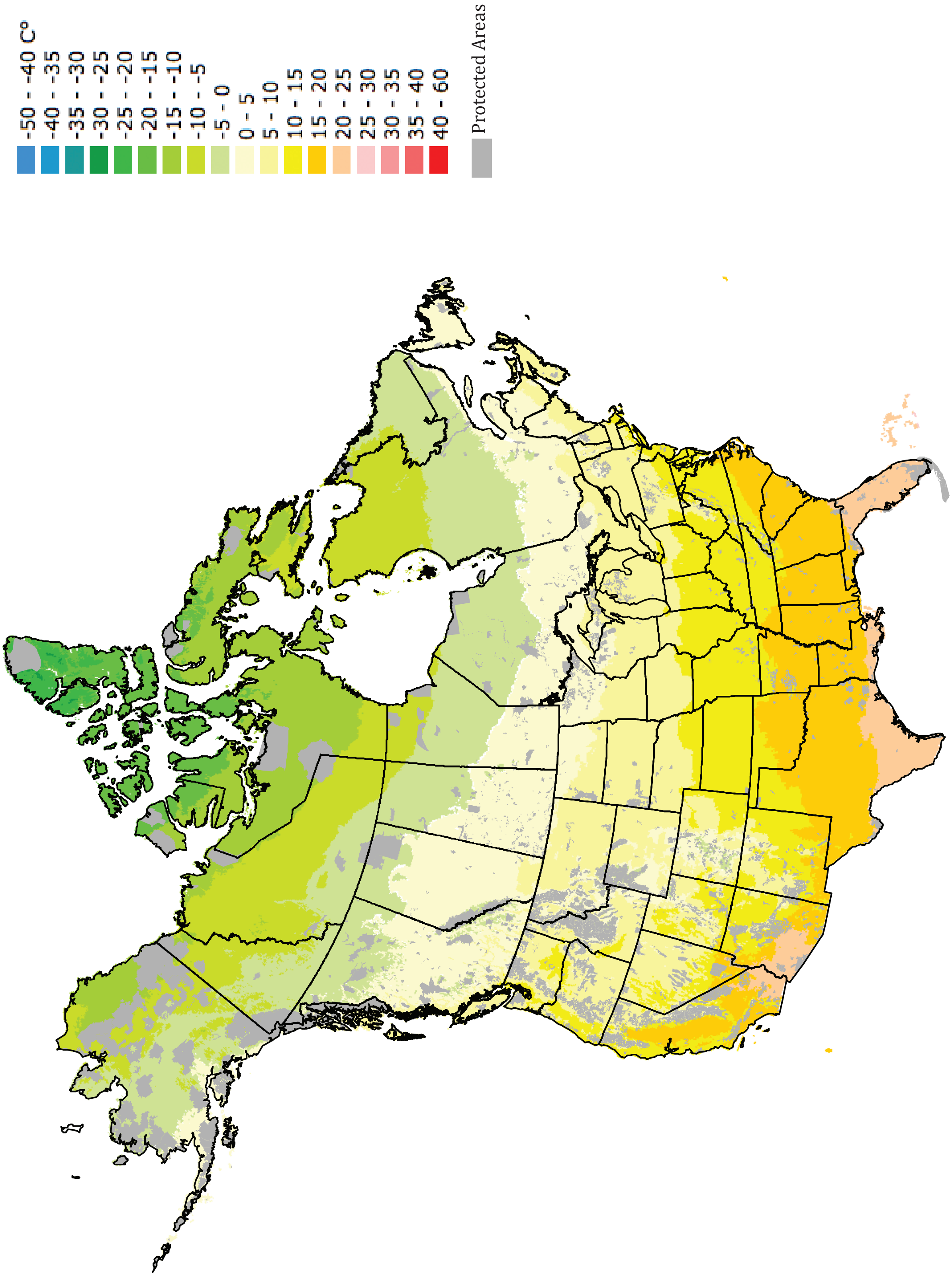
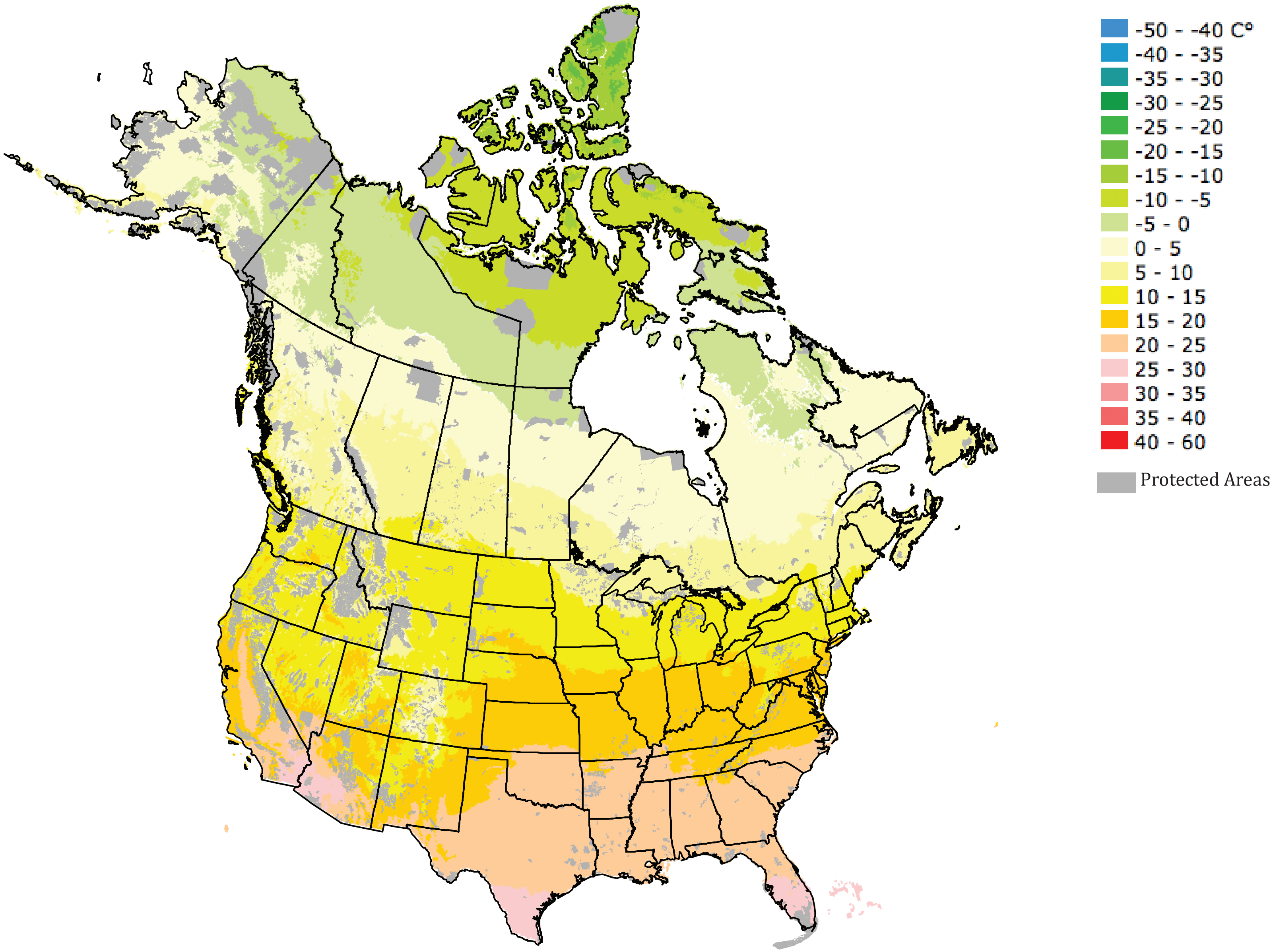


Figure 1: Annual Mean Temperature for Canada and the United States with protected areas > 10,000 ha overlaid under the CGCM2 Baseline (1971-2000) Scenario.

Figure 2: Projected Annual Mean Temperature for Canada and the United States with protected areas > 10,000 ha overlaid for the 2071-2100 time period (CGCM2-***A2*** Emissions Scenario).



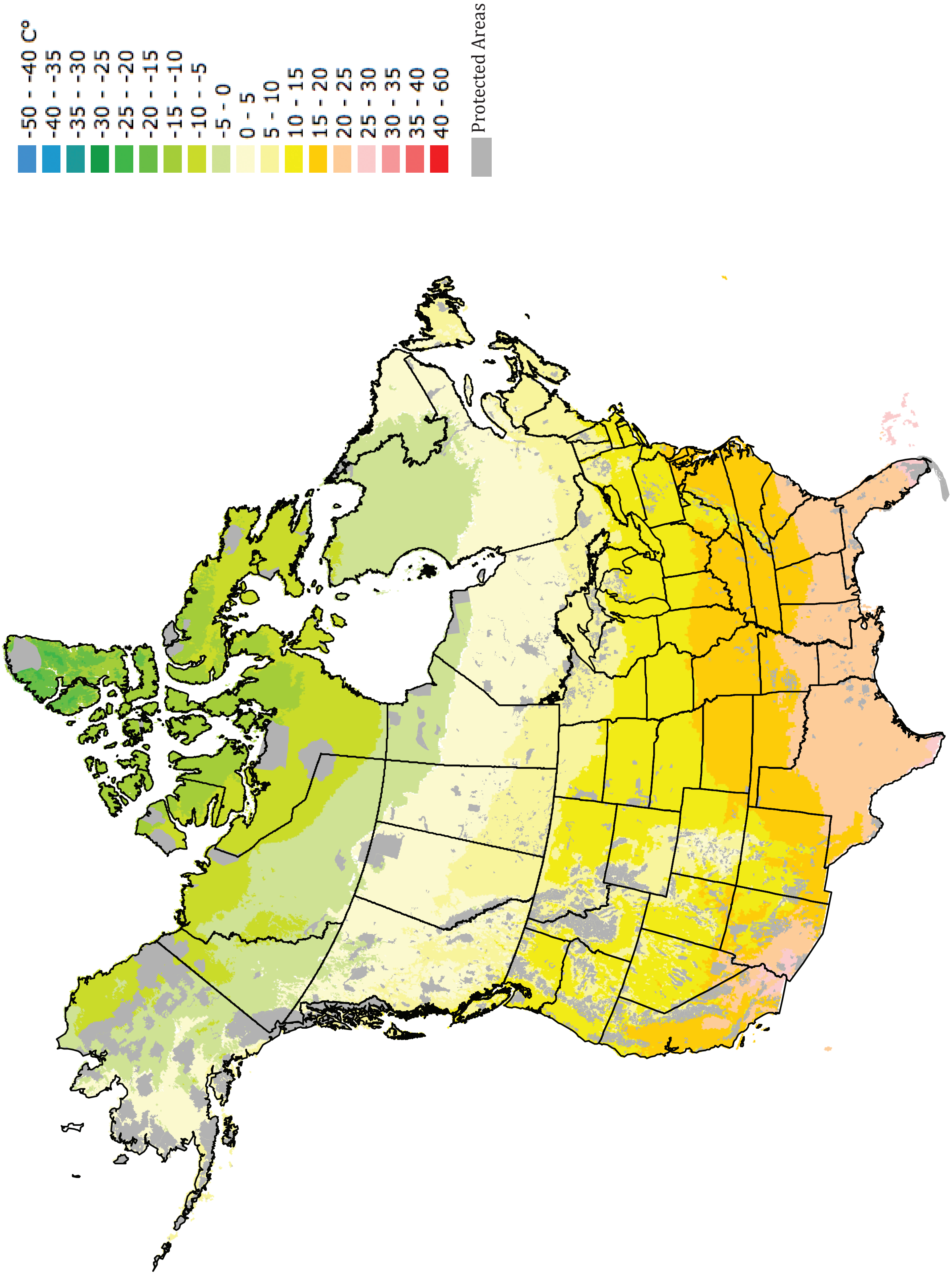


Figure 3: Projected Annual Mean Temperature for Canada and the United States with protected areas > 10,000 ha overlaid for the 2071-2100 time period (CGM2-***B2*** Emissions Scenario).

Annex 3: Species Responses to Modern Climate Change in Canada

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
Edith's checkerspot butterfly (*Euphydryas editha*)	Mexico to Canada (range)	• Northward shift of 92 km • Upward shift of 124 m • Population extinctions are four times as high along the southern range boundary (Baja, Mexico) than along the northern range boundary (Canada) • Recolonizations are rare (14% over 30 year period) Period of Record: 98 years	[1]Parmesan (1996), Parmesan (2005)
Black spruce (*Picea mariana*)	Eastern Hudson Bay coast (Québec)	• 12 km westward shift in treeline towards coast Period of Record: 100 years	[2]Lescop-Sinclair and Payette (1995)
27 bird species (arboreal and semi-arboreal insectivors and granivors)	Continental U.S., southern Canada, and northern Mexico	• 2.35 km/year shift northward Period of Record: 1967 to 1971 and 1998 to 2002 (26 years)	[3]Hitch and Leberg (2007)
Diatom and ivertebrate assemblages	Canadian arctic lakes	• Shift away from benthic species towards more planktonic and warm-water-associated communities Period of Record: 150 years of proxy data (diatoms, chironomids, chrysophytes)	[4]Smol *et al.* (2005)
Polar bear (*Ursus maritimus*)	Hudson Bay (southern range boundary)	• Population declines in opposite geographic boundaries Period of Record: 1981 to 1998 and 1980 to 2004	[5]Stirling *et al.* (1999) Stirling *et al.* (2006)
Engelmann spruce (*Picea engelmannii)*	Canadian Rocky Mountains (Banff, Yoho and Jasper national parks)	• Upward (elevational) movement of treeline and increase in density Period of Record: Various sampling dates	[6]Luckman and Kavanagh (2000)

Table 1: Ecological indicators of climate change in Canada – changes in geographic distribution and abundance (including migratory pathway, wintering area and breeding ground).

Table 1: Cont'd

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
Common buckeye (*Junonia coenia*) and Baltimore checkerspot (*Euphydryas phaeton*) butterflies	Manitoba	• Northward expansion of Common buckeye (*Junonia coenia*) and Baltimore checkerspot (*Euphydryas phaeton*) Period of Record: 1970 to 2004 (35 years)	[7]Westwood and Blair (2003)
Southern flying squirrel (*Glaucomys volans*)	Ontario	• 22 km estimated rate of spread • Expanded northern range boundary in Ontario by about 200 km between mid-1980s and 2003 • Currently rare or absent in a number of sites in southern or southwestern Ontario • Possibility that southern flying squirrels have expanded their range through the contiguous forests of central Ontario and Québec, but not through the fragmented forests of the southwest Period of Record: 1994 to 2004	[8]Bowman *et al.* (2005)
Swainson's thrush (*Catharus ustulatus*)	Boreal forest regions of the U.S. and Canada	• Coastal group has undergone a 2- to 3-fold demographic and range expansion, while the inland group has undergone a 6- to 12-fold demographic and range expansion since the last glacial maximum • Bioclimatic analyses strongly support the hypothesis that populations expanding out of the east into previously glaciated areas in the west were undergoing a natural extension of their range by tracking the changes in climatic conditions Period of Record: last glacial maximum (~21,000 yr BP) to 2006	[9]Ruegg *et al.* (2006)
Sockeye (*Oncorhynchus nerka*) and Pink salmon (*O. gorbuscha*)	Banks Island (NWT)	• Capture locations are well outside the known distributions for the species Period of Record: 2000	[10]Babaluk *et al.* (2000)

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
Mountain pine beetle (*Dendroctonus ponderosae*)	Canada (primarily BC and Alberta)	• Increase in the range of benign habitats and an increase (at an increasing rate) in the number of infestations since 1970 in formerly climatically unsuitable habitats • Successfully breached the Rocky Mountain geo-climatic barrier and established in north-eastern BC and adjacent Alberta Period of Record: 10 year increments between 1921 to 1950 and 1971 to 2000	[11]Carroll *et al.* (2006)
Arctic fox (*Alopex vulpes*) and Red fox (*Vulpes vulpes*)	Canada (Nunavut)	• The red fox expanded its range northward into traditional Arctic fox territory, as much as 965 km (Baffin Island) • Arctic fox has retracted its range northward either due to inferior competition with the red fox to the warming trend or both Period of Record: 30 years	[12]Hersteinnson and Macdonald (1992)
Virginia opossum *(Didelphis virginiana)*	Southwestern Ontario (Georgian Bay)	• Virtually non-existent in Ontario in the 1980s, the Virginia opossum has expanded its range northward into Georgian Bay Period of Record: n/a	[13]CCME (2003)
Several Grand River fish species	Grand River Watershed (Southwestern Ontario)	• Warm-water fish species are now colonizing the upper portions of the Grand River watershed, while cold water species have become less common Period of Record: 1983 to 1996 (14 years)	[14]CCME (2003)
White spruce *(Picea glauca)*	Kluane Region (Yukon Territory)	• Advance in spruce distribution indicated by the establishment of new individuals upslope, combined with an increase in canopy size and spruce density in areas below the treeline. Period of Record: 1947 to 1989 (aerial photographs)	[26]Danby and Hik (2007)

Table 1: Cont'd

Table 2: Ecological indicators of climate change across Canada – changes in phenology and evolutionary traits (i.e., life-cycle events).

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
Red squirrel (*Tamiasciurus hudsonicus*) 664 female, 325 followed throughout lifetime	Kluane region, Yukon Territory	• Parturition date advanced 18 days or 6 days per generation • Result of phenotype plasticity change (62%) and genetic change in population (13%) Period of Record: 1989 to 2002 (13 years)	[15]Reale *et al.* (2004), Berteuax *et al.* (2004)
Pitcher plant mosquito (*Wyeomyia Smithii*)	Florida to Canada (range)	• Evolved a shorter critical photo period in association with a longer growing season • Northern populations now use a shorter day-length cue to enter winter diapauses, doing so later in the fall than they did 24 years ago Period of Record: four sample collections -- 1972 compared to 1996 and 1988 compared to 1993	[16]Bradshaw and Holzapfel (2001)
Tree swallow (*Tachycineta bicolor*)	Contiguous U.S. and Canada	• 9 day advance in laying date highly correlated with mean May temperature Period of Record: 1959 to 1991 (32 years) (3,400 nest records)	[17]Dunn and Winkler (1999)
Brunnich's guillemot (*Uria lamvia*)	Northern Hudson Bay (southern boundary)	• Advanced laying date and increased weight trends correlated with changes in sea ice cover (area of open water) Period of Record: 1975 to 1977 and 2001 to 2003	[18]Gaston *et al.* (2005)
Polar bear (*Ursus maritimus*)	Hudson Bay (southern range boundary)	• Decline in physical (mean body weight) and reproductive traits (birth numbers) • Population declines in opposite geographic boundaries Period of Record: 1981 to 1998 and 1980 to 2004	[19]Stirling *et al.* (1999) Stirling *et al.* (2006)

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
16 butterfly species	Manitoba	• Extending adult activity periods into the late summer and fall in response to longer frost-free periods • Change in the length of certain life stages, including population peak periods and longer flight periods Period of Record: 1970 to 2004	[20]Westwood and Blair (2006)
Aspen poplar (*Populus tremuloides*), Saskatoon (*Amelanchier Alnifolia*) and Chokecherry (*Prunus virginiana*)	Edmonton, Alberta	• The timing of flowering by several species is largely a response to temperature, with earlier blooms seen in years of higher spring temperatures • Overall, spring flowering events have advanced 8 days over a 60 year period • Aspen poplar showed a 26-day shift to earlier blooming over a 98 year period Period of Record: various years dating back as far as 1901	[21]Beaubien and Freeland (2000)
96 migrant bird species	Delta Marsh, Manitoba	• Fifteen species showed significantly earlier arrivals due to increases in temperature Period of Record: 63 years	[22]Murphy-Klassen *et al.* (2005)
6 bird species	Continental U.S. and southern Canada	• Laying dates for four of six species were earlier when spring temperatures were warmer • Over the long-term, laying dates advanced over time for two species [red-winged blackbirds, *Agelaius phoeniceus*, 7.5 days and eastern bluebirds (*Sialia sialis*), 4 days)] • Laying date of song sparrows (*Melospiza melodia*) also advanced with increasing temperature when the analysis was restricted to eastern populations • The study showed that the relationship between climate change and breeding in birds is variable within and among species Period of Record: 50 years	[23]Torti and Dunn (2005)

Table 2: Cont'd

Table 3: Ecological indicators of climate change across Canada – changes resulting from indirect effects.

TAXON	GEOGRAPHIC LOCATION	ECOLOGICAL RESPONSE/PERIOD OF RECORD	SOURCE(S)
Ringed seal (*Phoca hispida*)	Western Hudson Bay	• Decrease in ice extent and snow depth corresponded to decrease in ringed seal recruitment, reduced pup survival, and a reduction in pregnancy rates Period of Record: 20 year old seals from two data sets 1999 to 2001 and 1991 to 1992	[24]Ferguson *et al.* (2005)
Narwhal (*Monodon monoceros*)	Baffin Bay	• Limited number of leads and cracks available to narwhals during the winter and localized decreasing trends in open water and high site fidelity • Decreasing trends in the fraction of open water, together with increasing trends in interannual variability, were detected on wintering grounds Period of Record: 1978 to 2001 (26 years)	[25]Laidre and Heide-Jorgensen (2005)

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Annex 4: Distributional Responses of Selected Native Trees to Climate Change

The projected shift of ecoregions attributed to climate change may cut both ways, reducing the southern distribution of some boreal trees and other species in northern Canada while creating opportunities for the extension of others, such as the Carolinian Cucumber-tree (*Magnolia acuminata*) and other flora and fauna now on their northern range limits in southern Canada. (Photo Credit: Allen Woodliffe)

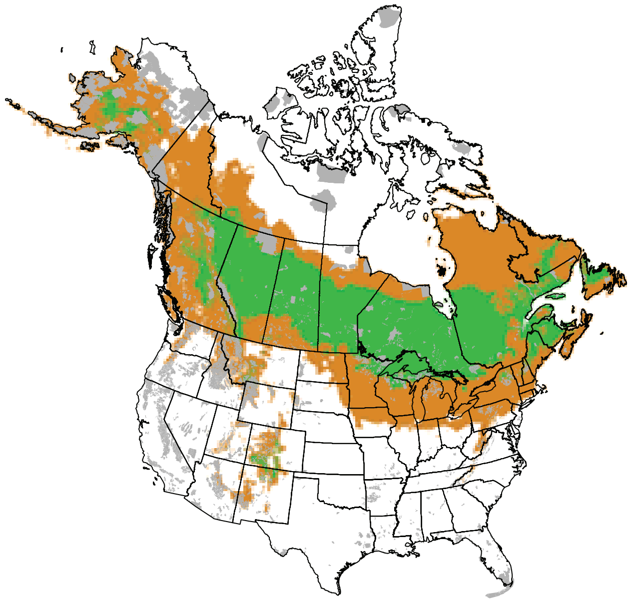
The species distributions interpolated from climate change scenarios presented within this Annex were produced with data provided by Dan McKenney, Natural Resources Canada. A climate change scenario is a description of a possible future climate based on assumptions of how the Earth's climate operates, future world population levels, economic activity and greenhouse gas emissions (see description of various SRES climate change scenarios in **Annex 2**).

McKenney *et al*. (2007a and 2007b) have interpolated species' climatic distributions based on future climate scenarios for use in climate change impact studies. Species range maps were developed using a climate envelope (CE) approach that indicates where climate is conducive to growth of a particular taxon. The "core range" is a subset of the full climatic range within which an organism is thought to maintain high rates of survival, growth, and re-productive success. The core range is defined as the climatic space bounded by the 5th and 95th percentiles, thus encompassing 90% of the climate values for each species (McKenney *et al*., 2007a).

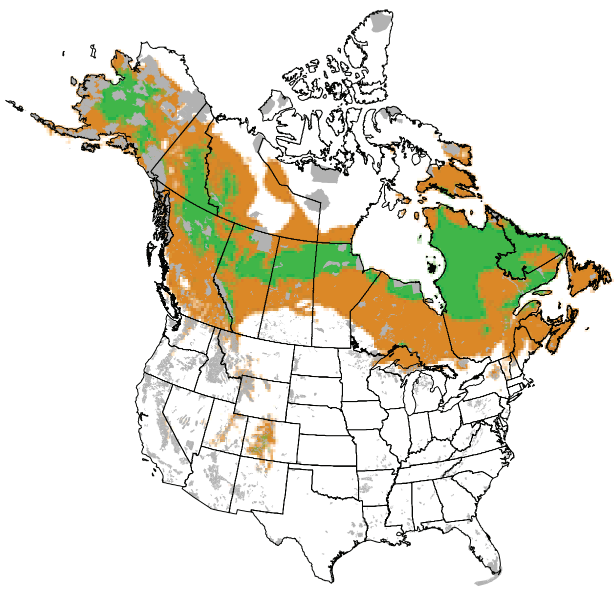
The following portfolio of maps features seven North American trees, six of which are currently native to Canada. The selected species include northern, eastern, western and southern species which illustrate possible patterns and scenarios for the future distribution and ranges of these trees and other species. For more information including technical details, please visit: http://planthardiness.gc.ca/ .

Figure 1: Existing and potential range distributions for Black Spruce (*Picea mariana*) under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

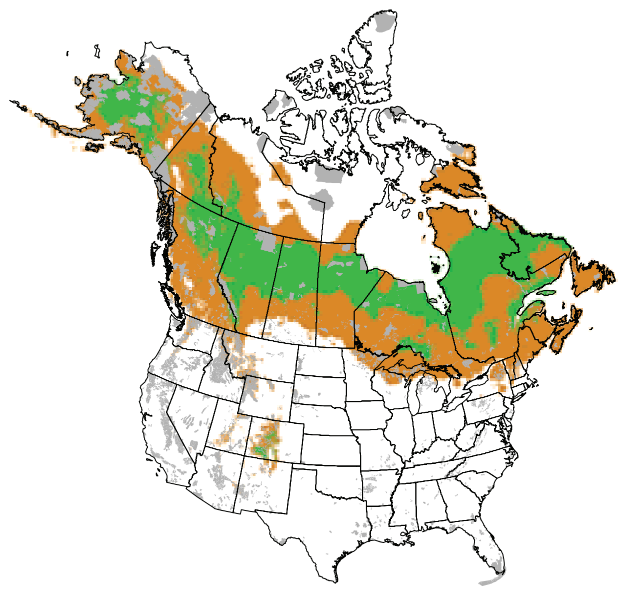
a) Current Potential Distribution (1971-2000)



b) CGCM2 A2 Emissions Scenario (2071-2100)



c) CGCM2 B2 Emissions Scenario (2071-2100)



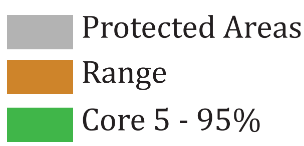
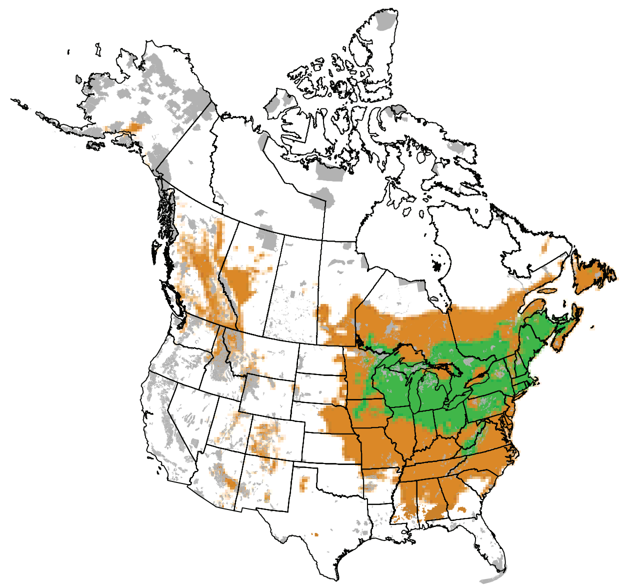
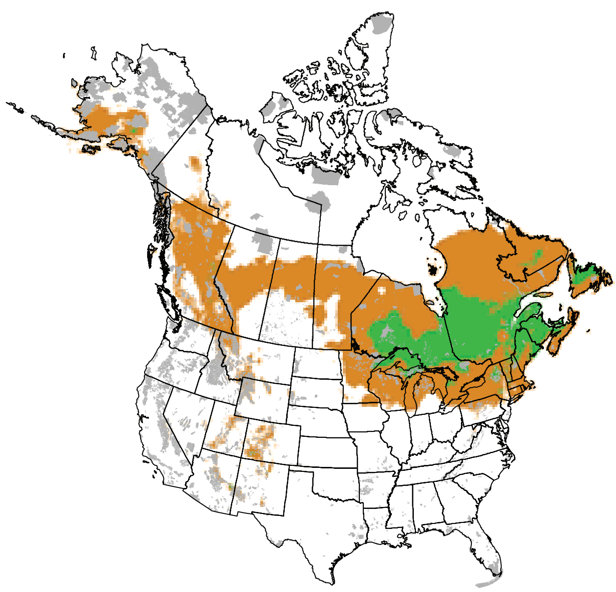


Figure 2: Existing and potential range distributions for White Pine (*Pinus strobus*) under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

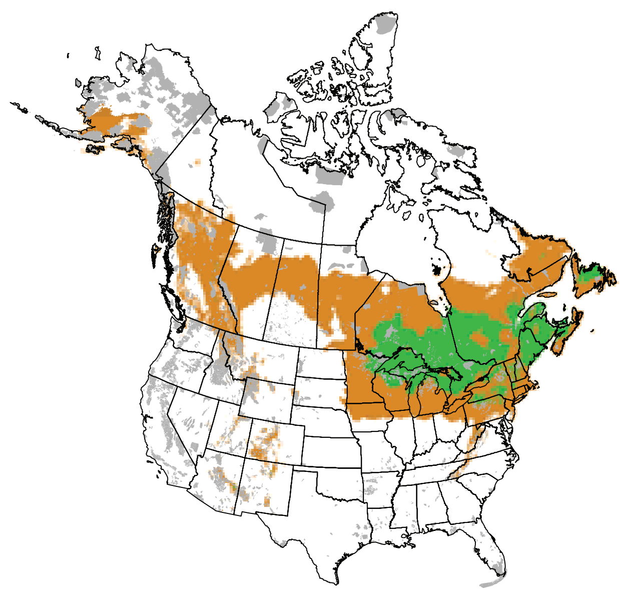
a) Current Potential Distribution (1971-2000)



b) CGCM2 A2 Emissions Scenario (2071-2100)



c) CGCM2 B2 Emissions Scenario (2071-2100)



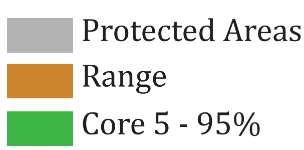


Figure 3: Existing and potential range distributions for Sugar Maple (*Acer saccharum*) under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

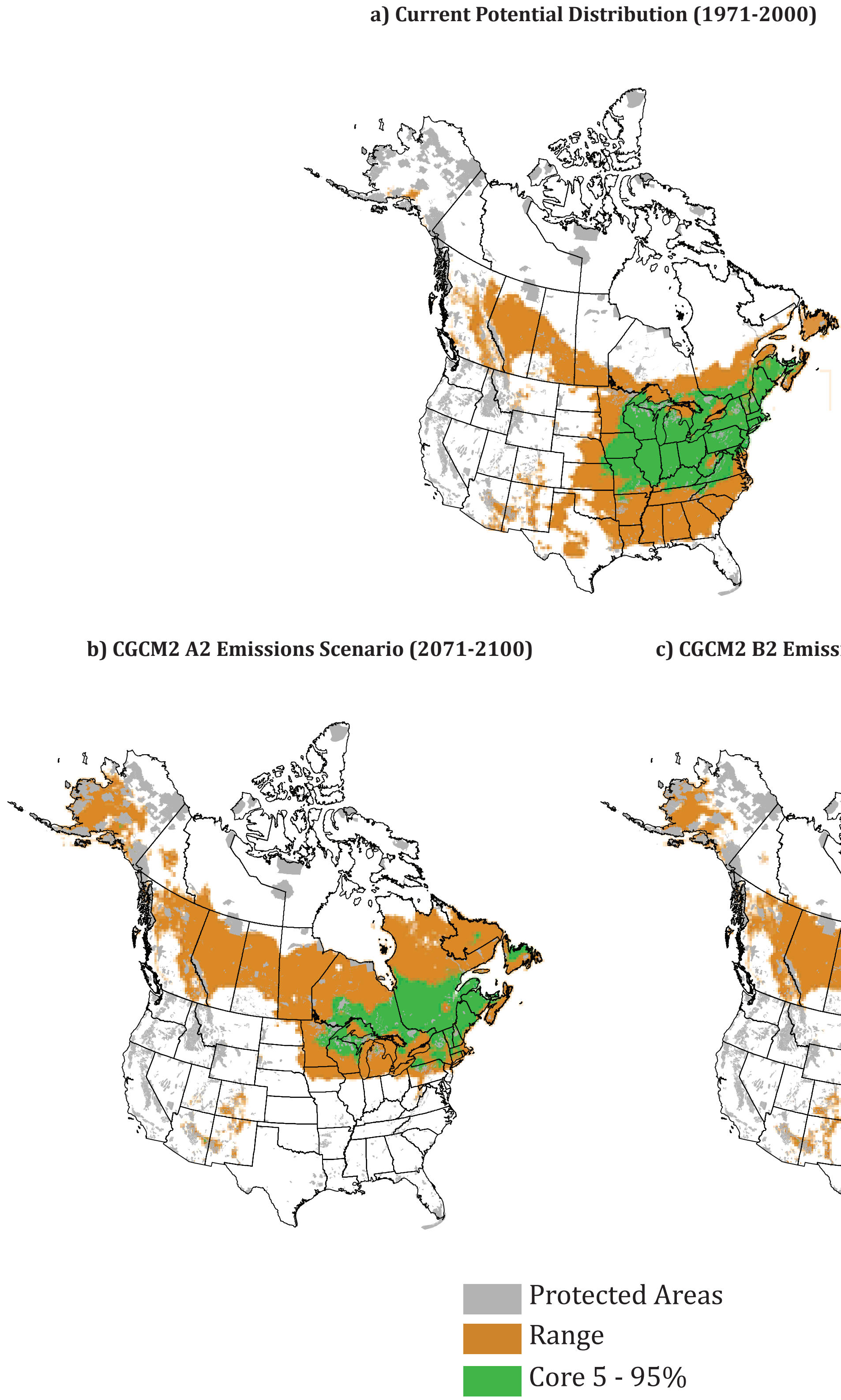


Figure 4: Existing and potential range distributions for Douglas Fir (*Pseudostuga menziesii var. glauca*) under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

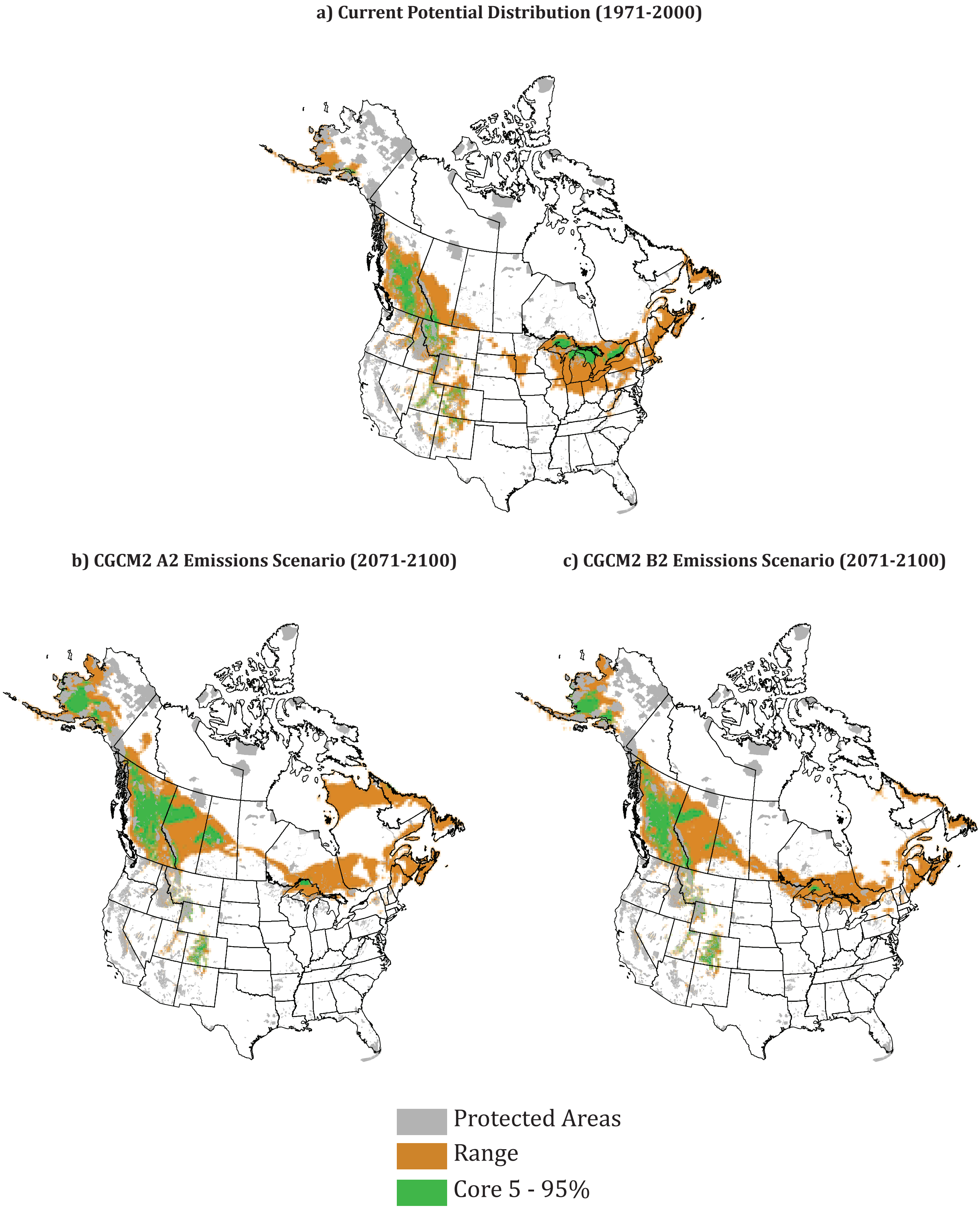


Figure 5: Existing and potential range distributions for Arbutus (*Arbutus menziesii)* under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

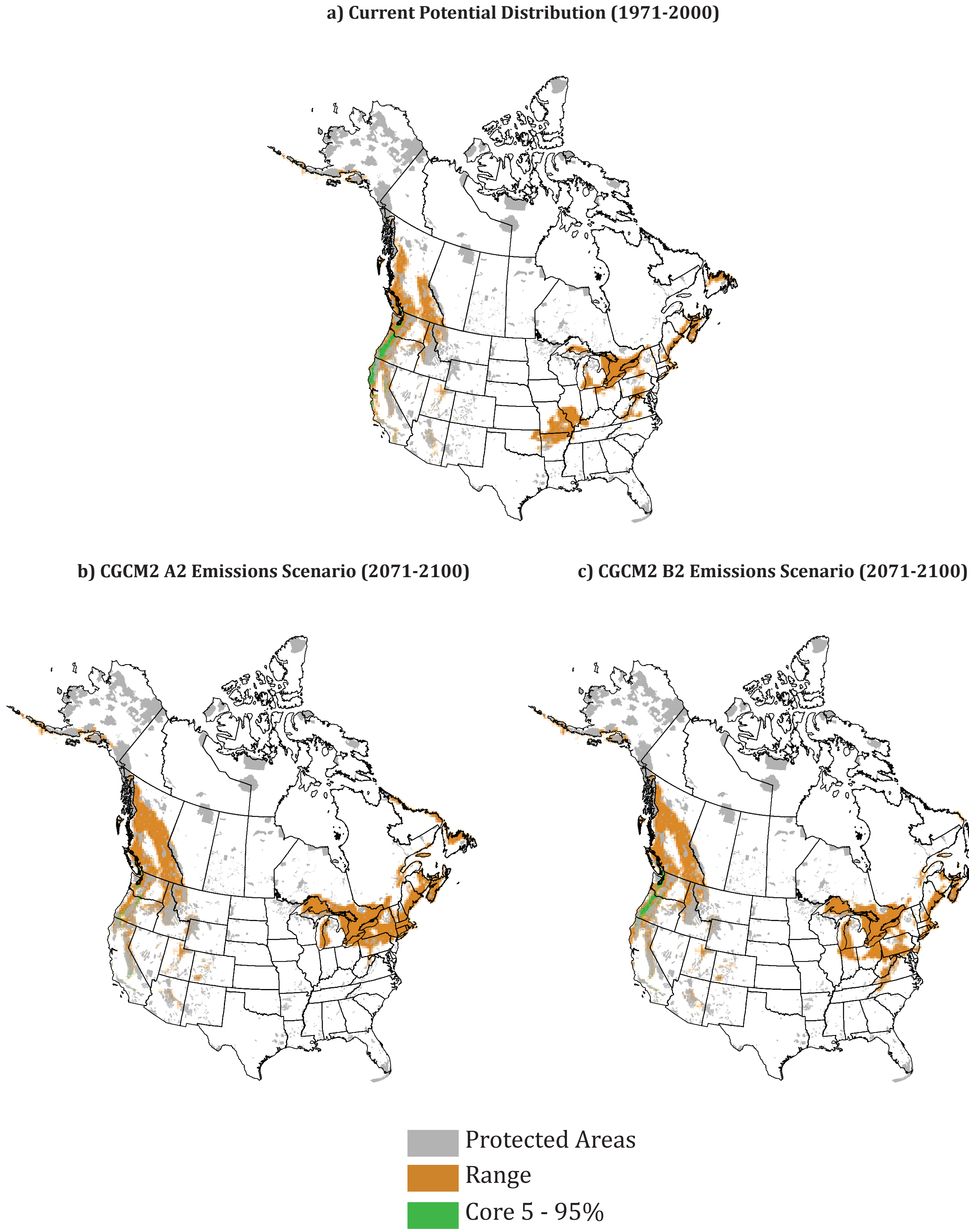


Figure 6: Existing and potential range distributions for Cucumber Magnolia (*Magnolia acuminata)* under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.

a) Current Potential Distribution (1971-2000)

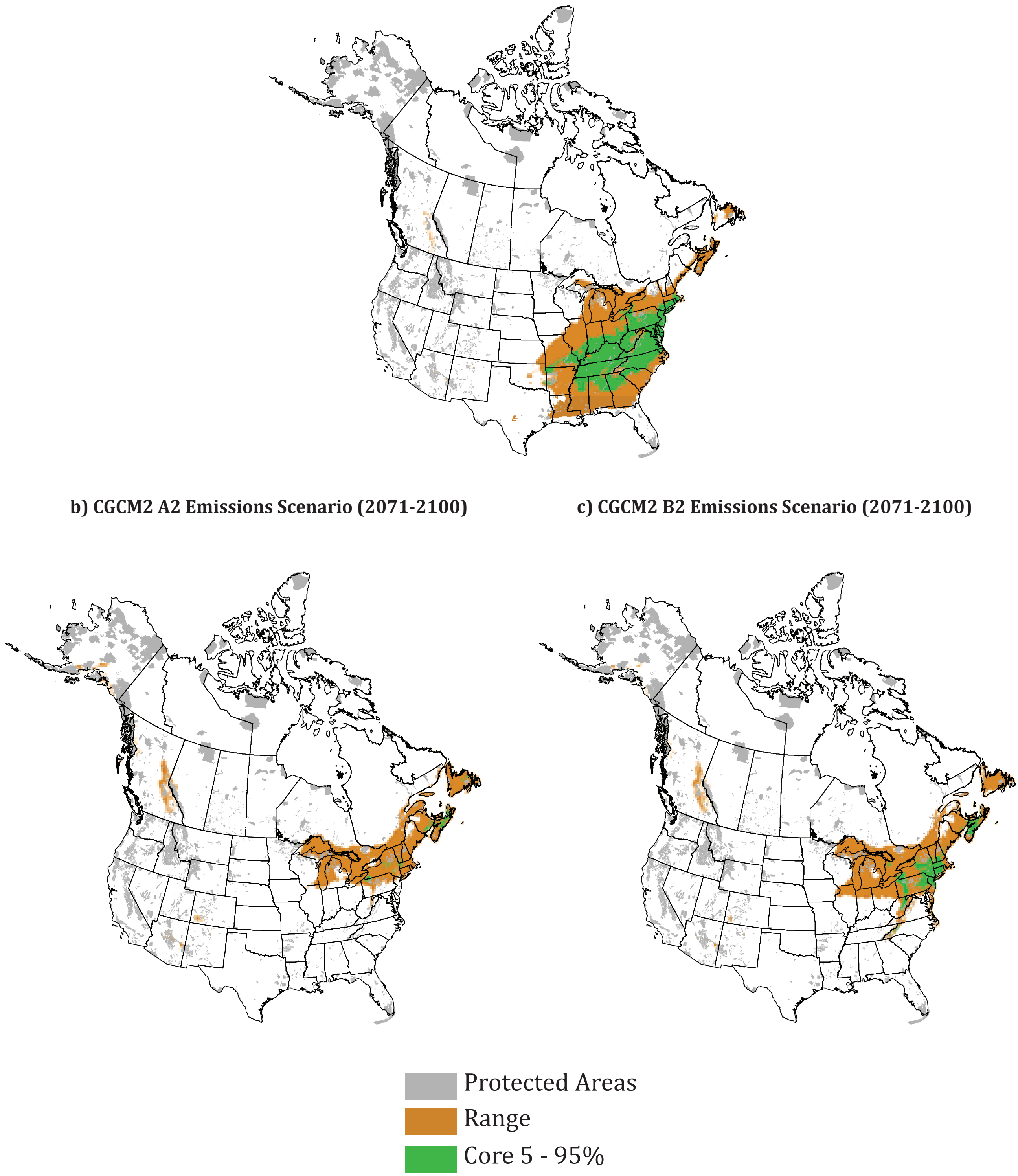
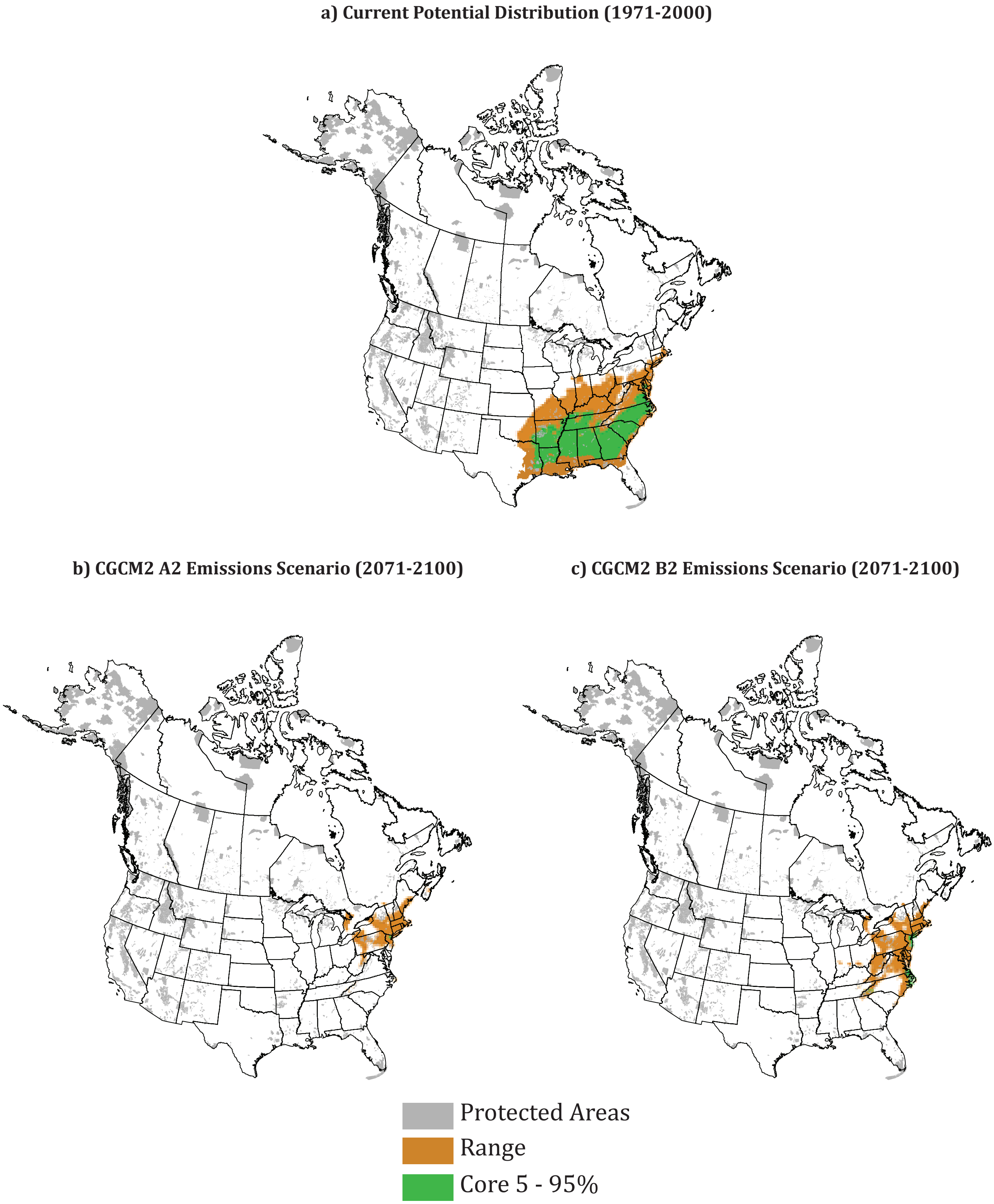


Figure 7: Existing and potential range distributions for Willow Oak (*Quercus phellos*) under current and projected climate change scenarios based on specified emission scenarios and Canada/U.S. protected areas >10,000 ha.



Willow oak is illustrative of a number of southern trees and many other species that may develop range extensions into Canada as a result of climate change.

Annex 5: The Canadian Protected Areas and Climate Change (PACC) Survey

AN E-SURVEY ON THE STATE OF PROTECTED AREAS AND CLIMATE CHANGE

A Collaborative Project between
the Canadian Council on Ecological Areas (CCEA) and the University of Waterloo

Dear Colleague,

I am writing to request your participation in a survey involving the completion of the following questionnaire aimed at gathering information on climate change and protected areas. The survey is a collaborative project being conducted by the *Canadian Council on Ecological Areas* (CCEA) and the *University of Waterloo.*

A central function of the *Canadian Council on Ecological Areas* (CCEA) is to mobilize experts and practitioners to advance work on subject areas and issues that are critical for designing, planning and managing protected areas. *Climate Change* has been recognized as an issue of high priority within the CCEA's current *Business Plan*[1], and one that has been further highlighted by all Canadian protected areas jurisdictions participating in a recent CCEA Northern Protected Areas (NPA) survey and assessment (report in press). Recent suggestions by the Intergovernmental Panel on Climate Change (IPCC) that earth is committed to climate change regardless of greenhouse gas mitigation efforts[2], and the World Commission on Protected Areas (WCPA)[3] that *"conservation actions are likely to fail unless they are adjusted to take account of climate change"*, emphasizes the need for protected areas agencies to begin integrating climate change into policy, planning, management and research.

This E-Survey seeks to gather information on: 1) climate change impacts currently being experienced, or anticipated to be experienced, in protected areas across Canada; 2) where the issue of climate change ranks in relation to other protected areas management issues within Canadian jurisdictions; and, 3) what policy and management, operations and development, monitoring and research, education and outreach, and other climate change responses (adaptation) efforts have occurred, or are being considered, by protected areas agencies across Canada. Accordingly, the survey seeks to document such efforts on the full range of Canadian protected areas (i.e., IUCN Protected Area Management Categories I-VI), including national parks, provincial parks, ecological reserves, wildlife areas/sanctuaries, demonstration/forest reserves, marine/aquatic reserves and other designations relevant to your jurisdiction. We would ask that throughout the survey, you focus your answers on protected areas within your agency's jurisdiction only.

The results of this survey will be compiled, analyzed and reported to provide an overview of the state of climate change in protected areas in Canada. The results will help to determine longer term initiatives that the project sponsors may take in collaboration with participating agencies and organizations across Canada that share this concern.

Please return the E-Survey to **Christopher Lemieux** (contact information can be found on the following page) no later than **Friday, April 28, 2006**. The E-Survey is attached as an MS-Word document, so it can be intermittently saved and completed at your convenience – there is no need to complete the E-survey in a 'single-sitting'. You are requested to return the E-Survey via e-mail, or if that is not possible, please print your survey and return it via mail or fax.

If you feel that someone else in your agency is better positioned to complete the E-Survey, or if you can suggest additional contacts whom you feel should be included in this survey, please forward their contact information (name, address, E-Mail address, etc.) directly to Christopher Lemieux and a copy will forwarded to them immediately.

Participation in this survey is voluntary. You may decline to answer any of the survey questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher. Your name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used. **All questionnaire responses will be used only for the purposes of this survey with no disclosure of respondent's names but we may use your agency's name to be able to compare climate change initiatives across Canada.**

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes of this office at (519) 888-4567 Ext. 6005 or ssykes@uwaterloo.ca.

If you have any questions or concerns regarding the survey, please feel free to contact me as soon as possible.

Please return the E-Survey via E-Mail, regular mail, or fax to:

Christopher Lemieux
Protected Areas and Climate Change (PACC) Survey Coordinator
E.S. 1, Room 103, Department of Geography
University of Waterloo
Waterloo, ON N2L 3G1
Tel. (519) 888-4567 ext. 5783
Fax. (519) 746-0658 – **PLEASE MAKE ATTENTION TO DR. DANIEL SCOTT**
E-mail. cjlemieux@uwaterloo.ca

Thank-you for your time in completing this survey!

Protected Areas and Climate Change (PACC) Project Team Members:

Christopher Lemieux, PACC Survey Coordinator, Department of Geography, University of Waterloo
Tel. (519) 888-4567 ext. 5783 | E-mail. cjlemieux@uwaterloo.ca

Tom Beechey, Associate Director, Canadian Council on Ecological Areas (CCEA)
Tel. (519) 658-6086 | E-mail. tombeechey@sympatico.ca

Dr. Daniel Scott, Assistant Professor and Canada Research Chair in Global Change and Tourism, Department of Geography, University of Waterloo
Tel. (519) 888-4567 ext. 5497 | E-mail. dj2scott@fes.uwaterloo.ca

Section 1: Respondent Information

Primary survey respondent information.

Name:

Title:

Affiliation:

Years with Organization:

Mailing Address:

Phone:

E-Mail:

Where would you rank your level of understanding with regards to climate change? Please select one option from the dropdown menu.
Please Select

Secondary survey respondent information (if applicable).

Name:

Title:

Affiliation:

Years with Organization:

Mailing Address:

Phone:

E-Mail:

Where would you rank your level of understanding with regards to climate change? Please select one option from the dropdown menu.
Please Select

For some of the questions within this survey, you are asked to rate the 'importance' of a number of issues or perspectives. The following scale defines what is meant by each category on the importance scale.

Importance Scale	Validation
Very Important	• A most relevant issue • First-order priority • Has direct bearing on major issues • Must be resolved, dealt with, or treated
Important	• Is a relevant issue • Second-order priority • Significant impact but not until other items are treated • This issue does not have to be fully resolved
Slightly Important	• Marginally relevant • Third-order priority • Has little importance • Not a determining factor to major issue
Unimportant	• No relevance • No priority • No measurable effect • Should be dropped as an item to consider

Section 2: Survey Questions

****Please note that text form boxes will expand to accommodate however much text that you wish to provide – there are no restrictions in terms of space.****

1. When do you think the issue of climate change will be relevant to protected areas planning and management in your agency?

- ☐ Now
- ☐ 2020s
- ☐ 2050s
- ☐ 2080s
- ☐ Never

2. How much do you agree with the following statements? **Please select one option.**

Climate change is going to substantially alter protected area policy and planning over the next 10 years.	**Strongly Agree**
Climate change is going to substantially alter protected area policy and planning over the next 25 years.	**Strongly Agree**

3. Have there been any formal climate change discussions within your agency (e.g., workshops, strategic/expert meetings, etc.)?

☐ Yes ☐ No

If Yes, briefly describe the nature of these discussions?

If Yes, please provide the reference for any proceedings/conference summary or forward as an E-Mail attachment if possible:

4. Has a comprehensive assessment on potential climate change impacts and implications for protected areas policy and management been completed by/for your agency?

☐ Yes ☐ No

If Yes, please provide study/report reference or forward as an E-Mail attachment if possible:

If No, have there been discussions regarding the need for such an assessment to be done?

☐ Yes ☐ No

5. For protected areas within your agency, how important of an impact, if any, do you think climate change will have on the following? **Please select one option from the dropdown menu.**

Policy	Very Important
Planning	Very Important
Management	Very Important
Infrastructure/Operations	Very Important
Wildlife	Very Important
Vegetation	Very Important
Watersheds (including wetlands, water quality and quantity)	Very Important
Tourism and Recreation	Very Important
Interpretation Programs	Very Important
Revenues	Very Important

6. The following question is designed to examine where you think the issue of climate change currently ranks in terms of importance relative to other protected areas management issues. **Please rank each issue using the dropdown menu (Ranking of "1" = Most Important; Ranking of "11" = Least Important).**

Climate change	Rank 1
Wildlife management (species richness, population dynamics, trophic structure)	Rank 1
Water quality/Air quality	Rank 1
Rare/endangered species management	Rank 1
Exotic species (animal and plant)	Rank 1
Visitor stresses (e.g., public facilities, interpretation centres, etc.)	Rank 1
Contamination/Pollution	Rank 1
External threats (surrounding land-use, habitat fragmentation)	Rank 1
Human land-use patterns (e.g., roads, population density, etc.)	Rank 1
Disturbance frequencies (e.g., fire, insects, flooding, etc.)	Rank 1
Other (please identify):	Rank 1

7. The following question is designed to examine where you think the issue of climate change ranks in terms of importance relative to other protected areas management issues 25 years from now. **Please rank each issue using the dropdown menu (Ranking of "1" = Most Important; Ranking of "11" = Least Important).**

Climate change	Rank 1
Wildlife management (species richness, population dynamics, trophic structure)	Rank 1
Water quality/Air quality	Rank 1
Rare/endangered species management	Rank 1
Exotic species (animal and plant)	Rank 1
Visitor stresses (e.g., public facilities, interpretation centres, etc.)	Rank 1
Contamination/Pollution	Rank 1
External threats (surrounding land-use, habitat fragmentation)	Rank 1
Human land-use patterns (e.g., roads, population density, etc.)	Rank 1
Disturbance frequencies (e.g., fire, insects, flooding, etc.)	Rank 1
Other (please identify):	Rank 1

8. Are any types of protected areas within your agency <u>currently affected</u> by climate change related impacts?

☐ Yes ☐ No ☐ Not Sure

If <u>No</u>, please skip to <u>Question 9</u>.

If <u>Yes</u>, please complete the following questions.

Please check any relevant types of impacts being observed:

☐ Species range shifts
☐ Changes in species composition
☐ Changes in disturbance regimes (e.g., forest fires)
☐ Changes in protected area physiography (e.g., glacial extent, change in water levels, etc.)
☐ Tourism/Recreation (e.g., increase in visitation due to extended 'warm' seasons)
☐ Other (please identify):

Has the nature and scale of such impacts been investigated through research?

☐ Yes ☐ No

If <u>No</u>, skip to <u>Question 9</u>.

If <u>Yes</u>, have these studies been conducted by (check any that apply):

☐ Your agency
☐ Another agency within your jurisdiction [please identify which one(s)]:
☐ Non-governmental organizations (NGOs) [please identify which one(s)]:
☐ University researchers including graduate students [please identify which one(s)]:
☐ Consultants [please state which one(s)]:
☐ Other (please elaborate):

Please provide any relevant research references in the field below (i.e., author, date, title of research publication) or forward as an <u>E-Mail attachment</u> if possible:

Is any response being taken or being considered to deal with any of the identified climate related impacts (e.g., further research or adaptation measures)?

☐ Yes ☐ No

If <u>No,</u> skip to <u>Question 9</u>.

If Yes, briefly identify the specific climate change responses being undertaken or being considered.

	Responses Being Undertaken	Responses Being Considered
Legislation, Planning, and Policy	☐	☐
Selection, Evaluation and Design of Protected Areas	☐	☐
Management Direction	☐	☐
Operations and Development	☐	☐
Research, Monitoring and Reporting	☐	☐
Education, Interpretation and Outreach	☐	☐
Other (please identify):	☐	☐

If you checked any of the boxes above, please provide any more additional details you wish in the space provided:

9. Is anybody in your agency specifically responsible for climate change issues (this includes legislation, policy, research, planning, management and monitoring)?

☐ Yes (individual) ☐ Yes (more than one individual) ☐ No

Equivalent Person Years (PYs) (optional):

10. Does your agency have its own climate change policy (i.e., not a provincial government policy but one specific to your agency and protected areas)?

☐ Yes ☐ No ☐ In Development

If Yes or In Development, what was (or is) the actual (or anticipated) time-line for implementation?

11. Does your agency have a climate change adaptation strategy (or action plan) directly related to protected areas?

☐ Yes ☐ No ☐ In Development

If Yes or In Development, what was (or is) the actual (or anticipated) time-line for implementation?

If Yes, please provide a report reference or forward as an E-Mail attachment if possible:

12. Does your agency have a climate change mitigation strategy (or action plan) directly related to protected areas (e.g., related to greenhouse gas emissions)?

☐ Yes ☐ No ☐ In Development

If Yes or In Development, what was (or is) the actual (or anticipated) time-line for implementation?

If Yes, please provide a report reference or forward as an E-Mail attachment if possible:

13. Indicate the response that best represents your agency's view on each of the following statements. **Please select one option from the dropdown menu.**

There is a need for more research on the impacts of climate change before any policy, planning or managerial responses are made.	Strongly Agree
Detecting and monitoring climate change should be a priority for protected areas agencies.	Strongly Agree
There are too many uncertainties regarding climate change to develop adaptation strategies for protected areas.	Strongly Agree

14. Research is being done on many climate change issues. Please rate the level of additional information your agency would like to have on the following climate change related topics. **Please select one option from the dropdown menu.**

Information on climate or atmospheric processes.	Much More Info
Errors and problems in computer modeling of the climate system.	Much More Info
Detecting climate change (e.g., temperature trends).	Much More Info
Ecological consequences of climate change (e.g., species distribution, composition).	Much More Info
Information on the impacts of climate change on physiography (e.g., glacial retreat, fluvial dynamics, coastal processes).	Much More Info
Information on the impacts of climate change on visitation (tourism and recreation).	Much More Info
Information on the impacts of climate change on planning, policy and management.	Much More Info
Information on the impacts of climate change on interpretation programs.	Much More Info
Strategies for managerial response (adaptation) to climate change impacts.	Much More Info
Information and strategies on how to effectively communicate the facts, issues, consequences and solutions to climate change.	Much More Info

15. Does your agency specifically monitor for climate change impacts (e.g., distribution of flora and fauna, species tracking, etc.)?

☐ Yes ☐ No

If Yes, please briefly identify specific monitoring initiatives:

16. Has your agency developed specific climate change indicators for detecting or monitoring climate change impacts (e.g., through weather stations, species monitoring, etc.)?

☐ Yes ☐ No

If Yes, please elaborate:

17. Has climate change been incorporated or considered in the development of protected areas management plans or other active management plans relevant to protected areas (e.g., fire/prescribed burning, environmental assessment, invasive species, etc.)?

☐ Yes ☐ No

If Yes, please elaborate or forward a sample management plan as an E-Mail attachment if possible:

If No, is your agency in the process or considering the incorporation of climate change into park management plans or other management plans relevant to parks and protected areas?

☐ Yes ☐ No

If Yes, please elaborate:

18. Does your agency have a public education program specifically related to climate change and its possible effects (e.g., through posters, park interpretation, park brochures, etc.)?

☐ Yes ☐ No

If Yes, please briefly describe the program (e.g., information delivery mechanism, when and where implemented):

If No, does your agency have plans to develop one?

☐ Yes (next 1-5 years) ☐ Yes (next 6-10 years) ☐ Yes (10+ years) ☐ No

19. What should be the approach to climate change adaptation among Canada's protected areas agencies (within all levels of government)? You may select more than one option.

☐ No specific adaptation strategy
☐ Coping with issues on an 'as needed' basis
☐ Operating with a comprehensive agency-based strategy
☐ Sharing in a Canada-wide protected areas collaborative effort on climate change

Why (optional)?

20. Is your agency actively involved (directly or indirectly) in climate change dialogue and capacity-building initiatives (e.g., staff participation in workshops, conferences, etc.)?

☐ Yes ☐ No

If Yes, please elaborate on types of capacity-building initiatives:

21. Do you feel that your jurisdiction currently has the capacity necessary to deal with climate change issues affecting protected areas (e.g., committed financial resources, knowledgeable/scientifically trained staff, etc.)?

☐ Yes ☐ No

Please elaborate:

22. Would your agency be willing to participate in a nation-wide working group on climate change and protected areas (you may select more than one option) or a national workshop on the topic?

☐ Yes ☐ No

If Yes, please provide the name(s) of individuals whom you think would be willing to participate:

If Yes, what resources, if any, would your agency be prepared to provide (you may select more than one option)?

- ☐ Advocacy
- ☐ Expertise
- ☐ Financial Support
- ☐ Communications Support
- ☐ Casework Experience/Research Presentation
- ☐ Case Application

23. Are there any other issues or concerns regarding climate change and protected areas not covered in this survey that you feel are important to consider? Please elaborate.

Please save your survey to your hard drive before closing it.

Thank-you for taking the time to complete the survey!

CCEA Publications

This report is one in the series of occasional papers issued by the Canadian Council on Ecological Areas (CCEA) to disseminate research findings and information on protected areas to conservation professionals. The CCEA Occasional Paper Series features reports that communicate the results of CCEA project work and other selected initiatives involving the CCEA and its partners. In addition to this series of technical reports, the CCEA issues summaries and proceedings of its annual meetings, conferences and workshops. A periodic newsletter, '*eco*', reports on the activities of the CCEA and international, federal, provincial, territorial, and non-governmental efforts on protected areas. References for the various reports, with PDF copies of many of them, are posted on the CCEA website. Printed copies of some of the reports are available through the CCEA Secretariat.

Canadian Council on Ecological Areas (CCEA)
Secretariat, c/o Canadian Wildlife Service, Environment Canada
3rd Floor, 351 St. Joseph Boulevard
Gatineau, Québec, Canada
K1A 0H3

www.ccea.org

Larger than the combined area of Germany and France, Canada's vast network of protected areas is a globally significant heritage estate that is working every day as a 'Natural Solution' to conserve biodiversity and to buffer the effects of climate change. This report provides a review and synthesis of climate change issues confronting protected areas in Canada, and it discusses challenges and opportunities for protected areas agencies and conservation professionals to develop novel approaches for climate change mitigation and adaptation to keep Canada's protected areas working effectively for Nature.

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