Climate change and protected area policy and planning in Canada

by Daniel Scott[1] and Christopher Lemieux[2]

ABSTRACT

Protected areas are the most common and most important strategy for biodiversity conservation and are called for under the United Nations' *Convention on Biological Diversity*. However, most protected areas have been designed to represent (and in theory protect for perpetuity) specific natural features, species and ecological communities *in-situ*, and have not taken into account potential shifts in ecosystem distribution and composition that could be induced by global climatic change. This paper provides an overview of the policy and planning implications of climate change for protected areas in Canada, summarizes a portfolio of climate change adaptation options that have been discussed in the conservation literature and by conservation professionals and provides a perspective on what is needed for the conservation community in Canada to move forward on responding to the threat posed by climate change.

Key words: climate change, protected areas, parks, conservation, system planning, impacts, adaptation

RÉSUMÉ

La protection du territoire constitue la stratégie la plus commune et la plus importante en matière de conservation de la biodiversité et se retrouve au sein de la Convention sur la diversité biologique des Nations-Unies. Cependant, la plupart des territoires protégés ont été établis pour représenter (et en théorie protéger perpétuellement) des caractéristiques naturelles spécifiques, des espèces et des communautés écologiques in situ et n'ont pas tenu compte des tendances possibles dans la distribution et la composition des écosystèmes qui pourraient être introduites par les changements climatiques mondiaux. Cet article constitue un survol des implications au niveau des politiques et de la planification des changements climatiques dans le cas des territoires protégés au Canada, résume un ensemble d'options de changement de conservation qui ont été discutées dans la littérature portant sur la conservation et par les professionnels du milieu et apporte une perspective sur ce qu'il faut à la communauté s'occupant de conservation au Canada pour aller de l'avant dans sa réaction à la menace posée par les changements climatiques.

Mots clés : changements climatiques, territoires protégés, parcs, conservation, planification, impacts, adaptation

Daniel Scott

Christopher Lemieux

Introduction

The international community has recognized the significance of global climate change for ecosystem change and biodiversity conservation. The United Nations *Framework Convention on Climate Change* (UNFCCC) (1997: Article 2) articulated the linkage between climate change and biodiversity early on when it indicated that, "The ultimate objective of this convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at such a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to *allow ecosystems to adapt naturally* to climate change…" (emphasis added). More recently, Thomas *et al.* (2004) stated that "Despite the uncertainties… the overall conclusions … establish that anthropogenic climate warming at *least ranks alongside other recognized threats to global biodiversity* [and] contrary to previous projections, it is *likely to be the greatest threat in many if not most regions*" (emphasis added).

Protected areas are the most common and most important strategy for biodiversity conservation (Woodley and Forbes 1995) and are called for under the United Nations' *Convention on Biological Diversity* (UNCBD 1992: Article 8). However, most protected areas have been designed to represent (and in theory protect for perpetuity) specific natural features, species and communities *in-situ*, and have not taken

[1]Canada Research Chair in Global Change and Tourism, Department of Geography, University of Waterloo, E.S. 1, Room 207, Waterloo, Ontario, N2L 3G1. E-mail: dj2scott@fes.uwaterloo.ca (corresponding author)

[2]Department of Geography, University of Waterloo, E.S. 1, Room 103, Waterloo, Ontario, N2L 3G1. E-mail: cjlemieu@fes.uwaterloo.ca

Table 1. Selected policy and planning implications of climate change for Canadian protected areas

Protected Areas System Planning	• System planning frameworks (e.g., natural region representation) may not be optimal for the selection of new protected areas. • System goals will require interpretation (what to protect – historic-current-future species, processes and not species?). • Because future non-analogue communities are unknown, they are excluded from current steady-state planning frameworks.
Park Management Plans	• Established management objectives will no longer be viable in some parks. • Park objective statements (e.g., to protect a highly valued species) will force protected areas managers to try to "hit a moving target" of ecological representativeness.
Active Management Plans	• Wildfire management plans (utilize to re-establish or maintain current ecological representation for facilitate adaptation?). • Individual species management plans (commit resources to species re-introduction?, how define invasive species?, exclude southern species from species at risk protection?). • Visitor management plans (how manage for potentially large increases in visitation due to extended and improved warm-tourism season?).

Compiled from: Scott and Suffling 2000, Scott *et al.* 2002; Suffling and Scott 2002, Lemieux and Scott 2005, Scott 2005, Welch 2005.

into account potential shifts in ecosystem distribution and composition that could be induced by global climatic change.

For two decades, climate change has also been identified as an important emerging issue for protected areas. Peters and Darling (1985) anticipated that the role of protected areas would change in an era of global climate change. Since then, a number of authors have concluded that protected areas are vulnerable to climate change and will need to be managed differently if they are to meet the conservation challenges of the twenty-first century and beyond (McNeely 1993, Markham 1996, Bartlein *et al.* 1997, Halpin 1997, Hannah *et al.* 2002, Scott *et al.* 2002, World Wildlife Fund 2003, Lemieux and Scott 2005, Lovejoy and Hannah 2005).

As Scott *et al.* (2002) observed, research on ecosystem impacts and the conservation implications of climate change has for the most part remained outside of the institutional contexts of the organizations responsible for the management of parks and protected areas. Comparatively few climate change studies have examined biophysical impacts in existing protected areas and even fewer have explicitly examined the implications for protected area policy and management frameworks.

The objectives of this paper are to: (i) provide an overview of the policy and planning implications of climate change for protected areas in Canada (using examples from national and provincial park systems); (ii) summarize a portfolio of climate change adaptation options that have been discussed in the conservation literature and by conservation professionals (government and NGO); and, (iii) provide a perspective on what is needed for the conservation community in Canada to move forward on better assessing and responding to the threat posed by climate change.

Implications for Protected Area Policy and Planning

Climate change has a number of important policy and planning implications for protected areas in Canada (Table 1), not all of which can be discussed in sufficient detail in this paper. Scott and Suffling (2002), Scott *et al.* (2002), Lemieux *et al.* (2005) and Lemieux and Scott (2005) can be consulted for additional information and specific case studies.

One of the more important policy implications of climate change is for protected area system planning frameworks. Public expectations of how protected areas should be managed and the science behind conservation have changed significantly over time. Sporadic and unsystematic protected area designations in North America from the late 1800s to the mid-1950s gave way to systematic approaches to protect "representative" samples of ecosystems in the 1960s. All federal and provincial-territorial jurisdictions in Canada have adopted some type of ecoregion or biogeoclimatic land classification system as the main system-planning framework for their terrestrial protected area systems. For example, in the 1970s Parks Canada (1997) delineated "natural regions" based on geologic and vegetation formations with the goal to "…protect for all time representative natural areas of Canadian significance in a system of national parks, to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations." The policy goal of the *System Plan* is to represent each of Canada's natural regions in the national parks system. As of 2005, 25 natural regions (of 39 classified by Parks Canada) are represented by the 41 national parks and national park reserves in the system. Efforts to create new national parks are concentrated on those natural regions that are not yet represented in the system. Similar policy goals exist in each province/territory and on November 25, 1992 the Canadian Parks Ministers Council, Canadian Council of Ministers of the Environment and Wildlife Ministers Council of Canada signed a *Statement of Commitment to Complete Canada's Networks of Protected Areas* (FPPC 2000).

Ecoregion-based protected area system planning is based on contemporary (last 50 years) information about the distribution and abundance of ecological features and shares a fundamental assumption of biogeographic stability. A growing body of scientific research indicates that global climate change would render this assumption untenable in the 21st

Table 2. Projected Biome Change in Parks Canada's Natural Regions[1]

Global Vegetation Model (GVM)[2]	MAPSS				BIOME3	
General Circulation Model (GCM)[3]	GFDL	GISS	UKMO	HAD CM2	HAD CM2	MPI
Novel Biome Type Appears in Natural Region[1]	27	24	30	28	14	18
Biome Change in >50% of Grid Cells in Natural Region	17	16	21	14	17	18
Complete Loss of Dominant Biome Type in Natural Region	8	5	12	3	5	5
Increase % in Dominant Biome Type in Natural Region	7	8	11	4	9	9
No Change in Dominant Biome Type in Natural Region	2	4	4	3	6	3

[1]39 natural regions are delineated within Parks Canada's National Parks System Plan (Parks Canada 1997) and changes represent the number of natural regions.
[2]MAPSS (Neilson 1995) and BIOME3 (Haxeltine and Prentice 1996) are equilibrium process-based models that simulate the potential distribution of generalized types of natural vegetation on the basis of the physiological properties of plants, average seasonal climate and hydrological conditions.
[3]Three equilibrium doubled-CO2 GCM scenarios from the IPCC First Assessment Report [IPCC 1990: UKMO (United Kingdom Met Office), GFDL-R30 (Geophysical Fluid Dynamics Laboratory), and GISS (Goddard Institute for Space Studies)] and two transient GCM scenarios from the IPCC Second Assessment Report (IPCC 1995: HadCM2-ghg (Hadley Centre) and MPI-T106 (Max Planck Institute)] were used in the analysis.

century. A series of meta-analyses (Hughes 2000, McCarty 2001, Parmesan and Yohe 2003, Root *et al.* 2003) have compiled evidence that physical and biological systems are already responding to the changing climate of the twentieth century. Vegetation modeling studies on the future impacts of climate change on terrestrial vegetation in Canada consistently project major shifts in vegetation types over much of the country (Rizzo and Wiken 1992, Hogg and Hurdle 1995, Lenihan and Neilson 1995, Henderson *et al.* 2003, Hamann and Wang 2005). Examining Parks Canada's "natural region" framework specifically (Table 2), combinations of doubled-CO_2 climate change scenarios and equilibrium global vegetation models (GVMs) (MAPSS and BIOME3) project that a new biome type could appear in 34–75% of natural regions depending on the scenario used. A complete loss of the dominant biome type was projected for three to 12 of the 39 natural regions and an even greater proportion of natural areas (one-third to one-half) were projected to experience a biome change over at least 50% of their area. These projected vegetation changes indicate that Parks Canada's system planning foundation of natural region representation is theoretically problematic in an era characterized by global climatic and ecological change. If more specific vegetation units were used for this analysis, the magnitude of change in the natural regions would be much higher. The time frame for landscape level biome change projected by equilibrium GVMs is uncertain. An inter-comparison study of a new generation of dynamic GVMs is underway and is expected to provide temporal estimates of when landscape level vegetation changes would impact protected areas to the extent identified above.

The policy implications of projected landscape level vegetation changes are twofold. First, the policy of completing existing protected area system plans without consideration for the effects of climate change should be reassessed so that limited conservation resources can be better optimized. Second, protected area system planners will be charged with protecting "a moving target" of ecological representativeness and can only hope to do so with resources to establish additional protected areas in strategic areas.

Of course, biomes and ecosystems do not shift as entities in response to climate change, but through the responses of individual species. Interpreting the paleoecology literature (Overpeck *et al.* 2005) and vegetation modeling of individual species in North America (Iverson and Prasad 1998, Malcolm *et al.* 2004, Hamann and Wang 2005), reveals an additional problem with existing ecoregion-based planning frameworks. As individual species respond to future climate change, current species communities will begin to break down and novel species associations with no current analogue will begin to evolve. Because future non-analogue communities are unknown, they are excluded from current steady-state ecoregion-based planning frameworks and comprehensive representation of future ecosystems in the current system of protected areas is an impractical objective.

Modeling of individual species response to projected climate change in North America also reveals another policy dilemma for protected area agencies. The northward shift of species from the US, with ranges not currently in Canada, would meet Parks Canada's existing definition of "alien species" and it could be interpreted that these species should be subject to management interventions (i.e., control and removal). Provincial level definitions of invasive species, generally considered a species beyond its "historical range," also do not anticipate or account for species response to climate change. 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 signal successful autonomous adaptation by a species to "unnatural" climate change. Are we therefore ethically justified in attempting to remove such a species? Further to this point, the *Canadian Species at Risk Act* defines a "wildlife species" as a species "native" to Canada and has been present in Canada for at least 50 years (Government of Canada 2003). A literal interpretation of this definition indicates that a species classified as endangered in the US 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.*

The conservation objectives of individual protected areas would also be affected by projected biome and species changes. Each of Canada's national parks, for example, is responsible for protecting ecosystems representative of the natural region within which it is located. For example, the stated purpose of Prince Albert National Park is to, "Protect for all time the ecological integrity of a natural area of Canadian significance representative of the southern boreal plains and plateaux …" All six vegetation change scenarios examined by Scott *et al.* (2002) projected the eventual loss of boreal forest in this park, suggesting that the park's mandate would be unsustainable in the long term. Furthermore, the decision to reintroduce natural fire regimes in ecotonal parks like Prince Albert National Park, where vegetation models project a shift from boreal forest to grasslands, would hasten the transition to grassland communities and therefore be ostensibly in conflict with the current park purpose.

Like protected areas around the world, certain protected areas in Canada were established with the intent of protecting highly valued individual species and their habitats. The ecological manifestations of climate change will be such that the established species management objectives of some protected areas will no longer be viable. Several examples can be found in national and provincial park systems, including polar bears in Wapusk National Park and Polar Bear Provincial Park (Ontario), woodland caribou in Nopiming Natural Park (Manitoba), Seager Wheeler Lake Representative Area (Saskatchewan), Woodland Caribou Provincial Park (Ontario) and Pinery Provincial Park (Ontario) (Scott *et al.* 2002, Lemieux *et al.* 2005).

As striking as the aforementioned ecological change scenarios in the literature are, they may actually present a conservative portrait of the ecosystem impacts that protected area agencies will need to adapt to. None of these studies have explored the implications of climate change scenarios for the latter decades of the twenty-first century or beyond, which ultimately will be the biogeography that protected area agencies must consider. Schmitz *et al.* (2003) contend that climate change may lead to changes in trophic interactions and ecosystem structure that current vegetation models do not contain, which may increase nonlinear and more immediate shifts in ecosystem states. Furthermore, protected areas are already faced with multiple stresses and synergies between existing stresses (e.g., habitat loss, habitat fragmentation, and invasive species) have not been factored into modeling of the potential impacts of climate change. Ecosystems that are under multiple stresses are more apt to behave in unpredictable ways (Hannah *et al.* 2005).

Climate Change Adaptation

Climate change adaptation in protected areas will occur in two ways. First, protected area managers and Canadian society will have to accept and adjust to the autonomous response of natural systems. Second, protected area managers can use planned adjustments in socio-economic processes, practices and structures to moderate potential risks or to benefit from opportunities associated with climate change (Smit *et al.* 2000). The focus the remainder of this section is the latter.

There are factors that make climate change adaptation more challenging for protected areas professionals than some other natural resource sectors. Unlike other managed resource systems (e.g., water, agriculture, fisheries) there are no past exposures or climate change analogues to learn from at the system planning level. The objectives of protected areas management have very long time horizons (twenty-second century and beyond). Fewer adaptation options exist for protected areas than for lands and waters that are actively and extensively manipulated.

Perhaps as a result of these additional challenges, there has been a limited number of publications that address climate change adaptation options specifically for protected areas. Table 3 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 and awareness. To evaluate the scientific and pragmatic merits of each adaptation option is beyond the scope of this paper; however, some important points about the state of adaptation discussions for protected areas are proffered.

While some recommendations identified in the 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.* 2005). Welch (2005) concluded that, "the limited protected area-climate change literature provides … little guidance to the managers of already established protected areas." Halpin (1997) also criticized the generic nature of adaptation strategies being proposed in the scientific literature and recommended that much greater investigation into their practicality and effectiveness was needed. As one example, increasing connectivity in the landscape is often proposed as an important adaptation to climate change. It is argued that such a strategy will enhance the dispersal and migration capabilities of most species, better enabling them to adapt autonomously to climate change. For some species, however, the greatest threat posed by climate change is not the direct affects of a changed climate but the introduction of new competitors, predators or pathogens resulting from a changed climate. For these species, increased connectivity would reduce their long-term probability of survival. Similarly, the translocation of populations at risk to climate change to areas more suitable is commonly proposed in the literature and would be interpreted as inconsistent with maintaining ecological integrity if the species in question was not native to the destination region and could have an adverse impact on species in existing communities. It is this disconnect at the science-policy interface that must become a strategic focus of future work if innovative, practical solutions to the challenge of climate change are to emerge.

Climate change adaptation by protected area agencies will vary by jurisdiction. Adaptation strategies that are appropriate in one jurisdiction may not be suitable in another because they are in conflict with existing policy and planning regula-

Table 3. Climate change adaptation portfolio for protected area agencies

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. • Selection of redundant reserves. • Selection of new protected areas on ecotones. • Selection of new protected areas in close proximity to existing reserves. • Improve connectivity or protected area systems. • Continually assess protected areas legislation and regulation in relation to past, anticipated or observed impacts of climate change.
Management (including active, adaptive ecosystem management)	• Include adaptation to climate change in the management objectives and strategies of protected areas. • Implement adaptive management. • Enhance the resiliency of protected areas to allow for the management of ecosystems, their processes and services, in addition to "valued" species. • 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. • Increased management of the landscape matrix for conservation. • Mimic natural disturbance regimes where appropriate. • Revise protected area objectives to reflect dynamic biogeography.
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. • Regional modelling of biodiversity response to climate change. • Incorporate climate change impacts in protected areas "state-of-the-environment" reporting.
Capacity Building and Awareness	• 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.

Compiled from: Peters and Darling 1985, Graham 1988, Halpin 1997, Scott and Suffling 2000, Hannah *et al.* 2002, Scott *et al.* 2002, Suffling and Scott 2002, IUCN 2003, Hannah *et al.* 2005, Lemieux and Scott 2005, Welch 2005.

tions. For example, some of the management recommendations that Henderson *et al.* (2003) put forward for maintaining forest cover on vulnerable and highly valuable Prairie island forests (e.g., countering potentially catastrophic insect or vegetation disturbances by biological, chemical or physical controls; introduction of new or non-native species best adapted to new climates; and undertaking forest harvest where appropriate) may be possible in provincial forests, but are not in accord with existing national parks policy. The non-availability of particular adaptation strategies in some jurisdictions may have important implications for determining the direction and magnitude of ecosystem change and the management objectives for individual protected areas.

Climate change will challenge protected areas managers and conservation objectives in ways like never before. Difficult choices will have to be made regarding which climate change impacts on Canada's protected areas are politically tolerable. As the adaptation portfolio in Table 3 suggests, protected area management may need to become more aggressive and interventionist than in the past. This will need to be communicated clearly to senior levels of government and Canadians.

A major consideration for protected areas policy development is whether adaptation should be a matter of responding to climate change as it manifests, or whether initiatives should be taken in advance to anticipate the potential effects of climate change (Smith 1997). The literature (Burton 1996, Smit *et al.* 1996, Smith 1997) suggests that *laissez-faire* approaches to climate change adaptation has several potential drawbacks, including the possibilities that: (i) forced, last-minute, emergency adaptation will be less effective and more costly than anticipatory or precautionary adaptation over the long-term; (ii) climate change may be more rapid or pronounced than current estimates suggest and, consequently, result in increased vulnerability of socio-ecological systems to unexpected events; and, (iii) not adapting now may result in irreversible impacts (e.g., species extinction). Further, some forms of adaptation will require considerable lead time, especially where major institutional changes or innovations are required (Smithers and Smit 1997). In such cases, institutional changes would need to be devised and implemented in advance in order to offset the effects, or even take advantage of, an abrupt, expected or unexpected climate change event (Smithers and Smit 1997). It is imperative for protected areas to begin to develop climate change adaptation strategies now, considering the length of time required for ecosystems to respond to some management interventions (i.e., changing the wildfire management regime) and planning horizon of their mandate (perpetuity in theory).

Despite the obvious need to begin to develop climate change adaptation strategies, protected area agencies cannot act unilaterally to develop and implement comprehensive contingency plans for climate change, as this would necessitate a comprehensive reassessment of agency mandates, policy frameworks, and resource allocations. Leadership from senior management will be required to provide the enabling institutional environment required for climate change adaptation within protected area agencies. Parks Canada deserves credit for having begun the difficult process of adapting to climate change. Welch (2005) outlined the initiatives taken by Parks Canada, including: completing a screening impact assessment for all parks (in 2000), developing park specific climate change scenarios for future research, collaborating on eighty-six climate change related research and monitoring activities, including climate change in the *State of Protected Heritage Area 2001* report (Parks Canada 2003), and providing internal professional development publications and seminars on climate change. Some of these initiatives have been the first of their kind internationally, and these pioneering efforts have not gone unnoticed, as Hannah and Salm (2005) observe that "Canada is perhaps the most advanced in this (climate change adaptation) respect."

Discussion

Climate change and the dynamic biogeography it brings about represents an unprecedented challenge for the agencies responsible for the planning and management of Canada's protected areas, and will usher in a new era of protected area management in the twenty-first century. Over a decade ago Lopoukhine (1990) argued "…climate change is poised to alter the rate of evolution in (Parks Canada) policies and Act." More recently, 89% of conservation professionals attending a Parks Research Forum of Ontario (PRFO) workshop on climate change believed that climate change will substantially alter protected area policy over the next 20 years (Lemieux *et al.* 2005).

Difficult theoretical questions, that have significant policy implications, will need to be confronted over the next two decades. What is considered "natural vegetation" (or a natural ecosystem)? What is the role of protected areas in an era of climate change and what ecological conditions are protected areas to represent (e.g., pre-European contact, contemporary "natural region-ecoregion," some projected future state)? An interpretation of existing policy and planning frameworks in Canada suggests that protected area management plans tend to support continued protection of current ecological communities, while the definition of ecological integrity, in contrast, supports protection of the processes that would facilitate ecosystem adaptation to climate change. This ambiguity cannot persist and protected area agencies will need to develop clear climate change policies.

The capacity of Canada's protected area agencies to adapt to climate change remains a significant uncertainty. As climate change will effectively alter the "rules of the game" for protected area managers, there will inevitably be a lot of learning in the process of adapting to climate change. Protected area agencies will require new professional skills and the research and monitoring needs for adaptive management in an era of climate change will increase tremendously. Institutional coordination by protected area agencies of all levels of government (even nations) and other conservation stakeholders will also be required as never before. Although governments and the broader conservation community in Canada have made a tremendous investment in protected areas and other conservation strategies over the past century, the impacts of climate change raise important questions about the adequacy of the existing protected areas to protect a representative sample of Canadian ecosystems in the twenty-first century and beyond. The IUCN (1993) reached a similar conclusion at the fourth World Congress on National Parks and Protected Areas, stating that, "Climatic change represents a critical and urgent threat to all ecosystems … (and that) Existing … protected areas may not provide adequate future safeguards for the continued survival of existing ecosystems and species in a changing world." Consequently, existing protected area systems will need to be augmented with additional protected areas in strategic areas.

Canadians are likely to place greater demands on their protected area networks and conservation professionals to protect species and ecosystems under stress from climate change. If these agencies are to respond to the demands of Canadians, governments will need to make major new investments in protected area establishment, personnel training, research and monitoring.

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References

Bartlein, P.J., C. Whitlock and S. Shafer. 1997. Future climate in the Yellowstone National Park region and its potential impact on vegetation. Conservation Biology 11: 782–792.

Burton, I. 1996. The growth of adaptation capacity: practice and policy. *In* J.B. Smith (ed.). Adapting to Climate Change: An International Perspective. Springer. New York, NY. 475 p.

Federal Provincial Parks Council (FPPC). 2000. Working Together: Parks and Protected Areas in Canada. Federal Provincial Parks Council. 64 p.

Government of Canada. 2003. Canadian Species at Risk Act. Chpt. 29. Government of Canada. Ottawa. 97 p.

Graham, R. 1988. The role of climatic change in the design of biological reserves: the paleoecological perspective for conservation biology. Conservation Biology 2: 391–394.

Halpin, P.N. 1997. Global change and natural area protection: management responses and research directions. Ecological Applications 7: 828–843.

Hamann, A. and T. Wang. 2005. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Centre for Forest Gene Conservation, Department of Forest Sciences. University of British Columbia. 42 p.

Hannah, L., T.E. Lovejoy and S. Schneider. 2005. Biodiversity and Climate Change in Context. *In* T.E. Lovejoy and L. Hannah (eds.). Climate Change and Biodiversity. pp. 3–14. Yale University Press. New Haven.

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

Hannah, L. and R. Salm. 2005. Protected Areas Management in a Changing Climate. *In* T.E. Lovejoy and L. Hannah (eds.). Climate Change and Biodiversity. pp. 363–374. Yale University Press. New Haven.

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

Henderson, N., E. Hogg, E. Barrow and B. Dolter. 2003. Climate change impacts on the island forests of the Great Plains and the implications for nature conservation policy – summary document. Prairie Adaptation Research Collaborative. Regina, Saskatchewan. 116 p.

Hogg, E. and P. Hurdle. 1995. The aspen parkland in western Canada: a cry-climate analogue for the future boreal forest? Water, Air and Soil Pollution 82: 391–400.

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

Intergovernmental Panel on Climate Change (IPCC). 1990. Scientific assessment of climate change, IPCC Working Group 1 First Assessment Report. Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change (IPCC). 1995. Technical Summary – Climate change 1995: The science of climate change, IPCC Working Group 1 Second Assessment Report. Cambridge University Press, Cambridge, UK.

International Union for Conservation of Nature (IUCN). 2003. World Parks Congress 2003: Recommendation 5.05, Climate Change and Protected Areas. Available at: http://www.iucn.org/themes/wcpa/wpc2003/pdfs/outputs/recommendations/approved/english/html/r05.htm

Iverson L. R. and A.M. Prasad. 1998. Predicting abundance of 80 tree species following climate change in the eastern United States. Ecological Monographs 68: 465–485.

Lemieux, C.J. and D. Scott. 2005. Climate change, biodiversity conservation, and protected areas planning in Canada. The Canadian Geographer 49 (4): in press.

Lemieux, C.J., D.J. Scott and R. Davis. 2005. A preliminary analysis of potential impacts and implications for policy, planning and management. *In* C. Rehbein, J.G. Nelson, T.J. Beechey and R.J. Paine. Parks and Protected Areas Research in Ontario 2005. Proceedings of the Parks Research Forum of Ontario (PRFO) 2004 Annual General Meeting. pp. 83–104. Parks Research Forum of Ontario. Waterloo, Ontario.

Lenihan, J. and R. Neilson. 1995. Canadian vegetation sensitivity to projected climatic change at three organizational levels. Climatic Change 30: 27–56.

Lopoukhine, N. 1990. National parks, ecological integrity, and climate change. *In* G. Wall and M. Sanderson (eds.). Climatic change: implications for water and ecological resources. Department of Geography, University of Waterloo. Waterloo, Ontario. Occasional Paper No. 11: 317–328.

Lovejoy, T.E. and L. Hannah (eds.). 2005. Climate Change and Biodiversity. Yale University Press. New Haven. 418 p.

Malcolm, J., D. Puric-Mladenovic and H. Shi. 2004. A Climate Change Atlas for 134 Forest Tree Species of Ontario, Canada. Available at: http://www.forestry.utoronto.ca/treeatlas/mainpage/main_page.htm

Markham, A. 1996. Potential impacts of climate change on ecosystems: a review of implications for policymakers and conservation biologists. Climate Research 6: 179–191.

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

McNeely, J. (ed.). 1993. Parks for life: Report of the IVth World Congress on National Parks and Protected Areas. International Union for Conservation of Nature (IUCN), Gland, Switzerland.

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

Overpeck, J., J. Cole and P. Bartlein. 2005. A "Paleoperspective" on Climate Variability and Change. *In* T.E. Lovejoy and L. Hannah (eds.). Climate Change and Biodiversity. pp. 91–108. Yale University Press. New Haven.

Parks Canada. 1997. National Parks System Plan. Minister of Canadian Heritage. Ottawa, Ontario.

Parks Canada. 2003. State of Protected Heritage Areas. Parks Canada Agency. Ottawa, Ontario. 89 p.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37–42.

Peters, R. and J. Darling. 1985. The greenhouse effect and nature reserves. Bioscience 35 (11): 707–716.

Rizzo, B. and E. Wiken. 1992. Assessing the sensitivity of Canada's ecosystems to climatic change. Climatic Change 21: 37–55.

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

Schmitz, O.J., E. Post, C.E. Burns and K.M. Johnston. 2003. Ecosystem responses to global climate change: moving beyond color mapping. Bioscience 53(12): 1199–1205.

Scott, D. 2005. Global environmental change and mountain tourism. *In* S. Gossling and M. Hall (eds.). Tourism and Global Environmental Change. Routledge, London. (in press).

Scott, D.J., J. Malcolm and C.J. Lemieux. 2002. Climate change and modeled biome representation in Canada's national park system: implications for system planning and park mandates. Global Ecology and Biogeography 11(6): 475–485.

Scott, D. and R. Suffling. 2000. Climate Change and Canada's National Parks, Environment Canada. Toronto, Ontario. 183 p.
Smit, B., I. Burton, R.J.T. Klein and J. Wandel. 2000. An anatomy of adaptation to climate change and variability. Climatic Change 45: 223–251.
Smit, B., D. McNabb and J. Smithers. 1996. Agricultural adaptation to climate change. Climatic Change 33: 7–29.
Smith, J.B. 1997. Setting priorities for adaptation to climate change. Global Environmental Change 7: 251–264.
Smithers, J. and B. Smit. 1997. Human adaptation to climate variability and change. Global Environmental Change 7(2): 129–146.
Suffling, R. and D. Scott. 2002. Assessment of climate change effects on Canada's national park system. Environmental Monitoring and Assessment 74: 117–139.
Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips and S.E. Williams. 2004. Extinction risk from climate change. Nature 427: 145–148.
United Nations Convention on Biological Diversity (UNCBD). 1992. Convention on Biological Diversity. 5 June 1992.
United Nations Framework Convention on Climate Change (UNFCCC). 1997. Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). FCCC/CP/1997/L.7/Add.1. Bonn, Germany.
Welch, D. 2005. What should protected areas managers do in the face of climate change? Ecological Integrity Branch, Parks Canada Agency. Ottawa, Ontario.
Woodley, S.J. and G. Forbes. 1995. Ecosystem management: principles, problems, and practicalities. *In* T. Herman, S. Bondrup-Neilsen, J. Willison and N. Munro. (eds.) Ecosystem Monitoring and Protected Areas. pp. 50–58. Science and Management of Protected Areas Association. Nova Scotia.
World Wildlife Fund (WWF). 2003. No Place to Hide: Effects of Climate Change on Protected Areas. WWF Climate Change Program. Washington, D.C. 11 p.