A Model Process for Developing Adaptation Options for Natural Heritage Areas in an Era of Rapid Climate Change

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Introduction

Climate change is implicated in a variety of coincident impacts, including perturbations to temperature and precipitation regimes as well as an increase in extreme weather events, which in turn alter ecosystem composition, structure, and function (IPCC 2007a, 2007b; Lemmon et al. 2007; Julius and West 2008). For the practitioner, climate change presents a series of challenges to effective planning and management of natural heritage areas (NHAs): (1) it is risky to make medium-to-long-term decisions that assume a stable climate; (2) every species and ecosystem will respond to climate change in a unique way; (3) there will be new and potentially increased threats to human health and well-being; (4) every NHA organization will need to plan to manage for a range of potential impacts with a corresponding range of adaptation strategies; (5) the concept/ideal/target of sustainability will require re-evaluation; and, (6) making decisions about the protection and use of natural assets in future climates may require new, more flexible governance techniques, including increased public participation in decision-making.

Adaptation is important because climate change is already affecting NHAs (see Baron et al. 2008; Lemieux et al. 2011; Mawdsley 2011), temperature regimes will continue to rise during the 21st century and beyond (see Anderson and Bows 2008; Rogelj et al. 2009), and a proactive approach will be more effective and cost-efficient in eliminating or reducing potential for irreversible damage (e.g., loss of habitat) and enhancing opportunities for mitigative actions (Stern 2007). Accordingly, many NHA organizations will embrace an adaptive approach to management to improve their chances of meeting long-term objectives that include the perpetual protection of representative elements of natural and cultural heritage. This article explores a model process to help NHA practitioners develop and/or implement an adaptive approach to management in a rapidly changing climate.

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An adaptive management process

A fundamental question facing every organization responsible for NHAs in a rapidly changing climate is whether or not it is adaptive in its decision-making and actions. The essence of adaptation is to "*learn while doing*" (Lee 1999). As such, adaptation is characterized by actions that reduce or eliminate negative impacts and increase the likelihood and magnitude of preferred outcomes. While humans have used adaptive behavior to survive, create, and maintain civilizations for thousands of years, it was not until the 1970s that a few strategic, forward-thinking scientists (e.g., Walters and Hilborn 1976; Holling 1978; see also Hilborn 1992; Walters 1997) formally advocated and described the use of experimentation to improve analyses of policy options and decision-making in a rapidly industrializing world (in which the allocation of natural assets had significant implications for survival and quality of life). Subsequently, and in recognition of the fact that humans cannot predict the future and always will need to respond to surprises and unforeseen events, a sizeable literature about learning-oriented decision-making techniques—ranging from reactive decision-making, to iterative decision-making , to decision-making on the basis of active experiments and comparative analyses—was created (e.g., Smit et al. 1999, 2000; Burton et al. 2002; Smit and Pilifosova 2003; Adger et al. 2005; Smit and Wandel 2006; Burton 2008).

Given the magnitude of ongoing social, cultural, economic, and ecological change, no single decision-making tool, technique, or system will equip practitioners to address all of the emerging threats to ecosystem function and human health and well-being. In fact, given the variety of uncertainties and cumulative impacts associated with climate change, a truly adaptive organization will ensure it has access to all available learning-oriented decision-making tools and techniques. While there is widespread agreement that preparing for and responding to climate change is necessary and includes the development and integration of risk management strategies into current and new programs, climate-sensitive, adaptive decision-making processes are only now being designed and tested by NHA organizations (see Lemieux and Scott 2011 and Weeks et al. 2011 for examples). The framework described in this paper represents one model that NHA organizations can use to strategically design and plan their way forward (Figure 1).

Step 1: Determine and establish organizational readiness to adapt

Organizational readiness is a unique combination of institutional structure and function, financial resources, knowledge, practical experience, and adaptive decision-making with which practitioners can manage for climate change. An organization can determine its readiness for adaptation by evaluating how it is positioned to deliver integrated place/time-based, community-empowered, and knowledge-driven programs (Gray et al. in preparation; Figure 2).

Figure 3 is a framework to help organizations evaluate their readiness to adaptively manage for climate change. The three categories and 10 themes are not mutually exclusive, and where possible, it is recommended that they be explored and evaluated in concert with each other. For example, an organization could develop questions and complete a "readiness assessment" tailored to meet its particular circumstances. Answering these types of questions could provide NHA practitioners with a sense and understanding of the strengths/capabilities and weaknesses/gaps requiring attention (Table 1).

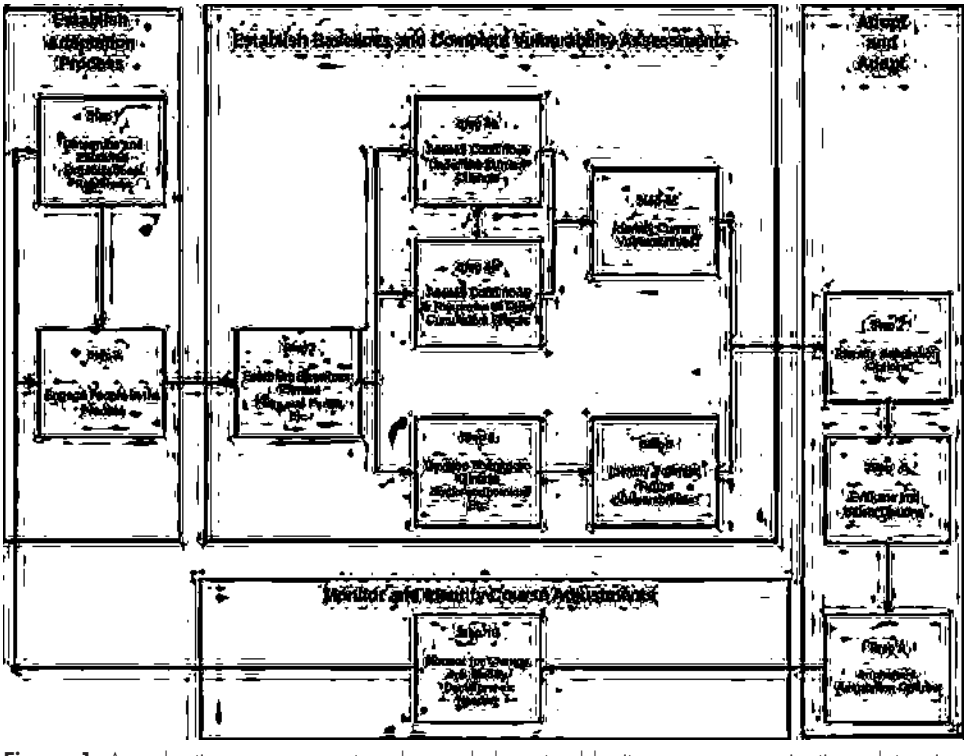


Figure 1. An adaptive management cycle can help natural heritage area organizations determine their readiness to adapt, engage people, complete vulnerability analyses, and develop, implement, monitor, and adjust adaptation options as required.

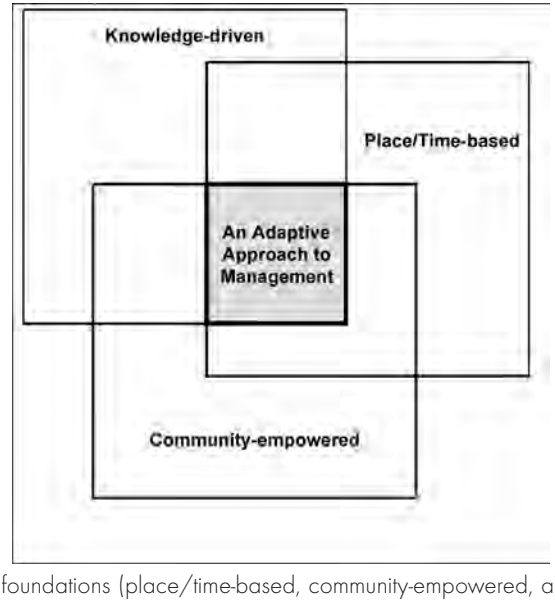


Figure 2. The three foundations (place/time-based, community-empowered, and knowledge-driven) of organizational readiness to respond to climate change (from Gray et al. in preparation).

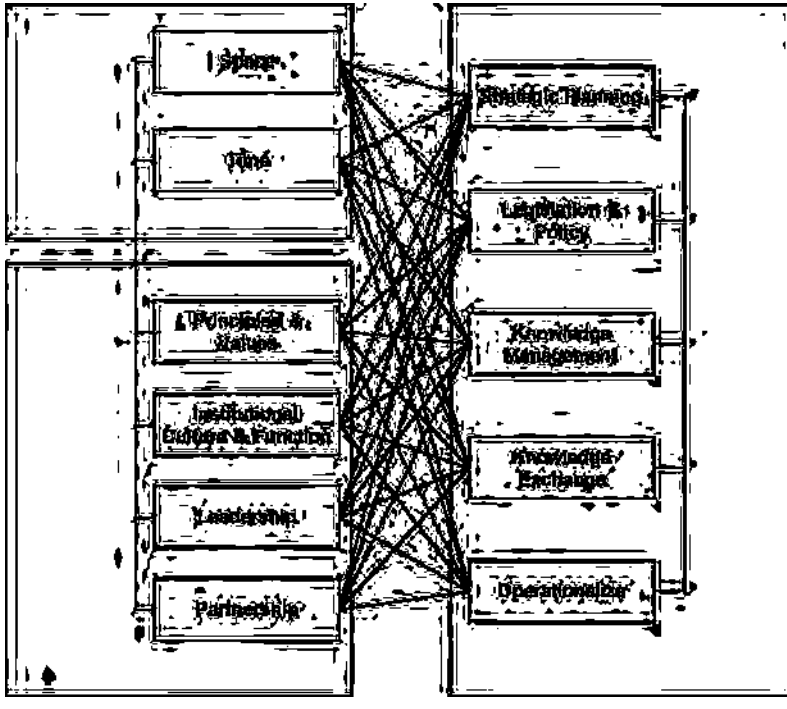


Figure 3. A framework to help organizations assess their readiness to manage for climate change (Modified from Gray and Davidson 2000 and Environment Canada 2000).

Category #1: Place/time-based (contextual scales).

- Theme 1: Describe ecosystems and other types of planning areas such as park boundaries in space and time.

Category #2: Community-based (enable a coordinated societal response).

- Theme 2: Use appropriate principles, establish and maintain trusting relationships, engage people, and account for natural asset values.
- Theme 3: Ensure institutional culture and function can foster an adaptive approach to decision-making.
- Theme 4: Promote informed leadership.
- Theme 5: Create and support the partnerships needed for decision-making.

Category #3: Knowledge-driven (implement the best mix of tools, techniques, and systems planning).

- Theme 6: Embrace an ecologically oriented approach to adaptive management by thinking and planning strategically for the long-term.
- Theme 7: Implement "climate-ready" policy, legislation, and regulation that contribute to the attainment of NHA area management objectives.

- Theme 8: Gather knowledge through research, inventory, monitoring, and assessment to support strategic decisions that reduce the impacts of surprises.
- Theme 9: Communicate and share knowledge through education and extension.
- Theme 10: Operationalize adaptation, including development of new science and information technology to enhance delivery of an adaptive approach to management.

Step 2: Engage people

NHA management benefits from the active engagement of people with a range of values and interests who can work together in trusting relationships based on the principles of sustainable living (Sparkes 2004), including adaptive decision-making. If society trusts in the abili-

Table 1. A sample of questions that natural heritage area (NHA) practitioners can use to assess organizational readiness to adapt to climate change.

Theme	Question
Mandate	What key issues will be addressed by your organization through application of an adaptive approach to management?
Spatial Factors	What scale(s) of ecosystem mapping and monitoring are available and how do mapping and monitoring programs support adaptive management in NHAs?
Temporal Factors	What time frames (e.g., frequency and duration of measurement) are needed to monitor the known and potential impacts of climate change on ecosystem composition, structure, and function in and adjacent to NHAs?
Principles	How do the principles used by your organization support its commitment to adaptive management in NHAs?
Engagement, Trust and Participation	How does your organization inspire and build trust in the community?
Values	How does your organization support research to determine how the known and potential climate change conditions impact the distribution and abundance of ecological goods and services, and associated cultural, social, and economic conditions?
Institutional Culture and Function	How is your organization structured to work collaboratively with other organizations to manage for climate change in small to large ecosystems?
Leadership	Does your organization support an internal process that provides staff an opportunity to understand critical issues like climate change, and, based on this understanding, support efforts to manage for uncertainty in the best interests of the public?
Partnership	How does your organization work to optimize involvement by clients and partners in decision-making (from conception to completion)?
Strategic Planning	How does your organization's strategic plan support ecologically meaningful management in a rapidly changing climate?
Legislation and Policy	What are the underlying values of nature on which NHA policy and legislation is based, and how will these values change in response to climate change?
Knowledge and Information Management	How does your organization's knowledge management system support climate-related data and information for use in adaptive management?
Knowledge Exchange	How do the communication tools and techniques used by your organization address adaptive management in a rapidly changing climate?
Operationalize	How does your organization establish and measure targets for sustainability, and are they relevant in a rapidly changing climate?

ty of NHA organizations to engage citizens on an ongoing basis and in the cultural and scientific knowledge used to inform decisions, then the chances of successfully implementing truly adaptive decision-making are improved. A "climate-ready" constituency is characterized by clients who are capable of participating in a variety of planning and management programs, and who are comfortable with the processes created to monitor and to adjust decisions as required. Participation can range from informal and easily organized information and feedback sessions to sophisticated co-management agreements.

Step 3: Establish baselines for selected natural assets

To detect and manage for change, an organization must establish a starting point (baseline) in-time-in-space and describe the status or condition of the NHAs using ecological, cultural, social, and economic indicators (e.g., Stoddard et al. 2006). For example, past and current fire frequency and intensity patterns could be used to detect change and re-evaluate fire management strategies. Or, user demand for access to NHAs could change as a result of longer summers and extended shoulder seasons. For example, Scott et al. (2005) used the following climatic thresholds for climate change impact indicators: the number of days with 15 cm of snow as an indicator of Nordic ski conditions and the number of days warmer than or equal to 23°C as an indicator of recreational swimming opportunities.

Step 4: Assess current vulnerability to climate change

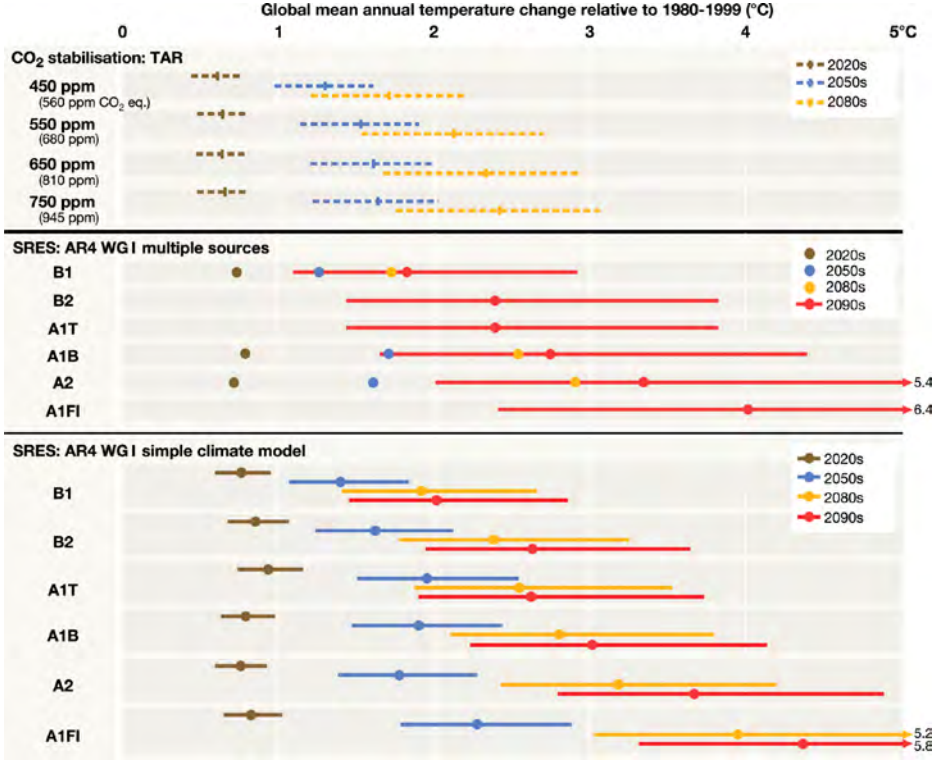
Vulnerability is a statement about the degree to which a natural or social system is susceptible and unable to cope with the effects of climate change (IPCC 2007a). The metric can be qualitatively or quantitatively based on "exposure" (e.g., the nature and extent of climate change), the "sensitivity" (i.e., the degree to which a species or an ecosystem will be affected by change), and adaptive capacity or the ability to cope with change (Glick et al. 2011). Ecological adaptive capacity can be described with parameters such as behavioral plasticity, species physiological tolerance levels, and species dispersal capabilities. Human adaptive capacity can be characterized as the ability of a social organization or an individual to cope with the change through decision-making and the application of tools and techniques. In the absence of quantifiable scientific studies, expert opinion can be used to rank exposure and sensitivity to climate change. For example, sensitivity and adaptive capacity can be evaluated, ranked (e.g., high, medium, and low), and described graphically to complement the decision-making process (e.g., Alberta Sustainable Resource Development 2010).

Scott et al. (2005) examined historical patterns of climate change in Canada's National Capital Region (in and adjacent to Ottawa). They reported that since the 1940s climate change had been significant enough for the National Capital Commission to adapt winter and summer programs to the new realities of a warmer climate (e.g., winters are now 1.5°C warmer than in the 1940s). For example, the timing of Ottawa's annual winter festival, "Winterlude," was changed from a consecutive 10-day period to a three-weekend event to increase the probability of suitable weather during some part of the event. In addition, many attractions were moved from ice to land locations, refrigerated trucks were provided for the ice sculpture contest, and organizers collaborated with local museums to provide non-climate-dependent activities.

Step 5: Develop scenarios to project climate change

Planning and management responses to global warming require an understanding of how our climate may change. Models project an increase in air temperature, but given the uncertainty of human behavior and associated greenhouse gas (GHG) emission rates and volumes, we do not know by how much. This is an important issue because it creates uncertainty about how to plan for the future. For example, if countries elect to increase reliance on fossil fuels, GHG emissions will increase faster than if the countries collectively elect to reduce their use of fossil fuels, introduce more renewable energy into the mix, and integrate energy conservation measures into their economies. Accordingly, climate models and emission scenarios based on different types of human behavior are a useful tool to engage people in strategic discussions (e.g., "what if" questions) and decisions about potential future climates, associated vulnerabilities, vision-based targets, and adaptive responses (Figure 4). Generally, experts recommend that organizations use a range of climate models and scenarios of human behavior to create mental pictures of the potential conditions that may require adaptive responses.

Figure 4. Global mean temperature change (oC) associated with examples of SRES scenarios (Special Report on Emissions Scenarios by Nakicenovic et al. 2000) describing the impacts of different types of human behavior through the 21st century. Source: IPCC 2007b, 66.



Step 6: Assess vulnerability of natural and socio-economic assets to climate change

As in Step 4, the vulnerabilities of selected natural and cultural assets to climate change are assessed. In this case, however, projections of future climates are used to provide a basis for thought experiments during which participants ask all sorts of "what if" questions about how the condition and status of natural and cultural assets could be affected by different climatic conditions. For example, what will happen to water levels in a park's wetlands if the average annual temperature increases by 2°C, evapotranspiration increases by 15%, and average annual precipitation decreases by 10% by 2090? Exploring the potential future vulnerability of ecosystem composition, structure, and function to climate change is an integral part of the adaptive process. From a natural systems perspective, the future may unfold linearly as a continuation of past and ongoing change, such as increasing average annual temperatures, or non-linearly in the form of abrupt change resulting from an extreme weather event or the breach of an ecological threshold that causes an ecosystem to radically change or "flip" from one type of system to another (e.g., from a forest underlain with permafrost to a wetland).

Climate change has important implications for nature-based recreation as well because visitor use is strongly correlated to climate and the types of activities that are available. Climate influences the physical resources (e.g., water levels, snow cover, and wildlife species) that provide the foundation for outdoor recreation (e.g., boating, Nordic skiing, birdwatching), defines when specific activities can take place (e.g., beach use and swimming), and influences the level of visitor satisfaction (Jones and Scott 2006a, 2006b). Often, potential vulnerability is explored by assessing how a changed climate will impact natural and social indicators. For example, Scott et al. (2005) used indicators to assess change in the thermal comfort of park visitors and optimal temperatures for Nordic skiing conditions.

Step 7: Identify adaptation options

Given the increase in air temperature that has occurred in the last 100 years, an increase of another 1°C or more has significant implications for the composition and patterns of natural and cultural assets in NHAs. Installing or enhancing adaptive capacity to respond to this change, therefore, will be important to NHA managers. Likely, successful adaptive responses will involve combinations of new and existing adaptation techniques aimed at reducing or eliminating vulnerability and/or enhancing opportunities that may result from climate change. For example, NHA networks that include core areas, connecting linkages, and buffers provide a hedge against uncertainty by increasing ecosystem resilience. Moreover, NHA practitioners who acquire expertise in ecosystem rehabilitation techniques that will be useful as new climates emerge will likely be more successful.

Many techniques are available to identify and to evaluate adaptation options, including: scenario planning (Peterson et al. 2003), emerging issues analysis, multi-criteria analysis, and, idea-generating procedures using workshops, focus groups, and policy Delphi surveys (see Linstone and Turoff 2002 and Donohoe and Needham 2009 for reviews). Each technique has strengths and weaknesses depending on the required outcome, location, available resources, and clients involved in the process. For example, the US National Park Service (NPS) Climate Change Response Program is exploring scenario planning as a tool for park

planning and management in an era of uncertainty (NPS 2010). The objective of scenario planning is to develop and test decisions under a variety of plausible futures. Since 2008, NPS has sponsored several training workshops to educate staff and partners on the utility of climate change scenario planning in support of adaptive management (see Weeks et al. 2011).

In a similar exercise, Lemieux et al. (2008) and Lemieux and Scott (2011) used a three-round policy Delphi survey to identify and evaluate climate change adaptation options available to a Canadian NHA agency, Ontario Parks. A policy Delphi is an iterative group-oriented idea-generating procedure used to identify the strongest possible opposing views on the potential resolutions of a policy issue (de Loë 1995; de Loë and Wojtanowski 2001; Donohoe and Needham 2009). The approach permits a diverse group of experts to interact anonymously on a subject or issue and provides a structured method for assembling ideas and recommendations. By design, participants are provided the freedom to present and challenge alternative viewpoints and to think reflectively and independently between iterations. On the other hand, the electronic version of the approach requires access to computers and the Internet, some computer expertise, and a commitment by respondents to spend a few hours of time responding to the questions.

In Round 1, questionnaires were electronically sent to experts to identify adaptation options in response to questions, while Rounds 2 and 3 (see Step 8, below) were used to evaluate the institutional feasibility of options. Lemieux et al. (2010, 2011) and Lemieux and Scott (2011) prepared a portfolio of adaptation options in response to a suite of seven questions about the role of NHAs in adapting to the impacts of climate change (Table 2).

To effectively respond to the challenges of climate change, NHA managers will assemble and assess adaptation options from a variety of sources, including literature reviews, on-site user surveys, scenario planning, workshop proceedings, and policy Delphi surveys. Currently, a number of portfolios with adaptation options are available to NHA practitioners (e.g., Scott and Lemieux 2005; Welch 2005; Julius and West 2008; Heller and Zavaleta 2008; Lemieux et al. 2011; Baron et al. 2009; West et al. 2009; Lemieux and Scott 2011; Mawdsley 2011) that can be used in support of new or ongoing adaptive management programs.

Step 8: Evaluate and select adaptation options

Adaptation options can range from broad strategies such as a commitment to an ecosystem approach to management at the landscape level of planning to site specific strategies that include engineering solutions for specific features or functions such as wetland rehabilitation or stormwater management. It is anticipated that adaptation options will collectively reduce threats across the spectrum of large to small ecosystems in and outside of NHAs by enhancing ecosystem resilience and the adaptive capacity of human decision-making processes, and providing new adaptive techniques. More often than not, the list of potential adaptation options will be larger than it should be, and some streamlining (and associated trade-offs) will be required to meet the specific realities faced by NHA practitioners. There are many techniques available to help NHA practitioners isolate the most important and relevant adaptation options, including expert judgement, cost–benefit analyses, and cost-effectiveness

Question	Response
What are the roles of protected areas in an era of climate change?	Continue to meet the conservation imperative because many NHAs encompass relatively undisturbed ecosystems, or parts of ecosystems, that contribute to the health of airscapes, landscapes, and waterscapes and the people who depend on them.
Should ecological representation remain a key objective for protected areas establishment?	Representation should remain an important objective because physiographically based representation schemes (e.g., topography and landforms) can provide a relatively stable spatial context in which ecosystems and species will respond to changing climatic conditions.
Is there a standard suite of guidelines for protected areas design in an era of rapid climate change that can be used to maintain or enhance resiliency? (In other words, a resilient ecosystem can absorb climate-induced stress, re-organize while undergoing change, and retain the same or similar function in a rapidly changing climate.)	No, each jurisdiction is unique. Generally, however, organizations can design for complexity (protected areas and networks that encompass a range of biophysical characteristics are likely to be more resilient), redundancy (replication), multiple scales (protect small-to-large areas directly and indirectly under the auspices of a "greater ecosystem approach"), and encourage innovation, which could potentially include assisted migration.
What types of management direction and programs are required for protected areas in a rapidly changing climate?	• Recalibrate management objectives and develop alternative governance regimes that could include implementation of an adaptive management process, develop plans for "clusters" of natural heritage areas, and introduce innovative governance techniques such as co-management arrangements. • Use rehabilitation to reconnect fragmented landscapes and waterscapes, increase carbon storage capacity, and implement assisted migration if it is selected as a management option. • Help the public connect with their natural heritage. • Promote NHAs as providers of ecological goods and services that contribute to ecosystem health and the well-being of people. • Institutionalize an adaptive approach to management that includes recognition of the dynamic nature of ecosystem boundaries and biodiversity. • Establish transboundary partnerships designed to meet regional to local socioeconomic needs, maintain or rehabilitate ecosystem integrity, and conserve biodiversity. • Integrate natural heritage area networks into regional land-use planning.
What research, monitoring, and reporting capabilities are needed to manage for climate change?	• Use NHAs as sources of knowledge for decision-making because applied science and research can improve understanding of the response of ecosystems to climate change. • Use natural heritage areas as benchmarks of change because relatively undisturbed protected area landscapes and waterscapes make them a valuable resource for climate change monitoring. • Use adaptive management that favors learning about ecological and social dynamics.

Table 2. Examples of climate change issues in Canadian natural heritage areas (NHAs) and selected adaptive responses (modified from Lemieux et al. 2010, 2011).

analyses (Lim and Spanger-Siegfried 2005). Selection criteria can include priority (e.g., along a continuum of very important to little importance), affordability, ease of implementation, and/or certainty of the adaptation option (e.g., highly certain to highly uncertain vulnerability) (e.g., Lemieux et al. 2008; Lemieux and Scott 2011).

Step 9: Implement adaptation options

Mainstreaming climate change into decision-making can be accomplished by ensuring an organization's commitment to address the issue is acknowledged and applied in strategic, management, and operational plans. For example, NPS, Parks Canada, and Ontario Parks staff have integrated climate change extension and education programs into park interpretative programs (see Lemieux et al. 2010; Bruff 2011), greened fleets and infrastructure, and in some cases embraced the "greater ecosystem approach" to management, which is particularly useful for establishing and maintaining "blueway" and "greenway" corridors across large landscapes and waterscapes.

In addition, an organization can create an implementation plan to guide practitioners in their efforts to systematically address questions related to mandate, internal/external support and responsibilities, access to financial and human resources, communications requirements, and ongoing participation (see ICLEI 2010; NPS 2010). Some of the questions created and answered in Step 1 will inform the climate change implementation plan as well.

Step 10: Monitor for change and adapt as needed

The climate change issue is confounded by significant uncertainty resulting from the type, timing, rate, and magnitude of ecological and social impacts (White 2004; Yohe et al. 2004), particularly when impacts are abrupt and non-linear (Lew 2010). NHA organizations improve their chances of successfully planning and managing their way forward if they support robust long-term, ongoing monitoring programs (and learn from case studies) that help staff to detect change and assess the success of decisions and related actions to respond to climate change impacts. Such analysis will, for example, help practitioners determine if an adaptive action has reduced or eliminated the vulnerability of an important natural or social asset to climate change. If the adaptation action is not working then managers are in a rational position to adjust the management regime.

Conclusion

Adaptive management is the convergence of a commitment to *"learn while doing"* (Lee 1999) leading to the maintenance of the long-term health of ecosystems in and adjacent to NHAs. While many current NHA management practices contribute to ecosystem resilience, decisions to protect existing NHAs and create new ones in a rapidly changing climate will also require adaptive and innovative approaches that draw upon evolving science; new information technologies, management tools and techniques; as well as an ongoing commitment by practitioners and their clients.

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