What tomorrow? What parks? Climate change, its impact on ecosystems, cultural resources and visitor use, and how protected area management should adapt.

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Abstract
Parks, historic sites and marine conservation areas are major assets for our quality of life, ecosystem services and tourism. Climate change will impact many of these assets directly. Much is known about melting ice, pending drought, biological responses, altered seasonality and visitor activities, but early impacts will more likely come more from extreme events, invasive species and new pathogens. Since we cannot predict the specifics of ecological responses we must manage them to foster auto-adaptation through natural resilience. Ecosystems should be nested within regions that are permeable for the movement of native species and that contain sufficient habitat for the self-perpetuation of their populations. Marine ecosystem management must focus on conservation, sustainable harvesting and pollution control. For both terrestrial and marine protected areas, natural resilience will best be achieved by redoubled efforts to remove local and regional threats to ecological integrity. Regarding historic or archaeological sites, little is known of the likely impacts, so risk assessments must be completed and plans developed to ensure their commemorative integrity. For both natural and cultural sites, the local stress abatement approach depends on knowledgeable and involved communities. Therefore public education and engagement are vital components to climate change adaptation.

Keywords: climate change, adaptation, resilience, ecosystems, cultural sites.

CLIMATE CHANGE IMPACTS ON PROTECTED PLACES

In recent decades climate is evolving at a rate unprecedented in geological time, attributed to greenhouse gases (GHG), primarily carbon dioxide (CO_2) emitted by fossil fuel burning. CO_2 lags in the atmosphere for decades to centuries, so warming will continue at least for decades and may exceed the temperatures of glacial and interglacial times. This will bring both challenges and opportunities to protected area managers, since ecosystems, cultural resources and visitor experiences will change in response to the impacts of climate change directly, of adaptive responses, and of policies to reduce fossil fuel use in transportation.

Terrestrial and freshwater protected areas will experience the same impacts as their unprotected surroundings, such as increasing droughts and heat waves, falling water levels, and more frequent weather extremes (Parks Canada 2003a, p.30-31; Scott 2003). Existing signs of climate change include permafrost and glacier melting, reduced snow seasons, and increased frequency of debris flows, avalanches, forest fires and insect outbreaks. In the future, vegetation patterns and wildlife ranges will be pushed further north or to higher elevations. New associations and ecosystems will emerge as plants and animal ranges shift differentially. The greatest warming will be in the Arctic, putting large areas of permafrost at risk. In mountain regions, vegetation zones will migrate upwards, and alpine communities that have nowhere higher to go may disappear. Declining water levels and increasing water temperatures will reduce freshwater fish populations. When national park locations are superimposed on these models, we see that over half the national parks of Canada could experience changes whereby boreal forest gives way to grassland, or tundra to subarctic forest.

Changes in weather systems will impact ocean currents, in turn affecting mixing and productivity. Other impacts will include increases in sea level, sea temperature, ultra violet radiation and ocean acidification. Turbidity will increase as precipitation acts through run-off and nutrient loading. The timing of food

availability will change as will life stage transitions, migrations, changes in ecosystem productivity and structure. Warming has already reduced Arctic ice pack area and thickness, adversely affecting species such as polar bears, ringed seals and arctic foxes that depend on sea ice and snow conditions for food, shelter and camouflage. The reduction of near shore pack ice will increase wave action on Arctic coasts, thereby increasing damage or destruction of cultural resources such as shallow water shipwrecks and aboriginal encampment sites near normal high water levels.

New soil climates will alter the balance between archaeological and historical values such as structures, features, stratigraphy and artefacts, and hydrological, chemical and biological processes in the soils and materials. This is of particular concern for sensitive materials such as wood. Pest infestations in areas not previously affected will weaken, and may eventually consume, organic materials such as the timber of historic buildings. In common with lakes and rivers, heritage canals will experience a greater frequency of floods and drought, curtailing navigation periods regardless of average flow.

Climate influences tourism directly through the length and quality of the travel and recreation seasons, the nature of visitor demand and participation, and satisfaction with the experience. People give meaning to landscapes and create connections with them. As charismatic native species and iconic cultural sites change or disappear, Canadians may lose their attachment to protected areas. Cold and wet or extremely hot days may reduce possibilities for hiking and enjoyment of nature. Increased water level variability and lower water quality will curtail recreational swimming, canoeing, rafting and kayaking. Marinas and boat ramps may need re-engineering and navigation channels more dredging. The length and reliability of downhill and cross-country skiing seasons will reduce as winter rains increase at the expense of snow. Longer and more intense dry spells will require more campfire bans and limit potable water supplies. Coastal storms may damage popular facilities like board walks and dunes. The spread of West Nile Virus and Lyme disease has already raised health and safety concerns at Point Pelee and Saint Lawrence Islands National Parks.

Along with threats come opportunities. Warmer Springs and Falls in some areas will extend shoulder seasons and visitation. Increasing opportunities for hiking, cycling, kayaking and canoeing will increase demands for recreational and learning experiences. More urban Canadians and international visitors may wish to escape city heat and pollution.

While there is a high level of certainty about climate trends, the degree of change through the 21st Century and beyond depends on how global society, energy use and emissions evolve. Also, there is great uncertainty as to how vegetation, wildlife niches and ecoregions will evolve with climate, sea level, hydrology and cryology.

In short, it is hard to describe what our present parks will contain, represent and present within our lifetimes.

CHALLENGES FOR PARK MANAGEMENT

There are fewer options to adapt to climate change in protected areas than in areas that can be actively manipulated. For example, a park's dedication to represent a natural region's biodiversity curtails options for carbon sequestration. On the contrary, restoration of natural fire regimes may, over decades, increase emissions. Or, the process of establishing a park in a democratic state with respect for property rights is not a simple one, and can take decades. Therefore it is not feasible to relocate parks in pursuit of migrating biomes, even without fixed resources such as archaeological sites or famous views.

Custodians must therefore seek ways to adapt management practices *in situ* to maintain biodiversity and

natural processes, to assist nature through her inevitable transitions, to participate in communications and house-in-order programmes, and to ensure the protection of historic places and artefacts. Benefits will accrue from removing or halting maladaptive policies, practices and stresses that increase vulnerability.

Parks do more than protect species. They contain historic sites, iconic vistas, and outstanding landforms and earth processes. They provide opportunities for recreation and environmental appreciation. Park managers must balance those aspects when considering action in the face of climate change. In Canada, for example, northern historic sites are subject to instability as permafrost melts. Coastal historic and archaeological sites are threatened by flooding and shore erosion. Opportunities for snow-based recreation are declining, but overall visitation levels will increase as an aging population takes advantage of warmer shoulder seasons. Public safety threats will increase with respect to, among others, heatwaves, storm hazards for small craft, thinning nearshore ice, and the northward spread of pathogens such as Lyme disease and West Nile Virus, both recent arrivals in Canada.

Most parks are operated by public agencies and are subject to many acts, policies and priorities. At the same time, parks are the primary place where governments meet their citizens on a friendly basis. These factors bring a public duty and leadership role to park agencies. Therefore as well as resource protection, managers must consider public education and engagement in GHG emission reduction.

Climate change is big news, big policy and big business, yet the reality for parks is that other stresses may be more important in some situations. Habitat loss and fragmentation threaten the viability of wide-ranging species. Invasive alien species out-compete, displace or kill native species. Acid aerosols and organochlorines are carried through airsheds, down waterways, across continents and over oceans, and threaten the life and reproductive health of many species. Human activities, even without habitat loss, disturb wildlife activities. The silver lining is that many of these stresses are local, regional and national in scope, so it is feasible to mitigate their causes, not just offset their effects.

The literature provides strong reasons for having parks and reserves, why there should be more of them, why they should be accorded enhanced protection, and how they might be selected. For example, the recommendations of Hannah *et al*. (2002) and Hansen *et al*. (2003) include:

- Locate parks with climate change in mind;
- Avoid fragmentation - provide connectivity and maintain buffer zones;
- Represent vegetation types and diverse gene pools across environmental gradients;
- Determine the necessity to transplant species and control rapidly increasing species;
- Involve local communities for management of biodiversity;
- Strengthen research capacity; and
- Monitoring the link between climate change and biodiversity.

PRINCIPLES FOR ADAPTATION

I propose the following core principles for a protected area climate change strategy.

House in order and public communications

A park agency can foster mitigation by putting its own emissions house in order, and can use its outreach and presentation activities to demonstrate leadership. Visitors are generally ready to absorb credible information and sound arguments. Citizen actions in response to interpretation, education and outreach can far exceed in-house emission reductions, but credibility depends on such reductions.

Resilience and partnerships

Environments have a degree of resilience and in some cases can accommodate climate change by species migration or *in situ* adaptation. However, there are many other stresses impinging on ecological integrity, so I recommend a risk management approach whereby tractable stresses are reduced or eliminated. Since most such stresses emanate from the region surrounding a park, this can only happen through stakeholder collaboration.

Focus on mandate

Protected area mandates increasingly emphasize ecological and commemorative integrity, outweighing tourism development, infrastructure and regional economic development. This assertive mission leads to more action on the ground and accountability, but less capacity to stray into related activities, such as primary research or public communication. Nevertheless, park agencies should cooperate when possible programmes related to climate change research, mitigation and communication.

Ecosystem services accrue from the maintenance and restoration of ecological integrity, but parks should not be manipulated deliberately for such things as flood protection, water supply or carbon sequestration. This would counter their mandate and open the door to the commercialization of natural resources.

Keep parks where they are

The parks we have are often all that remain as natural havens. The very presence of a well-distributed system of protected areas is one of society's best adaptations to climate change. The notion of relocating parks must be rejected for four reasons. First, it opens the door to move a park, e.g. to open land for the extraction of minerals or fibre. Second, park establishment is a lengthy process with no guarantee of success. Third, few natural areas remain for new park establishment within regions that already have park representation. Four, vegetation models can assess the potential range of individual species based on present climate niches, but cannot predict new associations and habitats.

THE VISION

The resilient matrix

We will never know enough, nor have enough resources, to micromanage natural ecosystems to coax them into balance with a continually and rapidly changing climate. The best we can achieve is to foster the presence of large regions with enough habitat and connectivity for the movement of native species. This means not just establishing and maintaining wildlife corridors but reducing impediments to natural movement across all lands. Examples include maintaining hedgerows and woodlots in agricultural areas, eliminating the cosmetic use of pesticides, reducing light pollution, installing wildlife crossings on major highways, reintroducing wildfire in boreal and montane forests and large grazing animals to grasslands, and, perhaps hardest of all, controlling invasive and alien species.

With this in mind, the management of terrestrial and freshwater ecosystems should focus on the restoration and maintenance of ecosystems, natural processes, and biotic and abiotic diversity. The desired outcome should be regional ecosystems free from local or regional threats to ecological integrity, cultural resources, human health, visitor enjoyment and appreciation. Protected areas would then be nested within regions that are permeable for the movement of native species and habitats and that contain sufficient habitat for the self-perpetuation of native wildlife populations. Fast and slow migrant species should be managed to permit orderly ecological transitions that favour the maintenance of high native biodiversity and the control of alien species.

Marine ecosystems may be connected and permeable in the sense described above, but their management should focus on the conservation of biotic resources and sustainable resource use, also freed from significant local and regional threats to wild populations and human health. The migratory and life-cycle ranges, both oceanic and riverine, of native species populations should be protected from threats to their self-perpetuation. Alien invasive species should be managed to minimize their presence.

Cultural resources and commemorative integrity

Protected area managers are concerned not only with ecology but also geology and cultural resources. However, climate change science has tended to focus on the natural world and its impacts on nature and society. The study of impacts on historic and archeological resources lags behind, a situation now recognized by UNESCO's World Heritage Committee. "Ancient buildings were designed for a specific local climate. The migration of pests can have adverse impacts on the conservation of built heritage. Increasing sea level and storm activity threaten many coastal sites. And the conditions for conservation of archaeological evidence may be degraded in the context of increasing soil temperature. But aside from these physical threats, climate change will impact on social and cultural aspects, with communities changing the way they live, work, worship and socialize in buildings, sites and landscapes, possibly migrating and abandoning their built heritage" (Colette 2007, p.10).

Protected area managers should conduct risk assessments of archeological and historic sites and other cultural resources under their stewardship. In some cases, no impact or risk will be revealed. In others, adaptation plans will be needed to offset certain impacts. In yet others, the impact may be so severe that rescue plans will be needed. One option is relocation, as has been done for the historic buildings at the Pauline Cove Whaling Station on Herschel Island, Yukon. Other options include documentation to establish a virtual record of a site, and the rescue of selected items for conservation in museums and visitor centres.

Conservation agencies worldwide are coming to recognize traditional cultural activities as an integral part of a protected ecosystem. These activities are seen not only as valued cultural resources in their own right, and part of the human condition, but in many cases as among the processes governing landscape evolution and wildlife condition. The challenge for protected area managers will be to work with local communities as they seek their own adaptations to climate change, and at the same time maintain a balance with ecological and commemorative integrity.

Visitor experience and public engagement

Regional adaptations and national policies depend on public support. The more that people are aware of the ways to address climate change, the easier it will be to catalyse policies and actions. Protected area custodians generally have a well-regarded public image, and they can lever this asset to promote and lobby for climate change mitigation and adaptation, both institutional and private. Parks should strive to demonstrate the values of biodiversity at the local level, and demonstrate to visitors the impacts of biodiversity loss, of invasive species and of the many other impacts. These demonstrations can take place during interpretive talks and walks, in visitor centres and in virtual visits via park web sites. Citizens should become aware of how to assist in the mitigation of climate change at home, at work and during their visits to parks, and of the role that they can play in spreading the word to family and friends. Regional stakeholders such as conservation authorities, resource industries, communities and individual land holders should be encouraged to consider climate change resilience and adaptation strategies in their land management practices.

ACTIONS TO GET THERE

Several lines of action are required to move parks towards the vision of resilience (Welch 2005).

Information, awareness and engagement

- Research, modelling and vulnerability assessments of valued heritage components and whole parks and sites.
- Communication of science results in ways useful to senior managers, ecosystem managers, outreach and education specialists
- Public outreach and education to foster citizen engagement in solutions.

Guidance and planning

- Incorporate climate change considerations in management tools like management planning guidelines, activity and investment plans.
- Consider climate change when developing park system plans and park establishment options.

Actions on the ground

- Mitigate other stresses within parks, and work with stakeholders to do likewise in greater ecosystems, watersheds and airsheds.
- Adapt park boundaries and purposes in consideration of vulnerable species and habitats.
- Monitor and report indicators of climate change impacts and resilience.
- Protect or rescue valued cultural resources.

CONCLUSIONS

A completed network of protected areas free of other stresses is one of society's and nature's best mechanisms to adapt to climate change. Park agencies can engage visitors and the general public, but this in turn requires well researched and monitored impact indicators as the basis for adaptive ecosystem management, accountability and reporting systems. House-in-order programmes complement the messages that governments should send to their people. Research on the synergy between climate change and other processes can provide the knowledge to guide the mitigation of local and regional stresses, thereby restoring and maintaining the natural resilience of ecosystems and wild species.

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