Multi-scale Challenges to Efficient and Effective Adaptation to Climate Change in North American Protected Areas Agencies

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Abstract

Despite the repeated calls for the mainstreaming of climate change into biodiversity conservation and protected areas policy, planning, management strategies by the international conservation community for over twenty years, there continues to be a relatively slow response by practitioners both in terms of the development and implementation of relevant policy and management strategies. The academic social science literature on the subject has been biased toward depicting adaptation to climate change as a rational decision-making process, with constraints being primarily access to financial resources and human capital. Rarely examined have been the multi-scale social-ecological factors that also influence choice and behavior from an integrated social science perspective. This qualitative exploration examines three selected but fundamental multi-scale challenges to effective and efficient adaptation to climate change in North American protected areas agencies: (1) protected areas system planning and the "problem of fit"; (2) climatic, ecological, and political "temporal mismatches"; and, (3) climatic and socio-ecological uncertainty and complexity through a transdisciplinary lens. While individually problematic, the interaction of these multi-scale social-ecological challenges make adaptation to climate change extremely difficult despite existing knowledge of mitigating measures and, consequently, asphyxiate the adaptive capacity of protected areas agencies. It is argued that a lack of interconnected and multi-scale conservation planning priorities both within and between nations will compromise conservation objectives and may result in unintended negative effects. The ability to better understand and effectively adapt to climate change will require a more integrated approach within government, among sectors, between a complex overlay of ecological and jurisdictional scales, from the international to the local, and from multiple social science perspectives. A focus on managing for resilience will enhance the likelihood of sustaining desirable pathways under unpredictable changing climatic environmental conditions where surprise is likely. Such adaptations imply a major paradigm shift in current conservation policy and practice and the social science of climate change research.

Introduction

The last two decades have witnessed the greatest global expansion in formal protected areas compared to any other in the era of human history. Area set aside for conservation more than doubled during this period and now covers approximately 11.6% of Earth's terrestrial base (IUCN and UNEP-WCMC, 2011). In the U.S., 6,770 terrestrial nationally designated (federal) protected areas protect 2,607,131 km^2 (1,006,619 mi^2), approximately 27% percent of the land area of the U.S., and one-tenth of the protected land area of the world (IUCN and UNEP-WCMC, 2011). Despite the substantial spatial coverage of protected areas in the U.S. and elsewhere, there has been increasing concern amongst international and national agencies and organizations over the loss of biodiversity. According to the 2007 International Union for Conservation of Nature (IUCN) *Red List of Threatened Species*, a total of

16,118 species are currently threatened with extinction, with more than 5,773 new species added to the list since 2000 (IUCN, 2007). These statistics parallel the findings of the United Nation's (UN) *Millennium Ecological Assessment,* which reported that 60% of the world's ecosystem services are degraded or used unsustainably (MEA, 2005).

Because climate plays a crucial role in determining the geographic distribution patterns of ecological communities, climate change has emerged in recent years as a topic of significant concern in addition to the more commonly acknowledged drivers of biodiversity loss and change (e.g., deforestation, invasive species, pollution, and exploitation). The Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (*AR4*) estimates that global mean temperatures have increase approximately 0.76°C over the past century and projects temperature increases of 1.8 to 4.0°C by the end of the 21st century (IPCC, 2007). A review of recent evidence related to climate system feedbacks indicates that the probability of exceeding +3.0°C has increased significantly (Pittock, 2006).

Temperature increases of this magnitude, occurring over a relatively short period of time in terms of ecological evolution, are anticipated to have significant consequences for global biodiversity and the conservation thereof. As fixed assemblages of lands and waters often designed to protect elements of biodiversity within a defined political or ecoregional context, parks and other forms of protected areas are designed to protect specific natural features, species, and ecological communities and processes *in-situ*, and have not taken into account potential shifts in ecosystem composition, structure, and function that are anticipated to occur as a result of global climate change. Indeed, studies by Root *et al.* (2003), Pounds *et al.* (2005), Parmesan (2006), and the IPCC (2007) have indicated that a number of species are already responding to climate change occurring over the 20th and early 21st centuries. Alarmingly, two coral species, staghorn (*Acropora cervicornis*) and elkhorn (*Acropora palmata*), and the polar bear (*Ursus maritimus*) were recently added to the U.S. *Endangered Species Act* (*ESA*), marking the first time any nation has listed species due to climate change-related impacts. Empirical analyses of species response to climate change over the remainder of the 21st century consistently project large species turnover and the potential for widespread species extinctions (Thomas *et al.*, 2004; Bomhard *et al.*, 2005; Schwartz *et al.*, 2006; IPCC, 2007; McKenney *et al.*, 2007a, 2007b; Lawler *et al.*, 2009; Araújo *et al.*, 2011).

While protected areas will remain keystones fundamental to biodiversity conservation and human health and well-being over the 21st century and beyond, these studies and events indicate that the implications of climate change for biodiversity conservation are considerable and may necessitate a fundamental rethinking in the global approach to biodiversity conservation and in the management of other protected areas assets. Fortunately, many adaptation options that would enhance the resiliency of protected areas and their constituent biodiversity to the impacts of climate change have been reinforced in the scientific literature for over thirty years (Lemieux *et al.*, 2011a). Examples include developing a suite of *in-situ* conservation-oriented measures to enhance the resilience of protected areas to direct and indirect climate change impacts (e.g., establishing systems of large and well-connected protected areas), minimizing external stressors (e.g., habitat loss and fragmentation), enhancing institutional capacity within protected areas agencies (e.g., increased investment in applied science and research), and developing place-based strategies focused on communicating climate change and conservation related issues to the public (see Hannah *et al.*, 2002; Dunlop and Brown, 2008; Baron *et al.*, 2009, Heller and Zavaleta, 2009, Lawler *et al.*, 2009; and, Lemieux *et al.*, 2011a for useful reviews).

Despite this readily available knowledge, and the repeated calls for the mainstreaming of climate change into biodiversity conservation and protected areas policy, planning, and management strategies by international conservation organizations for over twenty years (see McNeely, 1992), there continues to be a relatively slow response by practitioners both in terms of the development and implementation of relevant policy and management strategies. The conservation of forests, the conservation of endangered species, and climate change are examples of "wicked problems," as defined by Rittel and Webber (1973). Resolutions to wicked problems are difficult to achieve in practice because of the enormous interdependencies, uncertainties, complexities, and conflicting stakeholders implicated by any effort to develop a solution. Little evidence of strategic and proactive adaptation within the many critical policy and management areas of protected areas agencies exists currently (Lemieux *et al.*, 2011b), and independent audits of a number of federal conservation agencies in the U.S. and Canada have consistently identified a low capacity to manage for climate change and ecological integrity (GAO, 2007; OAGC, 2008a and 2008b; OAGBC, 2010; Government of Canada, 2010). Unfortunately, these assessments have been based largely on linear interpretations of institutional performance without any direct investigation into some of the underlying challenges that protected areas agencies face in their efforts to proactively prepare for and manage climate change related impacts. Overall, there is a poor understanding of the interplay and fit between social and ecological systems and climate change related management practices within protected areas agencies.

This manuscript offers a preliminary exploration of three selected socio-ecological characteristics that interact to make climate change an extremely challenging management issue within North American protected areas agencies. First, it is argued that the climate change and biodiversity conservation issue is a quintessential example of a "problem of fit" (Berkes and Folke, 1998; Folke *et al.*, 1998; Galaz *et al.*, 2008; Armitage and Plummer, 2010). That is, protected areas agencies (and, more importantly, the entire set of North American agencies) have both independently and collectively failed to take adequately into account the nature, functionality, and dynamics of the specific ecosystems that they are charged to protect. Second, it is argued that climate change is a long-term policy problem in which time lags between policy measures (or non-action) and effects often extend beyond one human generation (and almost certainly any single political cycle) (Underdal, 2010). Last, it is argued that climate change adaptation within any protected areas agency is embedded in very complex systems of which our understanding is still incomplete and in part clouded by profound social-ecological uncertainties (Folke, 2006; Armitage and Plummer, 2010). While each of these characteristics have important implications for adaptation and adaptive capacity, collectively they interact to make adaptation to climate change extremely difficult despite existing knowledge of solutions and, to a great extent, asphyxiate the creative potential and adaptive capacity of protected areas agencies.

Despite these challenges, it is clear and widely accepted that protected areas themselves will need to be established, planned, and managed differently if they are to achieve biodiversity conservation goals and other management objectives in an era of rapid climate change. The goal of this manuscript is to prompt a deeper discussion and examination of how these three interacting variables (problem of fit, temporal mismatches, and uncertainty and complexity) challenge multi-institutional adaptation planning in North America. The evidence and arguments presented in this manuscript are based on discussions and pre-workshop surveys from recent protected areas and climate change workshops hosted in the Rocky Mountain National Park (Estes Park, Colorado) and Badlands National Park areas (Rapid City, South Dakota) (see Thompson *et al.*, 2011), a review of the extant scientific literature, practitioner perceptions (Lemieux *et al.*, 2010; 2011b), and expert elicitation (Lemieux and Scott, 2011). Using this suite of case studies and anecdotal evidence from the Western U.S. and Canada is intended only to identify potential avenues for further empirical research on the interplay of these challenges in other contexts, regions, and institutional climates. This preliminary qualitative approach is essential to better understand: (1) the socio-ecological complexities associated with managing emerging global environmental change issues with no policy analogue; and, (2) the characteristics that influence adaptive capacity within conservation-oriented agencies.

Institutional Challenges to Adapting to the Wicked Problem of Climate Change: An Overview

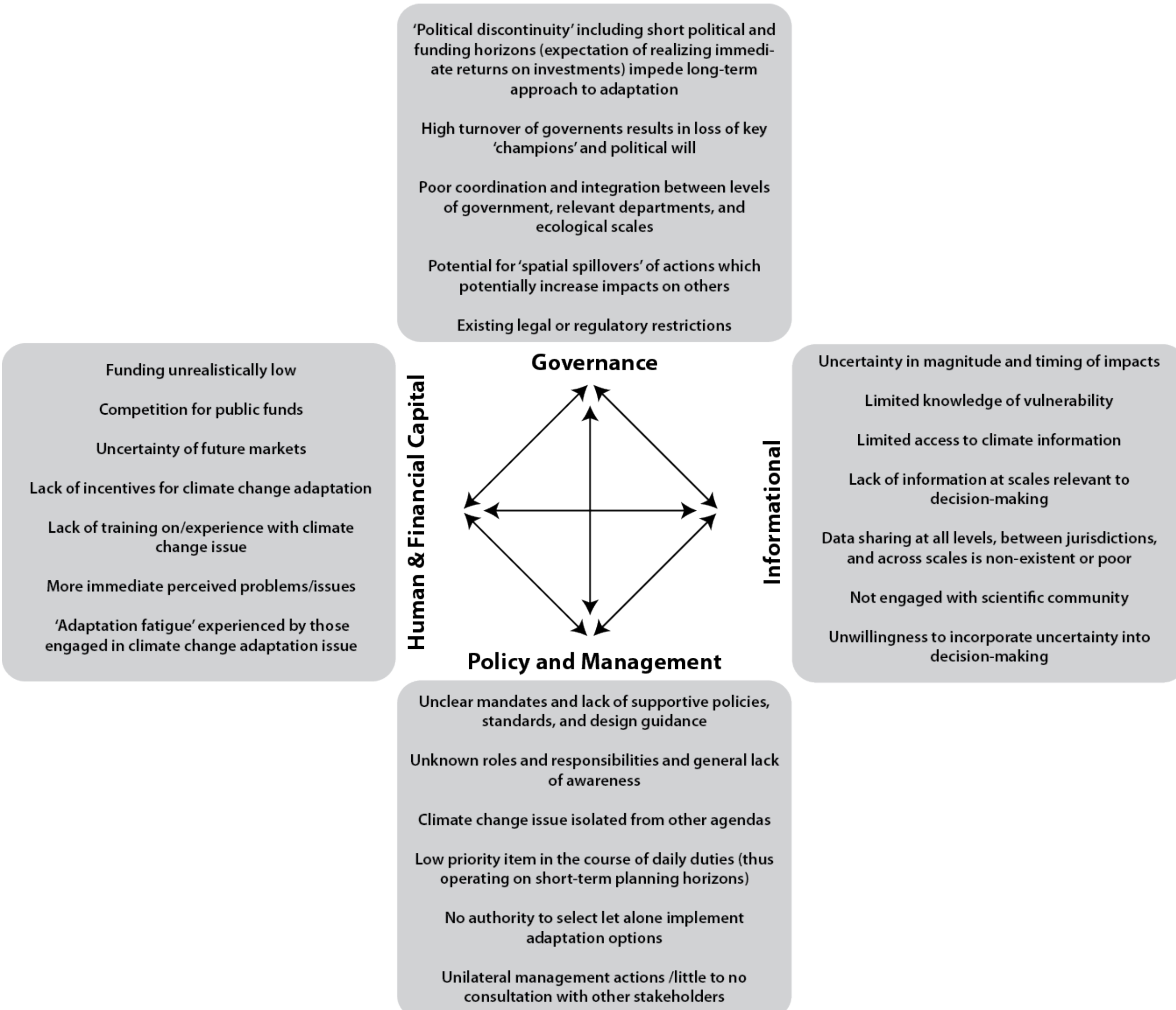
Studies on climate change adaptation in the protected areas sector have commonly assumed that conservation policy- and decision-makers should adopt all of the hypothetically available adaptation options without direct investigation into their desirability or feasibility by those actually responsible for their planning and management. The literature also has tended to make simple assumptions about adaptation (e.g., assuming complete changes in behavior) and has paid scant attention to the key actors or stakeholders involved. Overall, very few studies have examined specifically the challenges of managing for climate change within conservation-oriented organizations. The exceptions are Jantarasami *et al.* (2010) who examined institutional barriers to climate change adaptation in U.S. national parks and forests in Washington state, Lemieux *et al.* (2011b) who examined the state of climate change adaptation within Canada's protected areas sector, and Lemieux and Scott (2011) who engaged Ontario Parks[1] practitioners in a Policy Delphi methodology to evaluate the feasibility of climate change adaptation options across the agency's suite of major policy and management program areas.

The studies noted above revealed that adaptation efforts were stifled by rigidity and poverty traps due to lack of leadership, uncertainty about the magnitude and timing of climate change, delayed ecosystem responses, management values, unclear mandates, and a lack of adequate financial resources and internal scientific capacity. For example, of the 160+ climate change adaptation options evaluated by senior decision-makers within Ontario Parks in the study by Lemieux and Scott (2011), only 28 were evaluated to be "definitely feasible" to "possibly feasible". In many instances, adaptation options currently considered affordable, as well as "no-regrets" adaptations (i.e., adaptations that are beneficial even in the absence of climate change) were perceived as currently unfeasible (Lemieux and Scott, 2011). Similar capacity issues were brought forth by National Park Service and Forest Service practitioners in the Western U.S. When asked what the major influences were on collaborating with other agencies and organizations on climate change related action implementation, managers overwhelmingly cited the need for adequate communication channels (68.8%), adequate time (64.7%), adequate financial resources (64.7%), the need for clear roles and responsibilities (53%), the need for adequate information (53%) and human resources (53%). The best adaptation strategy or action plan is only going to be viable – or feasible – if practitioners have the capacity, institutional support and resources to put it into practice.

Survey results published in Lemieux *et al.* (2010, 2011b), Lemieux and Scott (2011), and Jantarasami *et al.* (2010), and reviews of unpublished respondent feedback from these and other surveys administered at the U.S. workshops noted above, revealed a number of diverse barriers and limits that protected areas agencies have encountered in their efforts to efficiently mainstream climate change into their relevant policy and management program areas (Figure 1).

Figure 1: Adaptation to climate change in protected areas agencies: barriers and limits across jurisdictional, ecological, and temporal scales.

[1] Ontario Parks is an agency within the Ontario Ministry of Natural Resources (OMNR) and is responsible for the planning and management of over 650 parks and other forms of protected areas in the province of Ontario, Canada.



These barriers and limits interact to result in what Lemieux *et al.* (2011) have termed "adaptation paralysis" – that is, the underlying socio-ecological characteristics that have limited the adaptive capacity of protected areas agencies to effectively and efficiently adapt to climate change. It is beyond the scope of this manuscript to address these characteristics individually. Instead, we will proceed by using an integrated social science perspective to address three fundamental challenges common to agencies trying to proactively prepare for and manage the wicked problem of climate change: (1) protected areas system planning and the "problem of fit"; (2) climatic, ecological, and political "temporal mismatches"; and, (3) climatic and socio-ecological uncertainty and complexity. Integrated social science, or a transdisciplinary perspective on the human dimensions of climate change adaptation planning is required, because no one discipline has the expertise to fully unpack and explore the interrelated challenges of fit, temporal mismatches, and uncertainty and complexity, which are essential barriers to address in order to promote more effective and efficient multi-scale adaptation planning.

Protected Areas and the "Problem of Fit"

Climate change impacts will be revealed across many scales, with effects measured across time and space. Accordingly, there is a need to understand how well the characteristics of agencies and wider governance systems at local to continental levels match the dynamics of biophysical systems (Galaz *et al.*, 2008). The "problem of fit", as described by Folke *et al.* (1998) and Galaz *et al.* (2008), is ubiquitous to North American protected areas system planning and management in relation to climate change in three main ways:

1. Protected areas agencies have failed to take adequately into account the nature, functionality, and dynamics of the specific ecosystems that they are charged to protect;
2. Protected areas agencies have employed system-planning methods that largely ignore important cross-scale and multi-scale synergies; and,
3. Climate change takes place at global scales, while it affects species at multiple-scales (e.g., in terms of geographic distribution and interspecific interactions) and in interaction with other drivers (e.g., habitat loss, fragmentation, and disturbances such as fire and insect outbreaks).

Going it Alone

The first "problem of fit" ascends from the inherent variances between biodiversity conservation traditions within and between nations. Protected areas in North America were first established to provide economical, recreational and, to a lesser extent, medicinal and spiritual benefits. In the late 1800s, the protection of natural heritage features was perceived as a secondary benefit. Now, however, protected areas are viewed as the most common and effective response to ecosystem decay and biodiversity loss and are called for under the United Nations' (UN) *Convention on Biological Diversity* (*UNCBD*) (Article 8). Systematic protected areas planning focusing on establishing a network of representative samples of the world's ecosystems was not introduced as a planning tool until the mid-20th century (Dasmann, 1972, 1973). Globally, support for the representation-based approach to system planning manifested itself in the early 1960s, and was substantiated by the preparation of a hierarchical classification system of natural regions for the purpose of conservation by the International Union for the Conservation of Nature (IUCN) and the establishment of UN International Biological Program (IBP) in 1963.

In Canada, *Canada's National Parks System Plan* (Parks Canada, 1997) and all provincially/ territorially-based system plans, with the exception of Nunavut, have adopted some form of enduring features, ecoregional, or biogeoclimatic-based classification framework as the main system-planning tool for their terrestrial protected natural areas system (Lemieux and Scott, 2005). Many of Canada's federal and provincial protected areas agencies have been using such approaches since the 1970s. In 2000, Mexico began to use systematic reserve selection approaches in response to a growing concern about the lack of organized planning to protect threatened biological and physical features (see Cantú *et al.*, 2004). The U.S. National Park Service, on the other hand, has no systematic approach to protected areas establishment whatsoever and, instead, selects new parks based on a number of criteria including, *inter alia*, characteristics of landforms or biotic areas that are widespread, uncommon, unusual, and/or threatened or endangered due to human settlement, and critical refuges that are necessary for the continued survival of species (NPS, 2011).

Several "problems of fit" are revealed when examining these approaches both individually and collectively. First, protected areas establishment approaches adopting representation-based principles are based on recent information about the distribution and abundance of ecological features. Although modern views of network architectures for protected areas promote and work toward enhancing the functional design of the contained areas and networks, they do so in the context of regional scale systems largely considered to be in dynamic equilibrium. Such approaches to conservation result in bias in the content of reserve systems, leaving some species, communities, or ecosystems without protection (Pressey, 1994). In essence, these approaches conserve snapshots of the current bioclimatic landscape at single slice in time and may manifest to not represent the species they were originally designed to protect. This manifests in different, sometimes adjacent agencies' missions. For example, a participate at the South Dakota Adaptation Planning Workshop explained:

> *"Some challenges [of adaptation planning] will be due to the fact that each agency has different missions and thus will focus on different facets of climate change and their effects on the resources. For example, the USFS may be more concerned [about] the effect of climate change on the growth and vitality of Ponderosa Pine since they manage and sell timber. The National Park Service may be more interested in allowing the species the ability to adapt by protecting larger tracts of habitat across jurisdictional boundaries."*

An Ontario Parks manager recognized the problem of fit and articulated the need for systemic change in protected area systems planning:

> *"I think we need to have a real think tank on how climate change will change our thoughts on ecological representation and protecting biodiversity. From this, we may likely have to take a multi-faceted approach that goes well beyond the current notion of protected area boundaries."*

Second, and relatedly, jurisdictions have failed to align system-planning approaches both within and between nations. Various jurisdictional authorities (e.g., federal, state, provincial, territorial, municipal), including non-governmental organizations such as the Nature Conservancy, have tailored their respective system planning approaches idiosyncratically based on different ecological criteria and using contrasting scales of analysis. These specific differences lead to contrasting approaches to ecosystem management and land use even within a similar suite of objectives (e.g., the perpetual representation of species). Such planning approaches, adopted at different administrative levels, lack interconnectedness and results in alignment problems between agencies. They also ignore important cross-scale (i.e., transboundary) and multi-scale synergies that will be critical to facilitating biodiversity response in an era of rapid climate change. When workshop participants were asked, *"What are the potential drawbacks or challenges associated with collaborating on climate change adaptation planning with neighboring agencies and organizations?"* overwhelming respondents cited issues such as: *"differing or conflicting management objectives, cultures and jurisdictional boundaries… different missions for each agency, meaning some things that are important in one agency might not be as important to the other."* One protected area manager in the Western U.S. explicitly noted the conflict in agencies' legislative mandates: *"[Let's] sacrifice aspects of the NPS mission in order to identify common values among all land managing agencies… [it's about] preservation versus multi-use conservation."* Similarly, a Canadian manager noted the barriers of system-planning approaches across jurisdictions:

> *"The influence that protected area agencies have outside their regulated boundaries is limited to influence and persuasion. At the end of the day, adjacent landowners and agencies do have the right to manage their properties as they see fit within the bounds of the law. Some of the more conservation-oriented and sympathetic landowners (and forest companies) can be very helpful in softening the boundaries. Others, less so."*

Clearly, transboundary and multi-scale planning approaches are challenged by the institutional structure and mandates that govern different types of protected areas in North America – within and across jurisdictions.

Climate Change and its Multi-scale Effects

The final "problem of fit" occurs when we attempt to take the issue of climate change and try to match it with its effects. Both scientists and protected areas managers alike need to better recognize that while many of the effects of climate change are global, the effects of climate change on species distributions, dispersal, performance, and interactions are multi-scale. For example, while it is widely known that climate change results in both species range expansions and contractions, evidence to-date suggests that these two effects display strikingly different distributional scaling (see, for examples, Wilson *et al.*, 2004 and Pocock *et al.*, 2006). At large scales, species' continental ranges are shaped by macroclimate, although historical disturbance factors such as fire may constrain potential ranges from being realized. At the smaller scale of many protected areas (especially those located in highly developed areas), however, topography modifies the macroclimate to produce an altitudinal climatic gradient along which species are distributed (Keil *et al.*, 2010). As Keil *et al.* (2010) noted, species ranges tend to expand in a spatially cohesive fashion (involving a substantial fine-scale gain as coarse-scale areas are colonized), but leave behind scattered populations as they contract (causing little loss at coarse-scale despite substantial fine-scale losses). To date, however, most studies looking at patterns of biodiversity have focused on static diversity distributions at distinct spatial scales; that is, focusing on a single snapshot of species richness pattern at a specific point in time. Practitioners and managers recognize this gap in the literature and management practices, urging for a more, multi-scale, landscape-ecosystem perspective:

> *"Yes, there should be an integrated and cooperative monitoring strategy to look at the impacts of climate change on species distribution, but [Parks] would only be one of the players at the table… Climate change is everyone's problem. Though the impacts of climate change on rare species is important, the impact on common species is much more important as they are what in essence make the ecosystem function. The barriers to implementation of and integrated and cooperative monitoring system lie in competitive behavior between organizations and institutional inertia. It is not that it can't be done, it is that people need to work together to make it happen, this requires stepping out of the comfort zone. This is true for most if not all of the organizations that would be involved."*

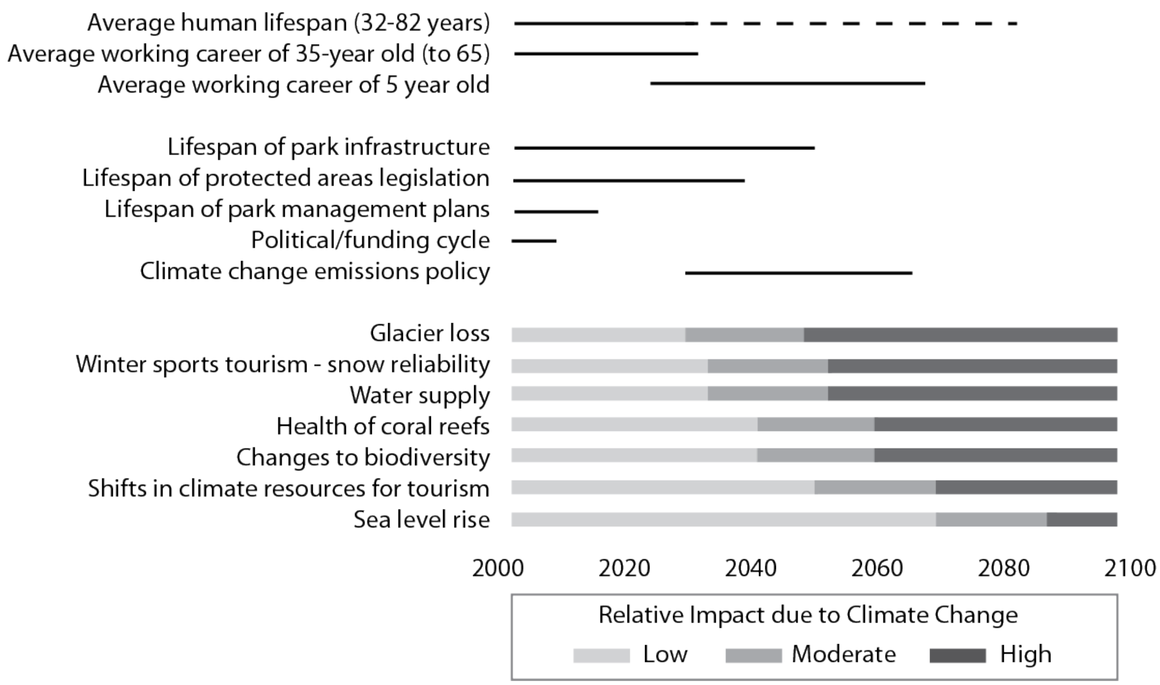
Consequently, there is a significant mismatch between the space scales of climate change projections and the information needs of protected areas policy-makers and planners. For example, the primary sensitivity of development activities to climate is at a local scale (such as that of many protected areas), for which credible climate change projections are often lacking. Major limitations associated with coarse-scale modeling efforts that highlight the difficulties and uncertainties associated with the practical implications of climate change models have been revealed in recent years. Trivedi *et al.* (2008) suggest that recent large-scale modeling studies overestimate some species' ability to cope with increasing temperatures, thereby underestimating the potential impacts of climate change. Specifically, the author's revealed that species persistence in microclimatic refugia might not be as widespread as previously speculated. Despite increased investments in research pertaining to bioclimatic modeling, there is no evidence to indicate that such models are being used to inform conservation planning and management decisions in any North American protected areas agency. As a Canadian protected areas manager cautioned, *"Climate change is inevitable but there is not much you can hang your hat on in terms of ecosystem and species responses."*

Finally, protected areas managers and other stakeholders need to recognize that climate change effects on species will interact with other drivers that are discernable at different scales (e.g., habitat loss, fragmentation, invasive species, and disturbance). It has been suggested that the synergistic interactions between, and cumulative impacts of, fire and insect outbreaks resulting from climate change will emerge to be more important agents of biological change and re-organization than increases in temperature and precipitation alone (Scott and Lemieux, 2007). The reality is that many issues in biodiversity conservation require information at spatial scales too coarse and too multi-layered to be surveyed effectively on an ongoing basis, rendering the current use of climate change models in policy development and decision-making extremely challenging.

"Temporal Mismatches" between Climate Change, Ecosystem Response, and Policy Reform

Most, if not all, protected areas agencies in North America target to conserve biodiversity or, in other words, they strive to prevent extinctions. By default, they have to deal with a time-horizon dilemma. Considering that climate change and its associated impacts are still relatively new issues to the public and to public officials, and given the failure of nations to determine who is responsible for implementing solutions, one cannot expect that the multi-scale system necessary to conserve biodiversity to have been implemented in the past or to be developed at any time in the immediate future. This is to a great extent because protected areas agencies are faced with two fundamental interacting challenges associated with "temporal mismatches". First, while the causes of climate change are largely the result of past or current human activities, its impacts are often regarded as remote future events. Second, there is a significant temporal mismatch between ecological responses, scientific information available for decision-making, political (and by extension funding) cycles, and conservation/protected areas policy revision. Figure 2 illustrates how these temporal mismatches interact to add further complexity to effective and efficient climate change adaptation within protected areas agencies.

Figure 2: A temporal perspective of the various climate change impacts relevant to protected areas policy, planning, management, and human capital (relative to 2000 baseline). Figure developed using information and projections from UNEP (2008) and IPCC (2007).



While the varied impacts of climate change are becoming more and more evident at locations around the world, climate change is often considered a remote future event for biodiversity and protected areas planning and management. As one Canadian protected areas manager emphasized, *"Though climate change is here and very real, it can be difficult to focus on a subject that still appears to be off in the future when there are other immediate and pressing needs in the office."* Public policy regarding biodiversity conservation lags far behind the established scientific consensus on climate change, namely that system planning and other management related management plans require revision (see Lemieux and Scott, 2005; Baron *et al.*, 2009; Jantarasami *et al.*, 2010; Lemieux *et al.*, 2011a). Despite recent advancements in policy, including the development of a climate change response strategy by the U.S. National Park Service, the threat of climate change is outpacing policy development, implementation, and unquestionably evaluation. All policies lack continuity and many cannot be used to help guide managers in an era characterized by rapid climate change and significant socio-ecological uncertainty. An Ontario Parks protected areas manager noted this challenge, stating that:

> *"Climate change is definitely an ecological issue, with some impacts occurring in the short term and others in the medium to long term - since Ontario Parks lacks the resources (funding and staff) to address climate change (monitoring and research), it is unlikely that this can be addressed in a comprehensive manner, therefore limiting the reporting that can be done - in addition, many of the information/data sources used have refresh rates that are not necessarily in sink with reporting timeframes and may/will not coincide with changes across the landscape."*

For example, the *Canada Wildlife Act*, which establishes and guides the management of National Wildlife Areas and Migratory Bird Sanctuaries, was passed in 1973 and was last updated in 1985. Most provincial/territorial protected areas acts in Canada are also significantly outdated, and amendments occur on decadal intervals (at a minimum). The Government of Ontario's *Provincial Parks and Conservation Reserves Act*, which administers the province of Ontario's 600+ protected areas, came into effect in September 2007 and was the first update of the *Act* in over 50 years. Furthermore, despite legislative requirements, the majority of provincial parks in the province do not have approved management plans, which are essential for determining how resources will be protected and what will happen inside a park over a 20-year period. The Environmental Commissioner's Office of Ontario (ECO) reported in 2004 that only 40 per cent of the provincial parks had an approved management plan and 72 per cent of those plans were at least 10-years-old. Only 19 per cent of non-operating parks (i.e., parks that charge no fees, have no staff on site, and offer only limited facilities) had approved management plans. Similar problems are also evident in the United States: the *Endangered Species Act* was passed in 1973 and last amended in 1982 and the *National Environmental Policy Act* (NEPA), which came into effect in 1970, was also last amended in 1982.

A *laissez-faire* approach to policy and management plan revision and, perhaps more importantly, integration, could have several major consequences. First, prolonged updates that forestall addressing the climate change issue in a timely fashion may result in time lags that make "correction" all the more less likely or more consequential (e.g., less effective or irreversible) and/or costly. Some authors have even cautioned that climate change may be more rapid or pronounced than current estimates suggest and, consequently, may result in increased vulnerability of socio-ecological systems to unexpected events (Pittock *et al.,* 2006). Moreover, some forms of adaptation will require considerable lead-time, especially where major policies, institutional changes or innovations are required (Smit *et al.,* 1996). 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.

Second, the question of who has legal primacy over a threat (responsibility and ability to enact and enforce regulation) and competency over a threat (mandate and capacity to address a threat) requires policies to be updated and to cooperate. de Loë and Kreutzwiser (2000) emphasized that the distributional inequalities of benefits and costs within specific resource use sectors (issues related to jurisdictional and legal authority) and across various institutional and geographic scales will challenge the social acceptability, and even the political realism, of certain adaptation options. For example, how are different conservation-oriented agencies to interpret an invasive species in an era of rapid climate change? Although the arrival of a new species, "invasives", may be identified as a negative outcome of climate change and a negative impact on a protected area (for example), it can also be interpreted as successful autonomous adaptation by a species to anthropogenic climate change thereby adding further complexity to species management decisions (Scott and Lemieux, 2005). Further to this point, the *Canadian Species at Risk Act* defines a "wildlife species" as a species "native" to Canada and one that has been present in Canada for at least 50 years (Government of Canada, 2002). A literal interpretation of this definition indicates that a species classified as endangered in the U.S. that naturally expands its range into Canada under changing climate would not qualify for protection as a species-at-risk under the Canadian *Species at Risk Act* (Scott and Lemieux, 2005). Moreover, policy related to the U.S. *Endangered Species Act* (1973) were revised recently to rate the threat to various species based primarily on their populations within U.S. borders, giving more weight to populations in Canada and Mexico, and changed the way species were evaluated under the act by considering where the species currently lived, rather than their historic distribution.

Finally, it usually takes a very long time for results of research to be integrated into conservation policy and application. Pyke *et al.* (2007) emphasized recently that most support resources for climate-related decisions are currently limited by the quantity and quality of available information. Moreover, practices that take into account historical climate are not necessarily suitable under future climate change. Recent studies in the conservation sector have shown that practitioners often have insufficient scientific evidence to assess their management decisions and, consequently, primarily use past experience (Cook *et al.,* 2009). In our surveys of land management practitioners in the Western U.S., only 16.3% (n=51) and 19% (n=21) of respondents indicated that there was either "enough information" or "more than enough information" to inform decisions on strategies for human response (adapting) to climate change, respectively. Even less (12.7% and 13%, respectively) indicated that there was "enough information" or "more than enough information" to inform decisions on the socio-economic impacts of climate change (e.g., those related to park visitation, tourism, and recreation). Similar results have been revealed in Canada, where 71% of Canada's protected areas agencies (including all federal, provincial and territorial agencies) indicated that they required "much more information" on strategies for climate change adaptation (Lemieux *et al.*, 2011b). 79% of respondents also indicated that they required "much more information" on the ecological consequences of climate change (Lemieux *et al.*, 2011b).

With a lack of information, missing information, or the lag in implementing scientific information into management policy and application, managers are often forced to default to old models and outdated management protocols. One practitioner admitted: *"Old beliefs and paradigms… we continue to make decisions based on land management strategies from the dark ages."* Baron *et al.* (2009) suggested past experience might not serve as a useful guide for novel future conditions. Further compounding this issue is that the end-of-the-century global average misleads in time because, under present greenhouse-gas (GHG) emissions trends and most reduction scenarios, warming will continue well beyond 2100. Biodiversity will have to cope with constant climate change, not just the end-of-the-century political yardstick currently promoted by the IPCC. Overall, there is a clear non-linear relationship between scientific knowledge and policy integration that has manifested over recent years.

Embracing Uncertainty and Complexity

The protected areas and climate change issue is one having no policy analogue and confounded by significant uncertainty and complexity. The importance of uncertainty in climate change mitigation and adaptation decisions is a well-recognized challenge (e.g. White, 2004; Yohe *et al.*, 2004). These challenges relate to uncertainty associated with the magnitude, rate, and timing of climate change and its impacts, as well as the uncertainty associated with the advantages (or benefits) resulting from the implementation of adaptation options. How short-term impacts will differ from the long-term impacts that will remain after natural and human systems have had time to adapt to the new climate is also a significant element of uncertainty.

The pervasive uncertainty inherent in many aspects of climate change presents policymakers and other decision-makers with several challenges when attempting to develop appropriate policies. As Lew (2010) aptly points out, long-term solutions to sustainability issues (such as climate change) are the most difficult to project because the problem will change over time and the nature of this change is often non-linear. This results in what is often called a "time inconsistency" effect – a situation in which a stakeholder's best plan for some future period of time will no longer be optimal when that time actually arrives (Kydland and Prescott, 1977 as described in Underdal, 2010). Moreover, because climate change impacts do not exist in isolation (as noted above, many impacts work cumulatively, synergistically, or even counteractively to change ecosystem composition, structure, and function), policies are faced with the difficult task of coping with numerous interacting gaps in scientists' understanding of ecosystems, as well as inherent difficulties in forecasting future climate variability and human behavior. One manager from Colorado explained, *"Knowing that conditions will get warmer and drier is interesting, but is of little value in making management decisions. For information to be useful to influence management decisions, there needs to be specificity and precision in anticipated effects."* Another manager in British Columbia echoed the concern: *"We don't have confidence in science's ability in this instance to predict in a suitable time frame what issues will emerge; therefore, issues will likely have to be addressed as they emerge."*

Overall, a part of our uncertainty about future climate change is unavoidable; projections of climate over long periods are likely to remain unpredictable to some degree and uncertainty is compounded when considering future markets and levels of human activities and technological change (Webster *et al.,* 2003). One thing we know for sure, however, is that climate has changed in the past and will continue to change in the future. While there may be some debate surrounding the scale, rate, and magnitude of warming (and its associated impacts), uncertainty over climate sensitivity is a further argument for action, not inaction. This is especially true when one considers the potential for abrupt climate change (see, for example, National Research Council, 2002) and non-linear ecosystem responses (ecological surprises).

Progress toward sustainable development will depend on our capacity to manage ecosystems in a manner that ensures continued provision of essential services under uncertainty -- a process which will require a better understanding of an integrated socio-ecological system (Berkes and Folke, 1998; Berkes *et al.*, 2003; Tomkins and Adger, 2004; Walker *et al.,* 2004; Olsson *et al.,* 2004; Folke, 2006;). Yaffee (1999) noted that an emphasis on the complexity of system-wide interactions highlights scientific uncertainty and results in the need to deal with this uncertainty explicitly by acting conservatively and managing adaptively. Emerging insights from adaptive management suggests that building resilience into both human and ecological systems is an effective way to cope with environmental change characterized by future surprises or unknowable risks (Folke *et al.*, 1998; Tomkins and Adger, 2004; Folke *et al.*, 2005). Adaptive management supports the notion that conservation policy must be designed to provide guidance and direction with uncertainty in mind, while simultaneously having the flexibility to cope with non-linear changes (e.g., abrupt climate change, ecological surprises).

Conclusions

The implications of anthropogenic climate change for biodiversity and biodiversity conservation have been discussed in the scientific literature for nearly 25 years. With the increasing strength of climate change science and observed ecosystem impacts, protected areas agencies have increasingly begun to explore the implications of climate change for their policies and management procedures. Generally, there is consensus that current policies are inadequate to cope with the challenges caused by even moderate climate change scenarios in the 21st century (Anderson and Bows, 2008; Rogelj *et al.*, 2009; Parry *et al.*, 2009) let alone the minimum +4°C of warming that policies for adaptation should now be preparing for given current greenhouse-gas emissions trajectories (Parry *et al.*, 2009). And while most academic literature on climate change adaptation suggests that adapting now will be more effective than adapting later (i.e., more cost effective and efficient in reducing the potential for irreversible impacts, such as species extinction) (see Burton, 1996; Smit *et al.*, 1996; Stern, 2007), protected areas planners, managers and decision-makers face a host of difficult issues in their efforts to efficiently and effectively adapt to climate change. The interactions of multi-scale social and ecological challenges including "problems of fit", "temporal mismatches", and climatic and socio-ecological uncertainty and complexity make adaptation to climate change extremely difficult within protected areas agencies despite existing knowledge of solutions and, consequently, asphyxiate the adaptive capacity of these agencies.

Integrated social science can assist in informing management and exploring such challenges (as problems of fit, temporal mismatches and uncertainty and complexity) in multi-scale climate change adaptation planning. Integrated social science presents a transdisciplinary perspective on the human dimensions of climate change planning, including governance, policy, decision-making, communication, and collaboration. Building cross-jurisdictional capacity is going to require that we develop a research program that examines the potential for organizational resilience and multi-scale collaboration through multiple social science lenses because it is such a layered and complex task to develop and ultimately implement cross-jurisdictional adaptation plans. Ecological science and models can help to inform the planning, but the ultimate struggle argued in this manuscript is transcending institutional barriers and facilitating the implementation of such plans.

Overall, the dynamic ecological and jurisdictional linkages and the politics of the construction of scale within and between protected areas jurisdictions are not well understood. Although unintended, the lack of cooperation and information sharing within and between nations has resulted in somewhat of a self-created rigidity. Conservation priorities that are not interconnected may result in many unintended negative effects. The ability to better understand and effectively adapt to climate change will require an integrated perspective, linking climate and the multi-scale biotic components and interactive drivers of the ecosystem as a whole. Accordingly, climate change adaptation by protected areas agencies can only progress by means of a more integrated approach within government and institutions, among sectors, between a complex overlay of ecological and jurisdictional scales, from the international to the local. Agencies cannot be insular in their approach to climate change adaptation. Each protected areas agency needs to be outward-looking and catalyzing discussion and action across the full breadth of the protected areas fraternity. The 1,000+ different types of protected areas globally (see Chape *et al.* 2005), with varying degrees of protection afforded to them (i.e., IUCN categories I-VI), will all need to be functioning toward a common strategy to build nodes, linkages, and connectivity to be most effective in an era of rapid climate change. Indeed, the lack of a coherent and harmonized continental system of protected areas may be the greatest challenge to protected areas agencies as they each strive to conserve biodiversity in an era characterized by rapid climate change.

At the same time, the protected areas sector needs to be cognizant that adaptations might result in "spatial spillovers"– while an adaptation may be effective in reducing the impacts of climate change or enhancing opportunities in one location or time period, it may also very well increase pressures "downstream", or lesson the abilities of others to adapt to climate change (see Adger *et al.* 2005). For example, assisted colonization (also referred to as assisted migration) of a valued species may result in unintended effects on host ecosystems within another agency's jurisdictional boundaries. The relative importance placed on different adaptations varies with the perceived limits to an agent's area of responsibility (Haddad, 2005; Adger *et al.*, 2005) meaning that protected areas agencies will be faced with the complex problem of deciding at what point the effects of climate change (and corresponding adaptations) become "someone else's problem" and/or when an issue or impact extends beyond the realm of protected areas themselves. As Adger *et al.* (2005) emphasized, adaptation success should not be assessed simply in terms of the stated objectives of individual adaptors. As a Canadian protected areas manager cautioned, *"What if we adapt our protected areas system and the other countries do not?"*

A key challenge for protected areas managers will be to decide how much uncertainty they are willing to adapt to without compromising their own values. The effectiveness of an adaptation option introduced by any organization is often reliant on the actions taken by others (for examples, those outside protected areas) and may well depend on the future-unknown-state of the world (i.e., future social and economic conditions) (Adger *et al.*, 2005). The reality is that we may never have enough data to design and manage a protected areas network with complete confidence that we are doing it correctly. Uncertainty will persist. In the face of uncertainty, the prudent course is to risk erring on the side of protecting too much. Options for land conservation, once lost, cannot easily be regained; and, while research to guide reserve design under climate change scenarios is needed, waiting for adequate information about dispersal, dynamics, and viability of a species under climate change could have an unfortunate negative result --- more of the remaining habitat would likely be gone. Indeed, the climate change adaptation issue is one that extends beyond any one agency and even any one nation necessitating a continental response to enhance the overall effectiveness of North America's system of protected areas.

Although there is much uncertainty over the timing, extent and manner in which ecosystems and other protected areas assets (e.g., tourism and recreational opportunities) might respond to evolving climatic conditions, this should not negate the necessity to identify, evaluate, and implement adaptation options aimed at enhancing the resilience of protected areas and their constituent biodiversity to climate change. As Lew (2010) aptly pointed out, even though it is more intellectually challenging and problematic for decision-makers with much shorter planning time-horizons, this does not mean that we should not try to think in terms of long-term sustainability. Currently, however, there is limited understanding of the scale of effectiveness and temporal sensitivity of conservation system planning approaches, policy instruments, policy mixes, and jurisdictional practices. A better match of the scales of policy and management to the scale of biological processes within and between nations will make biodiversity conservation much more effective in an era of rapid climate change. As such, there is a clear need to: 1) examine the coherence and ecological sufficiency of networks of protected areas within and between Canada, the U.S., and Mexico across jurisdictional levels; 2) improve the capacity of system planning approaches and active management regimes to deal with scale-related problems, with an emphasis on the interactions between different jurisdictional levels in various national and international settings; and, 3) integrate research information sharing and monitoring schemes to more effectively address conservation issues across scales. A multi-scale approach to the problem of climate change would also encourage experimentation and learning in the spirit of adaptive management within protected areas agencies. However, such adaptations imply a major paradigm shift in current conservation policy and practice.

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