Rethinking Biodiversity Conservation in an Era of Climate Change: Evaluating Adaptation in Canada's Protected Areas

by

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The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

Stephanie Barr was the sole author of Chapters 1 and 5 which were not written for publication. Chapters 2 through 4 were written for publication, are the collaborative efforts of multiple researchers, and have been or will be submitted for publication. Stephanie Barr is the first author on all papers and accordingly was responsible for development, data collection, data analysis, and preparation of each manuscript. The dissertation has been reviewed and edited in its entirety by supervisor Dr. Brendon Laron and committee members Dr. Andrew Trant, Dr. Daniel Scott, Dr. Vanessa Schweizer, and Dr. Christopher Lemieux. Exceptions to sole authorship are as follows:

Chapter 2:
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Dr. Brendon Larson, Dr. Daniel Scott, and Tom Beechey provided ongoing guidance and supervision regarding project design, implementation, and data analysis. Stephanie Barr drafted the manuscript and all co-authors reviewed the manuscript, and provided intellectual content, editorial advice, and guidance.

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Abstract

Protected areas worldwide face significant threats from rapid climatic and associated ecological change. The need to adapt to the impacts of climate change on biodiversity has been widely acknowledged for two decades; however, meaningful and effective adaptation within protected area agencies and organizations remains a widespread challenge. Given realized and projected future climate-induced ecological changes, conservation policy and practice in protected areas needs to be more proactive to adapt to changing climate conditions to preserve biodiversity. In light of this pervasive problem, the purpose of this dissertation is to review and advance climate change adaptation in and across Canada's protected areas organizations. To do this, I examined the current state of adaptation within Canada's protected areas organizations (Chapter 2), engaged practitioners working at the protected area site level to identify and evaluate adaptation options (Chapter 3), and examined the adaptation readiness of protected area organizations to identify strengths, challenges, and opportunies for capacity development (Chapter 4).

First, a survey was distributed to provincial, territorial, and federal governments as well as environmental non-governmental organizations (ENGOs) working in conservation in Canada (n=49). This survey revealed that little progress on adaptation in Canada's protected areas sector from 2006 to 2018 has been made despite greater certainty about climate change impacts and climate change being considered pertinent to protected area planning and management (Chapter 2). Second, through a case study at Bruce Peninsula National Park and Fathom Five National Marine Park, I found that most adaptation strategies identified by workshop participants were conventional (i.e., historically used and low risk) and direct change (i.e., aid transition towards new states) compared to the other categories (i.e., conventional/resist change, interventionist/direct change, and interventionist/resist change). Conventional strategies had the highest perceived effectiveness and feasibility ratings (Chapter 3). Third, an adaptation readiness assessment found that Bruce Peninsula National Park and Fathom Five National Marine Park have moderate overall adaptation readiness with higher readiness in terms of social-ecological systems (e.g., mapping and monitoring values) and lower readiness in terms of knowledge (i.e., knowledge management and exchange) (Chapter 4).

The results of this research identified limited progress and numerous barriers to adaptation. However, the potential for progress on adaptation exists if barriers can be overcome. Recommendations to increase adaptation include enhancing knowledge mobilization and partnerships, implementing a national adaptation strategy, having a climate change champion on staff in each park, and developing more flexible conservation objectives. This dissertation contributes to our understanding of progress on adaptation within Canada, the perceived effectiveness and feasibility of adaptation options, and adaptation readiness in a protected areas context. The results of this research can be used by practitioners to advance adaptation in Canadian protected areas organizations to better achieve their long-term conservation goals.

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Chapter 1

Introduction

1.1 Research Context and Problem Rationale

Protected areas represent a cornerstone of biodiversity conservation (Margules and Pressey, 2000; Hole et al., 2009; IUCN, 2013); however, historically, these protected areas have often relied upon an assumption of a static climate system and pattern of biodiversity (Hannah et al., 2002; Hole et al., 2009; Tingley et al., 2014; Thomas and Gillingham, 2015). In an era of climate change, biophysical impacts are being felt even within areas designed to safeguard biodiversity (Batllori et al., 2017). Atmospheric carbon dioxide, methane, and nitrous oxide levels are the highest they have been in at least the past 800,000 years, resulting in significant changes to sea ice, increased air and water temperatures, rising sea levels, and increased frequency of extreme weather events (IPCC, 2018). These changes affect biodiversity worldwide, with many species shifting their range and altering the timing of their life history events, among other impacts (Root et al., 2003; Parmesan, 2006; Chen et al., 2011; Thackeray et al., 2016). There is thus a concern about the effectiveness of current conservation practices to conserve biodiversity in light of climate change (Hole et al., 2009; Batllori et al., 2017; Berteaux et al., 2018; Maxwell et al., 2020; WWF, 2020).

Despite conservation efforts, biodiversity has declined over the past decades (Butchart et al., 2010) and climate change will continue to be a leading contributor to biodiversity loss in the future (IPBES, 2019; Sanderson and Fisher, 2020; Hannah et al., 2020). Climate change is substantially reducing suitable habitat for species, allowing for the colonization of invasive species, and altering species assemblages inside protected areas (Berteaux et al., 2018). Notwithstanding these challenges, protected areas still represent the best and most cost-effective way to preserve biodiversity (Batllori et al., 2017). Furthermore, the economic benefits of protected areas outweigh the costs of protected areas by at least three times (Claes et al., 2020). Therefore, ensuring the relevance and effectiveness of protected areas is necessary. Conservation policy and practice in protected areas needs to adapt to changing conditions to preserve biodiversity into the future (Bellard et al., 2012; Hagerman and Satterfield, 2014).

Climate change is frequently not addressed in protected area management plans despite being a major threat to biodiversity and needs to be mainstreamed into conservation practices (Heller and Zavaleta, 2009; Mawdsley et al., 2009; Geyer et al., 2017). There have been numerous calls to change conservation practices (Heller and Zavaleta, 2009; West et al., 2009; Stein et al., 2013; Hagerman and Satterfield, 2014; Abrahms et al., 2017); however, uptake on climate change adaptation – the adjustment of policy or actions to reduce negative impacts of climate change – in protected areas has been slow. Of the many adaptation strategies proposed in the conservation science literature, most are speculative or theoretical in nature with limited studies documenting or evaluating strategies that have actually been implemented (Ford and King, 2015; Prober et al., 2019). Moreover, the ability of conservation organizations to implement these strategies has rarely been evaluated. A science-policy gap exists whereby the best available science has yet to be incorporated into practice.

1.2 Purpose and Objectives

The findings of this research are organized as a collection of three interrelated manuscripts designed for publication – a dissertation by manuscript style. Each manuscript contains its own research objectives, literature review, methods, results, discussion, and conclusion. As such, some repetition may occur between this overall dissertation introduction and individual manuscript introductions. To achieve a holistic reading of this dissertation, this introductory chapter situates the three manuscripts within a broader picture outlined in the research context and problem rationale through a literature review related to climate change, protected areas management, and adaptation.

The overarching goal of this research is to advance climate change adaptation in Canadian protected areas. The specific aims of this research are to understand the current state of adaptation in Canada (*Aim 1/ Chapter 2*), to gain insight into practitioner preferences for adaptation (*Aim 2 / Chapter 3*), and to assess the adaptation readiness of protected area organizations (*Aim 3 / Chapter 4*). To accomplish this, each data chapter has its own objectives as follows:

Chapter 2, entitled *Assessing Climate Change Adaptation Progress in Canada's Protected Areas*, examines the current state of adaptation in Canada (*Aim 1*). Its objectives are as follows:

Objective 1: To evaluate progress over the past decade.

Objective 2: To examine whether institutions perceive climate change differently or have different responses to climate change

Objective 3: To determine which types of adaptation strategies are being employed.

Objective 4: To identify barriers to adaptation in Canada's protected areas sector.

Chapter 3, entitled *Evaluating Climate Change Adaptation Options at the Frontlines of Biodiversity Conservation: Conventional Strategies Dominate over Interventionist,* considers practitioner preferences for biodiversity conservation adaptation strategies (*Aim 2*). Its objectives are as follows:

Objective 1: To determine which adaptation options practitioners prefer.

Objective 2: To evaluate perceived effectiveness and feasibility of adaptation options.

Objective 3: To apply a typology to adaptation options.

Chapter 4, entitled *Assessing the Adaptation Readiness of the Bruce Peninsula National Park and Fathom Five National Marine Park to Adapt to the Impacts of Climate Change*, examines adaptation readiness in a protected areas context (*Aim 3*). Its objectives are as follows:

Objective 1: To provide a self-assessment of the BPNP/FFNMP's adaptation readiness to respond to current and potential climate-related issues.

Objective 2: To identify ways to strengthen the capacity of protected areas to respond to climate change.

1.3 Literature Review

1.3.1 Climate Change

Anthropogenic activities have led to an unprecedented increase in atmospheric greenhouse gasses (UNEP, 2019). Increased greenhouse gasses are leading to numerous planetary changes including increased air temperatures, increased sea surface temperatures, altered precipitation patterns, reduced snow and ice cover, ocean acidification, and sea-level rise (Steffen et al., 2018; WMO, 2020). Due to these changes, many plant and animal species, terrestrial and aquatic, have shifted their geographic ranges, phenology, and interactions, to better track suitable conditions, resulting in altered ecosystems (IPCC, 2018).

1.3.1.1 Observed Changes and Global Climate Projections

The past decade (2010-2019) is the warmest on record (WMO, 2020). Moreover, each decade after 1980 has been warmer than any previous decade since 1850 (WMO, 2020). Global mean surface air temperatures have increased by 0.87°C for the period 2006-2015 over 1850-1900 levels (IPCC, 2018). However, temperature increases are not uniform across the planet (Collins et al., 2013). In Canada, mean annual temperature has increased by 1.7°C over the period from 1948-2016 with the strongest warming occurring during winter and spring in the western and northern regions of the country (Vincent et al., 2015; Bush and Lemmen, 2019). Furthermore, global temperatures are projected to increase by 1.5°C over pre-industrial levels between 2030 and 2052 (IPCC, 2018). Heat waves have already increased in frequency and intensity and are also projected to become more frequent and last longer in the future (IPCC, 2019a; WMO, 2020). By 2081-2100, temperatures are projected to increase by 0.9-2.4 °C under RCP2.6 and by 3.2-5.4°C under RCP8.5, relative to a 1850-1900 baseline (IPCC, 2019b). In Canada specifically, temperatures are projected to increase by 1.8°C by 2081-2100 under RCP2.6 and by 6.3°C under RCP8.5, relative to a 1986-2005 reference period (Bush and Lemmen, 2019). RCP2.6 is the Representation Concentration Pathway (RCP) with the lowest greenhouse gas emissions whereas RCP8.5 has the highest (Riahi et al., 2011).

Precipitation projections are less certain than those for temperature, and changes in future precipitation will not be uniform across the planet, or across Canada, with some regions receiving more precipitation and others less (Collins et al., 2013; Pfahl et al., 2017; Vincent et al., 2018). At the global scale, the frequency and intensity of heavy precipitation events has increased over the second half of the 20th century (Hoegh-Guldberg et al., 2018; IPCC, 2019a). Averaged across Canada, precipitation has increased by 18.3% from 1948-2012 with larger increases occurring in northern Canada (Vincent et al., 2015; Bush and Lemmen, 2019). Moreover, the number of days with precipitation (>1mm) in southern Canada has increased by 10.4 days per year over the 1900-2012 period, with the greatest increases being in British Columbia and Ontario (Vincent et al., 2018). In Canada, it is projected that annual mean precipitation will increase over the majority of the country by 7.3% by 2031-2050 relative to 1986-2005 under RCP8.5 with the largest increases being seen in northern Canada (Bush and Lemmen, 2019). Additionally, in Canada, spring precipitation has shifted from snow to rain and the proportion of precipitation falling as snow has decreased (Vincent et al., 2018; Bush and Lemmen, 2019). Arctic snow cover has already significantly decreased and is projected to decrease by 5-10% under RCP4.5 and 15-25% under RCP8.5 compared to a 1986-2005 reference period (IPCC, 2019b).

1.3.1.2 Impacts on Biodiversity

The physical effects of climate change are well documented, and species responses, such as changes in phenology and species ranges, have been observed (Parmesan and Yohe, 2003; Root et al., 2003; Parmesan, 2006; Chen et al., 2011; Lenoir and Svenning, 2015; Pacifici et al., 2017; Pecl et al., 2017). In addition to climatic factors, species are affected by many non-climatic factors, such as multi-species interactions, which adds complexity to predicting the effects of climate change on biodiversity (Chen et al., 2011; Staudinger et al., 2013; Reside et al., 2018). Most studies examining the impacts of climate change on biodiversity focus exclusively on climate change and ignore other factors that affect biodiversity such as habitat fragmentation, overexploitation, and invasive species, thereby limiting their predictive abilities (IPBES, 2019).

The impacts of climate change on biodiversity are not equal around the planet. Local species extinctions occur more frequently than global extinctions and some regions experience fewer impacts from climate change than others (Bellard et al., 2012). Numerous impacts have been described to date. At the species level, reduced survival and fecundity (Mawdsley et al., 2009), reduced population size (Mawdsley et al., 2009; Pacifici et al., 2017), and decreased genetic diversity (Bellard et al., 2012) have been observed. There have also been range shifts (Parmesan, 2006; Staudinger et al., 2013; Pecl et al., 2017), an increase in spread of diseases and parasites (Parmesan, 2006), and an increase in spread of invasive and non-native species (Sorte et al., 2013). Ultimately, if species cannot cope or adapt, they may face extinction or extirpation (Parmesan, 2006; Bellard et al., 2012; Blois et al., 2013). To avoid or mitigate these impacts, species can respond through several mechanisms including species range shifts, genetic adaptation, and alterations in phenology. Understanding species responses to climate change is critical in developing effective biodiversity adaptation strategies.

In response to changing climatic conditions, species are shifting their ranges to locations that better match their climatic needs. Range shifts have been documented for a wide array of species ranging from algae to mammals, primarily between the latitudes of 30^{o}N and 60^{o}N (Lenoir and Svenning, 2015; Mason et al., 2015). Settele et al. (2014) concluded that terrestrial and aquatic plant and animal species have moved an average of 17 km per decade poleward or 11 m per decade upward in elevation. However, the response of many species lags behind climate change (Poloczanska et al., 2013; Lenoir and Svenning, 2015). Many species are facing a loss of suitable habitat due to climate change, which will lead to extirpation or extinction if they are unable to migrate (Berteaux et al., 2018). Conversely, some species at poleward limits may benefit from climate change through range expansion; for these species, currently limited at the northern edge of their range by cold climates, warming can open up new habitat space (Berteaux et al., 2018). However, other species in northern latitudes may be outcompeted when new species arrive.

Species composition in protected areas is being altered by climate change. In fact, in the United States, a study by Gonzalez et al. (2018) found a disproportionate impact of climate change inside national parks compared to outside. The majority of protected areas across North America (78.8%) may experience moderate to high forward and reverse climate velocities. Climate velocity is defined as the speed at which a temperature or precipitation isocline moves across the landscape and therefore the pace at which species need to migrate to remain in the same climatic conditions (Batllori et al., 2017; Kosanic et al., 2019). Northern latitudes and eastern Canada face the highest forward and reverse climate velocities (Batllori et al., 2017). Furthermore, Batllori et al. (2017, pg. 3223) state that "the majority of protected areas have outgoing and incoming climates that may terminate or originate outside of the current protected areas network." This means that species will need to migrate over significant distances outside of the protected area network to reach suitable climatic habitat. Additionally, species turnover – a composite measure of immigration and emigration/extinction – in protected areas is projected to increase due to climate change (Lawler et al., 2009). In a study of protected areas in Quebec, Canada, Berteaux et al. (2018) estimated a species turnover of greater than 80% in 49% of total protected area land in Quebec. These findings indicate that most species will need to migrate to new locations in order to track climate change, causing a change in species composition.

Species composition changes will lead to alterations of ecological communities, biodiversity patterns, and ecosystem services, resulting in novel biotic communities (Batllori et al., 2017; Pecl et al., 2017). However, not all species are able to shift their range in response to climate change. Some species may be restricted to isolated areas such as mountain tops or limited by human or natural barriers. Additionally, Jezkova and Wiens (2016) found that the rate of species niche change was much slower than projected rates of climate change for 56 plant and animal species across diverse taxonomic groups worldwide. Moreover, species that are habitat specialists, sedentary, or that live near the extremes of their physiological tolerances are more vulnerable to climate change and have difficulty tracking the climate (Chen et al., 2011; Lurgi et al., 2012; Staudinger et al., 2013). Those species that do not shift their range in response to climate change will need to adapt to avoid fitness losses (i.e., reductions in survival or reproductive rates) (Radchuck et al., 2019). Species unable to adapt by shifting their range may alter the timing of their life history events (phenology) or undergo microevolution (genetic adaptation).

If species are unable to shift their range, they must adapt to new climatic conditions *in-situ*. This can be accomplished through phenotypic plasticity or micro-evolution (Valladares et al., 2014; Matesanz and Ramirez-Valiente, 2019). Phenotypic plasticity allows individuals to adjust their phenotype to environmental variables but these changes are not heritable (Charmantier and Gienapp, 2014). According to Radchuk et al. (2019) (pg. 2) "a phenotypic change qualifies as an adaptive response to climate change if three conditions are met: 1) a climatic factor changes over time, 2) this climatic factor affects a phenotypic trait of a species, and 3) the corresponding trait change confers fitness benefits." Phenotypic plasticity allows species to respond quickly to climate change. Conversely, genetic adaptation is much slower to alter phenotypes than plasticity and occurs when the genetic makeup of a population changes through natural selection (Merila and Hendry, 2014). Genetic adaptation allows species to increase their fitness in response to changing climatic conditions if they are unable to disperse to climatically suitable habitats. Studies have found that evolutionary change can occur rapidly in populations on a time scale appropriate for adaptation to climate change but depends on many factors such as plasticity, fitness, and population size (Hoffmann and Sgro, 2011; Bush et al., 2016; Bay et al., 2017; Razgour et al., 2019).

In addition to range shifts and genetic changes, species are adapting to climate change through changes in the timing of biological events (e.g., reproduction, migration), also referred to as phenological changes (Radchuk et al., 2019). Many species across all trophic levels have shifted the timing of spring events to earlier in the spring with the strongest phenological advancement found in amphibians (Parmesan, 2006; Charmantier and Gienapp, 2014; Radchuk et al., 2019). Amphibian breeding in England is occurring one to three weeks earlier per decade (Parmesan, 2006) and many temperate bird species have advanced their breeding and migration behaviours in recent decades (Charmantier and Gienapp, 2014). Cohen et al. (2018) in their meta-analysis found that animals, on average, have advanced their phenology by 2.88 days per decade since 1950. However, not all species are undergoing adaptive change or adaptive change may not occur quick enough to keep pace with climate change (Radchuk et al., 2019).

Changes in species behaviour and distribution are not isolated processes but rather are connected through interactions with other species at the same or adjacent trophic levels (Walther, 2010; Pecl et al., 2017). Variation in species responses to climate is leading to the decoupling of species-species interactions. This decoupling can result in phenological mismatch (e.g., plants and pollinators, migratory birds and their prey, plants and herbivores) and community instability (Parmesan, 2006; Blois et al., 2013; Renner and Zohner, 2018). For example, in some arctic regions, a mismatch in timing between caribou calving and the availability of peak quality tundra forage plants has increased calf mortality (Post and Forchhammer, 2008). Similarly, increasing mismatch between snow geese hatching and peak forage quality in the Canadian arctic has been responsible for reduced gosling production (Ross et al., 2017). Phenological mismatch, and climate change more broadly, can lead to increased risk to ecosystem functionality and community structure (Thackeray et al., 2016).

1.3.2 Protected Areas

Traditionally, conservation practices have centered around the creation of protected areas. The International Union for Conservation of Nature (IUCN), defines protected areas as “an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means” (IUCN, 1994, p. 7). The term ‘protected area’ encompasses a wide variety of land and water designations including national parks, national marine conservation areas, wilderness areas, migratory bird sanctuaries, wildlife management areas, and community conserved areas. Furthermore, different protected area designations are associated with differing levels of management approaches. These range from highly protected areas where human presence is prohibited, to moderately protected areas where the focus is on conservation with limited visitation, to areas where less restrictive approaches integrate conservation with sustainable resource extraction. These variations are reflected in the IUCN’s six protected areas categories (Table 1.1).

Table 1.1: IUCN protected area categories and definitions (adapted from IUCN, 2013)

Category		Definition
Category Ia	Strict nature reserve	"Strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values." (IUCN, 2013, pg. 13)
Category Ib	Wilderness area	"Large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition." (IUCN, 2013, pg. 14)
Category II	National park	"Large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities." (IUCN, 2013, pg. 16)
Category III	Natural monument or feature	"Category III protected areas set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value." (IUCN, 2013, pg. 17)
Category IV	Habitat/species management area	"Category IV protected areas protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category." (IUCN, 2013, pg. 19)
Category V	Protected landscape/ seascape	"A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values." (IUCN, 2013, pg. 20)
Category VI	Protected area with sustainable use of natural resources	"Category VI protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area." (IUCN, 2013, pg. 22)

1.3.2.1 Protected Area Legislation

Biodiversity conservation is in part rooted in international policy. Canada is a signatory to the United Nations Convention on Biological Diversity (CBD), which was agreed upon at the 1992 United Nations Conference on Environment and Development (UNCBD, 1992). Through this treaty, 193 parties committed to reducing rates of biodiversity loss by 2010. The CBD requires countries to develop a national biodiversity strategy and Canada developed its first Canadian Biodiversity Strategy in 1995 in response to the convention (Environment Canada, 2011). This strategy had the goal of "conserving biodiversity and using biological resources in a sustainable manner" (Government of Canada, 1995, p. 16). The Canadian Biodiversity Strategy provided direction for ecological planning and management that included the creation and management of protected areas, restoration and rehabilitation of species and ecosystems, and the sustainable use of biological resources. In 2010, parties to the CBD agreed on a new set of biodiversity targets to be achieved by 2020 – the Aichi Biodiversity Targets. In response to the new targets, Canada developed the *2020 Biodiversity Goals and Targets for Canada.* Target 1 is: "By 2020, at least 17 percent of terrestrial area and inland water, and 10 percent of coastal and marine areas, are conserved through networks of protected areas and other effective area-based conservation measures" (ECCC, 2016a, p. 6).

1.3.2.2 Canadian Protected Areas

Canada has fallen short of meeting its Aichi Target 11 / Canada Target 1 goal. Currently, Canada's protected areas network covers 11.4% (1,133,947 km^2) of its terrestrial surface and 8.9% (511,906 km^2) of its marine area (ECCC, 2020). These protected areas are managed by various federal departments (i.e, Parks Canada, Environment and Climate Change Canada, Fisheries and Oceans Canada, and Indigenous and Northern Affairs Canada); provincial and territorial governments; Indigenous communities; and environmental non-governmental organizations (ENGOs). Parks Canada, and many other provincial/territorial protected area organizations, use an ecoregion-based approach to situating protected areas (Lemieux and Scott, 2005). For example, Parks Canada aims to establish a system of national parks in all 39 'natural regions' across the country with the goal of preserving a representative sample of each landscape (Parks Canada, 1997). However, to date, the system is only 77% complete with 31 of 39 natural regions protected by 47 national parks (Parks Canada, 2020a) (Figure 1.1).

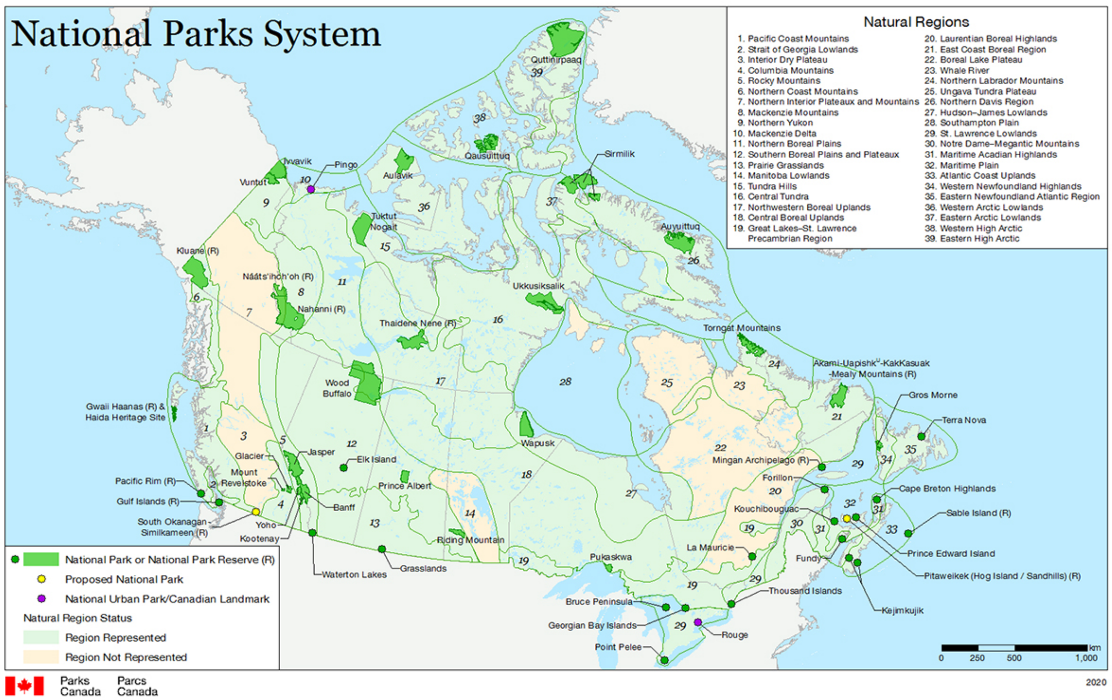


Figure 1.1: Parks Canada national parks systems map showing natural regions and established and proposed national parks. (Source: Parks Canada, 2020a)

In Canada, as well as globally, the number of protected areas has increased dramatically in the past half century (IUCN, 2013; ECCC, 2020). However, in the haste to create protected areas, often to save natural areas from development, protected areas have been set aside without consideration of the resources necessary to preserve their biodiversity (IUCN, 2013). Moreover, due to political and economic realities, the design of the protected areas network has been largely ad hoc (Batllori et al., 2017).

1.3.2.3 Traditional Approaches to Protected Areas Management

Historically, protected areas have been located based on an eco-region representation approach (Lemieux and Scott, 2005), available space, and political feasibility (Hannah et al., 2002), designed to protect specific threatened species (Hagerman and Chan, 2009; Lawler, 2009), and created on an assumption of a static pattern of biodiversity (Hannah et al., 2002; Hole et al., 2009; Tingley et al., 2014; Thomas and Gillingham, 2015). The concept of natural region representation is the basis for Canada's protected areas system plan and allows for examples of major ecosystem types across the country to be conserved (Dasmann, 1972; Parks Canada, 1997; WCPA, 1998). Conserving representative samples of ecosystems is a 'coarse-filter' approach to conservation that focuses on broad physical environments rather than specific species (Peters and Darling, 1985; Hunter et al., 1988). One representation approach to situating protected areas – conserving the stage – is based on underlying geophysical conditions. Conserving the stage is an approach to conservation that aims to conserve diverse geophysical landscapes to allow a diverse range of habitats for current and future species assemblages under various climatic conditions (Anderson and Ferree, 2010; Beier and Brost, 2010). Under a conserving the stage approach, management actions focus on preserving the underlying conditions (the stage) rather than specific species (the actors) (Beier and Brost, 2010). Recent studies have found that conserving geodiverse locations can facilitate species adaptation to climate change and support high biodiversity (Lawler et al., 2015; Bailey et al., 2017; Schrodt et al., 2019).

In the past few decades, there has been an increased recognition that connectivity between protected areas needs to increase to allow species to move between protected areas and to facilitate dispersal, especially in a context of climate change (Groves et al., 2012; McGuire et al., 2016; Saura et al., 2017; Keeley et al., 2019; Resasco, 2019; Hilty et al., 2020). For example, the Adirondack to Algonquin wildlife corridor has been proposed as a means to connect Canada's Algonquin Provincial Park with the United States' Adirondack Park and to encourage the migration of timber wolves and other species between parks (A2A, 2016). Similarly, the Yellowstone to Yukon (Y2Y) Conservation Initiative aims to create a habitat network to ensure wildlife survival over the long term (Chester, 2015). Recent developments in the science behind corridors, and their design, has allowed for any potential drawbacks of corridors, such as increased predator activities and the spread of invasive species, to be minimized and for benefits to be maximized (Hilty et al., 2020). In recognition of the vital importance of corridors to the conservation of biodiversity the IUCN recently released guidelines for corridors and ecological networks to assist with a shift from focusing on the management of individual protected areas to managing protected areas as essential parts of conservation networks (Hilty et al., 2020).

Current conservation practices also rely on ex-situ conservation and ecosystem restoration to maintain biodiversity, although to a much lesser extent than protected area creation. *Ex-situ* conservation aims to protect threatened species outside of their natural habitat (Mawdsley et al., 2009). This typically occurs through captive breeding programs that remove individuals from a threatened population and place them in zoos and aquariums as insurance against threats such as disease and invasive species (Conde et al., 2011; Canessa et al., 2015). Once habitat has been restored through ecosystem restoration, species in captivity can be re-introduced to their native habitat. *Ex-situ* conservation has played a major role in the successful recovery of many species worldwide such as the whooping crane (*Grus americana*) and the California condor (*Gymnogyps californianus*) (Conde et al., 2011; McGowan et al., 2017).

1.3.2.4 Climate Change Implications for Protected Area Management

The current suite of conservation practices has proven successful in some circumstances; however, due to the additional stresses that climate change is placing on biodiversity worldwide, there is growing concern that climate change may challenge a century of conservation efforts (Scott and Suffling, 2000; Hannah et al., 2002; Scott et al., 2002; Lemieux and Scott, 2005; Lemieux et al., 2007; Huntley, 2007; Secretariat of the Convention on Biological Diversity, 2014, Abrahms et al., 2017; D'Aloia et al., 2019). Canadians have made policy decisions to create protected areas that have been designed to safeguard certain species and represent diverse natural regions. As a result of climate change, some of these protected areas may no longer provide suitable habitat for the species they were designed to protect (Suffling and Scott, 2002; Lemieux et al., 2004; Lemieux et al., 2011a).

Conservation practice and policy has operated in much the same way for the past century, focusing on the creation of protected areas. In Canada, conservationists typically use well-established 'conventional' techniques such as preserving habitat, increasing connectivity between protected areas, and establishing captive populations of species that are at risk of extinction (Mawdsley et al., 2009). In light of climate change, biodiversity conservation tools and techniques need to expand, incorporate climate change considerations, and take a more dynamic approach (D'Aloia et al., 2019). While many of the tools required to conserve biodiversity under climate change are already employed by natural resource managers, managers will need to apply these tools in novel and innovative ways. Protected areas and corridors have an important role to play in the suite of conservation tools and remain the most cost-effective tool; however, a more diverse set of tools is required. In the future more interventionist conservation actions, such as assisted migration (Hagerman and Chan, 2009; Peterson and Bode, 2020) and triage-based conservation (Lawler, 2009; Wilson and Law, 2016), may be required to adapt biodiversity conservation policy to climate change.

1.3.3 Climate Change Adaptation

As previous discussions have shown, climate change is a topic of significant concern for protected area managers. Historically, protected areas have been managed under an assumption of a static pattern of biodiversity (Hagerman et al., 2010a; Aplet and McKinley, 2017), which, in a changing climate, is no longer valid (Scott et al., 2002; Abrahms et al., 2017). Current management practices have not taken into account changes in species composition, range shifts, and alterations to ecosystem structure and function. While uncertainty exists regarding the precise impacts of climate change on biodiversity in protected areas, a lack of action could have significant consequences. Therefore, new approaches to protected areas management are imperative. The following section examines climate change adaptation in the context of protected areas.

Climate change adaptation is defined by the IPCC (2014, pg. 118) as "[t]he process of adjustment to actual or expected climate change and its effects… In natural systems, human intervention may facilitate adjustment to expected climate and its effects." The concept of adaptation is intricately linked with adaptive capacity, vulnerability, and resilience. Adaptive capacity is "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014, pg. 118). Related to the concept of adaptive capacity, vulnerability is "the propensity or predisposition to be adversely affected" (IPCC, 2014, pg. 128). The IPCC Fifth Assessment Report (AR5) presents a risk-based framework and defines risk as resulting from “the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems” (IPCC, 2014, pg. 1046) (Figure 1.2). Adaptation strategies aim to reduce the risk of climate-related impacts. Previously, under a vulnerability-based framework, vulnerability was viewed as a function of exposure, sensitivity, and adaptive capacity (Smit and Wandel, 2006) and adaptation was viewed as aiming to reduce vulnerability and increase the resilience of a system (Smit and Pilifosova, 2003). Resilience is defined here as the ability of a system to respond to perturbations and resist damage or change (Holling, 1973).

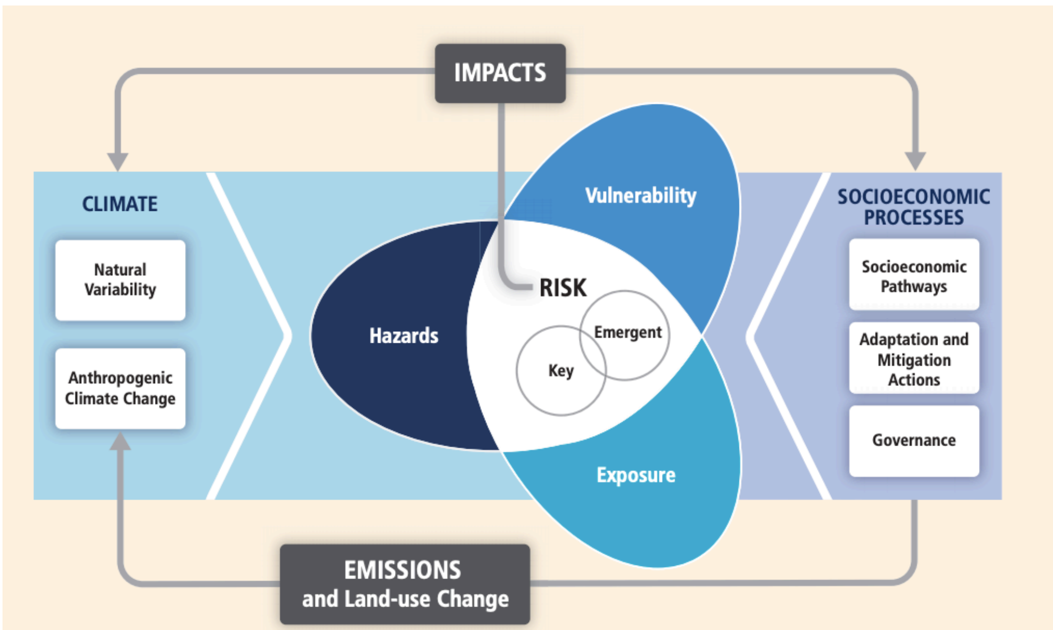


Figure 1.2: IPCC AR5 conceptualization of risk based on the interaction of climate-induced hazards, vulnerability, and exposure. (Source: IPCC, 2014, pg.1046)

1.3.3.1 Approaches to Adaptation

Many different approaches to adaptation exist (Table 1.2). Adaptation can be either proactive (i.e, anticipating and preparing for projected climate change impacts) or reactive (i.e., responding to the impacts of climate change as they occur) (Smit and Pilifosova, 2003). The literature suggests that proactive adaptation results in better outcomes than reactive adaptation (Lemieux et al., 2011a; Bierbaum et al*.,* 2013; Gross et al*.,* 2016). Accordingly, protected area organizations should begin to take steps to plan for future ecosystem changes. Additionally, adaptation can be autonomous or planned (West et al., 2009). Autonomous adaptation occurs when species have a biological reactive response to changing climatic conditions and does not involve human intervention (IPCC, 2007). Conversely, planned adaptation refers to actions that society takes to manage systems either in anticipation of or in reaction to changed conditions (IPCC, 2007). To plan adaptation actions to manage for a desired future ecosystem state, protected area organizations need to anticipate the autonomous adaptation of species and ecosystems.

Table 1.2: Categorization of adaptation strategies (adapted from Burton, 2008).

Based on	Type of adaptation	
Intent	Autonomous	Planned
Action	Reactive	Proactive
Degree of change	Incremental	Transformative
Aim	Resist change	Direct change
Novelty	Conventional	Interventionist
Spatial scope	Localized	Widespread
Temporal scope	Short term	Long term

Adaptation can be further dissected into incremental and transformative adaptation. Typically, adaptive responses are incremental ones to cope with climate change; however, these coping strategies are not always effective at reducing vulnerability to severe climate change impacts (Fedele et al., 2019). Transformative adaptation, on the other hand, refers to "fundamental changes in structural, functional, relational, and cognitive aspects of socio-technical-ecological systems that lead to new patterns of interactions and outcomes" (Patterson et al., 2017, pg. 2). When drivers of change, such as climate change, cause a shift from historic ecosystems to alternative ecosystem states, transformative adaptation could aid in directing these transitions and preserving ecosystem function (Colloff et al., 2017).

Strategies to address the impacts of climate change in the field of conservation biology can be categorized according to whether they resist change or direct change (Stein et al., 2014; Fisichelli et al., 2016a; Prober et al., 2019). Those that resist change aim to reduce stressors on species and maintain historical ecosystem composition whereas strategies that direct change aim to transform the ecosystem to a new suitable state in response to change (Fisichelli et al., 2016a; Prober et al., 2019). Strategies can also be categorized by their novelty and level of risk – conventional or interventionist (Tam and McDaniels, 2013; Hagerman and Satterfield, 2014) (Table 1.3). Conventional strategies are those that have been used historically, that are generally low risk, and that provide benefits regardless of realized climate impacts (e.g., establishing protected areas, reducing other threats). In contrast, interventionist strategies are typically more controversial and associated with higher risk due to their novelty, lack of historical analogues, and potential for unanticipated negative consequences (e.g., conservation triage, assisted migration) (Tam and McDaniels, 2013; Hagerman and Satterfield, 2014; Prober et al., 2019).

Table 1.3: Broad adaptation strategies for biodiversity conservation arranged from conventional to interventionist.

Adaptation Strategy	Definition
Establish protected areas (Lawler, 2009; Mawdsley et al., 2009; Lemieux et al., 2011a; Diaz et al., 2019; Elsen et al., 2020; MacKinnon et al., 2020)	Increase the size and number of protected areas.
Increase connectivity (Groves et al., 2012; McGuire et al., 2016; Saura et al., 2017; Keeley et al., 2019; Resasco, 2019; Hilty et al., 2020)	Reduce barriers to migration to allow species to shift their distribution in response to climate change. This can be achieved by modifying the size, placement, and number of protected areas, altering the shape of protected areas, creating linkages between protected areas, and enhancing land management.
Reduce other threats (Mawdsley et al., 2009; Lawler, 2009; Thomas and Gillingham, 2015)	Remove other non-climate related stressors such as invasive species, pollution, fragmentation, and overexploitation.
Conserve the stage (Anderson and Ferree, 2010; Beier and Brost, 2010; Anderson et al., 2015; Comer et al., 2015; Lawler et al., 2015)	Preserve underlying geophysical conditions and focus on preserving areas with high geophysical diversity (e.g., bedrock, soils, topographic positions, elevation). This approach focuses on the physical environment (the stage) rather than specific species (the actors).
Identify and protect refugia (Ashcroft et al., 2012; Morelli et al., 2016; Michalak et al., 2018; Stralberg et al., 2018)	Climate refugia are areas within a broader landscape that maintain favourable climates despite changes in the climate in the surrounding landscape. These areas can allow species to persist longer in an area as the climate changes.
Focus on ecosystem function (Groves et al., 2012; Staudinger et al., 2013)	Preserve ecosystem function over historical species assemblages.
Conservation triage (Bottrill et al., 2008; Lawler, 2009; Mawdsley et al., 2009; Wilson and Law, 2016)	Prioritize the allocation of resources to maximize conservation returns and preserve species of high ecological importance.
Dynamic reserves (Rayfield et al., 2008; Hagerman and Chan, 2009; D'Aloia et al., 2019)	Accept dynamic, changing ecological patterns and processes. Protected area boundaries and level of protection varies throughout time and space.
Assisted migration (Mawdsley et al., 2009; Schwartz et al., 2012; Gallagher et al., 2015)	Move species outside their historic range to areas where the climate is more suitable.

1.3.3.2 History of Adaptation

Historically, interest in adaptation was low and a debate between mitigation and adaptation existed. There was concern that discussing adaptation would detract from addressing the root cause of climate change (Burton, 1996; Schipper, 2006) and that action on adaptation could be seen as an admission of responsibility by developed countries (Verheyen, 2002; Klein et al., 2017). A lack of certainty regarding anthropogenic climate change in early IPCC reports also contributed to the reduced interest in adaptation (Schipper, 2006). More recently, adaptation has been recognized as a legitimate policy response and the IPCC Fifth Assessment Report identified adaptation as part of the planning process (IPCC, 2014).

Since its emergence in the 1990s, adaptation policy and practice has evolved, shifting from theory to implementation. Klein et al. (2017) describe four generations of adaptation policy and practice. Adaptation research began as descriptive in nature with the identification of impacts as its objective. The second generation of adaptation research (early 2000s) shifted towards incorporating social dimensions and asking normative questions. Policy and financial mechanisms to support adaptation actions became the emphasis of the third generation. Following the 2015 Paris Agreement, the fourth (present) generation of adaptation research emerged, centering on implementation of adaptation and disaster risk reduction. Despite progression towards implementation, action – particularly in the case of biodiversity conservation – remains limited. Significant barriers to the implementation of adaptation exist (Biesbroek et al., 2013; Eisenack et al., 2014). Adaptation research can also be divided into research 'for' adaptation and research 'on' adaptation. Research 'for' adaptation aims to inform adaptation action whereas research 'on' adaptation aims to explain the process of adaptation – how and why adaptation decisions are made (Adaptation Futures, 2016). The majority of the protected areas adaptation literature focuses on research 'for' adaptation whereas this dissertation focuses on research 'on' adaptation.

In the protected areas context, climate change became a concern to the Conference of the Parties of the United Nations Convention on Biological Diversity (UNCBD) in the early 2000s and in response the IPCC technical paper on *Climate Change and Biodiversity* was produced (IPCC, 2002). This report concluded that the placement and management of protected areas needs to take into consideration the impacts of climate change. Similarly, the

International Union for the Conservation of Nature's (IUCN) World Commission on Protected Areas (WCPA) recognized climate change as a threat to protected areas in 1992 (McNeely, 1992). The UNCBD and IUCN WCPA have continued to emphasize the need to adapt to the impacts of climate change, thereby moving from identifying climate change as a theoretical concern to a major threat to biodiversity worldwide and calling for networks of protected areas connected by ecological corridors (UNCBD, 2018; IUCN, 2019).

In the early 2000s, Canada was a leader in protected areas adaptation research (Scott and Suffling, 2000; Scott et al., 2002; Suffling and Scott, 2002; Scott and Lemieux, 2005; Lemieux and Scott, 2005; Scott and Lemieux, 2007; Lemieux et al., 2010; Lemieux and Scott, 2011; Lemieux et al., 2011a; Lemieux et al., 2011b; Gray et al., 2011). Since then the rate and frequency of Canadian publications related to adaptation in protected areas has decreased. As knowledge regarding climate change science has changed since the early 2000s, it is time for an update on the status of climate change adaptation in Canadian protected areas. Additionally, it is important to monitor for organizational change in response to climate change and to re-evaluate planning and management implications of climate change for Canadian protected areas.

1.3.3.3 Adaptation Monitoring and Evaluation

Through the Paris Agreement, countries are required to track and report on adaptation. Yet, assessing and comparing climate change adaptation progress at the global level is difficult due to different approaches to tracking and reporting on adaptation (Lesnikowski et al. 2017). Furthermore, reporting on adaptation tends to focus on planning and implementation rather than the effectiveness of actions in terms of reducing vulnerability (Morecroft et al., 2019). Recently, Canada developed indicators for monitoring progress on climate change adaptation, joining other countries such as Finland, Germany, the United Kingdom, Austria, France, and Australia who have developed national adaptation monitoring programs (ECCC, 2018). However, none of these indicators are ecologically based or related to biodiversity conservation.

A systematic review of National Communications submitted to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat found that progress has been made on conducting impact and vulnerability assessments and on adaptation research, but that progress is limited in terms of implementation of adaptation initiatives (Lesnikowski et al., 2015). Lesnikowski et al. (2015) found that Canada is a leader in adaptation action, along with Australia, Belgium, Finland, Italy, Mexico, New Zealand, Saint Lucia, South Korea, Spain, United States, and Uruguay. Although Canada is a leader in adaptation, progress varies at the provincial level. A study by Austin et al. (2015) found varied levels of climate change adaptation in the health sector across Canadian provinces, with Quebec having a significantly higher number of health adaptation initiatives than other provinces. Similarly, in the United States, progress on implementation of adaptation plans varies by state (Ray and Grannis, 2015).

Consistent with the finding of Lesnikowski et al. (2015) that Australia is a leader in adaptation, Palutikof et al. (2019), through an analysis of Australian conference abstracts, found that there has been a shift from planning to implementation of adaptation actions as well as a shift in sectoral focus from the natural environment to utilities and the built environment. This shift in sectoral focus indicates that more progress on adaptation is being made in the municipal and human context than in the natural resource context. In the health sector, Berry et al. (2018) found that the number of countries, both developed and developing, completing climate change and health vulnerability and adaptation assessments has increased in recent years. Similarly, in the water sector, Kamperman and Biesbroek (2017) found an increase in action on climate change adaptation by Dutch water boards but that most adaptation efforts are still at the groundwork level. Limited progress on adaptation has been found in US national parks (Nelson, 2015), the Arctic (Canosa et al., 2020), and in US national forests (Halofsky et al., 2018).

1.3.3.4 Barriers to Adaptation

Due to practical constraints, many proposed adaptation strategies may not be feasible, and as adaptation research transitions from theory to implementation, barriers are being discovered (Azhoni et al., 2018; Keeley et al., 2019). Barriers are defined here as “impediments that can stop, delay, or divert the adaptation process” (Moser and Ekstrom, 2010, pg. 2). Examples of barriers to adaptation include lack of funding (Bierbaum et al., 2013; Ekstrom and Moser, 2014); lack of information (Ekstrom and Moser, 2014); lack of political support and leadership (Ekstrom and Moser, 2014; Lonsdale et al., 2017); and competing priorities (Measham et al., 2011). Overcoming and reducing barriers will allow adaptive capacity to increase; however, the presence of capacity does not in itself guarantee that successful adaptation will occur (Adger and Barnett, 2009; Burch, 2010). In fact, adaptive capacity needs be harnessed and used effectively. Most barriers are not related to a lack of capacity but rather to how existing capacity can be translated into action (Burch, 2010; Azhoni et al., 2018).

1.3.3.5 Adaptation Readiness

Effectively translating capacity into action requires adaptation readiness. The concept of adaptation readiness refers to the preparedness of an organization (or human systems more broadly) to respond to the challenges associated with climate change. It is also an indication of the likelihood that adaptation will occur. Adaptation readiness is viewed as a complementary concept to adaptive capacity, which represents an organization's theoretical ability to adapt (Ford and King, 2015; Tilleard and Ford, 2016; Araos et al., 2017). However, adaptation readiness goes beyond adaptive capacity to examine if measures are in place to allow for adaptation to occur. It asks whether political and social will for adaptation are present, and whether conditions are suitable by examining the strength and existence of various governance structures that determine ability to carry-out adaptation (Ford and King, 2015; Tilleard and Ford, 2016). Assessing the adaptation readiness of protected area organizations (Chapter 4) provides insight into where resources can be directed to enhance preparedness to implement adaptation strategies.

1.3.4 Summary

Climate change is affecting biodiversity and the management of protected areas in numerous ways (Bellard et al., 2012). In light of climate change, a more future-oriented perspective towards conservation is required than the traditionally historically-focused perspective (van Kerkhoff et al., 2019). The conservation community largely agrees that practices need to change (Lemieux and Scott, 2011; Abrahms et al., 2017), yet achieving that change remains problematic. The uptake of climate change adaptation by the protected areas community, and scholarly publication on the topic, remains limited compared to other sectors (e.g., water, agriculture, urban planning). The scholarly literature that does exist regarding climate change adaptation in protected areas is largely theoretical with little empirical analysis of the effectiveness and feasibility of adaptation strategies or detailed case studies of implemented adaptation strategies. To make progress on climate change adaptation inside protected areas, climate change considerations need to be mainstreamed into protected areas management. This dissertation attempts to advance climate change adaptation in protected areas.

1.4 Research Approach and Methods

This section presents an overview of the methodological approach used to meet larger study objectives. A mixed qualitative and quantitative methods design was used to address the three research aims. The individual manuscripts form data chapters, and each manuscript has a methods section detailing the approach used to meet the respective manuscript's specific objectives. Manuscripts were motivated by and built from findings in the preceding manuscript(s) (chapters).

The theoretical underpinning of my research is at the nexus of social-ecological systems theory and complex adaptive systems with a focus on governance, decision-making under uncertainty, and resilience. Protected areas are social-ecological systems because they are human constructs heavily influenced by both social and ecological considerations (Cumming et al., 2015). Social-ecological systems theory emphasizes the interconnected nature of human and natural systems and assists in understanding the complex whole (Berkes and Folke, 1998; Ostrom, 2009). Protected areas can also be thought of as complex adaptive systems as the behaviour of the system is more complex than the sum of its parts and perfect understanding of individuals parts (e.g., species) does not lead to perfect understanding of the whole (e.g., the ecosystem) (Holland, 1992). Climate change adds another layer of complexity and uncertainty to protected areas management which necessitates decision-making under uncertainty. Taking a holistic social-ecological systems perspective is necessary to understand climate change adaptation in a protected areas context as protected areas are managed by human actors and are vulnerable to drivers of both social change (e.g., political change, economic change) and ecological change (e.g., changes in species composition) (Cumming et al., 2015). Accordingly, this research uses approaches that aid with decision-making under uncertainty to examine climate change adaptation in protected areas from a social-ecological systems perspective by taking into account uncertain drivers of both social and ecological change.

Initially, a survey was conducted of protected area organizations across Canada to assess the current state of climate change adaptation in Canadian protected areas (*Aim 1 / Chapter 2*). The survey was modelled on a similar survey conducted by Lemieux et al. (2011b) in 2006 to allow progress on adaptation to be measured. In addition to being cost effective compared to other methods (e.g., interviews), surveys enable research over a large geographic area (Hay, 2010). In this case, the use of a survey also improved comparability with data from Lemieux et al. (2011b). A weakness of surveys is that they may be inflexible and provide superficial coverage of complex topics (Babbie, 2004). To overcome this weakness, some open-ended questions were included to allow participants to expand upon their answers to the closed questions and provide further insights. Open-ended questions also help overcome the assumption that words and concepts carry the same meaning for all participants, which may not be the case, and allow participants to express their opinions in their own terms (Hay, 2010). Purposive sampling was used to recruit participants from protected area organizations across the country, ranging from federal government departments to provincial/territorial government departments to non-governmental organizations. Data analyses were primarily quantitative with qualitative findings providing corollary support.

Building off the nation-wide survey, a case-study approach was taken for Chapters 3 and 4. Each protected area faces its own suite of unique climate change impacts, challenges, and needs; consequently, the suitability of adaptation options will vary on a case by case basis. Therefore, the evaluation of adaptation options needs to take place at the local scale with close consideration of regional drivers of change. Accordingly, Aim 2 – to gain insight into practitioner preferences for adaptation (*Chapter 3*), and Aim 3 – to gain insight into the adaptation readiness of protected area organizations (*Chapter 4*) were evaluated in a case study context of the Bruce Peninsula National Park (BPNP) and Fathom Five National

Marine Park (FFNMP). BPNP/FFNMP was chosen as the case study location because park staff had been primed on the topic of climate change through having a national office climate change staff member on site. Additionally, the parks' close proximity to the University of Waterloo made travel for data collection logistically and financially convenient. Due to the COVID-19 pandemic, as of March 2020, field work was no longer possible as travel was restricted. A case study description for BPNP/FFNMP is provided in Chapters 3 and 4.

To gain insight into practitioner preferences for adaptation strategies (*Aim 2 / Chapter 3*), I collected data in association with a two-day workshop hosted, organized, and run by BPNP/FFNMP. Workshop participants represented various organizations including all levels of government, academia, and NGOs; they had knowledge of the local area and conservation; and they were experts in their fields. The workshop followed a scenario-planning approach whereby participants identified drivers of change and envisioned plausible future scenarios. For each scenario, participants identified climate change impacts within the park as well as adaptation strategies to address each impact. Scenario planning has the benefit of allowing for creative thinking about complex and uncertain futures to aid in the development of long-term strategies (Daconto and Sherpa, 2010; Polasky et al., 2011; Star et al., 2016). It also allows for thinking beyond norms and exploring a wide set of alternative futures to help overcome biased views of the world (Baron et al., 2009; Daconto and Sherpa, 2010; Rounsevell and Metzger, 2010). This approach lets participants break free of traditional conservation approaches and consider a wide variety of adaptation strategies. To analyze the workshop data, I applied a typology to adaptation strategies identified in the workshop and coded qualitative data using applied thematic analysis (Guest et al., 2012).

Following the adaptation strategies workshop, it became apparent that there was a need to assess the adaptation readiness of BPNP/FFNMP (*Aim 3 / Chapter 4*) to implement the adaptation strategies identified in the previous workshop. To assess adaptation readiness, I used a mixed methods approach by conducting a quantitative online survey of park staff and a qualitative post-survey workshop. A mixed methods approach combines the strengths of quantitative and qualitative approaches to address complex research problems (Plano Clark, 2017). Once the survey was closed, results were compiled and quantitatively analyzed. Additionally, results were thematically analyzed, and workshop questions were developed based on survey results. The workshop was designed to allow for learning amongst participants regarding aspects of park management they may have been unfamiliar with and to gain insight into survey responses. Together, survey and workshop results allowed inferences to be made regarding BPNP/FFNMP's adaptation readiness and for organizational strengths, weaknesses, and areas for improvement to be identified.

1.5 Dissertation Structure

This dissertation is structured in a 'manuscript' style that addresses the three aims of the work. The thesis offers an introductory chapter, three data chapters, and a concluding chapter according to the guidelines set out by the University of Waterloo. This introductory chapter (*Chapter 1*) describes the conceptual problem this dissertation addresses and contains the purpose and objectives of my dissertation as well as an overview of the methodological approach.

In the first data chapter, I examine progress on adaptation in Canadian protected areas over the past decade (*Aim 1*), a study that was published in the peer-reviewed journal *The Canadian Geographer* in 2020 (*Chapter 2*).

In the second data chapter, I examine practitioner preferences for climate change adaptation options (*Aim 2*) and the perceived effectiveness and feasibility of those options (*Chapter 3*). This manuscript has been submitted for publication to the peer-reviewed *Journal of Environmental Planning and Management*.

The third data chapter examines the adaptation readiness of the Bruce Peninsula National Park and Fathom Five National Marine Park to adapt to the impacts of climate change (*Aim 3 / Chapter 4*).

The formatting of these manuscripts has been modified to adhere to the requirements for this dissertation; however, no changes have been made to the content of these manuscripts. These data chapters are followed by a concluding chapter where the conceptual findings of Chapters 2 through 4 are brought together, the main findings of the data chapters are summarized, and overall recommendations are provided (*Chapter 5*). Finally, limitations of this research are discussed and ideas for future research are presented. A compiled reference list is provided after the concluding chapter.

Chapter 2

Assessing Climate Change Adaptation Progress in Canada's Protected Areas Sector

2.1 Abstract

Climate change represents a new era for protected areas and biodiversity conservation. With the redistribution of species and unparalleled declines in biodiversity, business as usual practices are unlikely to be effective. Despite progress on many facets of establishing, protecting, and managing protected areas over the past century, some of which may help to lessen or slow the impacts of climate change on biodiversity, more targeted efforts need to be developed and implemented to address growing climate challenges. Recently, there has been a move towards adaptation tracking, monitoring, and evaluation. To assess progress on climate change adaptation, a survey was distributed to provincial, territorial, and federal governments as well as environmental non-governmental organizations (ENGOs) working in conservation in Canada (n=49). Findings indicate that little progress has been made on adaptation in Canada's protected areas sector, despite greater certainty about the impacts of climate change. Differences in monitoring, adaptation strategies, and key barriers exist across organizations. Importantly, the majority of organizations continue to report they lack capacity to address climate change issues affecting protected areas and face persistent barriers to implementing adaptation strategies. Recommendations to increase adaptation include enhancing knowledge mobilization, implementing a national adaptation strategy, and developing more flexible conservation objectives.

2.2 Introduction

Protected areas represent one of the most effective ways to conserve biodiversity and have formed the cornerstone of conservation for the past century (Watson et al., 2014; UNEP, 2010; Secretariat of the Convention on Biological Diversity, 2014). Currently, protected areas cover 11.4% of Canada's terrestrial surface and 8.9% of its marine area (ECCC, 2020). These protected areas are managed by various federal departments (Parks Canada Agency

(PCA), Environment and Climate Change Canada, Fisheries and Oceans Canada, and Indigenous and Northern Affairs Canada), provincial and territorial governments, and ENGOs. Aichi Target 11 calls on parties to ensure that by 2020 17% of terrestrial and inland waters "are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures" (UNEP, 2010). However, climate change is challenging the effectiveness of protected areas, exacerbating existing threats, causing species redistribution, and leading to an unprecedented decline in biodiversity (Tittensor et al., 2014; Urban, 2015; Pecl et al., 2017; WWF, 2020).

Past and current methods of biodiversity conservation may no longer be sufficient in an era of accelerating climate change, particulary strategies that aim to maintain historical conditions. According to the Secretariat of the Convention on Biological Diversity (2014), "today's protected areas will not be adequate to conserve many species whose distributions will shift in the future due to climate change." Despite conservation efforts, biodiversity has continued to decline over the past decades (Tittensor et al*.,* 2014; IPBES, 2019; WWF, 2020). Some conservation practices assume a static pattern of biodiversity (Hagerman et al., 2010a), which, in a changing climate, is no longer valid (Scott et al., 2002; Abrahms et al*.,* 2017). This assumption leaves protected areas vulnerable to the impacts of climate change.

Many adaptation strategies proposed in the literature have yet to be implemented in practice (Armsworth et al., 2015). A gap exists between science and practice with current science not being employed by all protected area managers. Canada's current approach to climate change adaptation in protected areas is not coordinated, with individual organizations developing their own strategies. In contrast, Canada's approach to Aichi Target 11, through Pathway to Canada Target 1, is a much more targeted one with coordinated and concerted efforts set in motion by political officials and senior decision-makers (Biodiversity Convention Office, 1995; ECCC, 2016a; ECCC, 2016b; Standing Committee on Environment and Sustainable Development, 2017; Government of Canada, 2018a). However, climate change has not been explicitly factored into the Convention on Biological Diversity / Aichi Strategic Plan. This is a strategic limitation in Canada's trajectory for establishing, planning, and managing protected areas and networks of protected areas in Canada. A formalized strategic plan for climate change adaptation would aid in reducing the vulnerability of Canada's protected areas to the impacts of climate change.

Increasing adaptive capacity (decreasing vulnerability) will necessitate the updating of conservation practices; however, doing so is hampered by uncertainty about species responses to climate change, especially in light of related unknowns such as the rate of change, ecological impacts, and possible policy responses (Bellard et al., 2012; Kujala et al., 2013). Uncertainties, which add complexity to conservation decision-making and the implementation of appropriate conservation strategies, may in part be addressed by the use of multiple and varied approaches. Climate change adaptation strategies for biodiversity can be grouped into two categories, conventional and interventionist. Conventional adaptation strategies are generally low risk, familiar to practitioners, and provide benefits regardless of the realized future climate. Interventionist conservation strategies, such as assisted migration (Schwartz et al., 2012; Gallagher et al., 2015) and triage-based conservation (Bottrill et al., 2008; Wilson and Law, 2016), by contrast, due to their novelty and lack of historical analogues, can bring increased risk and unanticipated consequences (Heller and Zavaleta, 2009; Tam and McDaniels, 2013). Due to the impact climate change is now having on biodiversity, successful biodiversity conservation requires adaptation through the implementation of a combination of strategies to mitigate uncertainty and risk and a change in conservation practice.

Adaptation policy and practice has evolved over time since its emergence in the 1990s (Klein et al., 2017). According to Klein et al. (2017), initially, adaptation research was descriptive in nature, with a focus on identifying impacts. In the early 2000s, the second generation of adaptation research began to shift towards incorporating social dimensions and asking normative questions. The emphasis of the third generation was on policy and financial mechanisms to support adaptation actions. Currently, the fourth generation of adaptation research, following the 2015 Paris Agreement, centres on implementation of adaptation and disaster risk reduction. Furthermore, the Paris Agreement calls for documentation of adaptation progress; however, challenges have prevented substantive progress on adaptation tracking (Ford et al., 2015; Berrang-Ford et al., 2019).

As a consequence of practical constraints, the implementation of many proposed adaptation strategies may not be feasible, and as adaptation research transitions from concept to implementation, barriers are being discovered (Azhoni et al., 2018; Keeley et al., 2019). Barriers can be defined as "obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc." (Moser and Ekstrom, 2010) and distinguished from limits as something that can be overcome compared to a limit, which cannot (Eisenack et al., 2014; Klein et al., 2014). These obstacles add an extra layer of complexity to adaptation and can delay, halt, or derail the process of developing and implementing adaptation strategies. Identifying, overcoming, and reducing barriers will allow for adaptive capacity to increase.

Organizations are the primary actors in protected areas decision-making. Differences in organizational cultures may lead to different perceptions of and responses to climate change (Berkhout, 2012). Additionally, Lemieux et al. (2018) found that Canadian protected areas managers heavily rely on internal knowledge and assessments when making decisions rather than peer-reviewed literature or assessments by other organizations. This contributes to the science-policy gap whereby practitioners are relying on internal information rather than seeking out the best available science to base their decisions on. Due to the wide variety of organizational types (federal, provincial, ENGO) involved in protected area decision-making in Canada, and a lack of knowledge sharing, a single approach to conservation and adaptation may not be feasible.

A study conducted in 2006 by Lemieux et al. (2011b) found that Canada's protected areas agencies lack capacity to respond to the impacts of climate change and had taken little action. The Lemieux et al. (2011b) study provides a benchmark from which to evaluate adaptation progress. Building on their study, with the interest of monitoring progress that has emerged since that initial study, this paper's objectives are as follows: i) to determine the current state of climate change adaptation in Canada's protected areas sector, ii) to evaluate progress over the past decade, iii) to examine whether institutions perceive climate change differently or have different responses to climate change, and iv) to identify barriers to adaptation in Canada's protected areas sector. To do this, a survey of fifty federal, provincial, and territorial governments and ENGOs with a role in protected area decision-making was conducted.

2.3 Methods

This project builds upon a previous survey conducted in 2006 (Lemieux et al. 2011b), with 17 of 27 questions being repeated and new questions being developed in consultation with the Canadian Council on Ecological Areas (CCEA). Questions were designed to assess agencies' perceptions of climate change, responses to climate change, capacity to address impacts, and barriers to adaptation (Appendix A). Primarily closed-ended questions (i.e., Likert scale) were used because they can be statistically analyzed and allow for enhanced comparability. A weakness of surveys is that they may be inflexible and provide superficial coverage of complex topics (Babbie, 2004). To overcome this weakness, some open-ended questions were used to allow participants to expand upon their answers to the closed questions and provide further insights. The inclusion of open-ended questions also helps to overcome the assumption that words and concepts carry the same meaning for all participants, which may not be the case, and it allows participants to express their opinion in their own terms (Hay, 2010).

Prior to distribution, a committee of advisors reviewed the survey, and we conducted a pre-test (n=4) to assess clarity and appropriateness of questions. Following Dillman's survey methodology we attempted to maximize the response rate by adopting the following approach i) sending a notification letter informing participants of the research and alerting them to the survey's arrival; ii) ensuring the survey was concise; iii) sending a reminder letter two to three weeks after initial distribution; and, iv) allowing ample time for participants to complete the survey (Dillman, 2007; Hay, 2010). Qualtrics was used to administer the survey, including inviting participants. As suggested by Dillman (2007), an endorsement of the survey by the CCEA was included in the survey cover letter to enhance credibility and increase participation. Follow up emails were sent directly to participants. Participants originally had two months to complete the survey, but we had to extend this to six months to increase the response rate. The survey was available to participants from February to July 2018. Ethics approval for this survey was obtained from the University of Waterloo Office of

Research Ethics (ORE# 22445).

We used purposive sampling with survey participants chosen based on their position within an agency, jurisdiction, or organization that has a role to play in establishing, planning, and/or managing protected areas in Canada (Appendix B). CCEA jurisdictional representatives (representatives of each province and territory appointed to the CCEA) were chosen to represent the provinces and territories, and other agencies were selected to represent various jurisdictional and geographic scales across Canada (i.e., federal, regional, and non-governmental organizations). Respondents were asked to forward the survey to a colleague within their organization if they felt they were not the appropriate person to respond. We distributed surveys to 93 organizations and were able to resurvey 57% of organizations surveyed in 2006 and added seven new ones. Additionally, sending the survey to all of Canada's national parks, resulted in a sub-sample of 22 national parks, with 1 additional Parks Canada respondent representing a national perspective.

Quantitative results were analyzed in SPSS version 25. To determine if responses varied between 2006 and 2018, we used independent samples *t*-tests and descriptive statistics to examine whether a statistically significant change occurred in how participants responded to questions. When multiple choice options for a particular question varied between years (i.e., some survey questions in 2018 had an unsure option that was not present in the 2006 survey), the unsure responses were excluded from analysis. Independent samples *t*-tests were used to determine if there were significant differences in how organizations responded to questions. Comparisons between 2006 and 2018 included one PCA response from a head office employee representing the whole of PCA, whereas organizational comparisons used the entire PCA subsample with each respondent answering on behalf of their national park.

Assumptions of independent samples t-tests include independence of observations, normality or near normality for sample sizes less than 25, and equal variance (De Veaux et al., 2006). The survey data meets the first two assumptions as participants are unique between groups (i.e., year (2006 versus 2018) and organization type) and the sample size is greater than 25. SPSS conducts Levene's test for equal variances when running an independent samples t-test and reports t-test results under both conditions (i.e., equal variances assumed and equal variances not assumed). If the significance value of Levene's test for equal variance was greater than 0.05, t-test values under the assumption of equal variances were used and vice versa. SPSS automatically corrects the t-test calculation when equal variances cannot be assumed by using un-pooled variances and correcting the degrees of freedom (SPSS, 2020).

2.4 Results

We received 49 responses to our survey, for a 53% response rate. Sample sizes vary among questions as not all respondents answered every question (Appendix C). By organization type, the response rate was 50% (n=23) for the federal government (PCA), 85% (n=11) for provincial governments, and 44% (n=15) for ENGOs. Participants represented Parks Canada, most provincial governments (except Saskatchewan and Prince Edward Island), and key ENGOs. Geographically, all regions of Canada were represented (Figure 2.1). Compared to the Lemieux et al. (2011) study, the previous study successfully surveyed every provincial/territorial protected area agency whereas this study is missing two provinces. Both studies have an Ontairo-centric focus due to the realities of Canada's population distribution.

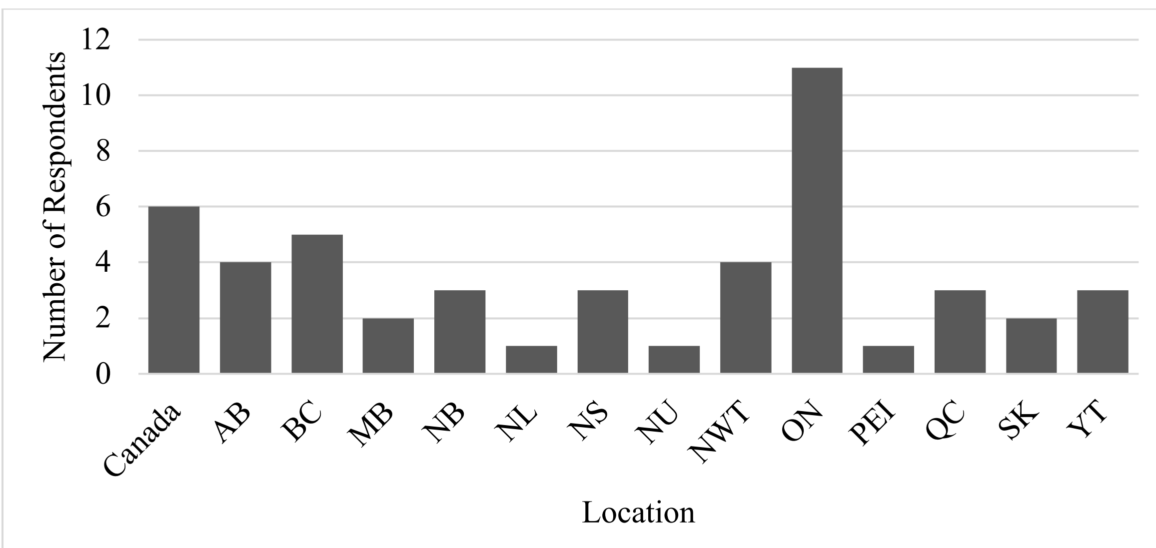


Figure 2.1: Geographic location of survey respondents. Canada indicates that the respondent's organization works across Canada.

2.4.1 Have we made progress over the past decade?

We detected little variation between 2006 and 2018 in respondent perceptions regarding the current relevance of climate change to protected area planning and management with a similar percentage of respondents indicating that it is currently relevant (91% and 89%, respectively, t=-0.330, df=60, p=0.742). Although these results indicate that respondents consider climate change to be pertinent, and 71% of 2006 respondents thought that they would substantially alter their practices over the next decade in response to climate change, only 26% of 2018 respondents indicated that it had already substantially altered their practices. Similarly, 74% of 2018 respondents foresee policy and planning changes in the next decade (t=0.442, df=58, p=0.330).

Among ten management issues facing protected areas, such as exotic species, visitor stresses, and pollution, climate change ranked tenth in order of importance in 2006 and tied for eighth place with water quality/air quality in 2018. In 2006 and 2018, when asked the same question for 25 years in the future, participants increased their ranking of climate change to share second place with human land-use patterns in 2006, and external threats and rare/endangered species management in 2018 (Table 2.1).

Table 2.1: Canadian protected areas agencies' perceived importance of management issues now and 25 years in the future (based on median of rankings, 1 being more important, 10 being least important). A "t" indicates a tie in ranking.

Protected Area Management Issue	Perceived Importance			
	2018		2006	
	Present	25 years in future	Present	25 years in future
Human land-use patterns	1	1	2	2(t)
External threats	2	2(t)	1	1
Rare/endangered species management	3	2(t)	3	4(t)
Visitor stresses	4	7(t)	4(t)	9(t)
Wildlife management	5(t)	5(t)	4(t)	4(t)
Exotic species (animal and plant)	5(t)	5(t)	7	6(t)
Disturbance frequencies	5(t)	7(t)	8(t)	8
Climate change	**8(t)**	**2(t)**	**10**	**2(t)**
Water quality/air quality	8(t)	9	4(t)	6(t)
Contamination/pollution	10	10	8(t)	9(t)

Although the percentage of agencies monitoring climate change impacts did not increase significantly from 2006 to 2018 (34% and 52%, respectively, t=1.389, df=60, p=0.170), some of them developed indicators over that period (14% and 41%, respectively, t=2.330, df=45, p=0.024). Despite a lack of monitoring, changes are nevertheless being observed. A similar percentage of respondents, in both 2006 and 2018, noted that they are observing climate change impacts in their jurisdiction (73% and 74%, respectively, t=0.223, df=55, p=0.824). However, an increase in organizations observing changes in disturbance regimes occurred from 2006 to 2018 (41% and 75%, respectively, t=-2.332, df=40, p=0.025) and though more of them also detected changes in i) species composition, ii) species range shifts, iii) physiography, and iv) tourism/recreation, these changes were not significant.

Perceived uncertainties regarding climate change have decreased from 2006, with fewer respondents indicating that uncertainty was too high to develop adaptation strategies in 2018 (31% and 4%, respectively, t=-2.985, df=50, p=0.004). Despite this decrease, action remains low, with 85% of respondents in both 2006 and 2018 reporting that their agency had not completed a comprehensive assessment on potential climate change impacts and implications for protected areas policy and management (t=-0.012, df=59, p=0.991). Furthermore, a similar percentage of respondents in 2006 and 2018 denoted that no person was responsible for climate change issues in their agency (45% and 52%, respectively, t=-0.274, df=60, p=0.785).

Progress does appear to have been made in the incorporation or consideration of climate change in protected area management plans, with 18% of respondents in 2006 indicating that this had been done, compared to 56% in 2018 (t=4.008, df=40, p<0.001). However, despite this increase, organizations still report that they do not have the capacity necessary to deal with climate change issues affecting protected areas (91% in 2006 and 73% in 2018, t=0.958, df=55, p=0.342); as one respondent stated, "[c]apacity is a large issue in both staff time and available funding."

2.4.2 Are there differences in responses between organization types?

There were relatively few differences in responses between organizations; however, when asked if climate change is going to substantially alter protected areas policy over the next 10 years, PCA respondents were more likely to strongly agree or agree with the statement than provincial government respondents (t=2.212, df=31, p=0.034). Furthermore, when asked how important of an impact climate change would have on infrastructure and operations, significant differences were found in responses from PCA and ENGOs, with PCA more likely to indicate an important or very important impact (t=3.672, df=32, p=0.001).

In terms of discussions regarding the need for a comprehensive assessment on potential climate change impacts and implications, the provinces were more likely to note that those discussions had taken place than the ENGOs (89% and 46% respectively, t=-2.351, df=20, p=0.029). Additionally, more provincial and PCA respondents suggested that their organizations specifically monitor for climate change impacts than ENGO respondents (PROV/ENGO, 73% and 15%, respectively, t=-2.070, df=24, p=0.049; PCA/ENGO, 73% and 15%, respectively, t=-2.509, df=35, p=0.017). Despite a lack of monitoring by ENGOs, they more often reported observing changes in species compositions than PCA organizations (67% and 29%, respectively, t=2.063, df=27, p=0.049) as well as changes in disturbance regimes (83% and 47%, respectively, t=2.160, df=27, p=0.040). No significant organizational differences were found in terms of incorporating climate change into protected areas management plans, the creation of adaptation action plans, or adaptive capacity.

2.4.3 What type of adaptation strategies are being employed?

Protected area agencies commonly employ conventional conservation strategies, such as expanding protected areas (68%), increasing connectivity (68%), and reducing other threats (64%). The least common strategies, including focus on ecosystem function (40%), conservation triage (20%), dynamic reserves (8%), and assisted migration (4%), are more interventionist strategies (Figure 2.2). When participants were asked to rank the same conservation strategies according to how likely their organization would be to implement them in the future, the results were similar, with conventional strategies being preferred.

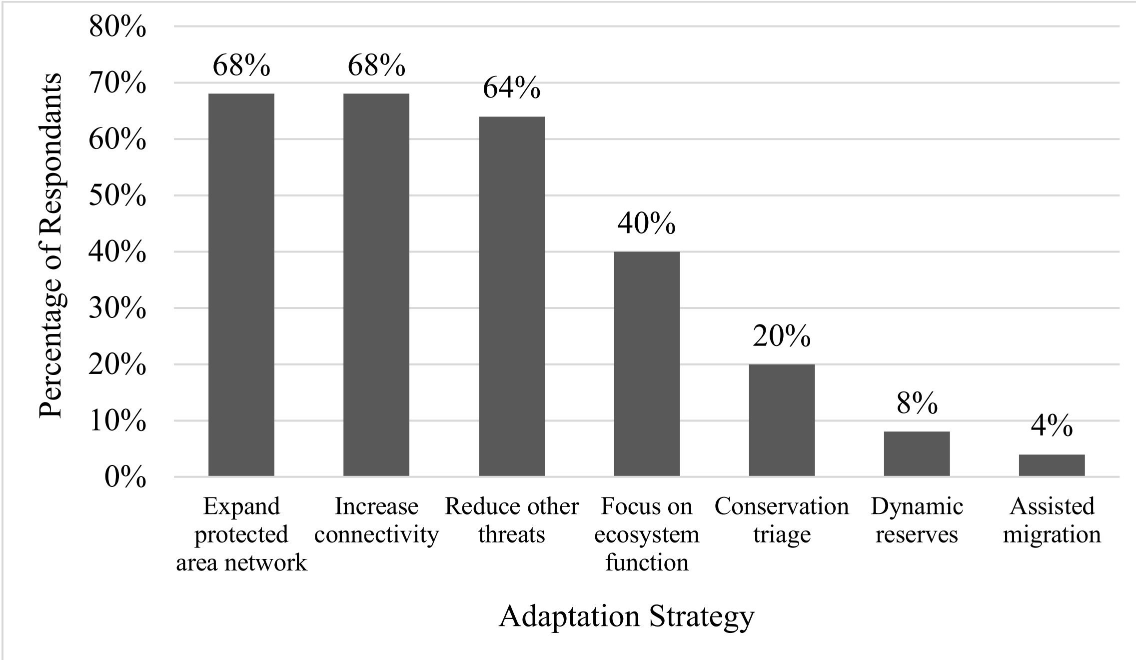


Figure 2.2: Percentage of respondents indicating that they are currently implementing various climate change adaptation strategies.

Organizational differences emerged between ENGOs and the provincial governments and PCA in terms of adaptation strategies they are currently employing as well as ones they are considering for the future. For example, more ENGO then PCA respondents indicated that they are currently increasing connectivity (86% and 39%, respectively, t=-3.061, df=30, p=0.005). Additionally, more ENGO than provincial and PCA respondents signaled that they are focusing on ecosystem function (ENGO/PROV, 64% and 10%, respectively, t=-3.264, df=22, p=0.004; ENGO/PCA, 64% and 28%, respectively, t=-2.148, df=30, p=0.040). All organizations ranked future possible adaptation strategies similarly except for increase connectivity, which ENGOs ranked first on average out of 7 strategies, PCA ranked 5th, and the provincial governments ranked 3rd.

2.4.4 Are there barriers to adaptation?

The majority of organizations (81%) reported that they face barriers or challenges to implementing climate change adaptation strategies in protected areas. According to one respondent, "[i]t is difficult for organizations with limited experience and resources to plan conservation actions that are going to be effective in a changing climate." The most commonly reported barriers include lack of capacity (human resources) (95%), insufficient funding / lack of resources (86%), and lack of knowledge (76%). Despite facing numerous barriers and challenges to climate change adaptation, the majority (78%) of protected areas organizations indicated that their organization was better equipped to deal with climate change than it was 10 years ago. The only barrier that organizations perceived differently was "lack of awareness of a problem." None of the ENGO respondents reported "lack of awareness of a problem" as a barrier; conversely, approximately half of provincial government and PCA respondents did identify it as a barrier (0% and 44%, respectively, t=2.675, df=17, p=0.016, and 0% and 56%, respectively, t=3.407, df=26, p=0.002).

2.5 Discussion

In this study, we first examined the current state of, and progress towards, adaptation in Canada's protected areas sector since an earlier similar assessment in 2006 (Lemieux et al., 2011b). Our findings suggest that in the past 12 years, organizations have failed to make substantial progress on adaptation in Canada's protected areas sector. In 2006, the majority of respondents thought that climate change would substantially alter protected area policy and planning in the next decade; however, in 2018 only 26% agreed that substantial change had occurred. Again, in 2018, the majority of respondents think change will occur in the next decade. The need for change is recognized but remains a challenge to realize.

One possible reason for the lack of action is that climate change is not perceived as a highly important management issue by protected area agencies (Table 2.1). Other factors such as external threats, exotic species, and endangered species are perceived as more immediate priorities. While Canadian park managers may place climate change as a lower priority, the inaction is contrary to clear evidence of climate change being a high priority as documented by the IPCC and others (Holmes et al., 2013; IPCC, 2014; IPBES, 2019). As one respondent noted, "management tends to be focused on problems with immediate consequences (e.g., managing recreation use, invasive species, infrastructure/asset management, revenue generation), and prioritization of issues based on minimal funding and capacity." This conflict may arise from the duality of many park mandates, with park managers having to service both recreational and biodiversity conservation mandates. With limited resources, conservation managers are likely to prioritize funds and actions towards the threats they perceive as most urgent. However, climate change acts synergistically with other higher perceived threats to exacerbate impacts (Chen et al., 2011; Staudinger et al., 2013). To achieve a holistic view of how biodiversity is going to change in the future and to prevent biodiversity loss, all stressors should be considered as well as the synergies and feedbacks between them. Biodiversity conservation measures that do not take into consideration stressors from climate change and species movements may no longer be effective in the future as climate change interacts with other stressors and protected areas may no longer provide the range of climate and habitat conditions needed to support the species they were designed to protect (Hagerman and Chan, 2009).

Despite concerns about the effectiveness of conventional biodiversity conservation approaches in light of climate change (Hagerman and Chan, 2009; Hagerman and Satterfield, 2013), this survey found they remain the most commonly implemented strategies in protected areas in Canada and are favoured by protected area organizations for implementation in the future. This finding is similar to those of Hagerman and Satterfield (2013) and Reside et al. (2018), who found that conventional actions are preferred over interventionist ones by experts around the world. The preference for conventional approaches may prevail since many interventionist strategies require increased human involvement in conservation (Dawson et al*.,* 2011; Hobbs et al*.,* 2011) and they are also perceived as riskier than conventional conservation techniques because they can have negative unanticipated consequences (Heller and Zavaleta, 2009; Tam and McDaniels, 2013). Several survey respondents noted that they would like to learn more about interventionist conservation strategies before considering them for implementation in their jurisdictions. With limited resources, protected area managers need to be relatively certain regarding the efficacy and co-benefits of a strategy before considering it.

Another possible reason for the lack of progress is the widespread reduction in support for environmental policies from Canada's federal government over the period of 2006 to 2015 (Kirchhoff and Tsuji, 2014). In 2012, federal spending on protected area management in Canada decreased by $30 million per year, and ecosystem science positions in Parks Canada were cut by up to 30% (CPAWS, 2012). Furthermore, the Canadian Environmental Assessment Act was repealed in 2012, thereby reducing government accountability (CPAWS, 2016). A lack of resources in protected area management has been cited as a leading cause of poor protected area effectiveness (Bruner et al., 2001; Watson et al., 2014). Additionally, Lonsdale et al. (2017) identified lack of political support and short political cycles as a main barrier to climate adaptation.

With changes in federal power in recent years, more support for environmental action is being observed. In the 2018 budget, the federal government committed $1.3 billion for nature conservation (Government of Canada, 2018b). This may translate into increased action on adaptation. As one respondent noted, "[w]e have a federal government that prioritizes action on climate change […]. Before, climate change could not be put on the agenda. Now, it is consistently discussed, and we look for opportunities to address it." Sustained support for protected areas is required to make lasting changes.

This study also sought to examine whether different organization types perceive climate change differently or have different responses to it. Few differences were found in responses between organization types. In most cases, where differences were found, they could be explained by organizational objectives. For example, most provincial and territorial governments and Parks Canada sites reported monitoring for climate change impacts, whereas most ENGOs did not. This finding can be explained by the mandate of governmental organizations and their relatively larger budget compared to ENGOs. Furthermore, ENGOs do not view lack of awareness of a problem and lack of agreement on the best way forward as barriers, whereas governmental organizations do. These differences in viewpoint may result from the structural differences between organizational types, with larger entities being more complex and requiring many levels of approval before decisions are made. The survey was not specific in defining "lack of awareness of a problem", so participants could have interpreted it as either a lack of internal awareness, a lack of public awareness, or both. Additionally, the difference in scale, ecological diversity/complexity, and geographic location of protected area holdings by a given organization may also influence the perception and actual impact of climate change, thereby organizational response.

We also examined barriers to climate change adaptation in Canada's protected areas sector. Most organizations reported that they face barriers to climate change adaptation and do not have the capacity to address climate change issues. This finding is similar to that of Whitney and Ban (2019) who found that coastal managers and planners in British Columbia lack capacity and face barriers in addressing climate change. Addressing these barriers and increasing capacity is of paramount importance. Systematically addressing barriers and challenges to biodiversity conservation efforts will increase opportunities for building adaptive capacity; however, the presence of capacity does not in itself guarantee that successful adaptation will occur (Adger and Barnett, 2009; Burch, 2010). In fact, adaptive capacity needs to be harnessed and used effectively; Burch (2010), for example, argues that most barriers are not related to a lack of capacity but rather to how existing capacity can be translated into action.

Institutional barriers such as lack of capacity and lack of funds can be addressed through increased governmental support. Several respondents noted that when funding is available for climate change initiatives, it is often targeted towards municipal and infrastructure adaptation rather than biodiversity and protected areas. According to one respondent "[m]ost funding currently supports municipal adaptation strategies." Another respondent echoed this claim, stating that "[f]ocus has tended to be on technological innovations for mitigation measures." Furthermore, few studies examining barriers to climate change adaptation relating to protected areas and biodiversity conservation have been conducted, with most studies occurring in the domain of water management, coastal zone management, and municipal planning (Measham et al*.,* 2011; Lehman et al*.,* 2015; Oulahen et al*.,* 2018). Future research should look at why barriers emerge, their underlying causes, and any interdependences (Biesbroek et al*.,* 2013; Azhoni et al*.,* 2018). Such research will assist in designing adaptation strategies, thereby enhancing the ability of protected area organizations to address the impacts of climate change.

Uncertainty has also been identified as a barrier to climate change adaptation; however, we found that uncertainty regarding climate change is decreasing among protected areas managers. Despite this decrease, action remains low, and the majority of agencies have not completed a comprehensive assessment of climate change impacts. Taking a multiperspective approach rather than a single solution approach to conservation will assist in overcoming remaining uncertainty as agencies will implement several adaptation strategies that span a range of temporal and spatial scales at a single site (Lawler, 2009; Mawdsley et al*.,* 2009; Perry, 2015). This approach has the primary advantage of reducing risk.

Canada is a leader in climate change adaptation action (Lesnikowski et al., 2015); however, this study found limited progress on adaptation in protected areas. Consistent with the findings of this study, a study of US National Park Service staff found that 26% of US national parks are monitoring and managing for the effects of climate change and an additional 35% of parks are undertaking monitoring activities without management interventions (Nelson, 2015). Limited progress on adaptation has also been found in the Arctic with no increase in reported adaptations over the time period 2014-2019 compared to 2004-2013 despite Arctic regions experiencing some of the most rapid changes (Canosa et al., 2020).

2.6 Conclusions and Recommendations

It is generally accepted that adapting now to the impacts of climate change (proactive adaptation) will lead to better outcomes than adapting later (reactive adaptation) (Lemieux et al*.,* 2011a; Bierbaum et al*.,* 2013; Gross et al*.,* 2016). However, limited resources and uncertainty have led to adaptation paralysis in protected area decision-making, resulting in the status quo prevailing. As the status quo and current conservation strategies are likely to be ineffective in an era of climate change, now is the time for action on adaptation. Waiting another decade to take action, or even continuing on the current very modest trajectory, will only exacerbate biodiversity loss. Recommending biodiversity conservation strategies is beyond the scope of this article; however, we propose several actions to enhance the transition towards implementing climate change adaptation strategies in protected areas.

First, enhancing knowledge mobilization and communication within and between organizations in the protected areas community regarding monitoring, successful adaptation approaches, and maladaptation is necessary. Doing so will allow ideas and best practices to be shared, thereby overcoming the existing barrier created by of lack of knowledge. Such communication is key to inter-organization collaboration, which Lonsdale et al. (2017), in a study of natural resource managers, found to be the second highest ranked opportunity related to adaptation. Moreover, most protected areas are small and influenced by external factors. Effective conservation of smaller areas requires coordinated efforts beyond protected area boundaries, and management on a landscape scale.

Second, protected area organizations need to develop and enhance current citizen science programs to improve their ability to monitor and respond to climate change impacts. In recent years, these programs have gained popularity and are recognized as a legitimate way to collect scientific information (Kosmala et al., 2016; McKinley et al., 2017). Expanding citizen involvement in this way will also enhance public understanding of climate change and biodiversity conservation potentially leading to increased support for conservation initiatives (McKinley et al., 2017; Turrini et al., 2018). Furthermore, such a program would assist with overcoming the barrier of lack of resources (both financial and human). One survey respondent noted that their organization developed a citizen science program in response to a lack of resources, in order to gather information regarding climate change impacts. Examples of such initiatives could include bird counts in protected areas, monarch and other butterfly census work, and BioBlitz events – citizen science events focused on finding and identifying as many species as possible in a specific location.

Third, agencies need to shift their conservation objectives from conventional strategies to more interventionist flexible interjurisdictional ones. In a changing climate, many species are forced to adjust their range or face population declines. Thus, future species assemblages at a particular location may no longer resemble historical ones without intensive human intervention (Burrows et al., 2014). Conventional practices that aim to maintain historical conditions are likely unwise and unachievable (Heller and Hobbs, 2014); however, strategic management actions that build adaptive capacity can reduce losses of valued ecosystem services and ease the transition towards new states (Gillson et al., 2013; Millar and Stephenson, 2015). Organizations need to make decisions regarding the desired future state of ecosystems within their jurisdiction (historical or novel) and adapt conservation strategies and objectives to match changing conditions. The shift in protection philosophy, policies and practices will need to be carefully crafted in weighing the need to retain strictly protected areas to serve as scientific benchmarks for environmental monitoring while determining where more interventionist management is needed to ensure species survival and meet other needs for climate change adaptation.

Lastly, a national climate change adaptation strategy and action plan for Canadian protected areas backed with commitment, leadership, training and technical support, well defined targets, adequate resourcing, monitoring and reporting akin to Canada's response to Aichi Target 11 is necessary to make substantial progress in this area. To drive such an initiative, a national climate change panel of experts and jurisdictional representatives (i.e., federal, provincial, territorial, municipal, ENGO, and First Nations governance organizations), similar in commitment to that of Pathway to Canada Target 1, is required to provide long-term guidance, monitoring and reporting on nation-wide climate change adaptation efforts. Protected areas organizations can no longer operate in independent silos, but rather need to work towards integrated plans. Our survey found overwhelming support for this change, with 96% of respondents being in favour of sharing in a Canada-wide protected areas collaborative effort on climate change. Furthermore, several respondents commented on the need for a more collaborative effort, with one respondent stating that "climate change impacts influence ecosystems across multiple scales (geo-spatial, time, political) and therefore require an adaptation strategy that is integrated across protected areas at multiple levels, including a Canada-wide collaboration and within the region." Another respondent indicated that "a national strategy for climate change and protected areas would help increase synergistic energy, making local efforts more effective and more efficient." The apparent dichotomy of perceptions and actions relating to climate change among protected areas organizations, and lack of progress on climate change adaptation, signifies the need for national leadership and a unified approach to drive coordinated action. Moreover, due to the scale at which change is occurring, cooperation and coordinated efforts by agencies and governments is required to meet conservation goals.

Chapter 3

Evaluating climate change adaptation options at the frontlines of biodiversity conservation: Conventional strategies dominate over interventionist

3.1 Abstract

In recent decades, scholars and practitioners have proposed numerous climate change adaption options; however, they have seldom been evaluated to compare their effectiveness and feasibility. Through a two-day workshop at Bruce Peninsula National Park and Fathom Five National Marine Park, in Ontario, Canada, participants evaluated climate change impacts to these parks and developed adaptation options. The objectives of this paper are to i) determine which adaptation options practitioners prefer, ii) evaluate perceived effectiveness and feasibility of these options, and iii) apply a typology to the options. We found that most (47%) adaptation options identified by participants were conventional and direct change. These strategies also received higher effectiveness and feasibility ratings. A shift from conventional strategies to more dynamic interventionist strategies is required as well as a shift from strategies that aim to resist change to those that direct change. By focusing on understanding factors that influence the identification and prioritization of adaptation options at the individual park or regional scale, we address a key implementation gap identified in the climate change adaptation literature. Recommendations for practice include taking a pro-active forward-looking approach to conservation, testing new conservation strategies and sharing results broadly, and incorporating social science perspectives and social values into conservation planning.

3.2 Introduction

Protected area managers are increasingly faced with conservation challenges arising from rapid ecological change. Existing biodiversity conservation practices were largely developed under the assumption of a static climate system (West et al., 2009; Hagerman et al., 2010), an assumption that is no longer valid under present given climate change scenarios (Wyborn et al., 2016; Abrahms et al., 2017). While uncertainty remains around precisely how ecosystems will respond, transformational change is highly likely (Polasky et al., 2011; Wyborn et al., 2016; IPBES, 2019). Accordingly, there have been many calls to change conservation practices (Hannah et al., 2002; Scott et al., 2002; Scott and Lemieux, 2005; Heller and Zavaleta, 2009; West et al., 2009; Lemieux and Scott, 2011; Stein et al., 2013; Hagerman and Satterfield, 2014; Abrahms et al., 2017) with concurrent proliferation in adaptation options.

The conservation science literature has proposed numerous adaptation options for biodiversity conservation (Heller and Zavaleta, 2009; Lemieux and Scott, 2011). Much literature describing adaptation options, however, is speculative or theoretical in nature with only a few studies documenting or evaluating strategies that have been implemented (Ford and King, 2015; Prober et al., 2019). Practitioners are often confused by the myriad of options and struggle to choose the 'correct' one for their situation (Abrahms et al., 2017). The result is delayed action due to barriers, such as cost and lack of knowledge, and uncertainty about risk—at a time when action is critically needed (Poianni et al., 2011; Schmitz et al., 2015). Furthermore, the literature tends to assume that practitioners should adopt these adaptation practices without evaluating their effectiveness, feasibility, or practicality in a park-specific context (Lemieux and Scott, 2011; Geyer et al., 2015). The exception being Lemiuex and Scott (2011) who evaluated climate change adaptation options for protected areas in Ontario, Canada for their perceived desirability and feasibility.

Strategies to address the impacts of climate change in the field of conservation biology lie along two complementary continuums: 1) conventional to interventionist, and 2) resist change to direct change (Tam and McDaniels, 2013; Hagerman and Satterfield, 2014; Fisichelli et al., 2016a; Aplet and Mckinley, 2017). The first, conventional vs. interventionist adaptation strategies (Hagerman and Satterfield, 2014), has also been referred to as low regrets vs. climate-targeted strategies (Prober et al., 2019). Conventional strategies are those that have been historically used and which have benefits regardless of realized climate impacts (e.g., expanding the protected area network, reducing other threats). Such strategies have been referred to as "managing for resilience", wherein strategies are focused on allowing ecosystems to persist in their current naturally evolving state (see West et al., 2009). In contrast, interventionist strategies are typically more controversial not least because they require greater human involvement in ecosystem management (e.g., conservation triage, assisted migration) (Hagerman and Satterfield, 2014; Prober et al., 2019). Strategies within this domain focus on changing management goals and managing transitions to new ecosystem states (Scott et al., 2002; West et al., 2009). Experts and the public tend to favour conventional management options (Tam and McDaniels, 2013; Hagerman and Satterfield, 2014; St-Laurent et al., 2018). However, conventional and interventionist options that aim to resist change (e.g., restocking a native fish species in a lake where the climate no longer matches its thermal needs (conventional/resist); maintaining historic water levels through engineered structures (interventionist/resist)) may no longer be sufficient given the rate of change and may even be counterproductive and weaken the ecosystem if resources are directed towards features unlikely to persist in the future (Abrahms et al., 2017; van Kerkhoff et al., 2019).

In addition to the conventional-interventionist continuum, adaptation strategies can be placed on a continuum of whether they resist change or direct it (Scott et al., 2002; Stein et al., 2014; Fisichelli et al., 2016a; Prober et al., 2019). Strategies that resist change aim to reduce stressors on species and maintain historical ecosystem composition (e.g., increasing shading over waterbodies to reduce water temperature and maintain cold-water fish habitat), whereas strategies that direct change aim to transform the ecosystem to a new suitable state in response to change (e.g., introducing warm-water fish species better adapted to increased water temperatures) (Fisichelli et al., 2016a; Prober et al., 2019). Resisting change and preserving the historical structure, function, and composition of the ecosystem may no longer be a realistic goal.

Climate change is altering ecosystems through changes in species phenology, abundance, and distribution, leading to new states that are unfamiliar to managers (Scheffers et al., 2016; Pecl et al., 2017). This forces managers to make difficult value-based decisions about desired future ecosystem characteristics that may be contrary to the park mandate (Abrahms et al., 2017; van Kerkhoff et al., 2019). Management practices have traditionally sought to preserve past conditions and park mandates typically dictate the preservation of such conditions (Suffling and Scott, 2002). However, to meet the challenges posed by climate change, conservation needs to take a future-oriented perspective (Bernazzani et al., 2012; Wyborn et al., 2016; van Kerkhoff et al., 2019). There is hence a paradox in the conservation field as managers are asked to facilitate change to allow ecosystems to adapt but also to resist change to maintain intact representative ecosystems (Heller and Hobbs, 2014). One way out of this paradox would be a shift in conservation mindset from preserving specific species and ecosystems to preserving ecosystem function, thereby allowing more resilient future ecosystems (Scott et al., 2002; Tanner-McAllister et al., 2017; van Kerkhoff et al., 2019). However, this approach will likely be challenged when charismatic species (e.g., polar bears) decline, or become extinct, as the Canadian public is likely to place pressure on conservation organizations to preserve these iconic species (Scott and Suffling, 2000; Scott et al., 2002). Furthermore, a transformative change in policy and park mandates is required before a shift from preserving historical ecosystems to focusing on ecosystem function can fully occur.

The conservation community largely agrees that conservation practices need to adjust to meet rapid ecological change, but how to develop and implement adaptation strategies at the scale of individual protected areas remains a challenge in practice and a key knowledge gap in the literature (Lemieux and Scott, 2011; Abrahms et al., 2017). The identification of adaptation options has largely occurred at high levels of planning and management (e.g., Baron et al., 2009; Heller and Zaveleta, 2009; Lemieux and Scott, 2011). However, it is at the park level where effects will be first realized, which necessitates local or regional decision-making. For example, changing climatic conditions may lead to shifts in species and vegetation in individual protected areas, and as such the goals for these reserves may need to be re-evaluated. While examples of adaptation at the park level are beginning to emerge (e.g., considering different species mixes in restoration efforts based on future climate projections), the extant literature remains scant overall. Key lessons are required across ecosystems and governance conditions to foster adaptive capacity and resilience at the scale relevant to management problems.

To address the knowledge gap associated with developing and implementing adaptation strategies at the park level, we examined practitioner preferences for adaptation options in Bruce Peninsula National Park and Fathom Five National Marine Park, Ontario, Canada, to develop a more complete understanding of viable adaptation options and what factors contribute to increased effectiveness and feasibility. Accordingly, our objectives were to i) determine which adaptation actions practitioners prefer, ii) evaluate the perceived effectiveness and feasibility of these options, and iii) apply a typology to the options. We conclude by outlining ways in which dynamic future-oriented conservation can be achieved.

3.3 Study Location

Located on the northern tip of the Bruce Peninsula in Ontario, Canada (Figure 3.1), Bruce Peninsula National Park (BPNP) was established in 1987 to protect a 156 km^2 representative example of the Great Lakes/St. Lawrence Lowlands natural region. BPNP is largely comprised of alvar, forest, old field, and inland lake ecosystems (Parks Canada 1998). Fathom Five National Marine Park (FFNMP), also established in 1987, is located north of BPNP and protects representative features of both aquatic and terrestrial systems over 114 km^2 in the Georgian Bay Marine Region (Parks Canada 2010).

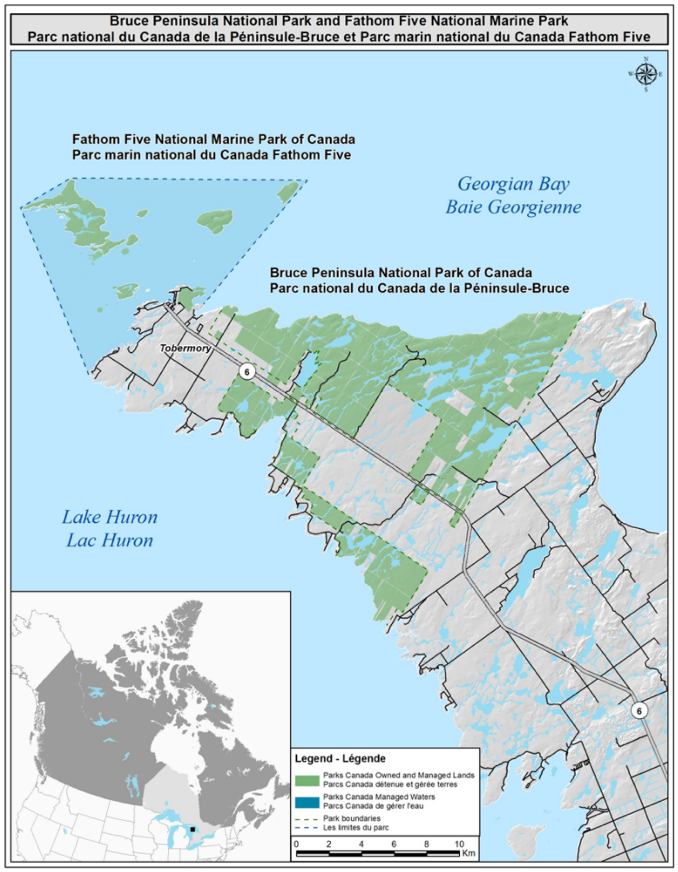


Figure 3.1: The location of Bruce Peninsula National Park and Fathom Five National Marine Park. Black box inlay shows the location of the park in relation to the rest of Canada. (Source: Parks Canada)

This study includes BPNP and FFNMP (henceforth referred to as 'the parks') because they are administratively managed and operated together. However, they are managed under different legislation and accordingly have different goals. BPNP is managed in the "spirit" of the *Canada National Parks Act* (2000) as it is not yet scheduled under the Act and therefore operates under a complex mix of provincial and federal legislation (Parks Canada 2010a). Similar to other national parks, the primary goal of management at BPNP is the maintenance of ecological integrity with vast areas being managed for their wilderness or natural environmental values (Parks Canada 1998a). Conversely, FFNMP is managed in the "spirit" of the *Canada National Marine Conservation Areas Act* (2002) with the primary goal being ecological sustainability and a focus on maintaining ecosystem structure and function;

accordingly, commercial and industrial activities, such as non-traditional fish harvesting, is permitted (Parks Canada, 1998b; Parks Canada, 2010b).

The parks are already experiencing warming and climate change effects related to this warming (Parker, 2018). Mean annual air temperature on the Bruce Peninsula has increased by ~1^0C from 1916 to 2016 and is expected to increase 1.9^0C-2.1^0C by 2021-2050 and 2.9^0C-4.3^0C by 2051-2080 relative to a 1976-2005 baseline (PCIC, 2014; Parker, 2018). Precipitation trends are less clear, but annual precipitation is expected to increase slightly relative to the 1961-1990 baseline (Wang et al., 2017; Parker, 2018). More-intense precipitation events are expected, with the "one in 100 year" event becoming a "one in 25 year" event (Parker, 2018). Additionally, the "one in 100 year" event is projected to become 25% more intense. Lake Huron's surface water temperature has already increased by 0.11^oC per year from 1994-2013 (Mason et al., 2016) and is projected to increase by 2.6-3.9^oC by the 2080s relative to a 1971-2000 baseline (Trumpickas et al., 2009). Furthermore, annual mean ice cover on Lake Huron has decreased by 1.6% yr^{-1} over the period of 1973 to 2010 (Wang et al., 2012) and the ice-free period is projected to increase by 45-62 days by 2071-2100 (Dove-Thompson et al., 2011; Parker, 2018).

3.4 Methods

3.4.1 Data collection

We collected our data in association with a two-day workshop in May 2019 that was hosted, organized, and run by Parks Canada at BPNP and FFNMP. The 28 participants were invited by Parks Canada based on their knowledge of the local area and conservation, and expertise in their fields. They represented Parks Canada (including personnel from other national parks in Southern Ontario), other federal government departments (e.g., Environment and Climate Change Canada), provincial and local governments (e.g., Ontario Ministry of Natural Resources and Forestry), environmental non-governmental organizations (e.g., Ontario Nature), universities, and local indigenous groups (e.g., Bagida waad Alliance). This study received ethics clearance from the University of Waterloo Office of Research Ethics (ORE# 40905) and a research and collection permit (#BPF-2019-32038) from Parks Canada.

A pre-workshop webinar held by Parks Canada provided an introduction to climate change trends and projections for the Bruce Peninsula (based on Parker, 2017) and introduced participants to the *Climate Change Adaptation Framework for Parks and Protected Areas* that was used to guide the workshop process (Nelson et al., 2020). The framework contains five steps:

1) build a strong foundation;
2) assess risk and vulnerability;
3) identify and select adaptation options;
4) implement adaptation actions; and,
5) monitor and evaluate.

Parks Canada developed this framework, based on scenario planning, to assist with envisioning future climates, considering alternative responses, and making decisions under uncertainty (Peterson et al., 2003; Star et al., 2016). Parks Canada staff completed step 1 prior to the workshop by identifying a climate change team and determining the scope and scale for adaptation actions. This paper concerns steps 2 and 3, which were conducted by participants during the workshop, to provide the basis for Parks Canada to subsequently enact steps 4 and 5.

On the first day, participants self-selected into three break-out groups representing different ecosystem types (terrestrial (n=12), inland aquatic (n=7), and coastal Lake Huron (n=9)) to complete step 2 of the framework. To focus their discussion, each group developed three plausible climate change scenarios based on climate trends and projections for the region. For each scenario, participants identified climate change impacts and vulnerabilities, and evaluated the likelihood, consequence, and associated risk of each impact. Protected area managers often have to allocate scarce resources, therefore considering the perceived risk of each impact allows them to prioritize higher risk impacts (Schliep et al., 2008). Participants were instructed to focus on scenarios, impacts, and adaptation options for the next 10 years through 2029 and to consider planning up to 2050 to keep discussions and responses achievable on a short to medium timeframe.

On the second day, participants completed step 3 of the framework by brainstorming a suite of potential management interventions (adaptation options) to address each impact identified as most urgent (Appendix D). Each option was given two ratings by the break-out group that proposed it, one with regard to perceived effectiveness at reducing the identified impact and the other for feasibility of implementation, on a scale of 1 to 5, with 1 being low and 5 being high. Additionally, advantages and disadvantages of each option were noted. Through further discussion, each break-out group selected the top adaptation options they concluded were most pertinent for consideration by park management (Appendix D).

By including diverse, local stakeholders, this methodology helps to prioritize adaptation options that are relevant to the context of the individual protected areas irrespective of strategies presented in the academic literature. As noted above, extant studies tend to be broader in scale or use adaptation options presented in the literature that are generally applicable to any region (Heller and Zavaleta, 2009; Lemieux and Scott, 2011; Prober et al., 2019). Additionally, this methodology likely had the added benefit of increasing climate change knowledge and awareness among Parks Canada Agency staff and other participants, thereby increasing the adaptive capacity of the protected area.

3.4.2 Analysis

To group adaptation options identified in the workshop, we applied a typology based on Fisichelli et al., (2016a) and Prober et al., (2019) (Table 3.1). Each adaptation option was categorized in terms of the continuums discussed above. Each adaptation option was categorized by two coders working independently. To ensure codes were consistent between coders, we went through multiple rounds of coding, and compared codes and revised definitions used for coding between each round. Effectiveness and feasibility ratings were averaged for each category. If an adaptation option was not given both an effectiveness and a feasibility rating by the break-out group that proposed it, or a range was provided, this option was excluded from analysis.

Table 3.1: Definitions of key typology terms.

Term	Definition
Intervention class	
Conventional (Tam and McDaniels 2013; Stein et al., 2014; Hagerman and Satterfield, 2014; Prober et al., 2019)	These interventions – also known as 'low-regrets' options – typically provide a broad suite of benefits regardless of realized future climatic conditions and are relevant under many possible futures. Often, they involve the redirection of existing activities, are embedded in institutional norms, focus on maintaining the status quo, and are familiar – being historically implemented. An example is the expansion of the protected area network.
Interventionist (Hagerman et al., 2010; Tam and McDaniels, 2013; Hagerman and Satterfield, 2014; Prober et al., 2019)	These interventions are often associated with higher risk due to potential unanticipated negative consequences and could also be referred to as 'climate-targeted' options. These actions may require major policy reconsiderations and involve more human involvement in and manipulation of the ecosystem, so they are often more contentious (e.g., assisted migration).
Effect	
Resist change (Scott et al., 2002; Suffling and Scott, 2002; Fisichelli et al., 2016a; Aplet and Mckinley, 2017; Prober et al., 2019)	These options aim to reduce stressors on species and ecosystems by targeting changing conditions and functions directly. The goal is to maintain historic biotic and abiotic conditions and to evade change, for example by reducing water temperatures or artificially augmenting water levels.
Direct change (Scott et al., 2002; Suffling and Scott, 2002; Hagerman et al., 2010; Fisichelli et al., 2016a; Aplet and Mckinley, 2017; Prober et al., 2019)	These options aim to help species and ecosystems respond to change, and to transition to new suitable states under new climatic conditions. These actions lead to increased resilience at a higher scale and assist with maintaining ecosystem function, for example, restoring an ecosystem with drought-tolerant species instead of drought-sensitive species in a drying environment or increasing genetic variability of a population through translocation.

We analyzed the workshop data using applied thematic analysis, a "rigorous, yet inductive, set of procedures designed to identify and examine themes from textual data in a way that is transparent and credible" (Guest et al., 2012, p. 15) (Appendix E). This method is similar to inductive thematic analysis and grounded theory but more practical in nature and not aimed at building theory. After coding the advantages and disadvantages identified by participants for each adaptation option, we conducted a qualitative thematic comparison of themes by intervention class and effect.

3.5 Results

Impacts were identified for each ecosystem type as follows. Terrestrial ecosystem impacts include increases in forest fire intensity and prevalence of exotic invasives and vector borne diseases, decreases in prevalence of native biodiversity and ecosystem resilience (cumulative impacts to functional diversity), as well as changes in species interactions. Inland aquatic ecosystem impacts include changed fish community composition, changed food chains, increased invasive species presence, flooded breeding sites, and dried wetlands and vernal pools. Finally, the coastal Lake Huron impacts include altered species abundance, distribution, habitats and fish community structure, and increased nutrient pollution and turbidity.

To address these impacts, a total of 68 adaptation options were identified for all ecosystem types (terrestrial, inland aquatic, and coastal Lake Huron). Among the 68 options, the top 5-6 options that participants felt were most pertinent to present to park management were identified (Appendix A). After removing adaptation options that did not have an effectiveness and feasibility rating, 56 adaptation options remained. Of the 56 adaptation options, most were rated as having an effectiveness of 3, 4, or 5 (25%, 45%, and 29%, respectively), with only one adaptation option being rated a 2 and no adaptation options receiving a 1 (Figure 3.2). In terms of feasibility, most options were rated a 3 or 4 (38% and 38%, respectively), with the remainder being 1(5%), 2(7%), or 5(13%).

The majority of adaptation options identified are conventional options that aim to direct change (Table 3.2/ Figure 3.2). This trend becomes more pronounced when considering only the top adaptation options identified by participants (Table 3.3). Strategies with the highest perceived effectiveness and feasibility ratings are primarily conventional strategies (Tables 3.2 & 3.3). Furthermore, every adaptation option that was rated a five for feasibility was conventional. Similarly, of the 16 options rated a five for effectiveness, most are conventional, with only two being interventionist options. In terms of the effect the strategy has on the ecosystem, little difference was observed in effectiveness or feasibility rating between the two effects (resist or direct change).

Table 3.2: Percentage of all adaptation options identified by workshop participants categorized by intervention class and effect the strategy has on the ecosystem (in parenthesis) with average effectiveness and feasibility (scored out of 5) of adaptation options for each category. Standard deviation (SD) is given in parentheses.

	Effectiveness	**Feasibility**
Intervention Class		
Conventional (71%)	4.16 (+- 0.74 SD)	3.82 (+- 0.94 SD)
Interventionist (29%)	3.63 (+- 0.81 SD)	2.81 (+- 0.83 SD)
Effect the strategy has on the ecosystem		
Resist change (41%)	4.09 (+- 0.79 SD)	3.52 (+- 1.04 SD)
Direct change (59%)	3.95 (+- 0.78 SD)	3.54 (+- 1.02 SD)

Table 3.3: Percentage of top adaptation options identified by workshop participants categorized by intervention class and effect the strategy has on the ecosystem (in parenthesis) with average effectiveness and feasibility (scored out of 5) of adaptation options for each category. Standard deviation (SD) is given in parentheses.

	Effectiveness	**Feasibility**
Intervention Class		
Conventional (86%)	4.5 (+- 0.76 SD)	3.79 (+- 0.89 SD)
Interventionist (14%)	3.5 (+- 0.71 SD)	3.5 (+- 0.71 SD)
Effect the strategy has on the ecosystem		
Resist change (25%)	4.75 (+- 0.5 SD)	3.75 (+- 1.26 SD)
Direct change (75%)	4.25 (+- 0.87 SD)	3.75 (+- 0.75 SD)

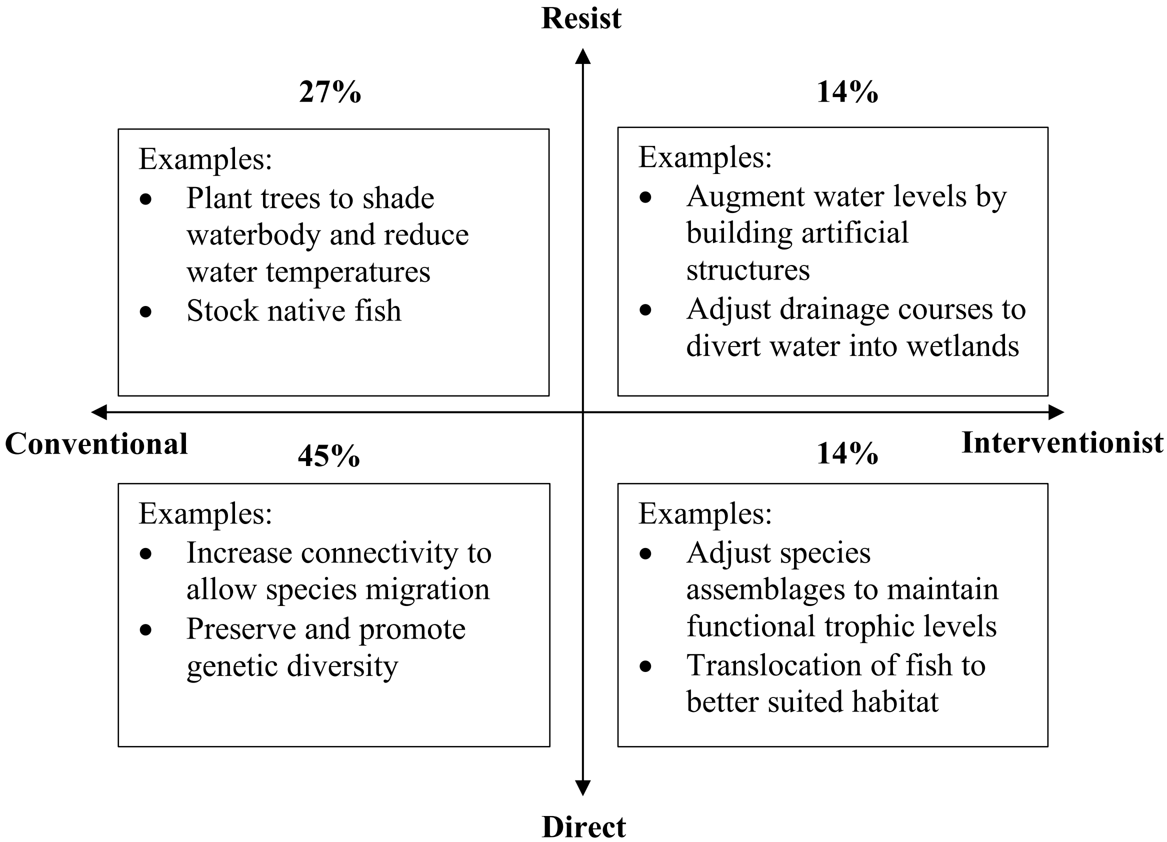


Figure 3.2: Both adaptation continuums with the percentage of all adaptation options that are categorized into each quadrant and examples for each quandrant.

The most frequently identified advantages across all adaptation options were 'maintains ecosystem function', 'builds public support and/or education', 'increases resiliency', 'increases ecosystem health and maintains species diversity', and 'provides co-benefits'. In terms of disadvantages, the most frequently cited include 'cost', 'negative public perception', 'high complexity / difficult to implement', 'labour intensive and time consuming', 'high uncertainty', and 'potential for unanticipated negative ecosystem impacts'.

An overlap in advantages between conventional and interventionist strategies was observed with 'maintains ecosystem function' and 'increases ecosystem health / maintains species diversity' among the top four most commonly identified advantages for both types of strategies. However, interventionist strategies tended to have the advantages of 'allows species dispersal' and 'increases / maintains resiliency' whereas conventional strategies ‘build public support’ and ‘provide co-benefits’. Little difference was noted in disadvantages between intervention classes.

Similarly, there was overlap in advantages between strategies that aim to direct change and those that aim to resist change with both types of strategies having the advantages of ‘maintaining ecosystem function’, ‘building public support’, ‘increasing ecosystem health’, and ‘providing co-benefits’. Strategies that aim to direct change had a higher rate of ‘allowing species dispersal’ and ‘increasing or maintaining resilience’ compared to those that resist change, which had the additional advantage of ‘already being implemented in other jurisdictions / knowledge exists’. There was little difference in the frequency of various disadvantages being noted between effects.

3.6 Discussion

Our research highlights certain key insights regarding climate adaptation for biodiversity conservation. The finding that the majority of adaptation options identified are conventional options that aim to direct change is consistent with that of Prober et al. (2019). Prober et al. (2019), in their meta-analysis of studies proposing adaptation options for species or ecosystems, found that conventional options that direct change are mentioned in the literature three times more frequently than the three other categories in their study (i.e., low regrets/evade, climate-targeted/build adaptive capacity, and climate targeted/evade). Moreover, Tam and McDaniels (2013), Hagerman and Satterfield (2014), and Hagerman and Pelai (2018), similarly found preferences for conventional adaptation strategies in their global studies. Additionally, St-Laurent et al. (2018), found preferences for conventional strategies in their study of adaptation strategies for forestry in British Columbia. Conventional options are generally considered ‘safe’ options, and are frequently politically salient, a fact that might explain their sustained popularity.

Conventional options, in addition to being the most frequently mentioned type of adaptation option, were also given higher feasibility and effectiveness ratings than interventionist ones, perhaps because they are most familiar to practitioners and thus best understood (Barr et al., 2020). Lack of knowledge or experience in implementing a given adaptation option, particularly the more-innovative ones, was a recurring concern in workshop discussions – a finding consistent with other studies (Moser and Ekstrom, 2010; Biesbroek et al., 2014; Azhoni et al., 2018; Barr et al., 2020). Participants also raised concerns about the efficacy of novel adaptation options. In order to counter these concerns and aid in transitioning towards interventionist options, knowledge sharing between organizations regarding their experiences with climate change adaptation should be increased (Burch, 2010; Lonsdale et al., 2017). This sharing would help to increase confidence and reduce uncertainty about untried strategies. For example, if all protected area organizations (i.e., provincial parks, land trusts, NGOs, and federal protected areas) worked together and shared experiences, the fear of trying something new and it failing could be reduced as would wasteful duplication of effort. Knowledge sharing could be improved through the establishment of regional climate change adaptation databases for biodiversity conservation that contain case study information on both successful and unsuccessful adaptation efforts.

The natural adaptive capacity of many species is unlikely to be enough to keep pace with rapid and transformative ecological changes (Malcolm et al., 2002; Millar and Stephenson, 2015). Practitioners can no longer work under the assumption of a stable climate system (Hagerman et al., 2010; Abrahms et al., 2017) and rely solely on conventional and interventionist strategies that aim to resist change (Aplet and Mckinley, 2017). The projected velocity of climate change demands a mixture of options (Aplet and McKinley, 2017), and in the future, when change reaches the point where conventional resistant strategies can no longer cope, the identification and implementation of more interventionist directional options will be inevitable (Burrows et al., 2014; Prober et al., 2019). Consequently, there is an opportunity cost associated with directing resources away from more targeted alternatives and sticking with the 'safe' option (Stein et al., 2014). Using proactive adaptation to address key vulnerabilities now, may act to reduce costs in the future (Lemieux and Scott, 2011).

A shift towards a suite of complementary adaptation options (both conventional and interventionist) implemented in conjunction with one another is likely to lead to more success and reduce risk and uncertainty associated with a single adaptation option (Lindenmayer and Hunter, 2010; Aplet and Mckinley, 2017). Moreover, strategies should be chosen that provide benefits across a range of possible climatic futures to account for uncertainties (Stein et al., 2013). In the case of BPNP/FFNMP, implementing a range of adaptation options may be easier due to the difference in legislation between the two parks. FFMNP is theoretically more amenable to interventionist options that direct change due to the weaker legislation with no strict enforcement or mandate for ecological integrity. Additionally, the possibility of vertical and horizontal zoning in marine protected areas (Venegas-Li et al., 2017) opens up more options for spatial variation in adaptation and provides more opportunities for interventionist options. However, the difference in legislation between the two parks was not acknowledged by participants in the workshop and no differences in intervention types identified by participants exists between the terrestrial and marine parks. Conventional strategies still prevail in FFNMP despite less conflict between the park mandate, which does not focus on maintaining and enhancing ecological integrity like its terrestrial counterpart, and interventionist options.

On the resist versus direct change spectrum, participants identified slightly more adaptation options that aim to direct change rather than resist change, with no difference in their perceived effectiveness and feasibility ratings. Directing change allows species and ecosystems to respond more effectively to changing environmental conditions and increases the resiliency of the ecosystem (Stein et al., 2014). Conversely, options that aim to resist change are a temporary fix and can lead to an overreliance on human intervention to maintain the ecosystem in a historical state that is incongruent with the current climate (Stein et al., 2014; Fisichelli et al., 2016a; Parker et al., 2018). However, in the short term, which was the focus of this workshop (i.e., the next ten years), resisting or slowing down change to allow time for adaptation may make sense. Additionally, the sustained use of adaptation options that aim to resist change, despite their known incongruence with long-term climate change, may stem from increased familiarity or certainty with those options. For example, increasing shading over streams to decrease water temperature and enhance survivability of cold-water fish (resisting change) is a logical and straightforward relationship that managers are familiar with whereas relocating cold-water fish further north to areas where the climate better matches their needs (directing change) is less familiar and associated with more uncertainty. The similarity in effectiveness and feasibility ratings between strategies that resist and direct change indicates that shifting more towards strategies that aim to direct change is not viewed as an onerous challenge by practitioners.

Similar to conventional and interventionist strategies, a mix of strategies that aim to resist and direct change is likely wise in the short-term to spread risk (Aplet and McKinley, 2017). Not all strategies need to direct change. Resisting change in certain circumstances is an acceptable choice; however, resisting change is a temporary solution, an interim coping method until a better solution can be developed and implemented, or until a decision is reached regarding the desired future state of the ecosystem. For example, if a keystone species is threatened, resisting change to allow that species to persist until a replacement for that ecosystem service can be found is an acceptable choice. In the long term, when faced with rapid and radical ecological change, transformative adaptation (directing change) is the more appropriate strategy (Pelling et al., 2015; Fedele et al., 2019).

The use of a near-term forecasting method in this study may have influenced the types of adaptation strategies that were considered by participants. Futures studies, and scenario planning more specifically, can take either a forecasting approach (i.e., an exploratory scenario that moves from the present to the future) or backcasting approach (i.e., a normative scenario that begins with a desired future state and works back in time to the present) (van Notten et al., 2003; Faldi et al., 2017). Decision-makers' orientation to the long-range future is liable to affect the type of adaptation strategies they choose. For example, decision-makers considering the near-term future using a forecasting approach, the approach used in this study, are prone to take a conservative approach and select adaptation strategies that are relatively similar to those that are currently being used and may select strategies that aim to resist change as the climate in the near-term is likely to be relatively similar to the current climate (Faldi et al., 2017). Several studies have noted that forecasting approaches support incremental adaptation (Gydley et al., 2009; O'Brien, 2012). Conversely, backcasting approaches are thought to favour transformative adaptation (van der Voorn et al., 2012). Therefore, decision-makers considering a more distant future (e.g., 100 years in the future) using a backcasting approach, where a desired future state is identified and actions are developed to achieve that state, may be more apt to consider less familiar, more interventionist options. Additionally, decision-makers using a long-term backcasting approach may tend to identify options that direct change towards that desired future state as drastic changes are more likely over a long time period. Furthermore, a decision-makers' orientation to the long-range future likely affects their perception of the effectiveness of a strategy with more familiar strategies (conventional) that maintain current conditions (resist change) more likely to be preferred in the short-term rather than the long-term.

The variance in preference in strategies under a near-term versus long-term orientation leads to questions around how to transition from one strategy to another as time and climate change progress. A dynamic adaptive policy pathways approach can aid in identifying a series of adaptation strategies that are ideal at various points in time and triggers that indicate when to switch from one strategy to the next (Haasnoot et al., 2013; Wise et al., 2014). Instead of making decisions regarding climate change adaptation on an ad hoc basis as impacts arise, a dynamic adaptive policy pathways approach provides a structured approach to decision-making. Furthermore, this approach would allow practitioners to continue using conventional and interventionist strategies that resist change while conventional and interventionist strategies that direct change are developed and tested. However, knowing when to change strategies is difficult. Flexibility in when to switch strategies, and what strategy to switch to, in response to new information or new conditions allow for better performing systems than systems that rely on a single static strategy (Buurman and Babovic, 2016). Empirical triggers, or tipping points, need to be clearly defined that would indicate when to switch strategies before a harmful adaptation-threshold is reached (Stephens et al., 2018).

3.6.1 Limitations

The *Climate Change Adaptation Framework for Parks and Protected Areas* presented here has broad applicability to the global protected area community; it can be used to develop and evaluate a suite of adaptation strategies to address specific climate change impacts. However, specific adaptation strategies identified in this paper are relevant to BPNP/FFNMP. BPNP, in particular, is unique compared to other protected areas in southern Ontario in that it is located on a peninsula which affects the mobility of migrating terrestrial species. This may have affected participants choice of adaptation strategies and their perceptions of feasibility. Furthermore, these adaptation strategies have yet to be tested, so their effectiveness is presently unknown. In light of this, it will be important to monitor and evaluate the implementation of adaptation options as part of Parks Canada's broader state of the park reporting (Lemieux et al., 2011).

Compared to other methods, a drawback of this framework is the lack of anonymity. Participants developed adaptation options in break-out groups whereas other methods are anonymous, such as the Policy Delphi method used in Lemieux and Scott's (2011) study of climate change adaptation options for protected and conserved areas managed by Ontario Parks. Participants in an anonymous study might be more innovative or put forth more controversial ideas without fear of reprisal, resulting in more interventionist options being identified and/or supported. In particular, the lack of focus on ecological integrity in legislation for NMCAs could perhaps provide the flexibility to be more innovative with respect to the implementation of more novel and less familiar adaptation options. Additionally, the Policy Delphi method uses expert opinion whereas this study included a range of participants with differing levels of knowledge regarding climate change and biodiversity conservation.

Other shortcomings of this methodology relate to the workshop process itself. First, due to the compressed two-day format of the workshop, participants were expected to identify and prioritize adaptation options quickly leaving little time for reflection, review, or research. This ultimately biases what options emerge and may lead to key risks and options being missed. Other more in-depth processes (e.g., Lemieux and Scott, 2011; CEC, 2017; Halofsky et al., 2018; Perdeaux et al., 2018) may be more robust, although more time consuming, resulting in more comprehensive adaptation options. Second, while future climate scenarios were informed by climate projections, they lacked the rigour that more structured scenario-based planning approaches bring (e.g., Peterson et al., 2003; Miller et al., 2017), nor do they represent a full suite of alternative plausible futures (Rowland et al., 2014; Star et al., 2016; Fisichelli et al., 2016b). A lack of rigour in this foundational step of the workshop could lead to further biases in the resulting adaptation options. Third, workshop participants were not instructed to exhaustively identify advantages and disadvantages for each adaptation option. The authors note many more advantages and disadvantages that are missing from the analysis. While this is a weakness of the workshop, the advantages and disadvantages identified are indicative of key ones foremost in participants' minds. Finally, workshop participants were instructed to focus on adaptation strategies for the next ten years and to consider planning up to the year 2050. Focusing on the near term means considering a climate that is relatively unchanged from the present day with ecosystems that have experienced a limited response to climate change thereby avoiding difficult decisions related to future more drastic climate change.

3.6.2 Future Research Needs

Workshop participants identified future research needs during the workshop. Across all break-out groups, participants frequently expressed the need for more information regarding species interactions and phenological mismatches. Additionally, they identified the need for more information on the trial application of certain adaptation options. The lack of a sound evidence base upon which to make informed decisions is increasingly being acknowledged as a widespread problem in the effective conservation of biodiversity not only in Canada (Lemieux et al., 2018) but indeed globally (Cook et al., 2010; Giehl et al., 2017). The development of a central repository for case studies would be beneficial, allowing for knowledge sharing. Furthermore, the evaluation of underlying factors that contribute to increased effectiveness and feasibility ratings would assist in designing adaptation options, in turn, enhancing the ability of protected area organizations to address the impacts of climate change. Future studies should also incorporate socio-ecological factors, such as changes in tourism rates, into the workshop process because those factors are likely to have substantial impacts on ecosystems and also to change as the climate changes.

This study evaluated the effectiveness and feasibility of hypothetical and theoretical adaptation options from a practitioner point of view; however, additional studies that empirically evaluate the effectiveness of implemented adaptation options are needed across ecosystems and diverse governance arrangements. Such evaluations may become more useable as more adaptation options are implemented (along both continuums) and reported on in both grey and academic literature. Additionally, as the impacts of climate change become more apparent, society will be forced to make difficult decisions and consider the trade-offs between conventional and interventionist strategies as well as strategies that aim to resist or direct change. Understanding public values surrounding climate change adaptation will become increasingly important. Implementing interventionist strategies that direct change could become contentious and such decisions should be grounded in societal values. According to Lemieux et al. (2011), engaging the public in management decisions will work to reduce conflict and build public support for more contentious management actions (e.g., conventional and interventionist strategies that direct change). As evidence from this study indicates, conventional options have the advantage of already having public support whereas interventionist ones may not. Public preferences and values must be considered to attract public and policy support for more controversial, uncertain, interventionist management decisions.

3.7 Conclusions

There was an assumption in the first half of the 20th century, when the concept of conservation was developed, that land can be set aside and the same species assemblages will be present in perpetuity (Heller and Hobbs, 2014). This assumption is reflected in park mandates; however, this is no longer, and maybe never was, a valid assumption. Climate change is not a temporary disturbance after which conditions will return to their baselines. Rather, it is a persistent directional shift in conditions (Fisichelli et al., 2016a). Therefore, our responses to climate change need to direct ecosystem change and recognize that climatic conditions are continuously changing. Beyond BPNP/FFNMP, the prevailing current approach to adaptation among conservation organizations is also one of coping (Wise et al., 2014); however, transformative, more directed, adaptation is necessary to address rapid ecological change (Colloff et al., 2017; Fedele et al., 2019).

A shift from accommodating change to embracing change is necessary. The need for transformative protected areas policies was identified thirty years ago (Lopoukhine, 1990; Scott and Suffling, 2000; Scott et al., 2002), yet still has not occurred. Coping and incremental change may result in maladaptation, reduce future options due to environmental degradation, and potentially result in systems collapse (Pelling et al., 2015). On the other hand, transformative change could ease the transition towards alternative sustainable pathways (Fedele et al., 2019). Recognizing the need for transformative adaptation expands the range of management options available to practitioners, avoids path dependency, and maintains dynamic adaptation pathway options (Wise et al., 2014; Pelling et al., 2015; Colloff et al., 2017). Despite transformative adaptation being a well recognized concept, conservation policy keeps focusing on the near-term and avoiding difficult long-term decisions. When will the impacts of climate change be sufficiently visible to warrant the application of transformative adaptation to conservation policy? Conservation carrying on as if things were stable is not productive. Conservation needs to take a pro-active forward-looking approach, work off an assumption of unpredictability, and take an inter-disciplinary approach incorporating multiple values.

To achieve a shift towards transformative forward-looking conservation, policies and park mandates need updating to reflect changing conditions and the need for a different approach to conservation. In the case of Parks Canada, they need to receive political licence from Parliament and Cabinet to consider transformative changes. Therefore, climate change presents a governance challenge for Parks Canada whereby substantial changes in policies are required to adjust to the reality of altered ecosystems. Canadians, governments, and scientists need to decide what to protect and policies and mandates need to be adjusted accordingly (Suffling and Scott, 2002). Scott and Suffling (2000) recommended a national climate change roundtable on protected areas with licence to broadly consider conservation mandates in an era of climate change 20 years ago and Lemieux and Scott (2011) found support for a national climate change working group among Ontario Parks senior decision-makers; however to our knowledge, this has yet to occur. Such an exercise is still needed today and would aid in re-envisioning park mandates and developing adaptation strategies for protected areas. Calls for reconsideration of Canadian protected area mandates, policies, and practices have been occurring for the past three decades, yet substantial change has yet to occur (Lopoukhine, 1990; Scott and Suffling, 2000; Scott et al., 2002; Lemieux et al., 2004; Lemieux and Scott, 2005; Lemiuex et al., 2011b, Lemieux and Scott, 2011). These calls for change are still valid today, and even more pressing, as the impacts of climate change become more apparent and urgent.

The impacts of climate change on ecosystems are being realized on-the-ground by protected area agencies and the need for a change in conservation practice is recognized by practitioners (Barr et al., 2020); however these changes may not be acknowledged at higher levels. The May 2019 two-day workshop held by BPNP/FFNMP echoes this reality. Conservation managers need to find a balance between interventionist strategies and conventional strategies as well as strategies that aim to resist or direct change. One reason why interventionist options are less popular may be that their implementation forces society to make difficult choices and requires a substantial shift in how we view and value nature and, therefore, how we approach conservation (Prober et al., 2019). As climate change progresses, and restoration type activities become less achievable, a change in thinking may be forced and a paradigm shift may occur from static (restoration) to dynamic (renovation) views of ecosystems (USGCRP, 2008; Prober et al., 2019; van Kerkhoff et al., 2019). In this new paradigm, society will be forced to make value judgements regarding desired future states (Scott et al., 2002). To achieve this paradigm shift, conservation managers will have to 1) make decisions regarding the future desired state of their protected area, 2) take an exploratory and experiential approach to conservation planning whereby new strategies are tested and results are shared broadly, 3) engage with the science and climate change community to become more familiar with interventionist approaches and directed conventional approaches and gain comfort, and 4) incorporate social science perspectives and social values into conservation planning. Increased knowledge and familiarity could lead to greater support among practitioners for interventionist options (St-Laurent et al., 2018); therefore, what was once unfamiliar and contentious (interventionist options) may become more accepted as climate change knowledge increases, impacts are realized, and examples of interventionist options become available.

Chapter 4

Assessing the Adaptation Readiness of Bruce Peninsula National Park and Fathom Five National Marine Park to Adapt to the Impacts of Climate Change

4.1 Abstract

Protected areas worldwide face significant threats from rapid climatic and associated ecological change. The need to adapt to the impacts of climate change on biodiversity is widely acknowledged; however, action on adaptation remains scarce. In this paper we present a multi-theme framework to assess the adaptation readiness of protected area organizations. Through an online survey and in-person workshop we applied the framework to the Bruce Peninsula National Park (BPNP) and Fathom Five National Marine Park (FFNMP) in Ontario, Canada. Based on survey and workshop data, the objectives of this paper are to i) provide a self-assessment of the BPNP/FFNMP's adaptation readiness to respond to current and potential climate-related issues, ii) identify ways to strengthen the capacity of protected areas to respond to climate change, and iii) test the adaptation readiness framework in a national park. Results indicate that the BPNP/FFNMP have moderate overall adaptation readiness with higher readiness in terms of social-ecological systems (e.g., mapping and monitoring values) and lower readiness in terms of knowledge (i.e., knowledge management and exchange). Recommendations to increase the adaptation readiness of protected areas include increasing partnerships and education, and having a climate change champion on staff. Concrete steps to enhance adaptation readiness are required to ensure that adaptation planning is translated into on-the-ground action.

4.2 Introduction

The need to adapt to the impacts of climate change on biodiversity in protected areas worldwide is becoming more pronounced (IPCC, 2014; IPBES, 2019). However, despite a proliferation of adaptation strategies proposed in the literature (Heller and Zavaleta, 2009), a disconnect between recommendations and on-the-ground action exists, and action on adaptation remains limited (Armsworth et al., 2015; Barr et al., 2020). Moreover, few studies have examined the adaptation readiness of protected area organizations to actually implement these strategies. Understanding of the organizational factors that allow adaptation to occur is lacking (Ford and King, 2015)

For protected area organizations to implement effective adaptation strategies as adaptation research transitions from theory to implementation, the need to assess adaptation readiness is paramount. Significant barriers to the implementation of adaptation options in protected areas include lack of knowledge, resources, and political or social will (Lonsdale et al., 2017; Keeley et al., 2017; Barr et al., 2020). Assessing the adaptation readiness of organizations will allow organizational strengths and weaknesses to be identified, thereby increasing the ability of organizations to overcome these barriers and respond to the impacts of climate change.

Adaptation readiness refers to the preparedness of an organization (or human systems more broadly) to respond to the challenges associated with climate change and gives an indication of the likelihood that adaptation will occur. It is viewed as a complementary concept to adaptive capacity which refers to an organization's theoretical ability to adapt (Ford and King, 2015; Tilleard and Ford, 2016; Araos et al., 2017). Adaptation readiness examines the degree to which policy processes and governance structures are in place to support adaptation whereas adaptive capacity examines whether tools are in place to facilitate the implementation of management interventions (Ford and King, 2015). Adaptive capacity could be high in the sense that there is an understanding of how to adapt and the tools are available to do so but adaptation readiness could be low in the sense that mandates and governance structures do support the implementation of adaptation strategies.

Adaptive capacity is defined by the IPCC (2007, pg. 869) as "the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequence." However, high adaptive capacity does not imply that adaptation is inevitable or automatic (Adger and Barnett, 2009; Yusuf and St John III, 2017). An organization can have all the necessary resources but still fail to adapt. Adaptation readiness goes beyond adaptive capacity to examine if processes are in place to allow for adaptation to occur. Additionally, adaptation readiness assesses whether political and social will for adaptation are present, and if conditions for adaptation are suitable by examining the strength and existence of various governance structures that determine the ability to develop, implement, and monitor adaptation initiatives (Ford and King, 2015; Tilleard and Ford, 2016). Combining the concepts of adaptation readiness and adaptive capacity provides a strong basis for institutional action and offers an indication of the likelihood that adaptation action will occur in the short- to medium-term (Tilleard and Ford, 2016). Moreover, it provides insight into where resources can be directed to enhance preparedness to adapt.

Although the concept of adaptive capacity is frequently discussed in the literature (Siders, 2019), the literature on climate change adaptation readiness is scant. The concept of readiness has been applied in diverse fields (e.g., public health, military planning, business management) to measure the preparedness of an organization to manage diverse threats (e.g., disease outbreaks, terrorism) or take advantage of change (Ford and King, 2015). However, the term has seldom been used in the context of climate change. Ford and King (2015) developed a framework to assess climate change adaptation readiness and a few studies have applied the term in the contexts of marine spatial planning (Khan and Amelie, 2015), trans-boundary river basins (Tilleard and Ford, 2016), arctic communities (Ford et al., 2017), sea-level rise (Yusuf and St. John III, 2017), and urban areas (Araos et al., 2017).

Several studies have proposed frameworks or criteria to assess adaptation readiness or related concepts (i.e., organizational readiness, adaptive capacity) (Yohe and Tol, 2002; Gupta et al., 2010; Gray, 2012; Ford and King, 2015; Tilleard and Ford, 2016; Araos et al., 2017). Initially, Yohe and Tol (2002) put forth six determinants of adaptive capacity – technological options, resources, international institutions, human capital, social capital, and processes. Later, Gupta et al. (2010) presented 'the adaptive capacity wheel' to assess the adaptive capacity of institutions using six dimensions similar to those presented in Yohe and Tol (2002) – variety, learning capacity, room for autonomous change, leadership, availability of resources, and fair governance. Most recently, Ford and King (2015) put forth a conceptual model for adaptation readiness similar to that of Gupta et al. (2010) consisting of six factors – funding, institutional organization, usable science, decision making, leadership, and support. This model was subsequently adopted by Tilleard and Ford (2016), Araos et al. (2017), and Ford et al. (2017), and tailored to the contexts of adaptation in trans-boundary river basins, global south megacities, and arctic communities, respectively. None of these scholarly peer-reviewed studies have considered adaptation readiness in a protected areas context; however, due to the impacts of climate change on biodiversity, it is important to assess the adaptation readiness of protected area organizations.

In this study, we adopt and update a framework proposed in the grey literature by Gray (2012) that is similar to the Ford and King (2015) model in that it uses similar assessment criteria but is unique to the protected areas context. The framework used in this study assesses adaptation readiness under the following five themes: social-ecological systems, institutional culture and function, planning and implementation, partnerships and public support, and knowledge. For the purposes of evaluation, these themes are examined independently but in reality, there are many interconnections among themes. Some themes may be contingent on the existence of other themes; tension may exist between themes; or themes may reinforce each other. To identify and prioritize adaptation actions and guide resources to where they are needed, this framework can be used in combination with other approaches such as Parks Canada's *Climate Change Adaptation Framework for Parks and Protected Areas* (Nelson et al., 2020). Moreover, the adaptation readiness framework can also assist with evaluating adaptation progress by assessing adaptation readiness now and in the future to measure progress.

A single prescriptive approach to assessing adaptation readiness is not feasible as each protected area faces its own unique suite of climate change impacts, challenges, and needs. Adaptation readiness assessments thus need to take place at a local scale with close consideration of regional drivers and challenges. In this paper we explore the role of adaptation readiness in a case study context of the Bruce Peninsula National Park (BPNP) and Fathom Five National Marine Park (FFNMP) (henceforth referred to as 'the Parks'). The Parks have developed/identified adaptation options to address climate change impacts; however, the organizational capacity of the Parks to implement those actions has not been assessed. According to Repetto (2008), "just because we can adapt does not mean we will." Therefore, it is important to assess the adaptation readiness of the Parks. The objectives of this paper are to i) provide a self-assessment of the Bruce Peninsula National Park and Fathom Five National Marine Park's adaptation readiness for response to current and future climate-related ecological issues, ii) identify ways to strengthen the capacity of protected areas to respond to climate change, and iii) test the proposed adaptation readiness framework in a national park.

4.3 Conceptual Framework

To assess the adaptation readiness of BPNP/FFNMP we draw from and build upon a framework developed by Gray (2012) which outlines factors that determine whether adaptation takes place in a protected areas context. We also integrate more recent scholarship, not specific to the protected areas context, to inform our updated framework (e.g., Ford and King, 2015; Tilleard and Ford, 2016). In particular, we re-organize the Gray (2012) framework into five themes and thirteen sub-themes, with the addition of two new themes and two new sub-themes, to allow for a thorough evaluation of adaptation readiness (Figure 4.1). The framework is broadly applicable to all protected areas; however, specific questions to assess each theme and sub-theme need to be tailored to the unique context of each protected area to account for protected area specific challenges.

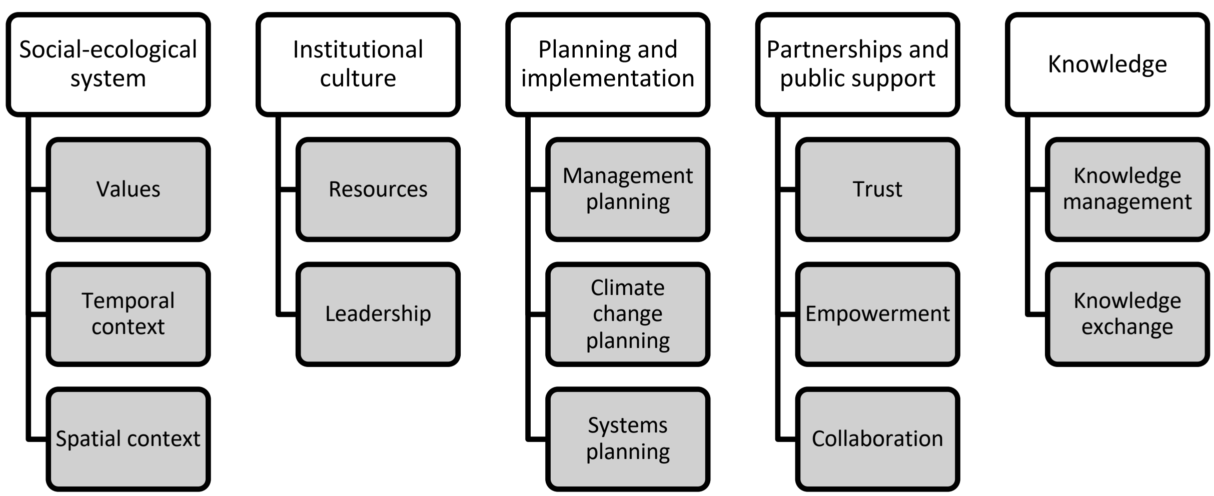


Figure 4.1: A framework for assessing adaptation readiness of protected area organizations (adapted from Gray, 2012).

4.3.1 Social-Ecological System

Protected areas can be viewed as social-ecological systems as they are influenced by and have an impact on broad social, ecological, and political systems (Cumming et al., 2015). Social-ecological systems are inextricably linked human and natural systems and social-ecological systems theory aids in understanding the complex multilevel whole (Berkes and Folke, 1998; Ostrom, 2009). Historically, ecological systems and human systems were managed separately but social-ecological systems theory acknowledges the need for them to be managed as a complex whole. Accordingly, protected areas need to consider social and ecological values in their planning processes.

Protected area organizations make decisions regarding where to direct limited resources and which features to preserve. Such choices require consideration of ***values, both social and ecological***, as complex ecological problems are underpinned by diverse and sometimes conflicting values (Adger et al., 2009; Rawluk et al., 2019). Values refers to what is important to people (Rawluk et al., 2019). Other adaptation readiness frameworks, such as that presented in Ford and King (2015), do not consider values; however, the consideration of values in protected areas adaptation work is critical to ensure natural features important to the public are preserved. Values are managed on diverse spatial and temporal scales (Gray, 2012; Cumming and Allen, 2017). The ***spatial context*** sub-theme assesses whether social and ecological values important to a protected area have been mapped and described. Understanding the spatial distribution of social and ecological values is necessary to develop and implement effective adaptation strategies (Adams et al., 2017). Time is another important scale in adaptive decision-making and modelling (Gray, 2012). The ***temporal context*** sub-theme assesses the Parks' ability to plan across various timeframes ranging from immediate (<1 year), to short-term (1-5 years), to long-term (5+ years). In the context of Parks Canada, management plans are prepared and reviewed every 5-10 years (long-term planning), state of the park reports are prepared every 2 years (short-term planning), and monitoring planning and assessments occur on an annual basis (immediate planning). The ability to plan across multiple timeframes is important in managing for the impacts of climate change and ensuring that values important to an organization persist into the future (Termeer et al., 2012).

4.3.2 Institutional Culture

An institutional culture that supports climate change adaptation is critical for ensuring adaptation readiness (Termeer et al., 2012; Eisenack et al., 2014; Ford et al., 2017). In this framework, institutional culture refers to the political and administrative structure that governs how an organization completes its core business and what ability it has to mobilize leadership and resources. Institutional culture, or institutional organization, is a common theme among adaptation readiness frameworks. ***Leadership*** is a key component of institutional culture, providing a direction for change and motivating others, and is required to initiate the process of adaptation (Gupta et al., 2010; Eisenack et al., 2014; Araos et al., 2017); it can occur at various spatial scales (national to local) and can come from individuals in different positions (Ford and King, 2015). The availability and generation of ***resources,*** both financial and human, has also been identified as a critical factor that can constrain or enable adaptation (Gupta et al., 2010; Termeer et al., 2012). Resources are mentioned in other adaptation readiness frameworks as a factor that contributes to institutional readiness (e.g., Gray, 2012; King and Ford, 2015); however, resources are featured more prominently in our framework as a sub-theme as they are thought to be critical to an organization's ability to adapt. Moreover, in the protected areas context, resources are often a limiting factor in meeting core mandates, let alone adapting to climate change. Therefore, resources are an important factor to explicitly consider in a protected areas adaptation readiness assessment.

4.3.3 Planning and Implementation

In the context of natural resource management, planning occurs on several different levels. Planning can be used as a tool to manage for and drive change by identifying, modifying, and/or establishing short- to long-term direction in support of an organization's vision for the future (Adams et al., 2017). ***Management planning*** provides detailed guidance on how to achieve measurable desired outcomes aligned with a future vision. Management planning tends to be location specific and focus on in-situ conservation practices. Given that the impacts of climate change on biodiversity occur on a landscape scale, ***systems planning***, integrated at the national, sub-national, and regional scale, is required for a coordinated approach to conservation in and outside protected areas (Leck and Simon, 2013; Adams et al., 2017). Finally, undertaking ***climate change planning*** exercises is necessary to consider various plausible futures. This is a new addition to the updated Gray (2012) framework. To support adaptation actions that may arise from various planning processes, it is important that policy and legislation (including guidelines, permits, and licenses) be kept current to guide activities as the climate changes.

4.3.4 Partnerships and Public Support

A culture of partnership with strong public support is key to decision-making under uncertainty (de Vente et al., 2016). Diverse partnerships at various geographic and jurisdictional scales are important, including partnerships with Indigenous communities. If society ***trusts*** the ability of an organization to implement fair, accountable, and transparent programs with meaningful public engagement and in partnership with other organizations, the chances of successfully managing for climate change are enhanced (Gray, 2012; Reed et al., 2013; Kettle and Dow, 2016). Furthermore, some climate change impacts occur on the landscape scale, such as species redistribution, therefore the best solutions will occur in ***collaboration*** with other organizations (Leck and Simon, 2013; Laursen et al., 2018). ***Empowerment*** of staff, partners, and the public is key to educating and sharing knowledge with salient groups outside the organization.

4.3.5 Knowledge

The concept of knowledge, or usable science, is present in all adaptation readiness frameworks we are aware of, highlighting its importance in adaptation across sectors. ***Knowledge management*** involves the gathering of information through research, inventory, and monitoring and assessment, and the use of an information management system. Different types of knowledge important to climate change adaptation and protected areas include scientific knowledge, local knowledge, and Indigenous knowledge (Tengo et al., 2014; Makondo and Thomas, 2018). The acquisition, use, and dissemination of different types of knowledge is critical in support of adaptive management (Termeer et al., 2012). The ***knowledge exchange*** sub-theme refers to how knowledge is acquired and shared both internally and among partners. According to Gupta et al. (2010), “adaptive institutions encourage actors to learn." Collating and sharing knowledge among diverse groups is critical to solving complex problems like climate change.

4.4 Study Location

The Bruce Peninsula National Park (BPNP) is one of 47 national parks in Canada (Parks Canada, 2020a) and Fathom Five National Marine Park (FFNMP) is one of four national marine conservation areas in Canada (Parks Canada, 2020b). The Parks, both established in 1987, are located at the northern tip of the Bruce Peninsula in Southern Ontario, Canada (Figure 4.2) and cover 156km^2 and 114km^2, respectively (Parks Canada, 2010a, 2010b). BPNP protects a representative example of the Great Lakes/St. Lawrence Lowlands natural region while FFNMP protects representative aquatic and terrestrial features of the Georgian Bay Marine Region (Parks Canada, 1998a, 1998b). The Parks are administratively operated and managed together with the same staff, therefore both Parks are included in this study. Despite being administratively managed together, the Parks are managed under different legislation with different management goals. The primary goal of BPNP, the terrestrial park, is the maintenance of ecological integrity (Parks Canada, 1998a) – "a condition that is determined to be characteristic of its natural region" (Canada National Parks Act, 2000, 1). Conversly, the primary goal of FFNMP, the marine park, is ecological sustainability (Parks Canada, 1998b) – "meet[ing] the needs of present and future generations without compromising the structure and function of the ecosystems" (Canada National Marine Conservation Areas Act, 2002, 4). Accordingly, commercial and industrial activities are permitted in FFNMP but not BPNP.

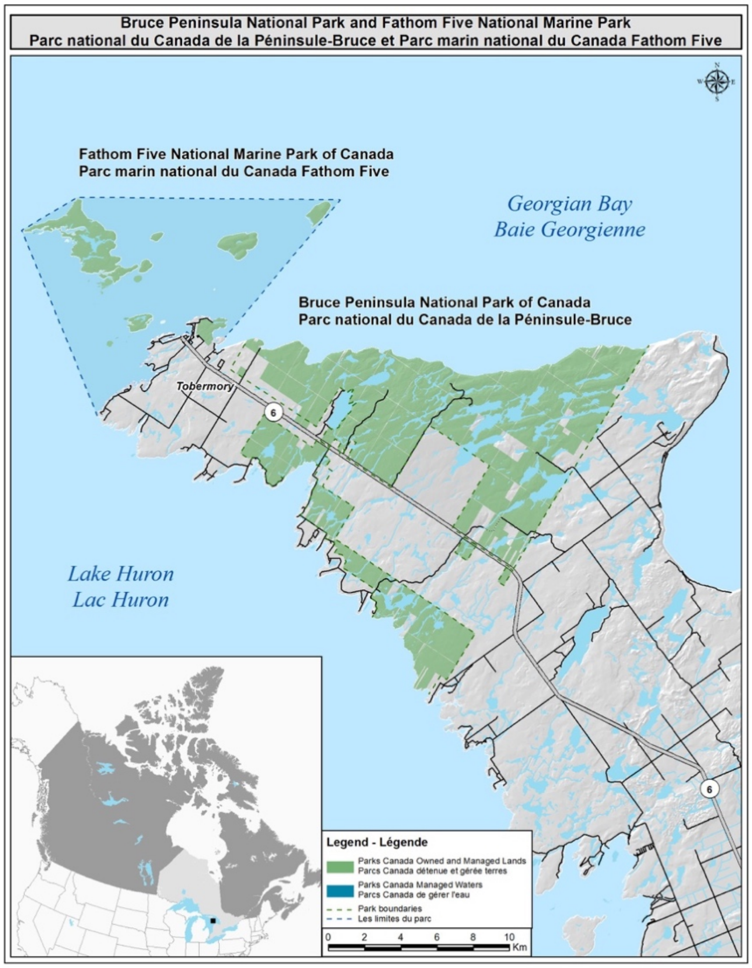


Figure 4.2: The location of Bruce Peninsula National Park and Fathom Five National Marine Park. Black box inlay shows the location of the park in relation to the rest of Canada. (Source: Parks Canada)

4.5 Methods

4.5.1 Data Collection and Analysis

To assess the adaptation readiness of BPNP/FFNMP to adapt to the impacts of climate change we used a mixed methods approach by conducting a quantitative online survey of park staff and a qualitative post-survey workshop. A prior version of the survey had previously been piloted with the Mississippi Valley Conservation Authority (Stager et al., 2014). This Mississippi Valley Conservation Authority survey contained 30 questions and was completed online by nine staff members. Following the online survey a face-to-face workshop was held to review survey results. This pilot study revealed that the approach has merit and is a valuable tool to aid conservation organizations in understanding strengths and weaknesses in their adaptive capacity (Stager et al., 2014). Based on feedback from Mississippi Valley Conservation Authority participants, the survey and framework were refined by the previous survey team (i.e., Stager et al., 2014). Present survey questions were also refined, in consultation with Parks Canada, to be pertinent to BPNP/FFNMP.

The survey contained four questions on respondent information (e.g., educational background, current work role), four questions regarding perceptions of climate change, and 28 closed-ended Likert scale questions pertaining to adaptation readiness (Appendix F). Each of the adaptation readiness questions followed the same format beginning with “to what extent does…” and had the same possible Likert-scale responses of ‘not at all’, ‘slightly’, ‘somewhat’, ‘mostly’, ‘completely’, and ‘not qualified to answer’. The adaptation readiness questions were grouped into five themes and 13 sub-themes according to the adaptation readiness framework (Figure 4.1).

To increase our survey response rate, we followed Dillman’s survey methodology (Dillman, 2007). Participants were notified by Parks Canada of the research and told that researchers would be contacting them. We then contacted participants via email inviting them to partake in the online survey. Participants were recruited based on their role at BPNP/FFNMP. The survey was distributed primarily to the park management team as they have overall knowledge of park operations, policies, and finances; however, a few additional staff members pertinent to park management were also included. The survey was administered online via Qualtrics (Qualtrics, 2020). Participants were given two weeks to respond to the survey and up to three reminder emails were sent. We distributed the survey to 19 staff, of which 15 staff completed it, for an overall survey response rate of 79%.

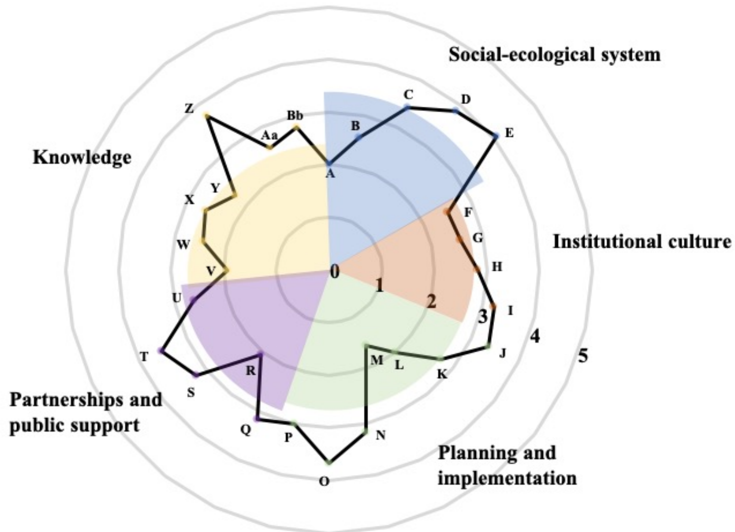
Once the survey was closed, results were compiled and analyzed (Appendix G). The mean and standard deviation for each of the Likert-scale questions were calculated by assigning a value of 1 to ‘not at all’, 2 to ‘slightly’, 3 to ‘somewhat’, 4 to ‘mostly’, and 5 to ‘completely’. If a participant responded ‘not qualified to answer’ to a particular question, their response to that question was excluded from analysis. Additionally, we calculated the mean value for each sub-theme. Parametric tests (e.g., mean and standard deviation) have been shown to be appropriate to use with Likert scale data, despite Likert scale data being ordinal data, if the sample size is sufficiently large (i.e., greater than 5) (Norman, 2010; Sullivan and Artino, 2013). Key results were thematically analyzed and clustered into groups of results that would elicit similar discussion in the workshop. Workshop discussion questions were developed based on survey results (Appendix H).

Eight participants, six of whom were from the park management team, who participated in the survey, were present at a three-hour workshop held at the Parks in November 2019. The purpose of the workshop was to gain further insight into survey results. Survey results were presented to participants in clusters and probing questions based on survey results were asked. The workshop was audio-recorded, transcribed, and content analysis was conducted to thematically-code discussion segments to the framework.

This research received ethics clearance from the University of Waterloo Office of Research Ethics (ORE #41301) and the survey instrument is available upon request.

4.6 Results

The overall adaptation readiness of the BPNP/FFNMP is 2.84 out of 5. Scores closer to 5 indicate higher adaptation readiness whereas scores closer to 1 indicated low adaptation readiness. Within the themes and sub-themes, the level of adaptation readiness varies. For example, the Parks have higher adaptation readiness in terms of social-ecological systems, with an average for that theme of 3.18, and low adaptation readiness in terms of knowledge, with an average for that theme of 2.62 (Figure 4.3).



Legend

A – Values – social
B – Values – ecological
C – Temporal context
D – Spatial context – social
E – Spatial context – ecological
F – Resources – financial
G – Resources – human
H – Leadership – priority actions identified
I – Leadership – supports mainstreaming
J – Management plan – enabling management plan
K – Management plan – adaptive governance
L – Management plan – climate change objectives
M – Climate change planning – assessed costs
N – Climate change planning – exercises undertaken
O – Climate change planning – Access to tools
P – Systems planning
Q – Trust
R – Empowerment
S – Collaboration - multiple scales
T – Collaboration – approach to partnerships
U – Collaboration – meet partner needs
V – Knowledge dissemination – staff training
W - Knowledge dissemination – partners
X – Knowledge dissemination – monitoring networks
Y – Knowledge management – local
Z – Knowledge management – scientific
Aa – Knowledge management – Indigenous
Bb – Knowledge management – monitoring

Figure 4.3: Adaptation readiness survey mean values by question for Bruce Peninsula National Park and Fathom Five National Marine Park. 1 indicates low capacity and 5 indicates high capacity. Letters correspond to survey question which are described in the legend. Coloured sections indicate adaptation readiness values by theme.

4.6.1 Climate Change Perceptions

Climate change is a concern for Park staff with nearly all respondents (93%) being either moderately or extremely concerned about climate change. Similarly, nearly all respondents (93%) have already noticed effects of climate change within the Parks and think that climate change will have a very negative or somewhat negative impact on the overall ecological integrity of the Parks and their ability to support current plant and wildlife populations. There is less consensus among respondents regarding the perceived impact of climate change on the enjoyment people get from visiting the Parks with half of the respondents indicating a somewhat negative impact (53%), some respondents indicating no impact (26%), and some respondents indicating a somewhat positive impact (20%). However, the majority of respondents think that climate change will have a very negative or somewhat negative impact on human safety and well-being within the Parks (80%).

4.6.2 Social-Ecological System

Concerning evaluation and reporting on potential future effects of climate change on important social and ecological values within the Parks, the Parks scored low for both social and ecological values with a mean score of 2.00 (+- 0.93 SD) and 2.57 (+- 0.65 SD) out of 5, respectively. Examples of social values in the context of a national park include aesthetics and archeological sites and examples of ecological values include migration corridors and breeding habitat. In terms of mapping and describing important values, the Parks scored moderately high, receiving a mean score of 3.86 (+- 0.36 SD) and 4.07 (+- 0.48 SD) out of 5 for both social values and ecological values, respectively; however, through workshop discussion the participants acknowledged that the Parks are better at mapping ecological values through the ecological integrity monitoring program than social values.

As for commitment to continuously monitoring these social and ecological values over time (the temporal context) to assess their condition as the climate changes, the Parks have a moderately high readiness, receiving a score of 3.42 (+- 0.90 SD). Again, workshop discussions revealed a difference between continually monitoring for ecological values versus social values with one participant stating that "ecologically we are committed to continuous monitoring but I'm not sure that currently we can say we are completely committed to monitoring social values." When asked "to what extent do inventory, monitoring, and assessment programs enable the evaluation of climate change impacts and associated 'state of' reporting", the mean response was 'somewhat' or 2.78 out of 5 (+- 0.83 SD) indicating that there is room for improvement in the Parks' monitoring program. According to one workshop participant, "[w]e don't monitor directly for climate change. Using the information we have, we could possibly make a conclusion that includes climate change but we haven't set out to monitor specifically for it. [The monitoring program] could be built better."

4.6.3 Institutional Culture

Priority actions for climate change monitoring and adaptation have 'somewhat' been identified (2.83, +- 0.58 SD). Similarly, respondents feel that the Parks' leadership 'somewhat' supports the mainstreaming of climate change into their programs (3.21, +- 0.98 SD). In terms of resources available to manage for the effects of climate change, most respondents felt that the Parks have 'somewhat' sufficient human resources and financial resources with an average score of 2.56 (+- 1.01 SD) and 2.50 (+- 1.20 SD), respectively. It should be noted that the questions relating to human and financial resources had a high number of respondents indicating that they were 'not qualified to answer', at 6 and 7 respondents respectively. Due to the high 'not qualified to answer' rate and the relatively high standard deviation of those questions, caution should be used when interpreting those questions. Furthermore, the Parks have not fully assessed costs to achieve the target of climate change adaptation, receiving a score of 1.60 out of 5 (+- 0.52 SD). On the topic of cost one respondent stated, "I think we have looked very short-term. We have looked at it's too expensive to do this, we don't have the funds so we are not going to do it, but we haven't looked at what the cost is going to be for us 20 years down the road because we didn't do it this way now."

4.6.4 Planning and Implementation

When asked about the extent that the Parks' management plan and Parks Canada projects enable the mainstreaming of climate change – the integration of climate change considerations into policies, strategies, plans, and guidelines, the average response was 'somewhat' (3.36, +- 0.75 SD). Respondents also indicated that the Parks' management plan 'somewhat' (2.71, +- 0.83 SD) recognizes the importance of adaptive governance; however, it only 'slightly' (2.00, +- 0.85 SD) provides objectives and actions that enable staff and partners to respond to the effects of climate change. It should be noted that the BPNP and FFNMP management plans are outdated, last updated in 1998, and the Parks are currently in the process of developing new management plans. When asked about ecosystem-level planning, respondents indicated that the Park 'somewhat' (3.00, +- 0.76 SD) engages in such practices. In terms of climate change planning, respondents indicated that the Park has ‘somewhat’ (3.15, +- 0.56 SD) undertaken planning exercises to identify knowledge gaps, impacts of climate change, or strategies to address climate change. When asked about the extent to which participants (staff) have access to climate change adaptation tools and techniques, the average response was ‘mostly’ (3.67, +- 0.89 SD).

4.6.5 Partnerships and Public Support

Collaborating with partners at multiple scales of decision-making is an area for improvement for the Parks with a mean score of 3.21 (+- 0.80 SD). Respondents felt that the existing information management system only ‘somewhat’ (2.63, +- 0.52 SD) meets client and partner needs. However, respondents felt that the Parks have moderately high readiness (3.54, +- 0.88 SD) in terms of the current approach to partnerships and the ability to use that approach to enhance their capacity to adapt to the effects of climate change. The extent to which stakeholders trust the Parks to make appropriate decisions is another area for improvement for the Parks, with respondents perceiving that stakeholders only ‘somewhat’ (3.15, +- 0.90 SD) trust the Park to make appropriate decisions. Furthermore, the Parks have low readiness in terms of providing outreach programs to help visitors and local residents understand various aspects of climate change and to increase awareness, receiving a score of 2.07 out of 5 (+- 0.96 SD).

The Parks have low readiness in terms of providing partners with access to their information management system, receiving a score of 2.44 (+- 0.88 SD). Furthermore, collaborative monitoring networks that facilitate the exchange of data at multiple scales are another area for improvement for the Parks with a score of 2.62 (+- 0.51 SD). As one respondent indicates, “I think something positive we can do is reaching out to partners…If we are just collecting information in isolation and not sharing it as much, we are not going to know as much. I think that is something we can do better at. Having a larger database of information across the area…”. When asked about the extent to which staff training opportunities focused on adaptive management tool and techniques are available, the average response was ‘slightly’ (1.92, +- 0.86 SD).

4.6.6 Knowledge

Three questions asked about the incorporation of various types of knowledge (Indigenous, local, and scientific) into decision-making on the implementation of climate change initiatives. The Parks scored lowest on local knowledge (2.27, +- 0.96 SD), moderately in terms of Indigenous knowledge (2.57, +- 1.16 SD), and highly for scientific knowledge (3.73, +- 0.88 SD). Workshop discussion revealed misinterpretation of this question with some respondents answering about the incorporation of these types of knowledge into decision-making broadly and others focusing on climate change initiatives more specifically. When asked about the extent to which current monitoring programs enable the evaluation of climate change impacts, the average response was 'somewhat' (2.77, +- 0.83 SD).

4.7 Discussion

In this paper we evaluate the perceived adaptation readiness of the BPNP/FFNMP using a novel thematic framework. We found that the perceived adaptation readiness of BPNP/FFNMP was moderate to high for several sub-themes including the spatial context and temporal context, but low to moderate for others including empowerment and knowledge exchange (Figure 4.3). An overarching factor contributing to the moderate to high sub-themes is political and organizational leadership as well as a mandate for these activities. Conversely, political and organizational leadership is lacking for the low to moderate sub-themes. We note that the Parks have undertaken some climate change planning initiatives, although none of the identified adaptation options have been implemented. Furthermore, until recently, the Parks had a national office climate change staff member on site, which may have contributed to higher ratings on some themes. At the national level, there is evidence of funding for adaptation through the Nature Legacy Program, high-level action on adaptation planning, and research into climate change impacts; however, support for transitioning adaptation research into on-the-ground action is limited, and there is a lack of direct political leadership for implementing adaptation actions or changing policy.

A key factor in the case of BPNP/FFNMP having relatively high adaptation readiness in the spatial and temporal contexts is a clear mandate for these activities from Parks Canada national office and accompanying protocols to achieve these activities. A core activity at the

Parks is the monitoring and mapping of social and ecological values (e.g., features of ecological importance, species locations, archeological sites). These activities occur through well-established ecological integrity monitoring programs that are implemented in national parks across the country (ECCC, 2019) and the new cultural heritage strategy (Parks Canada, 2017). Conversely, a lack of support from Parks Canada national office and a lack political will were frequently mentioned in the workshop and are contributing factors in the low to moderate sub-themes of empowerment and knowledge exchange. For example, until recently, according to workshop participants, the Parks were unable to conduct outreach programs in the community (i.e., school programming, etc.) due to political limitations that disallowed outreach beyond park boundaries. In order for adaptation to be a priority, political and organizational leadership needs to be present (Burch, 2010, Measham et al., 2011; Lonsdale, 2017). This requirement is echoed in both the academic literature and workshop discussions.

Adaptation to climate change involves overcoming inertia, responding to uncertainty, and taking risks in a risk averse culture (Gupta et al., 2010; Termeer et al., 2012; Ford and King, 2015). To overcome these factors and initiate adaptation, strong political leadership is needed to provide strategic direction and sustain momentum (Moser and Ekstrom, 2010; Ford and King, 2015; Henstra, 2017). Tilleard and Ford (2016) found in their study of adaptation readiness in various transboundary river basins that political leadership has a large impact on the potential for adaptation. Furthermore, Ford et al. (2017) report that political leadership on adaptation occurs when governments declare adaptation as a priority and lead the adaptation process. Similar ideas were expressed by workshop participants who suggested that climate change is a political issue and needs to be a priority for the Minister and the government before it becomes a priority for Parks Canada staff. Recently, climate action goals have begun to appear in mandate letters to federal ministers (PMO, 2019). Once climate change is a government priority, Parks Canada can integrate climate change more explicitly into management plans and actions plans that can translate those priorities into on-the-ground action. To increase adaptation readiness in protected areas, we provide four recommendations (below). These recommendations were developed in the context of our findings from BPNP/FFNMP yet the concepts are broadly applicable to all protected areas.

First, a climate change education program for staff and visitors should be developed to boost momentum for climate change adaptation to become a political priority, thereby bringing stronger leadership which is currently lacking. Parks Canada has a dual mandate to protect and present natural and cultural heritage to Canadians (Parks Canada, 2002). This mandate could be leveraged to grow public awareness of the impact of climate change on the natural ecosystem. As one workshop participant stated "…the biggest thing parks in general can do is to affect people's ideologies of what is important." Workshop discussions revealed that interpretation staff do not feel like experts on climate change and are therefore reluctant to have climate change conversations with park visitors. Developing a visitor experience staff training program related to climate change and incorporating climate change into existing programming (e.g., interpretive hikes, campfire programs, canoe program) would help communicate the impacts of climate change to the public. Communicating climate change science effectively to visitors may lead to a change in visitor attitude and voting behaviour and therefore political leadership on the issue (Fidelman et al., 2017). Additionally, increasing learning opportunities with visitors and the local public has the potential to increase trust (Gupta et al., 2010).

Second, effective climate change adaptation requires collaboration across levels of government and with non-governmental organizations (Gupta et al., 2010; Henstra, 2017). Increasing partnerships with local and regional conservation organizations would increase resources (financial, human, knowledge) available for adaptation and assist with overcoming political barriers and deficiencies in the political system (e.g., changing priorities every four years), thereby increasing the capacity of the protected area to address climate change impacts (Lawrence et al., 2015). Additionally, partnering with other organizations will allow for a broader systems approach to adaptation planning and for conservation to occur on biologically relevant scales (Monahan and Theobald, 2018). As one participant stated in regards to working with partners, "…there are certain periods where Parks Canada has good funding to be able to address some of the effects of climate change whereas other times it is our partners who have more capacity, so by building these partnerships…we all have much greater capacity to keep momentum going." Moreover, different partners bring different perspectives and different expertise to the table, further strengthening capacity. For example, a collaboration between BPNP/FFNMP and its partners has allowed for the creation of a collaborative long-term monitoring dataset. In the absence of political leadership, and during times when climate change is a taboo subject with the federal government, enhanced partnerships would allow the Parks to continue work through external organizations to achieve climate change adaptation goals.

Third, increasing knowledge exchange with partners, local residents, and Indigenous communities is necessary to increase adaptation readiness. Relying solely on natural science data is not sufficient to address a long-term complex problem like climate change that is both a scientific and moral issue (Termeer et al., 2012). Other sources of knowledge such as local knowledge, Indigenous knowledge, and social science information combined with natural science data leads to more robust adaptation solutions (Tengo et al., 2014; Makondo and Thomas, 2018; Garcia-del-Amo et al., 2020). Furthermore, the involvement of multiple actor groups enhances learning through the sharing of experiences (Fidelman et al., 2017). Knowledge exchange goes both ways in terms of the Parks sharing their information with others as well as them seeking out and receiving information from partners and the public. According to one workshop participant, the knowledge of local people who have lived in the areas for generations is undervalued (both Indigenous and non-Indigenous residents), not just by Parks Canada but by other groups as well. It was suggested that by tapping into that knowledge source, trends of ecological change could be better understood. For example, through the Parks Advisory Committee, oral history information about environmental change over the past 100 years could be obtained and incorporated into park planning processes. Additionally, Indigenous insights could lend knowledge about environmental change over millennia. Sharing best practices and lessons learned among diverse stakeholder groups will aid in advancing adaptation and developing more robust solutions (Bierbaum et al., 2013).

Fourth, going beyond merely consulting with Indigenous groups to incorporating Indigenous-led conservation and recognizing conservation as reconciliation is important in increasing adaptation readiness. Reconciliation involves restoring relationships between Indigenous and non-Indigenous Canadians and shifting the balance of power (Indigenous Circle of Experts, 2018; Wong et al., 2020). Using both Indigenous and Western knowledge systems to inform and make decisions regarding conservation and climate change adaptation can lead to more robust management practices (Ban et al., 2018; Maxwell et al., 2020). Historically, Indigenous knowledge has been used to complement Western science (Zurba et al., 2019). Going forward, Indigenous knowledge needs to be viewed as equal to Western science and holistically incorporated into conservation decision-making, in an ethical space, from the outset of projects in way that supports Indigenous rights and responsibilities (Indigenous Circle of Experts, 2018; Wong et al., 2020). Doing so will provide an opportunity for strengthening nation-to-nation relationships between Indigenous peoples and non-Indigenous Canadians (Zurba et al., 2019). A paradigm shift in conservation towards Indigenous-led conservation will increase the adaptation readiness of protected area organizations by strengthening partnerships and holistically considering various types of knowledge in decision-making processes.

Finally, our findings from BPNP/FFNMP highlight the importance of having a climate change champion in each protected area to provide local leadership in the absence of national political leadership on climate change. The Parks received a relatively high score on the sub-theme of climate change planning. This is likely attributed to the fact that a national office staff member, part of the climate change team, had been based at BPNP/FFNMP for several years. This arrangement gave BPNP/FFNMP staff direct access to a climate change expert and staff may have acquired more climate change knowledge because of this than staff at other national parks. Furthermore, Ford et al. (2017) found that climate change champions play an important role in facilitating and coordinating adaptation work as well as breaking down silos and increasing stakeholder involvement. We found similar results at BPNP/FFNMP where the climate change staff member initiated a climate change adaptation workshop involving stakeholders and other government departments to identify climate change impacts and adaptation strategies. Having a climate change champion on staff in all protected areas, who is trained to cross-communicate science, would allow awareness to be raised about the impacts of climate change on the protected area’s mandate, enhance mainstreaming of climate change into management plans and action plans, and create legitimacy for adaptation (Ford et al., 2017).

4.7.1 Limitations and Future Research

The findings presented here are relevant to BPNP/FFNMP and may in some cases be broadly applicable to Canadian National Parks. While caution is advised in generalizing results to other parks, we believe the recommendations made in this paper are applicable. Workshop discussions revealed that 4 of 28 questions were interpreted differently by participants, leading to a wide variety of responses for those questions. Future studies using this framework could use a modified policy Delphi approach where participants answer survey questions in a workshop format with a moderator to clarify any questions. This approach would also account for learning amongst participants through workshop discussions regarding aspects of park operations or initiatives they may be less familiar with, and a re-survey may reveal more accurate and consolidated answers. Additionally, future studies could weight themes and sub-themes in the framework differently. In this study all themes and sub-themes have the same weighting although in reality they may not all have the same influence on adaptation readiness. Moreover, paradoxes may exist between variables whereby increasing capacity on one variable may decrease capacity on another (Gupta et al., 2010). Overall, the framework was found to be applicable to the protected areas context and feedback from participants indicates that the process has value by providing insight into priorities for adaptation and a means by which to assess organizational change over time.

As a site, BPNP/FFNMP has limited control over some of its practices. Parks Canada, as the overarching organization, has standardized practices and protocols that must be followed. Therefore, national level change is required to make progress on adaptation readiness in some respects. An adaptation readiness comparison between national parks to identify which strengths and weaknesses are inherent to Parks Canada at the national level and which ones are park specific would allow for more directed improvements to be made. Moreover, research is needed that compares the adaptation readiness of organizations that have implemented adaptation strategies versus those that have not in order to validate the themes and sub-themes that we hypothesize contribute to adaptation readiness. As well, such research would aid in elaborating interactions between themes and their relative importance.

4.8 Conclusion

In conclusion, increasing adaptation readiness of protected areas is critical to ensuring the preservation of biodiversity. This study represents one of the first adaptation readiness assessments for a protected area. Much attention in the literature has been paid to how conservation organizations can adaptively manage ecosystems in response to climate change; however, comparable effort needs to be paid to the organizational structure and capacity of conservation organizations to be adaptive themselves. This can be achieved by conducting adaptation readiness assessments of protected area organizations and taking steps to increase adaptation readiness such as increasing partnerships with external organizations, sharing knowledge more broadly, and seeking political leadership. Developing adaptation strategies is comparatively easier than implementing them; however, implementing strategies and continually monitoring for progress is critical to advancing the climate change adaptation yardstick and preserving biodiversity.

Chapter 5

Conclusions

Climate change is causing profound impacts on protected areas worldwide and is anticipated to be the leading cause of biodiversity loss by the end of century (IPBES, 2019; Sanderson and Fisher, 2020; Hannah et al., 2020). The effectiveness of current conservation practices has come into question (Urban, 2015; Pecl et al., 2017). Despite many uncertainties about the precise impacts of climate change on ecosystems, protected area management practices need to adapt as changes occur. This thesis represents a benchmark of the state of climate change adaptation in Canadian protected areas and provides insight into the adaptation strategy preferences of practitioners as well as the abilities of protected area organizations to implement those strategies.

Research findings have been presented as distinct manuscripts (*Chapters 2 – 4*). The goal of this chapter is to integrate the findings of the data chapters and to provide overall recommendations. The findings from each of the three main study aims are described below followed by recommendations for practice and future research. This chapter concludes with final thoughts.

5.1 Major Research Findings

The first aim of this dissertation was to understand the current state of adaptation in Canada. Chapter 2 addressed this aim through a cross-Canada study of protected area organizations. It was found that, for Canadian protected areas, while multiple impacts of climate change have been observed, little progress was made on climate change adaptation in Canadian protected areas between 2006 and 2018. Climate change is perceived as an important future management issue, but many barriers exist that limit the capacity of protected area organizations to respond. These barriers and lack of progress exist across all organization types (i.e., federal, provincial/territorial, and ENGOs). Moreover, conventional conservation strategies are preferred, both now and in the future, over interventionist ones. In a more positive direction, however, an increase was observed in the number of organizations reporting that climate change has been incorporated or considered in their management plans.

Additionally, there is less uncertainty regarding climate change, and indicators to monitor for the impacts of climate change have been developed.

The second aim of this dissertation was to gain insight into practitioner preferences for adaptation in order to assist with designing practical and effective adaptation strategies and to help overcome the previously identified barriers. This was evaluated through a workshop at the Bruce Peninsula National Park (BPNP) and Fathom Five National Marine Park (FFNMP) as described in Chapter 3. Consistent with the findings of Chapter 2, it was found that most adaptation options identified in the workshop were conventional strategies. Furthermore, these conventional strategies had the highest perceived effectiveness and feasibility ratings. In addition to being conventional adaptation strategies, most adaptation strategies identified in the workshop aimed to direct change, although there was little difference in the perceived effectiveness and feasibility ratings between strategies that direct and resist change. BPNP/FFNMP demonstrated a willingness to adapt through holding this workshop, yet several barriers to implementing adaptation strategies were detected during the workshop. Similarily, a decade ago, Lemieux and Scott (2011) found a lack of capacity in Ontario Parks to implement adaptation strategies identified in their Policy Delphi study.

The third aim of this dissertation was to assess the adaptation readiness of protected area organizations to implement adaptation strategies. This was achieved through an online survey and an in-person workshop with BPNP/FFNMP. I found that BPNP/FFNMP have higher adaptation readiness on some factors than others. For example, the Parks have high adaptation readiness in terms of mapping social and ecological values and monitoring those values over time, but low adaptation readiness in terms of empowerment and knowledge exchange. Workshop discussions revealed that political and organizational leadership was a key element in enabling high adaptation readiness on certain factors. Conversely, a lack of leadership or political will was associated with low adaptation readiness factors. With concerted effort and increased political and organizational leadership on adaptation, the potential for successful adaptation at BPNP/FFNMP exists.

The results of these three studies suggest that limited progress has been made on adaptation but that the potential for progress exists, particularly at BPNP/FNMP—if barriers can be overcome and potential harnessed. Recurring themes that came up across the three studies include the need for leadership, the need for guidance on how to choose and implement adaptation strategies, and the need to overcome barriers.

5.2 Key Research Contributions

In addition to making significant original contributions to the scholarly literature, this research also aimed to make practical contributions to the protected areas community to advance climate change adaptation. Outlined below are the academic and practical contributions of this research.

5.2.1 Academic Contributions

Extensive research exists on the biophysical impacts of climate change and theoretical approaches to mitigate those impacts. However, research on the effectiveness and feasibility of those theoretical approaches is limited and few studies have reported on implemented adaptation strategies. Moreover, limited place-based research has been conducted on practitioner preferences for biodiversity adaptation strategies. Furthermore, the existing literature has not addressed the adaptation readiness of protected area organizations to implement those strategies. This section describes contributions to the literature that Chapters 2, 3, and 4 have made to fill the above-mentioned research gaps.

First, this dissertation contributes to the scholarly literature on advancing climate change adaptation for protected areas and evaluating progress on adaptation within Canada (Chapter 2). To do so, this study updates, and makes comparisons to, a previous 2006 study (Lemieux et al., 2011b). Additionally, Chapter 2 makes a theoretical contribution by identifying differences between organizational types regarding adaptation strategies and barriers to implementation. Knowledge regarding the current state of adaptation in Canadian protected areas was critical to set the stage for the rest of this dissertation.

Second, this dissertation examines practitioner preferences for climate change adaptation strategies in a case study context (Chapter 3). According to the literature, there is a need for the co-production of knowledge regarding conservation science, policy, and practice between researchers and practitioners (Preston et al., 2015; Wyborn et al., 2015; Colloff et al., 2017). The literature has largely ignored practitioner preferences, instead focusing on theoretical recommendations not rooted in practice. Examining the perceived effectiveness and feasibility of adaptation options developed largely by practitioners allows for on-the-ground realities of adaptation to be realized and for more relevant adaptation strategies to be developed.

Third, this dissertation makes a methodological contribution by applying an adaptation readiness framework to the protected areas context (Chapter 4). Previously, adaptation readiness studies in the academic literature were limited to marine spatial planning (Khan and Amelie, 2015), trans-boundary river basins (Tilleard and Ford, 2016), arctic communities (Ford et al., 2017), sea-level rise (Yusuf and St. John III, 2017), and urban areas (Araos et al., 2017). Adaptation readiness assessments of protected areas had previously been conducted but not published in the academic literature (i.e., Gray et al., 2012), so this study represents the first one. Assessing the adaptation readiness of protected area organizations to implement adaptation strategies is critical to making progress on adaptation.

5.2.2 Practical Contributions

In addition to the above-mentioned academic contributions, this dissertation also aimed to make practical contributions. Chapter 2 provides protected area organizations with insight into what other organizations are doing, or not doing, and allows them to situate their own progress in relation to others. Furthermore, by making tangible connections between a lack of resources and a lack of progress on adaptation, Chapter 2 provides protected area organizations with leverage, through data, for acquiring more resources. Moreover, Chapter 2 provides guidance for protected area organizations to assist with making progress on adaptation.

This dissertation makes a contribution to Parks Canada's broader adaptation planning process by providing insights and recommendations. At the case study level, Chapter 3 equips BPNP/FFNMP with a list of adaptation strategies tailored to their unique context that is categorized by intervention class and the effect of each intervention on the ecosystem. Indeed, BPNP/FFNMP is currently using selected dissertation findings for prioritizing these adaptation strategies and determining how to implement particular strategies. Furthermore, Chapter 4 presents a list of adaptation readiness strengths, weaknesses, and areas for improvement that BPNP/FFNMP can use as a benchmark to measure future progress. Ultimately, the research presented in this dissertation provides a foundation upon which climate change adaptation can be mainstreamed into conservation practice. Consequently, I next provide some recommendations for practice to aid in making progress on adaptation in the next decade.

5.3 Recommendations for Practice

To assist with advancing climate change adaptation in protected areas I make the following three recommendations for practice.

First, protected area organizations can no longer work under the assumption of a stable climate system and continue using conservation practices based on this assumption. A suite of diverse adaptation strategies is required.

What is needed is a shift in thinking from resisting change to embracing change and managing for healthy robust ecosystems that provide benefits for society rather than fighting to maintain a historical ecosystem in an incompatible climate system (Prober et al. 2019; van Kerkhoff et al. 2019). Chapters 2 and 3 found strong preferences for conventional conservation strategies among practitioners, some of which aim to resist change; however, it is likely that at some point conventional conservation practices that aim to resist change will fail to achieve their intended goals and that interventionist and conventional strategies that aim to direct change will be required. Therefore, there is an opportunity cost associated with choosing the safe option and failing to take proactive action on adaptation. Protected area managers need to take risks, experiment with new innovative conservation approaches that incorporate climate change considerations, and share results, both good and bad, widely. There are advantages and disadvantages associated with every adaptation option (Chapter 3). Experimenting with and implementing a suite of complementary adaptation options would act to optimize the advantages and minimize disadvantages. This will likely lead to more success and reduce risk and uncertainty associated with a single adaptation strategy. It is unlikely that any one adaptation option implemented in isolation will be effective in preserving something as complex as an ecosystem.

Second, establishing regional partnerships among protected area organizations would further reduce duplication of efforts and accelerate the sharing of knowledge.

Protected areas within the same geographical region are likely to face similar challenges associated with climate change; therefore, working together to tackle common problems further reduces duplication of efforts and increases knowledge sharing. Chapter 2 demonstrated a need for information sharing regarding climate change adaptation and identified lack of knowledge as a barrier. Additionally, Chapter 4 identified knowledge exchange as a weakness and collaboration with partners as an area for improvement. Towards achieving common objectives, regional partnerships would expand the sharing of resources, in particular, knowledge. With increased knowledge, what was previously unfamiliar and contentious (interventionist options) may become more accepted. Additionally, regional partnerships could act to overcome adaptation readiness weaknesses of individual organizations by benefitting from the strengths of multiple organizations. Moreover, regional partnerships would benefit from the various perspectives of different organization types (Chapter 2), leading to more robust adaptation strategies. Adaptation at the regional level has capacity to be more strategic and less ad-hoc and, thereby, more effective. Working in independent silos is no longer a viable option, rather a Canada-wide, or North America-wide, collaborative effort on climate change adaptation is required.

Third, in order for change to happen, political licence needs to be present to explore transformative adaptation, then social licence needs to be present to implement it.

Climate changes poses an unprecedented challenge to protected area agencies and needs to be considered in legislation before substantive action can occur. Transformative adaptation cannot occur if it is not supported by Parliament and the Canadian public. Chapter 4 identified a lack of political will as a contributing factor to low adaptation readiness. Furthermore, Chapter 3 came to the conclusion that political licence needs to be present to implement transformative conservation strategies that aim to direct change. Currently, there is a lack of goverance capacity to consider large-scale changes. To make progress towards transformative adaptation, the *Canada National Parks Act* should be updated to mandate the inclusion of climate change considerations in park management plans. Park management plans are required, by law, to be tabled in each House of Parliament and to go through a public consultation process (Canada National Parks Act, 2000). This process of being tabled in Parliament and going through public consultation would lend political and social licence to climate change considerations included in park management plans. To initiate this change, a national roundtable on climate change and proteted areas should be convened.

5.4 Recommendations for Future Research

Climate change is a persistent, pervasive problem and an important area of study in protected areas research. The research described in this dissertation advances understanding of practitioner preferences regarding climate change adaptation in the protected areas context (Chapters 2 and 3); yet, underlying factors shaping those preferences remain unknown. Furthermore, many barriers exist to the implementation of adaptation strategies (Chapter 2) and in-depth analyses of barriers to adaptation in protected areas are needed. Such research will assist in designing adaptation strategies, thereby enhancing the ability of protected area organizations to address the impacts of climate change.

Chapter 3 identified climate change adaptation options for BPNP/FFNMP and the park is in the process of prioritizing these options for implementation. However, as the climate and other ecological processes change, priorities may change, and adaptation options will need to evolve. A dynamic adaptive policy pathways approach would aid in avoiding path dependency and identifying adaptation tipping points—the point at which a new strategy is required (Haasnoot et al., 2013; Wise et al., 2014). Future research examining dynamic adaptive policy pathways in a protected areas context is needed to assist with adaptation decision-making in protected areas. In particular, research examining signposting (i.e., predefined triggers) would help organizations, such as Parks Canada, make decisions regarding when to switch paths (i.e., when a new adaptation strategy is required). Additionally, research into how a dynamic adaptative policy pathways approach can be incorporated into existing protected area monitoring programs is needed.

Throughout my research, values (e.g., political values, public values) kept coming up in conversations with practitioners as a major consideration in conservation planning. Practitioners, politicians, local citizens, tourists and developers, among numerous other stakeholders, all have diverse values they place on protected areas (Bennett, 2016). Decisions regarding biodiversity adaptation need to incorporate and consider these diverse social values and, in the future, these values will become more important as protected areas managers are forced to make decisions regarding which values to protect. As evidence from this study indicates, conventional options have the advantage of already having public support whereas interventionist ones currently do not (Chapters 2 and 3). Furthermore, interventionist approaches require more human involvement in natural processes and necessitate more value judgements to be made in a more uncertain environment. Moreover, stakeholder perspectives pose a challenge to the successful implementation of any conservation strategy, whether conventional or interventionist, because a strategy is unlikely to be successful if it is inconsistent with stakeholder beliefs and values (Tam and McDaniels, 2013). Reconciling diverse viewpoints regarding the intrinsic and extrinsic values of protected areas in a changed climate will become a challenge for protected area managers and should be a focus of future research.

5.5 Concluding Remarks

The overall goal of this dissertation was to advance climate change adaptation in Canadian protected areas. To accomplish this, after determining the state of adaptation in Canadian protected areas—thereby providing a benchmark to measure progress—I worked closely with BPNP/FFNMP to identify impacts, develop climate change adaptation strategies, and evaluate organizational strengths and weaknesses to implementing adaptation strategies. The research findings of this dissertation revealed that limited progress has been made on adaptation. Moreover, personal communication with numerous practitioners revealed that they are unclear about how to choose and implement adaptation strategies. Overcoming this stagnation and confusion regarding adaptation is critical to preserving biodiversity.

Presently, in protected area management contexts in Canada, climate change continues to be viewed as a future issue, not a current issue. However, delaying action on adaptation could lead to more dire circumstances in the future. Protected area models that aim to preserve a static version of the protected area are likely to fail as climatic conditions continue to shift across the landscape (Batllori et al., 2017). Climate change considerations need to be incorporated into management practices. Furthermore, adaptation is an iterative process whereby any decision needs to be evaluated for effectiveness over time. The recommendations contained within this dissertation have broad applicability to Canadian protected areas and hold the potential to advance climate change adaptation. With concerted effort, progress can be made by leveraging resources and developing partnerships.

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Appendices

Appendix A

State of Adaptation Survey Instrument

Q1 Thank you for agreeing to participate in this survey. Please complete the survey from the perspective of your organization not your own personal perspective.

You may close the survey at any point. Your answers will be saved automatically and you can return using the same link to complete the survey at a later time.

Q2 Please select one of the following options regarding participation:

- ◯ I do not wish to participate (1)
- ◯ With full knowledge of content contained in the information letter, I agree, of my own free will, to participate in this study (2)

Skip To: End of Survey If Please select one of the following options regarding participation: = I do not wish to participate

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Q3 Please select yes or no to the following statements regarding the use of quotations in publications:

Q4 I have the authority to speak on behalf of ${m://ExternalDataReference} and I agree to the use of the name, ${m://ExternalDataReference}, in any thesis or publication that comes of this research. (If NO, a pseudonym will be used to protect the identity of the organization)

- ◯ Yes (1)
- ◯ No (2)

Q5 I agree to the use of direct quotations attributed to ${m://ExternalDataReference}, only with my review and approval (please enter your e-mail address so that you may be contacted to review and approve quotes before use).

○ Yes (1)

○ No (2)

Q6 I agree to the use of anonymous quotations in any thesis or publication that comes from this research.

○ Yes (1)

○ No (2)

Q7 Please fill out the following information so we can contact you to obtain permission to use quotations if necessary:

○ Organization (1) ____

○ Job Title (2) ____

○ Name (3) ____

○ Email (4) ____

Q8 In what region does your organization primarily operate (e.g. Canada wide, British Columbia, Eastern Canada, Toronto)?

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Q9 At what point will / was the issue of climate change relevant to protected areas planning and management in your agency?

- ◯ Climate change has been relevant for the past decade (1)
- ◯ Now (2)
- ◯ 2020s (3)
- ◯ 2050s (4)
- ◯ 2080s (5)
- ◯ Never (6)

Q10 Indicate the response that best represents your agency's view on each of the following statements.

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Climate change has already substantially altered protected area policy and planning (1)	○	○	○	○	○
Climate change is going to substantially alter protected area policy and planning over the next 10years (2)	○	○	○	○	○
Climate change is going to substantially alter protected area policy and planning over the next 25years (3)	○	○	○	○	○

Q11 Indicate the response that best represents your agency's view on each of the following statements.

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
There is a need for more research on the impacts of climate change before any policy, planning or managerial responses are made. (1)	○	○	○	○	○
Detecting and monitoring climate change should be a priority for protected areas agencies. (2)	○	○	○	○	○
There are too many uncertainties regarding climate change to develop adaptation strategies for protected areas. (3)	○	○	○	○	○

Q12 For protected areas within your agency, how important of an impact, if any, will climate change have on each of the following?

	Not Important (1)	Slightly Important (2)	Moderately Important (3)	Important (4)	Very Important (5)	No Impact (6)	Not Applicable (7)
Policy (1)	○	○	○	○	○	○	○
Planning (2)	○	○	○	○	○	○	○
Management (3)	○	○	○	○	○	○	○
Infrastructure / Operations (4)	○	○	○	○	○	○	○
Wildlife (5)	○	○	○	○	○	○	○
Vegetation (6)	○	○	○	○	○	○	○
Watersheds (including wetlands, water quality and quantity) (7)	○	○	○	○	○	○	○
Tourism and Recreation (8)	○	○	○	○	○	○	○
Interpretation Programs (9)	○	○	○	○	○	○	○
Revenues (10)	○	○	○	○	○	○	○

Q13 The following question is designed to examine where the issue of climate change currently ranks in terms of importance relative to other protected areas management issues your agency is facing. Please rank each issue in order of importance (Ranking of “1” = Most Important; Ranking of “11” = Least Important).

______ Climate change (1)
______ Wildlife Management (e.g., species richness, population dynamics, trophic structure) (2)
______ Water quality / air quality (3)
______ Rare / endangered species management (4)
______ Exotic species (e.g., plant and animal) (5)
______ Visitor stresses (e.g., public facilities, interpretation centres) (6)
______ Contamination / pollution (7)
______ External threats (e.g., surrounding land-use, habitat fragmentation) (8)
______ Human land-use patterns (e.g., roads, population density) (9)
______ Disturbance frequencies (e.g., fire, insects, flooding) (10)
______ Other (please identify): (11)

Q14 The following question is designed to examine where the issue of climate change ranks in terms of importance relative to other protected areas management issues 25 years from now. Please rank each issue in order of importance 25 years from now (Ranking of “1” = Most Important; Ranking of “11” = Least Important).

______ Climate change (1)
______ Wildlife management (e.g., species richness, population dynamics, trophic structure) (2)
______ Water quality / air quality (3)
______ Rare / endangered species management (4)
______ Exotic species (e.g., plant and animal) (5)
______ Visitor stresses (e.g., public facilities, interpretation centres) (6)
______ Contamination / pollution (7)
______ External threats (e.g., surrounding land-use, habitat fragmentation) (8)
______ Human land-use patterns (e.g., roads, population density) (9)
______ Disturbance frequencies (e.g., fire, insects, flooding) (10)
______ Other (please identify): (11)

Q15 Have there been any formal climate change discussions within your agency (e.g., workshops, strategic / expert meetings, technical working groups, conferences)?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Unsure (3)

Skip To: Q18 If Have there been any formal climate change discussions within your agency (e.g., workshops, strate... = No

Skip To: Q18 If Have there been any formal climate change discussions within your agency (e.g., workshops, strate... = Unsure

Q16 Briefly describe the nature of any formal climate change discussions within your agency (e.g., workshops, strategic / expert meetings, technical working groups, conferences, etc.).

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Q17 Please provide the reference for any proceedings / conference summary or forward as an email attachment if possible. [Optional]

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Q18 Has a comprehensive assessment on potential climate change impacts and implications for protected areas policy and management been completed by / for your agency?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Unsure (3)

Skip To: Q19 If Has a comprehensive assessment on potential climate change impacts and implications for protected... = Yes

Skip To: Q20 If Has a comprehensive assessment on potential climate change impacts and implications for protected... = No

Skip To: Q20 If Has a comprehensive assessment on potential climate change impacts and implications for protected... = Unsure

Q19 Please provide study / report reference for any comprehensive climate change assessments that have been done, or forward as an email attachment if possible. [Optional]

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Skip To: Q21 If Please provide study / report reference for any comprehensive climate change assessments that hav... Is Empty

Skip To: Q21 If Please provide study / report reference for any comprehensive climate change assessments that hav... Is Not Empty

Q20 Have there been discussions regarding the need for a comprehensive assessment on potential climate change impacts and implications to be done?

○ Yes (1)

○ No (2)

Q21 Is anybody in your agency specifically responsible for climate change issues (this includes legislation, policy, research, planning, management and monitoring)?

○ Yes (one individual) (1)

○ Yes (more than one individual) (2)

○ No (3)

Q22 Does your agency specifically monitor for climate change impacts (e.g., distribution of flora and fauna, species tracking, coastal erosion, ice melt patterns)?

○ Yes (1)

○ No (2)

Skip To: Q23 If Does your agency specifically monitor for climate change impacts (e.g., distribution of flora and... = Yes

Skip To: Q24 If Does your agency specifically monitor for climate change impacts (e.g., distribution of flora and... = No

Q23 Please briefly identify specific climate change impact monitoring initiatives.

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Q24 Has your agency developed specific climate change indicators for detecting or monitoring climate change impacts (e.g., through weather stations, species monitoring, etc.)?

○ Yes (1)

○ No (2)

Skip To: Q25 If Has your agency developed specific climate change indicators for detecting or monitoring climate... = Yes

Skip To: Q26 If Has your agency developed specific climate change indicators for detecting or monitoring climate... = No

Q25 Please elaborate on any climate change indicators that your agency has developed. [Optional]

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Q26 Are any types of protected areas within your jurisdiction currently affected by climate change related impacts?

○ Yes (1)

○ No (2)

○ Unsure (3)

Skip To: Q27 If Are any types of protected areas within your jurisdiction currently affected by climate change re... = Yes

Skip To: Q34 If Are any types of protected areas within your jurisdiction currently affected by climate change re... = No

Skip To: Q34 If Are any types of protected areas within your jurisdiction currently affected by climate change re... = Unsure

Q27 Please check any climate change impacts being observed within your jurisdiction: (Select all that apply)

- ☐ Species range shifts (1)
- ☐ Change in species composition (2)
- ☐ Changes in disturbance regimes (e.g., forest fires) (3)
- ☐ Changes in protected area physiography (e.g., glacial extent, change in water levels) (4)
- ☐ Tourism / recreation (e.g., increase in visitation due to extended 'warm' seasons) (5)
- ☐ Other (please identify): (6) ____________________
- ☐ Other (please identify): (7) ____________________
- ☐ Other (please identify): (8) ____________________

Q28 Has the nature and scale of such impacts been investigated through research?

- ○ Yes (1)
- ○ No (2)

Skip To: Q29 If Has the nature and scale of such impacts been investigated through research? = Yes

Skip To: Q34 If Has the nature and scale of such impacts been investigated through research? = No

Q29 Have the studies examining climate change impacts been conducted by (check all that apply):

- ▢ Your agency (1)
- ▢ Another agency within your jurisdiction [please identify which one(s)]: (2) ____
- ▢ Non-governmental organizations (NGOs) [please identify which one(s)]: (3) ____
- ▢ University researchers including graduate students [please identify which one(s)]: (4) ____
- ▢ Consultants [please identify which one(s)]: (5) ____
- ▢ Other (please elaborate): (6) ____

Q30 Please provide any relevant research references regarding climate change impacts in your jurisdiction in the field below (i.e., author, date, title of research publication) or forward as an email attachment if possible. [Optional]

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Q31 Is any response being taken or being considered to deal with any of the identified climate related impacts (e.g., further research or adaptation measures)?

◯ Yes (1)

◯ No (2)

◯ Unsure (3)

Skip To: Q32 If Is any response being taken or being considered to deal with any of the identified climate relate... = Yes

Skip To: Q34 If Is any response being taken or being considered to deal with any of the identified climate relate... = No

Skip To: Q34 If Is any response being taken or being considered to deal with any of the identified climate relate... = Unsure

Q32 Briefly identify the specific responses to climate change impacts being undertaken or being considered.

	Responses being undertaken (1)	Responses being considered (2)
Legislation, planning and policy (1)	○	○
Selection, evaluation and design of protected areas (2)	○	○
Management direction (3)	○	○
Operations and development (4)	○	○
Research, monitoring and reporting (5)	○	○
Education, interpretation and outreach (6)	○	○
Other (please identify): (7)	○	○
Other (please identify): (8)	○	○
Other (please identify): (9)	○	○

Q33 Please elaborate on any of your responses in the previous question. [Optional]

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Q34 Does your agency have a public education program specifically related to climate change and its possible effects (e.g., through posters, park interpretation, park brochures, etc.)?

○ Yes (1)

○ No (2)

Skip To: Q35 If Does your agency have a public education program specifically related to climate change and its p... = Yes

Skip To: Q36 If Does your agency have a public education program specifically related to climate change and its p... = No

Q35 Please briefly describe your agency's public education program related to climate change and its possible effects (e.g., information delivery mechanism, when and where implemented):

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Skip To: Q37 If Please briefly describe your agency's public education program related to climate change and its... Is Empty

Skip To: Q37 If Please briefly describe your agency's public education program related to climate change and its... Is Not Empty

Q36 Does your agency have plans to develop a public education program related to climate change and its possible effects?

- ◯ Yes (next 1 - 5 years) (1)
- ◯ Yes (next 6 - 10 years) (2)
- ◯ Yes (next 10+ years) (3)
- ◯ No (4)

Q37 Has climate change been incorporated or considered in the development of protected areas management plans or other active management plans relevant to protected areas in your jurisdiction (e.g., fire/prescribed burning, environmental assessment, invasive species)?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Unsure (3)

Skip To: Q38 If Has climate change been incorporated or considered in the development of protected areas manageme... = Yes

Skip To: Q39 If Has climate change been incorporated or considered in the development of protected areas manageme... = No

Skip To: Q39 If Has climate change been incorporated or considered in the development of protected areas manageme... = Unsure

Q38 Please elaborate on your response to the previous question (has climate change been incorporated in the development of protected areas management plans) or forward a sample management plan as an e-mail attachment if possible. [Optional]

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Skip To: Q41 If Please elaborate on your response to the previous question (has climate change been incorporated... Is Empty

Skip To: Q41 If Please elaborate on your response to the previous question (has climate change been incorporated... Is Not Empty

Q39 Is your agency in the process or considering the incorporation of climate change into park management plans or other management plans relevant to parks and protected areas?

◯ Yes (1)

◯ No (2)

◯ Unsure (3)

Q40 Please elaborate on your response to the previous question. [Optional]

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Q41 Does your agency / jurisdiction currently have the capacity necessary to deal with climate change issues affecting protected areas (e.g., committed financial resources, knowledgeable/scientifically trained staff, etc.)?

◯ Yes (1)

◯ No (2)

◯ Unsure (3)

Q42 Please elaborate on your response to the previous question. [Optional]

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Q43 Does your agency have a climate change adaptation strategy (or action plan) directly related to protected areas?

- ◯ Yes (1)
- ◯ No (2)
- ◯ In development (3)

Skip To: Q45 If Does your agency have a climate change adaptation strategy (or action plan) directly related to p... = No

Skip To: Q44 If Does your agency have a climate change adaptation strategy (or action plan) directly related to p... = Yes

Skip To: Q44 If Does your agency have a climate change adaptation strategy (or action plan) directly related to p... = In development

Q44 What was (or is) the actual (or anticipated) timeline for implementation?

Please provide a report reference or forward as an email attachment if possible.

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Q45 Does your agency face any barriers or challenges to implementing climate change adaptation strategies in protected areas?

○ Yes (1)

○ No (2)

Skip To: Q46 If Does your agency face any barriers or challenges to implementing climate change adaptation strate... = Yes

Skip To: Q48 If Does your agency face any barriers or challenges to implementing climate change adaptation strate... = No

Q46 What type of barriers or challenges to implementing climate change adaptation strategies in protected areas does your agency face? (Select all that apply)

- ☐ Lack of knowledge (1)
- ☐ Insufficient funding / Lack of resources (2)
- ☐ Lack of capacity (human resources) (3)
- ☐ Institutional (political, administrative) (4)
- ☐ Public perceptions / lack of public support (5)
- ☐ Lack of awareness of a problem / issue (6)
- ☐ Lack of agreement on best way forward (7)
- ☐ Lack of leadership (8)
- ☐ Other (please specify): (9) ____________________
- ☐ Other (please specify): (10) ____________________
- ☐ Other (please specify): (11) ____________________

Q47 Please elaborate on any barriers or challenges to adapting biodiversity conservation strategies to climate change that your agency faces. [Optional]

Q48 What types of protected area climate change adaptation conservation strategies are currently employed by your agency? (Select all that apply)

- ▢ Expand protected area network (i.e., expand the boundaries of existing reserves and create new reserves) (1)
- ▢ Increase connectivity (i.e., establish corridors between protected areas to allow for the movement of species between reserves) (2)
- ▢ Reduce other threats (e.g., invasive species, over exploitation) (3)
- ▢ Dynamic reserves (i.e., where boundaries of a reserve may be changed as conditions change) (4)
- ▢ Focus on ecosystem function (i.e., prioritize the preservation of ecosystem services (e.g. water filtration, pollination) over the preservation of specific species) (5)
- ▢ Conservation triage (i.e., prioritizing the use of limiting resources to conserve species with a higher chance of survival or more significant role in the ecosystem, similar to the emergency medicine concept of triage) (6)
- ▢ Assisted migration (i.e., moving species from the southern edge of their range – where the climate may no longer be suitable – to a more northern or higher elevation location that matches their climatic needs) (7)
- ▢ Other (please specify): (8) ____
- ▢ Other (please specify): (9) ____
- ▢ Other (please specify): (10) ____

Q49 Please elaborate on the specific strategies that your agency is using to preserve biodiversity in protected areas in light of climate change. [Optional]

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Q50 Please rank the following climate change adaptation conservation strategies according to how likely your agency would be to implement each strategy in the future. (Ranking of "1" = Most likely to implement; Ranking of "7" = Least likely to implement)

______ Expand protected area network (i.e., expand the boundaries of existing reserves and create new reserves) (1)

______ Increase connectivity (i.e., establish corridors between protected areas to allow for the movement of species between reserves) (2)

______ Reduce other threats (e.g., invasive species, over exploitation) (3)

______ Dynamic reserves (i.e., where boundaries of a reserve may be changed as conditions change) (4)

______ Focus on ecosystem function (i.e., prioritize the preservation of ecosystem services (e.g. water filtration, pollination) over the preservation specific species) (5)

______ Conservation triage (i.e., prioritizing the use of limiting resources to conserve species with a higher chance of survival or more significant role in the ecosystem, similar to the emergency medicine concept of triage) (6)

______ Assisted migration (i.e., moving species from the southern edge of their range – where the climate may no longer be suitable – to a more northern or higher elevation location that matches their climatic needs) (7)

Q51 Have you heard of the concept of novel ecosystems?

◯ Yes (1)

◯ No (2)

Skip To: Q52 If Have you heard of the concept of novel ecosystems? = Yes

Skip To: Q54 If Have you heard of the concept of novel ecosystems? = No

Q52 Please define novel ecosystems in your own words.

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Q53 Do you think the concept of novel ecosystems has a valuable role to play in the management of protected areas in an era of climate change?

- ○ Yes (1)
- ○ No (2)

Q54 What should be the approach to climate change adaptation among Canada's protected areas agencies (within all levels of government)? You may select more than one option.

- ☐ No specific adaptation strategy (1)
- ☐ Coping with issues on an 'as needed' basis (2)
- ☐ Operating with a comprehensive agency-based strategy (3)
- ☐ Sharing in a Canada-wide protected areas collaborative effort on climate change (4)

Q55 Please elaborate on your answer to the above question. [Optional]

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Q56 Is there a specific protected area in your jurisdiction that is particularly impacted / affected by climate change? If yes, please name it and describe how it is affected.

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Q65 Does your organization actively work to address the Aichi targets?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Unsure (3)

Skip To: Q57 If Does your organization actively work to address the Aichi targets? = Yes

Skip To: Q60 If Does your organization actively work to address the Aichi targets? = No

Skip To: Q60 If Does your organization actively work to address the Aichi targets? = Unsure

Q57 While working towards the Aichi targets, does your organization explicitly take into consideration and plan for climate change?

○ Yes (1)

○ No (2)

○ Unsure (3)

Skip To: Q58 If While working towards the Aichi targets, does your organization explicitly take into consideratio... = Yes

Skip To: Q60 If While working towards the Aichi targets, does your organization explicitly take into consideratio... = No

Skip To: Q60 If While working towards the Aichi targets, does your organization explicitly take into consideratio... = Unsure

Q58 How does your organization propose incorporating climate change into initiatives to meet the Aichi targets? (Check all that apply)

- ▢ Utilizing climate change modelling for designing areas and networks (1)
- ▢ Enhancing other analytical capabilities (e.g., GIS/database upgrades) (2)
- ▢ Focusing efforts on protecting and managing ‘Key Biodiversity Areas’ (3)
- ▢ Establishing effective buffer zones around protected areas and other effective area-based conservation measures (4)
- ▢ Enhancing connectivity between protected areas and other effective area-based conservation measures (5)
- ▢ Increasing in-agency expertise and capacity (6)
- ▢ Collaborating with external climate change experts (7)
- ▢ Engaging in trans-boundary initiatives with neighbouring jurisdictions (8)
- ▢ Improving monitoring and reporting on management efforts (9)
- ▢ Expanding public awareness and understanding (10)
- ▢ Other measures and approaches (please describe) (11) ____

Q59 Please elaborate on any of the foregoing activities as necessary to convey any specific details that you feel are valuable to report on your agency's efforts to address climate change in the planning and management of protected areas for biodiversity conservation and the achievement of Aichi biodiversity targets related to this endeavor. [Optional]

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Q60 Is your agency better equipped to deal with climate change than it was 10 years ago?

- ○ Yes (1)
- ○ No (2)

Q61 Please elaborate on your response to the previous question with any specifics regarding key developments or milestones that your agency has made <u>over the past decade</u> to adapt to or mitigate the impact of climate change in your jurisdiction. [Optional]

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Q63 Are there any other issues or concerns regarding climate change and protected areas not covered in this survey that you feel are important to consider? Please elaborate.

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Appendix B

Organizations Surveyed

Table B.1: A list of organizations that responded to the State of Adaptation Survey.

Organization Type	Organization Name
Federal Government	Parks Canada
	Fisheries and Oceans Canada
Provincial Government	Government of British Columbia, Ministry of Environment, Parks and Protected Areas Division (BC Parks)
	Government of Alberta, Alberta Tourism Parks & Recreation, Parks Division
	Government of Manitoba, Manitoba Sustainable Development, Parks and Regional Services, Parks and Protected Spaces
	Government of Ontario, Ontario Parks
	Government of Quebec
	Government of New Brunswick, Department of Energy and Resource Development
	Government of Nova Scotia, Nova Scotia Environment, Protected Areas Branch
	Government of Newfoundland and Labrador, Fisheries and Land Resources, Parks and Natural Areas Division
	Government of Yukon, Department of Environment, Yukon Parks
	Government of Northwest Territories, Environment and Natural Resources
	Government of Nunavut, Department of Environment, Nunavut Parks & Special Places
ENGOs	Nature Conservancy of Canada
	Clayquot Biosphere Trust
	Fundy Biosphere Reserve
	Wildlife Habitat Canada
	Carolinian Canada Coalition (CCC)
	Ontario Nature
	Ducks Unlimited

	Yellowstone to Yukon (Y2Y)
	Algonquin to Adirondak (A2A)
	Dehcho Land Use Plan
	The Land Conservancy of BC
	Canadian Parks and Wilderness Society (CPAWS)
	The Couchiching Conservancy (Ontario)
	rare Charitable Research Reserve
	Grey Sauble CA

Table B.2: A list of Parks Canada sites that responded to the State of Adaptation Survey and which formed the Parks Canada sub-sample for the survey.

Cape Breton Highlands National Park
Forillon National Park
Grasslands National Park
Jasper National Park
Kejimkujik National Park and National Historic Site
Kootenay National Park
Kouchibouguac National Park
Kluane National Park and Reserve
La Maurice National Park
Mount Revelstoke National Park
Naatsihchoh National Park Reserve
Prince Albert National Park
Prince Edward Island National Park
Rouge National Urban Park
Thousand Islands National Park
Tuktut Nogait National Park
Vuntut National Park
Wapusk National Park
Waterton Lakes National Park
Wood Buffalo National Park of Canada
Fathom Five National Marine Park
Lake Superior National Marine Conservation Area

Appendix C

State of Adaptation Survey – Raw Data

Table C.1: Summary data for survey question 9.

Q9 - At what point will / was the issue of climate change relevant to protected areas planning and management in your agency?				
	2018		**2006**	
	Number	%	Number	%
Climate change has been relevant for the past decade	16	59.3%	NA	NA
Now	8	29.6%	32	91.4%
2020s	3	11.1%	3	8.6%
2050s	0	0.0%	0	0.0%
2080s	0	0.0%	0	0.0%
Never	0	0.0%	0	0.0%
Total	27		35	

Q10 - Indicate the response that best represents your agency's view on each of the following statements.

Table C.2: **Summary data for survey question 10A.**

A) Climate change has already substantially altered protected area policy and planning		
	2018	
	Number	%
Strongly Disagree	3	11.1%
Disagree	9	33.3%
Neutral	8	29.6%
Agree	7	25.9%
Strongly Agree	0	0.0%
Total	27	

Table C.3: **Summary data for survey question 10B.**

B) Climate change is going to substantially alter protected area policy and planning over the next 10years				
	2018		**2006**	
	Number	%	Number	%
Strongly Disagree	1	3.7%	1	2.9%
Disagree	0	0.0%	9	25.7%
Neutral	5	18.5%	NA	NA
Agree	18	66.7%	16	45.7%
Strongly Agree	2	7.4%	9	25.7%
Total	26		35	

Table C.4: Summary data for survey question 10C.

C) Climate change is going to substantially alter protected area policy and planning over the next 25years				
	2018		**2006**	
	Number	%	Number	%
Strongly Disagree	1	3.7%	0	0.0%
Disagree	0	0.0%	2	5.7%
Neutral	2	7.4%	NA	NA
Agree	14	51.9%	12	34.3%
Strongly Agree	9	33.3%	21	60.0%
Total	26		35	

Q11 - Indicate the response that best represents your agency's view on each of the following statements.

Table C.5: **Summary data for survey question 11A.**

A) There is a need for more research on the impacts of climate change before any policy, planning or managerial responses are made.				
	2018		**2006**	
	Number	%	Number	%
Strongly Disagree	6	22.2%	3	8.6%
Disagree	8	29.6%	12	34.3%
Neutral	5	18.5%	NA	NA
Agree	7	25.9%	9	25.7%
Strongly Agree	1	3.7%	11	31.4%
Total	27		35	

Table C.6: **Summary data for survey question 11B.**

B) Detecting and monitoring climate change should be a priority for protected areas agencies.				
	2018		**2006**	
	Number	%	Number	%
Strongly Disagree	0	0.0%	0	0.0%
Disagree	2	7.4%	1	2.9%
Neutral	8	29.6%	NA	NA
Agree	9	33.3%	18	51.4%
Strongly Agree	8	29.6%	16	45.7%
Total	27		35	

Table C.7: **Summary data for survey question 11C.**

C) There are too many uncertainties regarding climate change to develop adaptation strategies for protected areas.				
	2018		**2006**	
	Number	%	Number	%
Strongly Disagree	10	37.0%	11	31.4%
Disagree	12	44.4%	13	37.1%
Neutral	4	14.8%	NA	NA
Agree	1	3.7%	9	25.7%
Strongly Agree	0	0.0%	2	5.7%
Total	27		35	

Table C.8: **Summary data for survey question 12.**

Q12 - For protected areas within your agency, how important of an impact, if any, will climate change have on each of the following?							
	Very Important	Important	Moderately Important	Slightly Important	Not Important	No Impact	Total
Policy	4	6	10	6	0	0	26
Planning	11	12	0	4	0	0	27
Management	9	9	3	5	0	0	26
Infrastructure/ Operations	7	6	6	3	2	0	24
Wildlife	19	6	1	1	0	0	27
Vegetation	19	6	1	1	0	0	27
Watersheds	21	4	1	1	0	0	27
Tourism and Recreation	2	10	6	6	2	0	26
Interpretation Programs	2	14	3	6	1	1	27
Revenues	2	6	6	2	5	2	23

Table C.9: **Summary data for survey question 13.**

Q13 - The following question is designed to examine where the issue of climate change currently ranks in terms of importance relative to other protected areas management issues your agency is facing. Please rank each issue in order of importance				
	High	Low	Mean	# Respondents
Climate change	1	10	6.7	21
Wildlife management	1	9	5.1	21
Water quality/Air quality	2	10	7.3	21
Rare/endangered species management	1	9	4.0	21
Exotic species (animal and plant)	1	8	4.9	21
Visitor stresses	1	10	5.6	21
Contamination/pollution	2	10	8.2	21
External threats	1	10	3.4	21
Human land-use patterns	1	10	3.4	21
Disturbance frequencies	1	10	6.4	21

Table C.10: **Summary data for survey question 14.**

Q14 - The following question is designed to examine where the issue of climate change ranks in terms of importance relative to other protected areas management issues 25 years from now. Please rank each issue in order of importance 25 years from now				
	High	Low	Mean	# Respondents
Climate change	1	10	4.6	21
Wildlife management	1	9	5.3	21
Water quality/Air quality	2	10	7.0	21
Rare/endangered species management	2	9	4.4	21
Exotic species (animal and plant)	2	10	5.1	21
Visitor stresses	1	10	6.1	21
Contamination/pollution	3	10	8.5	21
External threats	1	7	3.6	21
Human land-use patterns	1	10	4.0	21
Disturbance frequencies	2	10	6.3	21

Table C.11: **Summary data for survey question 15.**

Q15 - Have there been any formal climate change discussions within your agency (e.g., workshops, strategic / expert meetings, technical working groups, conferences)?				
	2018		2006	
	Number	%	Number	%
Yes	19	70.4%	23	65.7%
No	6	22.2%	12	34.3%
Unsure	2	7.4%	NA	NA
Total	27		35	

Table C.12: **Summary data for survey question 18.**

Q18 - Has a comprehensive assessment on potential climate change impacts and implications for protected areas policy and management been completed by / for your agency?				
	2018		2006	
	Number	%	Number	%
Yes	4	14.8%	5	14.7%
No	23	85.2%	29	85.3%
Unsure	0	0.0%	NA	NA
Total	27		34	

Table C.13: **Summary data for survey question 20.**

Q20 - If No to Q18, Have there been discussions regarding the need for a comprehensive assessment on potential climate change impacts and implications to be done?				
	2018		2006	
	Number	%	Number	%
Yes	15	65.2%	13	50.0%
No	8	34.8%	13	50.0%
Unsure	0	0.0%	NA	
Total	23		26	

Table C.14: **Summary data for survey question 21.**

Q21 - Is anybody in your agency specifically responsible for climate change issues (this includes legislation, policy, research, planning, management and monitoring)?				
	2018		2006	
	Number	%	Number	%
Yes (one individual)	7	25.9%	9	25.7%
Yes (more than one individual)	6	22.2%	10	28.6%
No	14	51.9%	16	45.7%
Total	27		35	

Table C.15: **Summary data for survey question 22.**

Q22 - Does your agency specifically monitor for climate change impacts (e.g., distribution of flora and fauna, species tracking, coastal erosion, ice melt patterns)?				
	2018		2006	
	Number	%	Number	%
Yes	14	51.9%	12	34.3%
No	13	48.1%	23	65.7%
Unsure	0	0.0%	NA	
Total	27		35	

Table C.16: **Summary data for survey question 24.**

Q24 - Has your agency developed specific climate change indicators for detecting or monitoring climate change impacts (e.g., through weather stations, species monitoring, etc.)?				
	2018		2006	
	Number	%	Number	%
Yes	11	40.7%	5	14.3%
No	16	59.3%	30	85.7%
Total	27		35	

Table C.17: **Summary data for survey question 26.**

Q26 - Are any types of protected areas within your jurisdiction currently affected by climate change related impacts?				
	2018		2006	
	Number	%	Number	%
Yes	20	74.1%	22	73.3%
No	1	3.7%	0	0.0%
Unsure	6	22.2%	8	26.7%
Total	27		30	

Table C.18: **Summary data for survey question 27.**

Q27 - Please check any climate change impacts being observed within your jurisdiction: (Select all that apply)				
	2018		2006	
	Number	%	Number	%
Species range shifts	16	80.0%	15	68.2%
Changes in species composition	14	70.0%	9	40.9%
Changes in disturbance regimes (forest fires)	15	75.0%	9	40.9%
Changes in protected area physiography (glacial extent, water levels)	15	75.0%	15	68.2%
Tourism/recreation (increase in visitation)	9	45.0%	5	22.7%
Other	9	45.0%	1	4.5%
Total	20		22	

Table C.19: **Summary data for survey question 28.**

Q28 - Has the nature and scale of such impacts been investigated through research?				
	2018		2006	
	Number	%	Number	%
Yes	8	40.0%	12	52.2%
No	12	60.0%	11	47.8%
Total	20		23	

Table C.20: **Summary data for survey question 29.**

Q29 – Have these studies been conducted by (check any that apply):				
	2018		2006	
	Number	%	Number	%
Your agency	8	100.0%	4	33.3%
Another agency within your jurisdiction	5	62.5%	6	50.0%
ENGOs	2	25.0%	4	33.3%
University researchers including graduate students	7	87.5%	6	50.0%
Consultants	1	12.5%	1	8.3%
Other	0	0.0%	3	25.0%
Total	8		12	

Table C.21: **Summary data for survey question 31.**

Q31 - Is any response being taken or being considered to deal with any of the identified climate related impacts (e.g., further research or adaptation measures)?				
	2018		2006	
	Number	%	Number	%
Yes	6	75.0%	12	57.1%
No	0	0.0%	9	42.9%
Unsure	2	25.0%	0	0.0%
Total	8		21	

Table C.22: **Summary data for survey question 32.**

Q32 - Briefly identify the specific responses to climate change impacts being undertaken or being considered.				
	2018			
	Undertaken		Considered	
	Number	%	Number	%
Legislation, planning & policy	2	25.0%	2	25.0%
Selection, evaluation & design of PAs	1	12.5%	5	62.5%
Management direction	2	25.0%	4	50.0%
Operations & development	3	37.5%	2	25.0%
Research, monitoring & reporting	5	62.5%	1	12.5%
Education, interpretation & outreach	5	62.5%	1	12.5%
Other	0	0.0%	0	0.0%
Total	8			

Table C.23: **Summary data for survey question 34.**

Q34 - Does your agency have a public education program specifically related to climate change and its possible effects (e.g., through posters, park interpretation, park brochures, etc.)?				
	2018		2006	
	Number	%	Number	%
Yes	7	25.9%	6	17.1%
No	20	74.1%	29	82.9%
Total	27		35	

Table C.24: **Summary data for survey question 36.**

Q36 - If No, Does your agency have plans to develop a public education program related to climate change and its possible effects?				
	2018		2006	
	Number	%	Number	%
Yes (next 1 - 5 years)	4	22.2%	7	25.0%
Yes (next 6 - 10 years)	1	5.6%	0	0.0%
Yes (next 10+ years)	0	0.0%	0	0.0%
No	13	72.2%	21	75.0%
Total	18		28	

Table C.25: **Summary data for survey question 37.**

Q37 - Has climate change been incorporated or considered in the development of protected areas management plans or other active management plans relevant to protected areas in your jurisdiction (e.g., fire/prescribed burning, environmental assessment, invasive species)?				
	2018		2006	
	Number	%	Number	%
Yes	15	55.6%	5	17.9%
No	7	25.9%	23	82.1%
Unsure	5	18.5%	NA	
Total	27		28	

Table C.26: **Summary data for survey question 39.**

Q39 - If No, Is your agency in the process or considering the incorporation of climate change into park management plans or other management plans relevant to parks and protected areas?				
	2018		2006	
	Number	%	Number	%
Yes	2	16.7%	6	26.1%
No	5	41.7%	17	73.9%
Unsure	5	41.7%	NA	NA
Total	12		23	

Table C.27: **Summary data for survey question 41.**

Q41 - Does your agency / jurisdiction currently have the capacity necessary to deal with climate change issues affecting protected areas (e.g., committed financial resources, knowledgeable/scientifically trained staff, etc.)?				
	2018		2006	
	Number	%	Number	%
Yes	4	15.4%	3	8.8%
No	19	73.1%	31	91.2%
Unsure	3	11.5%	NA	
Total	26		34	

Table C.28: **Summary data for survey question 43**.

Q43 - Does your agency have a climate change adaptation strategy (or action plan) directly related to protected areas?				
	2018		2006	
	Number	%	Number	%
Yes	3	11.1%	2	5.7%
No	18	66.7%	29	82.9%
In Development	6	22.2%	4	11.4%
Total	27		35	

Table C.29: **Summary data for survey question 45.**

Q45 - Does your agency face any barriers or challenges to implementing climate change adaptation strategies in protected areas?		
	2018	
	Number	%
Yes	22	81%
No	5	19%
Total	27	

Table C.30: **Summary data for survey question 46.**

Q46 - If Yes, What type of barriers or challenges to implementing climate change adaptation strategies in protected areas does your agency face? (Select all that apply)		
	2018	
	Number	%
Lack of knowledge	16	76.2%
Insufficient funding / lack of resources	18	85.7%
Lack of capacity (human resources)	20	95.2%
Institutional (political, administrative)	10	47.6%
Public perceptions / lack of public support	6	28.6%
Lack of awareness of a problem / issue	5	23.8%
Lack of agreement on best way forward	7	33.3%
Lack of leadership	6	28.6%
Total	21	

Table C.31: **Summary data for survey question 48.**

Q48 - What types of protected area climate change adaptation conservation strategies are currently employed by your agency?		
	2018	
	Number	%
Expand protected area network	17	68.0%
Increase connectivity	17	68.0%
Reduce other threats	16	64.0%
Focus on ecosystem function	10	40.0%
Conservation triage	5	20.0%
Dynamic reserves	2	8.0%
Assisted migration	1	4.0%
Total	25	

Table C.32: **Summary data for survey question 50.**

Q50 Please rank the following climate change adaptation conservation strategies according to how likely your agency would be to implement each strategy in the future. (Ranking of "1" = Most likely to implement; Ranking of "7" = Least likely to implement)				
	2018			
	High	Low	Mean	Total
Expand protected areas network	1	7	2.7	20
Increase connectivity	1	6	2.8	20
Reduce other threats	1	7	2.7	20
Dynamic reserves	3	7	6.0	20
Focus on ecosystem function	1	7	3.8	20
Conservation triage	1	7	4.3	20
Assisted migration	3	7	5.9	20

Table C.33: **Summary data for survey question 51.**

Q51 - Have you heard of the concept of novel ecosystems?		
	2018	
	Number	%
Yes	13	48%
No	14	52%
Total	27	

Table C.34: **Summary data for survey question 53.**

Q53 - If Yes, Do you think the concept of novel ecosystems has a valuable role to play in the management of protected areas in an era of climate change?		
	2018	
	Number	%
Yes	6	46%
No	7	54%
Total	13	

Table C.35: Summary data for survey question 54.

Q54 - What should be the approach to climate change adaptation among Canada's protected areas agencies?				
	2018		2006	
	Number	%	Number	%
No specific adaptation strategy	0	0.0%	2	5.7%
Coping with issues on an 'as needed' basis	7	26.9%	3	8.6%
Operating with a comprehensive agency-based strategy	18	69.2%	14	40.0%
Sharing in a Canada-wide protected areas collaborative effort on climate change	25	96.2%	29	82.9%
Total	26		35	

Table C.36: **Summary data for survey question 65.**

Q65 - Does your organization actively work to address the Aichi targets?		
	2018	
	Number	%
Yes	21	80.8%
No	3	11.5%
Unsure	2	7.7%
Total	26	

Table C.37: Summary data for survey question 57.

Q57 - If Yes, While working towards the Aichi targets, does your organization explicitly take into consideration and plan for climate change?		
	2018	
	Number	%
Yes	8	40.0%
No	9	45.0%
Unsure	3	15.0%
Total	20	

Table C.38: **Summary data for survey question 58.**

Q58 - If Yes, How does your organization propose incorporating climate change into initiatives to meet the Aichi targets?		
	2018	
	Number	%
Utilizing climate change modelling for designing areas and networks	6	75.0%
Enhancing other analytical capabilities	6	75.0%
Focusing efforts on protecting and managing 'Key Biodiversity Areas'	5	62.5%
Establishing effective buffer zones around protected areas and other effective area-based conservation measures	4	50.0%
Enhancing connectivity between protected areas and other effective area-based conservation measures	5	62.5%
Increasing in-agency expertise and capacity	4	50.0%
Collaborating with external climate change experts	8	100.0%
Engaging in trans-boundary initiatives with neighbouring jurisdictions	6	75.0%
Improving monitoring and reporting on management efforts	6	75.0%
Expanding public awareness and understanding	7	87.5%
Total	8	

Table C.39: Summary data for survey question 60

Q60 - Is your agency better equipped to deal with climate change than it was 10 years ago?		
	2018	
	Number	%
Yes	21	77.8%
No	6	22.2%
Total	27	

Appendix D

Adaptation Options Tables

Table D.1: All adaptation options identified by workshop participants ranked for effectiveness and feasibility (from 1 to 5, with 1 being low and 5 being high) and categorized based on intervention class and mechanism targeted by the intervention

Adaptation Option	Effectiveness	Feasibility	Intervention class	Mechanism
Adjust drainage courses on the ground to divert water into wetlands	3	3	Interventionist	Resist
Augment flow • store water on the environment and release later • impound water above important recharge points and release at critical times • get groundwater discharge at the right time • ponds to irrigate similar to irrigation systems on farms • Lake Louise - store water so that they don't have to take water at critical times	4	1	Interventionist	Resist
Augment water levels by building artificial structures	5	4	Interventionist	Resist
Beaver management • manage beaver population beyond threat to infrastructure • remove beaver food source to make areas less appealing to them	3	4	Conventional	Direct
Build natural protective features (hard engineering) (i.e. break wall)	3	2	Interventionist	Resist
Build natural protective features (soft engineering) (i.e. reefs, vegetation)	3	3	Conventional	Direct
Clean equipment protocols for staff (clean heavy equipment, UTV, soil/fill, field gear)	4	4	Conventional	Resist

Climate SMART coastal infrastructure	4	3	Conventional	Direct
Connectivity for species migration (great lakes, north/central America)	3	1	Conventional	Direct
Consider functional diversity for restoration projects (diversify plantings consider functional traits)	4	4	Conventional	Direct
Consider maintaining / enhancing functional diversity in existing habitats	4	4	Conventional	Direct
Create and restore channel networks	4	3	Interventionist	Direct
Create shade • planting of tree species to shade the waterbody • not just trees (could be physical structure) • snow fence	5	5	Conventional	Resist
Creation and enhancement of vernal pools. Creation of deeper pools in wetlands for overwintering herpetiles and to increase water storage capacity.	4	4	Interventionist	Resist
Develop landscape design/plan (trail plan, enforcement of plan) (as it pertains to IAS)	5	4	Conventional	Direct
Encourage/influence climate SMART ecosystems/habitats/structure	4	3	Interventionist	Direct
Enhance public engagement as it pertains to SAR	3	3	Conventional	Direct
Facilitate connectivity / corridor between existing habitat (NBP)	4	3	Conventional	Direct
Fire breaks	4	4	Conventional	Resist
Fire management plan (first step)	5	5	Conventional	Direct
Fisheries management options (e.g., moratorium, stocking, exclusion zones, fishing reg.)	5	2	Conventional	Resist
Fuel load plan - mechanical removal	4	3	Conventional	Resist

Fuel load plan - prescribed burn	4	3	Interventionist	Resist
Habitat management and connectivity plan and implementation strategy (CPR)	5	3	Conventional	Direct
IAS firewood containment program	5	5	Conventional	Resist
Identify critical groundwater recharge zones and limit impacts in those areas • avoid development in these areas	4	3	Conventional	Resist
Implement terrestrial invasive alien species plan	3	4	Conventional	Resist
Improve culvert design and reduce barriers	5	4	Conventional	Direct
Improve tributary water quality and ag., reduce influence	4	5	Conventional	Direct
Invasive management (i.e. macrophytes, phragmites, and others)	5	4	Conventional	Resist
Inventory and response program for wetlands that are vulnerable to drying and invasion by invasive and undesirable species	5	5	Conventional	Resist
Limit access • fencing of sites to prevent access • limit fishing • limit taking water	5	3	Conventional	Resist
Limit development pressures adjacent to coastal habitat to facilitate migration (inland, longitudinal, and waterward) (i.e., permits, policies, lands, zoning bylaws)	5	3	Conventional	Direct
Limit development pressures adjacent to coastal habitat to make more resilient to storm events and erosion (i.e., permits, policies, lands, zoning bylaws)	5	3	Conventional	Direct
Maintain landscape mosaic diversity across the NBP (variable habitats and their associated successional stages)	4	4	Conventional	Direct

Maintaining functional trophic levels by adjusting species assemblages. Focus on ecosystem function as a whole.	4	2	Interventionist	Direct
Make expertise available for land development and management processes (for species population range)	3	2	Conventional	Direct
Manage for phenological mismatch	2	1	Interventionist	Direct
Opportunity for partnership networking and recovery collaboration within current and future species range; to create source populations	5	4	Interventionist	Direct
Planting around wetlands. Encourage topographic variability around and within wetlands. Restoration to include "pit and mound"	4	4	Conventional	Direct
Preserving and promoting genetic diversity	4	4	Conventional	Direct
Prevent establishment / eliminate IAS upon arrival (through policy, eradication teams, education, equipment)	3	3	Interventionist	Resist
Promote fire tolerant habitats / species	4	3	Conventional	Direct
Promote mixed or deciduous stands	4	3	Interventionist	Direct
Protect and preserve coldwater refugia (all #1's relate to coldwater refugia protection) • mapping • fencing of sites to prevent access • monitoring water temperatures in multiple locations	5	4	Conventional	Resist
Protect/promote socially charismatic species (black bear, turtles)	4	3	Conventional	Resist
Public education and awareness	3	5	Conventional	Direct

Re-establishing hydrological connectivity in prolonged low lake levels for vulnerable coastal wetlands and river mouths (i.e. channels)	3	3	Interventionist	Resist
Reduce natural or infrastructure barriers to movement	4	4	Conventional	Direct
Seed / vegetative propagule preservation	3	5	Conventional	Resist
Septic inspection and maintenance	5	4	Conventional	Direct
Short term rentals inventory and controls	4	4	Conventional	Resist
Strategically remove barriers above wetlands	4	4	Conventional	Direct
Targeted salvage for wetlands that are failing imminently - save turtles from drying wetland and move to new wetland.	3	3	Interventionist	Direct
Trans-boundary management	4	4	Conventional	Direct
Translocation of fish when barrier can't be addressed	3	3	Interventionist	Direct

Table D.2: Top adaptation options identified by workshop participants ranked for effectiveness and feasibility (from 1 to 5, with 1 being low and 5 being high) and categorized based on intervention class and mechanism targeted by the intervention

Adaptation Option	Effectiveness	Feasibility	Intervention Class	Mechanism
Terrestrial				
Opportunity for partnership networking and recovery collaboration within current and future species range to create source populations	5	4	Conventional	Direct
Implement fire management plan	5	5	Conventional	Resist
Facilitate connectivity / corridor between existing habitat (Northern Bruce Peninsula)	4	3	Conventional	Direct
Implement terrestrial invasive alien species plan	3	4	Conventional	Direct
Interagency vegetation mapping project that includes succession, functional traits, and assisted migration as climate change impacts	4	4	Interventionist	Direct
Coastal Lake Huron				
Public education and awareness	3	5	Conventional	Direct
Invasive management (i.e. macrophytes, phragmites, and others)	5	4	Conventional	Direct
Habitat management and connectivity plan and implementation strategy	5	3	Conventional	Direct
Climate smart coastal infrastructure	4	3	Conventional	Direct
Limit development pressures adjacent to coastal habitat to increase resilience to storm events and erosion (i.e., permits,	5	3	Conventional	Direct

policies, lands, zoning bylaws)				
Fisheries management options (e.g., moratorium, stocking, exclusion zones, fishing reg.)	5	2	Conventional	Resist
Inland Aquatic				
Monitoring and early response for invasive species	5	5	Conventional	Direct
Creation and enhancement of vernal pools. Creation of deeper pools in wetlands for overwintering herpetofauna and to increase water storage capacity.	4	4	Conventional	Resist
Reduce barriers (increase connectivity)	5	4	Conventional	Direct
Protect and preserve coldwater refugia through mapping, fencing of site to prevent access, and monitoring of water temperatures in multiple locations	5	4	Conventional	Resist
Targeted salvage for wetlands that are imminently failing (e.g., save turtles from drying wetland and move to new wetland)	3	3	Interventionist	Direct

Appendix E

Adaptation Options Codes for Advantages and Disadvantages

Table E.1: Codes that were used to thematically code advantages and disadvantages identified by participants for each adaptation option.

Advantages	Disadvantages
Enhance / preserve genetic diversity	Costly
Maintains ecosystem function	High uncertainty
Allows species dispersal	Jurisdictional issues / increased jurisdictional complexity
Builds public support / education	Competing priorities
Poltically appealing	Social implications / limits access to recreational users, fishermen, etc.
Builds partnerships	Negative public perception
Supports PC mandate	High complexity / difficult to implement / engineering requirements
Increases / maintains resiliency	Variable / uncertain efficacy
Already implemented in other jurisdictions / knowledge exists	Lack of agreement among partners / conflicting priorities
Protects infrastructure / buffers extreme storm events	Lack of consensus on desired future state
Cost efficient	Labour intensive / time consuming
Low risk	Contentious / controversial
Increase ecosystem health / saves species / maintains species diversity	Science and research needs (lacking info)
Reduces human impacts	Long time to see benefits

Provides more management control over ecosystem	Potential for unanticipated negative ecosystem impacts
Assists decision-making / helps prioritize actions	High monitoring or enforcement needs
Allows for quick response	Potential negative consequences on other non-target species
Reduces uncertainty	First Nations concerns/ rights (need input)
Provides co-benefits	Regulatory hurdles
Identifies / prioritizes critical areas to protect	Highly political
	Only delays impact

Appendix F

Adaptation Readiness Survey Instrument

Climate Change Adaptation Readiness Assessment – Bruce Peninsula National Park and Fathom Five National Marine Park

1. Introduction

Q1. Welcome to the Parks Canada Agency Adaptation Readiness Climate Change Assessment Survey

This survey is designed to evaluate the Bruce Peninsula National Park and Fathom Five National Marine Park's adaptation readiness to adapt to the impacts of climate change. Readiness is reflected in organizational member's beliefs, attitudes, and intentions regarding the extent to which changes are needed and the organization's capacity to successfully make those changes. Readiness is the cognitive precursor to the behaviors of either resistance to, or support for, a change effort.

For the purposes of this project, adaptive capacity is a suite of characteristics that describe (and measure) Parks Canada Agency's ability to respond to the effects of climate change. Characteristics include, but are not limited to, the ability of the agency to influence human behaviour, to make important decisions in response to variable weather and climatic patterns, communicate with the public, and establish and maintain the necessary partnerships.

Climate change is already having observable impacts in the park and further changes are projected. Mean annual air temperature on the Bruce Peninsula has increased by ~1^0C since 1916 and is expected to increase 1.9^0C-2.1^0C by 2021-2050 and by 2.9^0C-4.3^0C by 2051-2080 (PCIC, 2014; Parker, 2018). Precipitation trends are less clear, but annual precipitation is expected to increase slightly relative to the 1961-1990 baseline (Wang *et al.,* 2017; Parker, 2018). More-intense precipitation events are expected, with the "one in 100 year" event becoming a "one in 25 year" event (Parker, 2018). Additionally, the "one in 100 year" event is projected to become 25% more intense. Lake Huron's surface water temperature has already increased by 0.11°C (Mason *et al.,* 2016) and is projected to increase by 2.6-3.9°C by the 2080s relative to a 1971-2000 baseline (Trumpickas *et al.,* 2009). Furthermore, annual mean ice cover on Lake Huron has decreased by 1.6% yr^{-1} over the period of 1973 to 2010 (Wang *et al.,* 2012) and the ice-free period is projected to increase by 45-62 days by 2071-2100 (Dove-Thompson *et al.,* 2011; Parker, 2018). The Climate Change Adaptation Workshop held in May 2019 reviewed some of these impacts and started conversation regarding potential adaptation strategies to address climate change impacts.

The questions are organized in 4 inter-related themes. A brief description at the beginning of each category provides the context for the question(s). In some cases, key words and concepts are defined as well.

Response options to each question are displayed along a **five-point continuum** that assesses the extent of implementation of various themes, ranging from 'Not at all' to 'Completely' (Table 1). All questions may not pertain to your role but please do your best to provide an informed answer to the best of your ability to every question. If you are unable to answer a particular question, please select 'Not qualified to answer'.

Table 1: Likert scale anchor values and example qualifiers.

Anchor Value:	**1**	**2**	**3**	**4**	**5**
Extent of Implementation:	**Not at all**	**Slightly**	**Somewhat**	**Mostly**	**Completely**
Example Qualifiers:	-Not at all sufficient to achieve target of well-connected protected areas and OECMs -No capacity -No resources -No support -No action -Major gaps -Not a priority -Never	-Minor capacity -Issue or need has been recognized -A small extent -Major gaps remain -Low priority -Rarely	-Moderate capacity -Being developed -A moderate extent -Some gaps remain -Medium priority -Sometimes	-High capacity -Work underway -Assessment undertaken -A large extent -Most gaps addressed -High priority -Often	-Completely sufficient to achieve target of well-adapted ecosystems -Full capacity -Implemented and/or monitored, tracked, and reported on -Full extent -No gaps -Essential -Always

Note: When answering questions related to management plans, it is understood that the current 1998 management plan is dated. When answering these questions, please consider other relevant park projects, as well as planning work undertaken to date as preparation for the new 2021 management plan.

2. Participant Consent

Q2.

You are invited to participate in a research study conducted by Stephanie Barr, under the supervision of Dr. Brendon Larson of the University of Waterloo, and in collaboration with Dr. Chris Lemieux at Wilfrid Laurier University. The objective of the research study is to assess the capacity of the Bruce Peninsula National Park and Fathom Five National Marine Park to adapt to climate change.

If you decide to participate in the study, you will be asked to complete an online survey. The survey contains 36 questions and will take approximately 1 hour to complete but will ultimately depend on how much detail you choose to provide. Survey questions focus on factors that contribute to an organization's adaptive capacity, such as values and principles, commitment to public and partner engagement, institutional structure and function, financial and human assets, acquisition and use of information, know-how, and a mandate for adaptive decision-making. The results of this survey will be compiled, analyzed, and reported to provide an assessment of these characteristics.

Participation in this study is voluntary and you may withdraw your participation at any time by not submitting your responses. Additionally, you may decline to answer any of the survey questions you do not wish to answer. There are no known or anticipated risks to participation in this study beyond risks you face in everyday life. All of the data will be summarized, and no individual could be identified from these summarized results. Your name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used, but they will not identify you in any way.

You will be completing the study via an online survey operated by Qualtrics™. When information is transmitted over the internet privacy cannot be guaranteed. There is always a risk your responses may be intercepted by a third party (e.g., government agencies, hackers). University of Waterloo practices are to turn off functions that collect machine identifiers such as IP addresses. The host of the system collecting the data such as Qualtrics™ may collect this information without our knowledge and make this accessible to us. We will not use or save this information without your consent. If you prefer not to submit your survey responses through this host, please contact Stephanie Barr so you can participate using an alternative confidential method.

We will keep our study records for a minimum of 7 years on a secure network drive. Once you begin the survey you cannot withdraw consent to participate as we have no way of identifying which survey responses are yours. Only those associated with this study will have access to these records which are password protected. It is not possible to withdraw your consent once papers and publications have been submitted to publishers. All records will be destroyed according to University of Waterloo policy.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 41301). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

Once all the data are collected and analyzed for this project, I plan on sharing this information with the research community through conference presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please contact one of the researchers, and when the study is completed, anticipated by December 2019, and we will send you the information.

If you have any questions regarding this study or would like additional information to assist you in reaching a decision about participation, please contact me at s2barr@uwaterloo.ca. You can also contact my supervisor, Professor Brendon Larson at 1-519-888-4567 ext. 38140 or email blarson@uwaterloo.ca. Further, if you would like to receive a copy of the results of this study, please contact either investigator.

Your opinions are very much appreciated and necessary to the success of this project! Thank you for considering participation in this study.

Consent to Participate

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study. By agreeing to participate in the study you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

Yes I will participate [directed to question 1]

No I will not participate [web page closes]

3. Respondent Information

Q3. How many years have you been involved in conservation or natural resources planning and management?

A) With the current organization?

a. Less than 2 years
b. 2 – 5 years
c. 5 – 10 years
d. More than 10 years

B) In your career?

a. Less than 2 years
b. 2 – 5 years
c. 5 – 10 years
d. More than 10 years

Q4. What best describes your current involvement in conservation or natural resources planning and management (please select all that apply):

- ☐ Strategic planning (1)
- ☐ Legislation and policy development (2)
- ☐ Selection, evaluation and design of protected areas (3)
- ☐ Management direction (4)
- ☐ Operations and development (including recreation resource management) (5)
- ☐ Research, monitoring and reporting (6)
- ☐ Education, interpretation and outreach (7)
- ☐ Other (please specify) (8)

Q5: What is the highest degree, certificate or diploma you have obtained? (choose 1)

- ○ No certificate, diploma or degree (1)
- ○ Secondary (high) school diploma or certificate (2)
- ○ Registered apprenticeship or trades certificate or diploma (3)
- ○ College, CEGEP or other non-university certificate or diploma (4)
- ○ University certificate or diploma below the bachelor level (5)
- ○ Bachelor's degree (6)
- ○ Master's degree (7)
- ○ Doctoral degree (8)

Q6: What best describes your academic background and/or professional training (please select all that apply):

- ☐ Natural / physical sciences (1)
- ☐ Social sciences / humanities (3)
- ☐ Business/Economics (4)
- ☐ Engineering (5)
- ☐ Other (please specify) (7)

4. **Climate Change Effects**

Q7: How concerned are you about the issue of climate change in relation to your work? Please select from the following range to answer the question.

- ◯ 1 - Not at all concerned (1)
- ◯ 2 - Slightly concerned (2)
- ◯ 3 - Somewhat concerned (3)
- ◯ 4 - Moderately concerned (4)
- ◯ 5 - Extremely concerned (5)

Q8: To what extent do you agree or disagree with the statement: "I have noticed the effects of climate change within the park."

- ◯ 1 - Disagree strongly (1)
- ◯ 2 - Disagree a little (2)
- ◯ 3 - Neither agree or disagree (3)
- ◯ 4 - Agree a little (4)
- ◯ 5 - Agree strongly (5)

Q9: Which of the following climate change effects have you noticed in the park? (please select all that apply):

- ☐ Changes to seasons (e.g., longer growing season, warmer shoulder seasons) (1)
- ☐ Changes to weather/weather patterns (e.g., more extreme weather events occurring) (2)
- ☐ Changes in snowfall/rainfall (e.g., more/less snowfall) (13)
- ☐ Changes in air temperature (e.g., warmer temperatures) (14)
- ☐ Changes to water body levels (e.g., higher/lower water levels in lakes) (3)
- ☐ Changes to water body temperatures (e.g., warmer water temperatures) (4)
- ☐ Loss of ice cover (18)
- ☐ Increased drought occurrences (16)
- ☐ Increased fire occurrence
- ☐ Changes to distribution and abundance of native **animal species** and/or the presence of new animal species (e.g., invasives) (8)
- ☐ Changes in the distribution and abundance of native **plant species** and/or the presence of new plant species (e.g., invasives) (9)
- ☐ Changes in the biology of **animal species** (e.g., earlier breeding) (11)
- ☐ Changes in the biology of **plant species** (e.g., earlier flowering) (12)

- ☐ Impacts on human health (e.g., heat stress) (15)
- ☐ Economic impacts (19)
- ☐ Other (please specify) (20)

Q10: What type of impact do you believe climate change will have on the following? (please check one box for each statement)

	1 - Very negative impact (1)	2 - Somewhat negative impact (2)	3 - No impact (3)	4 - Somewhat positive impact (4)	5 - Very positive impact (5)
The overall ecological integrity of the national park (1)	○	○	○	○	○
The ability of the national park to support current wildlife populations (2)	○	○	○	○	○
The ability of the national park to support current plant populations (3)	○	○	○	○	○
The ecological function of the national park (e.g., the roles that species play in the community or ecosystem in which they occur) (4)	○	○	○	○	○
The enjoyment people get from visiting the national park (5)	○	○	○	○	○
Human safety and well-being (6)	○	○	○	○	○

Theme 1: The Social-Ecological System

Values in Social-Ecological Systems

The concept of 'value' is often contextual, so there are many definitions that need to be considered simultaneously, such as cultural value, economic value, financial value, life-support value, and aesthetic value.

The following are examples of values that may be of importance to your organization:
- Integrity of ecosystems and cultural resources of protected and other conserved areas
- Public appreciation, understanding, and enjoyment of protected and other conserved areas
- Ongoing traditional activities and subsistence usage in protected and other conserved areas

Q11. To what extent do park programs evaluate and report on potential future effects of climate change on important **social values** (e.g., visitor nodes, aesthetics, archaeological sites) in the national park?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q12. To what extent do park programs evaluate and report on potential future effects of climate change on important **ecological values** (e.g., migration corridors and breeding habitat) in the national park?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

The Spatial Context

Canada's parks include spaces of unique and substantial ecological and social value. The 'spatial context' category is included in this survey to assess whether the social and ecological values that are important to Parks Canada Agency, its clients, and its partners are mapped and described in support of effective decision-making.

The following are examples of values of importance to Parks Canada Agency:
- Integrity of ecosystems and cultural resources of the park
- Public appreciation, understanding, and enjoyment of the park
- Ongoing traditional activities and subsistence usage in the park

Q13. To what extent have important **social values** (e.g., visitor nodes, archaeological sites) in the national park been **mapped and described**?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q14. To what extent have important **ecological values** (e.g., wetlands, wildlife habitat, forest) in the national park been **mapped and described**?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

The Temporal Context

Timeframe is important for strategic planning, policy and legislation, scientific investigation, modelling, adaptive decision-making, monitoring, and partnerships. Timeframes can be immediate (<1 year), short-term (1-5 years), and/or long-term (5+ years). Generally, a capacity to plan across all timeframes is important for the successful implementation of an adaptive approach to managing for climate change.

Q15. To what extent is the park **committed** (i.e., funding, staff, policy) to **continuous monitoring** (i.e., short- and long-term monitoring) to assess the condition of important social and ecological values as the climate changes?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Theme 2: Governance

The governance theme is focused on understanding how lands and waters are legally and institutionally organized, and how government laws and policies are used to guide the tenure, management, and planning status of these assets.

Institutional Culture & Function

Institutional culture and function describes how an agency completes their core business (day-to-day and year-to-year) with tools and techniques such a procedures to update policies, implement monitoring programs, organize staff, allocate funding, train staff, manage information, organize outreach programs, and transfer information.

Leadership

Leadership of any initiative is a crucial function. For leadership to be successful, collaborative approaches that inspire 'ownership of the initiative' by many people and agencies will be required for the successful implementation of climate change initiatives.

Q16. To what extent have **priority actions** been identified for climate change monitoring and adaptation?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q17. To what extent does the park's leadership **support the mainstreaming** of climate change into its programs?

Mainstreaming is the integration of climate change considerations into policies, strategies, plans, and guidelines used by an organization to successfully meet its core business goals and objectives (such as protecting or maintaining ecological integrity). Mainstreaming can be applied at any spatial and temporal scale (e.g., habitat to ecosystem, on-site project level to international decision-making, days/weeks to years/decades), and to any decision-making activity (e.g., policy modification, plan updates, budgeting, operational adjustments, and the addition of new indicators to monitoring programs).

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q18. To what extent has the park **assessed costs** to achieve the target of climate change adaptation?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q19. To what extent does the park have sufficient **financial resources** to manage for the effects of climate change?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q20. To what extent does the park have sufficient **human resources (staff)** to manage for the effects of climate change? *That is, are there individuals in your organization that have expertise in managing for climate change impacts*?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Legislation & Policy

Given that decisions about the allocation of natural resources are complex and are likely to become more so as demand for access to resources increases, it is important to keep legislation and policy current and responsive as conditions evolve and new knowledge is acquired.

This includes policy, legislation, guidelines, permits, and licenses.

Q21. To what extent do the **park management plan and Parks Canada projects** enable the **mainstreaming** of climate change?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Empowerment

The implementation of climate change adaptation strategies benefits from the active engagement of people with diverse goals, values, interests, knowledge, and perspectives.

Q22. To what extent does **the park** provide **outreach programs** that help people understand the ethical, social, economic, and ecological aspects of climate change to increase awareness and participation in decision-making?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Partnership

Given the broad nature of climate change and the impacts it has beyond park boundaries, a culture of collaboration is key to successful management of climate change and partnerships are a fundamental requirement for most, if not all, proactive and adaptive decision making and program management strategies.

Q23. To what extent does the park **collaborate with partners** at multiple scales of decision-making? *Examples of multiple scales include different levels of government, different mapping scales, and different time regimes.*

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q24. To what extent can the park's **current approach to partnerships** (i.e., memorandums of understanding, contribution agreements, business licenses) be used to enhance its capacity to adapt to the effects of climate change?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Trust

If society trusts in the ability of an organization to sponsor fair, accountable, and transparent programs with meaningful public engagement, the chances of successfully managing for climate change are enhanced.

Q25. Considering the possible need for rapid response to the changes in weather and changes in season, and given the associated trade-offs often associated with decision making, to what extent do **stakeholders** (e.g., the general public, NGOs) **trust** the park to make appropriate decisions?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Theme 3: Planning & Implementation

Natural asset management is completed at strategic, tactical, and operational levels of planning. Strategic plans describe a vision of the future and provide high level direction in the form of forward-thinking action statements. Systems and management plans are focused on how the strategic actions will be implemented and operational plans outline on-site program delivery. Accounting for planning levels in programs designed to increase adaptive capacity is important because many adaptation options are scale-specific.

Systems Planning

Given that a commitment to biodiversity conservation requires decision-making about the allocation of natural assets in and outside of protected areas at the landscape and waterscape levels of planning, systems approaches are being integrated into national, subnational, and regional planning programs. The need for systematic approaches designed to keep ecosystems protected, managed, and connected are critical as demand for access to natural resources and/or assets grows.

Q26. To what extent does your jurisdiction engage in **ecosystem-level planning (i.e., planning on a larger scale including outside the park)**?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Management Planning

A management plan responds to the requirements prescribed in legislation, policy, and strategic plans. A management plan communicates management direction, usually developed through a formal process of consultation and collaboration involving stakeholders and practitioners who draw upon traditional knowledge, community knowledge, and science. Jurisdictions employ many different types of tactical plans to guide natural asset allocation decisions in protected areas and on the intervening landscapes and waterscapes (e.g., natural resource management plans, wildlife management plans, fire management plans, park management plans, fisheries management plans, forest management plans, subdivision plans, transportation corridor plans, human-wildlife conflict plans, and restoration plans). Most are written and implemented according to different planning processes, at different scales, for different types of ecological goods and services, and unique and time frames. Even so, there is a public expectation that the responsible agencies will coordinate their planning and decision-making at appropriate scales to provide simultaneous social benefit and environmental protection.

Q27. To what extent does the park management plan **recognize the importance of adaptive governance**, including adaptive management, to manage for the effects of climate change?

Adaptive governance denotes the structures (e.g., program design) and processes (e.g., policies) that an organization uses to shape actions to attain the cultural, social, economic, and ecological conditions to which it aspires.

Adaptive management is a systematic process designed to increase the chances of making the right decisions in an ever-changing social and ecological context. Adaptive management is about learning while doing, and can involve learning through different combinations of experimentation and experience.

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q28. To what extent does the current park **management plan** provide **objectives and actions** that enable staff and partners to respond to the effects of climate change?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

<u>Operations Planning</u>

An operations plan provides detailed guidance on how to achieve measurable outcomes. An operations plan tends to focus on the location and timing of *in-situ* conservation practices guided by best management practices, guidelines, and other tools and techniques.

Q29. Does the park **have access to the climate change adaptation tools and techniques** needed to achieve expected and acceptable social and ecological outcomes?
a) Not at all
b) Slightly
c) Somewhat
d) Mostly

e) Completely
f) Not qualified to answer

Q30. To what extent has the park undertaken planning exercises to identify knowledge gaps, impacts of climate change, or strategies to address climate change?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Theme 4: Knowledge

<u>Knowledge Management</u>

Traditional, community, and scientific knowledge comprise many knowledge management programs. Knowledge is gathered through living and working on the landscapes and in the waterscapes; research, inventory, monitoring, and assessment; and managed through user-friendly information management systems in support of an adaptive approach to management.

Q31. To what extent is **Indigenous traditional knowledge incorporated** into decision-making on the implementation of climate change initiatives?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q32. To what extent is **local community knowledge incorporated** into decision-making on the implementation of climate change initiatives?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q33. To what extent is **scientific knowledge incorporated** into decision-making on the implementation of climate change initiatives?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q34. To what extent do inventory, monitoring, and assessment programs **enable the evaluation of climate change impacts** and associated 'state of' reporting?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Knowledge Exchange

Knowledge exchange involves communication and knowledge sharing through education, extension courses, and other types of outreach activities such as news releases, webinars, fact sheets, website information, and face-to-face meetings.

Q35. To what extent are **staff training** opportunities focused on adaptive management tools/techniques to help with decision making under great uncertainty, available?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q36. To what extent does the park provide clients and partners access to its **information management system**?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q37. ***add skip logic*** If Q36 = 'not at all' then skip Q37
To what extent does the park's information management system **meet client and partner needs**?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Q38. To what extent are **collaborative monitoring networks** in place to facilitate the exchange of data and information at multiple scales to support climate change adaptation initiatives?

a) Not at all
b) Slightly
c) Somewhat
d) Mostly
e) Completely
f) Not qualified to answer

Appendix G

Adaptation Readiness Survey Raw Data

Table G.1: Summary data for <u>social-ecological values</u> questions of the adaptation readiness survey.

Theme 1: Social-Ecological Values					
Subtheme	Question	Number of Respondents	Median	Mean	Standard Deviation
Values	To what extent do park programs evaluate and report on potential future effects of climate change on important **social values** (e.g., visitor nodes, aesthetics, and archeological sites) in the national park?	15	2.00	2.00	0.93
	To what extent do park programs evaluate and report on potential future effects of climate change on important **ecological values** (e.g., migration corridors and breeding habitat) in the national park?	14	2.50	2.57	0.65
Temporal context	To what extent is the park **committed** (i.e., funding, staff, policy) to **continuous monitoring** (i.e., short- to long-term monitoring) needed to assess the condition of important social and ecological values as the climate changes?	12	3.00	3.42	1.17
Spatial context	To what extent have important **social values** (e.g., visitor nodes, archeological sites) in the national park been **mapped and described**?	14	4.00	3.86	0.36
	To what extent have important **ecological** values (e.g., wetlands, wildlife habitat, forest) in the national park been mapped and described?	14	4.00	4.07	0.48

Table G.2: Summary data for <u>institutional culture</u> theme questions of the adaptation readiness survey.

Theme 2: Institutional Culture					
Subtheme	Question	Number of Respondents	Median	Mean	Standard Deviation
Resources	To what extent does the park have sufficient **financial resources** to manage for the effects of climate change?	8	2.00	2.50	1.30
	To what extent does the park have sufficient **human resources (staff)** to manage for the effects of climate change? *That is, are there individuals in your organization that have expertise in managing for climate change impacts?*	9	2.00	2.56	1.11
Leadership	To what extent have **priority actions** been identified for climate change monitoring and adaptation?	12	3.00	2.83	0.60
	To what extent does the park's leadership **support the mainstreaming** of climate change into its programs?	14	3.00	3.21	0.98

Table G.3: Summary data for planning and implementation theme questions of the adaptation readiness survey.

Theme 3: Planning and Implementation					
Subtheme	Question	Number of Respondents	Median	Mean	Standard Deviation
Management planning	To what extent do the **park management plan and Parks Canada projects** enable the **mainstreaming** of climate change?	14	3.00	3.36	0.75
	To what extent does the **park management plan recognize the importance of adaptive governance**, including adaptive management, to manage for the effects of climate change?	14	3.00	2.71	0.83
	To what extent does the current park **management plan** provide **objectives and actions** that enable staff and partners to respond to the effects of climate change?	12	2.00	2.00	0.90
Climate change planning	To what extent has the park **assessed costs** to achieve the target of climate change adaptation?	10	2.00	1.60	0.52
	To what extent has the park undertaken **planning exercises** to **identify knowledge gaps**, impacts of climate change, or strategies to address climate change?	13	3.00	3.15	0.63
	Does the park **have access to the climate change adaptation tools and techniques** needed to achieve expected and acceptable social and ecological outcomes?	12	4.00	3.67	0.97
Systems planning	To what extent does the park engage in **ecosystem-level planning (i.e., planning on a larger scale including outside the park)**?	15	3.00	3.00	0.76

Table G.4: Summary data for partnerships and public support theme questions of the adaptation readiness survey.

Theme 4: Partnerships and Public Support					
Subtheme	Question	Number of Respondents	Median	Mean	Standard Deviation
Trust	Considering the possible need for rapid response to the changes in weather and changes in season, and given the associated trade-offs often associated with decision making, to what extent do **stakeholders** (e.g., the general public, NGOs) **trust** the park to make appropriate decisions?	13	3.00	3.15	0.93
Empowerment	To what extent does **the park** provide **outreach programs** that help people understand the ethical, social, economic, and ecological aspects of climate change to increase awareness and participation in decision-making?	15	2.00	2.07	0.96
Collaboration	To what extent does the park **collaborate with partners** at mutliple scales of decision-making?	14	3.00	3.21	0.63
	To what extent can the park's **current approach to partnerships** (i.e., memorandums of understanding, contribution agreements, business licences) be used to enhance its capacity to adapt to the effects of climate change?	13	3.00	3.54	0.84
	To what extent does the park's information management system **meet client and partner needs**?	8	3.00	2.63	0.58

Table G.5: Summary data for knowledge theme questions of the adaptation readiness survey.

Theme 5: Knowledge					
Subtheme	Question	Number of Respondents	Median	Mean	Standard Deviation
Knowledge management	To what extent is **local community knowledge incorporated** into decision-making on the implementation of climate change initiatives?	15	2.00	2.27	0.96
	To what extent is **scientific knowledge incorporated** into decision-making on the implementation of climate change initiatives?	15	4.00	3.73	0.88
	To what extent is **Indigenous traditional knowledge incorporated** into decision-making on the implementation of climate change initiatives?	14	2.00	2.57	1.16
	To what extent do inventory, monitoring, and assessment programs **enable the evaluation of climate change impacts** and associated 'state of' reporting?	13	3.00	2.78	0.92
Knowledge exchange	To what extent are **staff training** opportunities focused on adaptive management tools/techniques to help with decision making under great uncertainty, available?	13	2.00	1.92	0.86
	To what extent does the park provide clients and partners access to its **information management system**?	9	2.00	2.44	0.63
	To what extent are **collaborative monitoring networks** in place to facilitate the exchange of data and information at multiple scales to support climate change adaptation initiatives?	13	3.00	2.62	0.51

Appendix H

Adaptation Readiness Workshop Facilitation Guide

Introduction

- Introduce myself and my research
- Provide overview of what will happen in the workshop
- Get participants to sign consent forms
- Go over context and purpose of this study and the workshop

Perceived Impact of Climate Change on the Park

- Why do you think that human safety and well-being will be negatively impacted? What are specific negative impacts on human safety? How can the park better prepare to mitigate these anticipated impacts?

Extra:

- Are there specific aspects of the visitor experience that you think would be positively or negatively impacted by climate change?

Effects of climate change that have been noticed in the park

The most common effects that noted in the survey are:

1) Changes to weather
2) Changes to water body levels
3) Changes to seasons
4) Changes in snowfall/rainfall
5) Changes to the distribution and abundance of animal species

- Can you provide some examples of climate change related changes that are happening in the park?

Values

- Remind participants of the definition of values from the survey

10. Climate change impacts on social values / ecological values

How can social values be more incorporated into park programs? What social values should be tracked and monitored to make more informed decisions?

Extra:

Why is it easier to evaluate / report on ecological values?

11. Spatial context – mapping social and ecological values

Are there certain features that have been mapped / described more than others?

Monitoring

13. Continuous monitoring / monitoring enables CC evaluation

- Remind participants of the definitions of timeframes from the survey

How could monitoring programs / protocols change to better address / incorporate climate change considerations?
What would be two or three priority areas for monitoring?

Extra:

How frequently does monitoring occur? Do long-term data sets exist? If so, are they analyzed to see how populations are changing over time?
Is climate change explicitly considered?
What timeframes does planning occur on? Immediate, short-term, long-term?

Policy and Planning

15. Priority Actions / Planning exercises

What steps could the park take to better identify actions to monitor and adapt to climate change?

Extra:

What priority actions have been identified?
What actions should be undertaken?
Do actions relate more to monitoring or more to adaptation?
Is there a process/mechanism for identifying these actions?
What planning exercises have been undertaken?

16. Mainstreaming

- Remind participants of the definition of mainstreaming from the survey

How could climate change be further mainstreamed into park practices?

Extra:

Can you provide an example of how climate change is currently mainstreamed into park programs/ practices?

17. Park Management Plan

Has climate change been brought up in discussions about the new management plan? If not, should it? What should be addressed within the plan?

Extra:

Was climate change mentioned in the 1998 management plan?
Other than the management plan, are there other documents that provide objectives and actions for climate change? Is there a need for one?

18. Ecosystem-level planning

How could ecosystem-level planning be enhanced?

Extra:

Is ecosystem planning primarily undertaken within park boundaries or does this include planning outside park boundaries?
Can you provide an example of ecosystem-level planning that is currently being undertaken?
What factors are required to plan at a broader scale?

Partnerships

20. Outreach programs

Does the park have the capacity to provide climate change focused outreach programs? In what way can the park engage the public on climate change – both visitors and communities around the park?

Extra:

Are there examples of climate change currently being incorporated into outreach programs?

Does the park provide outreach programs within the community on other topics?

21. Collaborate with partners / Collaborative monitoring networks

Are there specific partners that the park's capacity to adapt to climate change could benefit from?

Extra:
Why doesn't the park partner with other organizations? (From Brian)
How can partnerships / collaboration be increased?
Do current conservation strategies take a trans-boundary perspective (i.e., do you work with organizations outside the park on species management)?
Do clients/partners request access to park information?
What types of information would partners be granted access to?

22. Partnerships enhance capacity

How do your partnerships help you adapt to the effects of climate change?

Extra:

What is the park's current approach to partnerships?
Who do you currently collaborate with?

23. Trust

Is there an example where stakeholders have trusted the park to make a decision in the past?
Why is trust not present? (From Brian) *(no one responded 'completely', some responded 'slightly'…why do the slightly respondents think trust is so low)*
Are there specific aspects that stakeholders trust the park on more than others?
How can trust be enhanced, especially related to climate change?
How can trust be maintained?
Are there specific stakeholder groups that trust the park more than others

<u>Knowledge</u>

25. Access to climate change tools

What additional tools / techniques do you need to respond to climate change?

Extra:

What climate change tools and techniques do you have access to?
Do you use these tools?

26. Types of knowledge

Why is there such a wide range of answers? Do different sectors within the park have different connections to indigenous / local groups?

Extra:

Are there examples of indigenous knowledge or local knowledge that has been incorporated into decision-making on climate change initiatives?
Is it a priority for the park to increase engagement with indigenous and local groups?

27. Staff training on adaptive tools/techniques

What type of training related to climate change / adaptive management would be useful?
What types of training are currently available?
Would training on adaptive management be useful to you?

29. Assessed Costs

Is there a need to assess costs?
What would it take for an assessment to take place?
What would a 'target of climate change adaptation' look like?
Who is looking at budget from a climate change perspective?
Do you have the financial and human resources necessary to adapt to the impacts of climate change?