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Open to change but stuck in the mud: Stakeholder perceptions of adaptation options at the frontlines of climate change and protected areas management

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Supplemental material (referred to herein as "Online Resources") may be found at https://parks.berkeley.edu/psf/?page_id=3034.

ABSTRACT

In recent decades, the literature on climate change and biodiversity conservation has proposed numerous climate change adaptation options; however, their effectiveness and feasibility have rarely been evaluated by those involved in frontline decision-making. In this paper, we use data from a two-day climate change adaptation workshop held at Bruce Peninsula National Park and Fathom Five National Marine Park, in Ontario, Canada, to understand stakeholder views on different types of adaptation options. We found that most (45%) adaptation options identified by participants were "conventional" (i.e., they are already in use and are relatively low risk and familiar to practitioners) and oriented towards directing change (i.e., they aim to help species and ecosystems respond to change and transition to a desired future state). These options also received higher effectiveness and feasibility ratings than "novel" ones. The remaining options (55%) were either "conventional" and aimed towards resisting change, or else were "novel." Our results suggest that practitioners are open to working with change; however, there is some management resistance to more dynamic "novel" options (e.g., adjusting species assemblages), which in many instances will be required to effectively deal with inevitable climate change impacts. By focusing on understanding the factors that influence the prioritization and feasibility of adaptation options at the regional scale, and by providing practical recommendations to enhance organizational capacity to adapt to climate change, we address key implementation gaps identified in the literature.

INTRODUCTION

Protected area managers increasingly face conservation challenges arising from rapid ecological change. Existing biodiversity conservation practices were largely developed under the assumption of a stable climate system (West et al. 2009), which is no longer valid under current climate change scenarios (Abrahms et al. 2017; Harris et al., 2018). Although uncertainty remains around precisely how ecosystems will respond, widespread changes to ecosystem composition, structure, and function are highly likely (IPBES 2019; IPCC 2022). Accordingly, there have been many calls to adapt conservation practices to better integrate the realities of climate change (Scott et al. 2002;

Heller and Zavaleta 2009; West et al. 2009; Lemieux and Scott 2011; Hagerman and Satterfield 2014; Abrahms et al. 2017).

Although the conservation science literature has proposed numerous adaptation options for biodiversity conservation (Heller and Zavaleta 2009; Lemieux and Scott 2011), much of this literature is speculative or theoretical in nature (Prober et al. 2019). Practitioners often lack resources and capabilities to identify and adopt proactive and potentially effective adaptation options relevant to their unique management contexts (Abrahms et al. 2017). Action on climate change is often delayed due to barriers such as cost, lack of knowledge, and challenges dealing with the uncertainty of future impacts—at a time when action is critically needed. An assessment of stakeholder views is a therefore a critical research need and is required to help determine the desirability and feasibility of available adaptation options. Such an assessment will also help identify areas where capacity for adaptation needs to be enhanced to better ensure management effectiveness in an era of rapid climate change.

Adaptation options to address the impacts of climate change in the field of conservation biology are often situated along two complementary typologies: (1) "conventional" to "novel," and (2) "resist change" to "direct change" (Tam and McDaniels 2013; Hagerman and Satterfield 2014; Fisichelli et al. 2016; Aplet and Mckinley 2017). The first, "conventional vs. novel" adaptation, has also been referred to as "low regrets vs. climate-targeted" adaptation (Prober et al. 2019) and "conventional vs. interventionist" (Hagerman and Satterfield 2014). Conventional options are those that are already in use and which have benefits regardless of their climate impacts (e.g., expanding the protected area network, reducing other threats). Moreover, experts and the public tend to favor conventional management options (Tam and McDaniels 2013; Hagerman and Satterfield 2014; St-Laurent et al. 2018; Prober et al. 2019). In contrast, novel options are typically more publicly and politically controversial, not least because they require greater human involvement in ecosystem management (e.g., species translocation outside of historical ranges) (Hagerman and Satterfield 2014; Prober et al. 2019) and focus on changing management goals and managing transitions to new ecosystem states (Scott et al. 2002; West et al. 2009).

Adaptation options can also often be placed within a dichotomy of "resist change" or "direct change" (Stein et al. 2014; Fisichelli et al. 2016; Prober et al. 2019). Options that resist change aim to reduce stressors on species and maintain historical ecosystem composition (e.g., increasing shading over waterbodies to maintain cold-water fish habitat), whereas options that direct change aim to transform the ecosystem to a new suitable state (e.g., introducing better-adapted, warm-water fish species) (Fisichelli et al. 2016; Prober et al. 2019). It is important to acknowledge that nuances in the language used to describe adaptation strategies exist, and that what is considered "conventional" or "interventionist" is not always clear and may not fit perfectly within the dichotomies detailed here. For example, "conventional" approaches to management (including, for example, prescribed burning, hydrological regulation, culling, predator control) can be both highly interventionist and sometimes controversial. Also, ongoing climate change beyond historical bounds means that some conventional approaches may now be risky (i.e., unlikely to achieve the goals for which they are being taken). Therefore, in this article, we use the terms "conventional" and "novel" (as opposed to "interventionist" for the latter) to deal with this dichotomy more effectively, and to recognize that conventional options that aim to resist change may no longer be sufficient given the current and projected magnitude and rate of climate change, and may even be counterproductive if resources are directed towards features unlikely to persist in the future (Abrahms et al. 2017; van Kerkhoff et al. 2019) (e.g., restocking a native fish species in a lake where the climate no longer matches its thermal needs ("conventional/resist") or maintaining historical water levels through engineered structures ("novel/resist")).

Climate change is altering ecosystems through changes in species abundance, distribution, and phenology, leading to new states that are unfamiliar to managers (IPBES 2019). These changes force managers to make difficult value-based decisions about desired future ecosystem characteristics that may conflict with protected area goals and objectives (Abrahms et al. 2017; van Kerkhoff et al. 2019). Management practices have traditionally sought to preserve past conditions, and many protected area goals, often detailed within management plans, typically dictate the preservation of such conditions (Scott et al. 2002). However, to meet the challenges posed by climate change, conservation needs to take a future-oriented perspective (van Kerkhoff et al. 2019). There is hence a paradox for conservation insofar as managers are asked to facilitate change to allow ecosystems to adapt, but also to resist change to maintain intact representative ecosystems. One resolution is a shift in management focus, from maintaining specific species and ecosystems to more resilient future ecosystems that maintain ecosystem function and conserve regional biodiversity through recognizing that species abundances and distributions will need to shift in response to climate change (van Kerkhoff et al. 2019; Schuurman et al. 2020). Policy and protected area goals will have to transform before such a shift can fully occur.

The conservation community largely agrees that practices need to adjust to meet rapid ecological change, but how to develop and implement adaptation options—at the scale of individual protected areas situated within unique ecosystems and planning and management contexts—remains a challenge in practice and a key knowledge gap in the literature (Lemieux and Scott 2011; Abrahms et al. 2017). It is at the protected area level (i.e., the “frontlines”) where effects will first be realized and decisions need to be made, yet the identification of adaptation options has largely occurred at more general levels of planning and management (e.g., Heller and Zaveleta 2009; LeDee et al. 2021). For example, changing climatic conditions may lead to shifts in natural communities within protected areas and require goal re-evaluation. It is protected area managers, with local experiential knowledge and observations, who are best suited to re-evaluate goals and practice. Although examples of adaptation at the protected area level are beginning to emerge (e.g., considering different species mixes in restoration efforts based on future climate projections), more are required.

To address this knowledge gap concerning adaptation options at the protected area level, we examined manager preferences for adaptation options in Bruce Peninsula National Park (BPNP) and Fathom Five National Marine Park (FFNMP), Ontario, Canada, to develop a more complete understanding of the viability, perceived effectiveness, and feasibility of adaptation options. Accordingly, our objectives were to: (1) determine which adaptation actions practitioners prefer; (2) evaluate the perceived effectiveness and feasibility of these options; (3) apply a typology to the options; and (4) understand stakeholder viewpoints on adaptation options. We conclude by outlining ways in which dynamic future-oriented conservation can be achieved.

STUDY LOCATION

Located on the northern tip of the Bruce (Saugeen) Peninsula in Ontario (Figure 1), BPNP was established in 1987 to protect a 156-km² representative example of the Great Lakes/St. Lawrence Lowlands natural region. BPNP is largely composed of alvar, forest, old field, and inland lake ecosystems (Parks Canada 1998a). FFNMP, also established in 1987, is located north of BPNP and protects representative features of both aquatic and terrestrial systems over 114 km2 in the Georgian Bay Marine Region (Parks Canada 2010b). Given their proximity to several large urban centers, BPNP and FFNMP, together, are Ontario’s most heavily visited national parks (Government of Canada 2020). FFNMP, with 272,059 visits in 2019–2020, attracts the second-highest number of visits among all national marine conservation areas (NMCAs) in Canada (Government of Canada 2020). Both protected areas have seen substantial increases in visitation over the past decade, with visits to BPNP increasing by 50% and those to FFNMP by 10% since 2011–2012.

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) because it is not yet officially included under the act and therefore operates under a complex mix of provincial and federal legislation (Parks Canada 2010a). The primary goal of management at BPNP is to maintain ecological integrity (Parks Canada 1998a). Likewise, FFNMP is managed in the “spirit” of the Canada National Marine Conservation Areas Act (2002) because it too is not yet scheduled officially included under the act. The primary goal of FFNMP is ecological sustainability through maintaining ecosystem structure and function (Parks Canada 1998b; Parks Canada 2010b).

FIGURE 1. The location of Bruce Peninsula National Park and Fathom Five National Marine Park. Inset shows the location of the parks in relation to the rest of Canada.
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The parks are already experiencing climate change (Parker 2018). Mean annual air temperature on the Bruce Peninsula has increased by ~1°C from 1916–2016 and is expected to increase another 1.9–2.1°C by 2050 and 2.9–4.3°C by 2080 relative to a 1976–2005 baseline (Parker 2018; Bush and Lemmen 2019). Total annual precipitation has increased by 20% since 1948, with the greatest increase in fall and winter precipitation (Bush and Lemmen 2019). In the future, more precipitation is projected to fall in intense events, with a "one in 100 year" event becoming a "one in 25 year" event (Parker 2018). Lake Huron's surface water temperature has already increased by 0.11°C per year from 1994–2013 and is projected to increase 2.6–3.9°C by the 2080s relative to a 1971–2000 baseline (Parker 2018). Water level fluctuations in Lake Huron are projected to be more variable, with greater extremes (Parker 2018). Furthermore, mean annual ice cover on Lake Huron has decreased by 1.6% per year from 1973–2010 and the ice-free period is projected to increase by 45–62 days by 2071–2100 (Parker 2018).

These climatological and physical changes are having impacts on ecosystems in both parks. Of the 64 tree species present, over half may experience extirpation due to changes in hardiness zones (Parker 2018). Approximately 25% of bird species in the region are projected to be different (i.e., through colonization or extirpation) by 2050 under the Representative Concentration Pathway (RCP) 8.5 climate change scenario (Gahbauer et al. 2022). Decreased ice cover is reducing protection to fish spawning shoals and coastal areas, and warmer water temperatures are allowing for the northward expansion of warm-water species (Wuebbles et al. 2019).

METHODS

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. Twenty-eight participants were invited by Parks Canada based on their knowledge of the local area and expertise in biodiversity conservation, protected areas management, and climate change. The participants represented a diverse cross-section of protected area stakeholders, including other federal government departments, provincial and municipal governments, non-governmental organizations (NGOs), Indigenous groups, and academics (Online Resource 1).

A pre-workshop webinar by Parks Canada provided an introduction to climate change trends and projections for the Bruce Peninsula and introduced participants to the workshop process, which was based on climate change vulnerability assessment frameworks put forth by Gross et al. (2016). Parks Canada utilizes the following five-step framework (Nelson et al. 2020):

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.

This process incorporates elements of scenario planning to assist with envisioning future climates, considering alternative responses, and making decisions under uncertainty (Star et al. 2016; Miller et al. 2022). 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 2–3 simplified climate change scenarios that were used to translate climate trends and projections for the BPNP/FFNMP region into climate events that need to be managed. For each scenario, participants identified climate change impacts and vulnerabilities, and evaluated their likelihood, consequence, and risks. Protected area managers often must allocate scarce resources, so considering the perceived risk of each impact allowed them to prioritize higher-risk impacts. Participants were instructed to focus on the next decade (through 2029) and to consider planning to 2050 to keep 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 adaptation options to address each impact identified as most urgent. Each option was given two ratings, on a scale of 1 (low) to 5 (high), by consensus of the group that proposed it: one about *perceived effectiveness* at reducing the identified impact and the other for *feasibility of implementation*. Additionally, advantages and disadvantages of each option were noted. Through further discussion, each group selected adaptation options that were most pertinent to the BPNP and FFNMP climate change and management context.

This methodology brings several advantages. First, by including diverse, local stakeholders, it helps to prioritize adaptation options that are most immediately relevant. 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 helped to increase climate change knowledge among Parks Canada staff and other participants, thereby increasing their adaptive capacity for managing the two parks.

Analysis

To group adaptation options identified in the workshop, we applied a typology based on Fisichelli et al. (2016) and Prober et al. (2019) (Table 1). Working independently, two coders categorized each adaptation option in terms of the dichotomous typologies discussed above. We compared codes and revised definitions through multiple rounds of coding. Effectiveness and feasibility ratings were averaged for each category and for the different ecosystem types. If an adaptation option did not have both an effectiveness and a feasibility rating, it was excluded from analysis.

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: 15). This method is similar to inductive thematic analysis and grounded theory, but its focus is more practical than theoretical. After coding the advantages and disadvantages identified by participants for each adaptation option, we conducted a qualitative comparison of themes by intervention class and effect. A one-way ANOVA was used to compare the ratings for the ecosystem types (i.e., inland aquatic, coastal, terrestrial) as well as the percentage of options that are classified as "conventional" or "novel" and that "resist change" or "direct change." Two-sample t-tests were used to examine whether there were statistically significant differences in the ratings between classes (i.e., "conventional" or "novel") as well as the two effects an option can have on the ecosystem (i.e., "resist change" or "direct change").

RESULTS

Climate change impacts relevant to BPNP and FFNMP

Based on climate scenarios (Table 2), priority impacts were identified for each ecosystem type as follows. Terrestrial ecosystem impacts included increases in forest fire intensity, exotic invasive species and vector-borne diseases; declines in native biodiversity and ecosystem resilience; and changes in species interactions. Inland aquatic ecosystem impacts included changes to fish community composition and food chains, increased invasive species, and dried wetlands and vernal pools. Finally, impacts to the coastal Lake Huron ecosystem type included altered species abundance, distribution, and community structure, as well as increased nutrient pollution and turbidity.

Evaluation of adaptation options

To address these impacts, 56 adaptation options were developed by participants and evaluated for all three ecosystem types (Online Resources 2 and 3). Among the 56 options, respondents identified 5–6 options for each

TABLE 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 set of benefits regardless of 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 by virtue of already being in use. An example is the expansion of the protected area network.
Interventionist (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-targete"' 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. An example is assisted colonization.
Effect	
Resist change (Scott et al. 2002; Fisichelli et al. 2016; 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 historical 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; Fisichelli et al. 2016; 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 as the climate changes. They increase resilience and help maintain 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.

TABLE 2. Simplified future climate change scenarios developed for each ecosystem type by workshop participants.

Ecosystem type	Scenario number	Scenario description
Inland aquatic	1	Warmer air, warmer water
	2	Drier warm season (increased evapotranspiration, summer heat waves, extreme heat events, decreased precipitation)
	3	Heavier precipitation and flood risk
Coastal	1	Lake levels outside historical range of variability. Changes to lake levels and periodicity of fluctuations.
	2	Warming air, warming waters: increase in air temperatures and cumulative degree days, reduction in ice cover, longer period of stratification
Terrestrial	1	Changing disturbance regime: increased wildfire risk, insects, disease, flood, wind
	2	Shifting species distribution and ecosystem composition, changes in abundance and productivity

TABLE 3. Mean effectiveness and feasibility ratings (scale of 1–5: 1 = not very effective / not very feasible, 5 = very effective / very feasible) of adaptation strategies identified by participants for each ecosystem type with the percentage of strategies that are interventionist or conventional and that aim to resist change or direct change (in parentheses).

	Effectiveness		Feasibility	
Ecosystem type (% of all recommended adaptation strategies)	Mean	SD	Mean	SD
Inland aquatic	***4.11***	***± 0.74***	***3.53***	***± 0.96***
Interventionist (42%)	3.75	± 0.71	2.88	± 0.99
Conventional (58%)	4.36	± 0.67	4.00	± 0.63
Direct change (47%)	3.80	± 0.63	3.50	± 0.71
Resist change (53%)	4.44	± 0.73	3.56	± 1.24
Coastal	***4.15***	***± 0.90***	***3.38***	***± 0.96***
Interventionist (15%)	3.00	± 0.00	2.50	± 0.71
Conventional (85%)	4.36	± 0.81	3.55	± 0.93
Direct change (38%)	4.25	± 0.89	3.63	± 0.92
Resist change (62%)	4.00	± 1.00	3.00	± 1.00
Terrestrial	***3.83***	***± 0.76***	***3.42***	***± 1.06***
Interventionist (25%)	3.67	± 1.03	2.83	± 0.98
Conventional (75%)	3.89	± 0.68	3.61	± 1.04
Direct change (37%)	3.87	± 0.83	3.20	± 1.15
Resist change (63%)	3.78	± 0.67	3.78	± 0.83

ANOVA test result:
Effectiveness: ($F_{(2, 53)} = 0.957$, $p = 0.391$)
Feasibility: ($F_{(2, 53)} = 0.095$, $p = 0.910$)
Percentage interventionist vs. conventional ($F_{(2, 53)} = 1.480$, $p = 0.237$)
Percentage resist change vs. direct change ($F_{(2, 53)} = 0.226$, $p = 0.798$)

ecosystem type that were most pertinent to present to park management (Online Resource 4). 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 none receiving a 1. 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%). No significant differences were observed for any of the comparisons between ecosystem types (Table 3, above).

Across all ecosystem types, the majority of adaptation options were conventional and aimed to direct change (Table 4; Figure 2). This trend becomes more pronounced when considering only the participants' preferred adaptation options (Table 5). Conventional adaptation options had significantly higher effectiveness than novel ones as well as significantly higher perceived feasibility ratings (Table 4). Furthermore, every adaptation option that was rated a 5 for feasibility was conventional. Similarly, of the 16 options rated 5 for effectiveness, most were conventional,

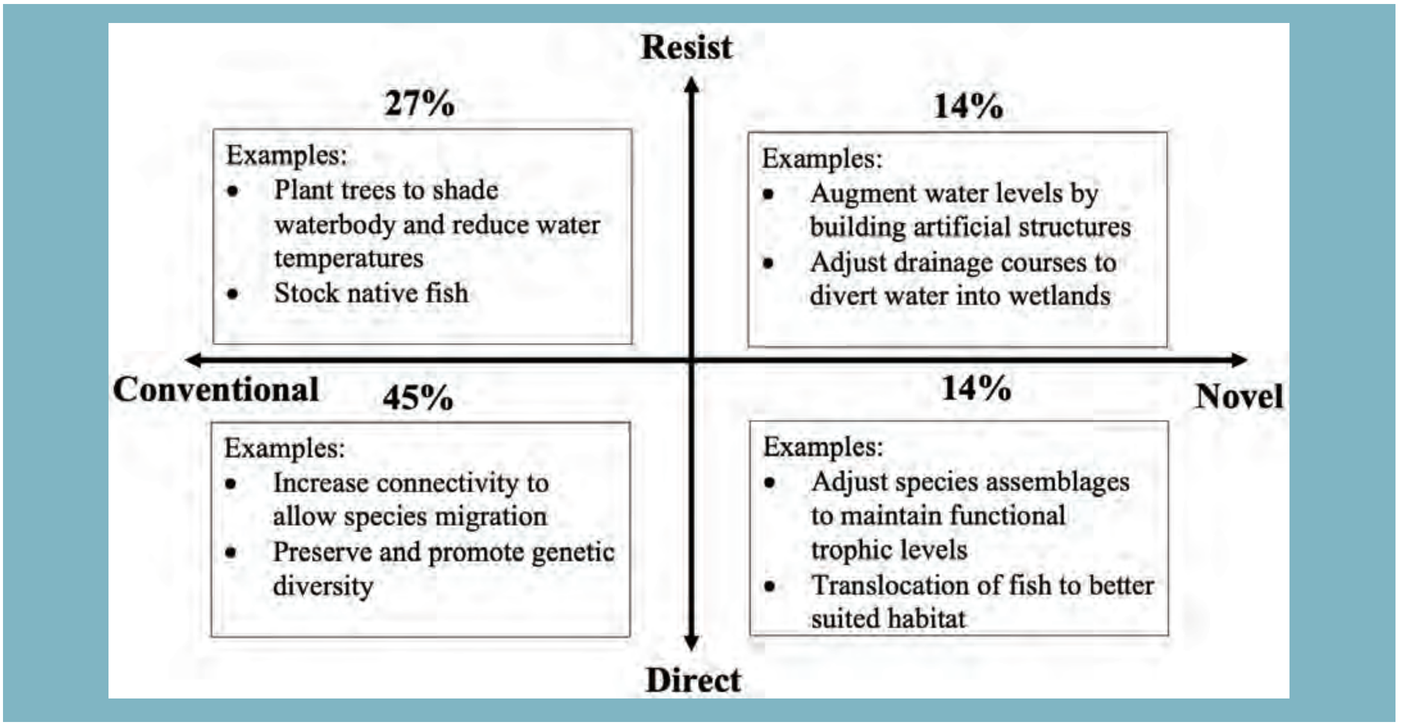
TABLE 4. Percentage of *all* adaptation options identified by workshop participants, categorized by intervention class and effect the strategy has on the ecosystem (in parenthesis) with average effectiveness and feasibility (scale of 1–5: 1 = not very effective / not very feasible, 5 = very effective / very feasible) of adaptation options for each category.

	Effectiveness		Feasibility	
	Mean	SD	Mean	SD
Intervention Class (% of all recommended adaptation strategies)				
Conventional (71%)	4.15	± 0.74	3.70	± 0.91
Interventionist (29%)	3.63	± 0.81	2.81	± 0.83
t-Test results	$t = -2.26$, $df = 26$, $p = 0.016$		$t = -3.29$, $df = 28$, $p = 0.001$	
Effect the strategy has on the ecosystem (% of all recommended adaptation strategies)				
Resist change (41%)	4.09	± 0.79	3.52	± 1.04
Direct change (59%)	3.94	± 0.78	3.39	± 0.97
t-Test results	$t = 0.69$, $df = 47$, $p = 0.248$		$t = 0.47$, $df = 45$, $p = 0.322$	

TABLE 5. 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 (scale of 1–5: 1 = not very effective / not very feasible, 5 = very effective / very feasible) of adaptation options for each category.

	Effectiveness		Feasibility	
	Mean	SD	Mean	SD
Intervention Class (% of all recommended adaptation strategies)				
Conventional (86%)	4.50	± 0.76	3.79	± 0.89
Interventionist (14%)	3.50	± 0.71	3.50	± 0.71
t-Test results	$t = -17.24$, $df = 13$, $p = 0.000$		$t = 0.52$, $df = 2$, $p = 0.329$	
Effect the strategy has on the ecosystem (% of all recommended adaptation strategies)				
Resist change (25%)	4.75	± 0.50	3.75	± 1.26
Direct change (75%)	4.25	± 0.87	3.75	± 0.75
t-Test results	$t = 1.41$, $df = 9$, $p = 0.095$		$t = 0$, $df = 4$, $p = 0.5$	

FIGURE 2. Both adaptation continuums with the percentage of all adaptation options that are categorized into each quadrant and examples for each quadrant.



with only 2 being novel options. In terms of the effect the option has on the ecosystem (resist or direct change), little difference was observed in effectiveness or feasibility ratings between the two effects (Tables 4 and 5).

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." The most frequently cited disadvantages were "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 novel options was observed, with "maintains ecosystem function" and "increases ecosystem health / maintains species diversity" among the four most commonly identified advantages for both options. However, novel options tended to have the advantages of "allows species dispersal" and "increases / maintains resiliency," whereas conventional options "build public support" and "provide co-benefits." Little difference was noted in disadvantages between classes.

Similarly, there was overlap in advantages between options that aim to direct change and those that aim to resist change, with both having the advantages of "maintaining ecosystem function," "building public support," "increasing ecosystem health," and "providing co-benefits." Options 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.

DISCUSSION

Our research reinforces previous studies that have shown a preference for conventional adaptation options (Tam and McDaniels 2013; Hagerman and Satterfield 2014; St-Laurent et al. 2018; Prober et al. 2019; Hagerman et al. 2021) and helps to situate these preferences in the context of decision-making at a regional level. These familiar options are generally considered "safe" by managers and are frequently politically salient, which helps explain their sustained popularity (Hagerman and Satterfield 2014). Besides being the most frequently mentioned, conventional options were also rated more highly for feasibility and effectiveness than novel ones in this study, perhaps because they are more familiar to practitioners and thus better understood (Barr et al. 2020). For example, planting trees to shade streams and reduce water temperatures, a conventional option, was given a score of 5 for effectiveness and feasibility, whereas translocating species to manage for phenological mismatch, a novel option, was given a score of 2 for effectiveness and 1 for feasibility.

Lack of knowledge or experience in implementing a given adaptation option, particularly if more innovative and untested, was a recurring concern in the workshop discussions—a finding consistent with those of other studies (Barr et al. 2020). Natural resource agencies are generally averse to risk (Allen and Gunderson 2011), because they may not have the expertise to judge and manage it, are constrained by existing rules, do not have access to adequate human and financial resources, or some combination thereof. Our results generally indicated that low-risk pathways are selected where both risk (the potential of a "bad" result) and uncertainty are high. A shift towards a set of complementary adaptation options (both conventional and novel) implemented in conjunction with one another is likely to improve success and reduce the risk and uncertainty associated with choosing a single adaptation option (Aplet and Mckinley 2017). Moreover, to account for uncertainties options could be chosen to provide benefits across a range of possible climatic futures.

Relatedly, participants also raised concerns about the efficacy of novel adaptation options (e.g., species translocation). Holling et al. (2002) argued that organizations that are regimented and resistant to novelty and innovation are more susceptible to new challenges. Difficult decisions are thus delayed. To counter these concerns, increased knowledge acquisition and sharing between organizations would boost confidence and reduce uncertainty about novel options. For example, if all protected area organizations (e.g., provincial parks, land trusts, NGOs, and federal protected areas) worked together and shared experiences, the fear of failing after trying something new could be reduced. Such an option could also lead to better harmonization and coordination among the conservation community and avoid wasteful duplication of efforts. Knowledge-sharing could be improved through the establishment of regional climate change collaborations (e.g., something like Landscape Conservation Cooperatives in the US) and the development of adaptation databases for biodiversity conservation that contain case study information on both successful and unsuccessful adaptation efforts (e.g., Climate Adaptation Knowledge Exchange; cakex.org).

For the "resist change" vs. "direct change" typology, participants identified more adaptation options that aim to direct change (e.g., preserving and promoting genetic diversity) rather than resist change (e.g., adjusting drainage courses on the ground to divert water into drying wetlands) and there was no difference in their perceived effectiveness and feasibility. Directing change allows species and ecosystems to respond more effectively to changing environmental conditions and increases ecosystem resiliency (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 or the current climate trajectory (Stein et al. 2014; Fisichelli et al. 2016). Furthermore, options that resist change will at some point reach their limit and adaptation options will need to move towards transformative change (i.e., "novel" options) (Dow et al. 2013). However, in the short- to medium-term, which was the focus of this workshop, resisting or slowing down change to allow time for adaptation may make sense (e.g., increasing shading over a stream to maintain coldwater habitat); in other words, resisting change is valid if it is done strategically. 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 options that resist and direct change indicates that shifting towards options that aim to direct change is not viewed as an onerous challenge by practitioners.

Similar to conventional and novel options, a mix of options that aim to resist and direct change is likely appropriate in the short term to spread risk (Aplet and Mckinley 2017). Not all options need to direct change. As just noted, resisting change in certain circumstances may often be an acceptable choice; however, resisting change is merely an interim coping method until a better solution can be developed and implemented, or until a decision is reached regarding the desired future state or trajectory of the ecosystem. For example, if a keystone species is threatened, it would seem acceptable to resist change to allow that species to persist until a replacement for that ecosystem service can be found. In the longer term, when faced with rapid and radical ecological change, transformative adaptation (directing change) would seem a more appropriate strategy (Fedele et al. 2019).

Because the preferability of near-term versus long-term options differs so much, questions arise around how to transition from one option to another as climate change progresses. A dynamic adaptive policy pathways approach can aid in identifying both a series of options that are ideal at various points in time, as well as triggers that indicate when to switch from one option to the next (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 structure to decision-making. Furthermore, such an approach would allow practitioners to continue using conventional and novel options that resist change while those that direct change are developed and tested. However, knowing when to change strategies is difficult and requires monitoring, resources, and spaces to reflect upon and learn from previous experiences. 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).

Limitations and future research needs

The workshop process detailed in this study has broad applicability to the global biodiversity conservation and protected area community; it can be used to develop and evaluate a set of adaptation options to address specific climate change impacts. However, adaptation options identified in this paper are most relevant to BPNP and FFNMP. Furthermore, these adaptation options have yet to be tested, so their effectiveness is presently unknown. Considering 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.

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 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 novel options being identified and/or supported. In particular, the focus on "sustainable use" rather than "ecological integrity" in legislation for national marine conservation areas could perhaps provide the flexibility to be innovative. with respect to the implementation of novel and less familiar/experimental adaptation options.

Other shortcomings of this methodology relate to the workshop process itself. First, due to the compressed two-day format, participants were expected to identify and prioritize adaptation options quickly, leaving little time for reflection, review, or research. This may have biased which options emerged and overlooked some risks and options. The use of a near-term forecasting method in this study may have influenced the types of adaptation strategies that were considered by participants. Other, more in-depth processes, such as futures studies, may be warranted to address uncertainty and prepare for a wide range of plausible future conditions more effectively. Futures studies 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) (Faldi et al. 2017). Studies have noted that forecasting approaches support incremental adaptation, while backcasting approaches are thought to favor transformative adaptation (van der Voorn et al. 2012). For nearly two decades, the US National Park Service has used scenario planning forecasting techniques to envision multiple possible futures and assess outcomes (Lawrence et al. 2021; Miller et al. 2022). However, managers who would like to consider a more distant future (e.g., 100 years in the future) may opt to use a backcasting approach, where a desired future state is identified and actions are developed to achieve that state.

Second, workshop participants were not instructed to exhaustively identify advantages and disadvantages for each adaptation option, so the authors note that some are missing from analysis. Although this is a weakness of the workshop, the advantages and disadvantages identified are indicative of those foremost in participants' minds. Finally, workshop participants were instructed to focus on adaptation strategies for the next 10 years and to consider planning up to the year 2050. This focus implies a climate that is relatively unchanged from the present day, which skirts difficult decisions related to drastic future change.

Participants identified several research needs during the workshop. They frequently expressed the need for more information regarding species interactions, phenological mismatches, and the trial application of certain adaptation options. The lack of sound evidence upon which to make informed decisions is increasingly acknowledged as a widespread problem for effective biodiversity conservation, not only in Canada (Lemieux et al. 2018) but globally (Giehl et al. 2017). The development of a central repository for case studies would be beneficial. Furthermore, the evaluation of underlying factors that contribute to increased effectiveness and feasibility would assist in designing adaptation options that, in turn, enhance 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, because those factors are likely to have substantial impacts on ecosystems, and 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 useful as more adaptation options are implemented and reported in both the 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 novel options as well those that aim to resist or direct change. Understanding public values surrounding climate change adaptation will become increasingly important. Implementing novel options that direct or resist 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 novel options that direct change). As evidence from this study indicates, conventional options have the advantage of already having public support, whereas novel, untested options may not. Public preferences and values must be considered to attract public and policy support for more controversial and uncertain management decisions.

CONCLUSIONS

The natural adaptive capacity of many species is unlikely to be enough to keep pace with rapid and transformative ecological changes (IPBES 2019; IPCC 2022). Practitioners can no longer work under the assumption of a stable climate system (Abrahms et al. 2017) and rely solely on options that aim to resist change (Aplet and Mckinley 2017). The projected pace of climate change demands a mixture of options (Aplet and Mckinley 2017), and if change reaches the point where conventional resistance options can no longer cope, novel approaches will be inevitable (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).

Our study has shown that a shift from resisting change to directing change is necessary and generally accepted; however, while the need for climate-responsive protected areas policies and management actions was identified decades ago (Scott et al. 2002), the literature continues to reveal significant challenges in moving the climate change adaptation yardsticks within Canada and globally (Lesnikowski et al. 2015; Barr et al. 2020). Recognizing the need for transformative adaptation expands the range of management options available to practitioners and avoids path dependency (Wise et al. 2014). Despite transformative adaptation being a well-recognized concept, conservation policy keeps focusing on the near-term and avoiding hard truths. It is not productive for conservation to carry on as if the climate is stable (Schuurman et al. 2022). Conservation needs to assume a proactive, forward-looking, and interdisciplinary approach that incorporates multiple values. If not, then conservation agencies may ultimately fail at implementing policies and management actions based on what has been learned. As Allen and Gunderson (2011) aptly noted, "procrastination leads to missed opportunities and more intractable problems in the near future."

The impacts of climate change on ecosystems are being experienced on the ground by protected area agencies, and the need for a change in conservation practice is recognized by practitioners (Barr et al. 2020). The May 2019 two-day workshop held by BPNP and FFNMP echoes this reality. However, the need for changes may not yet be acknowledged at higher levels of agencies. As climate change progresses, and restoration becomes less achievable, a shift from static to dynamic views of ecosystems will be required (Prober et al. 2019; van Kerkhoff et al. 2019). Forward-looking decision-making in a time of continuous change includes recognition that: (1) maintaining historical conditions may be increasingly costly or impossible as climate change proceeds; and (2) management action can help direct ecological change along preferred trajectories. Without this, novel and unfamiliar options will likely continue to face resistance even as learning about climate change increases and impacts mount.

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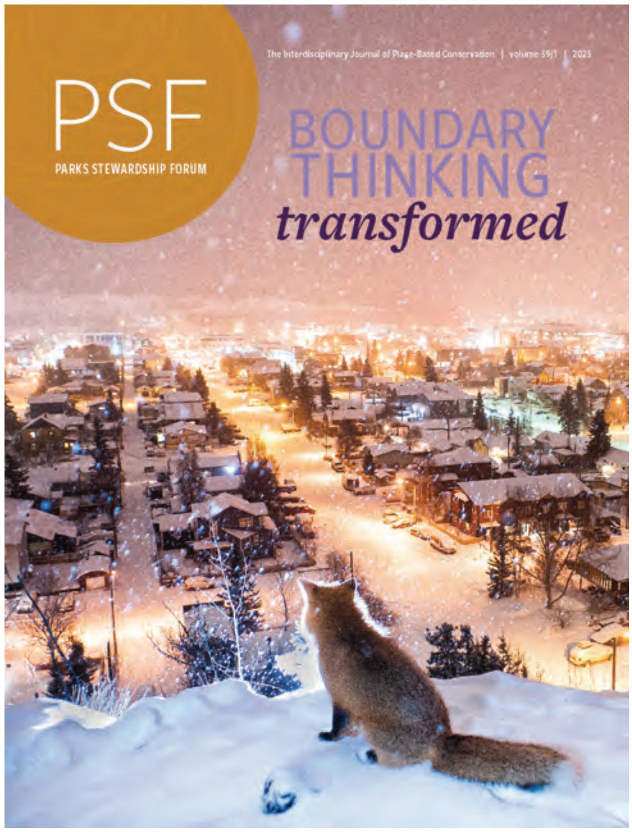

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A red fox on the clay cliffs above the city of Whitehorse, Yukon Territory.
PETER MATHER