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Emerging issues for protected and conserved areas in Canada

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Abstract

Horizon scanning is increasingly used in conservation to systematically explore emerging policy and management issues. We present the results of a horizon scan of issues likely to impact management of Canadian protected and conserved areas over the next 5–10 years. Eighty-eight individuals participated, representing a broad community of academics, government and nongovernment organizations, and foundations, including policymakers and managers of protected and conserved areas. This community initially identified 187 issues, which were subsequently triaged to 15 horizon issues by a group of 33 experts using a modified Delphi technique. Results were organized under four broad categories: (*i*) emerging effects of climate change in protected and conserved areas design, planning, and management (i.e., large-scale ecosystem changes, species translocation, fire regimes, ecological integrity, and snow patterns); (*ii*) Indigenous governance and knowledge systems (i.e., Indigenous governance and Indigenous knowledge and Western science); (*iii*) integrated conservation approaches across landscapes and seascapes (i.e., connectivity conservation, integrating ecosystem values and services, freshwater planning); and (*iv*) early responses to emerging cumulative, underestimated, and novel threats (i.e., management of cumulative impacts, declining insect biomass, increasing anthropogenic noise, synthetic biology). Overall, the scan identified several emerging issues that require immediate attention to effectively reduce threats, respond to opportunities, and enhance preparedness and capacity to react.

Key words: Horizon scan, emerging issues, protected areas, conserved areas, Indigenous-led conservation, Indigenous knowledge systems, biodiversity conservation, ecosystem services, systematic planning

Introduction

On a global scale, human impacts on the natural world are now driving a sixth mass extinction event (Ceballos et al. 2017; Díaz et al. 2019), and accumulating evidence indicates that biodiversity is not being effectively conserved (Geldmann et al. 2019; IPBES 2019). In Canada, populations of at-risk species have declined an average of 59% since 1970 (World Wildlife Fund (WWF)-Canada 2020)—a number of them despite protection and recovery efforts (Government of Canada 2020a). Many ecosystems in southern parts of the country have undergone centuries of extensive land-use change, continue to be under threat of development, and require urgent conservation prioritization (Kraus and Hebb 2020). Development in more northern regions has caused the endangerment of species, including ecological and cultural keystone species like caribou, which rely on large-scale intact ecosystems. Compounding these issues, climate change is already affecting species and habitats across scales (Parmesan and Yohe 2003; Nemésio et al. 2016; Musselman et al. 2021), and future scenarios project widespread ecosystem changes and substantial losses in biodiversity (Newbold 2018; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2019; Stralberg et al. 2020a, 2020b).

With habitat conversion and fragmentation constituting key drivers of biodiversity loss (Woo-Durand et al. 2020), area-based conservation is universally accepted as a fundamental conservation tool to abate loss (Lester et al. 2009; Butchart et al. 2012; Geldmann et al. 2013; Maxwell et al. 2020) and is called for under *Article 8* of the United Nations (UN) Convention on Biological Diversity (CBD). Since the UN CBD came into force in 1992, formal protection of global terrestrial area has increased by more than a factor of two (up to 16.64% in 2021), while marine area protection has increased by a factor of 20 (up to 7.74% in 2021) (UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) 2021). As of December 2020, Canada had reported 12.5% of its terrestrial area (land and freshwater) and 13.8% of its marine territory as conserved through protected areas and other effective area-based conservation measures (OECMs) (Environment and Climate Change Canada (ECCC) 2021).

Included among these recent advances is progress towards Indigenous Protected and Conserved Areas (IPCAs) amid heightened appreciation of the resurgent role of Indigenous-led conservation as essential for confronting the biodiversity crisis (Artelle et al. 2019; Zurba et al. 2019). Indigenous-managed lands represent a disproportionately high percentage of the world's remaining intact and biodiverse ecosystems (Garnett et al. 2018) and retain vertebrate diversity equivalent to or higher than levels in protected areas in Canada and elsewhere (Schuster et al. 2019). At the same time, Indigenous Peoples have been widely dispossessed of their lands, lifeways, and governance systems, including through the establishment of protected and conserved areas (Binnema and Niemi 2006; Sandlos 2008; Truth and Reconciliation Commission of Canada (TRC) 2015a, 2015b, 2015c). Transformations in protected areas' governance remain in their nascency, and there is still much to do to decolonize and develop meaningful relationships among Indigenous and non-Indigenous peoples and knowledge systems (Indigenous Circle of Experts (ICE) 2018; UNEP-CBD 2018a; Loring and Moola 2020).

Such ecological trends and social challenges suggest that immediate, concerted action will be required to maximize the potential of protected and conserved areas in their ability to effectively and equitably conserve biodiversity and related ecosystem services. At every jurisdictional level, however, managers and planners face a host of systemic barriers that make the effective management of protected and conserved areas challenging (Barr et al. 2020; Lemieux et al. 2021). Rarely do they have the time and opportunity to look beyond daily challenges to consider emerging opportunities and threats or to do so with the collective insights and experiences of practitioners from other jurisdictions, conservation sub-disciplines, ecological contexts, knowledge systems, and governance models (Rudd et al. 2011; Buxton et al. 2021). Key challenges include means to effectively braid together or weave different forms of knowledge (natural, social, and Indigenous) into conservation decision-making (Zurba et al. 2019; Lemieux et al. 2021; *M'sɨt No'kmaq* et al. 2021).

Horizon scans have gained prevalence in conservation science as one form of foresight research (Sutherland et al. 2021). In this paper, we identify emerging issues surrounding the management of Canada's protected and conserved areas[1]. Specifically, we ask, "What issues are emerging or on the horizon over the next 5–10 years that are (*i*) currently not emphasized or being addressed, yet are expected to have considerable impacts on ecosystems and ecosystem services and are (*ii*) delivered through protected areas and area-based conservation organizations in Canada?" By identifying issues that are both emerging and important, horizon scans can inform solutions-oriented research agendas and alert decision-makers to potential disruptive events.

Previous horizon scans have had a tangential bearing on protected and conserved areas, with foci that include policy and management (Rudd et al. 2011), pollinators (Brown et al. 2016), inland waters (Pérez-Jvostov et al. 2020), invasive species (Dehnen-Schmutz et al. 2018; Ricciardi et al. 2017), plastics pollution (Provencher et al. 2020), conservation physiology (Cooke et al. 2020), and biodiversity conservation (e.g., Reid et al. 2019; Seymour et al. 2020, Buxton et al. 2021, Sutherland et al. 2021). This horizon scan is complementary to these studies while, at the same time, addressing a critical research gap by focusing exclusively on protected and conserved areas in Canada.

The past 10 years has seen many changes in conservation priorities, needs, and pressures in response to global and national factors, some of which are noted above. The imminent release of the UN CBD *Post-2020 Global Biodiversity Framework,* to be agreed to in Kunming, China, by May 2022, will strongly influence global conservation efforts over the next 10 years and beyond. The most recent draft of the Framework suggests strongly that Parties to the CBD, including Canada, will be called upon to implement nothing short of transformational changes in the ways in which protected and conserved areas are established and managed. These include unprecedented expansion of well-connected networks of protected areas and OECMs and the integration of equitable planning and management approaches that respect and uphold Indigenous rights, governance, and knowledge systems. In fact, Canada has recently committed to protecting 25% of its land and ocean by 2025, working towards 30% by 2030, in partnership with Indigenous Peoples, and it has joined other countries in a High Ambition Coalition championing a global target of protecting 30% by 2030 (Trudeau 2019; ECCC 2021; Government of Canada 2021), setting itself upon an unprecedented pathway in conservation.

[1]Protected areas portfolio includes federal, provincial, and territorial parks and protected areas and other effective area-based conservation measures, managed by private, public, Indigenous, or any other entity, and situated within terrestrial or aquatic realms.

At the same time, the imperative to better understand emerging issues is no better illustrated than by unexpected consequences of the COVID-19 pandemic to individuals and societies. This event serves as a sober reminder of how quickly situations can shift as a consequence of new issues arising, and emphasizes the importance of being prepared to implement evidence-based, coordinated, and timely responses (Editorial 2021; Sutherland et al. 2021). It is with this backdrop and urgency that we proceed to identify emerging issues of concern for protected and conserved areas management in Canada, with the goal of enhancing the ability of researchers, practitioners, and decision-makers to understand and address threats.

Methods

This horizon scan originated as an initiative of Parks Canada and the Canadian Parks Collective for Innovation and Leadership (CPCIL). Indigenous perspectives were based primarily on the recommendations of the Indigenous Circle of Experts (ICE) Report, We Rise Together (ICE 2018). Parks Canada supported the Conservation through Reconciliation Partnership (CRP; 2019) to meet with the ICE leadership to refine emerging issues identified in the ICE report.

We adopted the approach developed in a series of horizon scanning exercises including annual scans carried out since 2009 (Sutherland et al 2021) that comprise a search for issues across a wide community followed by a rigorous process of identification of key issues (Sutherland et al. 2011). **Figure 1** outlines the process for collating issues and then reducing to the final list. To solicit emerging and horizon issues from a broad community of academics, environmental nongovernmental organizations (ENGOs), scientists, philanthropic foundations, policy makers, and managers of protected and conserved areas, we used a crowd sourcing approach via CPCIL (cpcil.ca). We followed this with an expert elicitation process using a modified Delphi technique to solicit, score, and rank the issues; the Delphi technique is an expert elicitation method for gathering information and forming agreement among participants across two or more rounds of consultations (Rowe and Wright 2011; Mukherjee et al. 2015). Eighty-eight participants submitted ~200-word summaries for horizon or emerging issues that, in their view, would have the potential to affect ecosystems and ecosystem services delivered in protected areas across Canada, over the next 5–10 years. These participants included 37% academics and researchers, 24% from ENGOs, 38% governments, and 1% Indigenous organizations. As shown in **Fig. 1**, this generated 187 issues, which a smaller group of 33 experts was first asked to triage to remove those deemed not to be either "emerging" or on the "horizon" based on the novelty, potential impact, and likelihood of occurrence of the issues. The expert group was made up of 32% academics, 26% from ENGOs, and 41% from governments. Seven of the 33 expert group members were identified with specific research portfolios (aquatic, fish, wildlife, social); the others had broad, applied research and management expertise crossing both natural and social science and practice.

Seventy-seven issues (**Supplemental Material 1**) were retained and then subject to a second round of ranking to identify the top 30 (**Supplemental Material 2**) for discussion during a virtual workshop. Experts were tasked with preparing two to three of these top issues for more in-depth discussion (often outside their areas of expertise, thereby helping to familiarize them with the issues). The main discussion occurred in a virtual workshop (due to the on-going COVID-19 pandemic) on 5 February 2021. During the workshop, experts proposed three additional issues, resulting in a total of 33, which they sequentially discussed, scored, and reassessed through a series of breakout and plenary sessions to identify the top 15 issues. In each round of ranking, issues were scored on a scale of 1–1000, converted to ranks, and then the median rank was used to reduce the impact of individual scores. Scoring was anonymous as this has been shown to improve accuracy when using experts (Sutherland and Burgmann 2015). While one individual retained a confidential record of the individuals' identities and the issues they submitted, all submitted ideas and assessments of the ideas,

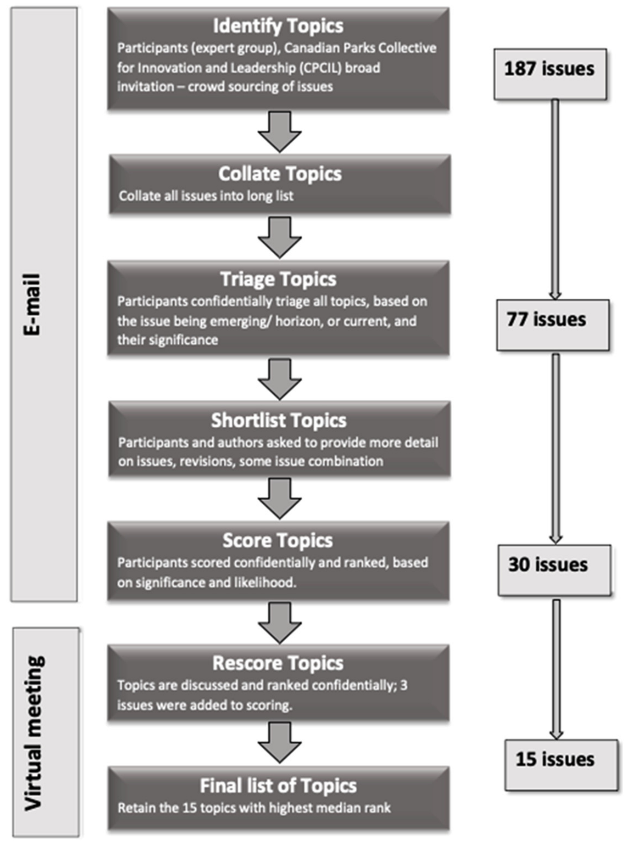

Fig. 1. Horizon scanning process (after Sutherland et al. 2021; see **Supplemental Material 3** for further methodological details and definitions).

including individual scores, were de-identified for consideration by the group of experts. For further detail on the methodology and definitions, see **Supplemental Material 3**.

Results

The 187 issues reflected a range of scales, from broad, national themes to specific, localised issues, and included current as well as emerging issues (all issues can be found at cpcil.ca/research-and-knowledge/horizon-scan). When they were triaged by the experts, approximately 50% were assessed to be current issues, rather than emerging or horizon and, thus, not retained for further consideration. Although they had emerging elements, they were considered to be well-acknowledged issues, albeit for which questions and adequate implementation or redress remain. Among the 77 retained issues, several distinct themes emerged. For example, the predominant issues focused on climate change (26%), anthropogenic impacts (21%), protected and conserved area planning and connectivity (21%), and Indigenous governance, rights, and knowledge systems (7%). Several other topics had lesser representation, such as invasive and non-native species, ecosystem services, management tools, and technology. The final set of 15 issues (**Table 1**) were grouped into four categories: (*i*) emerging effects of climate change in protected areas design, planning, and management; (*ii*) Indigenous governance and knowledge systems; (*iii*) integrated conservation approaches across landscapes and seascapes; and (*iv*) early responses to emerging cumulative, underestimated, and novel threats. A group of three to four experts was tasked with refining the description of each issue. Those responsible

Table 1. Top 15 emerging issues for protected and conserved areas in Canada, grouped according to theme (see Supplemental Materials 1 and 2 for lists of submitted and assessed issues).

Emerging effects of climate change in protected areas design, planning, and management
Long-term and large-scale ecosystem-level effects of climate change
Ecological integrity in a climate-change context
Translocations to and from protected areas
Effects of changing snow patterns on protected area management
Effects of interplay between wildland fire and climate change
Indigenous governance and knowledge systems
Indigenous governance and protected areas
Indigenous knowledge systems and western science
Integrated conservation approaches across landscapes and seascapes
Integration of protected areas into a wider suite of conservation instruments across terrestrial, freshwater, and marine ecosystems
Enhancement of ecological connectivity within aquatic systems
Mechanisms for integrating and balancing ecosystem values and services
Integration of freshwater in planning for terrestrial protected areas
Early responses to emerging cumulative, underestimated, and novel threats
Management of cumulative impacts from multiple environmental stressors
Declining insect biomass and biodiversity
Effects of increasing anthropogenic noise on aquatic ecosystems
Risks and benefits of synthetic biology for conservation and restoration

for refining the Indigenous issues that arose within the broader community process included individuals engaged in the CRP (2019), and issue refinements were made consistent with priorities identified by ICE (2018).

Emerging effects of climate change in protected areas design, planning, and management

Long-term and large-scale ecosystem-level effects of climate change

The localized nature of climate change impacts and asynchrony between changes—such as temperature, precipitation, acidification, permafrost thaw and sea-level rise—present a major challenge to Canada's protected and conserved areas (Gonzalez et al. 2018; Elsen et al. 2020). The timing, severity, and spatial pattern of climate change impacts differ among areas, and the dynamic nature of climate change is complicated by geographic bias (e.g., extreme or atypical landscapes; see Gonzalez et al. 2018) in the locations of protected and conserved areas (Elsen et al. 2020). Such challenges are compounded by uncertainty related to cross-scale impacts and interactions for ecosystems, communities, species, and populations (Srivastava et al. 2021). These challenges and complexities compounded by uncertainties contribute to social inertia in addressing climate changes that occur over the very long-term and across large geographical regions. Ecosystems within Canada's protected and conserved areas will continue to experience substantial changes to composition, structure, and function due to climate change. For 30 years, the scientific literature has identified potential implications of large-scale and ecosystem-level effects of climate change for policy, planning, and management of protected areas in Canada (Lopoukhine 1990). Many adaptation solutions have been proposed to more effectively conserve biotic communities and ecosystems in the face of climate change (Holdgate and Phillips 1999; Lemieux et al. 2011). Examples include establishing large protected and conserved areas that retain natural habitats and climatic heterogeneity and improving network planning to integrate connectivity and climate refugia (Coristine et al. 2018; Stralberg et al. 2020a, 2020b).

Ecological integrity in a climate change context

Ecological integrity (EI) relates to the concept that the ability of a system to be resilient and adaptive is best achieved when the components of the ecosystem are present and functioning within acceptable limits (Woodley and Kay 1993; Parrish et al. 2003). EI is embedded in few protected area policy and legislative frameworks as an overarching conservation goal, including in Canada's national parks (Canada National Parks Act 2000). Crucial ethical and practical questions are emerging around how to interpret and manage for EI in the context of climate change. Questions include, for example, how to determine the state that we are managing towards and the role of historical condition in ecosystem resilience, including the role of Indigenous Peoples in maintaining biodiversity and ecosystem function through traditional land management practices, such as cultural burning (Kimmerer 2013). Although many methods have been developed to assess species and ecosystem vulnerability to climate change (Grimm et al. 2013; Pacifici et al. 2015), research, policy, and management frameworks are lacking to guide decisions on which species, ecosystems, and functions warrant priority attention, how long efforts to maintain current conditions should be continued, and which species are likely to require movement corridors or assisted migrations or to be displaced and replaced by other species (McLachlan et al. 2007; Bottrill et al. 2009; Hagerman and Satterfield 2014; Gilbert et al. 2020). In responding to predicted shifts in species' distributions and natural disturbance rates, we lack novel ways of managing for EI that focus on retaining complex trophic interactions and biophysical processes rather than current species assemblages (Scott and Lemieux 2005; Lemieux et al. 2011). Guidance is also lacking for restoration efforts that focus more on ecological function than species composition (Higgs et al. 2014). Developing ways to manage socio-political pressures could be necessary, as the public may harbour expectations that protected areas maintain historical conditions and species.

Translocation to and from protected and conserved areas

Translocation is "the deliberate movement of organisms from one site for release in another" (International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) 2013). While reintroductions and reinforcements within a species' historical range are the most common translocations (Swan et al. 2018; Lamothe and Drake 2019; Berger-Tal et al. 2020), assisted migration is gaining traction, as the deliberate movement of organisms to a location better suited for their survival (Peterson St-Laurent et al. 2019; Natural Resources Canada 2020; Pelai et al. 2021). The idea of moving a species beyond its historical range to keep pace with changing climatic conditions is increasingly being considered as an adaptation option (Lunt et al. 2013; Vitt et al. 2016; Wang et al. 2019). Such prospects raise several daunting challenges for protected areas, including problems associated with translocations (Batson et al. 2015) and with the uncertainty of managing translocations in a context of unexpected consequences (Dudney et al. 2018; Schuurman et al. 2020), especially where there is already a negative bias due to previous impacts from human-transported invasive species (Richardson et al. 2020). However, if the persistence of a species in a specific area becomes untenable due to climate change or other environmental stressors, the species' very survival may depend on protected and conserved areas practitioners facing and managing the risks (Littlefield et al. 2019). As such, future-oriented conservation and experimentation approaches such as assisted migration may play an ever more prominent role in protected and conserved areas management. Alternatively, protected and conserved areas managers may resist active intervention, which in itself could create a challenging dynamic at a landscape level.

Effects of changing snow patterns on protected and conserved area management

In cold climate regions, climate change will have dramatic effects on distribution, abundance, timing of accumulation and melt, rain-on-snow events, and other trends in snow patterns (Brown and Mote 2009), which will impact multiple ecosystem components (Studd et al. 2021). Uncertainty about snow dynamics and how they influence different ecosystem components makes it difficult for protected and conserved area managers to mitigate such changes. From a restoration context, for example, planting decisions (what species and where) will be influenced by changing snow conditions but will also influence albedo and, thus, require careful planning if plants are to be used to help alleviate the impacts of climate change (Espeland and Kettenring 2018). Melt–refreeze events will affect foraging conditions (Rickbeil et al. 2020) and migration routes for caribou as well as habitat for small wildlife that use snow as shelter and protection from predators (Studd et al. 2021). Snow is an important factor in natural hazards (Nadim et al. 2008) (e.g., avalanches, floods, droughts, landslides), which needs to be considered for understanding changes in disturbance regimes and ensuring visitor safety. Snow also acts as an insulating layer, affecting the permafrost active layer in Arctic and alpine environments, which when altered may lead to shrub-dominated landscapes (Domine et al. 2016). Snow dynamics could influence species ranges and therefore, by extension, the traditional way of life, health, and food security of Indigenous Peoples and rural communities (Pearce et al. 2015).

Effects of interplay between wildland fire and climate change

Management mechanisms for adapting and mitigating the emerging interplay between wildland fire and climate change are lacking but will demand significant attention of land managers and financial resources. At its nexus are dramatic shifts in ecosystem type due to large, frequent, and intense burns as a consequence of climate change, fire as an important ecological process, and its biocultural role. High fire prevalence has occurred in periods of warmer and drier climate (Walker and Pellatt 2008; Jackson et al. 2000) and, as we now enter the "Pyrocene" (Pyne 2019), fire is impacting protected areas and their management. Fire is a critical driver of ecosystem change and has long been part of biocultural systems, including Indigenous land stewardship (White et al. 2011; Pellatt and Gedalof 2014). However, recent increases in fires globally (e.g., 2018 Attica fires in Greece, 2019–2020 Black Summer in Australia) and in Canada (e.g., Fort McMurray in 2016), including in National Parks (e.g., 2016 Waterton Kenow Fire) highlight the imperative to understand and develop new approaches to wildfire management (Coogan et al. 2021). Ways of addressing the effects of more intense and frequent fires are especially required in ecotones that transition to different types such as grassland–parkland–forest or alpine–subalpine (Higuera and Abatzoglou 2021). Management practices, such as prescribed fire, may warrant particular caution in the context of intensified fire regimes to avoid pushing ecosystems past a disturbance threshold, resulting in unknown and potentially negative consequences (Sankey et al. 2008; Hobbs et al. 2009).

Indigenous governance and knowledge systems

Indigenous governance and protected and conserved areas

Indigenous Peoples and their governments are still often mistakenly considered "stakeholders" rather than "rights holders" in decision-making processes (ICE 2018; CRP 2019). They are "self-determining nations with inherent rights and governance systems that pre-date colonial structures" (Reo et al. 2017). Protected and conserved areas managers and planners lack expertise and experience to facilitate the co-development of new ways to advance governance models that respect and uphold Indigenous Peoples as rights holders. Existing "[A]boriginal, treaty and other rights and freedoms" are acknowledged and reaffirmed in the *Canadian Constitution Act* (1982) and jurisprudence indicates that Indigenous Peoples be recognized as decision-makers over their traditional territories. Canada has stated its intent to implement the Calls to Action of the Truth and Reconciliation Commission of Canada (2015c) and, in 2016, endorsed and committed to implement the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (UN 2007). However, this work is just beginning. In recent years, recognition of the importance and value of Indigenous-led conservation has gained ground in Canada (Artelle et al. 2019; Zurba et al. 2019). The ICE (2018) report, "We Rise Together", identifies Indigenous governance models as crucial to advancing Canada's conservation commitments as well as to upholding treaty rights and responsibilities. Advancing these governance models in ways that respect Indigenous rights and contribute to conservation is urgently needed and managers and planners will need to learn quickly how to apply concepts such as IPCAs, support for Indigenous Guardians programs, ethical space for Indigenous and non-Indigenous structures and perspectives (Ermine 2007), cultural keystone species and sacred places, and biocultural approaches to land stewardship, all while respecting Indigenous self-determination and leadership (ICE 2018; CRP 2019).

Indigenous knowledge systems and Western science

In Canada and elsewhere, there is growing attention to the urgent need to co-develop and co-adopt appropriate mechanisms for reaffirming Indigenous knowledge systems alongside Western systems within protected and conserved areas and in conservation planning across traditional Indigenous territories (ICE 2018; CRP 2019). Emerging issues surround the development and implementation of novel ways of respecting and upholding Indigenous knowledge systems that re-emphasize recommendations and act in ways consistent with the ICE (ICE 2018) and the spirit and intent of existing treaties. New approaches are needed that move beyond practices and systems that force Indigenous knowledge and ways of knowing into Western frameworks, to approaches that braid all knowledge systems within an ethical space. Canada's protected and conserved areas have developed within structures that prioritize Western science over Indigenous knowledge systems (ICE 2018; CRP 2019). This approach causes harm to Indigenous Peoples and nature (Artelle et al. 2019; Zurba et al. 2019). Indigenous knowledge systems are carried by languages and stories, and are tightly linked to traditional territories (Reid et al. 2021). Although diverse, they share commonalities that are often universal or nearly so in terms of natural laws and reciprocal relationships and responsibilities among all beings and ecologies (Battiste 1997; Henderson 2000). Insights revealed through immersion in the land, community, and deep reflection are shared through stories, ceremony, guiding principles, and lived practice across generations (Young 2016; *M'sɨt No'kmaq* et al. 2021). In Canada, ICE (2018) has provided recommendations that are reflective of Indigenous knowledge systems (e.g., IPCAs, Guardian programs, Two-Eyed Seeing, cultural keystone species, ethical space, languages of the land) and the imperative now is to develop ways to implement them within protected and conserved areas planning and management (CRP 2019).

Integrated conservation approaches across landscapes and seascapes

Integration of protected areas into a wider suite of conservation instruments across terrestrial, freshwater, and marine ecosystems

There is emerging awareness of the lack of effective instruments for retaining and restoring biodiversity and ecosystem services that are applicable beyond protected and conserved areas. While there has been much conceptual development around ways to systematically design and prioritize ecological networks for zones of conservation and protection, effective methods to apply and establish systematic design and prioritization are lacking across broad regions (Woodley et al. 2019a, 2019b;

Hilty et al. 2020). On-the-ground provisions for protecting and restoring connectivity and increasing the capacity for adaption and resilience to climate change remain a challenge (Stralberg et al. 2020a, 2020b; Williams et al. 2020; Carrasco et al. 2021). Complementary approaches to conserve ecosystems outside of protected areas, such as through nature-inclusive agriculture, ecological forestry, and provisions in environmental assessments and infrastructure development proposals, are lacking at the scale required (Landis 2017; Kremen and Merenlender 2018; Wanger et al. 2020). Effective means of moving toward integration of coherent policies and mainstreaming of conservation across sectors and within levels of government have remained largely unexplored until recently and have not been institutionalized (CBD/COP/DEC/XIII/3 2016; Ray et al. 2021; Simmonds et al. 2021; but see Greening Government Strategy (Government of Canada 2020a, 2020b, 2020c)).

Enhancement of ecological connectivity within aquatic systems

While a growing body of research seeks to understand the combined impacts of climate change and other anthropogenic impacts on ecological connectivity within terrestrial ecosystems in Canada, comparable impacts to aquatic ecosystems remain relatively understudied (e.g., Jones et al. 2019). What were once permanent ponds may now be ephemeral, and what were once ephemeral freshwater bodies are now under accelerated threat from climate change and other human impacts (Smol and Douglas 2007; Acuña et al. 2014). Ecological connectivity is a fundamental requirement of protected and conserved areas (CMS 2020; Hilty et al. 2020) and, yet, human activity has altered the connectivity of aquatic ecosystems, directly through the installation of physical barriers (e.g., roads, converted lands, hanging culverts, and dams) and indirectly through anthropogenic climate changes, such as to hydrology, thermal barriers, and freshwater quality (Ficke et al. 2007; D'Aloia et al. 2019). Connectivity between aquatic and terrestrial ecosystems is also vital to ecological integrity yet, in many instances, these elements are managed as separate units (Tabor et al. 2019) despite their long-known interdependencies (Hynes 1975). An understanding of the role that climate change plays in affecting the ecological connectivity of both terrestrial and aquatic ecosystems is also critical to future efforts to effectively restore, enhance, and maintain overall connectivity in and among protected and conserved areas in Canada.

Mechanisms for integrating and balancing ecosystem values and services

Increasingly, terrestrial and aquatic managers and governments are expected to establish mechanisms to protect, preserve, and maintain a broad suite of ecosystem services (Mitchell et al. 2021). This expectation has become more pronounced with recognition of the role of protected and conserved areas as a potential natural climate solution (e.g., to reduce greenhouse gas emissions by sequestering and storing carbon). While synergistic approaches to ecosystem services and biodiversity conservation are possible, consideration of each category illuminates trade-offs (Cimon-Morin et al. 2013, 2014; Buchmann-Duck and Beazley 2020). The *2050 Vision for Biodiversity, Approaches to Living in Harmony with Nature and Preparation for the Post-2020 Global Biodiversity Framework* is clear that Parties should increase efforts to conserve, restore, and safeguard areas that deliver benefits essential for all people (UNEP-CBD 2018b). Looking to the future, we will need to systematically assess ecosystem services to aid in the identification of new protected and conserved areas and subsequent management in ways that maximize synergies. To do so effectively, we will need to have the necessary tools and resources in place to inform effective decision making related to the relative prioritization of services (Cimon-Morin et al. 2014; Mitchell et al. 2021), potential trade-offs between services and biodiversity conservation (O'Connell et al. 2018; IPBES 2020), and how services may change over time and space, including in response to a changing climate (Bastian et al. 2012; Qiu et al. 2018).

Integration of freshwater in planning for terrestrial protected and conserved areas

Explicit consideration and incorporation of freshwater biodiversity is lacking in protected and conserved area planning (Tickner et al. 2020). Freshwater biodiversity is among the most imperiled globally (Su et al. 2021), and yet most protected and conserved areas were not designed with freshwater biodiversity in mind (Mandrak and Brodribb 2006). Terrestrial ecosystem classification systems are often used to inform selection and design of systems of protected and conserved areas (Vold and Buffett 2008; Parks Canada 2021; Robertson et al. n.d.), but the development of classification systems for freshwater ecosystems lags well behind that of terrestrial ecosystems. Furthermore, the greatest threats to freshwater biodiversity are generally found in southern Canada (Chu et al. 2015), where protected and conserved areas are typically fewer, smaller, and more challenging to establish or expand due to extensive and intensive human land use (Deguise and Kerr 2006). Protected and conserved areas that are designed with a focus on terrestrial species do not tend to adequately capture freshwater systems; designs that integrate the needs of freshwater species can dramatically enhance freshwater conservation without compromising terrestrial outcomes (Leal et al. 2020). Development and implementation of novel approaches are crucial to integrative freshwater conservation.

Early responses to emerging cumulative, underestimated, and novel threats

Management of cumulative impacts from multiple environmental stressors

There is growing appreciation that effective management of protected and conserved areas requires an understanding of the net ecological effects of the various human-induced and natural-disturbance stressors (e.g., Allan et al. 2017; Mach et al. 2017; Schulze et al. 2018). Major knowledge gaps—that would enable a predictive understanding of these stressor interactions—remain. To this point, Côté et al. (2016) examined the importance of assessing multiple stressors and emphasized that limitations and uncertainties still face decision-makers. There is a need for approaches that move beyond using knowledge of a species response to a single stressor, but account for multiple stressors exerting synergistic, antagonistic, or additive net effects on protected and conserved area species, communities, and ecosystems (Côté et al. 2016; Smith et al. 2019; and see Srivastava et al. 2021). Examples of emerging approaches include a framework for assessing scientific activities by considering appropriateness, ecological impacts, cumulative impacts, and comparison to thresholds (Saarman et al. 2018) and an evaluation of stressor interactions across the Great Lakes by the International Joint Commission (2020).

Declining insect biomass and biodiversity

Globally, precipitous declines are now observed for many terrestrial insect species, although uncertainty remains as to whether declines also extend to aquatic insects (Sánchez-Bayo and Wyckhuys 2019; Van Klink et al. 2020; Wagner et al. 2021). Insects are fundamental to ecosystem functioning, providing crucial ecosystem services (Cardoso et al. 2020). In Canada, trends in insect declines are poorly understood for most taxa (Kharouba et al. 2019; Savage et al. 2019; but see Forister et al. 2019 and Soroye et al. 2020), and knowledge gaps are greater in remote areas (i.e., the majority of Canada) (García-Robledo et al. 2020). Models and mechanisms for implementing targeted insect conservation measures have been proposed, such as improving landscape heterogeneity, reducing pesticides and light pollution, and enhancing public awareness (Forister et al. 2019; Harvey et al. 2020). Yet, identification of priority target areas for strategic implementation is hindered by existing knowledge gaps in species presence and taxonomic-specific factors affecting declines in Canada. Recent advances in insect monitoring techniques, such as environmental DNA (eDNA; Carraro et al. 2020), computer vision and deep learning (Høye et al. 2021), bioacoustics (Jeliazkov et al. 2016), satellite remote sensing (Kirkeby et al. 2016; Wotton et al. 2019), and citizen science

(Soroye et al. 2020) are promising and warrant consideration. Coordinated mechanisms are lacking for implementing such advances in ways that enable cost-effective and large-scale management responses (Didham et al. 2020) that address declining insect biodiversity and biomass within protected and conserved areas.

Effects of increasing anthropogenic noise on aquatic ecosystems

The negative effects of increasing anthropogenic noise on terrestrial species is well documented Pijanowski et al. 2011), including in protected areas (Buxton et al. 2017). However, a similar understanding of increasing anthropogenic noise in aquatic systems is emerging, with a current heightened focus on marine (Duarte et al. 2021) rather than freshwater ecosystems (Proulx et al. 2019). Effects of increased anthropogenic noise vary with the species, its acoustic properties, and the ecosystem (e.g., marine, coastal, river, lake). While marine studies have concentrated on mammals and a limited number of invertebrates and fishes, freshwater studies to date have focused solely on fishes. Impacts are both behavioural and physiological (Mickle and Higgs 2018; Duarte et al. 2021; Hughes et al. 2021). Common sources of aquatic anthropogenic noise are boats (ranging from ocean liners to personal watercraft), resource development, energy and seismic surveys, roads, and other infrastructure (e.g., marine oil platforms, windfarms, and freshwater hydroelectricity installations) (Proulx et al. 2019; Duarte et al. 2021). Climate-induced changes to aquatic soundscapes include increased frequency and intensity of storms, increased iceberg calving, thinning of permanent ice cover, ocean acidification (due to decreasing sound absorption in more acidic environments), and changes in seasonality of glacial melt and freeze–thaw cycles. Marine and freshwater protected and conserved areas that explicitly exclude anthropogenic noise could provide refuge for some species. Essential to reducing impacts are an understanding of the extent to which aquatic species habituate to increased anthropogenic noise; landscape, population, and ecosystem impacts; and effects on an expanded suite of taxa (Kunc et al. 2016; Duarte et al. 2021).

Risks and benefits of synthetic biology for conservation and restoration

Synthetic biology that manipulates genetic material of living organisms (UN CBD 2017; Redford et al. 2019) holds both promise and peril for conservation and restoration. Two endangered species have been cloned recently (Associated Press 2021) and CRISPR (clustered regularly interspaced short palindromic repeats) technology can splice new sequences of DNA into a genome to knock out, repair, add, or activate specific genes. Engineered gene drives copy those changes onto the sister chromosome to ensure their subsequent inheritance to, for example, control malaria by rendering female mosquitoes infertile. Similar tools could potentially be used to eradicate invasive species (e.g., rodents on seabird islands; Browett et al. 2020), create disease resistance in threatened species (e.g., against blight of American chestnut, *Castanea dentata*; Steiner et al. 2017), and pre-adapt populations to anthropogenic climate change (e.g., increase temperature tolerance of corals; Chakravarti et al. 2020). To date, no gene drives have been released in the wild, partly because practical and ethical questions remain (Sandler 2019; Scudellari 2019). Uncertainty about potential for negative and unintended effects of introducing living manipulated organisms was the impetus for the 2003 Cartagena Protocol, which aims to reduce risk from such organisms. Canada is not a signatory to this protocol, choosing instead to evaluate such actions independently on a case-by-case basis (Government of Canada 2020b). The associated ethical, economic, and ecological questions will intensify with rapid and ongoing technological development for engineering genetic materials, organisms, and living systems.

Discussion and conclusions

Area-based conservation measures, including protected and conserved areas, provide habitat and resources for biodiversity, contribute to ecosystem services and nature-based solutions to climate change, and support visitor experiences that include education and interpretation. To fulfill these diverse roles, protected and conserved areas should be planned, governed, and managed for current and future conditions. Given the generally reactive nature of protected and conserved area planning and management, this horizon scan provides an overarching structure for emerging issues that are expected to increase in prominence for protected and conserved areas practitioners over the coming decade. Four key themes comprising fifteen issues were identified that reflect the unique and multifaceted challenges of protected and conserved areas and their context in broader landscapes and seascapes.

This horizon scan identifies issues that predominantly diverge from Sutherland et al.'s (2021) global biological conservation horizon scan. Two issues (fire risk and carbon sequestration solutions) were similar across the two scans. While the global scan specifically identified increased logging and tree planting as potential responses to those issues, respectively (Sutherland et al. 2021), our scan identified changing fire regimes as a broad issue, carbon sequestration as part of nature-based climate solutions and ecosystem services, and tree planting under the umbrella of restoration and resilience in response to climate change. In each instance of overlap, the reframing of issues likely relates to current media exposure (e.g., Natural Resources Canada 2021) and the specific context of protected and conserved area management. One apparent difference is that our scan demonstrated a predominant focus on terrestrial and freshwater issues, whereas the global scan explicitly identified three marine and two coastal issues to comprise a third of its total. The lack of explicit reference to solely marine-focused issues in our scan may be explained by the extent of freshwater systems in Canada, as well as a stated intent to encompass all realms as integrated systems and to consider issues as pertaining to and having implications across terrestrial, marine, and freshwater systems.

Recent Canada-specific scans identified key information needs for moving from knowledge to action (Buxton et al. 2021). Rather than a focus on protected and conserved areas, Buxton et al. (2021) addressed broad targets within the CBD, prioritizing those most important to transformative change to conserve biodiversity in the future. Despite this difference in focus, both emphasize the necessity of respecting Indigenous rights, governance, and knowledge systems, with approaches grounded in ethical space and processes for reaffirming and advancing Indigenous knowledge systems alongside Western systems (Ermine 2007; ICE 2018; NAP 2018; CRP 2019). Additionally, both scans identified the following needs: anticipate species and ecosystem responses to climate change, integrate ecological requirements into the larger landscape, foster co-beneficial practices that promote biodiversity across sectors (e.g., agriculture, forestry, fishery, etc.), integrate biodiversity conservation and ecosystem services, support transformative change through the inclusion of varied perspectives, and valuation of and approaches to biodiversity and ecosystems services. All these issues relate to synergies and trade-offs between planning and management for Canada's biodiversity within protected and conserved areas.

An earlier Canadian scan, developed to inform conservation policy and management in Canada, accorded 10 of 40 issues to protected areas (Rudd et al. 2011). Although scans emphasize emerging issues, there is sustained acknowledgement of issues relevant to protected and conserved areas in conservation (e.g., ecosystem services, invasive species, disease vectors, Traditional Knowledge in conservation) (see Rudd et al. 2011). The emerging priority of Indigenous governance and knowledge systems has gained prominence in the current horizon scan. As well, several previously identified issues (emphasis on resource extraction, design and connectivity, species and populations) (Rudd et al. 2011) can be seen as "wicked problems" (Churchman 1967; Rittel and Webber 1973), which are "incomprehensible and resistant to solution" (Head and Alford 2015). These include cumulative effects, integration across habitats and ecosystems, and the underlying emphasis on responding to rapid biodiversity loss. On balance, questions of how to conserve species and ecosystems have evolved over the past decade, from identifying issues to implementing effective conservation measures. Climate-related questions have transitioned to emergent issues for addressing the twin crises of precipitous biodiversity declines and climate change. Emerging issues related to conserving ecosystem services and freshwater systems remain, and there is a new imperative to centrally include Indigenous governance and knowledge systems in guiding protected and conserved area planning and management.

This horizon scan did not identify issues directly related to COVID-19 within the top 15, nor did Sutherland et al.'s (2021) global scan. Although COVID-19 was explicitly mentioned in one of the originally submitted issues, and diseases in general were mentioned in another, neither was retained beyond the selection of the top 77 issues. In some protected areas in Canada, domestic visitation rates have increased during COVID-19 with potential management implications (Geng et al. 2021). Fundamental or causal issues could also pertain to the role of biological conservation and protected areas in preventing or minimizing future zoonotic disease pandemics (IPBES 2019; Plowright et al. 2021). As human land uses encroach upon protected and conserved areas, instances of pathogen spillover are likely to increase and there is greater urgency to reduce risk of spread from reservoir hosts (Plowright et al. 2021). Unless such incursions are slowed and reversed, new zoonoses are inevitable, with potentially serious repercussions for humans and wildlife (Plowright et al. 2021; Mitchell et al. 2021). Certainly, the COVID-19 pandemic and associated societal responses demonstrate how quickly new situations may dominate global circumstances (Sutherland et al. 2021), and how quickly we can respond to existential and transboundary threats (Editorial 2021; Plowright et al. 2021). As such, the authors recognize that any scan is, at best, an incomplete viewfinder to the future.

As with other scans, this horizon scan has limitations. While efforts were made to minimize possible bias and variation, we recognize that these efforts did not eliminate them. Areas where limitations may be apparent include representation of Indigenous views and perspectives, variability of interpretation by experts, and the necessity of conducting the workshop in a virtual environment. To reduce participation bias, participants were sought from a variety of disciplines and fields and via both an expert network and crowdsourcing. Participants represented a diverse group, with equal numbers of issues submitted by academic researchers and government staff, followed by ENGOs and Indigenous participants. The expert group was multidisciplinary, with similar proportions of individuals from government, academia and ENGOs, and representing disciplines in both natural and social sciences, with most participants having broad interdisciplinary expertise. As such, the perspectives represented in the issue selection and description are numerous and well balanced, except Indigenous engagement; few contributed to our broader community process, with their submissions (2) comprising only 1% of the total. Nevertheless, the emerging issues that explicitly and directly address Indigenous rights, governance, and knowledge systems are consistent with recommendations arising from protection and conservation initiatives with Indigenous partners (ICE 2018; CRP 2019). Ongoing ethical engagement and formal consultation with Indigenous Peoples in Canada is crucial and warrants significant time and attention to do so properly.

Efforts were made to provide standardized definitions and clear instructions (**Supplemental Material 3**) to limit bias and variable interpretation. However, certain factors could not be adequately addressed, including: variability in the interpretation of issues and definitions, presentation effects, incomplete awareness of relevant literature by expert evaluators (Sutherland et al. 2020), and recruitment bias whereby experts disproportionately reach out to others with similar occupations and shared disciplinary histories (e.g., see Provencher et al. 2020). Distinguishing between current and emerging issues is challenging and may partially depend on the specific expertise and work focus. As such, the results of this scan reflect the perspectives and experiences of participants. However, the inclusion of a broad cross-section of experts, and a methodology including opportunities to discuss issues in breakout sessions, will have lessened any particular direction for bias. Despite the articulated limitations, this scan has value as a form of inclusive, strategic foresight with particular importance for conservation applications (Cooke et al. 2020; Provencher et al. 2020; Sutherland et al. 2020).

Our horizon-scanning process, consistent with others (e.g., Rudd et al. 2011; Buxton et al. 2021; Sutherland et al. 2021), has produced two primary benefits. First, it has brought together a diverse range of knowledge holders at a national level to debate and define issues of the future that are likely highly consequential for ecosystems, policy, and human engagement. The process has established a baseline of values for Canadian scientists, managers, and policy makers. Ideally, identification of the emergent issues will help to focus discussions about where to direct research and management resources in the future. Second, through its approach, this scan has prepared the ground for responding not only to the issues identified, but also other disruptive and unexpected developments, such as the current global pandemic. It has done so by providing an impetus for concerted and coordinated efforts to develop research, tools, strategies, and frameworks that better support management of problems anticipated to affect the function, health, and viability of protected and conserved areas in Canada, while also enhancing the capacity to respond to other, future unanticipated challenges.

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Author contributions

SD conceived and designed the study. All authors performed the experiments/collected the data. SD analyzed and interpreted the data. SD and KFB served as lead authors and editors. SD, KFB, CJL, CS, LC, EH, RS, and MP drafted or revised the manuscript. All authors contributed to issue submissions, drafts, and revisions and provided review and editorial refinements to the manuscript.

Competing interests

Two co-authors are members of the editorial board (S. Cooke and J. Smol).

Data availability statement

All relevant data are within the paper and in the Supplementary Material.

Supplementary materials

The following Supplementary Material is available with the article through the journal website at doi:10.1139/facets-2021-0072.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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