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A climate-resilient marine conservation network for Canada

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Abstract

Climate change and biodiversity loss are twin crises that are driving global marine conservation efforts. However, if unaccounted for, climate change can undermine the efficacy of such efforts. Despite this, integration of climate change adaptation and resilience into spatial marine conservation and management has been limited in Canada and elsewhere. With climate change impacts becoming increasingly severe, now is the time to anticipate and reduce impacts wherever possible. We provide five recommendations for an inclusive, proactive, climate-ready approach for Canada's growing marine conservation network: (1) integrating climate-resilience as a universal objective of the Canadian Marine Conservation Network, creating and implementing (2) national transdisciplinary working groups with representation from all knowledge holders and (3) necessary tools that integrate climate change into conservation design, (4) defining operational and climate-relevant monitoring and management objectives, and (5) strengthening communication and increasing knowledge exchange around the roles and benefits of protected areas within government and towards the public. Canada's extensive marine and coastal areas reflect national and international responsibility to engage on this issue. Canada is well positioned to assume a leading role in climate change adaptation for marine conservation and help accelerate progress towards international commitments around mitigating ongoing biodiversity loss and climate change.

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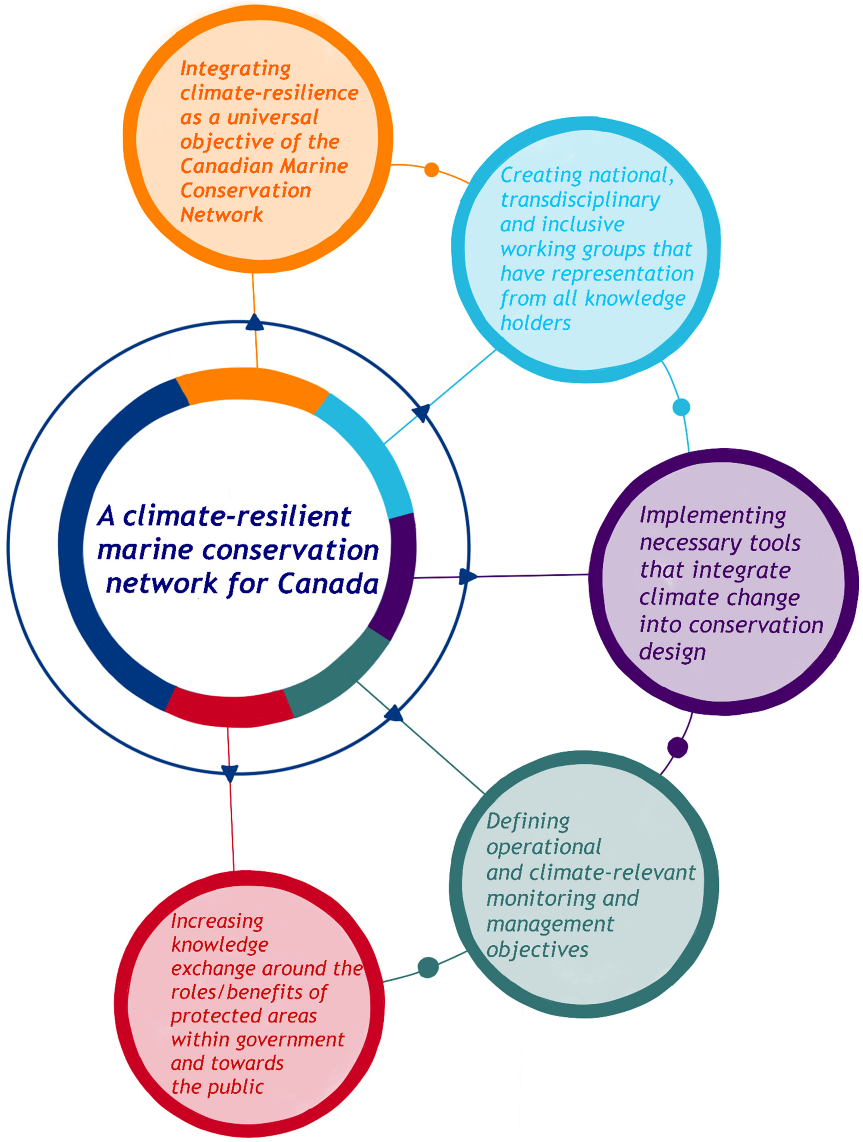


Key words: climate change resilience, climate change adaptation, marine spatial management, marine protected areas, marine conservation network, Canada

Introduction

Climate change is one of the most significant threats to global ecosystems and is a major driver of biodiversity loss (IPCC 2018). Documented climate change impacts on biodiversity include range expansions or contractions (Morley et al. 2018), changes in depth distributions (Dulvy et al. 2008), species compositions (e.g., García Molinos et al. 2016), species interactions (e.g., Grady et al. 2019), trophic efficiency (Barneche et al. 2021), and shifting phenology (e.g., Wilson et al. 2016), all of which can impact ecosystem function (Lotze et al. 2019; Pontavice et al. 2020).

Marine Protected Areas (MPAs) and Other Effective area-based Conservation Measures (OECMs) are key components of the global approach to counter biodiversity loss, promote sustainable fisheries, and support the sustainable management of marine ecosystems. These spatial management tools as well as any additional types of area-based conservation or wildlife reserves and sanctuaries are here collectively referred to as marine conservation areas (see also **Table 1**). The rapid growth of MPAs globally (~7.66% of global ocean area in 2021; UNEP-WCMC and IUCN 2021) over the past decade has occurred at the same time as the scientific community started to emphasize current and future challenges of climate change for marine ecosystem protection (Hoegh-Guldberg 2010; Tittensor et al. 2019; Wilson et al. 2020). However, such perspectives have not yet been well integrated into protected area design and management despite climate change being recognized as a key threat to the ability of protected areas to achieve their biodiversity objectives (Limieux and Scott, 2005; Bruno et al. 2018; Schram et al. 2019; Tittensor et al. 2019; O'Regan et al. 2021). Given the primarily static nature of protected areas and the dynamic responses of marine ecosystems to climate change, calls have been growing to consider climate change as a key component in marine conservation planning (D'Aloia et al. 2019; Tittensor et al. 2019) and more broadly into Marine Spatial Planning (MSP) initiatives seeking to find a balance between ocean use and conservation (e.g., Santos et al. 2018; Gissi et al., 2019).

Planning for and instituting scientifically rigorous, multi-governed, regional ocean conservation networks could support adaptation and resilience to the changing climate (Friesen et al. 2021b). This would also increase the effectiveness of such networks for biodiversity protection and the conservation of migratory species, such as marine mammals, that may use and move among protected areas (Lascelles et al. 2014). Furthermore, incorporating "blue carbon" capture of vegetated coastal habitats and marine sediments into protected area design and management, emphasizing improved conservation and potential restoration of seagrass meadows, tidal marshes, and sediment areas, contributes towards carbon sequestration and climate change mitigation (IUCN 2017; Lovelock and Duarte, 2019; Atwood et al. 2020; Northrop et al. 2020; CEC 2021; Murphy et al. 2021). If implemented correctly, protected areas can be an effective approach for achieving multiple benefits including preserving biodiversity, securing ocean carbon stocks, and enhancing fisheries productivity (Sala et al. 2021).

Climate change and the Canadian marine conservation framework

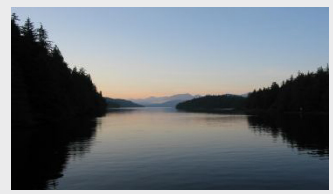
The need to implement and prioritize nature-based solutions to climate change is particularly urgent in Canada. Canada's Aquatic Climate Change Adaptation Services Program reported a high probability of significant climate change impacts in all of Canada's marine and freshwater basins across much of the Canadian exclusive economic zone (EEZ), with the largest impacts anticipated in the Arctic (DFO 2012; Niemi et al. 2019). Indeed, these rapid changes are creating many challenges for the Indigenous Peoples of Inuit Nunangat, the Inuit homeland (reviewed in Huntington et al. 2021), which encompasses 35% of the landmass and 50% of the coastline of what is now known as Canada (Inuit Tapiriit Kanatami 2021). Using an approach that draws upon science and Indigenous knowledge, Canada has committed to protecting 25% of its ocean in a conservation network by 2025 and is working towards 30% by 2030, an ambitious target that will require to more than double the area protected under some form of biodiversity conservation measure within 10 years (DFO 2021a). Currently, the Canadian Marine Conservation Network includes more than 800 individual

Table 1. Types and objectives of Canadian ocean conservation measures and the instituting governing body/department.

Type of spatial conservation tool	Governing body/ department	Overarching objective	Example
Oceans Act MPAs	Fisheries and Oceans Canada	Protects an area of the sea that forms part of the internal waters, the territorial sea or EEZ of Canada *Oceans Act*. Established to conserve marine species and their habitats, including species that are fished, endangered, or threatened marine species, as well as unique habitats and areas of high biological productivity or biodiversity (ECCC 2020).	The Gully Marine Protected Area  Image by Whitehead Lab (CC BY-SA 4.0)
National park	Parks Canada Agency	"To protect for all time representative natural areas of Canadian significance [. . .] and to encourage public understanding, appreciation, and enjoyment of this natural heritage so as to leave it unimpaired for future generations" Parks Canada (2017).	Pacific Rim National Park Reserve  Image by Roy Luck (CC-BY-2.0)
National marine conservation area	Parks Canada Agency	Protecting representative examples of natural and cultural heritage.	Saguenay–St. Lawrence Marine Park  Image by Pierre André (CC BY-SA 4.0)
National wildlife area	Environment and Climate Change Canada	Protecting major marine and nearshore areas for wildlife, research, conservation, and public education.	Polar Bear Pass National Wildlife Area  Image by Paul Gierszewski (CC BY-SA 4.0)
Migratory bird sanctuary	Environment and Climate Change Canada	Protecting major marine and nearshore areas for wildlife, research, conservation and public education.	George C. Reifel Migratory Bird Sanctuary  Image by D. Gordon E. Robertson (CC BY-SA 3.0)

(continued)

Table 1. (*concluded*)

Type of spatial conservation tool	Governing body/ department	Overarching objective	Example
Other effective area-based conservation measure OECMs/ Marine refuges	Fisheries and Oceans Canada	Protect important species and their habitats from fishing. Provide biodiversity conservation benefits in the long-term. OECM sites are established under the *Fisheries Act*.	Corsair and Georges Canyons Conservation Area  Image by Anna Metaxas (used with permission)
Provincial marine conserved areas	Provincial Governments	Different provinces conserve areas under different regulations e.g., transportation, fishing, recreation. Marine conservation efforts include support for the recovery of species at risk, prevention, and mitigation of the impact of aquatic invasive species and strengthening of Canada's response to ship-source marine pollution ECCC (2020).	Flores Island British Columbia  Image by djmonkeyboy (CC BY-SA 2.0)

Note: Adapted from Government of Canada (2020). MPA, marine protected area; EEZ, exclusive economic zone.

sites encompassing about 13.81% of the Canadian EEZ, or 793,096 km^2 of ocean area under some form of biodiversity protection (Fig. 1).

This marine network is established and administered by a broad range of federal, provincial, Indigenous, and territorial bodies. At the federal level, these include MPAs established by Fisheries and Oceans Canada under the *Oceans Act*, national park reserves and national marine conservation areas established by Parks Canada, national wildlife areas and migratory bird sanctuaries established by Environment and Climate Change Canada, and OECMs (e.g., marine refuges established and defined by Fisheries and Oceans Canada; Schram et al. 2019; DFO 2020). These also build on successes supporting Indigenous Protected and Conserved Areas on land, waters, and ice and include protected areas in Canada's Arctic, which are co-managed with Inuit and the Government of Canada (Government of Canada 2021a). It also includes Anguniaqvia niqiqyuam MPA, the first in Canada to have a Conservation Objective based solely on Traditional and Local Knowledge (DFO 2019). This network also includes the Northern Shelf Bioregion network of MPAs on Canada's Pacific coast, which involves 17 First Nations co-leading the establishment process with the Government of Canada and Province of British Columbia (Ban and Frid 2018). Collectively, these protected spaces represent, by area, ~99% of the conservation network (Fig. 1; Table 1). Provinces and territories can establish additional protected ocean areas using regulatory tools that provide biodiversity conservation benefits (Schram et al. 2019). For example, the Saguenay–St. Lawrence Marine Park was jointly set up as a national marine park by the province of Quebec and Parks Canada to preserve the unique ecosystem of the Saguenay Fjord. As well, momentum is building toward Indigenous-led marine conservation for new protected areas (Arctic Council 2019). For example, an initial step toward an Indigenous-led National Marine Conservation Area was recently taken by the Muchkegowuk Council and Parks Canada to protect Indigenous homelands in western James Bay and southwestern Hudson Bay region (Parks Canada 2021). While these represent important advances that support

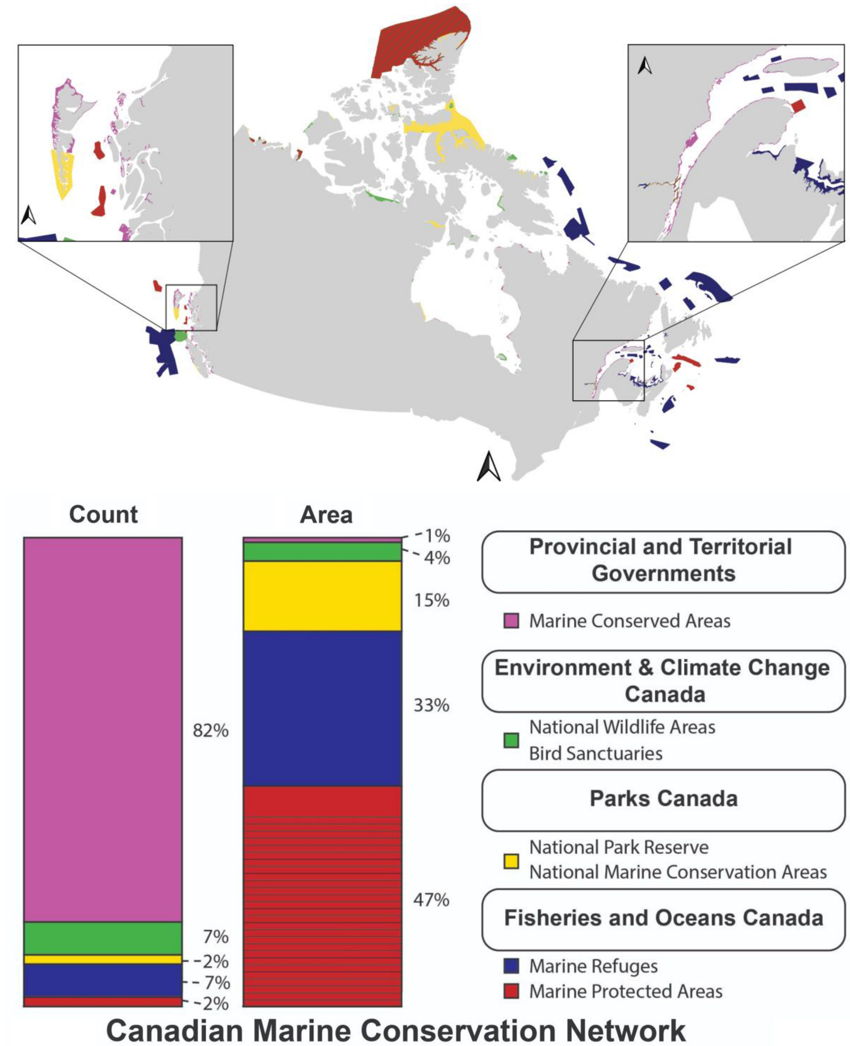


Fig. 1. Geographic and proportional distribution by area of spatial marine conservation measures in Canada aggregated by type and regulatory organization. Percentages calculated as the proportion of the total network area, which itself comprises ~ 13.81% of the Canadian EEZ 5,750,000 km^2 as of July 2021. Fill colours correspond to the regulatory organization and are consistent within the figure based on marine conservation areas managed by federal or provincial bodies listed within the Canadian Protected and Conserved Area Database bit.ly/2UHjdNd. Fill colours with hash marks relate to areas that are co-managed or are managed under a collaborative governance framework.

Indigenous leadership in marine protection, they also only touch on restoring relationships and developing the nation-to-nation co-governance arrangements needed to recognize and incorporate Indigenous rights in marine spatial planning and to support reconciliation efforts (Ban and Frid 2018; Zurba et al. 2019).

While Canada has ratified the Paris agreement and is committed to addressing climate change nationally, a recent study by O'Regan et al. (2021) found that Canada lags in comparison to other countries' incorporation of climate change into MPA management plans (Canada mean score 6.8; global average 10.9). Climate change was explicitly considered in 26% of Canada's MPA plans, while

57% of MPA plans in the United States and 55% of MPA plans in Oceania included climate change considerations (O'Regan et al. 2021). While MPAs established under the *Oceans Act* are just one type of spatial conservation measure, they encompass nearly half of the Canadian Marine Conservation Network by area (**Table 1**; **Fig. 1**). This makes the lack of climate change integration a significant issue for MPA management and highlights the need for a multidisciplinary pragmatic approach. This approach ideally integrates climate-smart management across all area-based conservation measures, which collectively comprise 53% of the Canadian Marine Conservation Network by area and ~ 98% of all individual closures by number (**Fig. 1**). While the Canadian MPA National Framework (henceforth referred to as National Framework) references climate change, it does not yet explicitly address how climate change will affect and possibly compromise biodiversity objectives of Canada's Marine Conservation Network (Government of Canada 2011). Moreover, the National Framework does not provide any measurable benchmarks for the successful integration of climate change focused objectives into conservation planning. Given the accelerating impacts of climate change and the rapid expansion of marine conservation measures in Canada, it is timely to further the goal of incorporating climate change into the protected area framework—a necessity to ensure that Canadian marine conservation is effective and simultaneously considers the challenges of biodiversity loss and climate change across all types of conservation measures.

Climate change adaptation needs to be explicitly embedded into Canada's biodiversity conservation policy, management, and protection targets (Hutchings et al. 2020). Because overexploitation by fisheries represents one of the most widespread threats to marine biodiversity (e.g., Coleman and Williams 2002), it is vital that any climate-change focussed conservation measure should be integrated with climate and ecosystem-based approaches to fisheries management (Bryndum-Buchholz et al. 2020). MPA networks are part of broader marine spatial planning, and any spatial shifts of populations will need to be considered in this wider context, especially as stocks of commercial interest or culturally important species move in and out of protected areas (Bryndum-Buchholz et al. 2021), to avoid fisheries conflicts and ensure continued effective protection (Mendenhall et al. 2020).While the process of integration of climate change goals into conservation has been explored and recommendations developed at the international level (e.g., Tittensor et al. 2019), there remains no specific guidance for adoption within Canada. Here we address this gap by discussing how to operationalize climate change adaptation in a Canadian context and provide five practical recommendations for building a climate-resilient marine conservation framework. Though the governing bodies and policies examined here are specific to this national context, the core principles are designed to be broadly transferable across scales and can help guide other national climate-resilient marine conservation networks.

In February 2021, a national workshop was held, led by the Fisheries and Oceans Canada Marine Conservation Targets Program and the Ocean Frontier Institute Future-proofing MPA Networks Module (bit.ly/3zgqXV8), to discuss the integration of climate change into the design, monitoring, and management of the Canadian Marine Conservation Network. This workshop included conservation research and marine governance professionals from across Canada. The authors of this manuscript represent the workshop steering committee and have taken into account insights gathered from all workshop participants and recent literature to develop core recommendations for a climate-adaptive marine conservation framework in Canada.

Recommendations

Climate change adaptation and mitigation as universal objectives in Canada's National marine conservation framework

The primary objective of the Canadian Marine Conservation Network, as first outlined in the National Framework of Canada's MPA Network (Government of Canada 2011), is to protect marine biodiversity, with secondary goals to preserve marine socio-economic and ecosystem services (e.g., cultural value, resilience to change, food-provision, tourism/recreation, carbon sequestration), as well as to enhance Canadians' cultural appreciation of the ocean. Climate change will impact the ability to achieve these goals and may compromise the effectiveness of some marine conservation measures (Tittensor et al. 2019).

The addition of an overarching climate change objective will be a key first step to bring climate change more directly into the development of a Canadian marine conservation network, in particular the Canadian network's development towards its 30% by 2030 target (growth of ~16% of the EEZ or 930,925 km^2 at the time of writing). This objective would recognize the pervasive nature of climate change, and that MPAs, and other conservation areas, can be a key component of Canada's climate change strategy. MPAs and other marine conservation areas are an important component tool for climate change adaptation and mitigation (Tittensor et al. 2019; Wilson et al. 2020). Here, we define "climate change adaptation" as actions that lead to increased resilience and reduced vulnerability of ecosystems and people to climate change (e.g., Campbell et al. 2009), and "climate change mitigation" as an intervention or process that results in reduced emissions, enhanced sequestration of greenhouse gases, or increased ecosystem resilience to the impacts of climate change (IPCC 2018). In the context of marine biodiversity conservation, climate change adaptation and mitigation can be complimentary, for example, protecting coastal marine vegetation to adapt to sea level rise can also act mitigative as marine vegetation acts as an important carbon sink.

Spatial coverage targets that integrate and span across a spectrum of vulnerability to climate change would ensure a range of possible ecosystem responses and adaptations. In addition, integrating climate change into management plans that explicitly consider risks of not fulfilling management objectives under climate change, and prioritizing habitats associated with carbon sequestration (i.e., coastal ecosystems, marine sediments) represent pragmatic approaches for climate adaptation and mitigation in marine conservation that can be associated with measurable targets. A revised, overarching objective for the National Framework will promote the establishment of climate-resilience targets for individual MPAs and the network as a whole, helping to ensure that climate change adaptation and mitigation are prioritized.

Recommendation 1: Revise the primary objective of the Canadian Marine Conservation Network in the National Framework to read "protect marine biodiversity, including ensuring effective protection under climate change".

- Recognize that MPAs can act as a proactive component of a climate change adaptation and impact mitigation strategy.
- Amend the *Oceans Act* to explicitly consider climate change impacts on marine ecosystems and species in regional ocean management with measurable progress indicators tied to management objectives.

Mandate Canadian climate and ocean resiliency working groups

Creating a resilient marine conservation network in Canada will require scientists and Indigenous knowledge holders working collaboratively across a transdisciplinary spectrum of science, management, and policy (sensu Mauser et al. 2013). While Canada's established ocean conservation measures include multiple decision-making bodies (Fig. 1), no technical or advisory groups are specifically tasked with ensuring the continued effectiveness of the conservation network at a national scale. A comprehensive national approach that is based on a strong knowledge co-production mandate, involving the design, monitoring, and testing of conservation networks, would strengthen the ecological benefits of area-based conservation areas (Mauser et al. 2013; Shackell et al. 2021).

We propose that collaborative, transdisciplinary, and inclusive national, technical, and advisory working groups focused on climate resilience for Canada's marine conservation areas be established to consolidate and share knowledge, expertise, and research capacities—the Canadian Marine Conservation and Climate Advisory Committee. The working groups should act as a collaboration hub to connect and build a community of researchers, practitioners, community groups, Indigenous rights holders and governments, provincial and nongovernmental agencies, and key stakeholder groups such as fisheries, ecotourism, and energy. Like the National Advisory Panel for Marine Protected Area Protection Standards (bit.ly/3hWTOrT), we propose that these working groups adopt a core mandate to provide co-produced practical and robust advice reflecting a broad spectrum of perspectives on climate change adaptation and mitigation, inclusive of Indigenous knowledge, the best available science, ecosystem considerations, and the precautionary approach.

Recommendation 2: Create national, transdisciplinary working groups for climate-resilient ocean conservation planning in Canada.

- Develop a fully funded, national science-based infrastructure for climate change adaptation and mitigation within ocean conservation programs.
- Ensure knowledge co-production and bridging of perspectives across Indigenous rights holders and the various stakeholders in the Canadian marine estate in the proposed national working groups through a dedicated advisory group that links Canada's Marine Spatial Planning and Climate Change Adaptation initiatives.
- Share climate change relevant expertise and data in support of standardization of indicators for design, monitoring, testing and management of current and future MPAs across regions.
- Explore the application of dynamic protection measures and develop guidelines and mechanisms for the integration into the network of static MPAs with dynamic closures and adaptive management.
- Participate in site- and (or) regional-scale advisory processes on monitoring and management evaluation (i.e., Canadian Science Advisory Secretariat science advisory processes) and work to help integrate national-scale, climate change relevant monitoring, indicators, and advice.
- Plan an annual national conference on climate change solutions for Canada's ocean conservation network.

These groups can be tasked to review approaches for climate-resilient ocean conservation planning, create and share data platforms to supply the necessary evidence base, perform climate vulnerability assessments, develop operational science advice to manage site- and regional conservation network level risk, explore new dynamic tools for protection, and develop climate-focused indicators. Ultimately, these groups would work towards developing an overarching "national toolbox" that includes pragmatic approaches, minimum standards, and measurable benchmarks for climate change adaptation, mitigation, and management of conservation areas that are applicable regionally such as within Canadian Federal Marine Bioregions (DFO 2009) and scalable nationally.

The success of the national working groups requires the meaningful inclusion of rights-holder and stakeholder groups active in Canadian waters. By committing to the Aichi Targets in the

Convention on Biological Diversity (CBD), Canada agreed to not only conserve ecosystems (Target 11), but to also focus on protecting those that provide essential services and contribute to health, livelihoods, and well-being of Indigenous peoples (Target 14) and to include the full and effective participation of Indigenous peoples and local communities at all relevant levels (Target 18) (CBD 2020). Expansion of the Canadian Marine Conservation Network with the 2025 and 2030 targets then represents an opportunity to further link conservation with strong, healthy communities through nation-to-nation partnerships that would shape marine protection in support of an Indigenous vision of a working landscape, ushering in a broader more inclusive set of ecological and social benefits to marine conservation (Simon 2017; Zurba et al. 2019; Buscher et al. 2021). This builds on the growing representation of ocean conservation areas in Canada and abroad that are established and managed through the leadership of Indigenous rights holders (e.g., National Indigenous Guardians Network) (Tran et al., 2020; Government of Canada 2021b; Indigenous Leadership Initiative n.d.) as the momentum for Indigenous Protected and Conserved Areas builds in parallel to international recognition of Indigenous rights through the adoption of the United Nations Declaration of the Rights of Indigenous Peoples (UNDRIP) (UN General Assembly 2007). In keeping with the mandate of Fisheries and Oceans Canada to work with fishers and Indigenous communities and to use scientific and Indigenous knowledge in decision-making (DFO 2021b), the working groups should therefore prioritize the inclusion and leadership of Indigenous Peoples and their knowledge, perspectives, and governance approaches. In addition, industry stakeholders relying on the ocean for business and livelihood must also be represented in the working groups. It is critical that the perspectives of those who live on the coasts and rely on the ocean for livelihood and that are disproportionately impacted by climate change are represented, particularly in high-impact or rapidly changing areas such as the Canadian Arctic (Simon 2017; Kourantidou et al. 2020; Belhabib 2021).

Developing tools to anticipate and monitor the impacts of climate change on marine conservation areas

Canada's climate-resilient marine conservation network needs to rest on a solid foundation of data collection, assessment, and monitoring efforts. We have identified two critical tools to help with these aims: (*i*) ecological vulnerability assessments for the impacts of climate change and (*ii*) climate-focused indicators of MPA performance.

Ecological climate vulnerability assessments should be developed and applied to existing and proposed marine conservation areas; they seek to evaluate which species and ecosystems are likely to be adversely impacted by climate change according to their climate sensitivity, exposure, and adaptability (Foden et al. 2019; Greenan et al. 2019). These assessments can build on existing planning processes and land use plans that consider species of key importance; steps that would further strengthen partnerships with Indigenous Peoples (Simon 2017). In the context of area-based marine management, the assessments can identify priority areas or species for climate adaptation measures and evaluate climate risks that might compromise the ability of conservation areas to achieve their conservation objectives in the long-term (e.g., Friesen et al. 2021a). Ideally, these vulnerability assessments should be spatially and taxonomically explicit, include projected climate changes, and evaluate climate vulnerability information on scales of absolute risk to species and ecosystems. Such assessments could identify overlaps between climate vulnerable ecosystems and existing or planned conservation areas, identify species and ecosystems that may show resilience to climatic changes (*sensu* Tittensor et al. 2019), characterize carbon sequestration potential (blue carbon; Howard et al. 2017; Atwood et al. 2020), and evaluate potential spatial shifts in marine resources (e.g., fished stocks; Greenan et al. 2019; Bryndum-Buchholz et al. 2020). In combination with analyses of the protection level of areas and ecosystems across multiple climate change scenarios (Tittensor et al. 2019), comprehensive vulnerability assessments can effectively inform marine spatial planning, where the risk of ecological change and potential shifts in fisheries can be balanced with conservation objectives when considering adaptive measures across a network of protected areas.

Recommendation 3: Implement climate vulnerability assessments to inform marine conservation planning and management.

- Establish, operationalize, and undertake ecological vulnerability assessments for existing and potential future marine conservation sites in collaboration with Indigenous partners, universities, federal agencies with marine regulatory authorities i.e., Parks Canada, Environment and Climate Change Canada, provincial and territorial conservation agencies.
- Develop spatial data layers on climate exposure, refugia, and variability to include in vulnerability assessments.
- Include projected changes in temperature, acidity, oxygen, salinity, productivity, and forecasted redistribution of species in vulnerability assessments.
- Incorporate transboundary collaborations with cross-boundary agencies i.e., National Oceanic and Atmospheric Administration (NOAA) to account for conservation implications caused by climate-related shifts in species.

Secondly, we recommend the integration of a set of climate-focused indicators of MPA performance into the existing ecological monitoring mandate for conservation areas in Canada as an essential first step towards climate-adaptive management. Given the diversity of ecosystems represented in Canada's Marine Conservation Network, we propose a hierarchical monitoring approach that would include standardized climate focused indicators e.g., temperature in addition to indicators suited to the unique ecological and environmental characteristics of each protected ecosystem (i.e., tailored to Canadian ocean systems or by oceanic bioregions (DFO 2009; Government of Canada 2011) and site e.g., specific biological responses expected from forecasted climate change impacts associated with core conservation objectives of the site; **Fig. 2**). This hierarchical approach can be achieved at scale through coordination among existing and proposed site- and network-level monitoring programs (see Recommendation 2). This strategic coordination will provide a mechanism to gauge the extent to which conservation objectives are affected by the impacts of climate change at the site, regional, and national scales. For example, evaluating whether the change characterized by the climate-focused indicators potentially impedes conservation objectives within a site or within a regional network and, if so, what adaptation or mitigation options are available, e.g., changing zoning of permissible activities. Conversely, if climate change leads to an enhancement of a conservation objective within a site or within a regional network, management may consider how current risk assessments for permissible activities such as zoning could be changed (Shackell et al. 2014, Storitini et al. 2015, Greenan et al. 2019). Associated with each indicator should be a threshold or "tipping" point denoting a state where changing climate has augmented or detracted from the ability of a conservation measure to achieve its conservation objective at a level that necessitates management intervention (Monaco and Helmuth, 2011; Selkoe et al. 2015). Whether the change is positive or negative, it is important that monitoring programs are positioned to track changes at scale and be based on indicators that are hierarchical and interoperable, so that adaptive management can be undertaken at both small sites and large regions and national scales.

Recommendation 4: Develop and operationalize climate-relevant monitoring objectives.

- Adopt standardized physical and biogeochemical climate monitoring indicators e.g., temperature, oxygen, pH, salinity, productivity, and develop protocols to evaluate against baseline conditions.

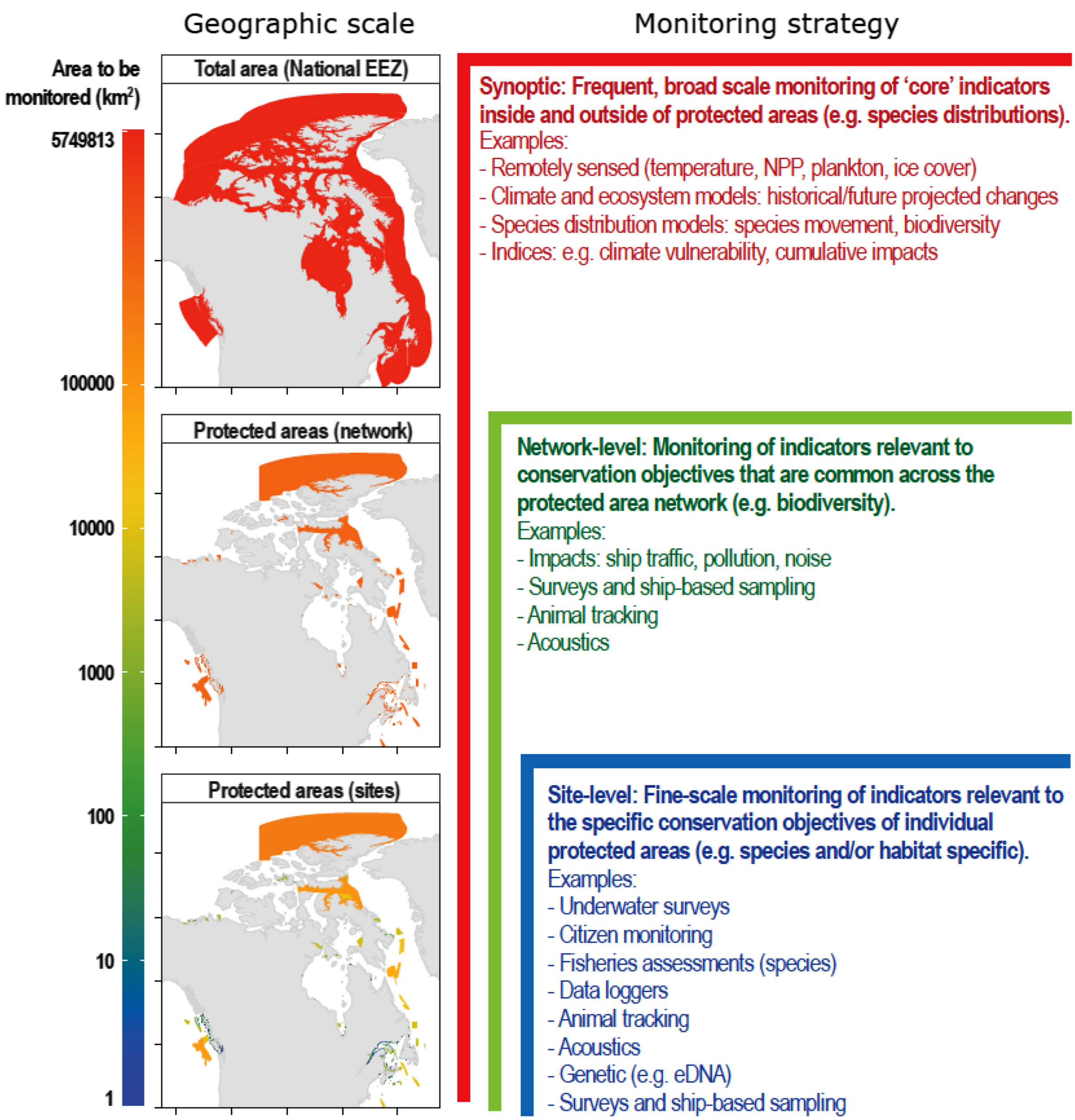


Fig. 2. Conceptual schematic of the recommended hierarchical monitoring approach.

- Implement a coordinated monitoring system across multiple scales within the network e.g., frequent, automated, lower-cost broad-scale geographic monitoring coupled with site-specific observations.
- Collaborate with existing data creators and modelers to create and expand fine resolution datasets and outputs within MPAs and across regions.
- Build a common open-access platform for compiling, aggregating, and disseminating monitoring data to further public engagement and participation.

Key trends generated from climate-focussed monitoring programs should be summarised by the national working groups and made available to the public through regular reporting on how climate change influences the effectiveness of the Canadian Marine Conservation Network. To be nationally inclusive and supportive of strengthening relationships with language and culture, the reporting should be guided by all representation on the working groups and be translated into appropriate languages, including Indigenous languages (Simon 2017). This report could take a similar form to, or be integrated with, the State of the Ocean Reporting program conducted by Fisheries and Oceans Canada (dfo-mpo.gc.ca/oceans/soto-rceo/index-eng.html).

Communicating the benefits of marine conservation areas as climate change mitigation tools

While the primary objective of Canada's Marine Conservation Network is to safeguard and restore marine biodiversity, conservation areas in the ocean can also contribute to carbon sequestration and thus serve as a tool in the adaptation and mitigation of climate change (Lovelock and Duarte, 2019) as part of the emerging blue carbon agenda (DFO 2021c). Ultimately, to facilitate the progress toward climate-resilient ocean conservation that achieves society's support, a comprehensive communication and outreach program is needed to inform on and highlight the benefits of marine conservation areas in adapting to and mitigating climate change (Whitney et al. 2020). Indeed, currently most Canadians who know about MPAs likely do not associate them with a climate change mitigation strategy in the broader context of nature-based solutions. The task of internal federal and provincial governing bodies and external to the Canadian public communications could be assigned to sub-committees of the national working groups (Recommendation 2). Ideally, communication to different governance levels and stakeholders should be commenced with the establishment of the national working groups and information continuously disseminated i.e., policy briefs and progress reports that clearly state successes, failures, and gaps progressing towards a climate-resilient marine conservation program.

While the role of MPAs as a risk-averse climate change mitigation tool is briefly acknowledged in the National Framework, it needs to be incorporated in all federal, provincial, and territorial bodies that contribute conservation areas to the conservation network (**Fig. 1**) and communicated to Indigenous leadership as well as the public. For example, communicating the need to prioritize protecting ecosystems rich in blue carbon as contributions to Canada's Nationally Determined Contributions under the Paris Agreement, MPAs can be highlighted as climate change mitigation tools. Protecting areas rich in blue carbon can help mitigate climate change by preventing the degradation of these ecosystems and subsequent release of carbon (Pendleton et al. 2012). Over time, as ecosystems recover, these conservation areas can safeguard and potentially expand as carbon sinks (Macreadie et al. 2019). These areas can also be modelled and mapped and could be included within an explicit spatial target within conventional systematic conservation planning (e.g., DFO 2018; see Recommendation 1).

Recommendation 5: Communicating the benefits of marine conservation networks as climate change tools for both adaptation and mitigation.

- Commit to marine and coastal areas as part of nature-based solutions to climate change and integrate them into the Nationally Determined Contributions under the Paris Agreement requiring collaboration among Environment and Climate Change Canada and Fisheries and Oceans Canada.
- Develop a comprehensive communications and outreach program to inform the Canadian public on and highlight the benefits of protected areas in adapting to and mitigating climate change.

- Initiate and communicate research on how permitted activities in MPAs contribute to maintaining blue carbon status.

Building climate resilience into marine conservation in Canada and beyond

In summary, we posit that to achieve the management objectives of Canada's growing marine conservation network, it is necessary to explicitly embed climate change adaptation and mitigation into conservation design, monitoring, and overall management frameworks. Developing a climate resilient marine conservation network now presents an opportunity for Canada to demonstrate proactive global leadership by supporting solutions that anticipate impacts and mitigate climate change.

Canada can learn from nations that have developed proactive climate change policies, strategies, and frameworks. For example, the Seychelles National Climate Change Committee developed its National Climate Change Strategy in 2009, including a detailed strategic framework and a priorities and action plan addressing several of the issues brought up here, such as cross-sectoral vulnerability assessments and the establishment of an overall coordinating body (The Seychelles National Climate Change Committee 2009). Further, O'Regan et al. (2021) reviewed how climate change adaptation principles have been incorporated into MPA management plans globally. Their results highlight protected area systems whose management plans can be used as examples for how to better incorporate adaptation principles, such as the recently published USA National Wildlife Refuge plans (US Fish and Wildlife Service 2020). This work, however, first requires a broad recognition of the extent of Canada's marine vulnerability to climate change and its regional drivers and consequences.

While some recommendations made here are tailored to the Canadian context, others, such as the identification of climate-smart objectives (Recommendation 4), tools (Recommendation 3), and communication (Recommendation 5), addressing climate change via marine spatial management are broadly applicable to marine conservation areas around the globe. Our recommendations align with the United Nations Framework Convention on Climate Change (UNFCCC) key messages to "increase climate ambition inclusive of the ocean" and "develop and/or strengthen integrated national policies for ocean and climate action" (UNFCCC 2021). Climate-ready MPAs as well as other adaptive options for marine spatial planning have been central recommendations from the UNFCCCs Ocean Dialogues for the UN Climate Change Conference COP26. The integration of our recommendations can also help Canada and other nations to better address national goals aligning with the fulfilment of the UN Sustainable Development Goals 13 ("Take urgent action to combat climate change and its impacts") and 14 ("Conserve and sustainably use the oceans, seas and marine resources for sustainable development"). Ultimately, through implementing the recommendations developed here, Canada has an opportunity to build an international reputation as being on the leading edge of climate change adaptation, mitigation, and blue carbon integration in marine conservation.

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Author contributions

AB-B, KB, RRES, IH, and DPT conceived and designed the study. AB-B, KB, RRES, IH, DGB, KMD, KLH, HKL, NLS, BW, and DPT drafted or revised the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Data availability statement

All relevant data are within the paper.

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