CPAWS
CANADIAN PARKS AND WILDERNESS SOCIETY

PROTECTED AREAS

AS A NATURE-BASED CLIMATE SOLUTION

DR. RISA B. SMITH
DECEMBER 2023

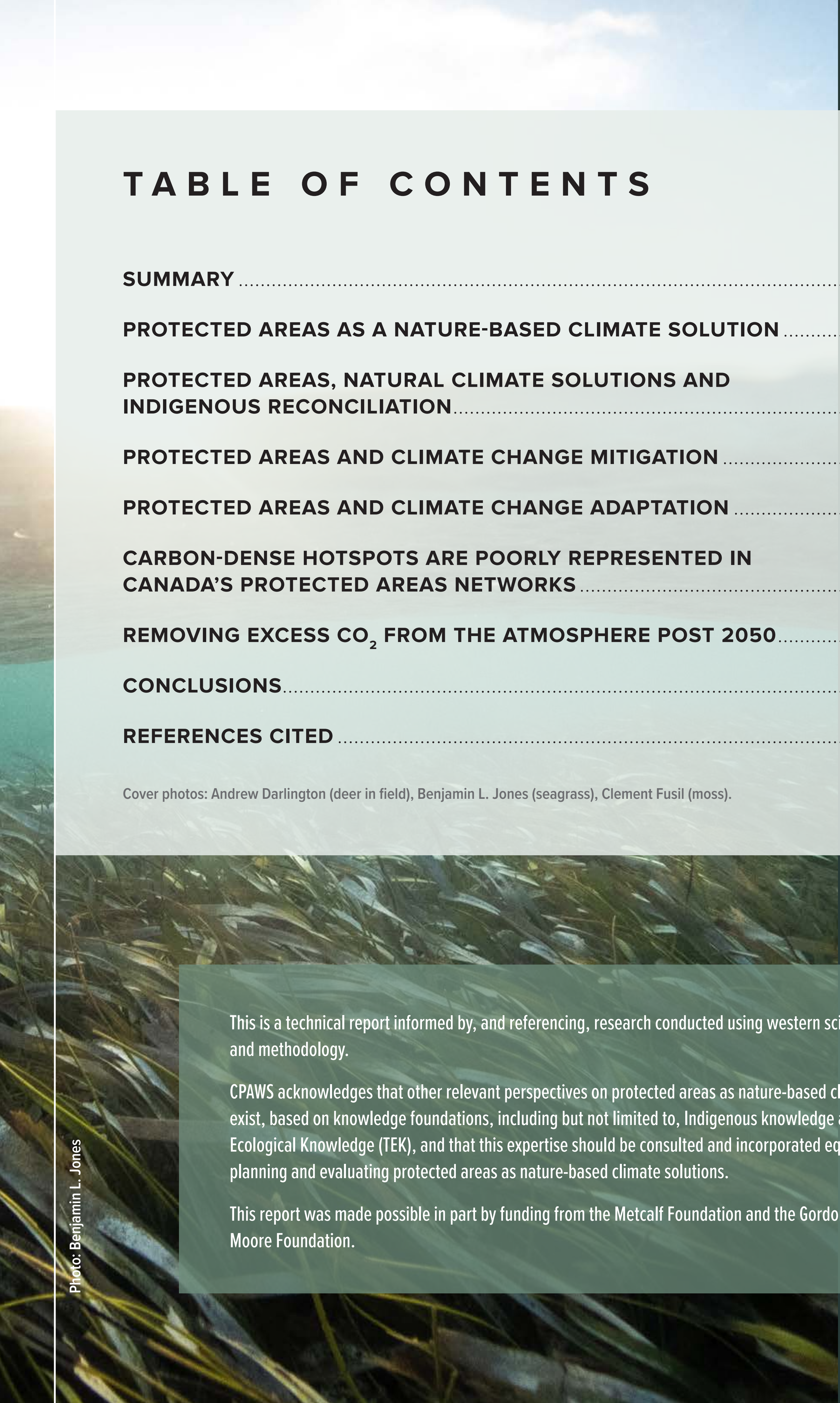


Photo: Benjamin L. Jones

TABLE OF CONTENTS

Cover photos: Andrew Darlington (deer in field), Benjamin L. Jones (seagrass), Clement Fusil (moss).

This is a technical report informed by, and referencing, research conducted using western science methods and methodology.

CPAWS acknowledges that other relevant perspectives on protected areas as nature-based climate solutions exist, based on knowledge foundations, including but not limited to, Indigenous knowledge and Traditional Ecological Knowledge (TEK), and that this expertise should be consulted and incorporated equitably when planning and evaluating protected areas as nature-based climate solutions.

This report was made possible in part by funding from the Metcalf Foundation and the Gordon and Betty Moore Foundation.

Photo: Shayd Johnson

Photo: Annie Spratt

Photo: Bryce Evans

> “Canada’s—and the world’s—future depends on how effectively Canada’s vast carbon stocks are preserved [1]”

SUMMARY

Canada can leverage nature as an important tool towards reducing its greenhouse gas (GHG) emissions by increasing the protection of key ecosystems, such as: northern peatland complexes in the Hudson Bay Lowlands and the Mackenzie River Basin; old-growth boreal and temperate forests; coastal blue carbon systems including remaining eelgrass meadows and salt marshes on all three coasts, and ancient prairie grasslands. The greatest short-term benefit (by 2030) comes from protection of carbon-dense ecosystems, to ensure that the carbon they are storing is secure and that their ability to remove CO_2 from the atmosphere is maintained. Restoration of damaged ecosystems is also important, but its benefits occur over the long-term (i.e. post 2050).

Implementation of nature-based climate solutions has to be conducted in the context of recognition of rights and title of Indigenous lands, respect for Indigenous knowledge, and assurances that Indigenous People have a dominant role in land-use decisions on their territories.

Canada’s carbon-dense ecosystems are generally poorly represented in the protected areas network. Although the proportion of remaining coastal marine systems protected (i.e. eelgrass and salt marshes), is high, so much has been lost that protecting what remains must be a priority, followed by restoring and then protecting what has been restored. The report provides evidence for including Canada’s carbon-dense ecosystems in the expansion of Canada’s protected areas network.


Photo: Clement Fusil

PROTECTED AREAS AS A NATURE-BASED CLIMATE SOLUTION

Nature-based solutions are “solutions to societal challenges that involve working with nature” to provide benefits for both human well-being and biodiversity[2]. Nature-based climate solutions (NBCS) are a subset of nature-based solutions that specifically address climate change mitigation and adaptation and at the same time provide multiple benefits for biodiversity and people. NBCS include many actions such as protection, restoration and better management of living resources. However, consensus is emerging that effectively designed and managed protected areas offer the highest total per hectare value as a NBCS[3-10].

Globally, in terrestrial ecosystems, NBCS can mitigate 10 to 12 billion tons of CO$_2$ equivalent per year (10 to 12 Gt CO$_2$e/year) by 2030 and 10 to 18 Gt CO$_2$e/year by 2050, enough to reduce peak warming by about 0.1°C to 0.3 °C[7,11,12]. The protection of primary terrestrial ecosystems (*i.e.* ecosystems with minimal human interference) could provide approximately 40% of the NBCS potential[7,13]. Studies in Southeast Asia and the U.S.A. have shown that landscapes inside terrestrial protected areas store more carbon and sequester more CO$_2$ from the atmosphere than those outside of protected areas, even though the protected areas were not created specifically for climate change mitigation[14,15]. A similar global analysis has not been done for marine protected areas (MPAs).


Photo: Hector John Periquin

Photo: Jill Dimond

Measuring Climate Change Mitigation

Climate change mitigation is most often measured as billions of tonnes (Gt) of CO_2 equivalent in a global context or million tonnes (Mt) in Canada. While CO_2 is a potent greenhouse gas (GHG), there are other GHGs released through decomposition and combustion, such as methane and nitric oxide, that are even more potent than CO_2. To standardize measurements, GHG emissions are converted into CO_2 equivalents (CO_2e).

Canada's Commitment to Reduce Greenhouse Gas Emissions (GHG)

In 2021, the most recent year for which there are statistics, Canada emitted 670 million tons (Mt) of carbon dioxide equivalent (CO_2e), decreasing emissions by 62 Mt (8.4%) from 2005. Canada has promised to reduce its emissions by 40-45% from 2005 levels (of 741 Mt CO_2e) by 2030, to between 408 and 444 Mt of CO_2e. To achieve its promise, Canada has to directly reduce emissions from the biggest sources – oil and gas and transportation[16,17]. However, protecting nature can also play an important role in helping Canada meet its GHG emission reduction commitments.

Photo: Pete Nuij

Photo: Damon on Road

PROTECTED AREAS, NATURAL CLIMATE SOLUTIONS AND INDIGENOUS RECONCILIATION

Past practices of displacing Indigenous Peoples from their lands in the name of wilderness protection are being replaced by a new paradigm, that of Indigenous-led conservation, Indigenous-led natural climate solutions, and Indigenous Protected and Conserved Areas (IPCAs). These new approaches recognize Indigenous knowledge systems, legal traditions, cultural practices for managing the land and waters, rights and title over Indigenous lands, and the imperative for inclusive decision-making and continued sustainable use[18-21].

Incorporating Indigenous knowledge and world views into protected area creation and management offers multiple benefits, such as ensuring conservation of some of Canada's most important biodiversity and carbon hot spots, while providing a framework for reconciliation.

A high percentage of the world's remaining primary ecosystems which are rich in biodiversity and carbon are found on the traditional territories of Indigenous Peoples in Canada[22-24], including much of the boreal forests, temperate old-growth forests, and northern peatlands. As Eli Enns, Tla-O-Qui-Aht First Nation, has so aptly expressed in the report "We Rise Together": "Whenever you find intact ecological biodiversity, you find intact, thriving, cultural holistic diversity" (page 73)[25].

Photo: Linda Szeto


Photo: Tim Foster

PROTECTED AREAS AND CLIMATE CHANGE MITIGATION

Protected areas can mitigate climate change by maintaining the ability of ecosystems to sequester CO_2 from the atmosphere and ensuring that stored carbon, which has accumulated over a long period (*i.e.* often hundreds of years or longer) is not emitted back into the atmosphere. In terrestrial ecosystems, IPCC[13] estimates that protecting forests, grasslands, and other ecosystems from conversion to other uses would reduce global emissions by ~4 Gt CO_2e per year. Protecting 30% of non-crop lands with low human population density and high connectivity could sequester 6.9 Gt CO_2e per year from the atmosphere, which is approximately 20% of the carbon emissions reductions necessary to limit temperature increases to 1.5 °C[26]. On the marine side, protecting 39% of the oceans could reduce emissions by an average of 16.2 Gt CO_2e from 2018 to 2060, or approximately 2% of emission reductions required to limit global warming to 2°C above industrial levels by 2050[27]. Protecting soil carbon would result in reductions of 5.5 Gt CO_2e/year, with most of it coming from the protection of wetland and grassland soils[28].

While equivalent numbers are not readily available in Canada, some Canadian estimates include:

» Protecting 900 km^2 per year of old-growth forests in Canada from 2021-2030 would sequester 17.2 Mt CO_2e by 2030, equal to 5 to 6% of emissions reductions that Canada has committed to[31];
» Protecting the 12,700 km^2 of remaining native Prairie grasslands[32] would sequester 2.42 Mt CO_2e per year, equal to 0.7 to 0.8% of emissions reductions that Canada has committed to, and protect 2 to 3 Gt carbon that is stored in these ancient grasslands, from release into the atmosphere[33].
» The Hudson Bay Lowlands, the second largest intact peatland complex in the world, sequester 74.6 Mt of CO_2 per year, equivalent to 11% of Canada's total emissions in 2020, and prevent the release of the 30 Gt of carbon that is stored[34].


Photo: Derek Sutton

GHG Emission Reductions Explained

In order to keep global warming to no more than 1.5°C above pre-industrial levels, GHG emissions must be reduced by 45% from 2010 levels in 2030 and reach net zero by 2050[29]. In 2010, global GHG emissions were 46 Gt CO_2e[30]; in 2020 total global GHG emissions were 54Gt CO_2e[29]. The table below provides a summary of the GHG emission reductions expected from different NBCS as a percentage of global reductions required by 2030. Note that for marine protected areas the calculation is from 2018 to 2060. **These estimates are not additive.** There is considerable overlap between the categories presented. For example, “protecting soil carbon” is partially included in “protecting forests and other ecosystems from conversion”.

Global emission reductions required by 2030 to meet 1.5°C target = 25.3 Gt CO_2e

	Percent of required emission reductions that can be met by NBCS in 2030 (estimates are NOT additive)
Protecting forests and other ecosystems from conversion	34.8%
Protecting 30% of non-croplands with low population density and high connectivity	24.0%
Protecting 39% of marine areas	2%
Protecting soil carbon	19.2%

The Canadian Council of Academies (2022)[1] estimated that increasing the potential of Canada’s ecosystems to sequester carbon would have only a modest impact on meeting emission reduction commitments. However, they also concluded that “Canada’s – and the world’s – future depends on how effectively Canada’s vast carbon stocks are preserved”.

In December 2022, the United Nations Convention on Biological Diversity set a target to protect at least 30 % of land, inland waters and marine areas by 2030[35]. Canada has adopted this target. As of December 2022, Canada had protected 13.6% of its terrestrial area and 14.66% of its marine and coastal areas[37,38]. Expanding Canada's terrestrial protected areas to 30% will require an additional 2.95 million km^2 and could, according to one study, sequester an additional 1.17 Gt CO_2 per year[39].

The growing recognition of the significance of marine carbon stores, including near-shore vegetation like salt marshes and eelgrass, as well as deep sediments, suggests that marine protected areas (MPAs) can also play a significant role in avoiding emissions from stored carbon and ensuring the continued sequestration of atmospheric CO_2 from marine ecosystems[40-42]. One global study suggests that marine systems could provide 2% of the total carbon mitigation needed to meet the Paris Agreement by 2050[27]. In addition, an understanding of the role of marine organisms in carbon cycling is emerging[27].

Photo: Eoin Anderson

Photo: Justin Hu

PROTECTED AREAS AND CLIMATE CHANGE ADAPTATION

Protected areas are also relevant for climate change adaptation. Protected areas enhance the integrity and resilience of ecosystems[43], provide buffers from increasingly unpredictable weather events, and create climate refugia for species to survive in habitat pockets less impacted by human activities and particularly climate change itself. For example, warming in protected boreal forests is 20% lower than in surrounding unprotected boreal forests[44]. Managing natural disturbances in protected areas, such as the incorporation of cultural burns as historically practiced by Indigenous People, can improve the resilience of protected areas[45]. Creating networks of protected areas, connected by ecological corridors, can facilitate the movement of species in a changing climate[46] and increase the resilience of ecosystems across a landscape[47-49]. Globally, on land, the percentage of connected protected areas was 7.7% in 2018[50]. A similar analysis has not been done for Canada or for MPAs. However, Canada's commitment to establishing MPA networks in five priority marine bioregions includes connectivity and planning for climate change.

Photo: Anastase Maragos

Carbon Density and Biodiversity

Carbon density refers to the amount of carbon per unit area that is stored in a particular ecosystem. It is usually measured as kilograms of carbon per square meter (kg C/m^2). Protecting ecosystems with high carbon density is recognized as one of the most cost-effective options for reductions in GHG emissions. How a focus on carbon density affects biodiversity depends on there being a relationship between carbon density and biodiversity. For some ecosystems, such as natural forests, vegetated coastal ecosystems (i.e. saltmarshes, seagrasses and mangroves), and along with boreal and northern peatlands, the relationship between carbon-density and biodiversity is well-established[8,51]. When biodiversity in these areas is degraded or destroyed, stored carbon is also lost[52,53]. Terrestrial carbon hotspots coincide with large intact migratory mammal populations and the world's remaining wilderness[54]. Marine carbon hotspots are associated with areas of high productivity and significance to marine species, including nursery habitats for many commercially, culturally, and ecologically important marine species such as salmon, herring, eels, and crabs.

Photo: Ryan Stone


Photo: Andrew Darlington

CARBON-DENSE HOTSPOTS ARE POORLY REPRESENTED IN CANADA'S PROTECTED AREAS NETWORKS

% CARBON HOTSPOTS PROTECTED

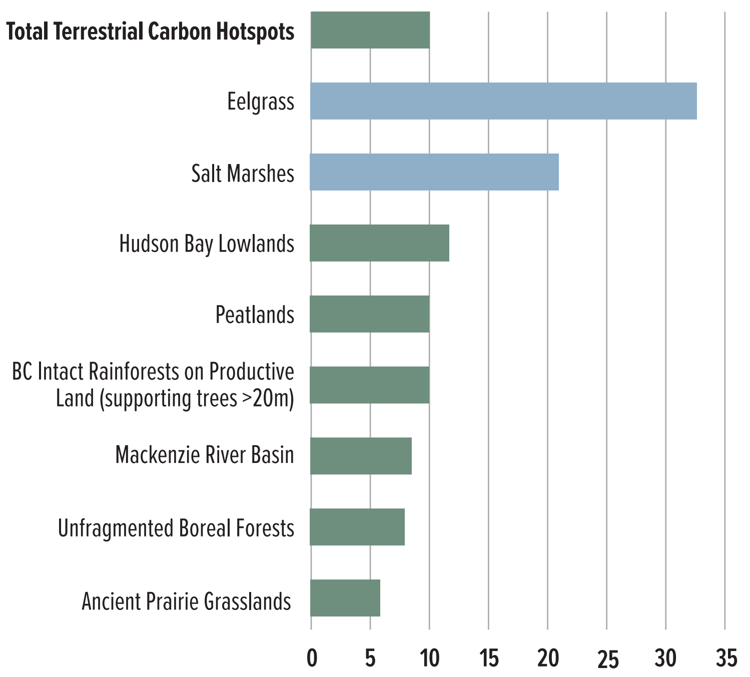


Figure 1: Percent of Carbon Hotspots Protected in Canada. Sources: Total terrestrial protected[55]; Unfragmented boreal forests[56], BC intact rainforest on productive lands that support 20m tall trees[57], ancient prairie grasslands[33], Hudson Bay Lowlands[58-60], Peatlands[34], Mackenzie River Basin[61]. Marine hotspots: Eelgrass[62],Salt Marshes[62]. These ecosystems are not mutually exclusive. Green bars represent terrestrial protected areas, blue bars represent marine protected areas.

One global analysis attempted to overlay important areas for biodiversity with carbon-density (Figure 2)[51]. Using what the authors called a 'proactive biodiversity index', which identifies areas with high species richness, range-size rarity, high local intactness and high to average habitat health, some of Canada's ecosystems emerged as carbon-dense/high biodiversity hotspots.

Photo: Erik McLean

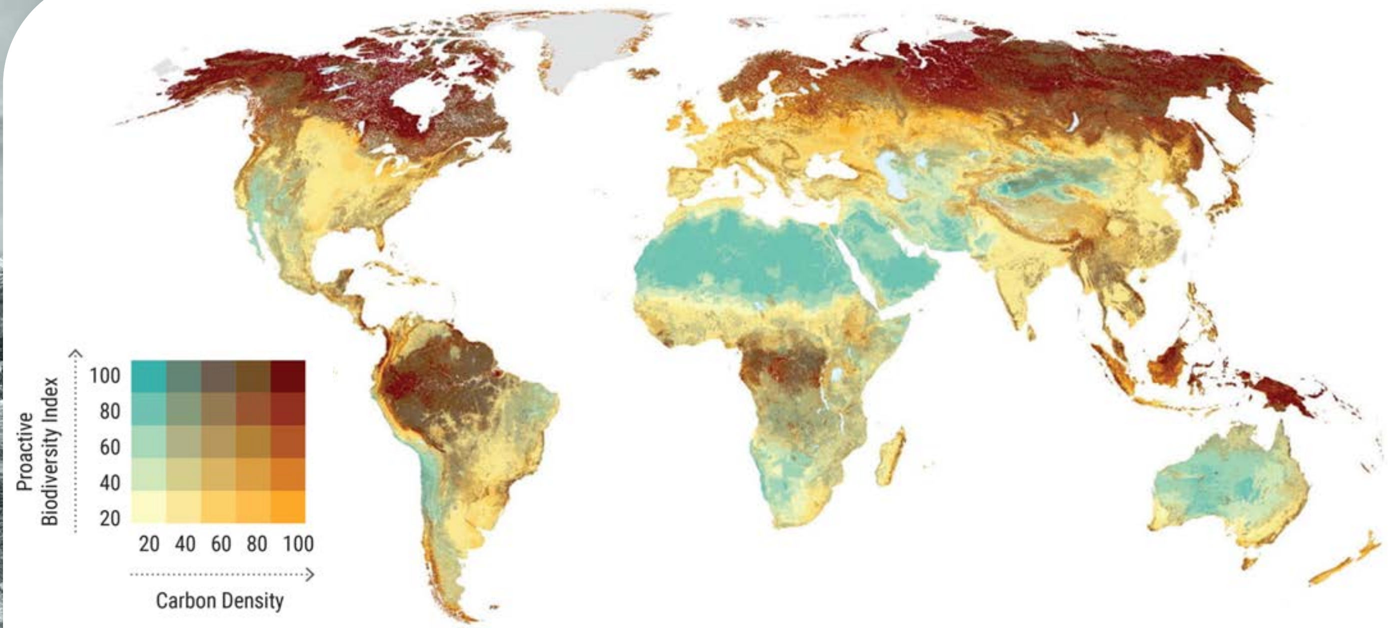
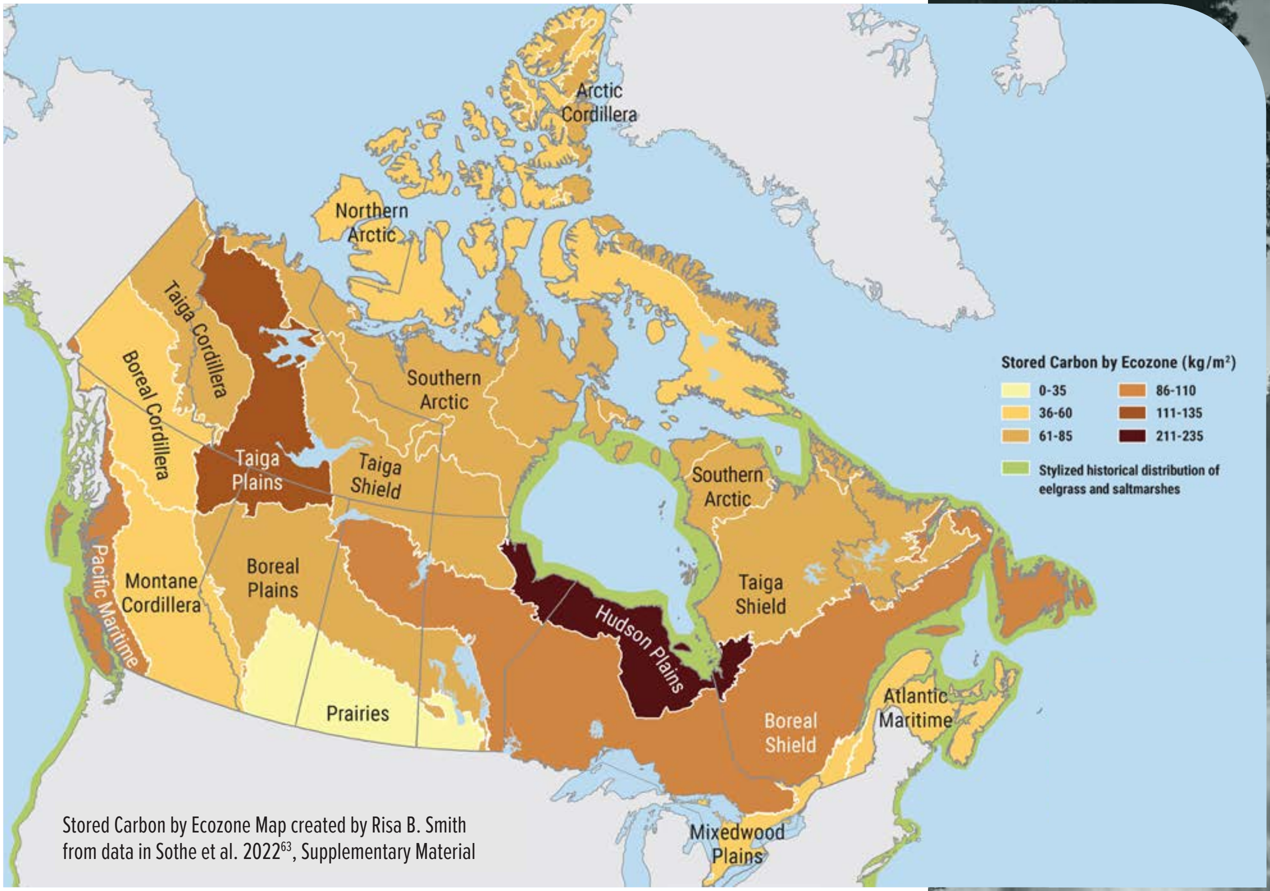


Figure 2: Convergence of Carbon-Density and Biodiversity. This map shows the overlap between carbon-rich ecosystems and a biodiversity index – the proactive biodiversity index – representing high species richness, range-size rarity, high-local intactness, and high average habitat health. The darker brown shows the greatest overlap. Yellow shows little overlap; 12% of the dark brown areas are represented in protected areas networks. Source: Soto-Navarro et al 2020[51]. Printed with permission.

Recently completed carbon density maps for Canada reveal the hotspots for carbon storage in terrestrial ecosystems (Figure 3)[63], although an overlay with biodiversity hotspots remains to be done in Canada. About 10% of Canada's carbon hotspots are within the existing protected areas network[55].

Photo: Yann Allegre



Stored Carbon by Ecozone Map created by Risa B. Smith from data in Sothe et al. 2022[63], Supplementary Material

Figure 3: Distribution of organic carbon stocks in kg C/m^2 by ecozone at 0-2 m depth for soil carbon. The Hudson Plains, Taiga Plains, Boreal Shield and Pacific Maritime ecozones have the highest density of stored carbon in terrestrial ecozone (Stored Carbon by Ecozone Map created by Risa B. Smith from data in Sothe et al. 2022[63], Supplementary Material). In the coastal marine area, the total extent of remaining eelgrass and saltmarshes are not known. However, local studies have shown that saltmarshes on the Pacific Coast and in the Bay of Fundy are not more carbon dense than terrestrial ecosystems[64-66].

Photo: Lukas Mann

CANADA'S BOREAL FOREST. Boreal forests cover ~30% of the global forest area, contain an estimated 32% of global terrestrial carbon stocks, sequester ~20% of the total carbon sink of the worlds' forests, contain more surface freshwater than any other biome, and contain large tracts of primary, unmanaged forests[67]. Canada's boreal forests represent over 16% of the world's remaining primary forests[68]. Boreal peatlands in eastern Canada and western Siberia store some of the highest concentrations of irrecoverable carbon (12.4 Gt) (*i.e.* carbon that, if lost, cannot be recovered in the 30 year timescale required to avert catastrophic climate change[69]). The carbon density in Canada's boreal zone, which includes carbon dense peat forests, old-growth forests, and non-peat forests, has been estimated as 20.4 to 212 kg C/m^2 [70,63]. This biome provides habitat for one to three million migratory breeding birds and large migratory mammals. About 8.1% of Canada's primary boreal forest is protected[56], yet the resilience of boreal forests across a landscape depends on well-distributed protected areas[67]. In Canada, only 1 to 2 Gt of irrecoverable carbon is located within protected areas[71].

Photo: Juan Davila

Photo: Manny Moreno

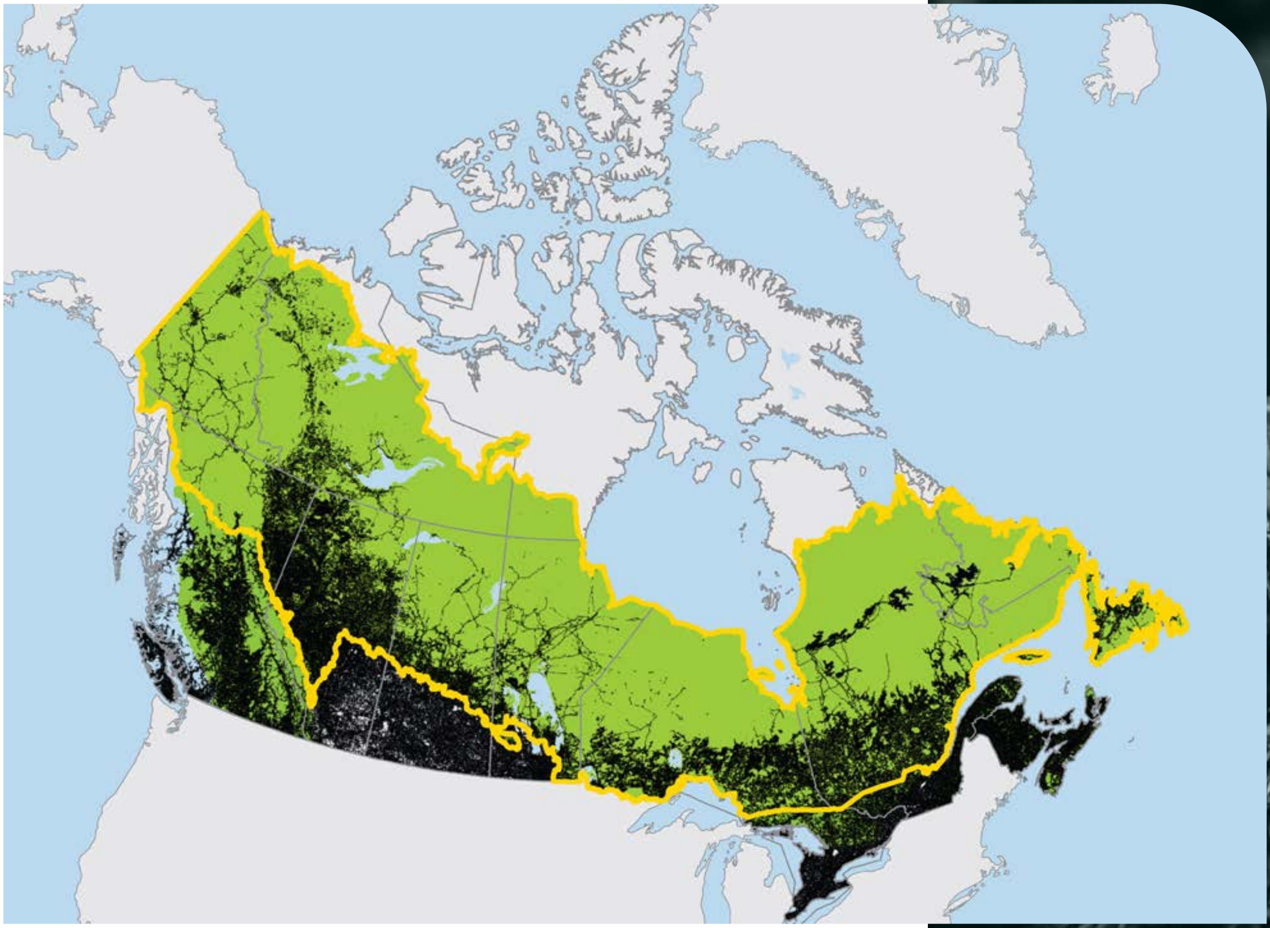


Figure 4: Extent of Canada's primary forests. This map depicts Canada's landscapes relatively free of human disturbance, in green, and those landscapes highly fragmented by human disturbance, in black. The boreal zone is outlined in yellow. The map provides a picture of how much of southern Canada, and the boreal forest, are already disturbed. Adapted from Global Forest Watch, Canada's Intact Forest Landscapes 2013[73].

BRITISH COLUMBIA (BC) TEMPERATE RAINFORESTS (on the coast and in the interior)[8,51,63,71], are some of the most carbon-dense forests on the planet. Estimates of carbon density in coastal and interior rainforests of BC range from an average 58.5 to 127.5 kg C/m^2 [74,75]. By comparison, the carbon density of old-growth ash forest in Australia is ~103.9 kg C/m^2, and in a protected tropical forest in southeast Mexico is 47.8 kg C/m^2 [76]. These BC forests are also home to endangered old-growth dependent species. Ten percent of BC's coastal forest that can produce trees 20 m or higher is protected[57].


Photo: Jesse Bauer

The Case for Protection of Old-Growth Forests.

Old-growth forests are diverse forested ecosystems that show minimal signs of human disturbance. They are often defined by the age of the oldest trees, although it is widely recognized that tree age alone is not an adequate descriptor of the complexity of old-growth forests. One recent study estimated that protecting 900 km^2 of unprotected old-growth stands per year would result in a reduction in Canada's GHG emissions of 17.2 Mt CO_2e in 2030[31]. This was twice the emissions reductions from other improved forest management practices and represents 5 to 6% of the total emissions reductions that Canada has promised in its Nationally Determined Contribution to the Paris Agreement*. It would also protect an irreplaceable biological legacy of nitrogen fixation, micro-climates for endangered species, phytochemicals and cultural heritage[77].

The replacement of old-growth forests with younger plantation forests has proceeded across Canada, at least partially justified by governments and industry, based on the now refuted myth that old-growth forests are ecologically decadent and better replaced by younger, faster growing forest plantations [78]. Research over the years has shown that forests continue to take up carbon even as they become old-growth forests[68,79-87]. Managed mature tree-farms store half the carbon of old forests [75,88,89], and the initial loss of carbon from harvesting cannot be recovered in a time frame relevant for preventing damaging levels of atmospheric CO_2, if ever[89-93]. The debate is not whether or not old-growth forests are carbon sinks, but rather the specific rate (*i.e.* tonnes of carbon sequestered per year) at which old-growth forests sequester carbon[79,83,94-96].

---

* Nationally Determined Contributions to the Paris Agreement are the promises in greenhouse gas emissions that each country submits to the Paris Agreement on Climate Change. Every 5 years, countries ratchet up their promises until the target to keep temperature below 2 °C is attained.


Photo: Trevor Minett

HUDSON BAY LOWLANDS[51,55,63,71], located in the boreal zone, represents the second largest intact peatland complex in the world. It sequesters 74.6 Mt of CO_2 per year and stores 30 Gt of carbon. This area has one of the highest carbon densities in Canada, at ~89 kg C/m^2 [60] to 212 kg C/m^2 [63]. Only 12 % is currently protected[60,97,98].

REMAINING ANCIENT PRAIRIE GRASSLANDS, like old-growth forests, store large quantities of carbon in the soil that are difficult to restore if lost or degraded[99]. Most of Canada's original 615,000 km^2 of native grasslands were lost prior to 1990[100]. The remaining 12,700 km^2 (2.1 %) of ancient temperate prairie grasslands store an estimated 2 to 3 Gt of carbon[32,100]. Protecting these remnants could maintain an annual carbon sink of about 2.41 Mt CO_2 and avoid emissions of about 380 to 1900 $MtCO_2e$[32]. Grassland species are among the most endangered in Canada: grassland birds have declined by 57% since 1970 and all species dependent on native grasslands have declined by 87%[101]. Approximately 6% of ancient prairie grasslands are protected[33].

THE ARCTIC[51,55], although not necessarily under as extensive and imminent threat from development, is under threat from climate change and provides habitat for millions of migratory birds and large migratory mammals, both on land and in the ocean. The carbon density of Canada's northern Arctic ecosystems ranges from 42.1 to 71.8 kg[63] C/m^2 [63]. The Arctic Ocean represents one of the last remaining marine wilderness areas[102]. In 2016, 20.2% of the terrestrial area and 4.7% of the marine area of the circumpolar Arctic was protected i[103]. The Canadian portion of this could not be determined. In 2019, Canada provided interim protection for Tuvaijuittuq, a large marine protected area (319,411 km^2) in the Arctic Ocean, off the northwest coast of Ellesmere Island, Nunavut[104].


Photo: Michael Shannon

COASTAL EELGRASS AND SALTMARSHES ON ALL THREE COASTS, also known as coastal blue carbon, are believed to be some of the most carbon-dense ecosystems on earth[105]. The small area occupied by blue carbon systems in Canada – confirmed at 1200 km^2 but believed to be larger[62] – compared to 3.62 million km^2 of forests, means that their potential to contribute to climate change mitigation is relatively small, but still significant. One estimate is that blue carbon protection and restoration in Canada could sequester 1.7 Mt CO_2e per year in 2030[106]. This compares to protection of 900 km^2 of old-growth forest per year which could sequester 10 times that, at 17.2 Mt CO_2e per year by 2030[31]. (Refer to Box 6 for the range of carbon densities found in Canada's and global blue carbon).

Approximately 32.7% of remaining eelgrass area, and 21.3% of remaining saltmarsh area in Canada is protected[62]. Marine protected areas, if well-managed, can help reduce impacts of climate change, such as ocean acidification, sea level rise, storm surges, shifts in species distribution, reduced oxygen availability, reduced productivity and cumulative effects of all of these, as well as mitigate anthropogenic GHG emissions[107-109]. The coastal vegetation protected by MPAs serves as nurseries and habitat for commercially important species and at-risk marine species.

Carbon-Density in Canada's Blue Carbon Ecosystems

There are few areas of Canada where blue carbon density has been measured and more data is needed. Where blue carbon density has been measured, estimates for Canada's salt marshes range from 25 to 34 kg C/m^2 [62,111]; for Canada's seagrass meadows they range from 1.8 to 2.8 kg C/m^2 [66]. Globally, estimates for carbon density in seagrass meadows ranges from 1.2 to 2.9 kg C/m^2 [112,113] and 16.2 kg C/m^2 [114] to 22.6 kg C/m^2 [115] for salt marshes.

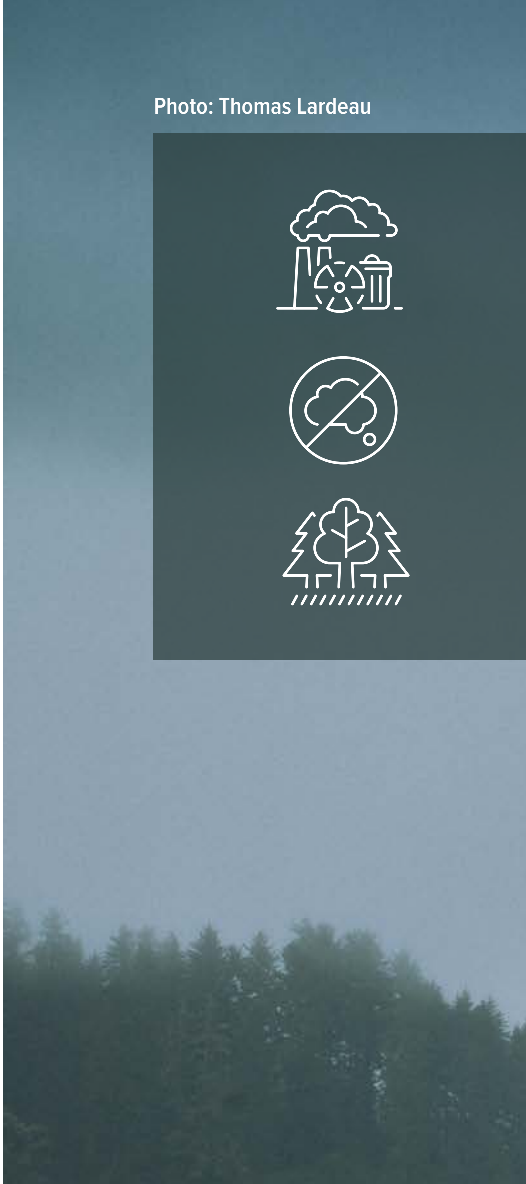


Photo: Thomas Lardeau

REMOVING EXCESS CO_2 FROM THE ATMOSPHERE POST 2050

Carbon sequestration refers to the ability of nature to capture CO_2 from the atmosphere. To attain the Paris Agreement goals*, approximately 730 Gt of CO_2, equivalent to all of the CO_2 emitted by the U.S.A., UK, Germany, and China combined since the industrial revolution, must be removed from the atmosphere by the end of the 21st Century[116]. While technological solutions to CO_2 removal have been suggested, none are currently operational on the scale and timeframe required. Protecting the ability of ecosystems to sequester CO_2 will become increasingly important post 2050, as the focus turns to removing excess CO_2 from the atmosphere. A global analysis of the ability of ecosystems to sequester CO_2 is provided in Figure 5[117]. Many of these ecosystems are found in Canada.

---

* The Paris Agreement, under the United Nations Framework Convention on Climate Change, commits signatories to "Holding the increase in global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change".


Photo: Mathieu Deslauriers

Photo: Yongwook Seong

GLOBAL CARBON SEQUESTRATION POTENTIAL FOR KEY ECOSYSTEMS (Mt CO_2/YEAR)

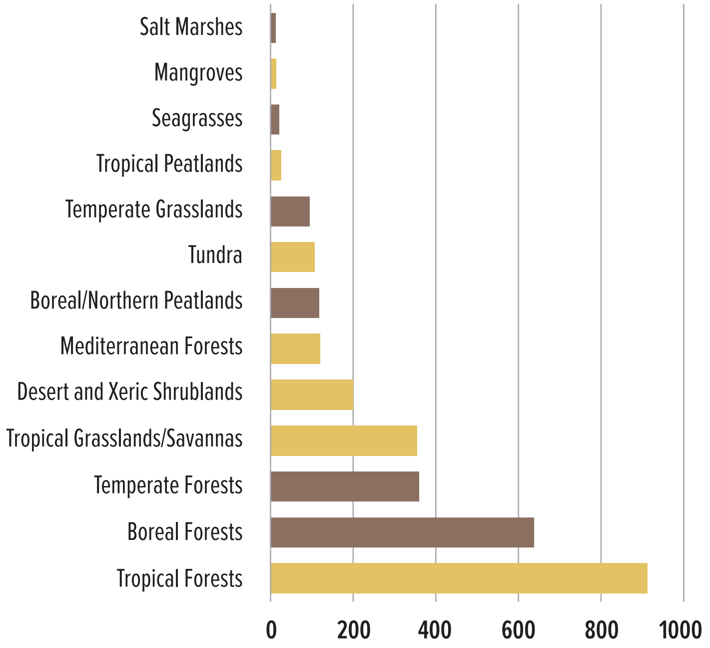


Figure 5. The estimated values of carbon sequestration for different ecosystems is derived from Taillardat et al 2018[117], supplementary material. Canadian ecosystems that can contribute to carbon sequestration, through protection, are identified in brown. They include saltmarshes, seagrasses, temperate grasslands, boreal/temperate peatlands, temperate forests and boreal forests.

Canada is home to some of the most carbon-dense ecosystems in the world. Remaining primary boreal and temperate forests, northern peatlands, ancient grasslands, and coastal marine ecosystems can make a significant contribution to attaining GHG emissions targets if an emphasis on "protecting what we have" is pursued. Canada's carbon-dense ecosystems are poorly represented in its protected areas.

CONCLUSIONS

1. Canada has recognized the importance of nature-based climate solutions (NBCS) as a contribution to climate change mitigation and adaptation. However, there needs to be greater emphasis on the specific role of protected areas in preventing the release of stored carbon, maintaining the ability of ecosystems to sequester CO_2 from the atmosphere, ensuring the permanence of restored areas, and realizing the benefits for biodiversity, water and food security, and other ecosystem services.

2. Canada's recent support to Indigenous people for the creation and management of IPCAs and Indigenous-led nature climate solutions should be expanded.*

3. Canada's focus on restoration as a NBCS provides long term benefits, post 2050. However, protecting areas where carbon density overlaps with areas of high importance to biodiversity will have more immediate results (by 2030) for both climate change and biodiversity.

4. The best NBCS strategy is to protect what we have, restore what is damaged, then protect what is restored, in that order. Where restoration is funded as a NBCS, protection of what is restored will ensure the long-term benefits from the investment.

5. The concept of NBCS is centered on multiple benefits from the same investment. Canada, like most countries, traditionally focussed its protected area efforts on the conservation of biodiversity. Shifting the focus, in at least some cases, to include protection of the carbon-dense/high biodiversity ecosystems identified here will provide benefits for climate change mitigation and adaptation as well as biodiversity conservation, human health and well-being, food security and recreational opportunities. This includes both terrestrial and marine protected areas.

6. It is important to ensure that criteria for existing federal NBCS funding opportunities incentivize proactive establishment and management of carbon-dense/high biodiversity protected areas, whether or not they are currently threatened. In some cases, these could be framed as carbon stabilization areas that would protect the carbon stores that have accumulated, sometimes over centuries, and the ability of these ecosystems to continue to sequester carbon from the atmosphere[8].

---

* For instance, the Nature-Smart Climate Solutions Fund (NSCSF) is a 10-year initiative launched by Environment and Climate Change Canada in 2020. It allocates $76.9 million to support Indigenous communities and organizations to lead in natural climate solutions, strengthening such initiatives enhances Indigenous-led conservation and promotes reconciliation.

Photo: Rye Jessen

CONCLUSIONS

7. Some gaps in analysis, at national and regional levels, need to be addressed to support decision-making on the locations of new protected areas and management of existing protected areas, so that the ability of ecosystems to store and sequester carbon is maintained. This includes national and regional maps of the overlap between carbon-density and biodiversity, best locations for ecological corridors, identification of climate refugia on land and in the coastal area, improved analysis of the extent and role of Canada's blue carbon ecosystems, the coverage of protected areas in Canada's most productive old-growth forests, blue carbon ecosystems, peatlands, and ancient grasslands. All gap analyses should include overlays with Indigenous territories.

8. While restoration is generally focused on damaged ecosystems, investments in restoration of carbon-dense ecosystems within protected areas is also needed.

9. Tools to support the creation of MPAs that address the overlap between carbon-density and biodiversity are particularly needed. Areas in need of investments include: mapping the remaining saltmarshes and eelgrass beds as well as mapping the biodiversity/carbon-density overlay in marine areas; quantifying the carbon stored in and sequestered by Canada's coastal marine systems, including in their sediment; identifying key marine areas for biodiversity; and identifying the relationship between carbon and biodiversity in the marine realm.

10. The gaps in knowledge on carbon stores in marine sediments need to be filled, particularly so that hot spots for carbon storage on the sea floor can be identified and protected from development.

11. Proactive assessments of areas that do not appear to be under imminent threat, but are particularly important for carbon and biodiversity, have largely been ignored. Protecting these areas now, before development pressure intensifies, will ensure better identification of areas appropriate for development and areas that should be more tightly regulated.

REFERENCES CITED

1 Canadian Council of Academies. Nature-Based Climate Solutions: The Expert Panel on Canada's Carbon Sink Potential. (Ottawa, Canada, 2022).https://cca-reports.ca/reports/canadas-carbon-sink-potential/

2 Seddon, N. ***et al.*** Getting the message right on nature-based solutions to climate change. *Global Change Biology* **n/a**, doi:https://doi.org/10.1111/gcb.15513 (2021).

3 Cook-Patton, S. C. *et al.* Mapping carbon accumulation potential from global natural forest regrowth. *Nature* **585**, 545-550, doi:https://doi.org/10.1038/s41586-020-2686-x (2020).

4 Nabuurs, G.-J. *et al.* in *IPCC Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Vol. Chapter 7 (eds P.R. Shukla *et al.*) (Cambridge University Press, 2022). IPCC 6th Assessment chapter 7

5 Pörtner, H. O. ***et al.*** IPBES-IPCC Co-sponsored workshop report on biodiversity and climate chanage. (Bonn, Germany, 2021).https://zenodo.org/record/5101133

6 Milner-Gulland, E. *et al.* Four steps for the earth: mainstreaming the post-2020 global biodiversity framework. *One Earth* **4**, 75-87, doi:https://doi.org/10.1016/j.oneear.2020.12.011 (2021).

7 Girardin, C. A. J. *et al.* Nature-based solutions can help cool the planet—if we act now. *Nature* **593**, 191-194, doi:https://doi.org/10.1038/d41586-021-01241-2 (2021).

8 Dinerstein, E. *et al.* A Global Deal For Nature: Guiding principles, milestones, and targets. *Science Advances* **5**, doi:https://doi.org/10.1126/sciadv.aaw2869 (2019).

9 Smyth, C. E., Xu, Z., Lempriere, T. C. & Kurz, W. A. Climate change mitigation in British Columbia's forest sector: GHG reductions, costs, and environmental impacts. *Carbon Balance Manag* **15**, 21, http://doi.org/10.1186/s13021-020-00155-2 (2020).

10 Strassburg, B. B. N. *et al.* Global congruence of carbon storage and biodiversity in terrestrial ecosystems. *Conservation Letters* **3**, 98-105, https://doi.org/10.1111/j.1755-263X.2009.00092.x (2010).

11 Roe, S. *et al.* Contribution of the land sector to a 1.5° C world. *Nature Climate Change*, 1-12, doi:https://doi.org/10.1038/s41558-019-0591-9 (2019).

12 Griscom, B. W. *et al.* Natural climate solutions. *Proceedings of the National Academy of Sciences* **114**, 11645-11650, https://doi.org/10.1073/pnas.1710465114 (2017).

13 IPCC. in *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assesment Report of the Intergovernmental Panel on Climate Change* (eds P.R. Shukla *et al.*) https://doi.org/10.1017/9781009157926.001 (Cambridge University Press, 2022).

14 Hayashi, M., Van Der Kamp, G. & Rudolph, D. L. Water and solute transfer between a prairie wetland and adjacent uplands, 1. Water balance. *Journal of Hydrology* **207**, 42-55 https://doi.org/10.1016/S0022-1694(98)00098-5 (1998).

15 Graham, V. *et al.* Southeast Asian protected areas are effective in conserving forest cover and forest carbon stocks compared to unprotected areas. *Sci Rep* **11**, 23760, doi:https://doi.org/10.1038/s41598-021-03188-w (2021).

16 ECCC. Greenhouse gas sources and sinks in Canada: Executive Summary 2022. (Ottawa, Canada, 2022) https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2022.html.

17 ECCC. National Inventory Report 1990-2021: Greenhouse Gas sources and sinks in Canada, Executive Summary. (Ottawa, Canada, 2023) https://canada.ca/ghg-inventory.

18 Black, K. & McBean, E. Increased Indigenous participation in environmental decision-making: A policy analysis for the improvement of Indigenous health. *International Indigenous Policy Journal* **7**, doi:https://doi.org/10.18584/iipj.2016.7.4.5 (2016).

19 Dietz, S. *et al.* Emerging Issues for Protected and Conserved Areas in Canada. *Facets*, https://doi.org/10.17863/CAM.76711 (2021).

20 Dohan, R. & Voora, V. First Nations Carbon Collaborative - Indigenous Peoples and Carbon Markets: An annotated Bibliography. (Winnipeg, Canada, 2010).

21 Indigenous Circle of Experts. We Rise Together. Achieving pathway to Canada Target 1 through the creation of Indigenous protected and conserved areas in the spirit and practice of reconciliation., 1-112 (Ottawa, Canada, 2018).

22 Garnett, S. T. *et al.* A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability* **1**, 369, doi:https://doi.org/10.1038/s41893-018-0100-6 (2018).

23 Artelle, K. A. *et al.* Supporting resurgent Indigenous-led governance: A nascent mechanism for just and effective conservation. *Biological Conservation* **240**, 108284, doi:https://doi.org/10.1016/j.biocon.2019.108284 (2019).

24 Zurba, M., F. Beazley, K., English, E. & Buchmann-Duck, J. Indigenous protected and conserved areas (IPCAs), Aichi Target 11 and Canada's Pathway to Target 1: Focusing conservation on reconciliation. *Land* **8**, 10, doi:https://doi.org/10.3390/land8010010 (2019).

25 ICE. *We Rise Together* (Ottawa, Canada, 2018).

26 Sreekar, R. *et al.* Nature-based climate solutions for expanding the global protected area network. *Biological Conservation* **269**, doi:https://doi.org/10.1016/j.biocon.2022.109529 (2022).

27 Jankowska, E., Pelc, R., Alvarez, J., Mehra, M. & Frischmann, C. J. Climate benefits from establishing marine protected areas targeted at blue carbon solutions. *Proceedings of the National Academy of Sciences* **119**, e2121705119, doi:https://doi.org/10.1073/pnas.2121705119 (2022).

28 Bossio, D. A. *et al.* The role of soil carbon in natural climate solutions. *Nature Sustainability* **3**, 391-398, doi:https://doi.org/10.1038/s41893-020-0491-z (2020).

29 UNEP. Emissions Gap Report: The Closing WIndow - Climate crisis calls for rapid transformation of societies. (Nairobi, Kenya, 2022).

30 EPA. Climate Change Indicators in the United States: Global Greenhouse Gas Emissions. (www.epa.gov/climate-indicators, 2016)

31 Drever, C. R. *et al.* Natural climate solutions for Canada. Supplementary Material. *Science Advances* **7**, doi:https://www.doi.org/10.1126/sciadv.abd6034 (2021).

32 Smith, R. Enhancing Canada's Climate Change Ambitions with Natural Climate Solutions. Report No. 978-1-7773950-0-1, (Canada, 2020).https://www.researchgate.net/publication/344754536_Enhancing_Canada's_Climate_Change_Ambitions_with_Natural_Climate_Solutions

33 Hisey, F., Heppner, M. & Olive, A. Supporting native grasslands in Canada: Lessons learned and future management of the Prairie Pastures Conservation Area (PPCA) in Saskatchewan. *The Canadian Geographer/Le Géographe canadien* **66**, 683-695, doi:https://doi.org/10.1111/cag.12768 (2022).

34 Harris, L. I. *et al.* The essential carbon service provided by northern peatlands. *Frontiers in Ecology and the Environment* **20**, 222-230 https://doi.org/10.1002/fee.2437 (2022).

35 UN Convention on Biological Diversity. Kunming-Montreal Global Biodiversity Framework. (CBD, Montreal, Canada, 2022, December 18).

36 Protected Planet. Marine Protected Areas. (Cambridge, UK, 2023).

37 Fisheries and Oceans Canada. Canada's marine protected and conserved areas. (Ottawa, Canada, 2023).

38 Redford, K. H. The Empty Forest: Many large animals are already ecologically extinct in vast areas of neotropical forest where the vegetation still appears intact. *BioScience* **42**, 412-422, doi:http://doi.org/10.2307/1311860 (1992).

39 Zeng, Y., Koh, L. P. & Wilcove, D. S. Gains in biodiversity conservation and ecosystem services from the expansion of the planet's protected areas. *Science Advances* **8**, doi:https://doi.org/10.1126/sciadv.abl9885 (2022).

REFERENCES CITED

40 Hutto, S. H., Hohman, R. & Tezak, S. Blue carbon in marine protected areas: Part 2. A Blue Carbon Assessment of Greater Farallones National Marine Sanctuary. (Washington, USA, 2021).

41 Zarate-Barrera, T. G. & Maldonado, J. H. Valuing Blue Carbon: Carbon Sequestration Benefits Provided by the Marine Protected Areas in Colombia. *PLOS ONE* **10**, e0126627, doi:https://doi.org/10.1371/journal.pone.0126627 (2015).

42 Burrows, M. T. *et al.* Assessment of carbon capture and storage in natural systems within the English North Sea (Including within Marine Protected Areas). (Scotland, 2021).

43 Pörtner, H.-O. *et al.* WGII contribution to the IPCC Sixth Assessment Report (AR6), climate change 2022: Impacts, adaptation and vulnerability; Summary for policymakers. (Switzerland, 2022).

44 Xu, X., Huang, A., Belle, E., De Frenne, P. & Jia, G. Protected areas provide thermal buffer against climate change. *Science Advances* **8**, eabo0119, doi:https://doi.org/10.1126/sciadv.abo0119 (2022).

45 Wang, W., Wu, W., Guo, F. & Wang, G. Fire regime and management in Canada's protected areas. *International Journal of Geoheritage and Parks*, doi:https://doi.org/10.1016/j.ijgeop.2022.04.003 (2022).

46 Hilty, J. *et al.* Guidelines for conserving connectivity through ecological networks and corridors. (Gland, Switzerland, 2020).

47 Lehikoinen, P. *et al.* Increasing protected area coverage mitigates climate-driven community changes. *Biological Conservation* **253**, 108892, doi:https://doi.org/10.1016/j.biocon.2020.108892 (2021).

48 MacKinnon, K. *et al.* Strengthening the Global System of Protected Areas post 2020: A Perspective from the IUCN World Commission on Protected Areas. *Parks Stewardship Forum* **36**, doi:https://doi.org/10.5070/P536248273 (2020).

49 Gillingham, P. K., Alison, J., Roy, D. B., Fox, R. & Thomas, C. D. High abundances of species in protected areas in parts of their geographic distributions colonized during a recent period of climatic change. *Conservation Letters* **8**, 97-106 (2015).

50 Saura, S. *et al.* Global trends in protected area connectivity from 2010 to 2018. *Biological Conservation* **238**, 108183, doi:https://doi.org/10.1016/j.biocon.2019.07.028 (2019).

51 Soto-Navarro, C. *et al.* Mapping co-benefits for carbon storage and biodiversity to inform conservation policy and action. *Philosophical Transactions of the Royal Society B: Biological Sciences* **375**, 20190128, doi:https://doi.org/10.1098/rstb.2019.0128 (2020).

52 Martin, T. G. & Watson, J. E. M. Intact ecosystems provide best defence against climate change. *Nature Climate Change* **6**, 122, doi:https://doi.org/10.1038/nclimate2918 (2016).

53 Duarte, C. M., Middelburg, J. J. & Caraco, N. Major role of marine vegetation in the oceanic carbon cycle. *Biogeosciences* **2**, 1-8, doi:https://doi.org/10.5194/bg-2-1-2005 (2005).

54 Watson, J. E. M. *et al.* The exceptional value of intact forest ecosystems. *Nature Ecology & Evolution* **2**, 599-610, doi:http://doi.org/10.1038/s41559-018-0490-x (2018).

55 Mitchell, M. G. *et al.* Identifying key ecosystem service providing areas to inform national-scale conservation planning. *Environmental Research Letters* **16**, 014038, doi:https://doi.org/10.1088/1748-9326/abc121 (2021).

56 Wulder, M. A., Cardille, J. A., White, J. C. & Rayfield, B. Context and opportunities for expanding protected areas in Canada. *Land* **7**, 137, doi:https://doi.org/10.3390/land7040137 (2018).

57 Price, K., Holt, R. F. & Daust, D. Conflicting portrayals of remaining old growth: the British Columbia case. *Canadian Journal of Forest Research* **51**, 742-752, doi:https://dx.doi.org/10.1139/cjfr-2020-0453 (2021).

58 Abraham, K. F. & McKinnon, L. M. Hudson Plains Ecozone+ evidence for key findings summary. vi + 98pp (Ottawa, ON, 2011).

59 Bergeron, Y. & Fenton, N. J. Boreal forests of eastern Canada revisited: Old growth, nonfire disturbances, forest succession, and biodiversity. *Botany* **90**, 509-523, doi:http://doi.org/10.1139/b2012-034 (2012).

60 Packalen, M. S., Finkelstein, S. A. & McLaughlin, J. W. Carbon storage and potential methane production in the Hudson Bay Lowlands since mid-Holocene peat initiation. *Nat Commun* **5**, 4078, doi:https://doi.org/10.1038/ncomms5078 (2014).

61 Opperman, J. J. *et al.* Safeguarding free-flowing rivers: the global extent of free-flowing rivers in protected areas. *Sustainability* **13**, 2805, doi:https://doi.org/10.3390/su13052805 (2021).

62 CEC. *North America's Blue Carbon: Assessing Seagrass, Salt Marsh and Mangrove Distribution and Carbon Sinks*. (Commission for Environmental Cooperation, 2016).

63 Sothe, C. *et al.* Large soil carbon storage in terrestrial ecosystems of Canada. *Global Biogeochemical Cycles*, doi:https://doi.org/10.1029/2021GB007213 (2022).

64 Chmura, G. L. & Van Ardenne, L. B. The Bay of Fundy Blue Carbon Story. (Montreal, QC, 2018).

65 Chastain, S. G., Kohfeld, K. E., Pellatt, M. G., Olid, C. & Gailis, M. Quantification of blue carbon in salt marshes of the Pacific coast of Canada. *Biogeosciences* **19**, 5751-5777 (2022).

66 Douglas, T. J., Schuerholz, G. & Juniper, S. K. Blue carbon storage in a northern temperate estuary subject to habitat loss and chronic habitat disturbance: Cowichan Estuary, British Columbia, Canada; Supplementary material. *Frontiers in Marine Science* **9**, doi:https://doi.org/10.3389/fmars.2022.857586 (2022).

67 Gauthier, S., Bernier, P., Kuuluvainen, T., Shvidenko, A. Z. & Schepaschenko, D. G. Boreal forest health and global change. *Science* **349**, 819-822 (2015).

68 Morales-Hidalgo, D., Oswalt, S. N. & Somanathan, E. Status and trends in global primary forest, protected areas, and areas designated for conservation of biodiversity from the Global Forest Resources Assessment 2015. *Forest Ecology and Management* **352**, 68-77, doi:https://doi.org/10.1016/j.foreco.2015.06.011 (2015).

69 Goldstein, A. *et al.* Protecting irrecoverable carbon in Earth's ecosystems. *Nature Climate Change* **10**, 287-295, doi:https://doi.org/10.1038/s41558-020-0738-8 (2020).

70 Bradshaw, C. J. & Warkentin, I. G. Global estimates of boreal forest carbon stocks and flux. *Global and Planetary Change* **128**, 24-30, doi:https://doi.org/10.1016/j.gloplacha.2015.02.004 (2015).

71 Noon, M. L. *et al.* Mapping the irrecoverable carbon in Earth's ecosystems. *Nature Sustainability*, doi:https://doi.org/10.1038/s41893-021-00803-6 (2021).

72 Wells, J. V., Dawson, N., Culver, N., Reid, F. A. & Siegers, S. M. The State of Conservation in North America's Boreal Forest: Issues and Opportunities. *Frontiers in Forests and Global Change* **3**, doi:https://doi.org/10.3389/ffgc.2020.00090 (2020).

73 Global Forest Watch. (Conservation Biology Institute, 2013).

74 DellaSala, D. A. *et al.* Estimating carbon stocks and stock changes in Interior Wetbelt forests of British Columbia, Canada. *Ecosphere* **13**, doi:https://doi.org/10.1002/ecs2.4020 (2022).

75 Fredeen, A. L., Bois, C. H., Janzen, D. T. & Sanborn, P. T. Comparison of coniferous forest carbon stocks between old-growth and young second-growth forests on two soil types in central British Columbia, Canada. *Canadian Journal of Forest Research* **35**, 1411-1421, doi:https://doi.org/10.1139/x05-074 (2005).

76 Navarrete-Segueda, A., Martínez-Ramos, M., Ibarra-Manríquez, G., Vázquez-Selem, L. & Siebe, C. Variation of main terrestrial carbon stocks at the landscape-scale are shaped by soil in a tropical rainforest. *Geoderma* **313**, 57-68 (2018).

77 Gilhen-Baker, M., Roviello, V., Beresford-Kroeger, D. & Roviello, G. N. Old growth forests and large old trees as critical organisms connecting ecosystems and human health. A review. *Environmental Chemistry Letters*, 1529-1538, doi:https://doi.org/10.1007/s10311-021-01372-y (2022).

78 Odum, E. P. The strategy of ecosystem development. *Science* **164**, 262-279, doi:https://doi.org/10.1126/science.164.3877.262 (1969).

REFERENCES CITED

79 Yang, Z. j. *et al.* A culture of conservation: How an ancient forest plantation turned into an old-growth forest reserve – The story of the Wamulin forest. *People and Nature* **3**, 1014-1024, doi:https://doi.org/10.1002/pan3.10248 (2021).

80 Fauset, S. *et al.* Hyperdominance in Amazonian forest carbon cycling. *Nature communications* **6**, 1-9, doi:https://doi.org/10.1038/ncomms7857 | www.nature.com/naturecommunications (2015).

81 Gray, A. N., Whittier, T. R. & Harmon, M. E. Carbon stocks and accumulation rates in Pacific Northwest forests: role of stand age, plant community, and productivity. *Ecosphere* **7**, e01224, doi:https://doi.org/10.1002/ecs2.1224 (2016).

82 Hudiburg, T. W., Law, B. E., Moomaw, W. R., Harmon, M. E. & Stenzel, J. E. Meeting GHG reduction targets requires accounting for all forest sector emissions. *Environmental Research Letters* **14**, 095005, doi:https://doi.org/10.1088/1748-9326/ab28bb (2019).

83 Sothe, C. *et al.* Large soil carbon storage in terrestrial ecosystems of Canada. *Global Biogeochemical Cycles*, doi:https://doi.org/10.1002/essoar.10507117.2 (2021).

84 Schulze, E.-D. *et al.* in *Old-Growth Forests* 343-366 (Springer, 2009).

85 Lutz, J. A. *et al.* Global importance of large-diameter trees. *Global Ecology and Biogeography* **27**, 849-864, doi:https://doi.org/10.1111/geb.12747 (2018).

86 Meakem, V. *et al.* Role of tree size in moist tropical forest carbon cycling and water deficit responses. *New Phytologist* **219**, 947-958, doi:https://doi.org/10.1111/nph.14633 (2018).

87 Lewis, S. L., Wheeler, C. E., Mitchard, E. T. A. & Koch, A. Restoring natural forests is the best way to remove atmospheric carbon. *Nature* **568**, 25-28 (2019).

88 Waring, B. There aren't enough trees in the world to offset society's carbon emissions - and there never will be. *The Conversation* (2021).

89 Waring, B. *et al.* Forests and decarbonization; Roles of natural and planted forests. *Frontiers in Forests and Global Change* **3**, doi:10.3389/ffgc.2020.00058 (2020).

90 Böttcher, H. & Lindner, M. in *Ecosystem goods and services from plantation forests* (eds Jurgen Bauhus, Peter van der Meer, & Markku Kanninen) Ch. 3, 43-76 (Earthscan, 2010).

91 Schulze, E.-D., Wirth, C. & Heimann, M. Managing forests after Kyoto. *Science* **289**, 2058-2059, doi:https://doi.org/10.1126/science.289.5487.2058 (2000).

92 Kurz, W. A., Beukema, S. J. & Apps, M. J. Carbon budget implications of the transition from natural to managed disturbance regimes in forest landscapes. *Mitigation and Adaptation Strategies for Global Change* **2**, 405-421 (1998).

93 Wilson, S. J. & Hebda, R. J. Mitigating and adapting to climate change through the conservation of nature. (Victoria, Canada, 2008).

94 Luyssaert, S. *et al.* Reply to: Old-growth forest carbon sinks overestimated. *Nature* **591**, E24-E25, doi:https://doi.org/10.1038/s41586-021-03267-y (2021).

95 Luyssaert, S. *et al.* Old-growth forests as global carbon sinks. *Nature* **455**, 213, doi:https://doi.org/10.1038/nature07276 https://www.nature.com/articles/nature07276#supplementary-information (2008).

96 Gundersen, P. *et al.* Old-growth forest carbon sinks overestimated. *Nature* **591**, E21-E23, doi:http://doi.org/10.1038/s41586-021-03266-z (2021).

97 Harris, L. *et al.* The essential carbon services provided by northern peatlands. *Frontiers in Ecology and Environment* (2021).

98 Abraham, K. F. *et al. Hudson Plains Ecozone+ Status and Trends Assessment.* (Canadian Councils of Resource Ministers, 2011).

99 Buisson, E., Archibald, S., Fidelis, A. & Suding, K. N. Ancient grasslands guide ambitious goals in grassland restoration. *Science* **377**, 594-598, doi:https://doi.org/10.1126/science.abo4605 (2022).

100 Wang, X., VandenBygaart, A. J. & McConkey, B. C. Land management history of Canadian grasslands and the impact on soil carbon storage. *Rangeland Ecology & Management* **67**, 333-343, doi:http://dx.doi.org/10.2111/REM-D-14-00006.1 (2014).

101 North American Bird Conservation Initiative Canada. (Ottawa, Canada, 2019).

102 Jones, K. R. *et al.* The location and protection status of Earth's diminishing marine wilderness. *Current Biology* **28**, 2506-2512. e2503 (2018).

103 CAFF & PAME. Arctic Protected Areas: Indicator Report 2017. (Akureyri, Iceland, 2017).

104 Govt of Canada. *Marine Protected Areas Across Canada*, <https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/index-eng.html> (2020).

105 Howard, J. *et al.* The potential to integrate blue carbon into MPA design and management. *Aquatic Conservation: Marine and Freshwater Ecosystems* **27 (S1)**, 100-115, doi:https://doi.org/10.1002/aqc.2809 (2017).

106 Drever, C. R. *et al.* Natural climate solutions for Canada. *Science Advances* **7**, eabd6034, doi:https://www.doi.org/10.1126/sciadv.abd6034 (2021).

107 Thomas, T. *et al.* Blue Carbon and Nationally Determined Contributions: Guildelines on Enhanced Action. 48pp (The Blue Carbon Initiative, 2020).

108 Saderne, V. *et al.* Role of carbonate burial in Blue Carbon budgets. *Nat Commun* **10**, 1106, doi:http://doi.org/10.1038/s41467-019-08842-6 (2019).

109 Roberts, C. M. *et al.* Marine reserves can mitigate and promote adaptation to climate change. *Proc Natl Acad Sci U S A* **114**, 6167-6175, doi:https://doi.org/10.1073/pnas.1701262114 (2017).

110 van Ardenne, L. B., Jolicouer, S., Bérubé, D., Burdick, D. & Chmura, G. L. The importance of geomorphic context for estimating the carbon stock of salt marshes. *Geoderma* **330**, 264-275, doi:10.1016/j.geoderma.2018.06.003 (2018).

111 Statistics Canada. Salt Marshes in Canada. (Ottawa, Canada, 2022).

112 Mazarrasa, I. *et al.* Factors determining seagrass Blue Carbon across bioregions and geomorphologies. *Global Biogeochemical Cycles* **35**, e2021GB006935, doi:https://doi.org/10.1029/2021GB006935 (2021).

113 Duarte, C. M. Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. *Biogeosciences* **14**, 301-310, doi:https://doi.org/10.5194/bg-14-301-2017 (2017).

114 Duarte, C. M., Losada, I. J., Mazarrasa, I., Hendriks, I. E. & Marbà, N. The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change* **3**, 961-968, doi:http://www.nature.com/doifinder/10.1038/nclimate1970 (2013).

115 Kennedy, H., Alongi, D. M. & Karim, A. Chapter 4: Coastal Wetlands. (Switzerland, 2014).

116 IPCC. in *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (eds V. Masson-Delmotte *et al.*) 1-26 (World Meteorological Organization, 2018).

117 Taillardat, P., Friess, D. A. & Lupascu, M. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. *Biology Letters* **14**, 20180251, doi:http://dx.doi.org/10.1098/rsbl.2018.0251 (2018).

CPAWS
CANADIAN PARKS AND WILDERNESS SOCIETY

Photos:
Tidal rocks: Vlad D.
Mushrooms: Jesse Bauer
Sea ice: Isaac Demeester