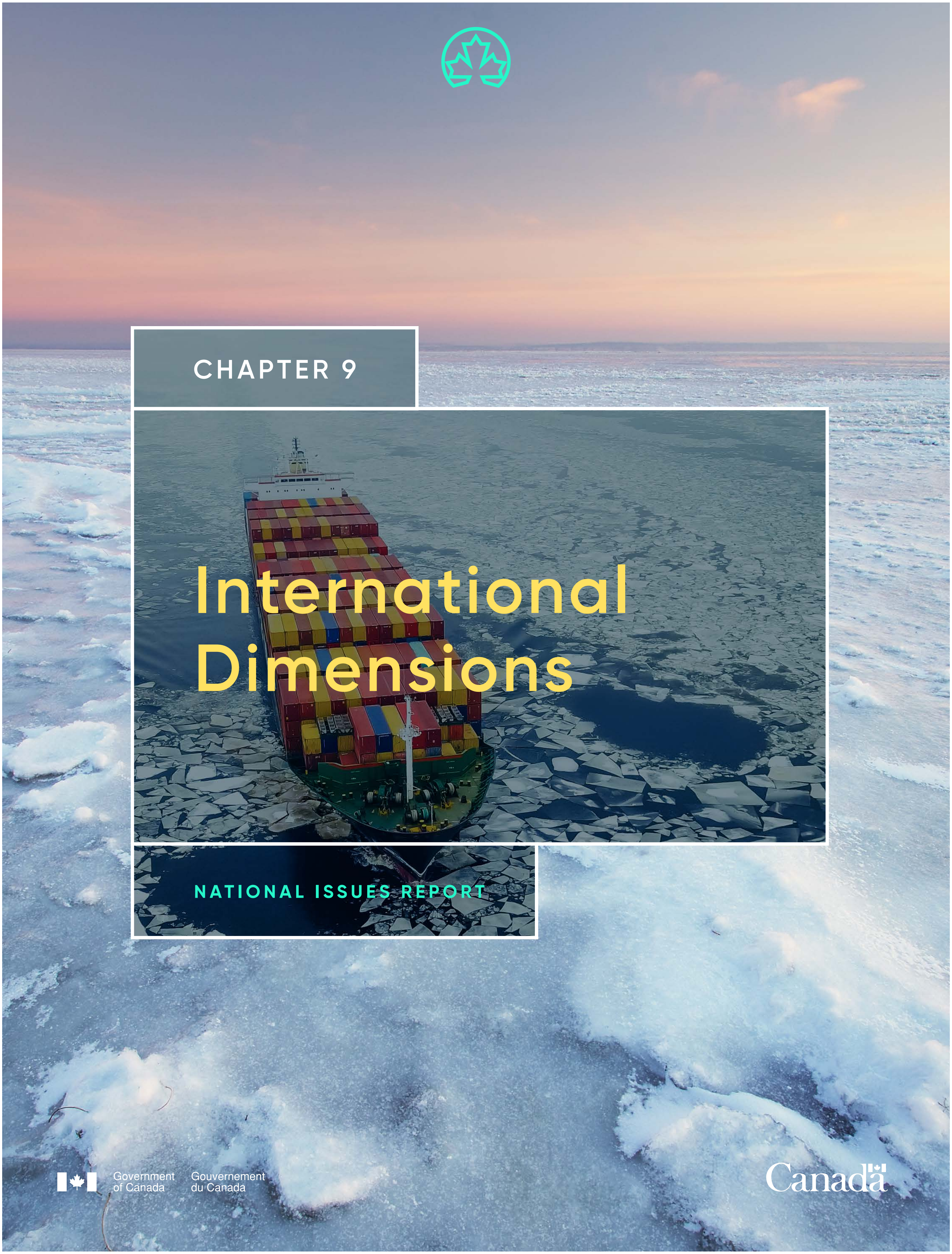

CHAPTER 9

International Dimensions

NATIONAL ISSUES REPORT

Government of Canada Gouvernement du Canada

Canada

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Key messages

Climate change affects Arctic shipping and threatens sovereignty (*see* Section 9.2)

Shrinking sea ice resulting from climate change allows for increased marine traffic in the Arctic Ocean, including through the Northwest Passage (NWP). Climate change and its impacts underscore the need to strengthen rules and capacities for demonstrating Canada's effective stewardship of the NWP and ensuring safe, secure and sustainable navigation as the ice melts.

Transboundary marine and freshwater agreements generally do not consider climate change (*see* Section 9.3)

Canada's transboundary marine and freshwater agreements were not created with climate change in mind. In collaboration with international partners, Canada has an opportunity to show leadership in preserving long-term cooperation and protecting shared resources by building on adaptive practices recognized as successful.

Climate change presents risks and opportunities for international trade (*see* Section 9.4)

Canada is dependent on international trade and will increasingly experience economic effects from extreme weather and climate change impacts and adaptation elsewhere in the world, especially when occurring in countries with which Canada has strong trade ties.

Climate-related human migration and displacement will increase demands for immigration to Canada (*see* Section 9.5)

Tropical cyclones, floods, droughts, wildfires and food insecurity displace millions of people each year. Climate change will generate growing numbers of migrants by mid- to late century, especially in Least Developed Countries in sub-Saharan Africa, Asia, and Latin America and the Caribbean. Canada will come under growing internal and external pressure to accept larger numbers of migrants from climate-disrupted regions.

Increased demand for international assistance is expected (*see* Section 9.6)

Climate change can undermine human security in developing countries and increase demands for Canadian international assistance. Canada is addressing climate risk to development and humanitarian goals by providing financial and technical assistance for adaptation and climate resilience.

9.1 Introduction

This chapter assesses the risks and opportunities facing Canada from indirect impacts of climate change and discusses action taken to assess and manage them. It focuses on Arctic shipping and sovereignty over the Northwest Passage, transboundary resource management, international trade, climate-related human migration and displacement, as well as Canada's role in supporting climate risk reduction and adaptation through international assistance. The impacts of climate change and variability do not stop at national borders; they interact with social processes, structures and institutions that can amplify, spread or dampen risk (Moser and Hart, 2015). These pathways of impact include biophysical flows (e.g., freshwater resource sharing), trade and flows of finance and people (Stockholm Environment Institute, 2013). Actions taken to adapt to climate change can also have ramifications beyond the areas targeted for implementation (Stockholm Environment Institute, 2018). Therefore, it is important to explore vulnerabilities and impacts originating outside of Canada's borders, as well as international dimensions of trends and events occurring in Canada, even though they are rarely accounted for in climate change assessments and adaptation planning (Challinor et al., 2017; Moser and Hart, 2015).

The scope of international dimensions of climate change and adaptation is vast, including transboundary, teleconnected and cascading effects (Benzie and Persson, 2019). Transboundary effects spread between neighbouring countries. Teleconnected effects spread through linkages over large distances. Cascading effects result from an initial hazard that generates a sequence of interacting impacts and responses. Figure 9.1 illustrates some of the indirect climate change impacts for Canada and related policy responses. Despite a growing awareness of the risks to a country from the observed and projected impacts of climate change globally, particularly in relation to national security (Canadian Forces College, 2018), the potential consequences for Canada remain poorly understood.

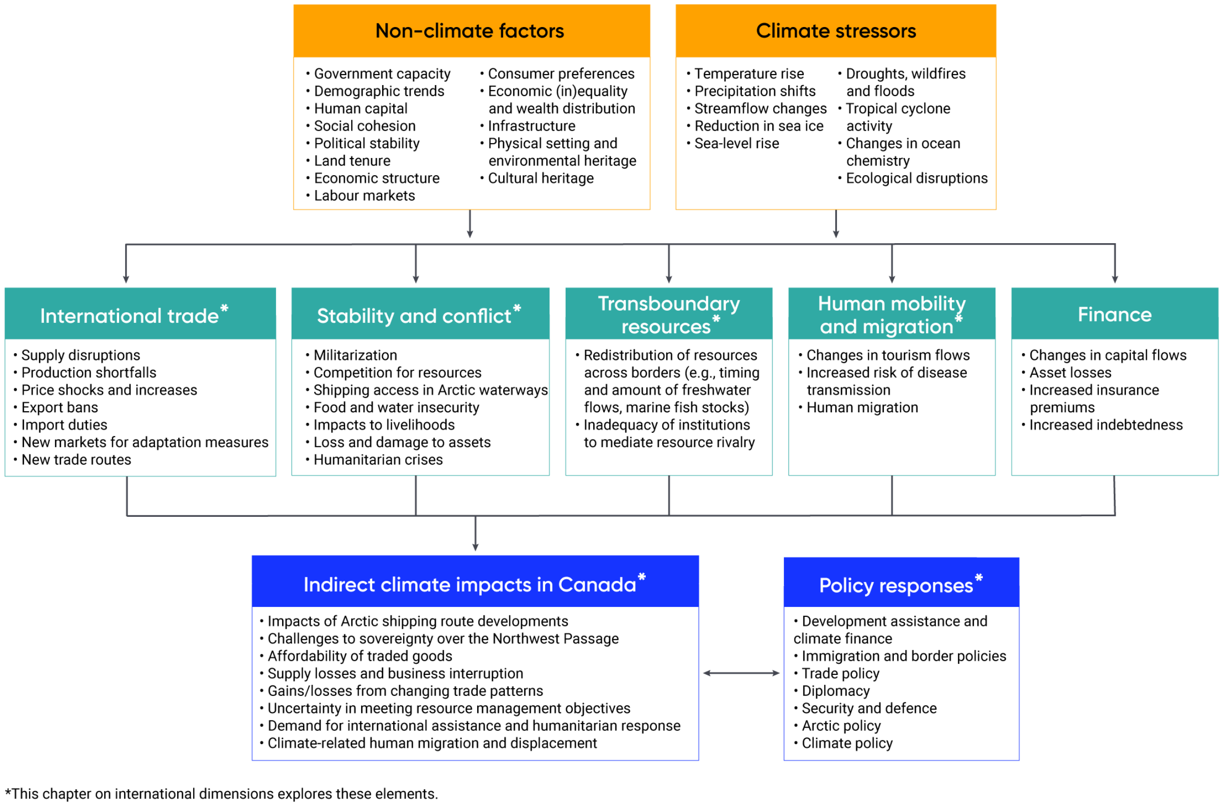


Figure 9.1: Examples of Canada's exposure to indirect impacts of climate change with international dimensions. Source: Adapted from Hildén et al., 2020.

This chapter draws from several sources of published literature to explore select indirect climate impacts for Canada, representing a mix of transmission mechanisms, scales of impact and opportunities for adaptation. The chapter starts by describing the risks to Canada from increased foreign shipping and transportation in Canada's Arctic waterways, focusing on the Northwest Passage and Canada's sovereign claims thereto. It then examines the capacity of transboundary marine and freshwater agreements to adapt to the increased uncertainties posed by rapidly changing climate and hydrologic and ocean conditions, contrasting agreements in place between countries or governing marine basins with adaptive best practices. For both Arctic shipping and sovereignty and transboundary resource management, climate change adaptation includes actions to promote environmental stewardship, preserve long-term cooperation and recognize the unique roles of Indigenous people. The chapter then explores economic risks and opportunities for Canada from climate-related disruptions to supply chains and distribution networks and from shifting patterns of global trade in response to climate impacts. Adaptation in this context not only focuses on protecting Canada's economic interests, but also acknowledges the negative effects of long-term adjustments in trade for communities beyond Canada's borders. The final two sections relate to Canada's capacity and will to engage on the global stage in stemming instability and conflict in climate-vulnerable regions of the world. After describing the links between climate and human migration, as well as climate and human security, the chapter assesses the implications of climate change on demands for immigration, refugee resettlement and international assistance programming in Canada.

The chapter concludes by identifying knowledge gaps and emerging issues that cut across impact areas. Further attention on adaptation governance in the context of cross-border risks, as well as Canada's role in strengthening the climate resilience of global food systems are two emerging issues. The need for increased use of assessment tools that address the methodological challenges of bounding complex problems, as well as improved capacity in economic modelling are also highlighted. Overall, it is evident that Canada has an opportunity to show leadership in developing knowledge and tools to prepare for multi-faceted, multi-scale climate risks and in strengthening international cooperation to support global stability and the well-being of communities in a climate-disrupted world.

9.1.1 Overview of findings from past assessments

Past assessments have covered international dimensions of climate change impacts and adaptation for Canada. *From Impacts to Adaptation: Canada in a Changing Climate* (Lemmen et al., 2008) included a chapter on Canada in an international context. This assessment concluded that climate change impacts elsewhere in the world and adaptation measures to address them could affect Canadians, the competitiveness of some Canadian industries, as well as international assistance, peacekeeping and immigration. It also found that Canada has the capacity and obligation under the UN Framework Convention on Climate Change to assist developing countries to adapt to climate change. The chapter emphasized that little research had been undertaken to understand the policy and business implications of these impacts from a Canadian perspective.

Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation (Warren and Lemmen, 2014) included two chapters of relevance. The Adaptation chapter included a section on the international status of adaptation to provide a context by which to measure Canada's own progress. Coverage focused on the status of adaptation in Organisation for Economic Co-operation and Development (OECD) countries. It concluded that adaptation implementation was in the early stages in most, if not all, developed countries, with rare instances of legislated mandates for adaptation. It also concluded that national adaptation strategies, although useful for signalling political commitment, did not always lead to action (Eyzaguirre and Warren, 2014). The Industry chapter assessed research on climate change adaptation and international trade (Kovacs and Thistlethwaite, 2014). It concluded that the topic remained an emerging field, highlighting evidence of exposure to climate change risk through disruptions to supply chains and distribution networks affecting Canadian trade markets and of opportunities to export financial risk-transfer tools to vulnerable regions. Canadian research was unavailable or not referenced.

9.2 Climate change affects Arctic shipping and threatens sovereignty

Shrinking sea ice resulting from climate change allows for increased marine traffic in the Arctic Ocean, including through the Northwest Passage (NWP). Climate change and its impacts underscore the need to strengthen rules and capacities for demonstrating Canada's effective stewardship of the NWP and ensuring safe, secure and sustainable navigation as the ice melts.

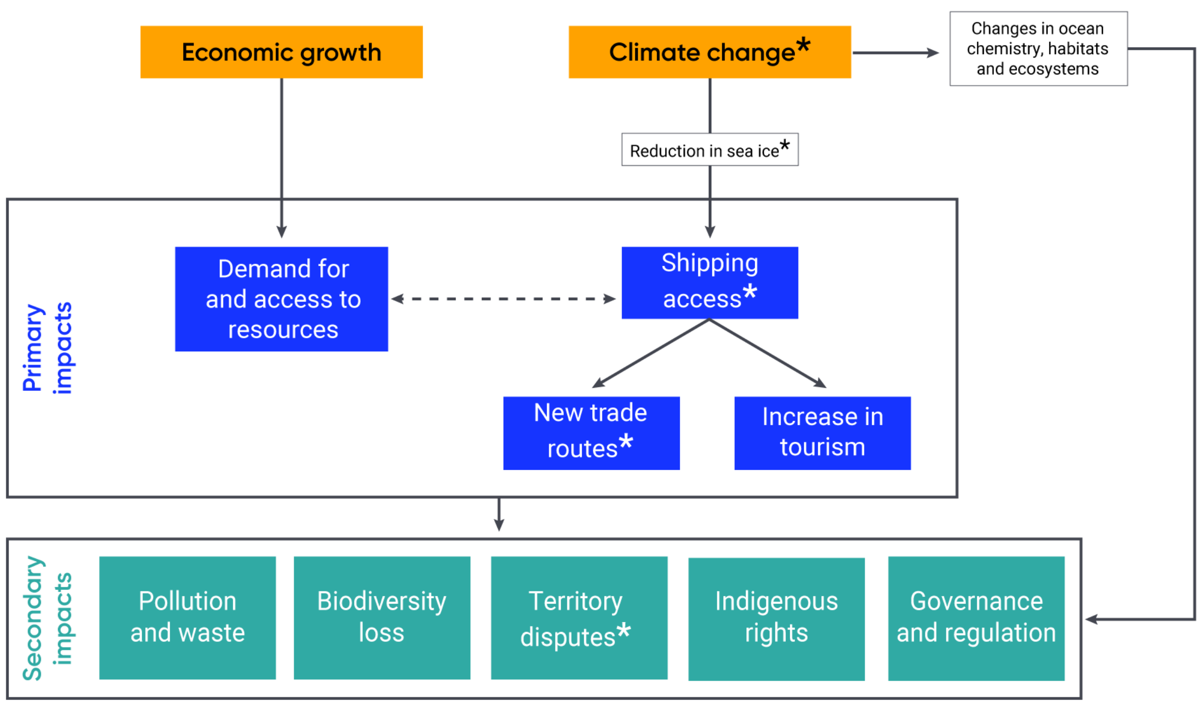
Over the past decades, the extent and thickness of summer sea ice in Canada's Arctic marine areas have steadily decreased. Physical access to Arctic resources and waters allows for increased economic activity and sea traffic, including through the Northwest Passage (NWP). The NWP links the Atlantic Ocean (Baffin Bay) and Pacific Ocean (Beaufort Sea). The shipping distance between New York and Shanghai through the NWP is about 20% shorter than that through the Panama Canal. On grounds of environmental protection, the United Nations Convention on the Law of the Sea confers coastal Arctic countries like Canada the right to regulate vessel traffic in ice-covered waters, even in straits where foreign vessels could otherwise enjoy the right to unimpeded transit passage. Although summer sea ice might not disappear entirely for another 30 years, increased warming under climate change and reductions in sea ice could pose challenges for Canada's legal arguments to regulate shipping across the channels and straits of the NWP. Sustained foreign use of these Arctic shipping lanes could render the NWP an international strait. Gradual physical access to maritime areas adds to the importance of bolstering Canada's ability to proactively exercise stewardship of the NWP to achieve a combination of diplomatic, informational, military and socioeconomic objectives, with the protection of the rights of Indigenous people cutting across them all.

9.2.1 Introduction

Canadian and international interest in the future of Arctic navigation increased in the mid-2000s, driven by warming temperatures, the rapid retreat of sea ice and a commodity boom that raised expectations about the profitability of developing northern energy and mineral resources (Exner-Pirot, 2016; Guy and Lasserre, 2016; Harber, 2015; Farré et al., 2014). This section provides information on sea-ice reduction and navigation in the Canadian Arctic, then focuses on climate-related risks to Canada's sovereignty over the Northwest Passage (NWP) and discusses the country's capacity for effective stewardship of the NWP through safe, secure and sustainable shipping as climate change intensifies.

9.2.2 Climate, sea ice and Arctic navigation

With the rapid retreat of sea ice in the Arctic Ocean (Derksen et al., 2019) and increased physical access to the region and its resources, the Arctic is now on the world stage. The rapid changes underway in the Arctic marine environment, including the declining extent, duration and thickness of sea ice and changes in the distribution and abundance of fish and other biological resources, fuel competing narratives for the future of the region. Economic narratives centre on the exploitation of, and competition over, natural resources (oil, gas and mineral resources, fish stocks), growth of the Arctic tourism industry and improved marine transportation (Ash, 2016; Arruda, 2015; Bader et al., 2014; Williams et al., 2011). Military security narratives focus on strengthened defence capabilities by northern circumpolar countries (e.g., Åtland, 2014) and potential threats from criminal elements (terrorists, smugglers, poachers) (Arctic Domain Awareness Center, 2017; Charron, 2015; Flake, 2014). Environmental narratives portray the Arctic as a maritime global commons with climate change implications for the entire planet (Bennett, 2015), and as a fragile and pristine area potentially threatened by resource or shipping disasters (Dodds and Hemmings, 2015). Finally, cultural and rights-based narratives portray Arctic lands, sea and ice as a homeland for Inuit peoples whose historic use and occupation have bolstered countries' credibility to sovereignty claims (Inuit Tapiriit Kanatami, 2017; Dodds and Hemmings, 2015; Arnold, 2012; Inuit Circumpolar Council, 2009). Common across all frames are global drivers of change in the region and the ripple effects of these drivers (*see* Figure 9.2). Climate change impacts, their links to new shipping lanes, and related disputes over Arctic waterways and territories are one slice of this complex cause-effect pathway.



*This chapter on international dimensions explores these elements.

Figure 9.2: Global drivers of Arctic marine change. Source: Adapted from Williams et al., 2011.

Sea ice patterns shape navigability in Arctic waters, as do strong and variable winds, wave conditions and storminess (Ng et al., 2018; Pendakur, 2017). Since the late 1960s, rising air temperatures have contributed to declines in the extent, thickness and age of summer sea ice in the Arctic Ocean. The extent of sea ice in the summer has decreased by 5% to 20% per decade in the Canadian Arctic, including areas that span the NWP (*see* Box 9.1; Derksen et al., 2019). Ice in the Canadian Arctic that used to accumulate over multiple years without melting is giving way to thinner, seasonal ice, with the greatest drop in multi-year ice seen in the Beaufort Sea and the Canadian Arctic Archipelago (Derksen et al., 2019). Under a range of future climate scenarios, scientists project continued reductions in seasonal sea ice, with the gradual opening of major waterways to ice-free conditions for part of the year (Derksen et al., 2019; Meredith et al., 2019; Ng et al., 2018). Increasing wave energy and heat released from wave mixing in the upper ocean can further accelerate sea ice reductions (Greenan et al., 2019). Predictions on the timing of ice-free conditions differ based on the definitions of "ice-free" and global greenhouse gas (GHG) concentration scenarios used. Relative to other sea routes in the Arctic Ocean, the Canadian Arctic Archipelago is likely to see continued sea ice further into the future, which will be transported southward into the NWP and pose an ongoing ice hazard for shipping (Derksen et al., 2019; Ng et al., 2018; Greenert, 2014). Analysis of wind, wave and storm conditions in the Arctic is limited by gaps in monitoring data and complex ice–ocean–atmosphere interactions (Ng et al., 2018). Studies indicate opposing trends for wind speed, but wave heights and wave-season duration in the Canadian Arctic are projected to increase over this century as sea ice declines (Greenan et al., 2019; Ng et al., 2018). Observations on sea ice changes by Inuit elders and experienced hunters in communities along the Canadian Arctic Archipelago support these scientific findings (Panikkar et al., 2018).

Box 9.1: Arctic sea routes are waterways to navigate through the Arctic Ocean

Three routes connect the Pacific and Atlantic Oceans: the Northwest Passage (NWP), the Northeast Passage (NEP) and the Transpolar Sea Route (TPR) (*see* Figure 9.3; Østreng et al., 2013). The NWP encompasses the straits and sounds of the Canadian Arctic Archipelago and follows along the northern slope of Alaska; it has five recognized passages (Arctic Council, 2009). The NEP follows the Russian and Norwegian coastlines. The TPR crosses the Arctic at the North Pole. Two additional waterways are the Northern Sea Route, which is the part of the NEP between the Bering Strait and the Kara Sea, and the Arctic Bridge that connects Russia to Canada through Hudson Bay.

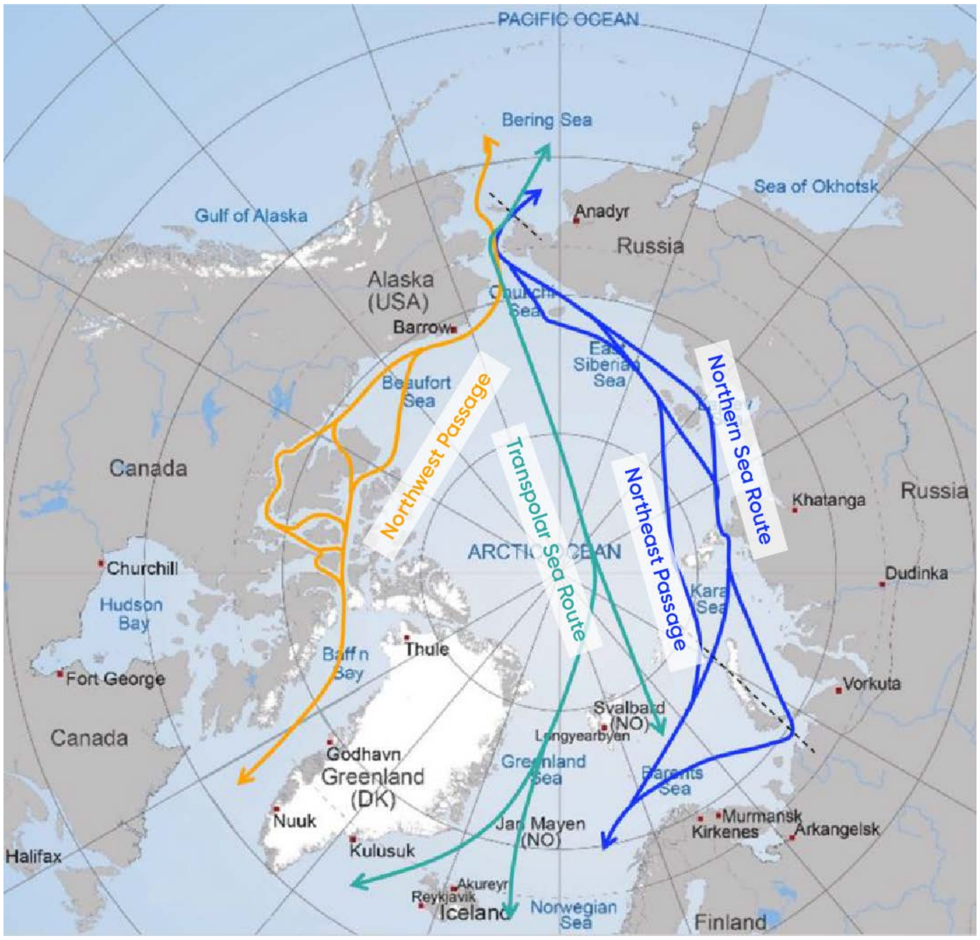


Figure 9.3: Map of Arctic sea routes. Source: Dyrcz, 2017.

Arctic navigation is attractive because of the potential to reduce shipping distances and costs, and save fuel and time, compared to southern sea routes (*see* Table 9.1).

Table 9.1: Distances (in kilometres) between major ports using two Arctic sea routes compared to standard routes

ORIGIN-DESTINATION	PANAMA CANAL	SUEZ AND MALACCA	NORTHWEST PASSAGE	NORTHEAST PASSAGE
London–Yokoyama	23,300	21,200	14,080	13,841
Rotterdam–Shanghai	25,588	19,550	16,100	15,793

ORIGIN-DESTINATION	PANAMA CANAL	SUEZ AND MALACCA	NORTHWEST PASSAGE	NORTHEAST PASSAGE
Hamburg–Seattle	17,110	29,780	13,410	12,770
Rotterdam–Vancouver	16,350	28,400	14,330	13,220
Rotterdam–Los Angeles	14,490	29,750	15,120	15,552
New York–Shanghai	20,880	22,930	17,030	19,893
New York–Hong Kong	21,260	21,570	18,140	20,985
New York–Singapore	23,580	19,320	19,540	23,121

Note: The Northwest Passage route uses the McClure Strait. Grey = shortest distance, blue = within 15%.

Source: Guy and Lasserre, 2016.

Vessel activity is increasing in Arctic waters and climate change and sea ice reductions are among the factors that have contributed to this rise (Guy and Lasserre, 2016; Pizzolato et al., 2016). The types of vessels operating in the region include bulk carriers and container ships for transit to southern markets; cruise ships, pleasure crafts, tankers, general cargo, and tug and barge as destination and resupply traffic; as well as government vessels and icebreakers (Dawson et al., 2018; Beveridge et al., 2016; Guy and Lasserre, 2016; Lasserre, 2016). Vessel traffic through Canadian Arctic waterways almost tripled between 1990 and 2015 (IPCC, 2019; Hildebrand et al., 2018, Guy and Lasserre, 2016; PEW Charitable Trusts, 2016; Charron, 2015). Distances travelled per vessel type have also increased (Dawson et al., 2018). Pizzolato et al. (2016) coupled spatial datasets on shipping activity and sea ice concentrations in the Canadian Arctic from 1990 to 2015, revealing a statistically significant correlation between these two variables in Beaufort Sea, Western Parry Channel, Western Baffin Bay and Foxe Basin. In other regions of the Canadian Arctic, sea ice conditions were not a predictor of trends in shipping activity (Pizzolato et al., 2016), with non-climatic factors—such as the ability to maintain predictable schedules—clearly influencing ship operators' decisions (Beveridge et al., 2016; Lasserre et al., 2016). At present, transit traffic in the NWP remains too low to attract significant commercial or military attention (Charron, 2015; Lackenbauer and Lajeunesse, 2014). Between 2000 and 2014 complete transits through the NWP ranged from six to 30 per year, with pleasure crafts accounting for the fastest growing transits (Beveridge et al., 2016; Guy and Lasserre, 2016; Government of Northwest Territories, 2015).

Although vessel traffic will almost certainly increase, affordable and safe Arctic shipping will be slow to develop, with the NWP unlikely to become the optimal route for international shipping (Lackenbauer and Lajeunesse, 2014). Medium-term projections (2030s to 2050s) indicate annual numbers of vessel traffic through Arctic sea routes in the hundreds (e.g., Greenert, 2014); over 5% growth in annual shipping activity (Williams et al., 2011); expanded navigability for open water and moderately ice-strengthened vessels in September (Smith and Stephenson, 2013); and shifts in trade flows (Bekkers et al., 2018). However, the potential of Arctic routes as substitutes for conventional southern trade routes is likely overstated (Guy and Lasserre, 2016; Farré et al., 2014). Opportunities for expansion in Arctic shipping are tempered by continuing challenges to navigation and safety posed by mobile summer sea ice, drifting ice that clogs straits and channels, older, thicker ice and other climate elements (Dirksen et al., 2019; Ng et al., 2018; Pendakur, 2017; Farré et al., 2014). Uncertainties in global markets, commodity prices and technological innovation, among other non-climate factors, also limit shipping potential (Johnston et al., 2017; Andrew, 2014). These challenges translate into risks and costs to operators: more expensive ship construction related to ice strengthening; seasonal scheduling challenges; the need for equipment to spot and cope with ice and crews with unique experience; and high insurance premiums (Beveridge et al., 2016; Guy and Lasserre, 2016). The economic viability of Arctic shipping, compared with southern routes, is also hampered by technological and infrastructure deficiencies, including a lack of modern deep-water ports and other services offered to transiting ships, limited search and rescue capabilities, poor charting and mapping of Arctic waters, and continued difficulties with seasonal-ice predictions (Melia et al., 2017; Guy and Lasserre, 2016). Within the global Arctic, Canada and Russia have adopted different patterns in developing shipping lanes (*see* Table 9.2; Guy and Lasserre, 2016). As a result, international shipping through the NWP, with underdeveloped infrastructure and services, may be less preferable than shipping through the Northern Sea Route (Beveridge et al., 2016; Bonds, 2016; Bennett, 2014; Farré et al., 2014). For example, according to survey research, European shipping companies strongly view icebreaker escort and navigational aids as essential Arctic navigation services (Lasserre et al., 2016), which are attributes of the Northern Sea Route.

Table 9.2: Differences in governance of the Northern Sea Route and the Northwest Passage for vessel traffic

RUSSIA AND THE NORTHERN SEA ROUTE	CANADA AND THE NORTHWEST PASSAGE
• Special administrative body created to manage traffic between the Bering Strait and Kara Gate (Northern Sea Route Administration) • Applications for transit • Mandatory transit fee in exchange for providing piloting, icebreaker escort services and the possibility of docking at small ports in the event of an emergency • Mandatory pilotage • Encourage ships to be escorted by icebreakers • At least nine deep-water ports • Network of search and rescue centres in the Arctic	• No mandatory transit fees • Mandatory registration of ships carrying over 300 tons of gross tonnage, or carrying pollutants or dangerous goods • No service provided other than navigation aids (seasonal buoys, frequent transmission of ice maps) • No deep-water ports • Search and rescue bases are located far to the south (Gander, Halifax, Trenton, Cold Lake and Comox)

Source: Guy and Lasserre, 2016

9.2.3 Climate-related risks to Canada's control over the Northwest Passage

Although a substantial rise in vessel traffic volumes and international transits through the NWP is unlikely in the short term, preparing for long-term growth in navigation and maritime trade through the NWP and related environmental, social, economic, cultural and geopolitical risks is prudent (Dawson et al., 2020a; Hauser et al., 2018; Cotter, 2017). However, the NWP has been held up as a contested resource and a source of future international tension, particularly with increased Asian interest in the Arctic and its natural resources (Levitt, 2019; Exner-Pirot, 2016; Landriault, 2016; Rothwell, 2015; Wallin and Dallaire, 2011; Huebert, 2010). Climate change impacts, including shrinking sea ice, could weaken Canada's sovereign claim to the NWP. Climate change also challenges the capacity of Canadian infrastructure and systems in place (e.g., search and rescue, offshore surveillance) to demonstrate effective stewardship of the NWP.

In legal terms, sovereignty refers to recognized rights of exclusive jurisdiction over a territory (Cox, 2015). Canada claims sovereignty over all waters of its Arctic Archipelago and regards the NWP as “internal” waters over which Canada has authority to regulate entry and control access to its various routes (*see* Video 9.1; Lalonde, 2019; Lackenbauer and Lalonde, 2017b). Historic occupation and use of Arctic lands, sea and ice by Indigenous Peoples, enclosure of the Arctic Archipelago within Canada’s baseline, and enforcement of environmental regulations in the NWP as part of the 1970 Arctic Waters Pollution Prevention Act (AWPPA) are key components of Canada’s sovereignty claims (Guy and Lasserre, 2016; Cox, 2015; Wright, 2014; Zellen, 2010; Carnaghan and Goody, 2006). As well, Canada has asserted military control in the North through human resource and infrastructure expenditures. This includes the expansion of the Canadian Rangers, a fleet of patrol vessels, a Canadian Forces training centre, a deep-water fuelling facility, and increased radar and satellite capacity. Maintaining the NWP as internal waters is also a priority for the Canadian Inuit, as the passage is part of their Arctic homeland, Inuit Nunangat (*see* Video 9.2; George, 2019a; Inuit Circumpolar Council, 2018). Pollution, oil spills and negative impacts on marine mammals are among the Inuit’s main concerns related to increased shipping activity (Dawson et al., 2020a; Arctic Council, 2009).

Video 9.1: Sovereignty: Political science and security scholars’ perspective on Arctic sovereignty and shipping in the Northwest Passage. Source: Baldassari, 2017, 2013. https://vimeo.com/104400714

Video 9.2: Nilliajut 2: Inuit perspectives on the Northwest Passage, shipping and marine use. Source: Inuit Tapiriit Kanatami, 2018. https://www.youtube.com/watch?v=0EGzKIQo0jY

Perceived threats to Canada's sovereign claim over the NWP arise from countries' differing opinions on the status of the NWP as internal Canadian waters (Lackenbauer and Lalonde, 2017b). Of the five states with Arctic coasts—Canada, Denmark, Norway, Russia and the United States—the United States has long viewed the NWP as an international strait where foreign ships and aircraft can freely transit the waters and airspace (Lalonde, 2019; U.S. Government, 2013). Non-Arctic nations have weighed in on the NWP controversy. Of note, Germany, a country with observer status at the Arctic Council, has campaigned for freedom of navigation in the Arctic Ocean (including the NWP) (Federal Foreign Office of Germany, 2013). In its 2018 Arctic Policy, China, another Arctic Council observer, invoked the importance of freedom of navigation and the right to use Arctic shipping routes (People's Republic of China, 2018). Despite alarmist concerns (Exner-Pirot, 2016), Canada's claims to the NWP have been largely unchallenged. To date, all maritime disagreements have been well managed by established international mechanisms, providing a foundation for future cooperation among Arctic states and beyond. Canada's claims and regulations in the Arctic are typically complied with, and there are no current threats to sovereignty (Charron and Fergusson, 2018).

Competing views exist on whether climate change weakens Canada's position on claims to the NWP (Burke, 2017; Rothwell, 2015). Critical uncertainties relate to the extent of international traffic in the NWP and the interpretation of Article 234 of the United Nations Convention of the Law of the Sea (UNCLOS), which grants coastal states the right to enact laws and regulations to control marine pollution from vessels in "ice-covered" waters within its Exclusive Economic Zone (UN Convention on the Law of the Sea, 1982). For the NWP to be considered an international strait, it would have to meet geographic and functional requirements: it must connect two bodies of the high seas (as it does) and must be considered "useful" as determined by a sufficient number of transits (Carnaghan and Goody, 2006). Legal precedents suggest that the small number of current transits and those expected in the medium term would not qualify the NWP as a useful route for international maritime traffic. However, if accelerated sea ice melting enabled a substantial rise in commercial shipping, perceptions of the NWP as an international strait would intensify (Lackenbauer and Lalonde, 2017a; Cox, 2015; Huebert, 2001). The power conferred by UNCLOS Article 234 to regulate shipping in the interest of environmental protection of ice-covered areas has served to expand Canada's jurisdiction in Arctic waters (Burke, 2017; Farré et al., 2014). As sea ice retreats and navigation becomes less hazardous, Canada's ability to count on Article 234 for international legitimacy could diminish (Rothwell, 2015; Farré et al., 2014). Russia, which also invokes Article 234 to regulate shipping activity in its Exclusive Economic Zone along the Northern Sea Route, could also face challenges to its claims as sea ice cover diminishes (Flake, 2014).

Regardless of legal stances over sovereignty in the NWP and the right to control activities of other nations, Canada can proactively exercise stewardship of the NWP (Cox, 2015) by focusing on safe, secure and sustainable development of shipping routes (Dawson et al., 2020a; Lackenbauer and Lajeunesse, 2014). At present, Canada is poorly equipped to enforce environmental protections in Canada's Arctic waterways (Giguère et al., 2017; Cox, 2015; McRae, 2007; Huebert, 2003). Canada remains deficient in infrastructure (e.g., charting; navigational, weather and communication support services; ports, harbours and terminals; ship repair and waste management for vessels) and emergency response capabilities, including for oil spills. Adequate infrastructure and the ability to respond to emergencies are critical for protecting the fragile Arctic environment (Hildebrand et al., 2018; Lajeunesse, 2018; Giguère et al., 2017; Arctic Council, 2009). Maintaining maritime domain awareness, and monitoring and serving such an expansive, remote and rugged region, will remain financially and logistically challenging (Guy and Lasserre, 2016; Dawson et al., 2014). Aside from pursuing coordination with Arctic littoral states, a practical focus on the needs of international operators serving resupply and destination traffic is one way to manage risk posed by international ships (Lackenbauer and Lajeunesse, 2014; Charron, 2005). This strategy also commands respect for Canadian sovereignty over the NWP, just as Russia's approach to providing pilotage and icebreaking services and mandating their use, as well as its investments in maritime infrastructure and search and rescue capabilities, support its claim to Northern Sea Route waters (Cotter, 2017).

9.2.4 Strategies to adapt to increased shipping activity in the Northwest Passage

Managing indirect impacts of climate change, such as increased international vessel traffic in the NWP, competition over new shipping lanes and affronts to Canada's sovereignty, is less about reducing specific climate threats and more about enhancing capabilities to meet valued outcomes even as the climate changes (Meredith et al., 2019; Stockholm Environmental Institute, 2013). Public opinion in Canada on how to assert Arctic sovereignty has shifted over the years, from a marked preference for military capabilities and surveillance in 2000–2005 to a mix that also includes diplomacy, attention to the needs of northern and Indigenous communities, science and environmental protection in 2011–2014 (Landriault, 2016). The following discussion on capabilities to build Canada's capacity to develop safe, secure and sustainably managed Arctic waterways in a rapidly changing environment draws on three frameworks: the Arctic

Resilience Action Framework (Arctic Council, 2017); a framework to foster strategic capabilities for climate security (Werrell and Femia, 2019); and the Circumpolar Inuit Declaration on Sovereignty in the Arctic (Inuit Circumpolar Council, 2009). The multi-faceted strategies to build adaptive capacity comprise diplomatic, informational, military and socioeconomic themes, and the protection of the rights of Indigenous people is an element of each.

Diplomatic capabilities include international cooperation and actively strengthening international standards governing the Arctic. Arctic governance comprises a patchwork of bilateral and multilateral agreements, stemming from the Arctic Council and International Maritime Organization, and anchored in UNCLOS (Arruda, 2015; Borgerson, 2013). Existing instruments have been effective in driving consistent and cooperative action to date (House of Commons, 2019; Plouffe, 2011; Byers, 2010; Government of Canada, 2010; Byers and Lalonde, 2009), but need to reflect changing conditions—climatic and otherwise (Byers, 2010). For example, the mandatory International Code for Ships Operating in Polar Waters ("Polar Code") adopted in 2017 clarifies shipping and navigation standards related to commercial vessels, operational concerns, search and rescue in polar waters, and environmental protection. Monitoring and forecasting of ice conditions will be critical to the Code's effective application (Guy and Lasserre, 2016). The rise in Arctic shipping has led to a higher rate of reported accidents per kilometre travelled compared to southern waterways (Council of Canadian Academies, 2016), noise and air pollution (Marelle et al., 2018; Halliday et al., 2017), as well as disruptions to wildlife and cultural activities of community residents (Olsen et al., 2019; Panikkar et al., 2018). These trends lend urgency to resolving practical issues among littoral states and, in partnership with Inuit, on management and funding of navigation services such as traffic control, navigation aids, environmental protection and clean-up procedures (Charron, 2005). Climate change adaptation of the rapidly evolving cruise shipping industry is one area of active research (*see* Case Story 9.1), as the cruise ship sector is in need of improved governance (Pashkevich et al., 2015).

Informational capabilities refer to collection and dissemination of information on climate change risk and responses. Climate change is one among many pressures that shape Arctic shipping and its effects on people and ecosystems. Therefore, governments and others are turning to holistic approaches that incorporate spatial, analytical and modelling methods to understand past and potential damages and opportunities brought by marine vessel activity (Pickard et al., 2019). The Arctic Corridors group, in partnership with Northern Voices, has studied and written many reports about climate change and the cumulative effects of marine shipping (Carter et al., 2019). A number of data resources and tools exist to facilitate the integration of direct climate change impacts (e.g., changing sea-ice patterns, precipitation events, strong and variable winds, changing sea levels and wave patterns, permafrost degradation and enhanced coastal erosion) into plans and decisions related to marine navigation and to assess the strength of management strategies (Debortoli et al., 2019; Pendakur, 2017). For example, efforts to determine safe navigation routes are building on data collected to measure the depths of Arctic water as part of Canada's submission to UNCLOS on its extended continental shelf (Global Affairs Canada, 2019b). Consistent with its mandate to maintain coastal infrastructure and safe secure waterways, the Department of Fisheries and Oceans developed a web-based planning tool to generate estimates of climate variability and change in the Beaufort Sea, Davis Strait and the Mackenzie Delta region (Department of Fisheries and Oceans, 2018). However, trends and projections of socioeconomic variables, including the indirect impacts of climate change, are less widely studied. Understanding and evaluating future climate-related risks of international vessel traffic in the NWP can be challenging because of the uncertainties involved. Foresight tools, such as scenario building and horizon scanning, can help identify management actions that are robust to a range of futures (Fetzek et al., 2017). Used in national security planning (e.g., Pezard et al., 2018) foresight tools also aid in climate change adaptation planning and in strengthening emergency response. Of equal importance to the creation of climate risk information are institutions charged with translating insights for decision makers to take action (Arctic Council, 2017; Fetzek et al., 2017).

Military capabilities correspond to those possessed by the armed forces and national defence agencies. As a member of the North Atlantic Treaty Organization (NATO), which has recognized climate change as a threat multiplier, Canada is aware of the potential security threats of climate change. Canada's Strong, Secure, Engaged defence policy commits to increasing enforcement capacity, situational awareness and monitoring of Arctic waters, referring to climate change as one of the drivers behind the need for these enhanced capabilities (Government of Canada, 2017b). A companion Defence Energy and Environment Strategy guides "greening" efforts by Canadian defence (Minister of National Defence, 2017). Both the defence policy and greening strategy outline investments and concrete actions to reduce the carbon footprint of defence installations and operations, but are far less specific on investments and actions required to adapt to climate change. Canada's military is already stretched to respond to climate-related emergencies at home and overseas, with climate change expected to increase the demand for military assistance (Major and Shivji, 2019). The integrity of military assets and facilities could be at risk from climate change. While the United States has identified its military assets and operations most vulnerable to climate change, as a basis for setting priorities (Center for Climate and Security, 2020), Canada has not. Symposia on climate change and security, such as those held by the Canadian Forces College in 2018 and 2020 (Canadian Forces College, 2021), can help raise the profile of these gaps to senior decision makers.

Capabilities in the realm of socioeconomic development centre on capital and infrastructure investments and public policies and regulations applicable to Arctic waters that incorporate climate risk. Climate change adaptation solutions for vessels and navigation in the Arctic and for maritime infrastructure are increasingly documented and include winter-operation risk assessments, ship-specific winterization (including for mixed-ice environments), and relocation of shore-based resupply infrastructure (Meredith et al., 2019; Pendakur, 2017). They apply to both private- and public-sector operators. At a strategic and policy level, the Arctic Northern Policy Framework, the Oceans Protection Plan's Cumulative Effects of Marine Shipping initiative, the Northern Marine Transportation Corridors (now known as "Low Impact Corridors") and Strategic Environmental Impact Assessments linked to Arctic resource development (e.g., Nunavut Impact Review Board, 2019) are initiatives that could support the safe and sustainable development of shipping in the NWP (Porta et al., 2017; PEW Charitable Trusts, 2016). The Low Impact Corridors initiative in particular is a promising response to increased Arctic shipping activity (Dawson et al., 2020a), as it proposes to install the necessary services (e.g., emergency response, navigational support) and infrastructure to ensure safer navigation while considering ecological and cultural significance (Levitt, 2019). Inuit communities acknowledge the potential benefits of shipping, but urge inclusive and collaborative research to determine corridor routes with minimal negative impacts on traditional activities and sensitive ecosystems (Dawson et al., 2020a).

Case Story 9.1: Adaptation strategies for cruise ship tourism in the Canadian Arctic

Cruise ship tourism in Canada's Arctic is increasing, with activity more than doubling between 2005 and 2013 (Dawson et al., 2016). Increased physical access, the Arctic's rich cultural and natural heritage, and an expanding range of products make the Northwest Passage a popular area to visit for "frontier tourism" enthusiasts and a growing base of baby boomers with disposable income. At present, management of expedition cruise shipping takes place within the complex, multi-jurisdictional regulatory framework applicable to all shipping in the region (Dawson et al., 2014). However, cruise shipping differs from industrial shipping in a number of ways, including deviating from main shipping corridors in pursuit of ice, wildlife and culture. This involves navigating in sometimes challenging, uncharted waters, seeking access to shore locations and interacting with local residents. Researchers, private operators and Canadian Inuit organizations see the need to improve governance of the sector. Limiting the size of cruise ships entering Arctic waterways, banning the use of heavy oil in Arctic waters, establishing site guidelines for highly visited areas, and regulating cruise ship disturbances to wildlife (birds and mammals) and their habitats are examples of potential measures (Inuit Tapiriit Kanatami, 2017; Kujawinski, 2017; The Maritime Executive, 2016; Dawson et al., 2014).

Successfully managing climate change-related risks is also critical to the sustainable growth and evolution of the Arctic cruise ship industry. Qualitative research led by Dawson et al. (2016) and involving over 300 local residents, cruise operators and regional decision makers identified the seven most feasible and desirable adaptation strategies for cruise ship tourism in the Canadian Arctic (*see* Figure 9.4). Bottom-up approaches to identifying adaptation needs and priorities in climate change management tend to address current vulnerabilities and risks. If genuinely participatory, they also generate results that are consistent with local priorities, goals, norms and institutions—a foundation for implementation success.

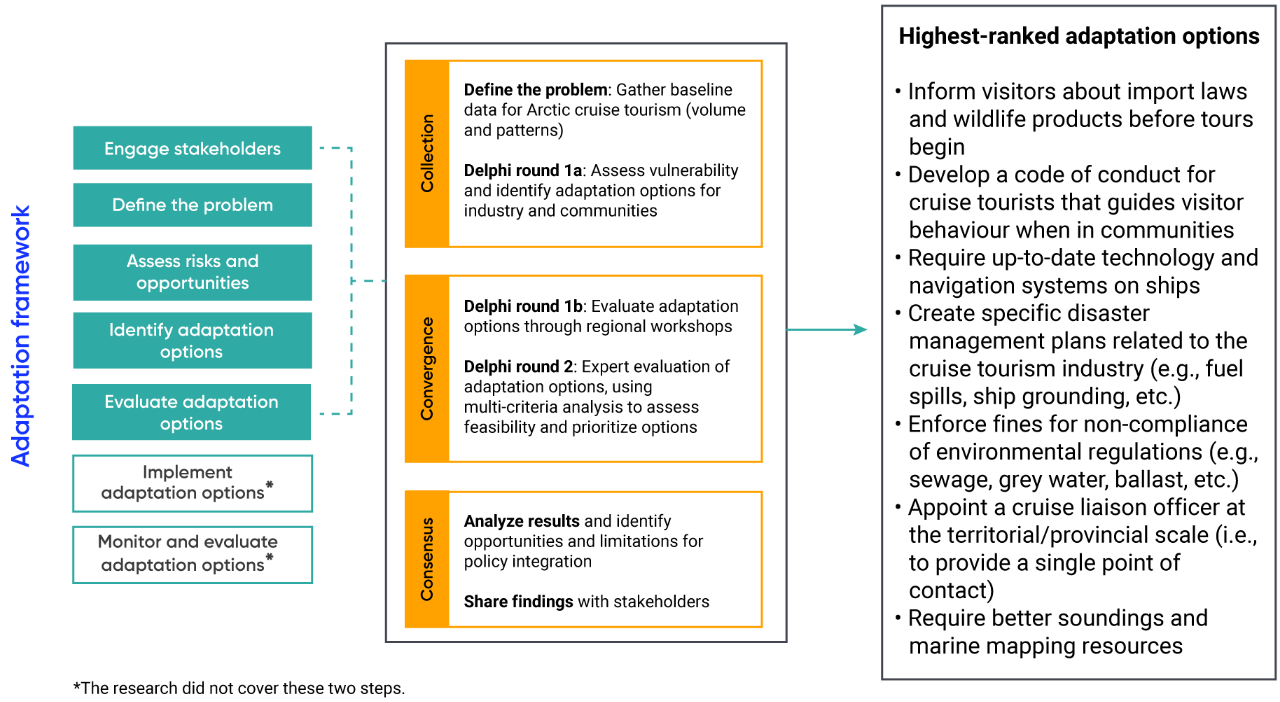


Figure 9.4: Summary of the research process used by Dawson et al. (2016) to identify promising adaptation options for cruise ship tourism in the Canadian Arctic. The Delphi technique uses iterative and structured expert elicitation to generate consensus judgments. Source: Adapted from Dawson et al., 2016.

9.3 Transboundary marine and freshwater agreements generally do not consider climate change

Canada's transboundary marine and freshwater agreements were not created with climate change in mind. In collaboration with international partners, Canada has an opportunity to show leadership in preserving long-term cooperation and protecting shared resources by building on adaptive practices recognized as successful.

Despite differences in agreements governing sharing of marine and freshwater resources across international borders, one commonality is the general assumption that environmental conditions would remain static over time. In a changing climate, relying on this assumption risks unsustainable resource use that may destabilize existing cooperative relationships. As a significant contributor to international environmental negotiations, Canada is well positioned to help modernize transboundary resource management institutions to provide more resilient frameworks for coping with uncertainty, promoting environmental stewardship and improving representation of affected groups and Indigenous governments.

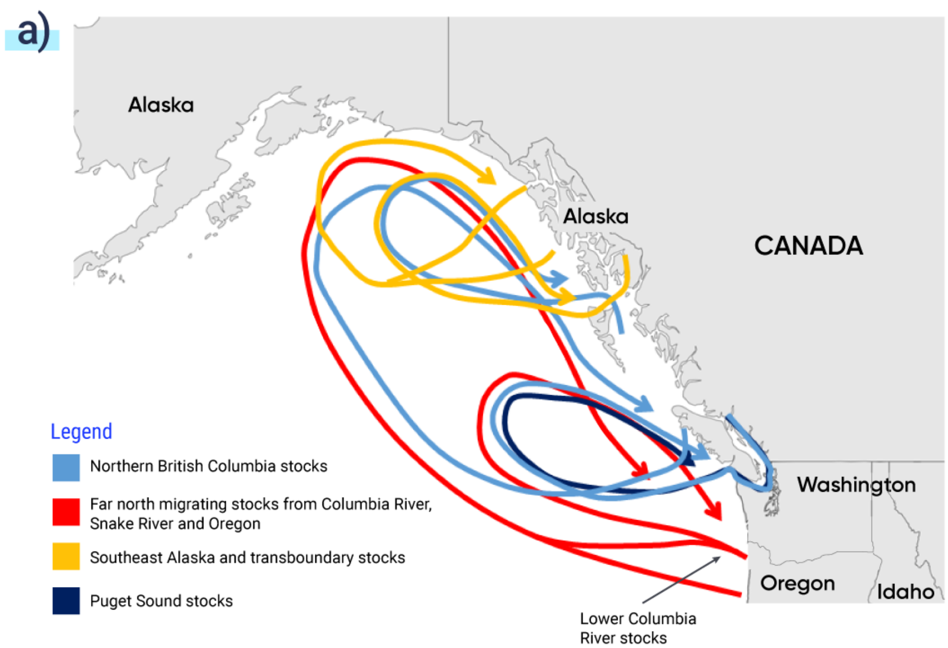
9.3.1 Introduction

Most of the agreements governing shared marine and fresh waters that cross the Canada–U.S. border were negotiated and signed before climate change was a recognized concern. These arrangements face new challenges since they assume "stationarity." Climate change invalidates the assumption that environmental conditions can be adequately predicted based on historical information; therefore, continued reliance on stationarity threatens sustainable resource use and the stability of cooperative relationships (Sumaila et al., 2020; Britten et al., 2017; Szuwalski and Hollowed, 2016; Criddle, 2012; Craig, 2010; Hanna, 2008; Milly et al., 2008). Physical impacts like changes in the timing and volume of flows or in the frequency and duration of floods and droughts will have different economic implications across the border and will likely challenge existing allocation mechanisms. Further, because climate-related risks differ in Canada and the United States, each country will discount future benefits from shared marine and freshwater ecosystems differently, thereby complicating the ability to agree on the value of those benefits (Sumaila et al., 2011; Sumaila, 2005).

Canada's marine and freshwater systems have different characteristics yet are highly interconnected and share climate-related risks. Compared to river basins, marine systems are harder to divide into discrete ecological units and associated agreements tend to focus on a single issue (e.g., navigation, pollution, invasive species, fisheries and environmental protection). Examples include the Pacific Salmon Treaty, the Antarctic Treaty's Environmental Protocol and the Canada–U.S. Marine Pollution Contingency Plan. Freshwater agreements often consider a bundle of shared benefits together, such as hydropower production, flood management, agricultural irrigation, navigation, fisheries and water quality management. Examples include the Columbia River Treaty, Great Lakes Water Quality Agreement and the Boundary Waters Treaty. Despite these differences, there are critical connections between marine and freshwater systems. Both are subject to long- and short-term climate variation (e.g., Pacific Decadal Oscillation, El Niño Southern Oscillation) and are sensitive to shifts in water temperatures (Di Lorenzo and Mantua, 2016; Pinsky et al., 2013; Cheung et al., 2009; Hollowed et al., 2001; Mantua et al., 1997; Wood and McDonald, 1997). Anadromous species like salmon that rear in freshwater, migrate to sea, then return to their natal streams to spawn, reinforce the need to consider cumulative effects across marine, riverine, and land-based ecosystems. Agreements that acknowledge these linkages are better positioned to cope with uncertain climate futures (*see* Case Story 9.2).

Case Story 9.2: The Canada–U.S. Pacific Salmon Treaty

The Pacific Salmon Treaty (PST) (Pacific Salmon Commission, 2016a) was ratified in 1985 to prevent overfishing and improve the management of five salmon stocks shared between Canada and the United States (Miller, 1996; Yanagida, 1987). The PST was successfully renegotiated in 1999 using a multi-stakeholder approach to address conflict over "interceptions" of fish—fish that originate in one country but are caught in the other (*see* Figure 9.5). At that time, the treaty also established a restoration and enhancement fund (Pacific Salmon Commission, 2016b) to support healthy salmon populations in both marine and freshwater environments. The agreement's focus on anadromous species illustrates how marine and freshwater linkages can be considered in a transboundary agreement. Joint recommendations put forward in 2018 for a new 10-year agreement explicitly acknowledge climate change and include provisions for long-term monitoring, science-based management, and renewed commitments to support conservation and sustainable-use opportunities for Indigenous, commercial and recreational fishers.



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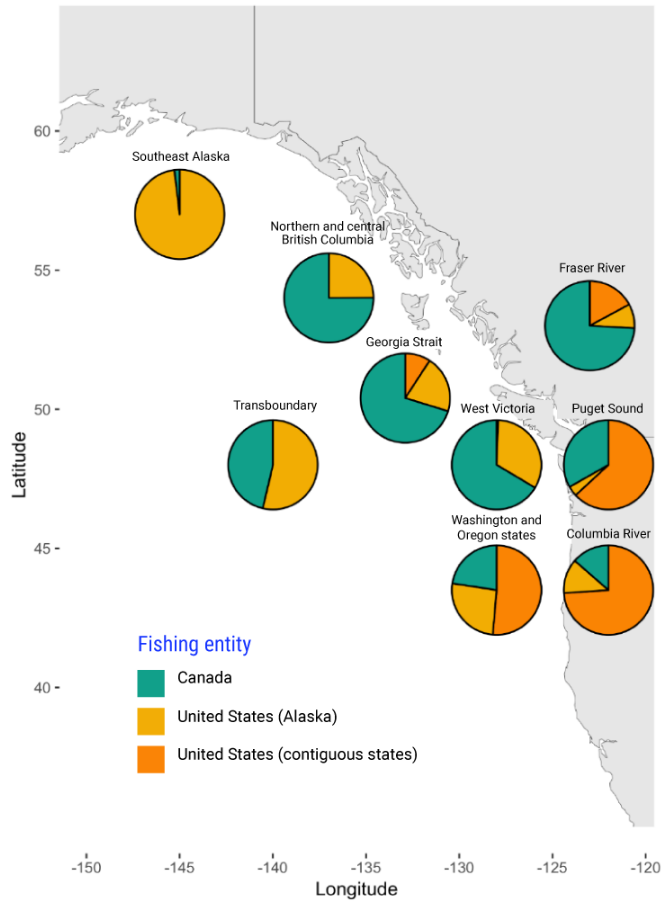


Figure 9.5: a) Migratory patterns of major Chinook salmon (*Oncorhynchus tshawytscha*) stock groups. Source: Adapted from the National Marine Fisheries Service, 2019. b) Average captures of regional Chinook salmon (*Oncorhynchus tshawytscha*) for the period 2009–2017 under managed fisheries of the Pacific Salmon Treaty. The values in the pie charts represent the proportion of each region's major chinook stock captured by individual fishing entities (averaged across regional stocks), and do not include escapement. Data source: Pacific Salmon Commission, 2019.

Further reading: McIntosh, 2016; Peterman et al., 2016; Temby et al., 2015; Criddle, 2012; McKinney et al., 2010; Munro et al., 1997; Miller, 1996; Munro and Stokes, 1989.

As a significant contributor to international environmental negotiations and global environmental governance (Stoett, 2018), Canada is well suited to promote adaptive and inclusive transboundary resource management solutions. Most of Canada's marine and freshwater agreements already observe widely accepted principles, such as the duty to cooperate, no-harm and equitable use (Koubrak and VanderZwaag 2020; Paisley, 2002; United Nations, 1970). Additionally, access to some of the world's largest anadromous fish stocks puts Canada in a unique position to champion integrated marine and freshwater management in transboundary systems. An overarching climate change adaptation goal for transboundary resources is to develop management institutions capable of responding to increased variability while still sustaining shared benefits in the long term. The following sections introduce challenges that climate change presents to shared governance of transboundary marine and freshwater resources and outline opportunities for adaptation.

9.3.2 Marine agreements

Canada is bordered by three oceans whose marine resources provide important ecological, social, economic and cultural benefits (Cisneros-Montemayor et al., 2017; Ommer, 2007; Nuttall, 2005; Fisheries and Oceans Canada, 2002). In 2016, British Columbia's exports of Pacific hake (*Merluccius productus*), Chinook salmon (*Oncorhynchus tshawytscha*) and Pacific halibut (*Hippoglossus stenolepis*) alone—all shared marine resources—accounted for $161.6 million (Government of British Columbia, 2017).

Changing ocean conditions due to climate change have led to substantial geographic shifts in marine animals, a pattern expected to continue or accelerate in the future. With rising ocean temperatures, marine species are already shifting poleward (Palacios-Abrantes et al., 2020a; Pinsky et al., 2018; Poloczanska et al., 2016; Weatherdon et al., 2016; Cheung et al., 2015; García Molinos et al., 2015; Kintisch, 2015; Peterson et al., 2015; Pinsky et al., 2013; Poloczanska et al., 2013; Fogarty, 2012) or into deeper water (Dulvy et al., 2008) to stay within their preferred temperature range. Movements can be temporary; for example, greater proportions of Pacific hake (whiting) migrated northward into Canadian waters during the warm 1998 and 2015 El Niño events (Berger et al., 2017). Shifts are also associated with ecological responses and altered food-web interactions that increase uncertainty about stock productivity and the vulnerability of fish to pollution and exploitation (Cheung, 2018; Cheung et al., 2016; Cheung et al., 2015; Doney et al., 2012; Gruber et al., 2012; Ainsworth et al., 2011; Perry et al., 2005).

Because the movement of fish stocks across international borders redistributes shared marine resources (*see* Figure 9.6), it challenges existing cooperative governance structures (*see* Table 9.3). Uncertainty surrounding this redistribution modifies the relatively static management context under which contractual and reciprocal rights and responsibilities were originally agreed (Gullestad et al., 2020; Hannesson, 2020; Mendehall et al., 2020; Østhagen et al., 2020; Palacios-Abrantes et al., 2020a, b; Bindoff et al., 2019; Wenar, 2015; Mills et al., 2013; Ringius et al., 2002; United Nations, 1970), potentially accentuating disagreements over fisheries allocations (Pinsky et al., 2018; Spijkers and Boonstra, 2017; Berkes, 2010). Uncertainty about the magnitude and timing of climate-mediated changes also makes it harder to collaboratively develop and implement clear and pragmatic transboundary policies (Engler, 2020; Pecl et al., 2017; Hollowed et al., 2013; Polasky et al., 2011; Miller et al., 2010; Brander, 2007; Miller, 2007).

Table 9.3: Agreements to which Canada is a member that deal with transboundary stocks

AGREEMENT	OCEAN	MEMBERS (CURRENT NUMBER OF MEMBERS)	SPECIES	NUMBER OF SPECIES / SPECIES GROUPS
Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea	Pacific	Canada and the United States (2)	Pacific halibut	1
Pacific Salmon Treaty	Pacific	Canada and the United States (2)	Pacific salmon: chum, chinook, coho, pink, and sockeye	5
Pacific Whiting Treaty	Pacific	Canada and the United States (2)	Pacific hake	1
Convention on Cooperation in the Northwest Atlantic Fisheries	Atlantic	Iceland, Japan, the Republic of Korea, Norway, the Russian Federation, Ukraine, Canada, Cuba, Denmark (Faroe Islands and Greenland), the European Union, France (Saint-Pierre et Miquelon) and the United States (12)	Atlantic cod, redfish, American plaice, yellowtail flounder, witch flounder, white hake, capelin, thorny skate, Greenland halibut, shortfin squid, Northern shrimp	11*
Convention for the Conservation of Salmon in the North Atlantic Ocean	Atlantic	Canada, Denmark (Faroe Islands and Greenland), the European Union, Norway, the Russian Federation and the United States (6)	Atlantic salmon	1

AGREEMENT	OCEAN	MEMBERS (CURRENT NUMBER OF MEMBERS)	SPECIES	NUMBER OF SPECIES / SPECIES GROUPS
Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean	Pacific	Canada, Japan, the Russian Federation, the Republic of Korea and the United States (5)	chum salmon, coho salmon, pink salmon, sockeye salmon, chinook salmon, cherry salmon and steelhead trout	7

*The North Atlantic Fisheries Organization's Convention on Cooperation in the Northwest Atlantic Fisheries applies to most fisheries resources of the Northwest Atlantic, with the exception of salmon, tuna/marlin, whales, and sedentary species. However, it officially manages only 11 species (and 19 stocks).

These challenges provide impetus to develop cooperative adaptation strategies for the responsible stewardship of shared resources. For example, enhancing collaborative monitoring and integrating multiple data streams into seamless transboundary datasets can support more effective and precautionary management, and enable better enforcement of transboundary marine agreements (Pinsky et al., 2021, 2018; Wendebourg, 2020; Aquorau et al., 2018; Mills et al., 2013; Link et al., 2011; McIlgorm et al., 2010). Greater responsiveness in management regimes would facilitate such developments (Bailey et al., 2016; Favaro et al., 2012), such as that being implemented by the Transboundary Resources Assessment Committee (TRAC), which is conducting and reviewing stock assessments and projections to support management of shared Eastern Georges Bank cod, haddock and yellowtail flounder across the Canada–U.S. boundary in the Gulf of Maine–Georges Bank region (Palacios Abrantes et al., 2020b).

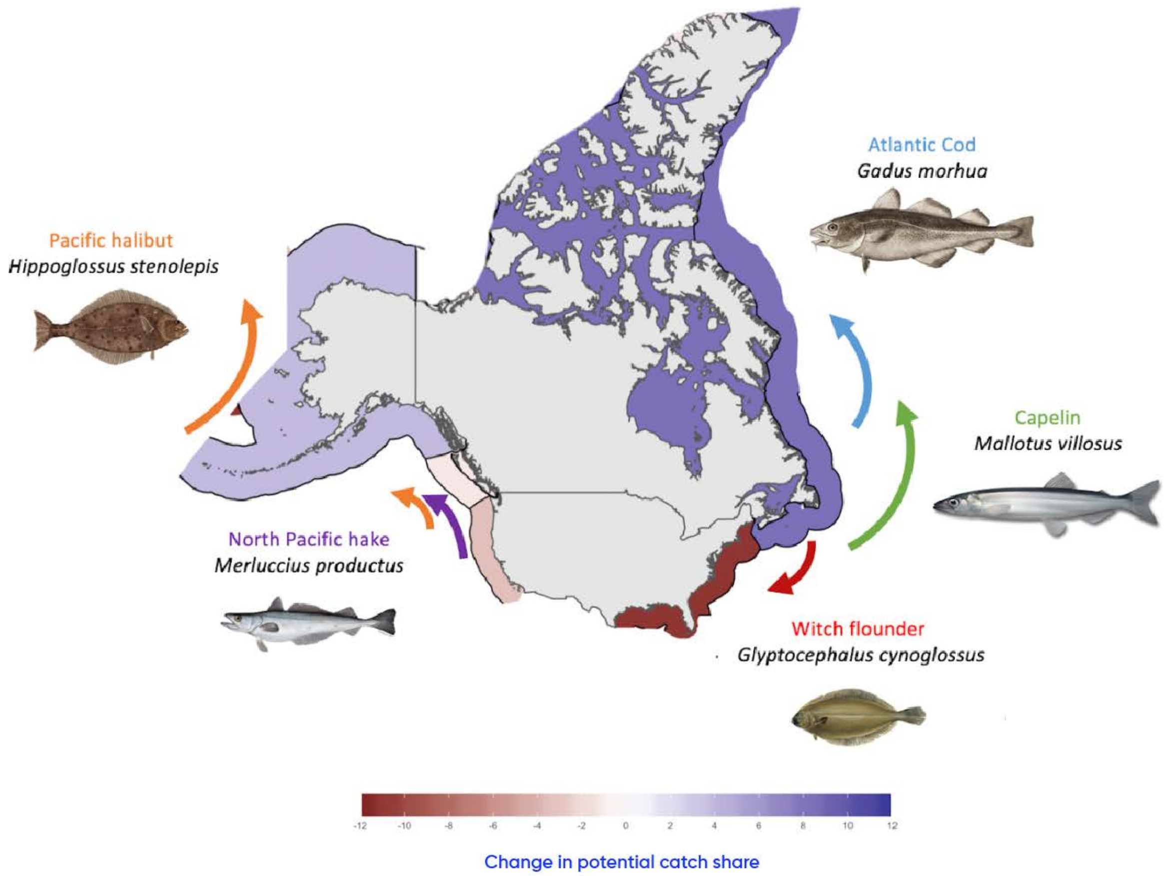


Figure 9.6: Map of projected shifts in the distribution of representative commercial transboundary fish species targeted by American and Canadian fisheries by 2050 under a high emissions scenario, relative to 2014. The coloured scale indicates the projected change in catch shares within the Exclusive Economic Zone (red = decline; purple = increase). The arrows on the map represent the direction of the shift in distribution for these five key fish species. Source: Adapted from Cheung et al., 2016.

To be effective, agreements also need to respond to shifts in societal norms (Stoett, 2018), such as the growing importance of accounting for equity and the unique rights of Indigenous people (Campbell, 2015; Dodds and Hemmings, 2015). Various strategies can support the development of transboundary marine agreements in ways that meet objectives adaptively while striving for equity. Key tools include fishing permit structures that facilitate entry into different/emerging fisheries, sustained monitoring at change-relevant scales, and catch limits or schemes that provide for capacity adjustments (e.g., license buy-back or tradable quota shares) (Aqorau et al., 2018; Mills et al., 2013). Also critical is meaningful participation of Indigenous peoples in negotiations and the inclusion of Indigenous ecological knowledge in the development of more adaptive strategies (Ojea et al., 2020; Armitage et al., 2015; Mills et al., 2015; Aswani and Lauer, 2014). Increasing the capacity of Indigenous communities and stakeholder groups to independently apply risk-based tools is one way to strengthen the role of these groups in transboundary decision-making (Le Bris et al., 2018; Payne et al., 2017; Mills et al., 2015).

9.3.3 Freshwater agreements

As with other Canadian river basins, changes in precipitation and snowpack, shifts in the timing and shape of annual hydrographs, water temperature increases, and increased frequency of floods and droughts (*see* [Water Resources](#) chapter) present challenges to the management of transboundary waters. These impacts will vary across the country (*see* Figure 9.7) and will test cooperative water relations by increasing the need for difficult trade-offs across competing freshwater uses, such as hydropower production, irrigation, flood control, recreation, navigation, and species conservation (Cooley et al., 2012; Cooley and Gleick, 2011; Hamlet, 2010; Cooley et al., 2009; Bruce et al., 2003). These uses form the basis of shared management considerations across the Canada–U.S. border, with climate change affecting Canada–U.S. hydro-relations differently depending on which shared management considerations are under threat (*see* Table 9.4). In addition, the effects of other non-climate stressors like increasing demand for electricity, misaligned domestic conservation laws in Canada and the United States, industrial and agricultural pollution, invasive species and increased water consumption will be amplified by climate change, further affecting cooperative relations.

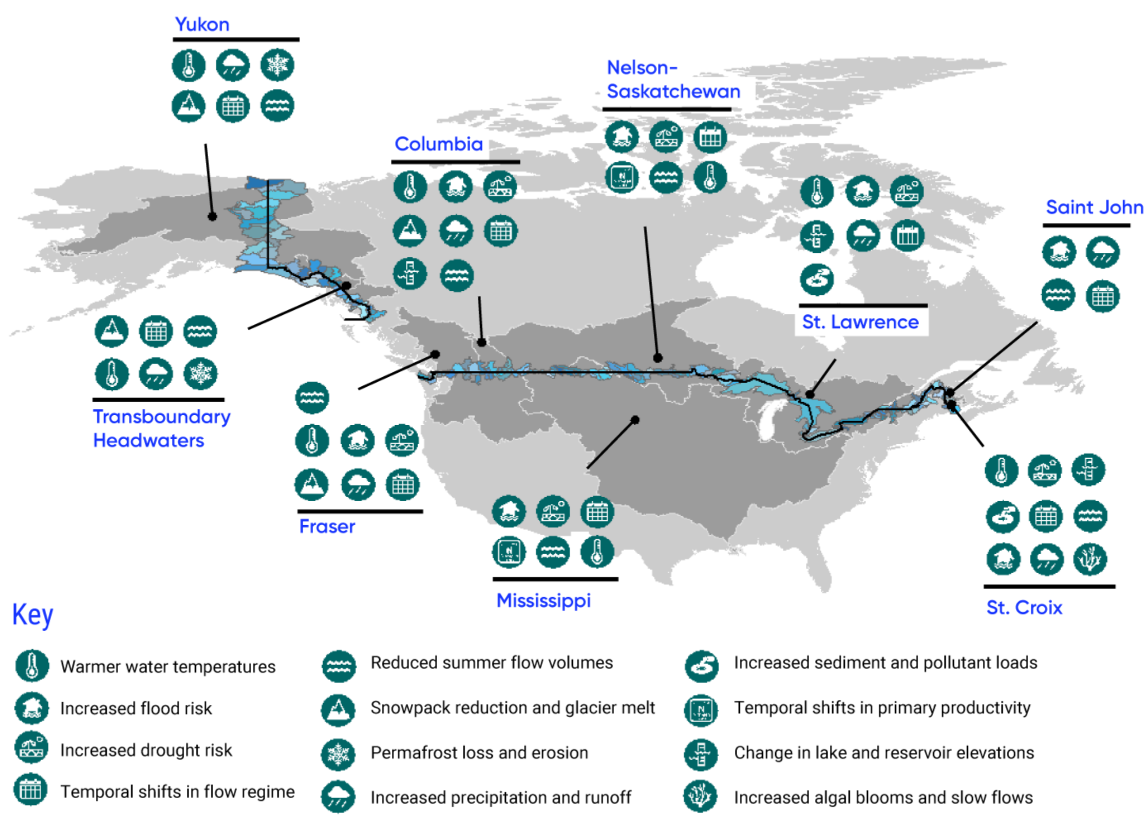


Figure 9.7: Projected climate change impacts for major drainage basins that are shared across Canada–US borders. Data sources: Adapted from George, 2019b; International Joint Commission, 2017; World Wildlife Fund-Canada, 2017; Bartolai et al., 2015; International Joint Commission, 2013; Shrestha et al., 2012; Hamlet, 2010; Mantua et al., 2010; International Joint Commission, 2009; Hamlet and Lettenmaier, 2007; Bruce et al., 2003; Hamlet and Lettenmaier, 1999.

Table 9.4: Shared management considerations, related climate change stressors and major shared drainage basins affected

SHARED MANAGEMENT CONSIDERATIONS	RELATED CLIMATE CHANGE STRESSORS	MAJOR SHARED DRAINAGE BASINS AFFECTED
Drinking water supply		• Fraser • St. Croix
Flood management		• Columbia • Fraser • Nelson-Saskatchewan • St. Lawrence
Fish conservation		• Columbia • Fraser • Nelson-Saskatchewan • St. Croix • St. Lawrence • Transboundary Headwater • Yukon
Hydropower production		• Columbia • Saint John • St. Croix • St. Lawrence
Agricultural irrigation		• Columbia • Nelson-Saskatchewan • Mississippi
Shipping and navigation		• Columbia • St. Lawrence

	SHARED MANAGEMENT CONSIDERATIONS	RELATED CLIMATE CHANGE STRESSORS	MAJOR SHARED DRAINAGE BASINS AFFECTED
	Recreation opportunities		• Columbia • St. Lawrence
	Water quality management		• Columbia • Fraser • Nelson-Saskatchewan • Saint John • St. Lawrence • Transboundary Headwaters

Key

- Warmer water temperatures
- Increased flood risk
- Increased drought risk
- Increase precipitation and runoff
- Reduced summer flow volumes
- Snowpack reduction and glacier melt
- Permafrost loss and erosion
- Temportal shifts in flow regime
- Increased sediment and pollutant loads
- Temporal shifts in primary productivity
- Change in lake and reservoir elevations
- Increased algal blooms and slow flows

Sources: International Joint Commission, 2020; Province of British Columbia and State of Alaska, 2015; Canada and U.S.A., 2013; Province of British Columbia and State of Montana, 2010; Norman and Bakker, 2005; State of Illinois et al., 2005; Great Lakes Commission, 1994; Province of British Columbia and State of Washington, 1992; Canada and U.S.A., 1985; Province of Ontario et al., 1985; Canada and U.S.A., 1964; Canada and U.S.A., 1954; Canada and U.S.A., 1952; Canada and U.S.A., 1950; Canada and U.S.A., 1932; Canada and U.S.A., 1925; Great Britain and U.S.A., 1909.

Freshwater governance across the Canada–U.S. border is defined by numerous transboundary agreements at federal and provincial/state levels (*see* Table 9.5). Several of these agreements were signed before climate change was a recognized issue and remain grounded in assumptions of stationarity (e.g., Boundary Waters Treaty, Columbia River Treaty and Convention on Great Lakes Fisheries).

Table 9.5: Transboundary freshwater agreements across the Canada–U.S. border with key water bodies indicated

MAJOR DRAINAGE BASIN	AGREEMENTS	KEY WATER BODIES
Yukon	• Pacific Salmon Treaty 1985 (federal) • Boundary Waters Treaty 1909 (federal)	• Yukon River
Transboundary Headwaters	• Pacific Salmon Treaty 1985 (federal) • Boundary Waters Treaty 1909 (federal) • BC-Alaska Memorandum of Understanding and Cooperation 2015 (provincial/state)	• Stikine River • Alsek River • Chilkat River • Taku River • Whiting River • Unuk River
Fraser	• Pacific Salmon Treaty 1985 (federal) • BC-Washington Environmental Cooperation Agreement 1992 (provincial/state)	• Fraser River • Abbotsford-Sumas Aquifer • Nooksak River
Skagit	• Boundary Waters Treaty 1909 (federal)	• Skagit River
Columbia	• Boundary Waters Treaty 1909 (federal) • Columbia River Treaty 1964 (federal) • Flathead Memorandum of Understanding and Cooperation on Environmental Protection, Climate Action and Energy 2010 (provincial/state) • BC-Washington Environmental Cooperation Agreement 1992 (provincial/state)	• Columbia River • Kootenay River • Osoyoos Lake • Flathead River

MAJOR DRAINAGE BASIN	AGREEMENTS	KEY WATER BODIES
Nelson-Saskatchewan	• Boundary Waters Treaty 1909 (federal)	• Souris River • Red River
Mississippi	• Boundary Waters Treaty 1909 (federal)	• Saint Mary River • Milk River • Poplar River
St. Lawrence	• Boundary Waters Treaty 1909 (federal) • Great Lakes Water Quality Agreement 2012 (federal) • Convention on Great Lakes Fisheries 1954 (federal) • Lake of the Woods Convention & Protocol 1925, 1979 (federal) • Saint Lawrence Seaway Project Agreement 1952, 1954 (federal) • Niagara River Water Diversion Treaty 1950 (federal) • Saint Lawrence Deep Waterway Treaty 1932 (federal) • Great Lakes Charter 1985 (provincial/state) • Ecosystems Charter for the Great Lakes and Saint Lawrence Basin 1994 (provincial/state) • Lake Memphremagog Environmental Cooperation Agreement 1989, 2003 (provincial/state) • The Great Lakes–St. Lawrence River Basin Sustainable Water Resource Agreement 2005 (provincial/state)	• Great Lakes • St. Lawrence River • Lake of the Woods • Rainy River • Lake Champlain • Richelieu River • Lake Memphremagog • Niagara River
Saint John	• Boundary Waters Treaty 1909 (federal)	• Saint John River

MAJOR DRAINAGE BASIN	AGREEMENTS	KEY WATER BODIES
St. Croix	• Boundary Waters Treaty 1909 (federal)	• St. Croix River

Sources: International Joint Commission, 2020; Province of British Columbia and State of Alaska, 2015; Canada and U.S.A., 2013; Province of British Columbia and State of Montana, 2010; Norman and Bakker, 2005; State of Illinois et al., 2005; Great Lakes Commission, 1994; Province of British Columbia and State of Washington, 1992; Canada and U.S.A., 1985; Province of Ontario et al., 1985; Canada and U.S.A., 1964; Canada and U.S.A., 1954; Canada and U.S.A., 1952; Canada and U.S.A.,1950; Canada and U.S.A., 1932; Canada and U.S.A., 1925; Great Britain and U.S.A., 1909.

Other countries can provide useful lessons for updating Canada–U.S. freshwater agreements. In 2015, under the United Nations Economic Commission for Europe's (UNECE) Water Convention, Belarus, Lithuania and Russia jointly created one of the first frameworks for climate change adaptation in a transboundary river basin—the Strategic Framework for Adaptation to Climate Change in the Neman River Basin (Korneev et al., 2015). The Neman Basin's primary environmental stressor is industrial pollution. Unless adaptation measures are put in place, industrial pollutants will become more concentrated as runoff decreases due to climate change. The Framework establishes a baseline status for basin-wide water monitoring and includes a common set of spatially explicit impact and risk projections. The agreement is closely aligned with the principles laid out in the EU Water Framework Directive, with adaptive features including "climate-proof" performance measures for monitoring that are capable of responding to non-stationarity (e.g., proportional rather than volumetric); a cyclical approach with periodic revisions to accommodate new developments in science and technology, address new uncertainties, and permit adjustment as existing uncertainties are resolved; the establishment of a river basin commission with multi-stakeholder representation capable of responding to shifting interests and priorities of affected parties as the impacts of climate change unfold; and consistent policy linkages across local, national and international levels that allow decision makers to be more agile, reducing bottlenecks from poor policy harmonization (European Commission, 2009).

Table 9.6 lists adaptive measures implemented in transboundary river basins globally and compares these with measures applied in key Canada–U.S. freshwater agreements. Except for the Great Lakes Water Quality Agreement (GLWQA), no more than a third of these measures are currently applied in any of Canada's major shared river basins. The Canada–U.S. International Joint Commission (IJC) has developed a high-level non-binding framework for its seventeen Boards and Committees, which lays out a process for climate change adaptation planning, knowledge sharing, and the use of adaptive management (International Joint Commission, 2018; Bernstein et al. 2017). The GLWQA was updated in 2012 and is currently Canada's most climate-ready freshwater treaty. The agreement explicitly includes obligations to apply adaptive management principles in response to climate change, but implementation has been slow. There remains no jointly developed basin-wide strategy for addressing climate change impacts (International Joint Commission, 2017).

Table 9.6: Adaptive practices applied in transboundary freshwater agreements (globally), compared with current practices under key Canada–U.S. freshwater agreements

TRANSBOUNDARY ADAPTIVE PRACTICES IN BASINS (GLOBALLY)	BOUNDARY WATERS TREATY	IJC* INITIATIVES UNDER BOUNDARY WATERS TREATY	PACIFIC SALMON TREATY	COLUMBIA RIVER TREATY	GREAT LAKES WATER QUALITY AGREEMENT	CONVENTION OF GREAT LAKES FISHERIES
Environmental						
Joint habitat quality targets (e.g., ecological flows)			■	■	■	
Flexible water quality standards and/or operating rules (e.g., proportional not volumetric allocations)						
"Climate-proof" performance measures for joint monitoring						
Coordinated flood, drought, and/or pollution management and early warning systems		■		■	■	
Ecological management units (e.g., river basin)		■	■	■	■	■
Integrated adaptive management (systems-based, including marine systems; test hypotheses to address uncertainties)					■	
Coordinated climate change modelling, analyses, and research		■			■	

TRANSBOUNDARY ADAPTIVE PRACTICES IN BASINS (GLOBALLY)	BOUNDARY WATERS TREATY	IJC* INITIATIVES UNDER BOUNDARY WATERS TREATY	PACIFIC SALMON TREATY	COLUMBIA RIVER TREATY	GREAT LAKES WATER QUALITY AGREEMENT	CONVENTION OF GREAT LAKES FISHERIES
Political/Governance						
Federal ratification of international policies laws for water management (e.g., Water Convention)						
Climate change adaptation obligations embedded explicitly in agreement					■	
Allowance for supplementary agreements				■		
Dispute resolution mechanisms	■	■		■	■	
Formal river basin organization(s) that include or consult with multiple interest groups	■		■		■	■
Explicit commitment to develop joint climate change adaptation management plan/framework					■	
Policy harmonization across borders and levels of government						
Frequent (e.g., 10–20 year) periodic review/revision of agreement					■	■
Open data sharing across multiple interest groups		■	■		■	

TRANSBOUNDARY ADAPTIVE PRACTICES IN BASINS (GLOBALLY)	BOUNDARY WATERS TREATY	IJC* INITIATIVES UNDER BOUNDARY WATERS TREATY	PACIFIC SALMON TREATY	COLUMBIA RIVER TREATY	GREAT LAKES WATER QUALITY AGREEMENT	CONVENTION OF GREAT LAKES FISHERIES
Economic						
Joint financial commitment to climate change adaptation					■	
Equitable sharing of benefits (e.g., payments for upstream ecosystem services)			■	■		

*The International Joint Commission (IJC)

Sources: UN Economic Commission for Europe, 2018; Escribano Francés et al., 2017; Honkonen, 2017; International Joint Commission, 2017; Bartolai et al., 2015; Norman, 2015; UN Economic Commission for Europe et al., 2015; Abdel-Fattah and Krantzberg, 2014; BC Hydro, 2013; Canada and U.S.A., 2013; Hamlet et al., 2013; International Joint Commission, 2013; UN Economic Commission for Europe, 2013; Bankes and Cosens, 2012; Cooley et al., 2012; Shrestha et al., 2012; Cooley and Gleick, 2011; UN Development Programme - Global Environmental Facility, 2011; Hamlet, 2010; Keskitalo, 2010; Mantua et al., 2010; Northwest Power and Conservation Council, 2010; Brown and Crawford, 2009; Cooley et al., 2009; de Loë, 2009; Huitema et al.. 2009; International Joint Commission, 2009; Pahl-Wostl et al., 2009; Timmerman and Bernardini, 2009; UN Economic Commission for Europe, 2009; Krysanova et al., 2008; Draper and Kundell, 2007; Hamlet and Lettenmaier, 2007; Ketchum and Barroso, 2006; Sneddon and Fox, 2006; Norman and Bakker, 2005; Bruce et al., 2003; Dietz et al., 2003; Muckleston, 2003; Paisley, 2002; Hamlet and Lettenmaier, 1999; Johnson, 1999; Wolf, 1998; Lee, 1994; Stoner et al., 1993; Canada and U.S.A., 1985; Blumm, 1980; Canada and U.S.A., 1964; Canada and U.S.A., 1954; Great Britain and U.S.A., 1909; Yukon River Panel, n.d.

The need for climate change adaptation, therefore, presents opportunities to modernize arrangements governing Canada's shared river basins in order to provide more resilient frameworks for coping with uncertainty, protecting environmental values and improving representation of affected groups and Indigenous governments. Review and revision of existing arrangements, as is currently occurring for the Columbia River Treaty, can aid in addressing adaptation gaps (*see* Case Story 9.3).

Case Story 9.3: Modernizing the Canada–U.S. Columbia River Treaty to consider climate change

The 1964 Canada–U.S. Columbia River Treaty (CRT) outlines rules for cooperative uses and responsibilities over hydropower production and flood management (Canada and U.S.A., 1964). The agreement was once an exemplar of international water cooperation due to its observance of the principle of "equitable use" via a 50/50 split of hydropower benefits (Paisley, 2002). Adaptive features also include the annual creation of two operating plans covering different planning horizons (upcoming year and six years out) and the use of sub-agreements. Additional shared values in the basin include recreation, navigation, agricultural irrigation and Indigenous cultural heritage (Government of British Columbia, 2013). The agreement is now outdated because it makes no explicit mention of these other values, assumes stationarity and lacks mechanisms for interested parties to be included in decision-making. Climate change projections show an increasing proportional contribution of Columbia River flows to the Canadian part of the basin, which will likely increase U.S. demand for Canadian water management (*see* Figure 9.8; Hamlet et al., 2013; Hamlet, 2010; Mantua et al., 2010; Hamlet and Lettenmaier, 2007; Hamlet and Lettenmaier, 1999). With the aim of better reflecting modern values, renegotiations of the CRT are currently underway. As part of the negotiations, ecosystem functions are being considered, modelled climate change projections are playing a role, and, in an unprecedented move for Canadian international negotiations, Indigenous communities have been included as observers at the negotiating table (Government of British Columbia, 2019; Government of British Columbia, 2014; U.S. Entity to the Columbia River Treaty, 2013). The extent to which the CRT will re-establish its status as an exemplar by embracing more adaptive principles remains to be seen, but the current policy window is an opportunity to re-craft a historic water agreement with an eye towards future climate uncertainty.

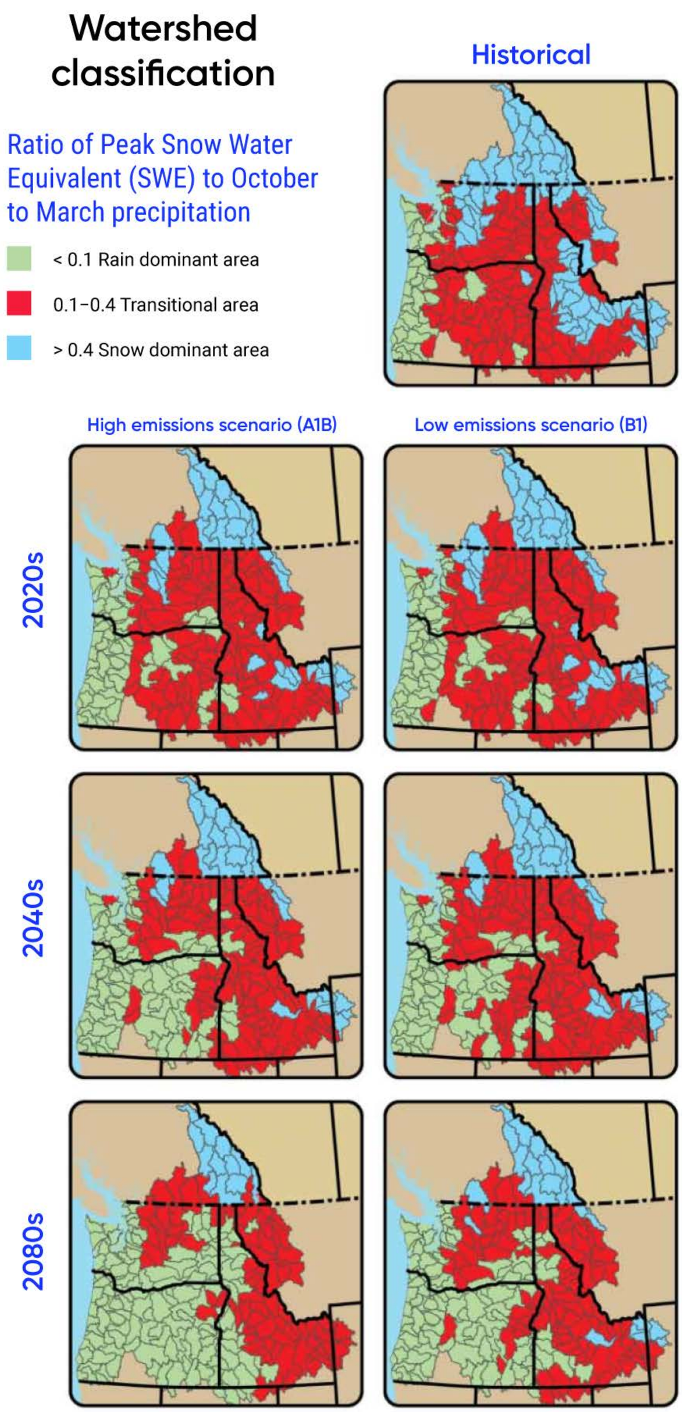


Figure 9.8: Historical and projected future watershed classifications for the Columbia Basin, based on the global emissions scenarios (the A1B relatively high emissions scenario and the B1 low emissions scenario) for the 2020s, 2040s and 2080s. As climate change progresses, 50% of the total reservoir storage is expected to lie in Canada. Canada is also expected to have an increasingly dominant portion of natural water storage as snowpack. Source: Adapted from Hamlet et al., 2013.

9.4 Climate change presents risks and opportunities for international trade

Canada is dependent on international trade and will increasingly experience economic effects from extreme weather and climate change impacts and adaptation elsewhere in the world, especially when occurring in countries with which Canada has strong trade ties.

Canada's mixed economy is reliant on trade as a source of wealth and to satisfy consumer needs. The impacts of climate change around the world, such as sea-level rise and more intense extreme events, as well as actions taken in response to these impacts will alter patterns of global trade, with consequences for Canadian businesses, consumers and the economy. Disruptions to supply and distribution networks, changes in the availability and price of traded goods, and the creation of global markets for new adaptation solutions are among the direct and indirect impacts of climate change. Weather-related disruptions to supply chains and short-term price spikes in staples heighten the need for Canadian firms and governments to assess the risks and opportunities that climate change impacts on global trade will present, including the negative effects of long-term adjustments in trade patterns for communities within and beyond Canada's borders. Little published research exists about these indirect impacts of climate change or assessments of action by Canadian businesses and governments to understand and manage resulting risks and opportunities.

9.4.1 Introduction

Canada relies on trade for economic and social well-being. Over half of the country's gross domestic product (GDP) derives from the export and import of goods and services in the global marketplace (Global Affairs Canada, 2019a). In 2018, Canada exported $706 billion and imported $753 billion in goods and services (Global Affairs Canada, 2019a), with goods accounting for just over 80% of trade by value. Five trade partners received 90% of Canada's exports and supplied over 85% of its imports in goods, with trade in consumer goods, energy and mining commodities particularly prominent, in dollar terms (*see* Figure 9.9). Although Ontario, Alberta and Quebec accounted for almost 80% of goods exported in 2017, exports originated from all provinces and territories (Global Affairs Canada, 2018). Ontario, Quebec and British Columbia received over 80% of imported goods in 2017. Every year, thousands of Canadian firms engage in international trade, with small- and medium-sized enterprises accounting for over 90% of trade activity, when measured by number of organizations. In dollar terms, large firms (over 500 employees) account for over 50% of trade value (Statistics Canada, 2018a, b).

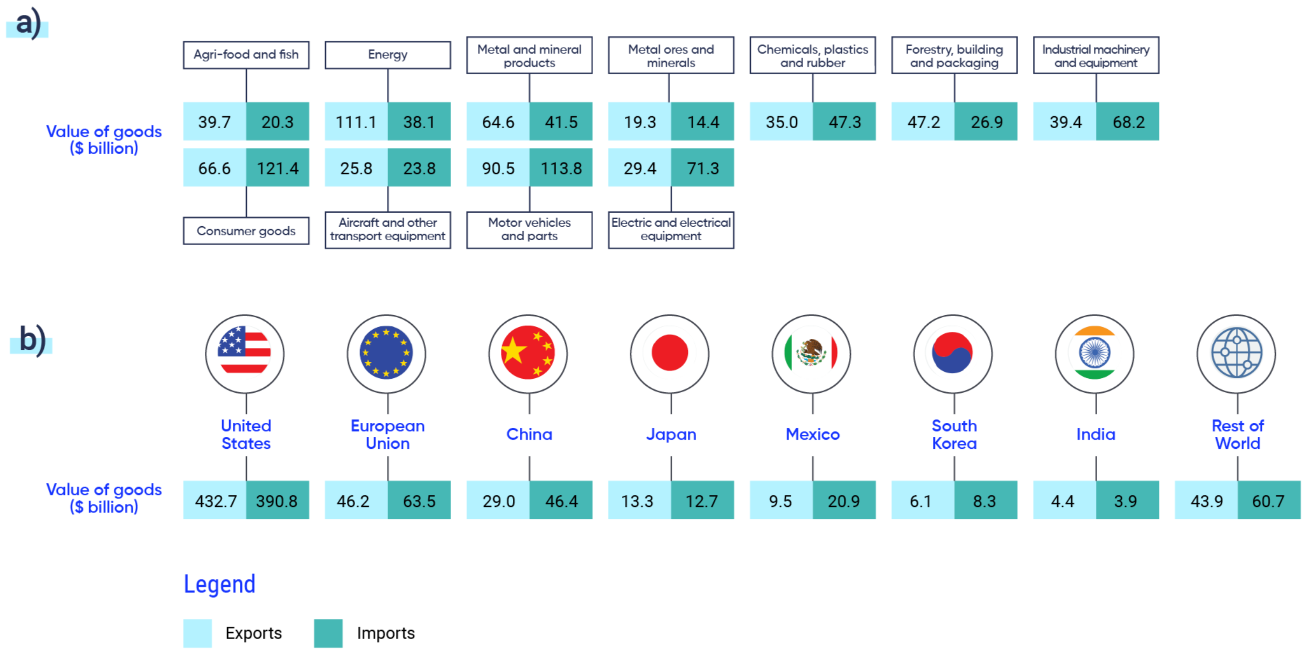


Figure 9.9: Canada's trade performance in 2018: a) value of exports (light blue) and imports (green) of goods in $ billions, by sector; b) Value of export (light blue) and import (green) of goods in $ billions, by trade partner or region. Source: Adapted from Global Affairs Canada, 2019a.

The impacts of climate change felt elsewhere in the world, such as increased temperatures, sea-level rise and more intense extreme events, have ripple effects for Canada's economy and population through international trade. As described elsewhere in this assessment, climate change impacts within Canada's borders shift the risks and opportunities faced by Canadian enterprises, with economy-wide consequences (*see* Costs and Benefits of Climate Change Impacts and Adaptation chapter and Sector Impacts and Adaptation chapter). Foreign enterprises competing with Canadian producers are exposed to climate change risks and opportunities in similar ways. Supply- and demand-side factors come into play, with benefits or costs tempered by the adaptive capacity at the enterprise, sector or country level (*see* Table 9.7).

Table 9.7: Examples of climate change risks and opportunities on the supply and demand sides of business

ADAPTIVE CAPACITY	PATHWAY OF EXPOSURE		EXAMPLES OF CLIMATE CHANGE-RELATED RISKS AND OPPORTUNITIES
Ability to adapt given size, resource endowments, geographic location, sector, policy and regulatory frameworks, information and partnerships	Supply	Infrastructure, capital goods and inventory	• Loss and damage from extreme events • Loss of coastal locations due to sea-level rise • Increased costs to pay for reconstruction and adaptation
		Employees and labour productivity	• Loss of hours worked due to disasters, infrastructure disruption, lack of access to workplace, temporary or permanent displacement • Loss of hours worked (or slower work) due to rising heat stress
		Supply chains and distribution networks	• Shortages of inputs (e.g., energy, water, food and other inputs) and disruptions in supply chains • Interruptions in delivery of goods and services to markets
		Products and services	• Changes in the cost of production and service delivery (e.g., increased input costs, increased cooling costs, higher insurance premiums)

ADAPTIVE CAPACITY	PATHWAY OF EXPOSURE		EXAMPLES OF CLIMATE CHANGE-RELATED RISKS AND OPPORTUNITIES
Ability to adapt given size, resource endowments, geographic location, sector, policy and regulatory frameworks, information and partnerships (continued)	Demand	Consumption / purchase	• Changes in quantity, quality or location of demand for goods and services
		Investment	• Changes in capital flows due to uncertainty of direct, indirect and cascading physical climate risks

Sources: Adapted from Batten, 2018; Surminski et al., 2018

In a global marketplace, countries and firms within them can specialize, producing goods and services for which they have a lower opportunity cost relative to foreign counterparts, while importing other goods and services. This principle—comparative advantage—is a key driver of international trade (Bruce and Haites, 2008). With the rise of emerging economies, trade flows and geographic centres of trade are expected to shift in the next few decades (Dellink et al., 2017). Producers in Atlantic Canada, for example, are forging connections with emerging Asian markets through the Suez Canal (Rapaport et al., 2017). Climate change stands to alter countries' comparative advantage (Costinot et al., 2014; Bruce and Haites, 2008) meaning that projected evolutions in world trade patterns may go unrealized (Dellink et al., 2017).

This section discusses the risks and opportunities to Canada from climate-induced disruptions to global supply chains and from changes in comparative advantage in a global marketplace. It also explores the interplay between climate change adaptation and international trade.

9.4.2 Trade and climate change risk

Climate change impacts can result in economic consequences for Canada by disrupting supply and distribution networks reliant on vulnerable trade infrastructure. Well-functioning transportation infrastructure is essential for trade. Globally, marine shipping and seaport operations account for about 80% of trade by volume and 70% by value (UN Conference on Trade and Development, 2018). Canada's transportation system moved $1.107 trillion in traded goods in 2017 (Transport Canada, 2017), with Port Metro Vancouver handling upward of 15% of the trade by value, with more than 160 countries (Nyland and Nodelman, 2017). International and Canadian Port authorities and operators indicate that weather and extreme climate events are already causing shipment delays and physical damage (UN Conference on Trade and Development, 2017; Ng et al., 2016). Changing climate conditions and extreme weather have numerous implications for seaports and land-based trade infrastructure (*see* Table 9.8), including disruptions that increase the cost of international trade and cause rerouting as firms opt for more reliable alternatives of the same mode or others (Dellink et al., 2017). Global food trade is particularly at risk because of a growing reliance on a small number of maritime, coastal and inland choke points to move food staples and fertilizers (Bailey and Wellesley, 2017).

Table 9.8: Examples of climate change risks for trade infrastructure

CLIMATE HAZARD	TRANSPORT MODE	EXAMPLES OF DIRECT IMPACTS	CONSEQUENCES ON TRADE INFRASTRUCTURE
Increased temperature and solar radiation	Road and rail	• Rail buckling • Pavement cracking • Loss of water seal causing potholing • Reduced life of asphalt	• Speed restrictions to avoid derailments • Increased maintenance and insurance costs
	Aviation	• Reduced life of asphalt • Reduced airlift capacity	• Increased maintenance and insurance costs • Need to construct longer runways to make up for reduced airlift
	Sea-based transport	• Reduced refrigeration capacity • Opening / expansion of Arctic shipping routes due to shrinking sea ice	• Increased need for cooling terminals and cargo • Reduced distances and time related to Arctic navigation, but need for additional navigation aids • Higher insurance costs for Arctic navigation

CLIMATE HAZARD	TRANSPORT MODE	EXAMPLES OF DIRECT IMPACTS	CONSEQUENCES ON TRADE INFRASTRUCTURE
Increased precipitation, inland flooding and fog intensity/ duration	Road and rail	• Flooding • Bridge scour	• Increased maintenance and insurance costs • Rerouting to avoid affected roads and bridges
	Aviation	• Flooding of runways and access roads • Damage to facilities • Reduced visibility	• Increased maintenance and insurance costs
	Sea-based transport	• Damage to land infrastructure, cargo and equipment • Reduced capabilities in loading/unloading cargo at ports • Increased rates of asset deterioration (e.g., corrosion) • Reduced visibility in ships and by terminal operations	• Risk of delays • Increased construction and maintenance costs
Sea-level rise and storm surges	Road and rail	• Temporary or permanent inundation	• Increased maintenance and insurance costs • Risk of delays
	Aviation	• Temporary or permanent inundation	• Higher maintenance and insurance costs • Relocation

CLIMATE HAZARD	TRANSPORT MODE	EXAMPLES OF DIRECT IMPACTS	CONSEQUENCES ON TRADE INFRASTRUCTURE
Sea-level rise and storm surges (continued)	Sea-based transport	• Lower clearance under waterway bridges • Damage to port infrastructure • Increased rates of asset deterioration (e.g., corrosion)	• Need for new ship design • Need for reconfiguration of operational areas • Increased maintenance costs and repair of port facilities
Extreme weather (e.g., high winds, storms)	Road and rail	• Disturbance to transport electronic infrastructure (e.g., signalling)	• Disruption to operations • Increased maintenance and insurance costs
	Aviation	• Disturbance to transport electronic infrastructure (e.g., signalling)	• Increased maintenance and insurance costs • Risk of delays
	Sea-based transport	• Temporary shutdown of ports • Worsened sailing conditions • Disturbance to transport electronic infrastructure (e.g., signalling)	• Risk of delays • Increased maintenance and insurance costs

Sources: Dellink et al., 2017; UN Conference on Trade and Development, 2017

Although direct impacts on international trade such as these will occur and potentially intensify with climate change, their consequences are uncertain. Statistical analyses of bilateral trade activity at a global level show that temperature rise and the occurrence of climate-related disasters reduce trade flows, partly because of increased transportation costs (Dallmann, 2019; Oh, 2017). Distance between trade partners, each country's socioeconomic status and strength of institutions shape vulnerability. One global study shows that sea-level rise consistent with a scenario of high global emissions will decrease the performance of sea transport worldwide by 2050 in terms of cargo handling capacity, reducing exports and economic welfare in all 13 regions modelled (Chatzivasileiadis et al., 2016). Another study suggests that disruptions to trade infrastructure due to climate events by 2060 could cause major economic consequences in specific regions, but may not be as pronounced as price and production adjustments induced by climate impacts (Dellink et al., 2017). Critical uncertainties in assessing the impact of climate change on trade infrastructure include the viability of Arctic shipping, the resilience of newly built and existing trade infrastructure and operators' levels of preparedness (The Economist, 2020; Food and Agriculture Organization, 2018; Becker et al., 2017; Dellink et al., 2017; Chatzivasileiadis et al., 2016). Canada's transport infrastructure, including trade infrastructure (Great Lakes–St. Lawrence Seaway, Port Metro Vancouver and Port Saint John), is vulnerable to climate-related damage and disruptions, with efforts to understand and manage future impacts still in early stages (Palko, 2017).

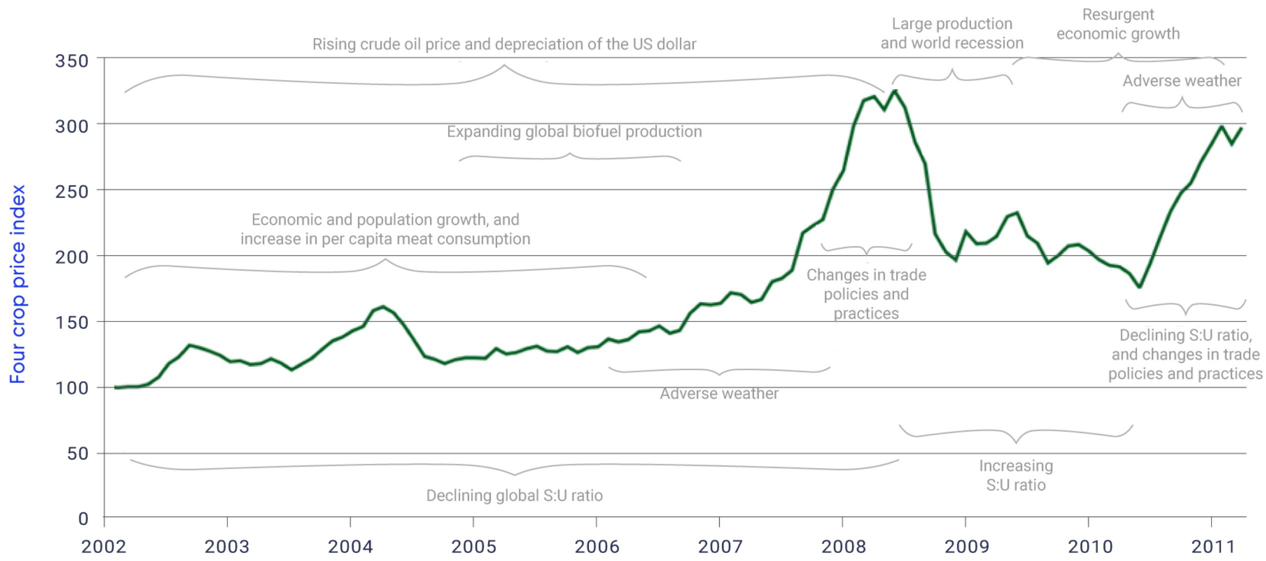
Indirect impacts of climate change on trade include shifts in the availability and prices of food and feedstock, timber, metals and other basic goods and services in the global marketplace. International trade comprises an increasingly complex, interdependent network of global supply chains, such that climate-induced disruptions to production can have economic ripple effects across sectors and geographies over the short and long term (Adams et al., 2020; Dellink et al., 2017; Wenz and Leverman, 2016). On the supply side, exposure to climate change impacts and the degree of concentration of suppliers are key risk factors (Gledhill et al., n.d.). Canada is among the top five global suppliers of wheat, fertilizer, petroleum and metal ores and top ten of corn (Bailey and Wellesley, 2017; Gledhill et al., n.d.). On the demand side, dependency and buffering capacity in local markets are among the traits that shape vulnerability to shocks (D'Amour et al., 2016; Wenz and Leverman, 2016). Climate-related disruptions in wheat, corn, rice and soybeans (so-called agricultural commodities or food staples) to major suppliers can affect global prices. Supply- and demand-side factors interact in complex ways. For example, drought conditions and heat waves in 2010 and 2011 in Russia and other supply regions reduced wheat yields and global food production, and, combined with market and policy responses (e.g., export bans), contributed to a spike in prices for wheat globally, as well as food insecurity and social unrest across the Middle East (*see* Box 9.2; Challinor et al., 2017; D'Amour et al., 2016; Coulibaly, 2013). In contrast to food staples, energy and mining supplies are more diversified and disruptions are more likely to relate to non-climate factors, such as resource availability, technological advances and politics (Goldstein et al., 2019; Gledhill, n.d.). The global COVID-19 pandemic highlights the vulnerability of Canadian manufacturing sectors to disruptions in international supply chains, due to their reliance on foreign suppliers for inputs and foreign sales (Global Affairs Canada, 2020).

Box 9.2: Climate, global spikes in food prices and domestic impacts

The price of food staples or commodities (grains, oilseeds, vegetable oils, meat, seafood, sugar and fruit) can rise and fall abruptly. In the past 40 years, five periods of price volatility have occurred. In the aftermath of price spikes, markets adjust and prices typically return to within historic levels (Trostle, 2011). However, food price spikes—even for a short term—and new price plateaus have social consequences. Price spikes in commodities are particularly concerning for developing countries dependent on imported staples for nutrition and calories. Countries in Northern Africa and the Middle East, for example, depend strongly on imported wheat and consumer diets rely on its steady supply (D'Amour et al., 2016). A drop in global stocks of commodities combined with higher prices can outstrip a country's financial capacity to import the food needed to satisfy domestic consumption.

Sharp food price spikes occurred in 2007–2008 and 2010–2011, reflecting a combination of long-term factors and short-term shocks (Trostle, 2011). The price of food staples has seen a general rise since 2002 due to both consumption and production-related factors, including population growth, higher per-capita incomes, increased consumption of animal products, exchange rates, rising energy prices, land-use conflicts due to a rise in global biofuel production and slower growth in agricultural productivity. Added to these long-term trends, short-term shocks drove price spikes in 2007–2008 and 2010–2011. Shortfalls in production caused by severe weather events, a drop in world stocks of grains and oilseeds and changes in trade policies and practices (e.g., export bans and lifting of import levies) were the main short-term factors contributing to price spikes in both time periods, although the importance and sequencing of these factors differed (*see* Figure 9.10a). As a major wheat producer, crop losses in Canada due to wet weather in 2010 was one among several adverse weather events contributing to global food price spikes (*see* Figure 9.10b).

a)



b)

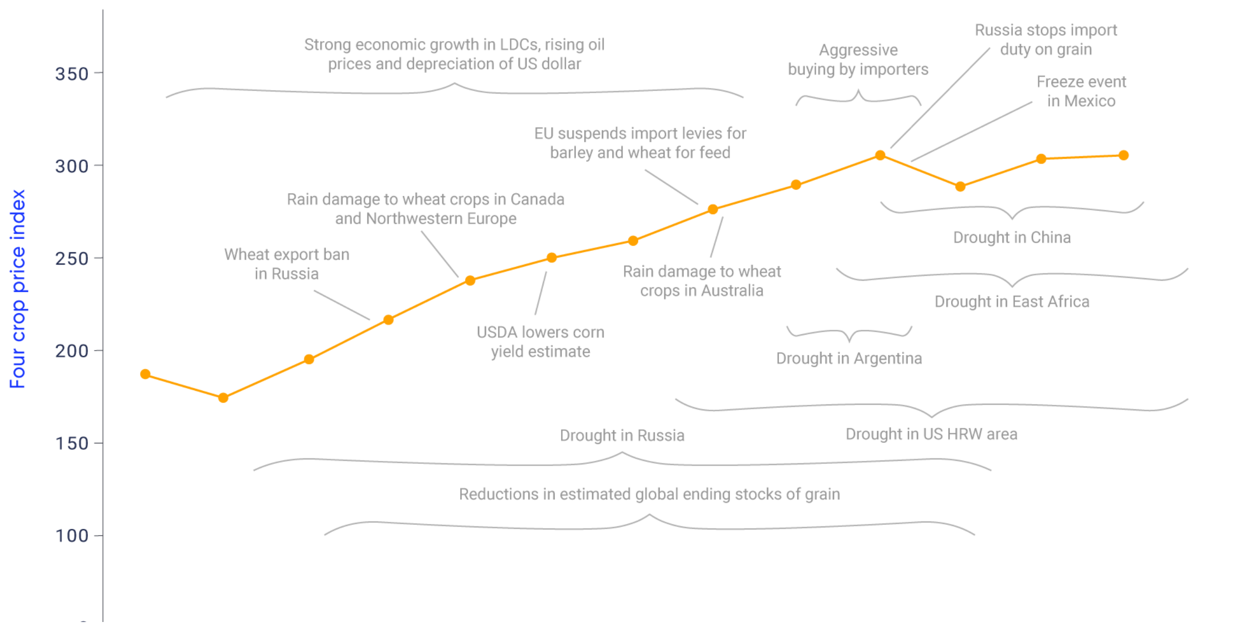


Figure 9.10: Primary factors contributing to increases in global food prices, based on a four-crop price index (wheat, rice, corn and soybean). a) Shows the change in crop prices (green line) for the period 2002–2011, and identifies long-term and short-term factors that contributed to price changes over time. Tighter supply-demand balances (as depicted by global stock-to-use ratio "S:U ratio") and economic growth/recession, for example, are a backdrop to weather events and trade policies. b) Change in crop prices between May 2010 and April 2011 in relation to weather-related events that resulted in supply shortfalls. Both wet and dry conditions, which were not isolated to one global region, contributed to a reduction in global crop supply. Source: Adapted from Trostle, 2011.

As a trading nation, Canada is not immune to the influence of global spikes in food staples. Food prices in Canada, as measured by the Consumer Price Index (CPI), increased markedly between 2007 and 2012 (Rollin, 2013). The CPI measures changes in prices by tracking the cost of a fixed basket of goods and services through time, with food as one of eight items captured in the CPI. Between 2007 and 2012, the food component of the CPI grew at a faster pace than the all-item CPI, with food prices rising by 19% over the period and all-items CPI excluding food rising by 10.7% (Rollin, 2013). Canadian households that allocate a greater proportion of their budgets to food are most vulnerable to inflation in food prices. These groups include low-income households, households headed by seniors with fixed incomes and households in remote areas. Nationally, one in eight Canadian households experienced some level of food insecurity in 2011, as measured by an inability to access adequate food due to financial constraints (Tarasuk et al., 2011).

Food prices in local markets show year to year variability, so it is important to consider the interplay among macro-level factors, such as climate-related shocks to global food supplies, alongside sectoral and local-level factors in projecting future changes in food prices and in understanding the role of climate change in these shifts. For the past 10 years, researchers from Dalhousie University and the University of Guelph have produced a report forecasting potential price changes in eight food categories ("Canada's Food Price Report"). In recent years, this research has included a qualitative risk assessment of twelve supply and demand-side variables and their influence on Canadian food prices (*see* Table 9.9). Geopolitical risks, actions of the food processing industry and consumer purchasing power were the top risks in 2019, 2020 and 2021 forecasts at the macro, sectoral and domestic level, respectively.

Table 9.9: A range of macro (global), sectoral and domestic factors shape food prices Canadians see in local markets

LEVEL	FACTOR	2019		2020	
		IMPACT	LIKELIHOOD	IMPACT	LIKELIHOOD
Macro-level	Climate change (~)	4	4	5	5
	Geopolitical risks (~)	5	5	5	5
	Input costs (+)	4	4	4	4
	Energy costs (*)	3	4	3	4
	Inflation (+)	4	5	3	4

LEVEL	FACTOR	2019		2020	
		IMPACT	LIKELIHOOD	IMPACT	LIKELIHOOD
Macro-level (continued)	Currencies and trade environment (~)	4	5	4	5
Sectoral-level	Food retail and distribution landscape (-)	5	4	4	4
	Food processing industry (+)	4	5	5	4
	Policy context (-)	5	5	3	5
	Consumer food awareness and trends (-)	4	5	3	4
Domestic-level	Consumer indebtedness (-)	4	5	5	5
	Consumer income and income distribution (-)	4	5	5	5

Note: This table provides a qualitative forecast of each of these factors for 2019, 2020 and 2021 along two dimensions: likelihood of occurrence and impact on food prices should it occur. Likelihood is represented on a 5-point scale, with 4 representing "likely" and 5 "very likely." Impact is represented on a 5-point scale, with 3 representing "moderate," 4 "significant" and 5 "very significant." Factors can affect prices in several ways: they can exert downward (-) or upward (+) pressure on prices, or their effect can be variable (~) or negligible (*).

Source: Authors' elaboration, based on Dalhousie University and University of Guelph, 2019, 2020, 2021.

Agriculture and food products are particularly climate-sensitive and heavily traded (Dellink et al., 2017), consequently, the nexus of international trade, climate change and food security is receiving international attention (Mbow et al., 2019; Food and Agriculture Organization, 2018; Mosnier et al., 2014). Studies project a drop in global agricultural production, an increase in world food prices, increased bilateral food trade activity and a loss in economic welfare resulting from climate change by the 2050s and 2080s (*see* Table 9.10; Food and Agriculture Organization, 2018). Another common thread is the uneven impact among global regions, with food-importing tropical countries particularly vulnerable to climate change because of high economic sensitivity to yield and terms-of-trade shocks and high exposure to climate hazards (Gouel and Laborde, 2018; Distefano et al., 2017). In contrast to global projections, these same studies show positive outcomes for Canada for some indicators, including an increase in agricultural wages and in economic welfare. However, evaluating the bottom line on food security is subject to several sources of uncertainty, including: the magnitude of climate change and its diverse local impacts; the climate hazards considered; the future productivity and nutritional value assumed for a range of agricultural staples and food items; the interactive effects between climate change, domestic production and imports; adaptation by producers and consumers; and the responsiveness of trade to price signals. For example, one study modelling climate change impacts on global markets for 18 crops to 2050 suggests a change in crop calories available for Canadian consumers of between -15% to +4% relative to a pre-climate change baseline (Mosnier et al., 2014), which reflects uncertainty in the direction as well as the magnitude of change.

Table 9.10: Summary of selected international studies of climate change impacts on agriculture and trade

STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES	
			GLOBAL	*CANADA*
Costinot et al. (2014)	Climate-driven agronomic changes for 10 crops by the 2080s under a high (IPCC SRES A1F1) global emissions scenario, allowing for plant carbon dioxide fertilization Three counterfactual scenarios: full adjustment, no production adjustment (countries free to trade) and no trade adjustment (farmers can adjust operations)	Impacts on agricultural productivity for 10 major crops (banana, corn, cotton, oil palm, rice, soybean, sugarcane, tomato, wheat, white potato) across 50 countries Welfare changes as a % of GDP relative to "pre-climate change" baseline (using a computable general equilibrium, or CGE, model)	Welfare change as a % of total GDP in the 2080s of -0.26% (full adjustment); -0.78% (no production adjustment); -0.27% (no trade adjustment)	Welfare change as a % of total GDP in the 2080s of +0.59% (full adjustment); +0.47% (no production adjustment); +0.63% (no trade adjustment)

STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES	
			GLOBAL	*CANADA*
Mosnier et al. (2014)	Climate-driven agronomic changes for 18 crops by the 2050s under a high global emissions scenario (IPCC SRES A2) and 3 global climate models (GCMs) Assume growth in calorie demand driven by population and economic growth. Counterfactual scenarios allow for adjustments in production, management, trade and consumption	Impacts on crop yield for 18 major crops (barley, cassava, chickpeas, corn, cotton, dry beans, groundnut, millet, oil palm, potato, rapeseed, rice, sorghum, soybeans, sugarcane, sunflower, sweet potato, wheat) Changes in crop calorie availability for food consumption relative to "pre-climate change" baseline using the GLOBIOM partial equilibrium model	Change in global crop calorie availability in the 2050s between +2% and -3% depending on the GCM	Change in crop calorie availability in the 2050s between -15% to +4% Change in domestic production (tons) in the 2050s between -18% to +5% Change in total imports (tons) in the 2050s between -8% to 0%

STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES	
			GLOBAL	*CANADA*
Cui et al. (2018)	Climate-driven changes in yield of all major food and agricultural commodities by 2050 under a moderate emissions scenario (IPCC RCP6.0) Counterfactual baseline scenario assumes GDP, population and crop yields due to technological change grow by 134.7%, 38.7% and 38%, respectively, from 2011 to 2050. Counterfactual trade liberalization scenario removes all import tariffs and export taxes/subsidies for agricultural and food	Impacts on yields of major crop, livestock and processed foods Changes in 1) GDP, 2) food and agricultural trade and 3) agricultural worker wages relative to the baseline at 2050 (using a CGE model)	Change in global GDP in the climate change scenario in 2050 relative to baseline is -0.18% Change in global GDP in the climate change + trade liberalization scenario in 2050 relative to baseline is -0.17% Change in global food and agricultural net exports (billion US$2011) under climate change + trade liberalization in 2050 relative to baseline is +$62 billion, balanced by the same amount of increase in net food imports by net food importing regions Change in global agricultural wage in the climate change scenario in 2050 relative to baseline is -0.24%	Change in GDP in the climate change scenario in 2050 relative to baseline is +0.12% Change in food and agricultural net exports (US$2011) under climate change + trade liberalization in 2050 relative to baseline is -$1 billion Change in agricultural wage in the climate change scenario in 2050 relative to baseline is +8.0%

STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES	
			GLOBAL	*CANADA*
Gouel and Laborde (2018)	Climate-driven changes in yield of 35 crops, livestock and other commodities by the 2080s under a high emissions scenario (IPCC SRES A1F1) Counterfactual scenarios include no adjustments in production and trade-restriction assumptions	Impacts on agricultural productivity for 35 crops across 50 countries Welfare changes as a % of GDP relative to "pre-climate change" baseline (using a CGE model)	Welfare change as a % of total GDP in the 2080s of -1.72% relative to pre-climate change baseline Welfare change as a % of total GDP in the 2080s (relative to climate change scenario) from limits to production adjustments is -3.71%; from limits to bilateral import shares is -e3.02%; from limits to export shares is -2.18%	Welfare change as a % of GDP in the 2080s of +2.36% (agriculture terms of trade) and +0.49% (productivity change), relative to pre-climate change baseline Welfare change as a % of GDP in the 2080s (relative to climate change scenario) from limits to production adjustments is +6.92%; from limits to bilateral import shares is -0.28%; from limits to export shares is +3.65%

There are few studies that evaluate future climate change impacts and patterns of international trade (Dawson et al., 2020b), with results for Canada available in a limited number of them (*see* Table 9.11). Studies employ economic simulation models and introduce climate change impacts—also referred to as damages—as external shocks to subnational, national and regional economies, examining interactions across sectors, geographies, producers, consumers, as well as economy-wide phenomena (*see* Costs and Benefits of Climate Change Impacts and Adaptation chapter for key definitions). Comparing results across studies is difficult due to differences in scope (temporal and spatial), coverage (climate change impact categories, goods and sectors), baselines, scenarios (climate, socioeconomic and policy) and simplified assumptions about economic systems, among other factors. Even studies focused on a single sector can generate wide-ranging projections, since there can be differences in model structures (e.g., single sector versus whole economy, regions represented), trade specifications, goods included, price and consumption sensitivities (Food and Agriculture Organization, 2018). Canadian studies assessing the economic impacts of climate change on forestry alone and in combination with impacts on agricultural land services illustrate the importance of multi-regional and multi-sectoral modelling in improving the accuracy of analysis (Ochuodho et al., 2016; Ochuodho and Lantz, 2014).

Table 9.11: Summary of select international studies on the economic consequences of climate change impacts on international trade

SECTOR AND STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES		
			GLOBAL	*CANADA OR NORTH AMERICA*	*UNITED STATES*
Transport (global) Chatzivasileiadis et al. (2016)	Climate-driven sea-level rise (SLR) by 2050 under a high emissions scenario (RCP8.5) “Middle of the road” shared socioeconomic development pathway (IPCC SSP2) and three scenarios of SLR-induced transport disruption	Coastal land and capital losses due to submergence and sea-flood damage as well as SLR-induced transportation disruptions Direct and indirect economic effects (changes in production technologies, consumption patterns and international trade patterns), including changes in trade activity, terms of trade and welfare relative to “no-climate change” (using a CGE model)	% change in global exports in 2050 across three scenarios is 0.51% (0.44% to 0.61%) Change in global terms of trade (US$) in 2050 across three scenarios is -$7 million (-$4.3 to -$11.4 million) Global welfare change (US$) in 2050 across three scenarios is $50 billion (-$42 to $61 billion)	% change in North American exports in 2050 across three scenarios is 0.49% (0.39% to 0.53%) Change in terms of trade (US$) in 2050 for North America across three scenarios is +$535 million ($380 to $630 million) Welfare change (US$) in 2050 for North America across three scenarios is -$9.7 billion (-$7.8 billion to -$12.4 billion)	

SECTOR AND STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES		
			GLOBAL	*CANADA OR NORTH AMERICA*	*UNITED STATES*
Multi-sector (global) **OECD (2015)**	Average global temperature change of 2.5˚C (likely range of 1.6˚C to 3.6˚C) above pre-industrial levels by 2060 “No damage” baseline includes annual average growth in GDP. Market-driven adaptation measures are considered	Impact on crop yields and fish catches; coastal zones; human health; labour productivity; energy demand; tourism flows and damages from hurricanes Direct and indirect economic effects, including % change in GDP relative to “no-damage” baseline by 2060 from all impact categories and from agriculture impacts alone (using a CGE model)	% change in global GDP by 2060 from all impact categories of -1.52% % change in global GDP by 2060 from climate impacts on agriculture of -0.48%	% change in Canadian GDP by 2060 from all impact categories of +0.88% % change in Canadian GDP from climate impacts on agriculture of -0.11%	% change in US GDP by 2060 from all impact categories of -0.47% % change in US GDP by 2060 from climate impacts on agriculture of -0.27%

SECTOR AND STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES		
			GLOBAL	*CANADA OR NORTH AMERICA*	*UNITED STATES*
Multi-sector (global) Dellink et al. (2017)	Average global temperature change of 2.5˚C (likely range of 1.6˚C to 3.6˚C) above pre-industrial levels by 2060 “No damage” baseline includes annual average growth in GDP. Market-driven adaptation measures are considered	Impact on crop yields and fish catches; coastal zones; human health; labour productivity; energy demand; tourism flows and damages from hurricanes Direct and indirect economic effects, including % change in trade volumes relative to “no-damage” baseline by 2060 from all impact categories and from changes in revealed comparative advantage from climate change impacts on agriculture (using a CGE model)	% change in global trade volumes in 2060 compared to “no damage” baseline is -1.8% (exports) and -1.6% (imports)	% change in trade volumes in 2060 compared to “no damage” baseline of +0.2% (exports) and +0.1% (imports) % change in revealed comparative advantage levels for food products at 2060 relative to “no damage” baseline of +0.2%	% change in trade volumes in 2060 compared to “no damage” baseline of -0.5% (exports) and -1% (imports) % change in revealed comparative advantage levels for food products at 2060 relative to “no damage” baseline for the US is +0.6%

SECTOR AND STUDY	CLIMATE AND SOCIOECONOMIC SCENARIOS	PHYSICAL AND ECONOMIC IMPACTS	TRADE-RELATED CONSEQUENCES		
			GLOBAL	*CANADA OR NORTH AMERICA*	*UNITED STATES*
Multi-sector (United States) Zhang et al. (2018)	Annual mean temperature rise in the US on a decadal basis from 2020 to 2100 under a moderate emissions scenario (RCP4.5) Population and economies fixed at 2012 values, (reference year)	Impact on agricultural yield, energy demand and labour in the US Economic ripple effects on the rest of the world from direct economic damage and indirect economic impact of climate change in the US (using an International Ripple Effect Input-Output model)	Economic ripple effects on the world in 2050 (annual mean temperature rise of 1.51°C compared to 2012) are 51.5% of the direct economic damage in the United States	% change in Canadian GDP by 2050 from the economic ripple effects of climate change impacts in the US of -0.4% (-0.1% to -0.6%) % change in Canadian sectoral GDP by 2050 from the economic ripple effects of climate change impacts in the US of -0.16% (mining); -0.12% ("other services"), -0.10% (manufacturing)	

Because studies are limited and their methods inconsistent, confidence in numerical results is low. However, there are some qualitative findings on climate change and trade that are noteworthy. Studies show that Canada is among the few global regions with the potential to experience positive GDP impacts, gains in terms of trade and a rise in exports by mid-century from climate-induced changes across multiple sectors (Dellink et al., 2017; Chatzivasileiadis et al., 2016; OECD, 2015). Relative to other parts of the world, Canada's macro-economy may not be as affected by climate change impacts due to gains (or relatively fewer losses) in competitiveness in domestic and international markets (Dellink et al., 2017). Economic benefits to Canada relate to increased demand for energy, health services and tourism (OECD, 2015). Trade links between different regions can propagate or attenuate risk, so a closer look at the climate sensitivity of major trading nations is warranted (Kovacs and Thistlethwaite, 2014). One study modelled the global economic consequences of climate change impacts on crop yields, energy demand and labour productivity in the United States to 2100, under a range of temperature-rise scenarios (Zhang et al., 2018). The economic ripple effects globally are a sizeable portion of direct damages in the United States and are greater for Canada than for other regions modelled, including negative economy-wide and sectoral impacts (e.g., on mining, manufacturing and "other services", in particular) (Zhang et al., 2018). Similarly, researchers in Europe have modelled the trade-related effects of climate change impacts occurring outside of the region, showing that the worst effects on welfare in the EU stem from impacts in either the Americas or Asia (Szewczyk et al., 2013). These types of analyses can help provide a more balanced view on the potential distribution of trade-related impacts of climate change in colder versus warmer regions of the world.

9.4.3 Adaptation

Climate change adaptation in international trade occurs at multiple scales. This includes actions by industry and economic actors to manage climate-induced disruptions to trade and take advantage of emerging markets for adaptation goods and services. It also includes spontaneous (i.e., market-driven) and planned actions to build climate resilience into global trade systems.

Canadian industry recognizes the relationship between climate policy and international competitiveness (Canadian Chamber of Commerce, 2019), but there is little evidence of action to assess and manage trade-related impacts from extreme events and climate variation (Kovacs and Thistlethwaite, 2014). In 2016, the Canadian Chamber of Commerce included climate change among the top ten barriers to competitiveness, pointing to the need for a national adaptation strategy (Canadian Chamber of Commerce, 2016). Its 2019 recommendation report on climate policy acknowledges the role of trade in Canada's low-carbon transition, but does not discuss adaptation (Canadian Chamber of Commerce, 2019). The Canadian Federation of Agriculture (2017) advocates for tools and financial incentives aimed at supporting adaptation planning by Canadian producers to protect farmers' livelihoods domestically, and to improve food security and the stability of global prices for staples in the event of crop failures in other producing regions. Despite some recognition of these indirect impacts of climate change as a business issue to be managed, evidence of the extent of business action to adapt to related risks and opportunities is patchy. Responses to a voluntary disclosure initiative in 2015 concluded that, in comparison with companies in 10 other countries, Canadian publicly listed companies underperformed in water risk assessment, a critical aspect of supply chain resilience (CDP, 2015). Conversely, case study research highlights some Canadian leadership in identifying and acting on climate change risk from overseas assets, suppliers and distribution networks (CPA Canada, 2015). Strategies to manage supply chains risks resulting from climate change include understanding how risks from climate impacts interact with other risks, using scenario planning to inform risk management plans and building partnerships to support sustainable sourcing of inputs in the event of resource scarcity (Das and Lashkari, 2015; Gledhill et al., n.d.). In managing supply chain risks, adaptation by port and terminal planners and operators is key to enhancing climate resilience of critical trade infrastructure, but incentives to take action are not always aligned (Ng et al., 2016). Since ports provide benefits at a range of scales, it is not always clear who should take the lead and how adaptive measures, including changes in technology, engineering, design and maintenance and insurance (Scott et al., 2013), should be financed (Becker et al., 2017). Experience with the Port of Vancouver—Canada's largest port in terms of tonnage—illustrates the gap that exists between adaptation planning and implementation (Becker et al., 2017). The Port Authority's strategy has centred on understanding and responding to coastal hazards, with a commitment to monitoring the effects of climate change and taking action, where necessary (Port of Vancouver, n.d.).

Adaptation involves taking advantage of potential opportunities resulting from climate change, such as the business and employment opportunities created by enhanced trade in climate change adaptation solutions (Trabacchi et al., 2020; Conference Board of Canada, 2017). As measured by the thematic focus of Nationally Determined Contributions submitted to the UN Framework Convention on Climate Change, countries in Latin America and the Caribbean, Africa and South Asia regard adaptation as a core development priority (Trabacchi et al., 2020). Countries that invest in building climate resilience and enabling growth in adaptation markets domestically could be at an advantage as global suppliers of adaptation solutions (Deloitte and ESSA Technologies Ltd., 2016). At a minimum, firms demonstrating international leadership in key areas of climate finance (i.e., funds given by industrialized countries to emerging economies), such as agriculture, engineering and construction, water and wastewater solutions, geomatics, professional consulting services, and information and communication technologies could benefit from the estimated US$60 billion to US$100 billion per year in global finance needed for adaptation in developing countries to 2050 (IPCC, 2014). Canada's expertise in forestry and forest products, engineering and coastal infrastructure, ocean technologies, water and wastewater and financial risk-transfer tools, among other sectors, could be harnessed to meet the growing global demand (Deloitte and ESSA Technologies Ltd., 2016; Kovacs and Thistlethwaite, 2014). Since 2018, Global Affairs Canada has increased support to Canadian firms' participation in emerging adaptation markets, including establishing a global network of Canadian trade commissioners dedicated to this task and providing market intelligence.

Short and long-term adjustments in trade in response to climate variability or extreme weather are essentially examples of adaptation, driven by market signals, and so enhancing trade activity could play a role in alleviating the future consequences of climate change. Imports and switches in suppliers can reduce pressure from year-to-year shocks in production and higher prices (Dellink et al., 2017; Baldos and Hertel, 2015; Mosnier et al., 2014; Stephan and Schenker, 2012). In the long term, production can shift to areas that have the comparative advantage of climate resilience (Baldos and Hertel, 2015; Stephan and Schenker, 2012). For example, a longer growing season in Canada and proactive adaptation by domestic producers could lead to agricultural surpluses, soil and water permitting, which could offset production shortfalls in other areas. Historical trade patterns illustrate the feasibility of relying on well-functioning trade as insurance against climate change risk. Demand-driven shocks to the forest sector over the past century that were transmitted through trade led to management responses of the scope and scale envisioned for climate change adaptation (Sohngen and Tian, 2016). Conversely, tariff and non-tariff barriers (e.g., export bans) to trade have hindered historical adjustments in global food trade in response to economic shocks (Baldos and Hertel, 2015). Studies modelling the future economic impact of climate change on global food and agriculture show a potential moderating effect of trade liberalization on climate-induced global food insecurity and production decline (Cui et al., 2018; Gouel and Laborde, 2018), as well as the important role of farmer-level adaptation in reducing economic loss (Costinot et al., 2014). These economic and modelling studies suggest that wealthier countries are more likely to capture gains from the adaptive effect of trade than are regions in the Global South, which sometimes lack resources and infrastructure for spontaneous adaptation. Financial support for planned adaptation, including through international assistance (*see* Section 9.6), could thus be justified on grounds of economic self-interest, alongside fairness and equity (Stephan and Schenker, 2012). Stylized representations of the evolution of international trade under climate change can fail to account for dynamics such as planned investment in trade infrastructure and removal of trade policies causing market distortions (e.g., subsidies) (Gouel and Laborde, 2018). Adaptation in this context involves, for example, promoting growth in sectors and regions to counteract scarcity in other countries as a result of climate change impacts, reducing import dependency for staples, diversifying trade partners and addressing weaknesses in trade institutions (Dallman, 2019; Mbow et al., 2019; Gouel and Laborde, 2018; Kovacs and Thistlethwaite, 2014).

9.5 Climate-related human migration and displacement will increase demands for immigration to Canada

Tropical cyclones, floods, droughts, wildfires and food insecurity displace millions of people each year. Climate change will generate growing numbers of migrants by mid- to late century, especially in Least Developed Countries in sub-Saharan Africa, Asia, and Latin America and the Caribbean. Canada will come under growing internal and external pressure to accept larger numbers of migrants from climate-disrupted regions.

Human migration and displacement can occur as a direct result of extreme weather and climate events, such as tropical cyclones, floods, droughts and wildfires, or as an indirect result of climate impacts on food supplies, freshwater availability and livelihoods. Migration responses to climatic risks are mediated by societal factors that affect adaptive capacity and by household characteristics. Globally, an average of 21 million people are displaced each year by floods, drought, storms, wildfire, extreme heat and other weather-related hazards. Climate change will exacerbate the frequency and severity of these events in many regions, and have particularly strong impacts on migration and displacement in Least Developed Countries in sub-Saharan Africa, South and Southeast Asia, Latin America and the Caribbean. Recent studies project a 50% increase in displacement risks with each additional degree Celsius of warming. Sea-level rise is already necessitating the relocation of small coastal communities in Alaska, Chesapeake Bay, the Gulf of Mexico, Fiji and Papua New Guinea. By 2100, rising seas will force the relocation of tens of millions of people living in coastal plains, river deltas and small island states, particularly in the Global South. Poverty and weak governance and institutions are root causes of large-scale or sudden displacements. As climate change intensifies, Canada can expect increased future demand for immigration from current source countries that are highly exposed to climate risks, such as the Philippines, China, India, Pakistan and Syria. The international community may also increasingly look to Canada to provide financial assistance and serve as a resettlement destination for people from highly vulnerable developing countries with historically few ties to Canada. Many heavily-populated coastal areas of the United States are highly exposed to extreme storms and floods, which will be amplified by rising sea levels. Most of those displaced will likely resettle within the U.S., but the scale of potential social and economic disruption that ensue merit monitoring for potential effects on established migrant networks to Canada.

9.5.1 Introduction

This section describes the relationship between climate change and human migration, discusses current and future estimates and trends of global climate-related migration, and outlines specific future concerns for Canada.

9.5.2 The climate-migration nexus

Migration movements are the cumulative result of cultural, economic, political, social and environmental drivers that operate at local to global scales (van Hear et al., 2018; Foresight, 2011). Links between climate change and migration are context specific and not always obvious, often because climate stressors alone rarely determine decisions to migrate (McLeman, 2014). Climatic events may directly stimulate displacement and migration, such as from New Orleans following Hurricane Katrina (DeWaard et al., 2016), or have an indirect influence, such as through climate-related shocks to food production or prices (Maharatna, 2014). International migrants may not disclose environmental motivations to officials, as receiving countries typically do not consider these as valid reasons for moving (for examples from Canada, *see* McLeman et al., 2017; Mezdour et al., 2015; Veronis and McLeman, 2014).

Current research identifies three sets of links between climate change and migration:

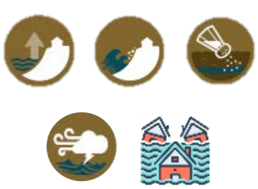
- Migration as household-level adaptation to climate risks (referred to hereafter as "adaptive migration");
- Displacement or planned relocation of people from areas impacted by, or highly exposed to, climate risk; and
- Immobility, or the inability to migrate, that traps people in highly exposed locations.

Adaptive migration ranges from temporary or seasonal moves to indefinite relocation; it can be a response to adverse climate events or an effort to take advantage of beneficial climate conditions. The most common adverse climate events associated with migration and displacement are extreme storms, floods and droughts (IDMC, 2020). Climate change can influence local, regional and international migration in multiple ways, depending on the specific impacts of climatic events and the mediating effects of societal and household characteristics (*see* Table 9.12). These can include changes in migration destinations, duration or timing, direction of net migration flows and migration participation rates (*see* Table 9.12; Suckall et al., 2017; Gray and Wise, 2016; McLeman, 2014; Black et al 2011).

Migration responses vary by the type of climate event and its characteristics, such as the rate of onset, duration and nature of the damage that it causes to infrastructure, property and households' livelihood assets (*see* Table 9.12). For example, tropical cyclones present three hazards at once: high winds that bring down trees and power lines, heavy rains that trigger flash floods and landslides, and storm surges that inundate low-lying areas. Such events generate short-term evacuations from affected communities; residents' likelihood to return, rebuild and stay depends on the extent of damage to homes and infrastructure and the ability of governments to assist in reconstruction (Fussell, 2018; Mallick and Vogt, 2012). In the weeks and months following the storm, out-migration from the affected area can increase as young workers seek wages to send home and assist in rebuilding homes and livelihoods (Loebach, 2016). This occurred, for example, in the surge of Puerto Rican workers who moved to the U.S. mainland in the wake of Hurricane Maria (Echenique and Melgar, 2018). In contrast, a slow-onset hazard, such as drought, may not stimulate migration immediately. A lag occurs as households seek to adapt through other, less disruptive means, with migration ensuing only as drought conditions persist and other adaptation options falter (Nawrotzki and DeWaard, 2016). Because homes or property tend to be intact, some household members can stay behind while, commonly, young adults migrate in search of work (Baez et al., 2017).

Table 9.12: Summary of key climatic drivers of migration, societal and household factors that mediate migration and potential outcomes of interactions

CLIMATE CHANGE STRESSOR	SOCIETAL-LEVEL MEDIATING FACTORS	HOUSEHOLD-LEVEL MEDIATING FACTORS	POTENTIAL MIGRATION OUTCOMES FROM INTERACTIONS OF FACTORS LISTED IN THE OTHER COLUMNS
Changes in the frequency, severity and/ or spatial extent of:  Changes to the following, associated with the above stressors: 	**Environmental** • Physical setting (e.g., tropical, temperate, sub-Arctic, coastal versus inland) • Topography, watershed characteristics, groundwater resources • Land cover • Baseline environmental damage (or remediation) from human activity	**Pre-existing characteristics** • Composition (e.g., family structure, number of members, ages, sex, dependents) • Human capital (e.g., education, employment skills, health) • Financial capital (e.g., direct & indirect sources of income, access to remittances, asset ownership) • Social capital (e.g. kinship ties, extended family networks, membership in formal and informal community organizations)	**Migration destinations** • Choice between short-distance destination over long-distance destinations • Choice of common destinations or new destinations **Migration duration or timing** • Temporary or seasonal versus indefinite migration • Unplanned migration, deferral of planned migration

CLIMATE CHANGE STRESSOR	SOCIETAL-LEVEL MEDIATING FACTORS	HOUSEHOLD-LEVEL MEDIATING FACTORS	POTENTIAL MIGRATION OUTCOMES FROM INTERACTIONS OF FACTORS LISTED IN THE OTHER COLUMNS
(continued from previous page)	**Economic** • Structure of the economy • Robustness of economic sectors and labour markets • Economic (in)equality and wealth distribution • Land tenure regimes	**Nature of impacts of specific climate-related events** • Injury or loss of life among household members • Damage to/loss of home • Loss of income, livelihood opportunities, assets • Losses experienced by neighbours, extended family members or local community • Temporary versus indefinite impacts	**Direction of net migration flows** • Rates of migration to specific locations may rise or fall • Source locales becoming destinations and vice versa • Climate event stimulating return migration to assist with recovery
Risks related to sea-level rise 	**Political** • Financial capacity of government • Government activity and effectiveness • Political stability, unrest or conflict • Corruption • Border controls and immigration regimes of neighbouring states		**Migration participation rates** • Rates of migration to specific locations may rise or fall • Migration rates of particular groups may change relative to others

CLIMATE CHANGE STRESSOR	SOCIETAL-LEVEL MEDIATING FACTORS	HOUSEHOLD-LEVEL MEDIATING FACTORS	POTENTIAL MIGRATION OUTCOMES FROM INTERACTIONS OF FACTORS LISTED IN THE OTHER COLUMNS
(continued from previous page)	**Social** • Demographic structure and population trends • Urbanization • Cultural norms about mobility and migration • Gender norms • Treatment of Indigenous groups, minorities and marginalized populations • Social networks and linguistic/cultural ties (domestic and foreign)	**Migration readiness** • Past migration experience • Transferability of job skills • Geographical extent of social networks • Ability of household to endure prolonged absence of individual members • Ability to finance migration	**Organized relocations and planned retreats** • Institutions actively assist the movement of individual households or communities **Immobility** • Relocating is the preferred response but is not feasible for households, resources are not forthcoming from institutions • Strong resistance to relocation may arise from cultural/social connections to place and/or indigeneity

Key

Enhanced erosion

Extreme heat

Extreme storms and related flooding

Floods

Food scarcity

Salinization of groundwater, soil

Droughts

Water scarcity

Inundation of low-lying coastal areas

Wildfires

Enhanced storm surges

Sources: McLeman, 2020; Hauer et al., 2020; Cattaneo et al., 2019; Baez et al., 2017; Suckall et al., 2017; Adams, 2016; Gray and Wise, 2016; Hunter et al., 2015; McLeman, 2014; Black et al., 2011.

Aside from the characteristics of the climate event, the propensity of people to migrate is also a function of the adaptation options available to affected households (Black et al., 2011). Household options are influenced by a wide range of economic, social, political and cultural processes that operate beyond the control or influence of the household, such as labour markets, government programs and safety nets, health care accessibility and insurance regimes, to name a few (*see* Table 9.12). Characteristics of households and their members, such as age, health, education, job skills, gender and extended family networks, also influence choices between *in situ* adaptation and migration by some or all household members (*see* Table 9.12).

9.5.3 Current and estimated climate-related migration

Estimates of global numbers of people displaced or who have migrated for climate-related reasons carry significant uncertainty. Global migration data are coarse, and attributing causality within these datasets is problematic. Most migration, whether for climatic or other reasons, is internal (within countries), flowing from rural to urban areas (Samers, 2010). Estimates of international migration produced by the Population Division of the UN's Department of Economic and Social Affairs are the accepted standard, registering 258 million international migrants worldwide in 2017 (UN Department of Economic and Social Affairs, 2017). These estimates are conservative and likely underestimate actual levels since they do not, for example, consider return migration (Azose and Raftery, 2019).

The most reliable data on climate-related migration are annual estimates by the International Disaster Monitoring Centre (IDMC) of the number of people that are internally displaced by disasters from natural hazards. These data include both temporarily and indefinitely displaced people, as well as climate and non-climate hazards. Since the IMDC began publishing annual statistics in 2008, an average of 21 million people have been displaced annually due to weather-related disasters.[1] The largest weather-related displacements occurred in India, the Philippines, Bangladesh, China, and the United States, with storms (13 million people worldwide in 2019) and floods (10 million people worldwide in 2019) as the main causes. IDMC statistics underestimate global environmental migration flows as they primarily record people who are involuntarily displaced within their home country by large disaster events, and do not count: 1) those displaced by smaller or ongoing events; 2) people who move for adaptive reasons beyond the confines of a disaster; or 3) international migrants.

Climate-related migration and displacement is commonly seen among subsistence agricultural populations, pastoralists and other groups that pursue resource-based livelihoods (e.g., fishers) in Least Developed Countries (LDCs), and may take the form of temporary, seasonal and longer-term migration (Afifi et al., 2016; Gautier et al., 2016; Gray and Wise, 2016). Many LDCs already have high rural–urban migration rates for social and economic reasons; extreme climate events and conditions amplify these already high rates, placing great strain on city services (Ishtiaque and Nazem, 2017). This in turn can reduce the quality of life and human security in cities and can lead urban professionals to pursue migration abroad, as has been observed within the movement of skilled worker migrants to Canada from Bangladesh, Haiti and several West African countries

1 Visit http://www.internal-displacement.org/ for latest statistics; at time of writing this chapter, the most recent IDMC statistics available were for 2019.

(*see* Figure 9.11; McLeman et al., 2017; Mezdour et al., 2015; Veronis and McLeman, 2014). Such migration is to the benefit of the receiving country, but represents a loss of human capital for the sending community.

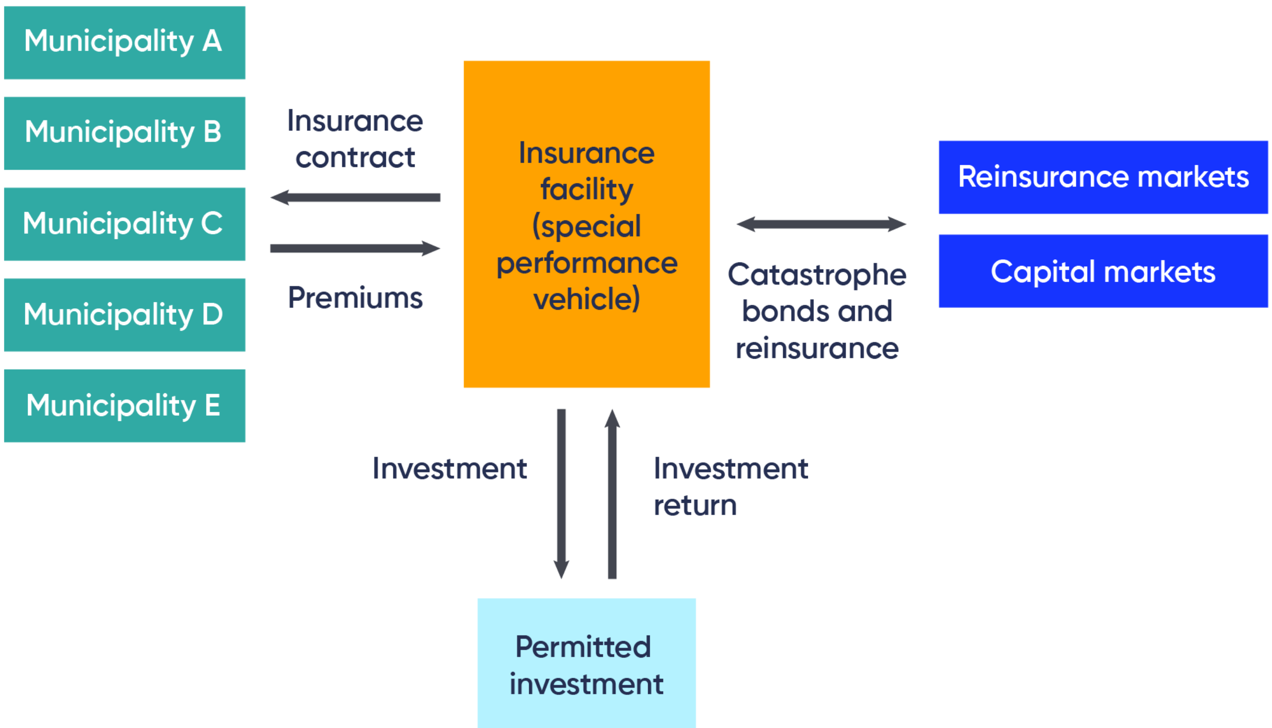


Figure 9.11: Cascading effects of environmentally induced rural to urban migration in Least Developed Countries.
Source: Adapted from Veronis and McLeman, 2014.

Climate migration does not occur exclusively in LDCs. In the United States, Hurricane Katrina is the most infamous example, with the population of New Orleans being 40% smaller today than it was immediately before the storm (DeWaard et al., 2016). The U.S. federal government is actively relocating several Indigenous communities in Alaska situated in rapidly eroding locations (Marino and Lazrus, 2015), as well as the Mississippi delta community of Isle de Jean Charles, Louisiana. Such efforts are costly; the cost of the Isle de Jean Charles relocation, for example, is reaching US$43 million (Sack and Schwartz, 2018).

Future levels and patterns of climate migration are difficult to estimate as they depend on the combined effect of many factors (Beneviste et al., 2020; McLeman, 2019), chiefly:

- Future levels of GHG emissions and consequent impacts on temperatures and precipitation patterns;
- Future rates of change in frequency and severity of storms, floods, droughts;
- Future rates of relative sea-level rise;

- Future population growth levels in areas highly exposed to climate risks;
- Future socioeconomic growth, progress towards the UN Sustainable Development Goals and the success of adaptive capacity building in LDCs; and
- Future immigration and border control policies of developed countries.

A recent World Bank study (Rigaud et al., 2018) estimated that up to 143 million people could be displaced by the impacts of climate change in LDCs by mid-century in the absence of concerted actions to reduce global GHG emissions and to accelerate sustainable development. Combining flood displacement data from the IMDC with standardized scenarios for GHG emissions, socioeconomic development and population growth, it is estimated that each additional degree Celsius of warming increases global displacement risks by 50% (Kam et al., 2021). By the year 2060, it is estimated that one billion people will live in low-elevation coastal zones (LECZs)—areas less than 10 m above mean sea level—and thus be exposed to sea-level rise and accelerated coastal hazards (Neumann et al., 2015). The greatest proportion at risk lives in densely populated coastal deltas in Bangladesh, China, India, Indonesia and Vietnam, with coastal populations in Africa and the United States also growing rapidly (Merkens et al., 2016). For example, southeastern Florida's population is expected to grow to nearly 10 million by the year 2030 (Curtis and Schneider, 2011). A mean sea-level rise of 0.8 m by the end of this century would necessitate the relocation of up to 4.2 million people in the United States (Hauer et al., 2020, 2016). There is a pressing need for further research and modelling to generate statistical projections of future climate-related migration at global and regional scales under a range of climate and development scenarios (McLeman, 2019). Uncertainty in these projections is likely to remain high, making research on conditions that shape migration choices and on the effectiveness of adaptive strategies perhaps even more pressing (McMichael et al., 2020).

9.5.4 Future outlook for Canada

Canada is an attractive destination for international migration, and this will be magnified by adverse climate change impacts. Canada's immigration policies stand in growing contrast with recent trends in Australia, the European Union and the United States towards less liberal migration policies, greater levels of border enforcement and criminalization of unauthorized migration (de Haas et al., 2019; McLeman, 2019). These latter trends are at odds with international development needs in a climate-disrupted future. The 2018 *United Nations Global Compact for Safe, Orderly and Regular Migration*, to which Canada is a signatory, provides instructive policy guidance and objectives for ensuring that management of climate-related migration is done effectively, benefits sending and receiving areas, and protects the rights of migrants and their families (McLeman, 2019). Most international migration, including instances of climate-related migration, occurs between countries with contiguous borders (Stojanov et al., 2017; Hunter et al., 2013). Canada is anomalous in that five of its six largest immigration source countries are in Asia and the Middle East (India, the Philippines, China, Syria and Pakistan), with the United States representing the fourth-largest source of permanent migrants. Canada's largest source countries of international migrants are expected to experience increased risks of extreme weather events, droughts, water scarcity and sustained heat events by 2050 and beyond, and (with the exception of Syria) have large populations residing in low-lying coastal areas (IPCC, 2014).

Most people seeking to migrate to Canada for climate-related reasons are likely to be people with family or social connections in Canada that can facilitate their travel and settlement, and third-country nationals (most likely from Latin America and the Caribbean) that enter Canada from the United States, seeking admission as refugees or for humanitarian and compassionate reasons. For the latter group, the number of future arrivals will be heavily mediated by U.S. immigration and border policies (McLeman, 2019). Most future climate-related migration and displacement in the U.S. is likely to be internal, but the sheer scale of involuntary displacement under high emissions scenarios projected by Hauer et al. (2017) and socioeconomic disruptions that would ensue bear monitoring for potential effects on established migration flows between Canada and the U.S. Migrants with family connections are unlikely to place excessive demands on Canadian social services. The poorest, most vulnerable people in LDCs typically lack the financial wherewithal to undertake long-distance migration to Canada or other high-income countries and are more likely to be trapped in their home countries (Zickgraf, 2018; Black et al., 2011). International assistance to address the underlying causes of involuntary climate-related migration in the near term will help make LDCs more resilient in the long run and enhance their chances of meeting the Sustainable Development Goals (Rigaud et al, 2018). Global Affairs Canada projects that address water scarcity in rural Ethiopia are a practical example of future development programming of this type (Government of Canada, 2017a).

Canadian immigration and refugee programs currently do not take climate change into account when determining eligibility, and the *UN Convention Relating to the Status of Refugees* does not apply to people moving for climate-related reasons. Canada should expect increasing pressure in coming decades from the international community to accept the relocation of people displaced by climate change in countries that are not historically significant migration sources for Canada. Small Island States are obvious candidates, given the limited adaptation and internal relocation options that they have with respect to sea-level rise (Kelman, 2015). A petition made by a Kiribati family to the UN Human Rights Committee fighting deportation from New Zealand on the grounds that their home island was no longer viable due to rising sea levels, resulted in a decision that receiving countries should not repatriate people whose lives are threatened by climate change impacts (UN Human Rights Committee, 2020). Unlike New Zealand, Canada has yet to receive significant numbers of humanitarian or refugee claims for permanent residence, but this can be expected to change as the impacts of climate change become more pronounced in countries where political instability is ongoing (Veronis, 2014).

The potential association between adverse climate conditions, migration and occurrences of violence and conflict in LDCs is subject to active investigation (*see* Section 9.6.2). Climate-related violence between groups competing for resources may lead directly or indirectly to internal and international migration in affected regions (Abel et al., 2019). Climate-related migration can increase or alternatively decrease the risk of violence and conflict within LDCs, depending on local circumstances (Freeman, 2017), but there is no evidence that climate-related migration triggers conflict between states. Research from East Africa finds that climate migrants are more likely to be victims of violence than perpetrators (Linke et al., 2018). A recurrent conclusion in published research is that the relationship between climate change and conflict is not deterministic, with numerous points for intervention before violence emerges (Mach et al., 2019; Selby et al., 2017; Brzoska and Fröhlich, 2016; Burrows and Kinney 2016). The impacts of climate change in water-scarce and politically unstable LDCs in sub-Saharan Africa could conceivably generate future demands for international intervention (*see* Case Story 9.4).

Case Story 9.4: The role of climate change in conflict and migration in Mali

In August 2018, Canadian Armed Forces personnel were deployed to Mali to support the UN Multidimensional Integrated Stabilization Mission for a 12-month mission. Mali is a semi-arid sub-Saharan nation where agriculture is the principal livelihood base for the majority of the population. Environmental factors and conflicts over land use have been significant factors in the emergence and persistence of conflict in Mali. Severe droughts in the late 1980s triggered high levels of rural out-migration (Findley, 1994). Migration between rural and urban areas for socioeconomic reasons is common. However, adverse climate events have changed the patterns and duration of short-term population movements (Liehr et al., 2016). Drier conditions in a changing climate could depress crop yields and fodder for livestock (Butt et al., 2005).

Studies on the conflict in Mali conclude that climate events, such as drought, do not directly cause violence and conflict but can contribute to it. For example, in Mali's Mopti region, four factors led pastoralists to join militant jihadist groups that are challenging government authority (Benjaminsen and Ba, 2019; Benjaminsen et al; 2012; Benjaminsen, 2008):

- Droughts, which led to increased migration of young Tuareg men to Libya, where they were radicalized;
- Encroachment of crop farming on land traditionally used by pastoralists that constrained the mobility of people and livestock;
- A lack of sound governance structures and clear land tenure arrangements in rural areas; and
- Corruption and predatory rent-seeking in rural areas by government officials, often under the guise of measures to combat desertification.

Promoting better governance and adaptive capacity in rural areas is essential for the long-term success of international interventions in Mali. This includes land-tenure reforms that recognize rural small holders and programming that balances the interests of pastoralists with crop farmers. Emerging research on drought and food security in Mali identifies diversified livestock and crop farming as an important development pathway to increase the climate resilience of rural Malians (Giannini et al., 2017).

9.6 Increased demand for international assistance is expected

Climate change can undermine human security in developing countries and increase demands for Canadian international assistance. Canada is addressing climate risk to development and humanitarian goals by providing financial and technical assistance for adaptation and climate resilience.

Developing countries have less capacity to adapt and are therefore more vulnerable to the impacts of climate change than developed countries. Reasons for this include structural challenges that lead to political or economic marginalization, weakened institutions, environmental degradation, inadequacies in existing infrastructure and different abilities to pay for adaptation. Climate change can undermine human security and increase demands on international assistance. Climate change can also act as a multiplier of existing threats and pressures unrelated to climate, increasing exposure to harm, social unrest, and the removal of freedoms and capacities to live with dignity. Global stability and the welfare of citizens in countries abroad is a long-standing focus of Canadian foreign policy. As climate change impacts increase and intensify, Canada can expect increased future demand for international assistance, including responding to humanitarian crises, particularly in countries where Canada is already active. In anticipation of these pressures, Canada is working with developing-country partners to address the impacts of climate change through its international assistance activities. This includes helping to strengthen vulnerable nations' capacities to adapt to climate change through funding and programs that, among other outcomes, generate, increase access to, and facilitate the use of, knowledge, skills, infrastructure and technology needed to build climate resilience.

9.6.1 Introduction

Global stability and the welfare of citizens in countries abroad are tenets of Canadian foreign policy (Seyle, 2019; Bernard, 2006), as is accounting for local context in working with the international community to deliver stability and welfare (Government of Canada, 2017a, b). The impacts of climate change and variability are already affecting communities globally, particularly in the Least Developed Countries. This section examines the potential impacts of climate change on Canada's international assistance priorities. It describes the relationship between climate change and human security, discusses the implications of climate change on demands for international assistance and assesses evidence of Canada's responses to date.

9.6.2 The climate-security connection

Climate change will impact developing countries more than developed countries due to differences in vulnerability and capacities to adapt (Ahmadalipour et al., 2019; King and Harrington, 2018; Adger et al., 2014), in some cases resulting in human insecurity. Human security is "a condition that exists when the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity" (Adger et al., 2014, p. 759). Human insecurity, therefore, encompasses threats to health and well-being, economic and political inclusion and threats to culture. The mechanisms by which climate change can lead to human insecurity in developing countries are an active area of study in Canada and globally (De Souza et al., 2015; Busby et al., 2014; Ericksen et al., 2011). These mechanisms relate to complex and multi-faceted trends affecting the capacity of countries to cope with shocks and to adapt in the long term, including, structural challenges that lead to political or economic marginalization, weakened institutions, environmental degradation, inadequacies in existing infrastructure, varying levels of wealth to offset the costs of adapting to climate impacts (Harrington et al., 2016), changing demographics (e.g., growing populations and increased rural-to-urban migration) and other important factors (e.g., prior conflict experience).

Research to evaluate the links between climate change and violent conflict in particular has improved over the past decades. Security experts generally agree that climate change is a "threat multiplier", exacerbating existing political instability and conflict, or potentially tipping stable countries into instability. Although the concept adds complexity to the task of understanding the specific relationships between climate change and conflict (Busby, 2020), linking environment and conflict without capturing the underlying mechanisms at play can lead to ineffective interventions. Research in the 1990s (Homer-Dixon, 1991) without this lens led some researchers and policymakers to assume scarcity directly led to conflict. Another research gap was the excessive reliance on a small number of case studies from sub-Saharan Africa and the Middle East, such as conflicts in Darfur and Syria, to generalize insights (Adams et al., 2018; Hendrix, 2018). A robust academic field has now developed, demonstrating that climate is related to armed conflict that takes place within countries, but is not the most significant driver of large-scale conflict (Mach et al., 2019; Hsiang and Burke, 2013). Research on the connection between climate and conflict increasingly focuses on the important roles of governance and institutions, adaptive capacity and cooperative behaviour (Koubi, 2019; Gilmore et al., 2018; Gilmore, 2017; Theisen, 2017; Buhaug, 2016; Buhaug, 2015; Rüttinger et al., 2015; Meierding, 2013; Gleditsch, 2012).

Current research efforts serve to move beyond the "threat multiplier" concept in order to identify context-specific interventions that can address climate-related risks of violent conflict (Busby, 2020). Based on expert elicitation research, recent work points to low socioeconomic development, diminished state capacity and intergroup inequality as factors relating climate with internal armed conflict (Mach et al., 2019). Others have found that countries with high rates of political exclusion and high dependence on agricultural labour are at risk of prolonged or worsened conflict and humanitarian emergencies when faced with climate-related hazards like severe droughts (Busby and von Uexkull, 2018). The need to consider local factors when assessing how climate change shapes conflict risk is key. For example, in sub-Saharan Africa, the impacts of drought on crop production and on the availability of water and forage for livestock have a weak association with outbreaks of violent conflicts, with intervening political and socioeconomic factors having a more direct influence (Ayana et al., 2016; Buhaug, 2015; Buhaug et al., 2014). Climate change mitigation efforts associated with land-use change can add to the potential for conflict (Froese and Schilling, 2019), which highlights the need for conflict sensitivity in designing initiatives to reduce GHGs or enhance carbon sinks.

The link between conflict and climate-related migration is being increasingly studied in an effort to understand this complex relationship (Boas et al., 2019; Brzoska and Fröhlich, 2016) and match humanitarian responses to needs (*see* Section 9.6). An example of where the conflict narrative has been studied and challenged among scholars relates to the contribution of water scarcity due to prolonged drought to the emergence of the Syrian civil conflict (Ide, 2018; Feitelson and Tubi, 2017; Selby et al., 2017; Kelley et al., 2015; Gleick, 2014). Statistical analysis of climatic and non-climatic factors in global patterns of conflict and asylum-seeking between 2006 and 2015 found that drought conditions were likely secondary in generating conflict and asylum-seeking outmigration from Syria in the years 2010 to 2012, with non-climatic factors playing the primary role (Abel et al., 2019). Extreme events and changing climate conditions interact with political, economic, social, cultural and other factors and can generate or exacerbate conflicts and forced migration, but a conflict and refugee crisis of the scale of Syria is not solely attributable to climate factors.

9.6.3 Demands on international assistance

Heightened demand for international assistance as a result of climate change is foreseeable—even if the causal pathways are complex. Climate change may lead to complex humanitarian crises through threats to food security, livelihoods, public health, mobility and geopolitical stability (Norwegian Red Cross, 2019). Beyond humanitarian assistance and development organizations, a number of national security and other international institutions note the potential for climate change to require additional international assistance, including the U.S. Department of Defense (U.S. Department of Defense, 2014), the United States Executive Office of the President (United States Exec. Order 14008, 2021) and intelligence community (Coats, 2019), think tanks (Guy et al., 2020), the United Nations Security Council (UN News, 2019) and the G7 (UNFCCC, 2015). Canada's Feminist International Assistance Policy draws attention to the destabilizing effects climate change can have on the poorest and most vulnerable communities (Government of Canada, 2017a). Similarly, Canada's Strong, Secure, Engaged defence policy recognizes the potential for climate change to exacerbate existing fragilities in some countries, increasing tensions and contributing to humanitarian crises (Government of Canada, 2017b).

Many developing countries have made significant progress on climate change adaptation and climate-related disaster risk reduction to date, with important lessons to be drawn for developed countries (*see* Case Story 9.5). Countries' progress in defining their adaptation priorities, establishing governance structures that facilitate adaptation efforts, implementing adaptation-focused projects and programs, and leveraging financing for priority adaptation efforts is highly variable (Parry and Terton, 2016). In some cases, community-level action is outpacing action at the national level, so care must be taken to avoid generalizing the climate resilience of developing countries based on their national efforts alone.

However, for many developing countries with lower income, including LDCs, building climate resilience and adapting to the impacts of climate change is unaffordable without assistance from developed countries as partners. Accurate and consistent assessments of the overall economic costs of climate change impacts on developing countries are a work in progress. Nevertheless, research and policy communities generally agree that the costs will be substantial. The World Bank and the UN Framework Convention on Climate Change (UNFCCC) have estimated adaptation investment needs in developing countries by 2030 in the range of US$60 to $100 billion per year (Fankhauser et al., 2016). In addition, there is growing recognition that climate change adaptation should be mainstreamed into regular international assistance efforts. There is also the potential for climate considerations to compete with investments for ongoing development priorities (e.g., healthcare, social welfare and education).

9.6.4 Canada's response and outlook

Canada's response to the increased threats posed by climate change to developing countries over the last decade has focused on contributing to global climate finance (*see* Box 9.3), supporting knowledge generation relevant for adaptation in developing countries and identifying priorities for action that address climate risks through international assistance activities. Canada's approach is continuing to evolve, as exemplified in the 2019 mandate of the Minister of National Defence, which made a commitment to draw on the expertise of the Canadian Armed Forces to help other countries at greater risk of disasters due to climate change (Trudeau, 2020). Because the lines between post-disaster humanitarian work and development interventions to reduce poverty are becoming increasingly blurred, improved collaboration between these two communities of practice could help address root causes of vulnerability and contribute to long-term adaptation (Marin and Naess, 2017).

Box 9.3: Climate finance

Climate finance refers to financial support for mitigation and/or adaptation actions that address climate change. It differs from official development assistance in that climate finance is intended to be additional to international development commitments. The Paris Agreement calls for financial assistance from Parties to the UNFCCC, with more financial resources to less wealthy and more vulnerable Parties. Climate finance is an important tool to help build the resilience of countries for which the costs of adaptation could be unaffordable. As a Party to the UNFCCC and the Paris Agreement, Canada has obligations to provide finance to developing countries to support their efforts to adapt to climate change.

Advocacy by governments and non-governmental organizations led developed countries to commit to raising US$100 billion annually by 2020 from public and private sources for climate finance in developing countries, but progress has been mixed in meeting that target (African Development Bank et al., 2019; OECD, 2019, 2018a-c, 2016). Progress has been made in total financing made available by developed countries in the years between 2013 and 2017 in increasing annual investments (up to US$71.2 billion annually from US$52.2 billion), but a significant skew remains towards GHG emissions reduction (73%) over adaptation funding (19%) as of 2017 (OECD, 2019).

More information is available on the UNFCCC's website at this link: https://unfccc.int/topics/climate-finance/the-big-picture/introduction-to-climate-finance.

Canada's leadership on global climate finance has varied over the years. Most recently, Canada has committed to contribute C$2.65 billion between 2016 and 2021 towards global climate finance (Government of Canada, 2018). Between 2016 and 2018, Canada ranked 9th among 24 OECD contributors to climate finance (Tomlinson, 2020). Canada's ranking for this period drops to 14th among 24 OECD donors when taking into account the contribution of climate finance relative to countries' Gross National Income (Tomlinson, 2020). Tracking climate finance flows is an inexact science (Furlow et al., 2011), not least because it can be impractical to isolate the additional finance destined for climate action—particularly when tracking climate finance for adaptation, given the strong linkages between adaptation and broader development investments (Church and Hammill, 2019). Transparency in climate finance tracking and reporting is a standing focus of work for the UNFCCC and OECD (Clapp et al., 2012).

Canada is taking steps to build the resilience of developing countries through development and assistance programming. Over 2017 and 2018, Canada delivered C$1.5 billion to developing countries for climate action—of which C$704 million was part of the Government of Canada's C$2.65 billion climate finance commitment; C$246 million was part of the Government of Canada's regular international assistance projects with a climate change component; C$17 million was associated with provincial and municipal support; C$509 million was provided from Export Development Canada by mobilizing private finance; and US$30 million was delivered by FinDev Canada, a newly established development finance institution (Government of Canada, 2020). Of these investments, C$192 million targeted climate change adaptation, as compared to C$315 million for GHG emissions reduction initiatives, and C$498 million was dedicated to initiatives that cut across adaptation and GHG emissions reduction priorities. This adaptation investment includes Canada's C$30 million contribution to the Least Developed Countries Fund, which addresses urgent adaptation needs of the least wealthy and most vulnerable countries. Projects funded by Canada include C$100 million in support of the expansion of climate risk insurance coverage in climate-vulnerable countries, with the aim of helping communities build back better and faster following disasters related to natural hazards such as hurricanes and flooding (Government of Canada, 2020). Current top recipients of Canadian official development assistance—Haiti, Mali, South Sudan, Syria, and Tanzania—are projected to experience significant climate impacts in the years ahead. This underscores the potential for increased demands for climate-related development assistance in the years to come. Case Story 9.4 in the previous section illustrates how climate change may have played a part in increasing demands for Canada's assistance by Mali.

In line with the Feminist International Assistance Policy, Canada's climate finance investments have a strong focus on gender equality and on the empowerment of women and girls. Attention to gender equality is important as evidence shows females and males differ in their vulnerability to climate change and preferences for adaptation solutions, with women and girls continuing to be disproportionately impacted by the adverse effects of climate change (Rao et al., 2019; Assan et al., 2018; Vincent et al., 2010). Projects that are gender-blind have the potential to increase disparities between the sexes and perpetuate structural challenges that limit access to resources and power.

Canada has also contributed to building knowledge and local research capacity on vulnerability to climate change impacts and feasible adaptation options in developing countries. One example is the body of research produced through the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), jointly funded by Canada's International Development Research Centre (IDRC) and the United Kingdom's Department for International Development (International Development Research Centre, 2019). Alongside many other initiatives led by the IDRC, this collaborative effort is yielding lessons, good practices and innovations applicable to Canada's future investments in development assistance (*see* Case Story 9.5). These lessons include practical approaches to integrate disaster risk reduction and climate change adaptation into project and program designs centred on local contexts to encourage the pursuit of low-carbon benefits and also to avoid inducing maladaptation (UN Environment Programme, 2017; Adger et al., 2014).

Case Story 9.5: Researching risk-pooling initiatives in the face of climate change in South Africa

Floods are a common and damaging climate-related hazard in South Africa (Zuma et al., 2012). In the Western Cape, for example, expected urban damage per year is estimated to be US$66 million (World Resources Institute, 2017). South Africa's Disaster Risk Financing strategy is primarily focused on a form of self-insurance. Climate change will test the resilience of this strategy. The use of risk-transfer tools, such as risk-pooling, is an option to increase the financial capacity of provincial governments if losses become exorbitant. Risk pooling has the potential to extend coverage to those individuals who are not covered by commercial insurance, and thereby acts as a safety net.

Funded by Canada's International Development Research Centre (IDRC), the Municipal Risk Pooling project (IDRC, 2020) is examining the feasibility of developing subnational risk pools as a mechanism for managing climate risk, with the aim of generating guidance for others. It is led by the University of KwaZulu-Natal, endorsed by the Western Cape subnational government and involves a number of partners, including SouthSouthNorth and the Munich Climate Insurance Initiative.

Figure 9.12 illustrates the proposed structure for a Municipal Risk Pooling project. A risk-pooling facility based at the municipal level would allow South African entities to accrue all benefits from premiums paid, with governance and decision-making power retained within South Africa. Under this model, municipalities pay premiums towards the risk pool (either from their own budget or supported by donors), determined by the type of coverage required (e.g., 1-in-5-year event) and the risk profile of the municipality. Participating in risk pools could allow local governments to access insurance on better terms than if they applied as an individual entity. The risk pool would grow the capital reserves over time through investments that yield returns, while also reducing exposure of the pool by passing on risks to reinsurance and capital markets.

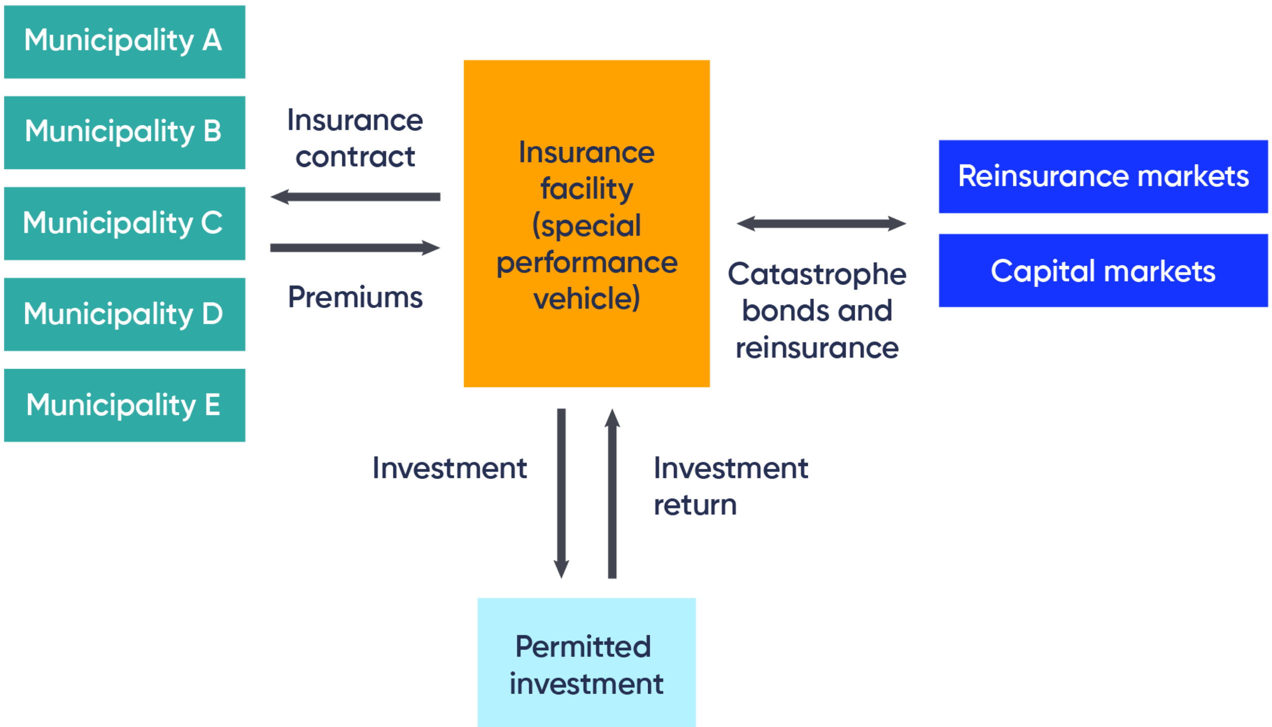


Figure 9.12: A proposed structure for the Municipal Risk Pooling Facility project led by the University of KwaZulu-Natal.

9.7 Moving forward

9.7.1 Knowledge gaps and research needs

Research on the risks and opportunities to Canada stemming from climate change impacts, events and adaptation that occur or are amplified beyond Canadian borders remains underdeveloped. All of the topics discussed here—tensions over Arctic sovereignty as sea ice retreats; the potential for strained relationships from climate-induced shifts in freshwater flows and marine resources shared across international boundaries; economic impacts to Canada due to changes in global trade exacerbated by extreme events and climate change; the potential for increased pressure on Canada's immigration and resettlement infrastructure; as well as demand for Canadian international assistance—are within the top twelve climate risk areas identified for

Canada (Council of Canadian Academies, 2019). Defence and foreign policies acknowledge the role of climate change in exacerbating existing vulnerabilities in the Arctic and fragilities in some countries as well as the need for enhanced capabilities to address increased demands. Climate-related disruptions in global supply chains highlight the potential for trade to propagate or dampen economic risk, and widespread adoption of climate-related financial disclosure by firms in Canada's trade sectors may well yield the data needed to understand the degree to which product, market, logistics, security and other dynamics interact with climate change risk. Agencies managing transboundary resource-sharing agreements are starting to revisit assumptions of static environmental conditions, since these risk unsustainable resource use and threaten the stability of cooperative relationships. Despite a growing awareness of the international dimensions of climate change risk for Canada, the knowledge base is insufficient to reliably assess the extent of current and future risk exposure as climate change intensifies. This assessment relied on a number of strands of research and evidence; in some cases, there was a continued need to make inferences.

Nevertheless, with the evidence available it is possible to highlight early indicators for decision makers to respond to, while academic and practitioner communities continue to address knowledge gaps. Table 9.13 provides a qualitative account of the likelihood of risk factors described in previous sections of this chapter. There is least confidence in risk factors related to international trade.

Table 9.13: Qualitative assessment of risks and opportunities to Canada from transboundary impacts of climate change over the next 30 years

RISK/OPPORTUNITY FACTOR	LIKELIHOOD	CONFIDENCE
Arctic shipping and sovereignty		
Decreased extent, thickness and age of summer sea ice in the Arctic Ocean and gradual opening up of major waterways to ice-free conditions for part of the year		
Increased physical access to Canada's Arctic resources and waters		
Increased vessel traffic in Canadian Arctic waterways, including in the Northwest Passage		
Development of economically competitive and safe Arctic shipping and trade routes		

RISK/OPPORTUNITY FACTOR	LIKELIHOOD	CONFIDENCE
Increased perception of the Northwest Passage as an international strait linked to substantial rise in commercial shipping		
Diminished Canadian ability to use Article 234 under the UN Convention of the Law of the Sea for legitimacy over regulation of Northwest Passage waters		
Increased pollution, oil spills and negative impacts on marine habitats due to shipping in the Northwest Passage		
Diminished capacity to enforce environmental protections in Canada's Arctic waterways linked to inadequate infrastructure and operations		
Transboundary marine and freshwater agreements		
Increased migration of marine species poleward or to deeper water, resulting in redistribution of marine species across borders		
Changes in water quantity and timing of flows, water temperatures, and intensity, frequency and/or duration of floods and droughts, resulting in spatial and temporal redistribution of freshwater resources across borders		
Changes in perceived benefits from resource sharing, partly driven by regional differences in climate change impacts and vulnerabilities		
Increased uncertainty of meeting management objectives under existing transboundary cooperative structures		
Increased need for difficult trade-offs across competing freshwater water uses		
Increased application of adaptive measures in most key Canada–U.S. freshwater agreements (beyond the Great Lakes Water Quality Agreement)		

RISK/OPPORTUNITY FACTOR	LIKELIHOOD	CONFIDENCE
International trade		
Increased economic impacts to Canada through disruptions to supply chains and distribution networks		
Increased resilience of new and existing trade infrastructure networks worldwide		
Increased global markets for adaptation solutions		
Changes in the availability and prices of basic goods, including disruptions to the global food system		
Increased spread of economic risk to Canada through climate change impacts to major trade partners		
Increased relative gains to Canada from long-term shift in trade patterns		
Increased global disparities from the unequal adaptive effect of trade		
Human migration and displacement		
Increased displacement of millions of people each year around the world due to tropical cyclones, floods, droughts, wildfires and food insecurity, combined with non-climate stressors		
Increased future demand for immigration to Canada from countries highly exposed to climate risk, especially from Canada's largest source countries of international migrants		
Increased skilled worker migration to Canada from climate-disrupted regions		
Increased pressure to provide financial assistance for refugee procedures and serve as a resettlement destination		

RISK/OPPORTUNITY FACTOR	LIKELIHOOD	CONFIDENCE
Evolution of climate-related migration arrivals into Canada shaped by disparate immigration and border policies between Canada and the United States		
International assistance		
Increased future demand for international assistance, including responding to humanitarian crises, particularly in countries where Canada is already active		
Increased need for international assistance to address root causes of involuntary climate migration		
Increased future demand for intervention in water scarce, politically unstable Least Developed Countries		

Note: Likelihood is represented on a graduated colour scale: dark green = negligible, light green = unlikely, yellow = possible, orange = likely, and red = almost certain. Confidence is represented on a 4-point scale, with grey = unclear, green = low, yellow = medium, and red = high. Confidence ratings take into account the extent of evidence and relative influence of non-climate drivers. The likelihood and confidence scores were based on the expert opinion of the author team.

Based on the assessment in this chapter, four emerging themes stand out as needing further consideration as adaptation science and knowledge evolves in Canada.

9.7.1.1 Governance and mainstreaming

Academic and practitioner research recognizes the advantages of advancing adaptation through its integration into existing institutions, policy and planning processes (e.g., Lemmen et al., 2008). Mainstreaming is a strategy promoted in each of the discussions in this chapter and is a concept tightly connected to governance. Each topic addressed in this chapter has its own web of actors and institutions already governing the evolution of each system at different scales. International agreements (e.g., transboundary river basin treaties) and customary laws (e.g., UNCLOS), multi-lateral institutions (e.g., Arctic Council, World Trade Organization, trade agreements), national or subnational policies (e.g., trade, military defence, immigration, international assistance), and sectoral or organizational strategies all form part of issue governance. Governance is itself dynamic and subject to shifts in societal expectations, politics, social norms and review schedules, among others, such that adaptation mainstreaming can occur within a moving target. This can include the need to dismantle or modify existing institutions and create new ones where none exist. Options for increasing consideration of indirect, cross-border climate change impacts in adaptation governance include: 1) national or bilateral responses that, for example, aim to increase self-sufficiency and ensure cooperation among strategic partners; 2) transnational responses characterized by leadership of non-state actors; and 3) international responses focused on reforming existing institutions, including expanding the mandate of the UNFCCC (Benzie and Persson, 2019).

At present, key issues gaining prominence in governance in Canada that also shape adaptation governance include reconciliation with Indigenous peoples and the rise of populist politics. The former has fundamental implications for resource use and development, among other domains. For example, for Inuit peoples, Arctic sovereignty is connected to self-determination, the right to cultural integrity and empowerment (Inuit Circumpolar Council, 2009). Addressing these issues requires supporting healthy and sustainable communities informed by Inuit needs and knowledge (Gerhardt, 2011) and cooperating with governments in setting the rules for Arctic development (Dodds and Hemmings, 2015). Shifts in Canadian public sentiment in favour of populism can temper Canada's role as a destination for migrants from climate-disrupted regions and as a source of international development assistance tagged for adaptation and resilience. Insular attitudes of the Canadian public may also diminish political will to act on Canada's commitment to multilateralism and step in as a global broker of cooperative solutions. With increased pressure to deliver results from public budgets, knowledge about the effectiveness and equity impact of adaptation efforts funded by governments is critical. At the same time, coherence among all parts of Canada's international policies with respect to climate, trade, migration, international assistance and security efforts will become increasingly important.

9.7.1.2 Global food systems

Combined with other pressures, such as population growth and shifting diets, climate change threatens global food systems, with implications for food security. Food security is a multi-dimensional concept comprising availability (quantity), access (physical and financial), utilization (nutrition) and stability (Food and Agriculture Organization, 2018). Although all dimensions are subject to climate change threats, quantitative studies focus on availability and, to a lesser extent, access. Canada's role in supporting food security outside its borders now and in the future, including as a net exporter of fertilizer, grains, fish and seafood, through international assistance and through partnered research merits closer consideration. The role can be explored from several dimensions, including economic interest, global stability and contributions to meeting the 2030 United Nations Agenda for Sustainable Development. In examining Canada's potential contribution to future food availability, access and stability, a more balanced view than what is captured in global modelling efforts may be needed to estimate the impact of climate change on food production in Canada and what this means for exports. For example, Canadian agricultural producers will face a mix of opportunities and challenges (*see* Sector Impacts and Adaptation chapter), and the aggregate functions included in studies such as Dellink et al. (2017) can fail to capture realistic impacts on Canada's agricultural productivity and nutritional content. A lack of research on how the impacts of climate change elsewhere in the world could affect food supplies in Canada is an important knowledge gap, since consumer choices could be restricted as food exports from tropical countries become less reliable.

9.7.1.3 Assessment tools that accommodate uncertainty and complexity

For many years, Canadian and international research has recognized that climate change vulnerability and decisions to adapt are rarely shaped by climate factors alone (IPCC, 2007). This conclusion aptly applies to understanding the international dimensions of climate change risk for Canada and how Canadians should adapt. Assessment of all issues in this chapter emphasized that climate change and its impacts are rarely the sole risk driver or reason for adaptation. For example, resource markets, technology and strategic interests are important drivers of shipping in Arctic waterways; disappearing sea ice only enables shipping activity. Population migration is the cumulative result of environmental, social, economic and cultural factors. Although some climate hazards directly displace people (e.g., hurricanes), the role of climate variability or climate change in motivating population movement is not always clear. Because of the complexity in both assessing and managing risks (and opportunities) resulting from the interactions of multi-layered cause-and-effect chains, decision makers may need assistance to define the problem. This can include clarifying the outcomes they wish to safeguard, isolating the drivers most likely to threaten or enrich these outcomes, implementing and monitoring management actions targeting drivers over which they have some control or ability to predict and tracking the evolution of other drivers. Use of foresight tools (e.g., scenario planning and horizon scanning) as well as holistic approaches, like systems mapping (e.g., Cradock-Henry et al., 2020) and cumulative effects assessment, which combine climate and non-climate drivers and outcomes in one framework, will help to bound the range of probable outcomes and management levers worth pursuing. Capacity for systems thinking, adaptive leadership and iterative learning are all important qualities of decision makers navigating large-scale transformations (Eyzaguirre et al., 2017).

9.7.1.4 Strengthened economic modelling

Aside from improvements in modelling the agriculture and food sector, strengthening the breadth and depth of economy-wide modelling efforts in Canada would help improve its overall assessment of economic risk. A knowledge gap exists in the analysis of the economic impacts of climate change on patterns of domestic production, as it does in the analysis of the projected impacts on the economies of the regions with which Canadian producers compete in international markets. Studies such as those carried out by Szewczyk et al. (2018), who modelled the spillover effects of climate impacts occurring outside the EU but affecting the EU via trade, and by Zhang et al. (2018), who modelled the spillover effects of climate impacts occurring in the United States affecting other global regions via trade, provide foundations to build on, as do assessments undertaken in Germany and Switzerland (Stockholm Environment Institute, 2018).

9.8 Conclusion

This chapter focused on risks and opportunities facing Canada from indirect impacts of climate change with international dimensions. For all issues considered, the research remains underdeveloped, particularly as it relates to international trade. Indirect impacts of climate change have long been neglected in Canadian adaptation research, partly because of the methodological complexities and multiple disciplines involved. Although adaptation—planned or proactive—is either not documented or not yet occurring in a consistent way across the policy and management issues assessed, there are examples of spontaneous or market-driven adaptation. The increase in Arctic shipping, migration decisions in response to climate-related disasters and diversification of raw material suppliers are just a few examples. It is challenging to assess the significance of excluding these transboundary, teleconnected or cascading effects in measuring Canada's progress in adapting to climate change. Nevertheless, the information presented in this chapter sheds light on the potential perils of lagging behind in laying the groundwork for adaptation and in addressing the weaknesses in resilience and adaptive capacity that have already been identified (e.g., for Arctic shipping and sovereignty as well as transboundary resource management). In any case, without deep cuts in global GHGs to limit future climate change, it will become increasingly costly and challenging to sustain Canadians' well-being in a climate-disrupted world (Curtin, 2019).

9.9 References

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