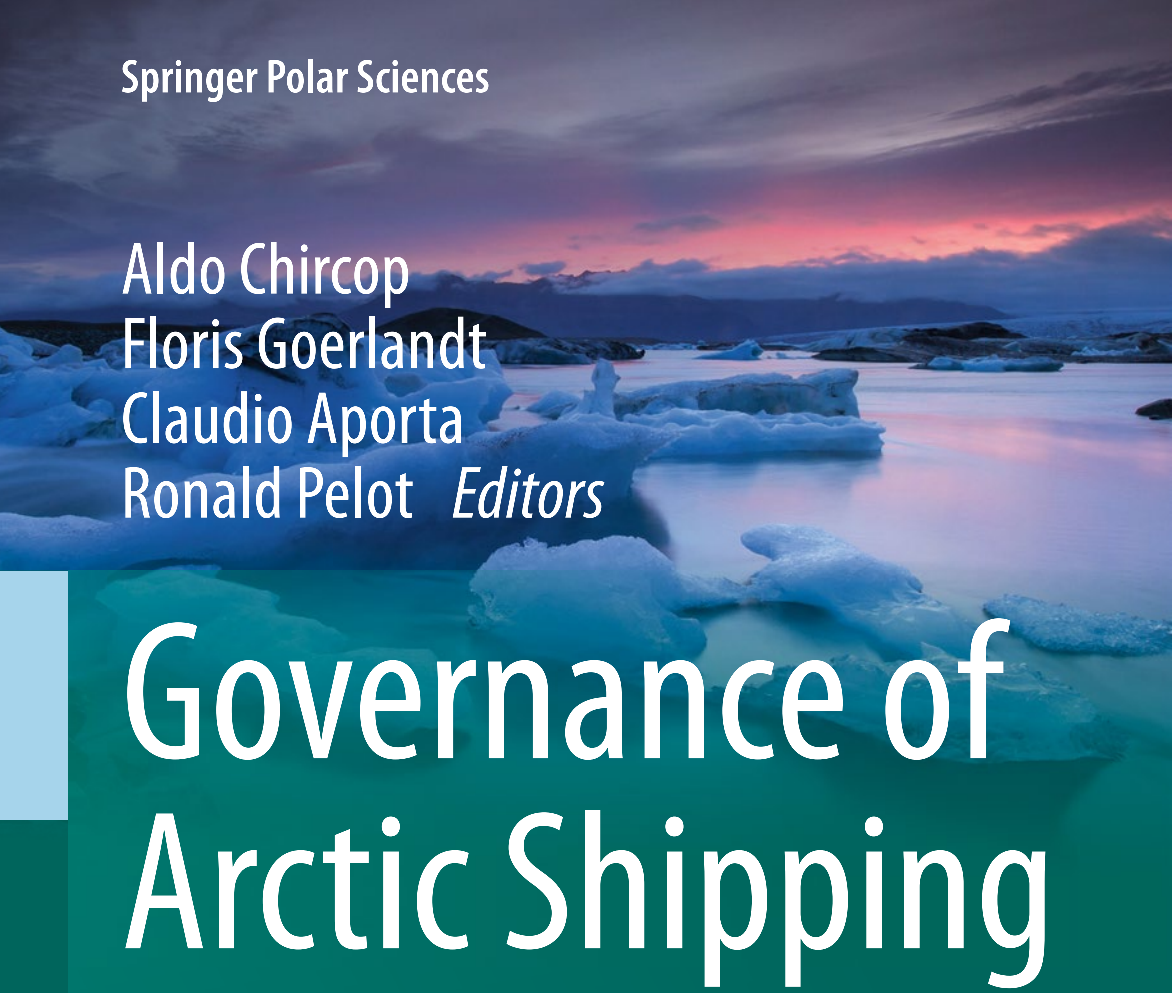

Springer Polar Sciences

Aldo Chircop
Floris Goerlandt
Claudio Aporta
Ronald Pelot *Editors*

Governance of Arctic Shipping

Rethinking Risk, Human Impacts and Regulation

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Halifax, NS, Canada The Editors
2 December 2019

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Chapter 1
Introduction

Aldo Chircop, Floris Goerlandt, Claudio Aporta, and Ronald Pelot

Abstract This chapter introduces a multidisciplinary collection of chapters addressing various aspects of governance of Arctic shipping written by leading international scholars. It investigates how ocean changes and anthropogenic impacts affect our understanding of risk, policy, management and regulation for safe navigation, environment protection, conflict management between ocean uses, and protection of Indigenous peoples' interests in Canadian Arctic waters. The book is divided in three parts, together providing a multi-faceted and interdisciplinary view on governance of Arctic shipping. The first part addresses conceptual and empirical aspects of risk governance, management, and assessment in the Canadian Arctic. The second part focuses on the human dimensions of a changing Arctic, providing insights in Inuit perspectives and knowledge, occupational safety issues onboard cruise and other commercial vessels, and aspects of fishing vessel safety. The third part focuses on regulatory considerations of shipping and ocean use, with contributions addressing the IMO's framework for Arctic shipping, the Polar Code implementation in Canada, and contemporary topics concerning ship emissions, heavy fuel oil, and maritime spatial planning. It is hoped that the contributions encourage further multi- and interdisciplinary work by established and emerging scholars, and that these can assist decision-makers in planning, managing, and regulating Arctic Shipping.

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1.1 Purpose

Over the last decade, there has been an exponential increase in the literature on the governance of Arctic shipping, especially in the wake of the Arctic Council's seminal *Arctic Marine Shipping Assessment Report* (Arctic Council 2009) and following the commencement of the International Maritime Organization (IMO) deliberations on a mandatory code for polar shipping. There are several multidisciplinary monographs and collected works focused on Arctic shipping (Østreng et al. 2013; Beckman et al. 2017; Hildebrand et al. 2018; Rothwell 2018; Lasserre and Faury 2019). There are also monographs and handbooks on polar law and policy containing individual chapters on Arctic shipping, as well as numerous articles in the refereed journal literature and technical publications.

In an era when climate change is of high societal concern and a political priority, academia has mobilized to highlight and explain what is at stake for the Arctic as one of the most fragile marine regions and the implications of a changing Arctic for the planet as a whole. Work focuses on the effects of climate change on oceans and marine ecosystems but also on economic implications and social impacts on Arctic populations, most especially Indigenous peoples. Furthermore, academia scrutinizes the efficacy of global, regional and national governance structures and processes in meeting the various challenges. This book joins the body of literature on the governance of Arctic shipping and aims to add value through the perspectives of risk, the human dimension and regulatory strategy, with a particular focus on Canadian Arctic waters.

This book is a product of a research project led by Dalhousie University entitled "Module N: Safe Navigation and Environment Protection". The project is supported by a grant from the Ocean Frontier Institute's Safe and Sustainable Development of the Ocean, funded by the federal government's Canada First Research Excellence Fund (CFREF).

1.2 Context

The Arctic is undergoing profound change with far-reaching consequences for accessibility, the marine environment, regional economies, infrastructure, Indigenous peoples and coastal communities, more than any other region and at a much faster pace (IPCC 2019; Arctic Council 2009; Østreng et al. 2013). Until approximately two decades ago, most of the Canadian Arctic was inaccessible to shipping, and, when reachable, vessels usually required icebreaker assistance. The purposes of shipping in those times were limited and primarily related to the transportation of minerals, northern community supply logistics, scientific research and services provided by government ships, such as aids to navigation, surveillance and search and rescue (SAR). The progressive loss of sea ice caused by climate change has changed the intensity and purposes of shipping. Today, record-breaking sea ice loss leads to enhanced mobility for a range of commercial and non-commercial ships, including cruise ships and recreational vessels engaged in opportunistic voyages. These developments are having profound impacts on navigation routes, the infrastructure needed, ship operations and the well-being of Arctic communities, triggering concerns for sustainability (Hildebrand et al. 2018; Lasserre and Faury 2019).

In theory, and regional destination shipping aside, there are three potential major routes for intercontinental transits through the Arctic (Arctic Council 2009; Østreng et al. 2013). The first, and most realistic, is the Northeast Passage, which includes the Northern Sea Route through Russian Federation waters. The latter has been seeing growing, albeit incremental, commercial traffic since the first transits of the German-owned heavy lift vessels *Beluga Fraternity* and *Beluga Foresight* from Asia to Europe in 2009 (Østreng et al. 2013). The second is the transpolar route through the central Arctic Ocean, which has not yet been tested by commercial shipping and is thought not to be feasible for several more decades. The third is the Northwest Passage, mostly through Canadian Arctic waters. This route has seen very few pilot commercial transits. To date, the bulk of shipping in the Canadian Arctic consists of destination shipping, with more occasional activity by small cruise ships and recreational vessels (Wright 2016). While it is too soon to determine whether new and sustainable international shipping routes will take hold in the Northwest Passage, considerable efforts have been invested by public authorities and research institutions to anticipate and understand the potential impacts.

A stark reality is that even under the most optimistic forecasts for navigational accessibility, navigation in Arctic waters will remain challenging for the foreseeable future. There is a need for developing marine transportation policies, where risk reduction strategies adequately represent the changing geophysical processes that pose risks, such as marine visibility, meteorology, sea ice and ocean-atmosphere interaction (Koračin et al. 2014). Even with rising temperatures, sea ice will be present for most of the year, as ice lost in the summer season will form again during the winter months. Even during the summer navigation season, there could be variable and unpredictable sea ice movement, bad weather and limited visibility for prolonged periods, making for extreme conditions and posing particular risks for efficient and safe navigation (Arctic Council 2009; Snider 2018). In addition, Arctic shipping, most especially in Canadian waters, has to contend with remoteness and minimal infrastructure, including absence of, or insufficient, charting, and limited services such as pilotage, salvage, spill response and SAR (Arctic Council 2009).

Conversely, especially without appropriate standards and controls, the increasing shipping activity could adversely impact the fragile Arctic environment through toxic emissions, black carbon, oil spills, habitat damage, introduction of exotic species and underwater noise, with potential disruptions to humans, species and ecosystems (Richardson et al. 1995; Weigart 2007; IMO 2009; Arai et al. 2009; Slabbekoorn et al. 2010).

There is very limited capacity to respond in a timely and effective manner to a spill of heavy fuel oil in an area with extensive sea ice presence. Virtually the entire response capacity would need to be transported over great distances because of the poor infrastructure and geographical remoteness. Many oil spill response techniques have limited usefulness in Arctic environments (EPPR 2017). A major pollution or SAR incident, such as a cruise ship in distress, would easily overwhelm Inuit and other coastal communities and existing response capacity. In Canada, even with capacity built under the recently launched Oceans Action Plan (OPP) (DFO 2016), the response times are very long (Ford and Clark 2019). There are further dangers of physical, mental and community health impacts (Eykelbosh 2014; Chang et al. 2014). Spills and other incidents have the potential to erode social license for shipping in the region. Hence, emergency prevention, preparedness and response based on sound risk assessment and conforming to the highest practicable standards, grounded in solid scientific understanding of ocean and weather pattern changes and other sources of knowledge such as traditional knowledge by Indigenous peoples, are essential (Nevalainen et al. 2017). There is need to enhance efficiencies in the use of scarce resources through a better understanding of risk leading to greater integration of planning for SAR and spill response, especially in remote areas.

Underwater noise is a risk, as reports of whale strandings following explosive noises and high-intensity sonar trials demonstrate elsewhere (Ketten et al. 1993; IMO 2014; Urick 1984). Sublethal consequences can also affect marine mammals due to chronic noise that interferes with normal animal activities, causing changes in stress hormones in whales (Rolland et al. 2012). Elevated anthropogenic noise has been shown to negatively impact commercial fish catch rates (Engås et al. 1996). Conditions are exceptionally and dynamically variable in the Arctic, so the effect of noise from a single ship may vary significantly from one day to the next. Current standards for ship-generated noise are only voluntary at this time (IMO 2014).

Coastal communities could be exposed to harmful atmospheric emissions that can pose public health risks, such as premature mortality and respiratory illnesses (IMO 2009). In this context, it is interesting to note that the northernmost limit of the IMO North American Emission Control Area for controls of emissions of sulphur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM) from ships is located at 60 degrees North. The IMO International Code for Ships Operating in Polar Waters (Polar Code) does not address atmospheric pollution (Chircop 2016; Polar Code 2014/2015).

Several of the risks posed by shipping have the potential to generate conflict. Conflicting interactions between shipping and Inuit activities, coastal communities and other ocean user interests can be prevented or mitigated. Conflict prevention and mitigation benefit from marine spatial planning (MSP) and ship routeing measures (Ehler and Douvere 2009; IMO 1985, 2015). MSP 'is a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process' (UNESCO n.d.). Despite ocean management efforts in Canada, to date MSP has not been embraced in the Arctic as in European waters. MSP in the Canadian Arctic context would need to be driven in great part by Inuit perspectives. This is especially significant because the traditional marine bias of MSP needs adaptation to a different Indigenous conception of space involving land, ice and sea as a continuity (Boucquey et al. 2016; Aporta 2010a, 2010b). MSP supported by ship routeing and reporting measures could help address Inuit concerns regarding impacts of shipping on land, ice, sea and air quality and facilitate the prevention and mitigation of other conflicts.

The risks posed by shipping to Indigenous peoples and other coastal communities are accompanied by other human impacts produced by this industry. In particular, the growth of traffic entails a corresponding increase in the numbers and diversity of workers in the maritime industries, most especially in commercial shipping, cruise shipping and fishing industries. Subsequent to the adoption of the Polar Code, the IMO scaled up the training and certification requirements for seafarers employed in polar regions (STCW 1978/2016). While this is good news for commercial traffic, the full extent of application of these higher standards to personnel other than traditional seafarers on cruise ships is unclear. On the one hand, rules of the International Labour Organization (ILO) include all workers on board ships as seafarers for occupational health and safety standards; on the other hand, the IMO rules on training concern only seafarers responsible for the safe navigation of the ship (MLC 2006; STCW 1978/2016). Moreover, personnel on fishing vessels are not covered by the Polar Code, the IMO rules on training and certification seafarers and the ILO rules. The only international safety rules dedicated to fishing vessels are not yet in force (Cape Town Agreement 2012). There are serious gaps in occupational health and safety standards for maritime workers, other than seafarers, in polar regions.

How are principles, structures and processes for the governance of Arctic shipping positioned to address the challenges of increased shipping in the region? There is much unfinished business in the governance of Arctic shipping. At the global level, the recently adopted Polar Code, accompanied by amendments to major safety of life at sea and pollution prevention instruments, has achieved much in mitigating the risks of Arctic shipping (Polar Code 2014/2015). It introduced new international safety and environmental standards for polar shipping effective on 1 January 2017 (Chircop 2016; Beckman et al. 2017). However, important gaps remain. The safety provisions of the Polar Code do not apply to non-SOLAS ships, such as fishing vessels. During deliberations on the Polar Code, the need to establish appropriate standards for ship emissions in polar and other waters to protect public health was identified but left for future work. Similarly, the regulation of use and carriage for use of heavy fuel oil (HFO) was left to a future time and is currently under consideration at the IMO. It is remarkable that Arctic ship emissions are regulated to a lower standard than that applicable to the sub-Arctic waters of North America. In Canada this means there is a dual standard: ship atmospheric emissions south of 60 degrees are far more stringent than in Arctic waters.

In the last few years, Canada has shifted its northern policy from an almost exclusive focus on sovereignty, reinforced by annual prime ministerial pilgrimages, to a more general and contemporary concern with rules-based governance to support development, safety and environment protection and a strong role for communities (Canada 2018). It includes an express goal to '[E]nsure safe and environmentally-responsible shipping' (ibid. Goal 5.9). The OPP adopted by the Trudeau government in 2016 prioritized maritime safety and oil spill response in partnership with Indigenous peoples and coastal communities, including in the Arctic (Canada 2016). The numerous contemplated actions for the Arctic include the assessment of potential cumulative effects of shipping, modern hydrographic surveys, increasing the number of marine safety inspectors, extending the operational season of the Canadian Coast Guard and creation of CCG Auxiliary chapters, strengthening inshore rescue capacity, expanding the National Aerial Surveillance Program for marine pollution, and a real-time marine traffic information system accessible by local communities and local traffic management. The Polar Code has been implemented through new regulations. High profile is being given to Indigenous peoples, such as in land claims agreements and marine conservation areas that potentially interact with shipping. Canadian action in the Arctic Council and in the IMO with respect to the governance of shipping has been vigorous and sustained (Chircop et al. 2018). For example, Canada currently co-chairs the Shipping Expert Group of the Protection of the Arctic Marine Environment (PAME) working group with the United States, and in 2009 Canada was the first to table a full draft of the future Polar Code (ibid.). Canada has thus adopted a range of domestic measures, including investments in the North, and has taken steps to develop low-impact navigation corridors in Arctic waters with engagement of Indigenous communities (Chénier et al. 2017).

1.3 Objective and Contributors

Against the above backdrop, this book is multidisciplinary and investigates how ocean change and anthropogenic impacts affect our understanding of risk, policy, management and regulation for safe navigation, environment protection, conflict management between ocean uses and protection of Indigenous peoples' interests in Canadian Arctic waters. Some of the most pressing and under-addressed concerns in the governance of shipping are addressed, including conceptualization of risk types and risk governance strategies for risk-based ship design for ice loads, SAR and oil spill preparedness response planning, planning for the deployment of limited search and rescue assets and capabilities in remote regions, impact of ship noise on the marine environment, risks of heavy fuel oils, atmospheric emissions from ships producing impacts on public health and the environment, and safety of maritime workers.

These concerns were addressed at a workshop in Halifax, Nova Scotia, in August 2018, following which contributors, working in a team and/or individually, proceeded to research and write the chapters in this book. The contributors hail from several disciplines and fields (anthropology, industrial engineering and risk management, law of the sea and maritime law, marine management, oceanography, social work, sociology) and countries (Canada, China, France, Germany, Italy, the Philippines, South Korea and Sweden), as well as personnel at the IMO participating in their personal capacities.

1.4 Structure

The book has 16 chapters divided in three parts, each chapter drawing individual and separate conclusions. Part A is on 'Rethinking Maritime Risks' and contains five chapters. The first contribution, Chap. 2, is entitled 'An Exploratory Application of the International Risk Governance Council's Risk Governance Framework to Shipping Risks in the Canadian Arctic' and is authored by Floris Goerlandt and Ronald Pelot. The chapter introduces the IRGC risk governance framework and explores its application for management strategies for risks associated with operation of ships and responding to requests for assistance in Arctic waters. It highlights the importance of articulating risk governance strategies aligned with the characteristics of the risks under consideration. Chapter 3 is entitled 'Historical Maritime Search and Rescue (SAR) Incident Data Analysis' and is authored by Mark A. Stoddard and Ronald Pelot. Using incident data from the Canadian Search and Rescue Program Information Management System database, the authors identify and visualize temporal and spatial patterns in maritime SAR activities. The work serves to highlight the potential benefits of enhanced cross-border coordination of SAR planning and response. This is followed by Francesco Munari's Chap. 4 on 'Search and Rescue at Sea: Do New Challenges Require New Rules?' Munari argues that the original conception of SAR and related responsibilities in international law needs to be updated to better reflect the diversity of situations demanding assistance at sea, such as emergency response resulting from activity by recreational vessels, cruise ships and venture vessels in dangerous waters, as well the increasingly pressing phenomenon of migrants in distress at sea. He demonstrates that traditional SAR necessitates additional forms of international cooperation. Authored by Jinho Yoo, Floris Goerlandt and Aldo Chircop, Chap. 5 further considers SAR through the lens of emerging technologies through a contribution entitled 'Unmanned Remotely Operated Search and Rescue Ships (RO-SARS) in the Canadian Arctic: Exploring the Opportunities, Risk Dimensions and Governance Implications'. The authors discuss the traditional Canadian approach and assets dedicated to Arctic SAR, noting the challenges in responding to requests for assistance in the large, harsh and remote environment as the region becomes increasingly accessible to diverse shipping. The chapter considers the role of autonomous technologies, including remotely operated unmanned ships, in addressing the gaps of SAR response in Canadian Arctic waters and discusses the related risk governance implications. Chapter 6 is the last in this part and redirects discussion to an emerging concern, in addition to the safety and environmental and SAR response risks discussed by the previous chapters. In ‘Ambient Noise and Underwater Sound Propagation in the Canadian Arctic’, David Barclay, Emmanuelle Cooke and Clark Richards discuss ocean ambient noise and under-ice acoustic propagation and reverberation in the Canadian Arctic. An updated seasonal baseline for ambient noise in Barrow Strait is calculated and compared against historical measurements. The chapter observes that there is a role for underwater acoustic modelling in marine spatial planning to enable quantification of the impact of seasonal noise from industrial activity.

Shifting from maritime risk, the theme of Part B moves the discussion to ‘The Human Dimension’ through five chapters with a focus on Indigenous peoples and maritime workers in Canadian Arctic waters. The first two chapters consider Inuit conceptualizations and knowledge of Arctic spaces, which differ fundamentally from conceptualization for ocean policy, management and legal purposes and are key to decision-support systems in the region. In Chap. 7, Leah Beveridge discusses ‘Inuit Nunangat and the Northwest Passage: An Exploration of Inuit and Arctic Shipping Conceptualizations of and Relationships with Arctic Marine Spaces in Canada’. Beveridge notes that until recently Inuit have not participated in the governance of Arctic shipping but that there are now efforts to engage them through partnerships and collaboration. Drawing on ethnographic and anthropological literature, the author highlights the importance of understanding the Inuit worldview, exploring further the cross-cultural collaborations in the governance of shipping in Canadian Arctic waters. This is followed by Chap. 8 on ‘Knowledge and Data: An Exploration of the Use of Inuit Knowledge in Decision Support Systems for Marine Management’ co-authored by Claudio Aporta, Breanna Bishop, Olivia Choi and Weishan Wang. The co-authors discuss the significance of Inuit knowledge in the data hubs essential for coastal and ocean management in the Arctic and identify ontological tensions and difficulties in converting that knowledge to data. They propose an approach to integrating Inuit knowledge in decision-support systems and management tools.

The next three chapters address the situation of maritime workers on cruise, commercial and fishing vessels. Chapter 9 by Joseph Anthony Loot discusses ‘Seafarers and Arctic Cruise Shipping: Protecting Those Who Work While Others Explore and Sightsee’. Loot discusses the concerns of the wide range of workers on board cruise ships, including traditional seafarers responsible for the navigation of the ship, and the rest of the crew complement providing leisure, tourism, travel and hospitality services on board. He observes the dearth of data on these workers on Arctic cruise ships and argues for the need to profile their work and assess labour, employment and social conditions to ensure compliance with labour and human rights standards. Desai Shan follows with a focused discussion on traditional seafarers in Chap. 10 on ‘Mapping the Maritime Occupational Health and Safety Challenges Faced by Canadian Seafarers’. Shan draws upon qualitative semi-structured interviews with 25 Canadian seafarers and a preliminary legal review of Canadian maritime occupational health and safety law to discuss common challenges confronted by Canadian seafarers. She observes challenges related to climate change, intensified work-related mobility and insufficient legal protection. Moving from seafarers, Part B concludes with Chap. 11, which looks at 'Insights from the History of Fishing Safety: Preparing for Increased Fisheries and Shipping in the Canadian Arctic', co-authored by Barbara Neis, Joel Finnis, Ronald Pelot and James Shewmake. Fishing has always been one of the most hazardous industries, and in the harsh operating conditions of the Arctic, the dangers are exacerbated. The authors make a strong case to study the history of occupational health safety aspects of fishing in subpolar and low-Arctic seas to anticipate and respond to the issues that can be expected to arise as fishing activity moves deeper into Arctic waters.

While various regulatory concerns are addressed in Parts A and B, Part C provides a more focused discussion on international standards for marine safety and vessel-source pollution in Arctic waters. Titled 'Regulating Shipping and Ocean Use', Part C consists of five chapters focusing on the governance of shipping through the IMO, ship emissions, the Polar Code and heavy fuel oil and includes a discussion on marine spatial planning. Setting the stage for subsequent chapters, Chap. 12 is on 'The IMO Regulatory Framework for Arctic Shipping: Risk Perspectives and Goal-based Pathways' and is co-authored by Anish Hebbar, Jens-Uwe Schröder-Hinrichs, Maximo Q. Mejia Jr., Heike Deggim and Sascha Pristrom. As the competent international organization with respect to international shipping, the IMO adopts global standards for safety, security and environmental performance of shipping. The chapter discusses the organization's goal-based approach to regulation and the instruments relevant to Arctic shipping, including the Polar Code, and approaches to implementation by flag and coastal states as well as regional cooperation. The next two chapters concern unfinished business in the regulation of the environmental aspects of polar shipping. Authored by Aldo Chircop, Chap. 13 is on 'The Regulation of Ship Emissions in Canadian Northwest Atlantic and Arctic Waters: Is there a Need for Consistency and Equity?' The author argues that while the Polar Code has raised standards for the prevention of vessel-source pollution, it stopped short of addressing the environmental impacts and public health concerns of ship emissions, including PM, SOx and NOx. The author argues for the designation of an emission control area in Canadian Arctic waters consistent with the standards applicable in the North American Emission Control Area. Chapter 14 concerns 'The Regulation of Heavy Fuel Oil in Arctic Shipping: Interests, Measures and Impacts' and is co-authored by Jiayu Bai and Aldo Chircop. The Polar Code failed to address HFOs in Arctic waters, and the IMO continues consideration on whether to adopt a standard for ships operating in Arctic waters similar to those in Antarctic waters, where HFOs are banned. The authors discuss the nature of the regulatory challenge and explore a possible strategy consistent with public and private maritime law. In Chap. 15, the discussion moves to the implementation of the Polar Code. In 'A Change in the Ice Regime: Polar Code Implementation in Canada', Drummond Fraser discusses how Canada proceeded with the implementation of the Polar Code through domestic regulation. While Canada continued to protect essential interests in its waters, it largely implemented the new international standards and effectively harmonized much of its domestic regulation. The last contribution is Chap. 16 authored by Annie Cudennec on 'Integrated Ocean and Coastal Zone Management in France: Some Perspectives'. This final chapter opens up discussion to the national implementation of integrated ocean management pursuant to the regional policies and directives adopted by the European Union, focusing on the French approach and the challenges it faces in domesticating regional standards.

The editors and contributors hope that this book complements the existing literature by providing new insights into the complex challenges in the governance of Arctic shipping, especially in Canada. We hope that the findings in the various contributions will encourage further multi- and interdisciplinary scholarship. We further hope that the findings on planning, management and regulatory concerns will assist Canadian decision-makers in policy and law-making for Arctic shipping.

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Part I
Rethinking Maritime Risks

Chapter 2
An Exploratory Application of the International Risk Governance Council's Risk Governance Framework to Shipping Risks in the Canadian Arctic

Floris Goerlandt and Ronald Pelot

Abstract The diminishing extent of sea ice in Arctic areas brings opportunities for increased shipping activities in the Canadian Arctic. However, it also causes concerns, e.g., related to environmental pollution to vulnerable areas and impacts on ecosystems at local, regional, and global scales, which can further impact human health. Increased shipping activity also causes concerns about safety risks associated with the navigation of vessels, for instance, related to the response to vessels or people in distress. Appropriate risk management strategies, tools, and equipment are essential to successfully mitigate these risks, with due consideration of concerns of rights-holders, stakeholders, and society at large. In this chapter, an exploratory application of key elements of the International Risk Governance Council (IRGC) risk governance framework is presented, focusing on selected risks associated with shipping in the Canadian Arctic. After introducing the IRGC framework, selected shipping risks in the Canadian Arctic are classified in terms of the type of risk problem these represent. Subsequently, a discussion is given on the implications of this pre-screening for selecting appropriate risk governance strategies. The chapter concludes with a discussion on suggestions for future work on risk governance in a Canadian Arctic maritime shipping risk context.

Keywords Canadian Arctic · International Risk Governance Council · Marine pollution · Maritime safety · Oil spill · Pollution preparedness and response · Risk characterization · Risk governance · Search and rescue · Shipping risk

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2.1 Introduction

The effects of global warming are projected to lead to a significant decrease of the extent of sea ice coverage in Arctic and sub-Arctic marine environments (Barnhart et al. 2016; Höglund et al. 2017). This has already led to increased maritime activities in Arctic areas, whereas future conceptualizations and images of a changing Arctic include increased human activities such as hydrocarbon development, mining, shipping, fisheries, and tourism (Arbo et al. 2013).

Developments in offshore oil and gas extraction have attracted significant attention, with Norway and the Russian Federation leading exploration and exploitation efforts in offshore Arctic areas including, for instance, the Barents Sea and the Pechora Sea (Morgunova 2015). Despite the large offshore hydrocarbon reserves, there is considerable uncertainty about the prospects of sustained oil and gas developments in the Arctic (Arbo et al. 2013) due to the multitude of related climatological, economic, and geopolitical uncertainties (Harsem et al. 2011). In the Canadian Arctic, a moratorium on new oil and gas exploration licences was announced in 2018, with most existing licences clustered in the Beaufort Sea off Yukon and the Northwest Territories, and in the Arctic Islands Region in Nunavut. Currently, no production licences have been issued (CIRNAC 2018).

Another major prospect for increased maritime activity in the Arctic is shipping. Arctic shipping routes are increasingly seen as viable transport connections between global markets, with possible benefits such as decreased voyage time and associated costs (Lasserre et al. 2016; Beveridge et al. 2016). Nevertheless, economic uncertainties and concerns about navigational safety remain important reasons why, on a global scale, Arctic shipping currently still accounts for a relatively insignificant share of the total commodity flows (Lee and Kim 2015; Meng et al. 2017). In a Canadian context, there is a long history of maritime activities in the Arctic, consisting mainly of destinational traffic to support northern communities and mining industries (Arctic Council 2009; Brooks and Frost 2012). Due to a combination of factors, including changing sea ice conditions and trends in resource exploration and community re-supply needs, there has been a steady and significant increase in the vessel traffic in Canadian Arctic waters (Engler and Pelot 2013; Pizzolato et al. 2014), a trend which continues to manifest itself and which is projected to continue in the future (Council of Canadian Academies 2017). Questions related to possible tolls based on sovereignty considerations, as well as other economic uncertainties and safety concerns, nevertheless currently preclude Canadian Arctic transportation routes from becoming significant trade routes for commercial transit traffic (Lu et al. 2014). A market segment where the lengthening of the ice-free season has led to a remarkable increase in activity is the tourism industry, where more cruise vessels and recreational vessels have been navigating in Canadian Arctic waters in recent years (Lasserre and Têtu 2015; Halliday et al. 2018; Palma et al. 2019).

These developments towards increased maritime activities in Arctic marine areas raise various concerns. Focusing on shipping risks in the Canadian Arctic, various safety and environmental risks have been identified and studied, with possible effects on local, regional, or global scales (Council of Canadian Academies 2016). The increased recreational boating and cruise vessel activity presents challenges for ensuring the safety of human life at sea, in particular for implementing effective search and rescue in remote and harsh environments (Ford and Clark 2019; Drewniak and Dalaklis 2018). Environmental and ecosystem risks related to increased shipping activity in Arctic waters with comparatively local effects are associated with disturbances to marine mammals by shipping noise (Halliday et al. 2017), vessel–whale strikes (Elvin and Taggart 2008; Hauser et al. 2018), and exposure to chemical pollutants (McWhinnie et al. 2018). Risks that possibly affect larger areas include, for instance, oil spills from shipping accidents (Nevalainen et al. 2018). Especially collision and grounding accidents present scenarios with a possibly significant oil outflow and widespread related ecosystem damage (Afenyo et al. 2017; Tabri et al. 2018). Finally, shipping emissions of black carbon, sulphur dioxide, and nitrogen oxides can impact the regional Arctic climate and ecosystem (Winther et al. 2014), where black carbon emissions in the Arctic can even have global implications as such emissions can reduce snow albedo, leading to increased heat absorption by the earth (Zhang et al. 2019a).

Focusing on maritime transportation, there is a growing body of academic literature presenting models, approaches, and frameworks for assessing safety and environmental risks (e.g., Lim et al. 2018; Kulkarni et al. 2020). Several risk models and analyses have also been presented for shipping risks in Arctic and sub-Arctic environments, mostly related to navigational accident and oil spill occurrence, and the associated ecosystem and socio-economic impacts (e.g., Valdez Banda et al. 2016; Nevalainen et al. 2018; Zhang et al. 2019b; Afenyo et al. 2019). Guidelines for preventive and response-related shipping risk assessment have also been developed by several international organizations (e.g., IMO 2010, 2018; IALA 2013; HELCOM 2018a).

Despite these advances, academic work on maritime transportation risks has mostly addressed empirical investigations and technical risk analyses and model development. However, there is a growing awareness that in addition to developing technical models and tools, and deriving risk assessment results based on these, there is a need for developing risk management approaches to incorporate these results into organizational risk management processes. For instance, Sepp Neves et al. (2015) proposed a framework for oil spill risk management, based on the ISO 31000 risk management standard (ISO 2018), focusing on how different tools can be integrated to support oil pollution preparedness, planning, and risk communication, with a case study in the Mediterranean Sea area. HELCOM (2018a) further adapted the ISO 31000 standard, defining four interrelated risk management processes for facilitating oil spill preparedness and response risk management at a regional, transnational level. These processes each address particular risk management questions associated with different decision contexts, for which an associated risk assessment toolbox has been developed. A case study is presented in HELCOM (2018b). Haapasaari et al. (2015) propose a regional risk governance framework for maritime safety policy-making in the Gulf of Finland, where scientific assessments are applied alongside stakeholder deliberation to assess maritime risks and to ensure maritime safety, reminiscent of earlier proposals for scientific proceduralism by Shrader-Frechette (1991) and Stern and Fineberg (1996).

While these proposals and developments are valuable, they lack clear mechanisms for framing shipping risk problems. It is known that different stakeholder groups can conceptualize risk problems based on distinct types of knowledge and consequently favour different possible risk mitigation measures (Parviainen et al. 2019). In addition, in the absence of an explicit phase focusing on characterizing important dimensions of the addressed risks, suboptimal risk management strategies may be applied. This can lead to a situation where stakeholder concerns are insufficiently addressed, possibly leading to distrust and societal conflict. Conversely, for certain risks, investing time and resources in broad stakeholder consultations and extensive risk communication campaigns may lead to undue delays and excessive costs (Klinke and Renn 2002). For addressing such issues, organizational risk management falls short due to a focus on the particular values, objectives, and context of a given organization. Instead, a systematic risk governance approach needs to be defined, spanning multiple institutions and stakeholders, while aligning processes and mechanisms by which risk problems are framed and characterized, assessed, communicated, and related decisions taken (Renn et al. 2011).

In the Canadian Arctic context, the Northern Marine Transportation Corridors (NMTC) initiative aims to adaptively govern ship traffic in the region to reduce the likelihood of marine incidents and to enable more effective emergency response. The aim of the NMTC is to focus services on the most frequented routes, inducing shipping companies to further intensify the use of these routes, although there are no intentions to mandate this. Recommendations have been made to create a forum and governance structure for Arctic shipping corridor development and management (The Pew Charitable Trusts 2016). Considering also the recent decline of offshore hydrocarbon developments in the area, there is an opportunity to improve the governance of offshore energy exploration and production and related shipping activities (Gulas et al. 2017).

In light of the above, this chapter aims to outline the International Risk Governance Council (IRGC) risk governance framework, suggesting it as a feasible basis for further developing shipping risk governance in the Canadian Arctic. Particular attention is given to how risks are characterized during the pre-screening in the pre-assessment phase and the implications that this has for implementing an appropriate risk governance process. This is presented in Sect. 2.2. Subsequently, in Sect. 2.3, these generic risk-theoretic concepts are linked with selected shipping risks in the Canadian Arctic. An exploratory risk pre-screening is presented for these examples, and tentative risk governance implications are drawn. Section 2.4 presents a discussion, whereas Sect. 2.5 concludes the chapter.

2.2 IRGC Risk Governance Framework: A Brief Overview

2.2.1 IRGC Framework: Introduction

The IRGC risk governance framework (IRGC-RGF) was developed as a comprehensive approach for understanding, analysing, and managing risks. As opposed to organizational risk management standards such as ISO 31000:2018, which focus on managerial decision-making within an organization, its focus is on societal governance of risk, that is, on how to perform decision-making when various actors are involved. This requires interaction, coordination, and possibly reconciliation between various roles, perspectives, goals, and activities (IRGC 2017). The IRGC-RGF pays particular attention to the qualitatively different nature of different risk problems and the implications that this has for how the related interaction, coordination, and reconciliation mechanisms are implemented.

As illustrated in Fig. 2.1, the IRGC-RGF consists of several interlinked phases, where cross-cutting aspects involve processes and considerations that affect these phases throughout its application. In the remainder of this chapter, the focus is on the pre-assessment phase, in particular on risk pre-screening, which is elaborated on in Sects. 2.2.2 and 2.2.3. The phases are briefly outlined below; for further details the reader is referred to IRGC (2005, 2017) and Aven and Renn (2010).

The *pre-assessment phase* aims first to frame the problem in relation to issues which different societal actors may associate with the risk, setting the boundaries to

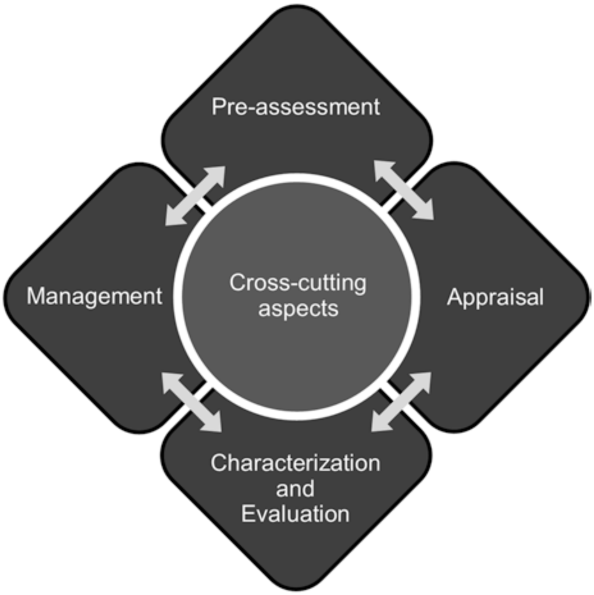


Fig. 2.1 IRGC risk governance framework. (Based on IRGC 2017)

achieve a common understanding of the risk issue, or to establish awareness of different risk perceptions. Second, through identification of early warning and monitoring mechanisms, evidence is detected to establish whether the risk realization is plausible. Third, a pre-screening is performed to assign a risk to predefined assessment and management routes.

The *risk appraisal phase* aims at enhancing understanding about the risk through knowledge-focused activities. A technical/scientific assessment of the risk provides knowledge about the causes and consequences of the risk; about vulnerability, the occurrence likelihood and consequence severity, and possible mitigation measures; and about the associated uncertainties. A concern assessment provides insights into risk perceptions and addresses questions from societal actors about its social and economic implications.

In the *characterization and evaluation phase*, a judgement is made about the acceptability of risk, providing a bridge between the knowledge and value-based dimensions of risk governance. The characterization compiles the evidence from the risk appraisal phase, whereas the evaluation involves broader value-based issues, which can also influence the judgement. Risks are considered acceptable when their occurrence likelihood and the consequence severity are limited, so that no further risk reduction measures are required. If the risk is not considered acceptable based on the decision-making mechanisms of the particular context, while the activity is nevertheless considered worthwhile to pursue, additional measures are required to reduce the occurrence likelihood or the consequence severity. Issues such as the societal needs for the risk to be present, the choice of technology and substitution potential, and the equity-related compensation mechanisms are relevant here as well, that is, issues related to policy-making and societal risk balancing.

The *risk management phase* addresses the design and implementation of actions and measures to reduce, transfer, avoid, or retain the risks. This involves issues such as the realization of options, monitoring their implementation, and obtaining and acting upon feedback from the risk management practice.

The *cross-cutting aspects* include consideration of context, risk communication, and stakeholder involvement. Given the different sociocultural, institutional, political, and economic contexts in which risks require consideration, it is important to recognize issues such as organizational capacity, actor networks, political and regulatory culture, and social climate when contextualizing and implementing the risk governance processes. Legal dimensions, including possible impacts on Indigenous rights, require consideration as well. Risk communication aims at exchanging risk-related information between different groups. It is central to achieve trust in risk management and allows risk assessors and scientists to disseminate findings, societal actors to have their voices heard and provide inputs, and risk managers to explain the rationale of policy decisions. The involvement of various societal actors ensures appropriate consideration of the plurality of values and interests and seeks to design effective risk management strategies with increased relevance and social license of the decisions.

2.2.2 Risk Pre-screening According to the IRGC Framework

A fundamental idea underlying the IRGC risk governance framework is that risks can be qualitatively different. Further, these differences can have important implications for which risk management strategies are effective in managing risks, in particular with respect to the types of discourse applied in the risk appraisal phase, which actors are to be included in the risk governance processes, what types of conflicts one may expect to find related to the risk, and what role risk perception may have. Three aspects are considered fundamental to pre-screen risks in the pre-assessment phase, which are useful to devise an appropriate "route" for implementing a risk governance process: complexity, uncertainty, and ambiguity.

Complexity refers to the difficulty in identifying and analysing the causes of events and the consequences these may lead to (IRGC 2017). While it is broadly accepted to be a central notion in risk research, different views on its exact meaning co-exist (Perrow 1999; Dulac 2007; Johansen and Rausand 2014a). In the IRGC-RGF, complexity relates to the characteristics of the system (activity, phenomenon) under investigation. It relates to the number of causal factors with (possible) relevance to the event occurrence and its consequences; interindividual variations; interactive effects among the causal factors, such as non-linear feedback loops which modify the relative importance of causes as the system under study evolves over time; or long delay periods between cause and effect.

Uncertainty refers to a state of knowledge in which the likelihood of adverse consequences, or the severity of these consequences, cannot be accurately described. While there are also several interpretations of uncertainty in the risk literature (Rowe 1994; Winkler 1996), the dominant feature of the concept focuses on the knowledge limitations of an assessor in describing risk (Flage et al. 2014). A common distinction is made between outcome uncertainty and evidence uncertainty. The former focuses attention on the assessor's uncertainty about the possible occurrence of the event and its consequences, while the latter focuses attention on the strength of the evidence for making statements about these occurrences (Goerlandt and Reniers 2016). Evidence uncertainty can manifest itself due to the limitations of available data, wide variations of expert estimates, significant simplifications and inaccurate results of models, or the important role of assumptions in the evidence base.

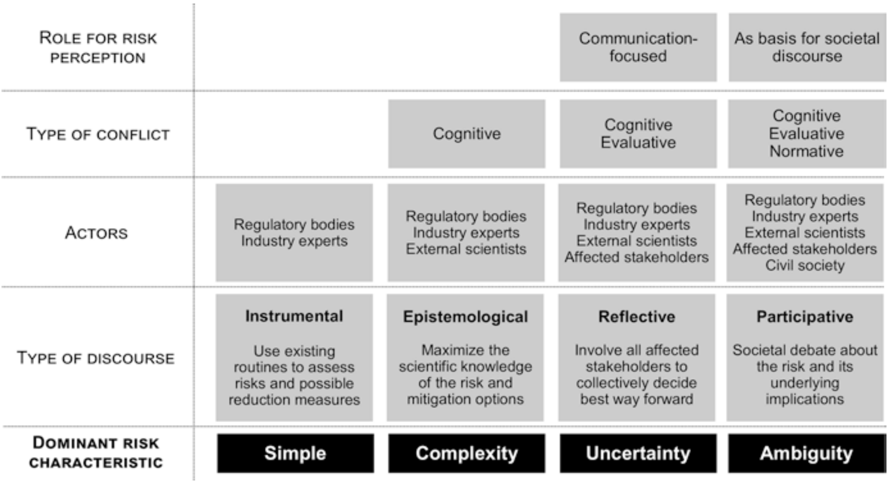
Ambiguity has attracted less focus in risk research compared to uncertainty and complexity, but is commonly understood as relating to different interpretations of the meaning of evidence or the results of a risk analysis (Johansen and Rausand 2014b). Normative ambiguity is the condition where there are significantly different concepts about what can be regarded as tolerable, acceptable, or equitable. A condition of ambiguity emerges where there are ethics-based difficulties in agreeing on the appropriate values, priorities, or boundaries in defining possible consequences and analysing risk (IRGC 2017).

In the IRGC-RGF, a careful consideration of whether the risks in focus in the problem at hand are complex, uncertain, and/or ambiguous is made in the pre-assessment phase. Depending on this meta-characterization, different actions and processes are recommended to be implemented in the risk governance process, which is outlined next.

2.2.3 Implications of Risk Pre-screening for Implementing Risk Management

Figure 2.2 shows the so-called risk governance escalator, which systematically depicts the implications of the dominant risk characteristic (simplicity, complexity, uncertainty, ambiguity) on how risk governance can be effectively implemented for a given risk in the different phases shown in Fig. 2.1.

Depending on which risk characteristic is found to be predominant in the pre-screening of the pre-assessment phase, a different "route" can be chosen to implement the risk governance processes. These "routes" contain distinct focal points for what knowledge should be obtained in the risk appraisal phase and how this can be achieved, which relates to what types of conflicts can be expected among different stakeholders. They also suggest which actors are to be included in the risk governance processes and what mechanisms can be expected to be appropriate for doing this. Finally, the routes suggest what role risk perceptions may have in the risk governance. In the following sections, these aspects of the risk governance escalator are briefly explained for the different routes associated with the four risk types shown in Fig. 2.2: simple risk problems and complexity-, uncertainty-, and ambiguity-induced risk problems.



Role for risk perception			Communication-focused	As basis for societal discourse
Type of conflict		Cognitive	Cognitive Evaluative	Cognitive Evaluative Normative
Actors	Regulatory bodies Industry experts	Regulatory bodies Industry experts External scientists	Regulatory bodies Industry experts External scientists Affected stakeholders	Regulatory bodies Industry experts External scientists Affected stakeholders Civil society
Type of discourse	**Instrumental** Use existing routines to assess risks and possible reduction measures	**Epistemological** Maximize the scientific knowledge of the risk and mitigation options	**Reflective** Involve all affected stakeholders to collectively decide best way forward	**Participative** Societal debate about the risk and its underlying implications
Dominant risk characteristic	**Simple**	**Complexity**	**Uncertainty**	**Ambiguity**

Fig. 2.2 Risk governance escalator: implications of risk characterization. (Based on IRGC 2005, 2017; Aven and Renn 2010)

2.2.3.1 Simple Risk Problems

In simple risk problems, the cause–effect relationships associated with the risk are well understood, there are relatively few relevant causal factors, and there are few interactive effects between these factors. There are, furthermore, only little interindividual variations in the mechanisms underlying the occurrence of the risk event or its consequences. There is strong evidence for making statements about the risk, that is, experts have ample experience with handling these, there are sufficiently accurate models available, and/or there are data to make reliable risk estimations. Stakeholders agree on boundaries in defining possible consequences and on what constitutes acceptable risk.

An example of such a risk in the maritime domain may be the design of a conventional cargo vessel according to traditional prescriptive statutory and class design rules. Such a design involves risks such as loss of watertight integrity, capsizing, or structural collapse, but the regulator and maritime industry have ample experience and good models to design such vessels and verify compliance with the prescriptive rules. The risk associated with such vessel designs is broadly accepted across stakeholders through experience-based codification in the ship design rules.

As indicated in Fig. 2.2, the relevant actors in such risks are the regulatory bodies and industry experts. An instrumental discourse is maintained in the risk appraisal and in their communication, that is, the focus is on existing routines (e.g., the prescriptive rules and associated documentation requirements throughout the ship design).

2.2.3.2 Complexity-Induced Risk Problems

As outlined in Sect. 2.2.2, complexity-induced risk problems are characterized by the large number of causal factors, interindividual variations, interactive effects among causal factors, and/or long delay periods between cause and effect. Nevertheless, the evidence for analysing the risk is strong, in the sense that good models are available for analysing event occurrences and associated consequences, there is relevant expertise available, and/or there are good data to perform the analysis. Moreover, there is a broad agreement among the key societal actors in framing the risk and in what constitutes acceptable risk. An example of such a risk in the marine domain, further elaborated in Sect. 2.3.1 below, may be the risk-based ship structural design of vessels operating in Arctic environments.

As indicated in Fig. 2.2, the type of conflict is cognitive in nature: causal mechanisms are complex and there are variations in the mechanisms leading to the risks. Existing routines are insufficiently well developed to analyse the risks and the effects of risk mitigation measures. Hence, an epistemological discourse is adopted, that is, the knowledge of the risk is maximized, for example, by gathering and analysing data or by developing new models for estimating the event occurrence or the consequences. Actors involved in this risk problem include regulatory bodies, industry experts, and external scientists.

2.2.3.3 Uncertainty-Induced Risk Problems

As outlined in Sect. 2.2.2, uncertainty-induced risk problems are characterized by the limited knowledge about the possible occurrence of events and their consequences. There is a lack of expertise on which to base reliable risk judgements, there are little data or information available, and models are non-existing or very simplified and crude. Thus, various strong assumptions are made in the risk appraisal, and uncertainties are high. Usually, uncertainty is exacerbated by the presence of complexity, that is, by the presence of multiple causes, non-linear interactions, variabilities, and long incubation periods. Nevertheless, there is broad agreement among societal actors on how to frame the risk and about what constitutes acceptable risk. An example of such risk in the maritime domain, further elaborated in Sect. 2.3.2, may be the safety risks related to an increase in shipping activity in the Canadian Arctic, the implications this has for search and rescue preparedness, and the various impacts this may have on community first responders.

As indicated in Fig. 2.2, the type of conflict is cognitive and evaluative in nature: causal mechanisms are complex, and there are variations in the mechanisms leading to the risks, which are moreover poorly understood, with limited data or experience available, and models are tentative, crude, or non-existing. Hence, a reflective discourse is adopted, whereby efforts are made to increase the scientific knowledge of the risk, the affected stakeholders are systematically consulted, and reflective interaction processes are implemented to collectively decide on an acceptable way forward. Multicultural considerations, such as principles related to free, prior, and informed consent in these interaction processes, are important to account for. Actors involved in this risk problem include regulatory bodies, industry experts, external scientists, and the affected stakeholders.

2.2.3.4 Ambiguity-Induced Risk Problems

As outlined in Sect. 2.2.2, ambiguity-induced risk problems are challenging due to the substantially different conceptualizations between, or even within, different societal actor groups as to what constitutes acceptable or equitable risks. The different value systems and worldviews lead to different conceptualizations of the boundaries of the risk problem, leading to fundamentally different priority settings between stakeholders. Ambiguity-induced risk problems are often exacerbated through the complexity of the risk problem, that is, through the large number of causal factors, their interaction effects, variabilities, and delay periods. Moreover, uncertainties are typically high, that is, there is limited knowledge about the possible occurrence of events and their consequences. An example of such a risk in the maritime domain may be the risk of a severe oil spill in the Canadian Arctic, as further elaborated in Sect. 2.3.3.

As indicated in Fig. 2.2, the type of conflict is cognitive, evaluative, and normative in nature: causal mechanisms are complex and there are variations in the mechanisms leading to the risks. These risks, moreover, are poorly understood, with limited data or experience available, and the models are tentative, crude, or non-existing. Importantly, the different worldviews and value systems of stakeholders lead to fundamental conflicts between societal actors about the acceptability of risk, the need for additional risk-reducing mechanisms, the equity of the risk distribution across stakeholder groups, the urgency of seeking technical or procedural substitutions, and even the need to allow the risk-bearing activity to take place at all.

Hence, a participative discourse is adopted, whereby efforts are made to increase the scientific knowledge of the risk, the affected stakeholders are systematically consulted, and reflective interaction processes are implemented to collectively decide on an acceptable way forward. Additionally, a wider societal debate is held, where the views of civil society and the public at large are considered. This debate is spearheaded by opinion leaders from not-for-profit organizations and industry, scientists, and political actors and is facilitated by the media through debate programmes, documentaries, investigative reports, and opinion polls. Actors involved in this risk problem thus include regulatory bodies, industry experts, external scientists, affected stakeholders, and civil society at large. In the Canadian Arctic, focusing on shipping risks, Indigenous organizations such as the Inuit Circumpolar Council and the Qikiqtani Inuit Association have an important role to represent rights-holders. In addition, international organizations such as the Arctic Council, through the Protection of the Arctic Marine Environment, Emergency Prevention Preparedness and Response, and Sustainable Development Working Groups play a significant role in building knowledge on the impacts of shipping in the Arctic, as evidenced by the various reports these groups have issued on shipping (Arctic Council 2009).

2.2.3.5 The Role of Risk Perception in Uncertainty- and Ambiguity-Induced Risk Problems

Risk perception is a collection of notions which people form about risks based on common sense reasoning, personal experience, social communications, and cultural traditions (Aven and Renn 2010). They are associated with the experiential system of human thinking and judgement, which is holistic, affective, associative, experiential, and based primarily on images, metaphors, and narratives. In contrast, risk analysis is conceived to be based on factual evidence, such as data, models, and judgements rooted in the analytic system of human thinking, which is logical and conscious, and based primarily on symbols, words, and numbers (Slovic 1987).

Societal risk governance and management involves allocating scarce public resources to the protection of human health and safety and environmental protection. Hazards and adverse consequences manifest themselves in the real world, whereas risk perceptions are not necessarily aligned with the factual evidence about the possible event occurrence and consequences. This disparity has led to scholarly debate about the appropriateness of relying on public risk perceptions for risk management decision-making (Cross 1998; Pidgeon 1998). Arguments against include the prejudiced or even discriminatory nature of public attitudes, the potential for a misguided focus on perception management rather than addressing actual issues, and the heterogeneity of public risk perception. Arguments in favour of accounting for risk perception include that these reflect basic public values, that stakeholders should have input into risk decisions that affect them, and that perceptions have real consequences, because they lead to actions which can entail costs and new risks, which can make the situation worse.

In the maritime domain, risk perceptions are comparatively less well studied than the technical aspects of risk analysis, and they are considered peripheral to the decision-making processes (Skjong and Wentworth 2001). Commentators have voiced expectations that risk analyses should be objective and fact-based and that risks should be balanced with monetary costs (Skjong 2005; Psaraftis 2012).

Nevertheless, in the IRGC-RGF, risk perceptions are considered important especially in uncertainty- and ambiguity-induced risk problems. For uncertainty-induced risks, risk perceptions are seen to have a role in the reflective discourse among regulators, industry experts, external scientists, and affected societal actors. The stakeholders are able to express their concerns and views, which can then be addressed in stakeholder engagement processes. Thus, risk perceptions are primarily considered in the context of risk communication. In ambiguity-induced risk problems, understanding and accounting for risk perceptions is also important in risk communication and is embedded in the wider societal discourse. In these risk problems, the different underlying worldviews and value structures of societal actors can give rise to conflict; thus, it is important to acknowledge and to act upon risk perceptions to build trust in the risk governance process and to ensure a wide societal acceptance of the outcomes of the decision processes (IRGC 2017; Aven and Renn 2010).

2.3 Exploratory Risk Pre-screening of Selected Shipping Risks in the Canadian Arctic

As mentioned in the introduction, increased shipping in the Canadian Arctic brings various risks to the area. There are risks to the vessel from the environment: for instance, hull damage can lead to loss of watertight integrity and loss of stability, and the harsh cold environments can lead to freezing of water spray and icing on deck, which can lead to occupational accidents such as slips and falls. Conversely, the ship can be considered as a hazard, which can cause adverse consequences to the environment. For instance, vessel movements lead to underwater noise, which can have harmful effects to marine biota. Vessels can strike large marine mammals such as whales, leading to increased mortality in vulnerable populations. Accidental oil spills from damaged vessels can have disastrous consequences to entire ecosystems. Even the mere navigational presence of vessels in ice-covered waters may disrupt ice-bound transport or hunting routes used by Indigenous populations when navigation lanes are broken in sea ice fields and hence present a sociocultural risk.

Unregulated tourism can also overwhelm small local Inuit communities, presenting another example of sociocultural risks with a specific relevance in the Arctic.

Various risk mitigation measures are already in place to reduce the occurrence likelihood and the consequence severity. For instance, the adoption of the Polar Code has set new ship design and operational requirements for vessels operating in the Arctic (Polar Code 2014/15). Under the auspices of the Arctic Council, agreements have been made between Arctic states addressing cooperation on marine oil pollution preparedness and response (Arctic Council 2013) and aeronautical and maritime search and rescue in the Arctic (Arctic Council 2011). Within Canada, recent activities to mitigate Arctic shipping risks include the Low Impact Shipping Corridors Initiative, where voluntary shipping corridors are proposed to enhance maritime safety and to minimize environmental impacts on ecologically sensitive areas (The Pew Charitable Trusts 2016; Chénier et al. 2017). The implementation of these corridors is made in partnership with Indigenous communities and Arctic stakeholders under the Oceans Protection Plan (Transport Canada 2017).

In this section, an exploratory pre-screening of selected Arctic shipping-related risks is presented. As outlined in Sect. 2.2.1, this is part of the pre-assessment phase of the IRGC-RGF and serves as a basis for assigning the risk to an assessment and management route, as presented in Sect. 2.2.3. Section 2.3.1 focuses on risk-based structural ship design, Sect. 2.3.2 addresses maritime search and rescue, while Sect. 2.3.3 explores preparedness and response to accidental oil spills.

2.3.1 Arctic Risk-Based Ship Structural Design in Sea Ice Conditions

Ship design is an important way to mitigate risks to and from vessels. Ship concept design involves many interconnected issues that jointly affect the ship safety level. These include the design of lines and body plan, hydrostatics and buoyancy, freeboard, hull structure, propulsion and manoeuvring arrangements, and damage stability (Evans 1959). Further essential design aspects affecting vessel safety include the arrangements for fire protection, detection, and extinction and life-saving appliances.

Traditionally, the complex interdependencies of hull and equipment design are encoded in prescriptive requirements derived from statutory and classification rules, which together aim to ensure an appropriate safety level. These stipulate exact technical specifications to which a design must conform. Since 2003, through concepts such as goal-based standards and risk-based ship design, there have been developments towards increased design flexibility (Hoppe 2005). In goal-based standards, the technical implementation is not strictly prescribed. Rather, goals are defined at a high level, aimed at building and operating safe and environmentally friendly ships. A set of functional requirements should be made to comply with these high-level goals, but the rules do not specify how these requirements are to be achieved.

In risk-based design, the compliance of the design with the functional requirements is demonstrated through a risk assessment of the design, that is, by identifying what can go wrong, estimating the associated probabilities and consequences, and comparing the results with risk acceptance criteria (Papanikolaou 2009). The Polar Code also allows for such a goal- and risk-based design approach (Polar Code 2014/2015), but many requirements of, for example, the International Convention for the Prevention of Pollution from Ships (MARPOL) are mostly prescriptive.

In Arctic and sub-Arctic waters, hull damage occurs relatively frequently due to the high local ice pressures on the ship hull. In the Canadian Arctic, despite the implementation of operational procedures such as the Arctic Ice Regime Shipping System (AIRSS) (Transport Canada 2018) or, more recently, the Polar Operational Limit Assessment Risk Indexing System (POLARIS) (Stoddard et al. 2015; IMO 2016), such damages range from slight deformations to the hull plating to large holes, which have led to the sinking of vessels and can lead to pollution incidents (Kubat and Timco 2003). Rather than relying on prescriptive design standards, risk-based design approaches for ice-class vessels, focusing on the hull design, have been proposed (Kujala et al. 2019).

As indicated in Sect. 2.3.2, this is an example of a complexity-induced risk. Risk-based hull design for ice-class vessels involves many interrelated issues, including the characteristics of the expected sea ice cover during the vessel's lifetime, ice loads resulting from the ice-hull structure interaction, the hull structural response, and limit states. These issues involve many interrelated factors: there are different ice environments with many ice types, including level ice, ridges, and compressive regions. These lead to a range of failure mechanisms and ice-hull interaction modes such as ice crushing, bending, and spalling and hence different ice loads. The hull structural response is implicated by the characteristics of the ice pressure distributions, the material characteristics, and the structural particulars. These factors stand in a complex relationship to one another, with interactive effects between, for example, hull form, structural design, and ice loads, and variations, for example, in ice characteristics and materials.

For many of these phenomena, there are data and models available, so that, in principle, a ship can be designed with an explicit calculation of the expected hull damages in operations in ice environments over its life cycle (Bergström 2017). Conceptual approaches for risk metrics and acceptance criteria in risk-based design have been proposed (Papanikolaou 2009). Further developments in modelling the ice environment and the ship-ice interaction are however desirable. Risk metrics, evaluation criteria, and cost-effectiveness criteria for environmental effects associated with ship hull failures in Arctic environments especially require further work (Kujala et al. 2019).

Referring to Fig. 2.2 and Sect. 2.3.2, this means that to effectively mitigate Arctic shipping risk through risk-based design approaches, there is a need for collaboration between regulators, marine industry experts (including ship designers and construction yards), operational experts (such as experienced master mariners and ice navigators), and scientific experts. The focus should be on an epistemological discourse aimed at maximizing the scientific knowledge about the phenomena outlined above. Subsequently, a more instrumental discourse should be targeted to translate the scientific knowledge into suitable engineering tools that are aligned with regulatory requirements and the industrial contexts in which these tools would be applied.

2.3.2 Human Safety at Sea: Maritime Search and Rescue Response Preparedness

When maritime accidents endanger the life of people on board vessels, search and rescue is an important operational response mechanism. In the Canadian Arctic, there have been a number of navigational accidents where search and rescue services have been essential to avoid human casualties. For instance, the *Clipper Adventurer* grounded in 2010 with 128 passengers on board in Coronation Gulf, Nunavut, while on a cruise (TSBC 2012). More recently in 2018, the *Akademik Ioffe* grounded near Kugaaruk, Nunavut, with 163 people on board (TSBC 2019). Considering the harsh environment and the remoteness of the area, such ship accidents can lead to human casualties. Recent increases in recreational boating activity also cause concern for human safety at sea (Dawson et al. 2013), which further underlines the need for effective search and rescue in the Canadian Arctic. This is acknowledged in regulatory efforts, for example, through the agreement on cooperation on aeronautical and maritime search and rescue in the Arctic (Arctic Council 2011).

As indicated in Sect. 2.2.3.3, maritime shipping accidents and the associated search and rescue response preparedness are an example of an uncertainty-induced risk, with cognitive and evaluative conflicts. For effective search and rescue preparedness and response planning, there are several key questions which need consideration. This includes issues such as where accidents can be expected to occur, under which conditions, and what consequences accidents would have. Other questions relate to how effective the response system is in ensuring human safety, what assets are needed, and where to mount a cost-effective response. Also, organizational issues such as training and knowledge management need to be considered to ensure an appropriate response. Compared to other sea areas, uncertainties about the maritime transportation system and the search and rescue system in the Canadian Arctic are higher. These systems moreover are complex, involving many interacting factors, exacerbating the risk management challenge.

In the Canadian Arctic, data about past incidents for response preparedness planning are relatively scarce (Ford and Clark 2019). There are also large uncertainties as to where possible accidents, for which different levels of response would be required, might occur. Here, two accidents types can be distinguished for illustrative purposes: recreational boating accidents and accidents in commercial vessel operations, such as cruise vessels. Experience from other sea areas show that recreational boating incidents, which are relatively frequent, occur largely proportionate to the number of such vessels navigating the area (Venäläinen and Sonninen 2013). Hence, if it is possible to predict where such activities would take place, relatively good estimates can likely be obtained of where and under which conditions recreational boating incidents can be expected to occur. However, large-scale accidents involving commercial vessels are rare events, so that accident data are not very useful for obtaining insights in these for response planning purposes. Moreover, due to the complexities involved in the accident causation mechanisms, there are much higher uncertainties about where, and under which conditions, such accidents may be expected to occur (Hänninen 2014). There is a variety of risk models aiming to provide insights in this, but research indicates that these may provide unreliable results even in areas with higher traffic densities (Goerlandt and Kujala 2014). This limits their usefulness in Arctic environments with far less vessel traffic, of which the future traffic intensities are moreover also highly uncertain due to various factors such as economic and geopolitical drivers (Lu et al. 2014).

The search and rescue response effectiveness also involves high uncertainty. There is operational experience in the Canadian Arctic, including with large-scale evacuation operations for shipping accidents, as indicated above. However, there have to date not been major time-critical disasters involving ship fires, capsizing, or sinking of cruise vessels, for which mass rescue operations would be necessary. Uncertainty about the response effectiveness to such events is high, and arguments have been made that the current Canadian Arctic search and rescue preparedness is insufficiently developed to cope with such disasters (Ford and Clark 2019). Moreover, insights from other sea areas suggest that effective response involves a wide array of factors, including environmental conditions, the physical characteristics of the distressed vessel, the accident circumstances and its organizational preparedness, and the availability of suitable aeronautical and maritime response resources, including the presence of vessels of opportunity (Norrington et al. 2008). There is a lack of systematic knowledge about many of these aspects in Arctic environments.

Given the complexities and uncertainties associated with the organization of the search and rescue system, operations research models can be useful for obtaining insights into the cost-effectiveness of different assets for responding to maritime incidents and accidents. Such models can also help in optimizing the fleet composition and in deciding the location of the assets. There have been developments to create such models, for example, Akbari et al. (2018). To the authors' knowledge, however, no comparable models have been developed that can account for the uncertain conditions of the Canadian Arctic environment.

Given the large uncertainties about many aspects of the Arctic maritime transportation system and the search and rescue response system in the Canadian Arctic, uncertainty can be considered the predominant characteristic of this shipping risk problem. Referring to Fig. 2.2 and Sect. 2.2.3.3, the characterization of the risk as uncertainty-induced signifies a need for a reflective discourse among regulators, affected societal actors, industries, and external scientists. In these interaction processes, there should be room for the various actors to express concerns and voice their risk perceptions and suggest approaches for mitigating the risks. The focus of discussions should be on obtaining a shared understanding of acceptable ways forward. This may involve questions about the role of local communities in search and rescue response (Senate Canada 2018), the development and implementation of transport corridors to cluster available resources in more manageable geographical areas (The Pew Charitable Trusts 2016), the support for acquisition or development of specialized response assets such as icebreaking vessels or autonomous response systems (see Chap. 5 in this volume), or questions related to the locus of responsibility for the financial burden of the response system operation (see Chap. 4 in this volume).

Simultaneously, however, there is a need for collaboration between regulators, marine industries, scientific experts, and local communities. Recognizing the findings from the reflective stakeholder-oriented discourse, this collaboration should focus on an epistemological discourse, aimed at maximizing the scientific knowledge about the phenomena outlined above and towards developing suitable models and decision support systems to plan effective search and rescue risk management strategies in the area.

2.3.3 Accidental Oil Spills from Shipping: Pollution Preparedness and Response

Oil spills are known to have the potential for disastrous impacts on marine ecosystems, can have detrimental impacts on economic sustainability of industries and coastal communities, and can have health implications for affected people (Chang et al. 2014). In coastal areas inhabited by culturally vulnerable groups, oil spills can furthermore lead to dramatic shifts in sociocultural patterns (Miraglia 2002). In the Canadian Arctic, navigational accidents such as the groundings of the *Clipper Adventurer* (TSBC 2012) and the *Akademik Ioffe* (TSBC 2019) fortunately only led to minor pollution incidents. However, as suggested by historic accident cases, such as the spill of the *Exxon Valdez* in sub-Arctic waters (Miraglia 2002) and accident risk models of ship navigation in ice-covered and Arctic waters (Afenyo et al. 2017; Valdez Banda et al. 2016), there is a possibility of a major spill in the region. Examples of oil spills in ice-covered waters include the accident with the *Antonio Gramsci* on 6 February 1987 (IOPC Fund 1989) and the *Runner 4* on 5 March 2006 (Wang et al. 2008), both in the Gulf of Finland. These are testament to the challenges for oil spill response in ice conditions, even in areas with much better infrastructure and more response assets. Apart from regulatory efforts to prevent accident occurrence in the Arctic, for example, through the provisions of the Polar Code (2014/2015), such as mandatory carriage of a Polar Water Operational Manual, it is essential to implement a performant oil spill preparedness and response system. This is acknowledged, for instance, through the Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic (Arctic Council 2013). Another possible mitigation measure to reduce the risk of oil spills in the Arctic is the ban of the use and carriage for use of heavy fuel oil (HFO), which is currently under consideration in the International Maritime Organization (see Chap. 14 in this volume).

As indicated in Sect. 2.2.3.4, maritime shipping accidents and the associated preparedness and response to oil spills are an example of an ambiguity-induced risk, with cognitive, evaluative, and normative conflicts. For effective oil spill preparedness and response planning, there are several key questions which need consideration. These include where accidents can be expected to occur, under which conditions, how much oil would be released from the vessel, where it would drift to, and what ecosystem, economic, health-related, and sociocultural impacts a spill would have, for example, on Inuit communities acting as first responders. Other questions relate to how effective the response system is to collecting the oil or otherwise mitigating its negative impacts and what assets are needed for maximizing the response effectiveness (HELCOM 2018a). Compared to other sea areas, uncertainties about the maritime transportation system and the oil response system are higher. Moreover, these systems are complex, which further complicates appropriate risk management. Importantly, there is also a normative dimension to the risk problem, caused by different worldviews and value structures of the involved parties, leading to normative ambiguities, which further complicate the risk management and governance.

In the Canadian Arctic, there are little data about past oil spill incidents given the comparatively low traffic volumes and low accident rate. Large-scale accidents involving commercial vessels are rare events, for which accident data generally are insufficient. Ship accident risk models are considered as an alternative, and several such models have been proposed (Lim et al. 2018), including in Arctic and sub-Arctic environments (Afenyo et al. 2017; Valdez Banda et al. 2016). The complexity of accident causation mechanisms in socio-technical systems such as maritime transportation, together with the limited knowledge about the risk-influencing factors and the fact that these factors interact and change over time, however, results in large uncertainties about where maritime accidents may occur and under which conditions (Hänninen 2014). Even in areas with more intense traffic, more experience, and better data availability, research indicates that maritime accident risk models may be unreliable, limiting their practical usefulness (Goerlandt and Kujala 2014). Moreover, there are large uncertainties about the development of the transportation flows across and into the Canadian Arctic for various social, economic, and geopolitical reasons (Lu et al. 2014; Gulas et al. 2017).

The effectiveness of the oil spill response system also involves high uncertainty. While there is operational spill response experience in Arctic environments, past accidents and risk analyses show that the effectiveness of spill response is not easy to ensure even in more populated areas with better infrastructure (Wang et al. 2008; Lu et al. 2019) and that there are important gaps in the response capacity in the Canadian Arctic (Council of Canadian Academies 2016). It is worth mentioning in this context that unlike in other Canadian marine regions, there currently is no standing response organization in the Arctic (WWF 2017). Insights from spill response in ice environments furthermore suggest that effective spill response involves many interrelated factors, including environmental conditions, the operability of response assets, and organizational preparedness (Lu et al. 2019). There is a lack of systematic knowledge about many of these aspects in Arctic environments.

Given the complexities and uncertainties about the spill response system, several models and tools are available for pollution preparedness and response planning (e.g., HELCOM (2018a). However, there are important gaps in existing modelling approaches for spill preparedness and response risk management in Arctic environments (Li et al. 2016).

Despite the above outlined complexities and uncertainties involved in Arctic maritime transportation and oil spill response, oil spill risks from shipping in the Canadian Arctic can be considered as an ambiguity-induced risk problem. The wide range of possible impacts of oil spills, including environmental, economical, health-related, and sociocultural consequences, can lead to disagreement between stakeholders about what to protect and where priorities for spill preparedness should lay. More fundamentally, stakeholders representing maritime industries, coastal communities, and non-governmental organizations may have different views about the desirability of increased shipping traffic in the Canadian Arctic: where some see economic opportunity, others may see unnecessary disruption of marine environments or threats to traditional ways of life. The issue of offshore oil spill risks is also an issue that regularly appears in the national media, attracting interest from the public at large.

These different stakeholders' views about the need for the risk-imposing activity give a normative dimension to this risk problem. The different views of involved stakeholders and the diverse opinions held by the public at large lead to challenges in framing the risk problem and to agreeing on appropriate priorities and on what constitutes acceptable and equitable risk. These different views are related to fundamentally different worldviews and value systems, characteristics of ambiguity-induced risk problems.

Referring to Fig. 2.2 and Sect. 2.2.3.4, the characterization of the risk as ambiguity-induced signifies a need for a normative discourse among regulators, affected stakeholders, industries, and external scientists, where the perceptions, concerns, and opinions of the public at large also are considered. The focus of this discourse should be on understanding the underlying reasons for the concerns and views of the different parties; risk perceptions will also have a fundamental role as a basis for this societal discourse. Rather than focusing on the immediate concerns about the oil spill risk from shipping activities in the Arctic, it may be appropriate to have more fundamental discussions and engagement, with more far-reaching governance and policy implications. Such debates may, for example, focus on the desirability of shipping activities in the Arctic in light of the economic opportunities and ecological and sociocultural risks this entails. Possible alternatives for shipping, or technological alternatives for the use of oil, also can be considered in these discussions. This focus relates to the importance of reaching a consensus about appropriate risk framing in the pre-assessment phase of the IRGC-RGF, as introduced in Sect. 2.2.1. Simultaneously, there is a need for an instrumental discourse and collaboration between regulators, industries, and scientific experts to better understand the risks and stakeholder concerns and to develop improved ways to assess the risks and ensure that these are appropriately mitigated.

2.4 Discussion

In the previous section, selected Arctic shipping-related risks have been considered in light of their predominant risk characteristics and implications of this pre-screening categorization for the implementation of risk governance processes. It is, however, stressed that this analysis is exploratory: according to the pre-assessment phase of the IRGC-RGF, the characterization of a risk as one of the risk problem types should be made in stakeholder consultation processes with societal actors. This is essential, as framing the risk problem and setting the boundaries of issues to consider in risk management is a value-laden decision, not the direct result of a science-based analysis (Shrader-Frechette 1991). Hence, the presented analysis should be considered as an input to such discussions.

As shown, risk pre-screening can assist in deciding the scope of the processes in risk governance, including which actors to involve, what type of discourse to engage in, and the extent to which risk perception is considered. Further details about how to engage in risk communication and what are suitable stakeholder engagement processes for the different risk problem types are described in Aven and Renn (2010).

Furthermore, the risk governance framework can also be used to identify and resolve risk governance deficits, both in the assessment and understanding of risks and in managing the risks (IRGC 2009). Liaropoulos et al. (2016), for example, offer a case study involving search and rescue at offshore platforms in Greece. It may be a worthwhile endeavour to map out how risk governance is implemented for various shipping risks in the Canadian Arctic, to identify gaps in the risk governance processes, and to propose improvements. Here, it is important to be mindful of the need to consider the context in which the risk governance takes place, as indicated in Sect. 2.2.1 and further elaborated in IRGC (2017).

An issue of particular importance in the Canadian Arctic context is the role of Indigenous peoples in shipping risk governance. In the IRGC-RGF, the affected stakeholders have a role in the uncertainty- and ambiguity-induced risk problems, as explained in Sects. 2.3.3 and 2.3.4. However, Indigenous peoples in Canada have constitutionally protected rights in matters relating to resource development projects located on their lands or which could infringe on their rights (Boyd and Lorefice 2018). Hence, Indigenous peoples in the Canadian Arctic are not merely stakeholders in the sense intended in the IRGC-RGF (IRGC 2017). Instead, they have the right to be consulted and their free, prior and informed consent is required, and they can resort to legal procedures when this right is violated. Hence, the Indigenous peoples in Canada are better understood as rights-holders rather than stakeholders, making their involvement in matters related to their rights essential. Moreover, compared to Indigenous peoples in other Arctic states (e.g., the Nordic countries), the rights of Indigenous peoples in Canada do not derive from international instruments per se, such as the United Nations Declaration on the Rights of Indigenous Peoples, as they pre-exist that instrument and are constitutionally recognized rights reflected in various provisions of the Canadian legal system (Allard 2018). It is stressed that the exact role of Indigenous peoples in the IRGC-RGF consistent with their rights and in relation to the various risk types should be further clarified in future work. Further consideration should be given to what their role is in the characterization and evaluation phase, particularly in relation to judgements about risk acceptability and the need for risk mitigation measures.

Another related issue, which is not explicitly considered in IRGC (2017), is the role of traditional knowledge in building evidence for the risk appraisal and risk characterization. Questions requiring more in-depth consideration include how to handle the principles of ownership, control, access, and possession in collecting and using such knowledge for risk appraisal purposes and how to facilitate complementarity of, and how to handle possible contradictions between, traditional knowledge and results from Western science. This also relates to the issue of interpretive ambiguity in the IRGC-RGF, as outlined in Sect. 2.2.2 (see also Chap. 8 in this volume).

Finally, it is noteworthy that existing guidelines for maritime risk analysis and management, such as IMO (2010, 2018), IALA (2013), and HELCOM (2018a), do not distinguish different risk types. These focus exclusively on the risk management process and associated tools for risk identification, analysis, and evaluation. No distinctions are made between different risk problems, that is, characterizations of risks in terms of complexity, uncertainty, or ambiguity are not performed. The presented case studies of shipping risks in the Canadian Arctic nevertheless illustrate that risks can be qualitatively different, which may warrant different risk governance processes. Implementing an appropriate risk pre-screening combined with risk framing and boundary setting in a pre-assessment phase, along with a conscientious appreciation of which actors to include and how to handle risk perceptions, may facilitate finding consensus among different societal actors and improve maritime risk governance processes.

2.5 Conclusion

In this chapter, an exploratory application of the risk governance framework by the International Risk Governance Council is presented. A high-level overview has first been given of the different phases in the framework, covering pre-assessment, risk appraisal, characterization and evaluation, and management, and the cross-cutting aspects of consideration of context, risk communication, and stakeholder involvement.

Subsequently, the focus has been on the concepts of complexity, uncertainty, and ambiguity, which form the basis of risk pre-screening in the pre-assessment phase. The implications of considering a risk as being representative of one of these problem types are outlined through presentation of the risk governance escalator. This framework guides decision-makers in understanding the types of conflicts involved, the appropriate actors to involve in the risk governance, the predominant type of discourse to adopt, and the role of risk perception.

The complexity-, uncertainty-, and ambiguity-induced risk problems are illustrated for selected shipping-related risks in the Canadian Arctic, including risk-based ship structural design in ice conditions, maritime search and rescue preparedness and response planning, and oil spill pollution preparedness and response planning. An exploratory justification is given for categorizing these risk problems, and a discussion is given about the governance implications in light of the aspects of the risk governance escalator.

While it is acknowledged that the analysis and discussion is exploratory, it is hoped that the consideration of Arctic shipping risks in a risk governance context can be useful to heighten appreciation of the complexities involved and especially about the importance of carefully considering the risk problem type and the associated governance implications.

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Chapter 3
Historical Maritime Search and Rescue Incident Data Analysis

Mark A. Stoddard and Ronald Pelot

Abstract Since the 1980s the Canadian Coast Guard has maintained a database of maritime search and rescue (SAR) incidents involving response assets and personnel. This information is stored in a national database known as the Search and Rescue Program Information Management System (SISAR). SISAR contains a spatiotemporal record for all serious incidents that occur within Canada's coastal search and rescue area. In addition to providing a record of all response operations, it provides a rich historical dataset for analysts to use to support a wide range of decision-making applications. In this chapter we illustrate the use of SISAR incident data to identify and visualize temporal and spatial patterns in the maritime SAR incident data. Temporal phenomena were examined at three temporal scales: yearly, monthly, and hourly. Spatial phenomena were examined using the spatial location and density of incidents. Several useful visualizations to explore and exploit SISAR data are provided. Lastly, we provide a short discussion of several topics relevant to SAR incident analysis, including (1) under-reporting in incident databases, (2) sharing of national SAR incident data, and (3) linking environmental conditions and accident data to add context to historical SAR incidents and to improve SAR response time estimation.

Keywords D3 · Data analytics · Incident analysis · Search and rescue · Visualization

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3.1 Introduction

In Canada, search and rescue (SAR) is one of the primary responsibilities of the Canadian Coast Guard (CCG). The CCG's SAR programme is needed largely due to the size of Canada's coastal search and rescue area (~5.3 million km^2), consisting of both extensive inland waterways and open ocean (Government of Canada 2019c). Through the effective use of SAR resources, the CCG responds to approximately 6000 maritime incidents per year (Government of Canada 2019a). As with most emergency response services, such as police and fire, incident reporting and record-keeping is a critical part of the response. Following each response operation, CCG incident reports and logs are entered in a database known as the Search and Rescue Program Information Management System (SISAR). SISAR is a web-based database that integrates all regional response data into one national system. SISAR incident data is one of the primary data sources used to capture statistics relating to SAR cases to help inform demand for programme services and the achievement of outcomes (Government of Canada 2019a).

This chapter provides an overview of the CCG SISAR database, a short background of spatiotemporal analysis of SAR incident data, and several interactive web visualizations that have been developed to specifically explore and exploit spatial and temporal trends in available SISAR incident data. Section 3.2 provides an overview of spatiotemporal analysis of SAR incident data and related research. Section 3.3 introduces the CCG SISAR database and the key elements that were used to construct the visual analytics presented in Sect. 3.4 and applied in Sect. 3.5. Section 3.6 discusses the results from the analysis completed in Sect. 3.5 and potential future work. Lastly, Sect. 3.7 provides some concluding remarks.

3.2 Spatiotemporal Analysis of Search and Rescue Incident Data

SAR incident data provides a rich multivariate spatiotemporal dataset that can support a wide range of analyses. The availability of spatial attribute data enables the use of spatial statistics and geo-referenced data processing techniques (Shahrabi 2003), while temporal attribute data allows for the use of time series analysis and the study of temporal phenomena and trends (Malik et al. 2012). This form of data has been widely used by the CCG and academic researchers to examine issues related to maritime SAR resource planning and evaluation, such as assessing manning levels (Marven et al. 2007; Government of Canada 2019b) and identifying critical locations for permanent SAR resources (Akbari et al. 2017; Akbari et al. 2018; Pelot and Plummer 2008).

Shahrabi (2003) completed an early example of spatial and temporal analysis of fishing and marine traffic incidents off the coast of Nova Scotia using available SISAR data. The emphasis of this work was on developing a better understanding of the location of fishing incidents and their time of occurrence. Using a geographic information system (GIS) and a variety of spatial statistical methods, such as kernel density estimation and hierarchical clustering methods, Shahrabi was able to identify areas of higher risk to fisherman off the coast of Nova Scotia. Furthermore, by analysing temporal incident attributes, the author was able to highlight times of the year where the likelihood of a SAR event was elevated. Pelot and Plummer (2008) expanded on this work to provide a complete assessment of the risk in the Atlantic coastal zone, largely based on maritime traffic modelling and historical SAR incident data. A similar SAR incident analysis was completed by Goerlandt, Venäläinen, and Siljander (2015), focusing on SAR incidents in the Finnish part of the Gulf of Finland. The authors successfully combined historical SAR incident analysis and information derived from GIS methods to perform a risk-informed capacity evaluation of voluntary SAR services. Their method relied on SAR incident data, meteorological data, and Search and Rescue Unit (SRU) data to derive several quantitative risk indicators. These risk indicators were used to assess the SAR response performance for recreational boating incidents.

In addition to the use of SAR incident data to support spatiotemporal analysis, it can also be used to support decision-making. Marven, Canessa, and Keller (2007) show how SAR incident data can be used to support SAR resource planning. Using exploratory spatial data analysis (ESDA) methods suitable for point pattern analysis, these authors proposed several resource allocation modelling approaches based on historical incident data that utilized linear programming, Monte Carlo simulation, and process simulation. More recently, Akbari, Eiselt, and Pelot (2017) proposed a goal programming multi-objective model for locating and allocating maritime SAR vessels. The model considered three objectives for the maritime SAR location-allocation problem: (1) primary coverage, (2) backup coverage, and (3) mean access/response time. When considering historical SAR incident data and the current arrangement of SAR vessel by type and location in their study area (Atlantic Canada), it was shown that substantial improvements, in terms of access time and coverage, may be possible by using the optimal location-allocation solution from their multi-objective model.

Malik et al. (2012) proposed a visual analytic process for maritime response, asset allocation, and risk assessment. The resulting visual analytic system, Coast Guard Search and Rescue Visual Analytics (cgSARVA), was developed to exploit the US Coast Guard (USCG) historical response operations database, covering operations in the Great Lakes region from 2002 to 2011. cgSARVA allows USCG analysts to visually interact with historical SAR incident data, helping to better understand data quality issues and to effectively perform data exploration and analysis. Recently, cgSARVA became part of the USCG initiated Station Optimization Process (US Department of Homeland Security 2018). This process was meant to analyse USCG boat stations and identify those that could be closed because they provide overlapping and/or unnecessarily duplicative SAR coverage.

Lastly, Sonninen and Goerlandt (2015) have explored the meteorological context of maritime SAR missions in the Gulf of Finland using visual data mining techniques to better understand which SAR incident types occur under challenging wind and wave conditions. The researchers associated wind and wave data with incident data from a SAR operations database. The associated data was then used to compare different SAR mission types, as well as the activity of different SAR organizations, during challenging wind and wave conditions. Using visual analytic techniques, the authors were able to identify the densest areas of challenging wind and wave conditions and areas that had the highest density of incidents.

3.3 Search and Rescue Program Information Management System

In Canada there are three primary SAR regions, each associated with a Joint Rescue Coordination Centre (JRCC), which are jointly operated by the Department of National Defence (DND) and CCG personnel. The JRCC is responsible for promoting the efficient organization of SAR services and for coordinating the conduct of SAR operations within an associated SAR region (Government of Canada 2019a). Currently, when a JRCC receives a report of a vessel in distress, they dispatch the most appropriate SAR resource to provide assistance. Following each SAR event, a new record is added to the SISAR database. SISAR provides a spatiotemporal record of all the serious incidents that required SAR response within Canada's coastal search and rescue area. SISAR was created to provide CCG personnel with easy access to essential information to support SAR planning, management, and operations (Marven et al. 2007).

The incident description fields of the SISAR database are used primarily for CCG internal accounting of events. A unique ID is assigned to each event and is used for all subsequent reporting. Example incident description attributes include the alert method used by the vessel in distress, location of the incident, start and end date time group (DTG), and a text summary of the event provided by the first responders. The incident description data that was used in this study included the incident ID, location, start and end DTG, and severity.

The SAR resource usage fields are used to identify the SAR resource used to respond to the incident and details of the mission. These fields try to capture the nature of the response operation. Fields such as incident severity, distance to the incident, alert time, on-scene time, and distance towed are used to describe CCG resource usage. The SAR resource usage data that was used in this study included the incident severity, incident distance from shore, and alert time. Incident severity is rated by the CCG using a four-point scale, with one being the most severe and four being a false alarm.

The SAR resource deployment fields are used to identify the region, base, and squadron of the SAR response asset. Often this information is associated with a SAR region. Currently, Canada is broken up into three regions: (1) Eastern, (2) Pacific, and (3) Central and Arctic. Each region is then further broken up into smaller SAR areas. The smaller SAR areas are used for aggregating and reporting marine incident statistics to support resource allocation planning (Marven et al. 2007). SAR resource deployment data were not used in this study.

The final descriptor, unit assisted field, describes the various characteristics of the vessel that was involved in the incident, including vessel dimensions, flag state, vessel type, class, and the number of persons on board. This information is used by the JRCC to select the most appropriate asset to respond. This information is useful when examining issues related to asset suitability and capacity given the expected unit characteristics that may be encountered during an incident. The only unit assisted data that was used in this study was the vessel length (metres).

3.4 Visual Analytics for SISAR Data Analysis

In this section we introduce several useful visualizations that were implemented in Data-Driven Documents (D3) to explore a SISAR dataset containing approximately 36,000 SAR response records. This dataset covers a date range from 2005 to 2013 (excluding 2007, which is not available) and includes records from incidents that have occurred within Canada's coastal SAR areas requiring a physical response by a CCG SAR asset. The use of a multi-year dataset was required to enable the visualizations presented in Sect. 3.4.2. The date range from 2005 to 2013 was arbitrarily chosen because the focus of this study was on the development and potential use of the visual analytics for historical SAR incident analysis presented in this section, rather than the specific results generated by these analytics when used to analyse a dataset.

D3 is an open-source JavaScript library that enables the manipulation of web visualizations, such as charts and graphs, based on underlying data (David and Tauro 2015). D3 accomplishes this by providing a declarative framework for mapping underlying data to visual elements in a web page. This mapping enables the direct inspection and manipulation of a native data representation through user interaction with the web browser (Bostock et al. 2011). Bostock (2019) provides open access to D3 documentation and a large repository of web visualization examples submitted by the D3 user community.

Using D3, each SAR incident is treated as an entity with associated attributes, and this information can be used to visualize the temporal and spatial relationships that exist within the data. To identify temporal phenomena in the data, ordinal classes were used to organize entity temporal attributes by year, month, day, and hour to construct a variety of data visualizations. Figure 3.1 provides a simple hierarchical view of the relationship between SAR incidents and attribute data used in this study.

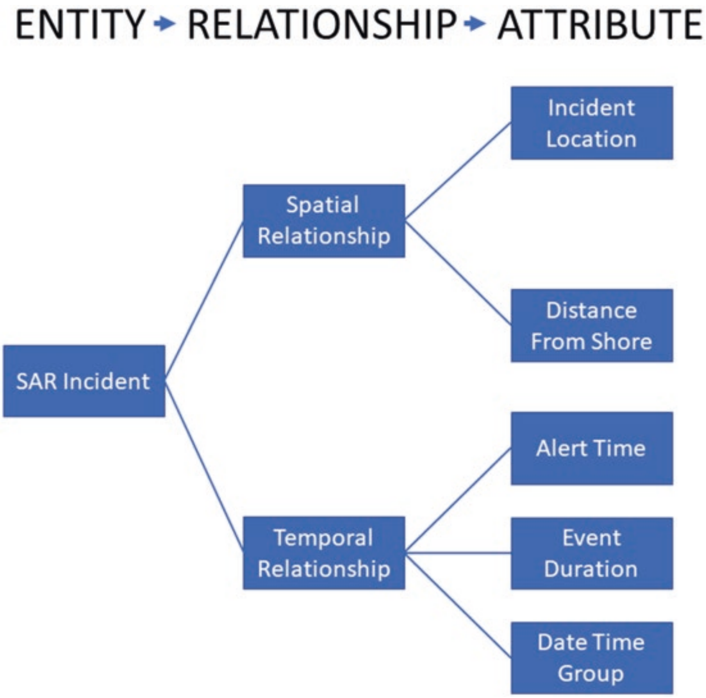


Fig. 3.1 Hierarchical view of entity relationship model

3.4.1 Interactive SAR Incident Dashboard

The interactive SAR incident dashboard provides a web visualization for exploring the temporal distribution of SAR incidents contained in the SISAR database. This interactive visualization allows the user to quickly examine the monthly and daily distribution of total incidents from the SISAR dataset using a standard web browser. The data visualized in this section is for calendar year 2013 and contains a total of 4062 SAR incident records. The distribution of monthly total incidents for 2013 is visualized as a bar chart. The dashboard pie chart is used to visualize the weekday distribution of total incidents. A seven-sector pie chart is used to conveniently display the information, with each sector representing a day of the week. The pie chart is initialized using the total number of incidents that occurred on each weekday during the 2013 calendar year. Figure 3.2 shows the initialized interactive incident dashboard visualization using 2013 SAR incident data.

The interactive elements of the SAR incident dashboard are used to enable the exploration of the temporal distribution of SAR incidents in the SISAR. These elements of the dashboard allow the user to rapidly sort and filter the SAR incident data by hovering the mouse pointer over a single bar in the bar chart to select a particular month or hovering over a single sector in the pie chart to select a particular day of

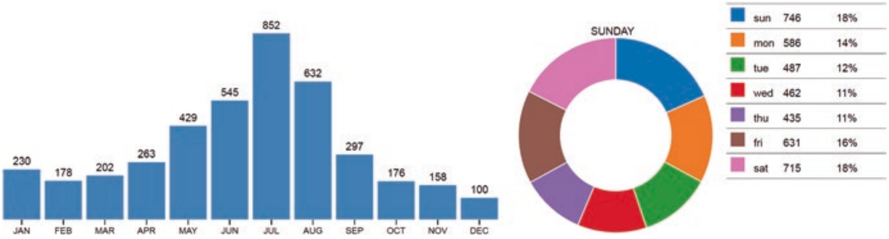


Fig. 3.2 SISAR interactive monthly/weekday SAR incident dashboard for calendar year 2013 (all data for figures and tables in this chapter from Canadian Coast Guard 2017)

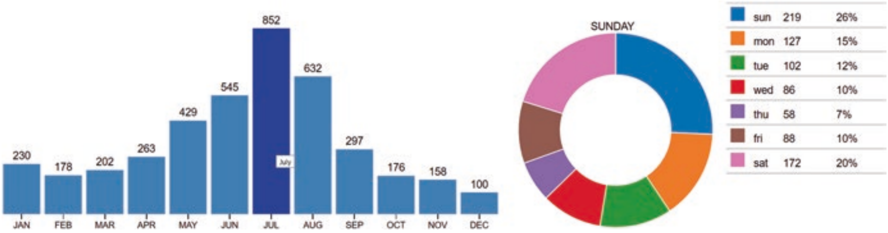


Fig. 3.3 Interactive dashboard result showing the weekday distribution of the total number of incidents that occurred during July 2013

the week. Hovering over these elements of the visualization will automatically render the corresponding analysis result on the web page. Hovering over a single bar in the bar chart will cause the pie chart to render the distribution of monthly total incidents by day of the week. Hovering over a single sector in the pie chart will cause the bar chart to render the distribution of yearly total incidents for a selected day of the week.

Figures 3.3 and 3.4 illustrate the use of the interactive elements of the SAR incident dashboard. Figure 3.3 shows the same monthly distribution of SAR incidents as shown in Fig. 3.2. The month of July has been selected in the bar chart by hovering the mouse over the appropriate bar (highlighted column in bar chart). The result of this user interaction is that the corresponding pie chart automatically renders to show the weekday distribution of incidents for the month of July. Figure 3.4 shows the monthly distribution of total SAR incidents that occurred on Sunday. In this case, Sunday has been selected by hovering the mouse over the sector of the pie chart that corresponds to Sunday. The result of this user interaction is that the bar chart automatically renders to show the monthly distribution of total SAR incidents that occurred on Sunday.

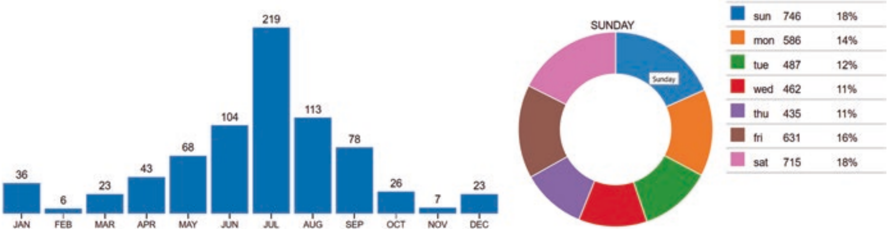


Fig. 3.4 Interactive dashboard result showing the monthly distribution of total incidents that occurred on Sunday during 2013

3.4.2 Multi-year Monthly Incident Analysis

The incident dashboard previously described only allows a user to visualize the monthly and weekday distribution of SAR incidents for a single calendar year. In order to satisfy the need to visualize longer-term trends in the SISAR incident data, three multi-year visualizations were used: (1) multi-year monthly incident time series graph, (2) multi-year monthly incident time series chart, and (3) multi-year monthly incident heat map. All three visualizations display the same information, but use three different approaches. Van Wijk and Selow (1999) provide an extensive description of calendar-based visualization of time series data like those presented in this chapter.

3.4.2.1 Multi-year Monthly Incident Time Series Graph and Chart

Using the date and time information associated with a SAR incident enables the visualization of SAR incident data as a time series. Each month was paired with an incident total and plotted. Using simple linear interpolation, a line was constructed that connects the dots that represent the total incidents for a month. Typically, continuous lines are not valid for categorical data and a bar graph should be used. An exception exists when the categorical data is ordered, which is the case in Figs. 3.5 and 3.6 where the data is ordered by calendar month. By overlaying multiple years of data, we can compare the set of line plots to gain insight into multi-year trends. Figure 3.5 shows a multi-series line chart of monthly total incident data from 2005 to 2013. For comparison, Fig. 3.6 shows the same data as a multi-year time series graph. Figure 3.6 more clearly emphasizes the cyclical nature of total monthly SAR incidents over a multi-year period and the exclusion of data from 2007 that was noted at the beginning of this section.

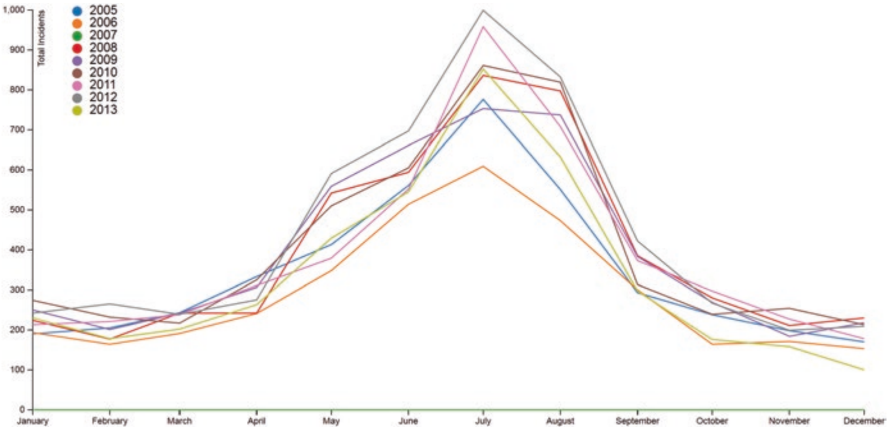


Fig. 3.5 Multi-series line chart of monthly incident totals (2005–2013)

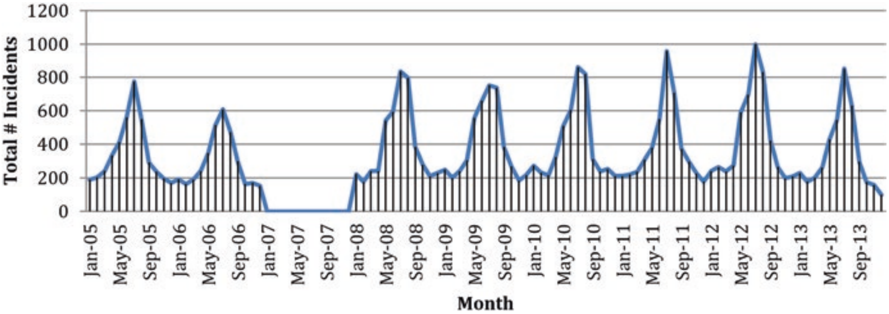


Fig. 3.6 Multi-year time series graph of monthly incident totals (2005–2013)

3.4.2.2 Multi-year Monthly Incident Heat Map

A heat map can most simply be thought of as a two-dimensional representation of data, where colour is used to represent attribute value. The heat map value used for this study was the total number of incidents, and the two dimensions are the month (y-axis) and the year (x-axis). Trends are identified by locating areas of common attribute value (colour) in both dimensions. In Fig. 3.7, darker blue areas are associated with a higher number of total monthly incidents, while the lighter areas represent a lower number of monthly incidents.

3.4.3 Hourly Total Incident Heat Map

The hourly total incident heat map allows the user to visualize the 24-hour distribution of SAR incident alert time as a simple circular heat map. The heat map was broken up into 24 sectors, with each sector representing an hour of the day. The

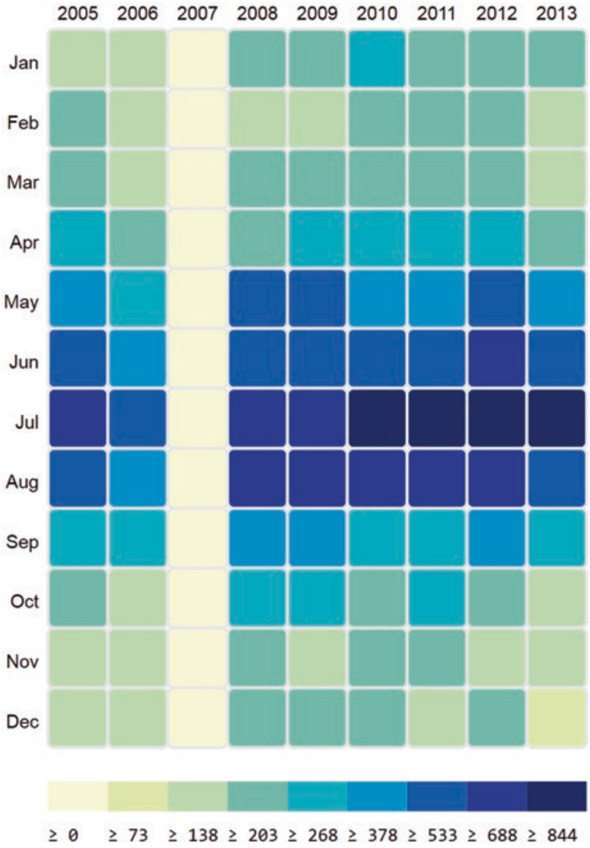


Fig. 3.7 Multi-year monthly total incident heat map (2005–2013)

colour coding was used to represent the total number of SAR incident alerts that were received during each hour of the day, where dark red represents the hour with the maximum number of incidents and dark blue represents the hour with the minimum number of incidents. This visualization allows the user to quickly identify the hours of the day where the greatest number of SAR alerts is expected to be received. Figure 3.8 shows the aggregate hourly distribution of SAR incident alerts from 2005 to 2013.

3.4.4 Spatial Analysis Map

The spatial analysis map allows the user to visualize the location of SAR incidents on a map. This visualization allows the user to exploit the spatial proximity and similarity of events to extract meaning (Ware 2004). Figure 3.9 provides a coastline

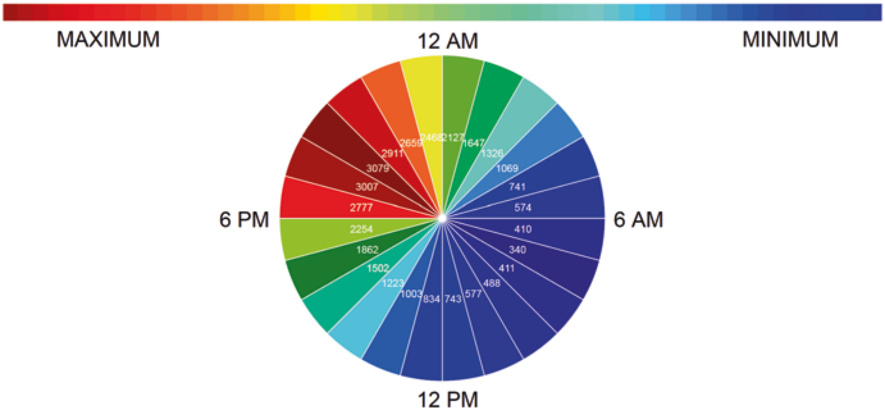


Fig. 3.8 Aggregate hourly total incident heat map of SAR incident alerts from 2005 to 2013

contour to allow the user to reference the incident location to a known geographic area. Two aspects of the spatial analysis map are discussed below, the analysis map and the SISAR data layer.

The analysis map was constructed using a GeoJSON of the Canadian coastline and the D3 default map projection library (Murray 2013). The size and shape of the country being mapped determines the most suitable projection. Since the SISAR data used in this study covers all of Canada, selecting a map projection that could be used to display the location of all incidents is challenging. Maps of very large countries like Canada often appear distorted due to the curvature of the earth. The distortion is minimal over small distances, but for maps of Canada that include the Canadian Arctic, it can be extreme. Since the majority of the SISAR incident data is located below 60° North, we have chosen to use a standard Albers map projection. The Albers projection is commonly used for land masses that extend in an east-to-west orientation, like Canada and the United States (ESRI n.d.). Figure 3.9 shows a zoomed-in map view of Atlantic Canada.

The SISAR data used in this study covers all of Canada's coastal search and rescue area. The dataset contains roughly 36,000 incidents, each with an associated geo-referenced position. By plotting the position of each incident on the analysis map, we can visualize the spatial distribution of incidents. By looking at the spatial proximity among incidents, we can identify areas of higher incident concentration. Shahrabi (2003) provided an excellent example of how this information, when combined with kernel density estimation and hierarchical clustering methods, can be used to identify areas of higher risk. The approach taken in this study was to try and use attribute data from the SISAR dataset to produce a visual analytic to help identify and localize areas of higher risk.

The approach uses the severity of the incident to determine the opacity of the plotted SISAR data. The visual effect is that more severe incidents appear as opaque bright red dots, while false alarms appear almost transparent (Fig. 3.10). The use of

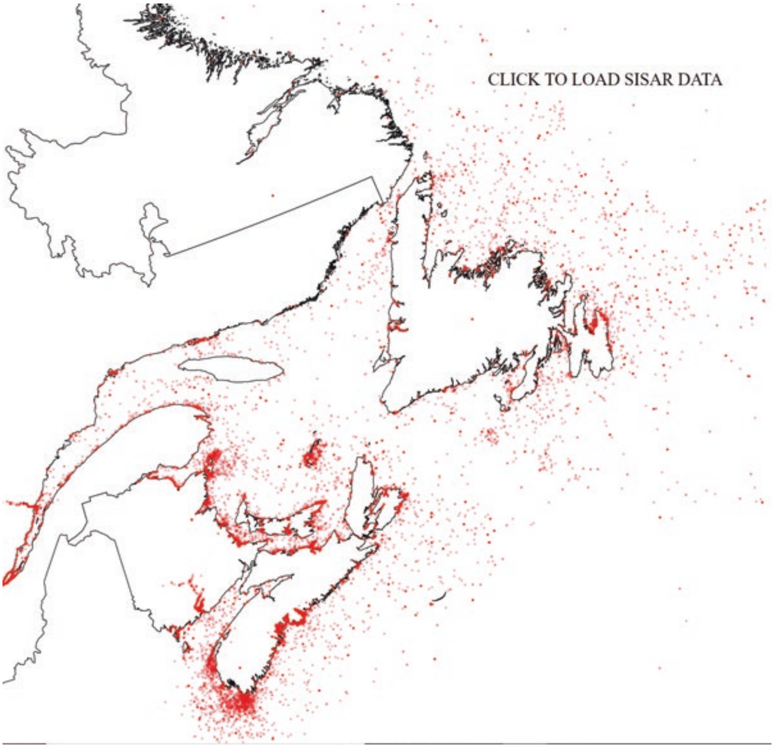


Fig. 3.9 Geospatial analysis map with incident location shown as red point locations

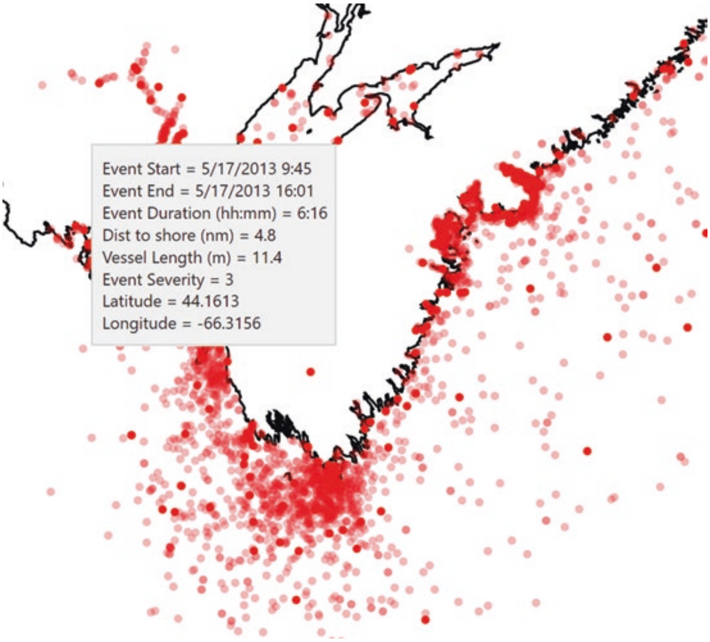
this visual analytics will be discussed in the next section. Equation 3.1 describes how opacity is derived using SAR incident severity data.

$$\text{Opacity} = \frac{1}{\text{Incident Severity}^2} \tag{3.1}$$

3.5 SISAR Data Analysis and Results

This section showcases a few potential use cases for the visualizations presented in this chapter. Visualizations have been selected that allow an analyst to explore both temporal and spatial trends in the SISAR dataset using a standard web browser. Specifically, three questions are addressed:

1. What was the temporal (by hour, month, and day of week) distribution of the 2013 SAR incidents?



Event Start = 5/17/2013 9:45
Event End = 5/17/2013 16:01
Event Duration (hh:mm) = 6:16
Dist to shore (nm) = 4.8
Vessel Length (m) = 11.4
Event Severity = 3
Latitude = 44.1613
Longitude = -66.3156

Fig. 3.10 Zoomed-in map view showing the geo-referenced position of incidents plotted as bright red circles with the opacity determined by Eq. 3.1. Hovering the mouse pointer over each geo-referenced data point provides the detailed summary of the incident

2. Based on the historical data for all SAR cases, what was the expected annual response case demand broken down by month?
3. Based on the historical data for all SAR cases, what regions show a high concentration of most severe incidents?

3.5.1 What Is the Temporal Distribution of the Response Case Load?

The interactive incident dashboard introduced in Sect. 3.4 allows the user to quickly identify monthly and weekday trends in the SISAR data. For any given calendar year in the study period, the user can quickly examine the total number of incidents responded to in a month or on a given weekday. Figure 3.2 showed the 2013 monthly distribution of incidents. A distinct peak in the total number of incidents is easily observed during the summer months (June–August). The peak during the summer months is observed during every year in the SISAR data and was best illustrated by the multi-year time series line chart of monthly incident totals shown in Fig. 3.6. This was likely due to the increase in pleasure boat activity associated with the summer months, previously observed and reported by Malik et al. (2011), Sonninen and Goerlandt (2015), and the Government of Canada (2019a).

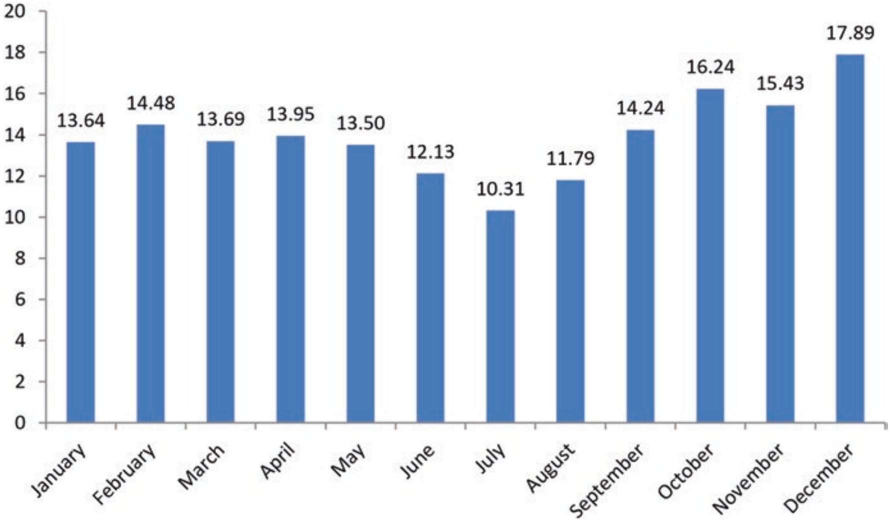


Fig. 3.11 Average SAR incident vessel length (metres) by month (2005–2013)

In an attempt to substantiate this claim using a visual analytic approach, the available SISAR data was processed to produce a bar chart visualization showing the monthly distribution of average vessel length involved in each SAR incident from 2005 to 2013. Figure 3.11 shows a decrease in average vessel length during the summer months, which is likely due to the increase in the number of smaller pleasure boats involved in incidents. Figure 3.12 also shows a decrease in the SAR incident distance from shore during the summer months, which is also likely due to the increased number of pleasure boats on the water.

In addition to the increase in the total number of incidents experienced during the summer months, it was also observed that during the summer months a greater proportion of incidents occurred on the weekend (Saturday and Sunday). For example, a user selecting July will see that the weekend accounted for 46% of the total number of incidents. Compare this with January where the weekend only accounted for 24% of the total number of incidents. For comparison, Fig. 3.13 shows the weekday distribution of SAR incidents for July and January.

Lastly, the hourly distribution of SAR incidents was examined. By aggregating all incidents found in the SISAR database, we can generate the hourly total incident heat map discussed in Sect. 3.4.3 and shown in Fig. 3.8. There was an elevated number of incidents between the hours of 6 pm and 11 pm. This reporting behaviour is typically associated with pleasure boat activity where a mariner is performing a day trip, where no overnight boating activity is expected (Government of Canada 2003). The SAR incident is triggered by a failure to arrive at the intended destination, return to port on time, or is generally considered overdue (ibid). Malik et al. (2012) also report a very similar hourly distribution of SAR incident case load for the USCG Great Lakes region.

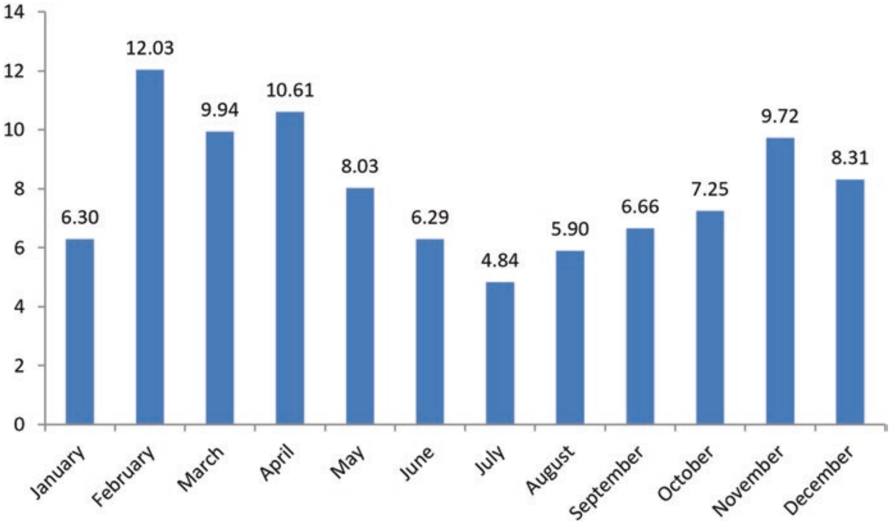


Fig. 3.12 Average SAR incident distance from shore (kilometres) by month (2005–2013)

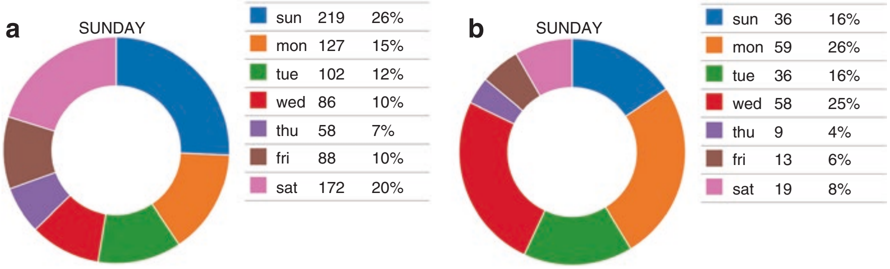


Fig. 3.13 (**a**) Weekday distribution of July 2013 total SAR incidents, (**b**) weekday distribution of January 2013 total SAR incidents

3.5.2 What Is the Expected Annual Response Case Demand?

Response case demand exhibits a strong seasonal variation. As was previously discussed, summer months show a significant increase in the number of incidents, while the remainder of the year is relatively consistent. Figure 3.7 provided a multi-year heat map of SISAR incidents. Over multiple years, incident levels increase significantly between May and September and drop significantly outside of this time frame. The CCG experiences a peak in SAR incidents during the month of July (829 ± 121 incidents) and a low during the month of January (227 ± 29 incidents).

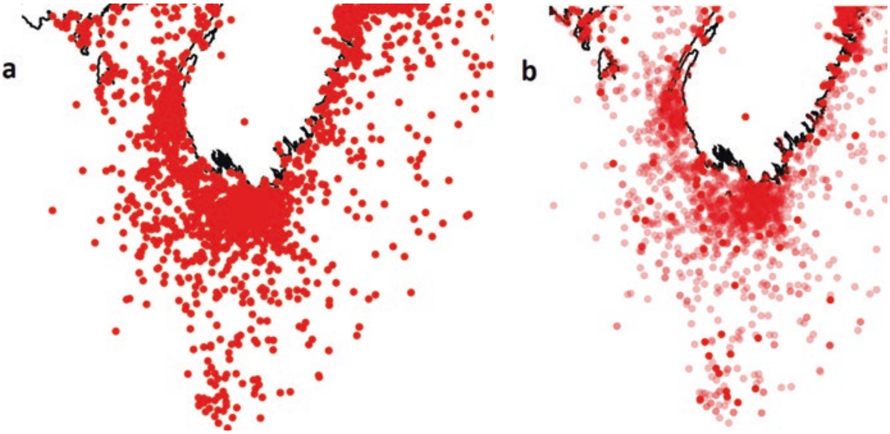


Fig. 3.14 (**a**) Spatial distribution of SAR incidents, (**b**) Spatial distribution of SAR incidents with opacity determined using incident severity (Eq. 3.1)

3.5.3 What Areas Show a High Concentration of Most Severe Incidents?

Understanding the spatial distribution of incidents is critical in planning emergency response operations and the allocation of resources (Marven et al. 2007; Akbari et al. 2017; Malik et al. 2011). Resources are often pre-positioned in areas with a higher concentration of SAR incidents to minimize response times and ultimately reduce the cost of providing lifesaving services. SISAR data provides a rich source of historical geo-referenced SAR incident data. The challenge is producing a visualization that allows the user to understand the significance of areas of higher SAR incident concentration. A visual analytic was created that uses the severity of incidents to aid in the interpretation of incident spatial location data. Figure 3.14 shows how using incident severity to control the opacity of incident location markers improves the definition of areas of severe incidents. This also improves the localization of hot spots, where more severe incidents are tightly grouped.

3.6 Discussion

Under-reporting in historical SAR incident databases can significantly affect the outcome of quantitative analyses, potentially leading to poor decision outcomes (Psarros et al. 2010). Under-reporting in the SISAR database used for this study could have a significant impact on the results discussed in Sect. 3.5. Under-reporting in SISAR is known to the CCG and believed to be largely due to technical challenges and human errors in constructing the database (Government of Canada 2019a). The CCG has determined the total missing cases, by region from 2006 to 2010: Quebec 0.9%, Newfoundland and Labrador 2.9%, Central and Arctic 2.7%, Maritimes 4.6%, and Pacific 30.9%. Furthermore, to mitigate bias concerns related to the missing cases, a CCG evaluation team examined a sample of the missing cases and concluded that the missing cases are not biased (ibid). The fact that the total missing cases have been measured and that there was no bias in the missing cases helps to ensure that the SISAR database remains a primary data source supporting SAR incident data analysis in Canada.

Several times in this chapter we mentioned the USCG visual analytic tool cgSARVA (Malik et al. 2011), which focused on USCG historical response operation incident data in the Great Lakes region from 2002 to 2011. The Great Lakes region represents a major inland waterway where SAR is a shared responsibility between two nations. Canada and the United States have a long history of providing cross-border SAR in this region. It would seem reasonable that a complete assessment of maritime response, asset allocation, and risk assessment should reflect the cooperative nature of SAR in the Great Lakes region.

The inclusion of Canadian SAR stations and incident data in cgSARVA would undoubtedly influence the risk profiles generated by cgSARVA and reported in Malik et al. (2012). The generation of updated risk profiles that account for Canadian data could provide insight into the benefits of enhanced cross-border SAR coordination. Looking more broadly, maritime search and rescue in the Arctic also demands a high degree of international coordination and collaboration. The great importance of cooperation among Arctic nations in conducting SAR operations in the North is detailed in the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (Arctic Council 2011). The pooling of historical incident data and SAR resource locations and capabilities from all the parties to the Agreement could enable a more comprehensive analysis of SAR capabilities in the region and ultimately improve the delivery of SAR services.

Many researchers are also now starting to link environmental conditions and accident data to add context to historical SAR incidents. Wu, Pelot, and Hilliard (2009) have studied the influence of weather conditions on the relative incident rate of fishing vessels in Atlantic Canadian waters. Their analysis considered the following environmental factors: wave height, sea surface temperature, air temperature, ice concentration, fog presence, and precipitation. Ice concentration was shown to have the greatest influence on the magnitude of the relative incident rates for fishing vessels. In areas with low ice concentration, wave height was associated with higher incident rates. The presence of fog and precipitation was found to not be an important influence on relative incident rate.

More recently, Rezaee, Pelot, and Ghasemi (2016) extended the analysis of Wu, Pelot, and Hilliard (2009) and determined that the influence of weather conditions on relative incident rates in Atlantic Canadian waters is also largely dependent on vessel length. Similar studies have been conducted in other maritime areas. Goerlandt et al. (2017) examined navigational shipping accidents in the northern Baltic Sea area, successfully integrating accident data and environmental conditions. Atmospheric and sea ice data were used to reconstruct the navigational conditions that existed at the time of the accident to contextualize the incident, aimed at improving wintertime maritime transportation risk analysis.

Lastly, SAR response time estimation is receiving increasing attention in the literature and is a key factor in determining optimal SAR station location and assignment of SAR units. Siljander, Venalainen, Goerlandt, and Pellikka (2015) applied GIS-based tools and methods to evaluate SAR response time, considering environmental conditions. Their analysis considered the capabilities of the SAR unit and prevailing wave conditions at the time of the incident to improve estimates of response time for use in strategic SAR planning. SAR response times can be significant in the remote areas of the northwest Atlantic and Arctic. Not only are these regions remote, the environmental conditions can be very harsh, further increasing SAR response times. New methods are required to improve estimates of ship speeds in adverse environmental conditions, such as sea ice conditions, to improve the accuracy of response time estimation.

3.7 Conclusion

The CCG has collected data and information about SAR incidents involving CCG assets and personnel since the 1980s. This data provides CCG personnel with necessary information to support SAR planning, management, and operations. This rich SAR incident dataset provides researchers and analysts with a multivariate dataset that can be used to support a wide range of analysis and visualizations. In this chapter we discussed the use of SISAR incident data to explore temporal and spatial trends in the data using interactive web visualization techniques. The most prominent trends observed in the data included the increase in SAR incidents during the summer months, predominately on weekends and in the evening hours between 6 pm and 11 pm.

In addition to temporal trends, the spatial location of SAR incidents was also examined. By plotting the coordinates for each SAR event on top of a map projection of the Canadian eastern coastline, it was possible to identify areas of high concentration of incidents. In this chapter we highlight the high concentration of incidents off the southern tip of Nova Scotia (see Fig. 3.14). In addition to plotting the location of the incident, the severity of the incident was used to create a visual analytics to control the opacity of the incident location point symbol (red circle). The use of opacity was effective in refining regions of higher concentration of severe incidents.

These interactive visualizations were effective in identifying several temporal and spatial patterns in the SISAR data. These visualizations could be used by an analyst to support decisions regarding SAR station manning, SAR station location, and employee shift scheduling (monthly, daily, and hourly). The continued use of SISAR data to improve decision-making in the CCG will help to ensure the delivery of SAR services is cost-effective and that response times are minimized, ultimately saving more lives.

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Chapter 4
Search and Rescue at Sea: Do New Challenges Require New Rules?

Francesco Munari

Abstract Search and rescue (SAR) at sea has been always carried out under principles of the customary law of the sea obliging vessels and states to help persons whose ships are in distress at sea. International treaties define more detailed conditions and obligations to provide adequate SAR. The rationale of all these principles and rules, as well as of the associated duties affecting the obliged persons/states to carry out and organize SAR activities, was that of increasing safety at sea and taking care of seafarers and fishermen (or passengers on board vessels) who were at sea mainly for the purpose of work.

The safety of ships has increased enormously in recent decades. Therefore the number of classical SAR operations has become a minimal fraction of those actually carried out to rescue, for example, leisure yachts, migrants and cruise ship tourists that venture into dangerous waters (including the Arctic) in pursuit of adventure.

Thus, the original SAR rationale has drastically changed. We need to consider whether the obligations set at the international level for rescuers and affected states should be updated to deal with current rescue missions. To deal with the migration problem in the Mediterranean, the normal SAR schemes – while not being abandoned – have been largely supplemented by other forms of international cooperation. This chapter investigates these new forms of cooperation and presents some proposals for updating the SAR international regime to meet the new challenges posed by persons venturing to sea.

Keywords Arctic navigation · Beneficiaries of search and rescue · Cruise and leisure ships · Immigration · Search and rescue · Search and rescue regime update

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4.1 Introduction: The Rationale for the Customary Rule to Save Lives in Danger at Sea

For centuries, ships in distress have been assisted; this is not only a well-rooted solidarity principle among seafarers but also corresponds to a very old customary rule in the international law of the sea, being linked with an obligation to assist vessels in danger and to offer salvage and rescue to persons on board (ILC 1956, 281; Reuter 1975; Trevisanut 2012, 56; Pallis 2002, 334; Papanicolopulu 2016; Barnes 2010, 134; Oxman 1997, 415; Nordquist et al. 1995, 170; Treves 1985; Scovazzi 2014). Such a customary rule was established when sailing was a perilous activity. People (including seafarers) ventured to sea mainly because they needed to for various reasons: fishermen to catch fish and make their living thereof; merchant mariners to bring cargo to its destination and receive a salary or at least food and shelter; warships and other state ships to obey their sovereigns; finally, even ordinary people, when passenger vessels were the only long-distance transportation means, to move across the seas mainly to seek jobs at a time when migrations were not only tolerated but also often encouraged to inhabit and “exploit” the newly “discovered worlds”.

At that time, and indeed until not very many decades ago, the dangers of navigation brought about frequent loss of lives at sea, and such a risk was de facto implicitly accepted by seafarers and their families. This danger was compounded by poor technology in building, maintaining and operating ships, which were therefore unable to deal with bad weather conditions and storms. At the same time, state presence at sea was scarce; aside from a much less populated earth, coastal states devoted few resources to patrolling their waters. Further, interest in enforcing their jurisdiction and powers in their (territorial) seas was certainly unrelated to enhancing safety of navigation and saving lives in danger of being lost.

In essence, it can be reasonably argued that, at the time in which the customary rule was formed, persons going to sea were a separated community from their nation state. This community knew the perils each of its members was facing on a daily basis and was prepared to offer solidarity in case of distress at sea, because this solidarity would be reciprocated among all the community’s members. This was the rationale of the duty to save lives at sea that developed over the centuries as a customary rule of international law: reciprocity and solidarity were the backbone of this rule, under the assumption that persons at sea are almost per se in danger, with no one else but another vessel to help them in case of distress. This situation has gradually changed over time. In general, states developed systems to protect persons from any danger (wherever it may occur), but among mariners the duty to save lives in danger at sea has always remained.

In recent years, there has been a radical change of this perspective. This chapter begins by examining the progressive implementation and codification into treaty law of the customary rule relating to the duty to save lives at sea. It explores solutions imposed on sovereign states that have been traditionally found at the treaty level to implement the specific duty to organize SAR operations and the possible rationale of this (vertical) approach to the duty to save lives at sea. The evolution of the customary rule of international law as embodied in Article 98 of the United Nations Convention on the Law of the Sea (UNCLOS 1982) and, in parallel, the general increase of safety and security of maritime navigation when international standards are complied with are also considered. This is followed by analysis of the new type of situations in which rescue of vessels is needed today and how international bodies have tried to cope with these new situations. Finally, the chapter addresses specific problems connected with SAR in particular situations and concludes with proposals for recasting existing international rules in order to restore the balance of interests that initially founded the international SAR regime.

4.2 The Search and Rescue at Sea Regime

4.2.1 From Customary Law to Treaty Law

As it is often the case in international law, customary law is supplemented by treaty law. However, the progressive implementation and codification of search and rescue at sea custom into treaty law followed different paths, depending on the specific international convention.

Indeed, the customary rules were captured by the Geneva Convention on the High Seas (1958). Article 12 codified the duty of every state, *inter alia*, to require the master of a ship sailing under its flag, insofar as possible without serious danger to the ship, the crew or the passenger, to assist persons at sea in danger of being lost and proceed to rescue persons in distress under reasonable circumstances. Further, Article 12 introduced the duty of coastal states to promote the establishment and maintenance of a search and rescue service and to cooperate with neighbouring states for this purpose. These obligations were maintained in UNCLOS, whose Article 98 is identical to Article 12 of the Geneva Convention (Treves 1985, 886; Nordquist et al. 1995, 169ff; Treves 1990, 44).

But much earlier than this, states already had agreed on rules to reduce perils at sea, taking different lines of action. The oldest treaty concerning rescue and salvage was not focused on human beings, but rather on cargo. Salvage was (and sometimes still is) a dangerous task. States decided to lure salvors into undertaking this task through the adoption of a convention, the 1910 Brussels law of salvage. The aim of the convention was to provide a reward for salvors of a ship who were able to avoid totally or partially the loss of cargo of another ship in distress and meanwhile discourage piracy (Attard et al. 2016, 475; Tetley 2002; Reeder 2011; Rose 2017; Brice 1993; Hill 1992, 2003; Lefebvre D'Ovidio et al. 2016; Carpaneto 2017; Kerr 1990; Ferrarini 1964). This convention was re-crafted in 1989, mainly in order to introduce compensation when environmental pollution is prevented (International Convention on Salvage 1989). The Salvage Convention does not provide any compensation for salvors that save lives, and therefore at-risk individuals benefit from the international regime on salvage only indirectly and as a "by-product" of salvage operations at sea (Hill 1992, 336).

An outcome of the *Titanic* tragedy was a fundamental thrust towards reducing the dangerousness of sea-going. In 1914, 2 years after the sinking of the ship, the first version of the International Convention for the Safety of Life at Sea (SOLAS) was adopted. SOLAS (ultimately recast in 1974 and in force since 1980) has always had as main goal to specify and update at the international level minimum standards for the construction, equipment and operation of ships, compatible with their safety. While the oceans remained a place where the possibility to help people in need was substantially lower than on land, states agreed that rules ought to be adopted at the international level in order to prevent accidents and loss of lives, as well as to reduce the "inherent" dangerousness of going to sea.

SOLAS and its implementing instruments have been undoubtedly successful: indeed, with the exception of the Second World War, SOLAS implementation caused a gradual and constant decline in the number of vessels (and persons) lost at sea, which impressively improved with the adoption of SOLAS 1974 (see below; Allianz 2019). With the important exception of migrants by sea, which is discussed below, one can hardly doubt that, progressively, the safety of navigation has increased significantly and the number of accidents and sinking of vessels truly has diminished, even if at the same time transportation by sea has grown hugely.

In combination with enhancing vessel safety standards, another important measure to improve navigation safety has been to increase the training and education of seafarers. Under the auspices of the International Maritime Organization (IMO), the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 1978) was adopted and over the years modified (IMO n.d.-b; Vallario 1986; Rizzo and Ingratoci 2014). STCW has contributed to building capacity and education in seafarers, creating uniform standards at the global level to supplement national legislation and introducing relevant rules to enhance professionalism on board vessels, especially in states where seafarers have been carrying out their jobs on board foreign flag vessels. This approach is clearly based on prevention of accidents. States agree on the necessary tasks at the international level and then introduce at the domestic level statutes to discharge these obligations. Such statutes could oblige seafarers to acquire relevant professional qualifications and maintain them with training throughout their working life, while shipowners could be required to hire exclusively skilled personnel and comply with relevant STCW obligations.

These evolutions in treaty law can be considered as the first-best solution implemented by states to cope with the need to avoid the loss of lives at sea: enhanced safety standards for ships and training of seafarers would (enormously) reduce situations of distress at sea. However, over the decades, other rules have been established to work as a second-best solution: by the end of the 1970s, states agreed on a set of rules implementing the customary (but inevitably vague) rule as now codified by Article 98 of UNCLOS concerning search and rescue in order to further reduce ship losses and consequent casualties.

The 1979 International Convention on Maritime Search and Rescue (SAR Convention) was adopted with the aim of developing an international SAR plan so that, no matter where an accident occurs, the rescue of persons in distress at sea would be co-ordinated by a SAR organization in co-operation with neighbouring SAR organizations (IMO n.d.-c; Button 2018). Under the SAR Convention, contracting states are required to ensure that arrangements are made for the provision of adequate SAR services in their coastal waters. Further, they are encouraged to enter into SAR agreements with neighbouring states to establish SAR regions (SRR), to pool facilities, to establish common procedures and to facilitate training and liaison visits.

In fact, the pace of implementation of the SAR Convention was very slow, a situation that might be connected to the delay in UNCLOS entering into force (1994). In any case, in 1998, a revised technical annex clarified governments' responsibilities and put greater emphasis on a regional approach and coordination between maritime and aeronautical SAR operations. Chapter 3 of the annex (cooperation between states) requires parties to coordinate SAR organizations and, where necessary, search and rescue operations with those of neighbouring states, including allowing immediate entry into or over its territorial sea or territory for rescue units of other parties. In 2004, a second revision of this annex, *inter alia*, added a new paragraph in Chap. 3 of the Convention relating to coordinating the provision of assistance to the master of a vessel in delivering persons rescued at sea to a place of safety.

The parallel and converging goals of these treaties have had substantial results. Indeed, as far as the merchant marine is concerned, even in the face of steady growth of maritime traffic, recent data show that, even if collisions at sea continue to occur, severe casualties involving merchant vessels have remained low in number (EMSA 2017). During 2018, the loss of ships decreased by 50% relative to 2017 and by more than 50% over the past decade. In short, over millions of voyages by merchant marine vessels recorded in a year, total ship losses account for only a few dozen (46 in 2018, Allianz 2019).

4.2.2 The Enhanced Solidarity for Seafarers Generated by the SAR Convention

A remarkable innovation of the SAR Convention, which actually substantiates the general principle stated in Article 12(2) of the 1958 Geneva Convention on the High Seas as replicated in Article 98(2) of UNCLOS, is the involvement of coastal states as the main actor in organizing, coordinating and implementing SAR operations. The creation of SAR regions under the (quasi) exclusive jurisdiction of the coastal state has replaced the customary law "horizontal" scheme (from vessel to vessel) with a "vertical" one (from coastal state to vessel in distress).

Yet, within the "traditional" situation of vessels in distress, this change of perspective does not alter fundamentally – and indeed enhances – the solidarity rationale embodied in the obligation to save lives in danger at sea: vessels in distress often navigate the coastal waters of their flag states or at least are leaving or directed to their ports. This is true – with limited exceptions – for fishing boats and merchant marine ships, that is, those categories of vessels for which the rules and principles have been created and implemented over the centuries.

Solidarity thus extends from the seafarers' community to a broader community that includes coastal state citizens who benefit from navigation. As long as transportation by sea or fishing activities "serve" the needs of a coastal state's population, it seems equitable and fair that, together with other first-best instruments to reduce perils for persons at sea, coastal states also organize SAR operations for those vessels and seafarers somehow "connected" with it, for example, those engaged in domestic maritime trades (Brooks 2018).

If we look at this phenomenon from an economic analysis viewpoint, we can further add that – in its original rationale – the SAR Convention tends to reduce externalities of navigation: in order to decrease risks to lives at sea, coastal states are obliged to organize, coordinate and implement their SRR and pay the consequent burdens. In turn, these burdens are shifted to taxpayers, that is, the individuals living in the coastal state who are requested to contribute to the "costs" arising out of the sale and purchase of products carried by sea or harvested in the seas in their interest.

4.3 The Changing Framework of Persons in Danger at Sea

4.3.1 The New "Beneficiaries" of Rescue Operations at Sea

The enormous decrease in losses of merchant marine and fishing ships (and their crew), arising out of the combined force of the conventions discussed above, shows beyond any doubt that, if the 1979 SAR Convention did not exist, almost certainly the customary obligation to rescue vessels in distress would be implemented in ways not resembling the complex and expensive system elaborated by the Convention. Possibly, the customary law enshrined in Article 98(2) of UNCLOS would be reset into an "obligation" onto states to maintain an adequate organization to provide safety at sea along their coasts, and citizens would demand that their governments guarantee such safety as it happens on land. Yet, considering the trend to reduce public spending, not much more would be required to provide such measures. As discussed above, for merchant marine vessels, going to sea is no longer such a dangerous activity and the risks do not appear to be higher (and are probably much lower) than most other work.[1] However, even if safety standards are

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[1] The ILO records around 2,300,000 fatal accidents at work and many more nonfatal injuries and illnesses (ILO 2014). These figures are double compared to the beginning of this century (ILO

improving, fishing remains a dangerous profession (ILO 1999b; Windle et al. 2008), especially in geographic areas characterized by extreme conditions (Rezae et al. 2016). Generally, however, the achievement of adequate safety standards in fishing probably is hampered by the fact that it is often carried out under sub-standard (if not illegal) conditions, and, because of that, enforcement of existing laws can be very weak (Petursdottir et al. 2001). For instance, the number of contracting parties to the treaties increasing safety standards for vessels and training for fishermen is substantially lower than for SOLAS and STCW.[2] By contrast, as far as salvage of ships is concerned, in many instances, and not only because of the 1989 Salvage Convention, salvage has transformed into a business or at least into a service that is offered against a reward (Parent 2006, 91; Kilpatrick and Smith 2016; Coppens 2013).

This being the situation, one would expect a sharp decline of SAR at sea. And yet, this is not the case at all: there continue to be a high number of search and rescue operations. As statistics show, the US Coast Guard carries out thousands of rescues each year, with thousands of lives saved (USCG 2016). The situation is the same in Canada where 56,769 SAR cases were recorded in the period 2012–2018, with 6250 cases reported with life at risk for 20,523 passengers on board, out of which 1338 were assisted before their boats were lost and 18,883 people were saved.[3] In the seas surrounding Italy, the area where SAR probably reached a peak in 2016, there were 2269 SAR operations, with total rescued persons numbering 4605 individuals. These Italian SAR operations are exclusive of those concerning migrants, for which, in the same year, an additional 1424 missions were coordinated by the Italian Coast Guard, with the rescue of the amazing number of 178,415 migrants (Italian Coast Guard 2016, 5).[4]

These data show that lives continue to be at risk at sea. However, these dangers are now little connected with navigation for working reasons or with a solidarity principle established among the members of the seafarers' community (or the coastal communities and seafarers serving their needs). At present, the main SAR activities carried out worldwide have a different nature than those on which search and rescue obligations arose in international law and practice and which justified the adoption of the SAR Convention.

If going to sea for professional seafarers is no longer very dangerous, then we must ask who are endangered at sea nowadays. Quite probably, most of these persons are migrants, who are not seafarers, and find themselves on board a boat for the

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1999a), when it recorded around 1,000,000 mortal accidents/sicknesses at work. In industrialized countries, the European Union, for example, averages a little less than 4000 casualties at work per year, which represents a ratio of approximately 830 nonfatal accidents for every fatal accident (Eurostat 2018).

[2] The 1995 STCW-F Convention (where "F" stands for fishing personnel) has been ratified by 31 states only, and the 1993 Torremolinos Protocol relating to the Torremolinos International Convention for the Safety of Fishing Vessels 1977 is not yet in force (IMO 2019, 424, 492).

[3] Canadian Coast Guard statistics, personal communication, Robert Brooks, Director, Incident Management, Canadian Coast Guard

[4] Fortunately, these figures have been decreasing since 2017.

first (and last) time in their life, a boat that has standards of safety that are totally inconsistent with basic conditions as established by international conventions. Moreover, their movement by sea has little to do with navigation in its traditional sense: they embark on a desperate journey by sea – invariably being exploited by transnational criminal organizations – since there are no alternatives for them to reach their country of destination, and they leave their boats as soon as possible. Further, such migrations at sea and the circumstances in which they take place can give rise to a "new" danger for other navigators.

Another important category of beneficiaries of search and rescue are people going to sea for leisure. Yachtspersons (this category includes whoever goes by sea in pleasure boats) benefitting from SAR operations amount to three quarters or more of all missions in many areas (as noted in the statistics presented above). And even if, so far, only a relatively few accidents have occurred with cruise vessels and their passengers,[5] the growth of this sector very probably will become an important source for SAR operations, especially if one considers the thrust to offer customers increasingly "exciting" destinations.[6]

Against the backdrop of present perils at sea, one should therefore evaluate whether the first-best (SOLAS and STCW) and second-best solutions (SAR regime) are still adequate international legal instruments to reduce accidents. More precisely, two more questions are worth posing: Are the solidarity and reciprocity rationales behind the search and rescue rules still working? Can the SAR system alone successfully and equitably constitute a response to the "new" perils at sea?

4.3.2 Differences and Analogies Between Past and Present Perils at Sea

Given that, in most instances, present beneficiaries of SAR are no longer those on which the international legal regime has been developed and progressively set up, then we should question whether these differences may imply also a modified approach vis-à-vis the existing rules.

Considering migrants, there are no doubts that enormous differences exist: migrants are often packed on board vessels breaching all SOLAS and related standards, with the vessels being furthermore manned by migrants alone or by persons with little or no professional skills. Hence, the entire set of rules depicted as the first-best solution to avoid dangers at sea is not applicable. In fact, if we consider

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[5] The latest accident, however, involved the rescue of hundreds of passengers on board *Viking Sky* off the Norwegian coasts in March 2019 (DW 2019; BBC 2019; CruiseMapper n.d.). The *Costa Concordia* accident attracted substantial interest in the media, even if the closeness of this accident to the Italian coast made the search and rescue operations somehow "atypical" compared to the traditional groundings.

[6] The possible expansion of cruises in polar areas is discussed in Chap. 9 by Joseph Loot in this volume. The consequent risks of this are discussed further below.

exclusively the maritime/law of the sea perspective, no individual solidarity or reciprocity principle even comes into play, because migrants are not seamen and do not belong to the community of seafarers that developed the traditional obligation to help and rescue persons in danger at sea. Further, these migrants do not even serve any need of the "coastal community": indeed, the contrary is true, at least if we leave aside any considerations based on human rights law.[7] Of course, coast guards and seafarers will certainly (and rightly) continue to consider any SAR operation their duty, no one discusses that SAR is not applicable to migrants, and NGOs are increasingly operating at sea to rescue migrants, as do yachtspersons sometimes. However, such a duty is based on humanitarian concerns, not on ancient solidarity principles among seafarers.

Yachtspersons have some – and occasionally even high – skills in navigation, but are not subject to the STCW rules and standards. The craft they use are normally much smaller and less resistant to bad weather and sea conditions than merchant or fishing vessels and – with limited exceptions – are not subject to the SOLAS regime.[8] In addition, their ability to avoid dangers at sea is reduced because they are amateurs, not professional seafarers, and they are not (or are less) able to anticipate the risks of adverse weather and sea conditions. In a certain way, they are part of a "maritime community", but such a community goes to sea for leisure, not for necessity or work reasons. Again, this makes the first-best set of international rules established to reduce dangers at sea nonapplicable. Yachtspersons may share some solidarity with other persons at sea in distress, but often their boats are unfit for the purpose of rescue.

The final confirmation that going by sea is (and is perceived) as not being a dangerous activity comes from the cruise industry, the third category of actual and prospective beneficiaries of search and rescue operations. These persons have a lot in common with people going to sea for pleasure, with some additional upsides, but also downsides as far as search and rescue is concerned. On the one hand, cruise vessels (i.e., passenger ships) are subject not only to SOLAS and STCW but also to an enhanced set of regulations established by the IMO, including the obligation to ensure safe return to port for passenger ships in damaged condition (IMO n.d.-d).[9] In addition, the IMO has adopted specific rules to enhance the standards for ships navigating in polar regions, which clearly encompass passenger ships.[10]

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[7] However, there exists an interstate obligation, especially within the European Union, to implement migratory policies based on solidarity principles (Munari 2010, 2018; Morano-Foadi 2017).

[8] Some aspects of Chapter V SOLAS apply to pleasure craft under 150 GT and are (relatively) implemented at the domestic level (UK Maritime and Coastguard Agency 2014; Small Vessel Regulations 2010 (Canada)).

[9] SOLAS (1974) Regulation V/7.3 provides: "Passenger ships … shall have on board a plan for co-operation with appropriate search and rescue services in event of an emergency. The plan shall be developed in co-operation between the ship, the company as defined in regulation IX/1, and the search and rescue services. The plan shall include provisions for periodic exercises to be undertaken to test its effectiveness. The plan shall be developed based on the guidelines developed by the Organisation".

[10] The IMO Polar Code (IMO 2017) focuses specifically on safety measures (including special training for seafarers) and pollution prevention measures (Kirchner 2018; Byers and Baker 2014;

On the other hand, however, the number of persons involved in case of distress of a cruise ship is at least one to two orders of magnitude higher than a merchant marine vessel. Moreover, all the passengers and hotel crew members of a cruise ship are not seafarers, and many or most of them have no confidence at all in dealing with the sea (and certainly with the potential evacuation from a ship in distress). Finally, business and market forces push cruise lines to venture into remote and dangerous areas, such as Antarctica and the Arctic, which present not only high environmental risks but also produce a tremendous impact on the SAR organizations of coastal states in the polar regions.[11]

Cruise ships generally comply with the highest safety standards. Yet, passengers are so numerous and so poorly trained that, in the event of an accident, the second-best solution offered by the SAR regime may become totally inadequate and in any case is extremely expensive. While arguably the SAR regime obliges coastal states to organize their SRR in order to be able to respond to distress situations contemporaneously involving a few persons, and very occasionally a few hundreds, it is virtually impossible and beyond the implied scope of the Convention to assume that coastal states should be able to face accidents at sea involving many hundreds – or even thousands – of (largely untrained) people.

4.3.3 The New Search and Rescue Challenges and the IMO

Given the role played by the IMO in shaping international rules on navigation, including those discussed above, it is useful at this stage to consider its current initiatives. Indeed, the IMO has not remained idle in respect of the "new" risks at sea. However, the IMO has a confined mandate; it can neither encroach on other international conventions nor on the sovereign powers of states. The results that can be expected from the IMO – even if remarkable – are limited to enhancing the existing pillars on which it works, namely, safety, environmental protection, working and training conditions of seafarers and therefore are not sufficient.

Molenaar et al. 2013; Rothwell 2013; Lalonde and McDorman 2015; Moiseev 2016; Vestergaard et al. 2018; Franckx 1993; Pharand 1988). The IMO is studying a Polar Code "Phase II", in order to include noncommercial ships (i.e., fishing boats and yachts) within some of the Polar Code provisions (see Chap. 15 in this volume).

[11] In 2007 a small cruise ship, the *Explorer*, hit an iceberg and sank during a voyage in Antarctica, with about 150 persons having been rescued and no victims. The flag state's competent authority, the Liberian Bureau of Maritime Affairs, issued a report on the accident (Republic of Liberia 2009). In 2009 the *Ocean Nova* grounded off the Antarctic coasts with a few dozen passengers and a similar number of crew on board (Attwooll 2009). In 2010 the *Clipper Adventurer* grounded in the Arctic waters, with 128 passengers and 69 crew members (TSBC 2012). The present size of cruise ships and the number of tourists they can host on board cast in doubt the possibility to repeat nowadays the successful rescue of the *Explorer*'s passengers.

As far as the rescue of people on board pleasure boats is concerned, only very limited attention has been paid to this category of persons at the IMO.[12] More has been done for rescuing migrants at sea. Since the vessels on which they are boarded are unfit for addressing any "first-best" maritime solution (as discussed above), these persons are clearly – albeit not exclusively – within the SOLAS and SAR Conventions' scope of application. Thus, the IMO has adopted several recommendations, resolutions, guidelines and other instruments to adapt the existing regime to this phenomenon (IMO 2001, 2004a, b, c, 2009), and has also agreed to enhance migrants protection under the SAR Convention. However, it is widely recognized – even within IMO documents – that the IMO must coordinate its work with other international organizations as well as with states. Rescuing migrants at sea is strictly intertwined with other areas of international law, and even if the IMO continues to work on SAR of migrants, it has clarified that "issues other than rescue relating to asylum seekers, refugees and migratory status are beyond the remit of IMO, and beyond the scope of the SOLAS and SAR Conventions", implying awareness by states

> of assistance that international organizations or authorities of other countries might be able to provide in such cases, be able to contact them rapidly, and provide any instructions that their RCCs may need in this regard, including how to alert and involve appropriate national authorities. States should ensure that their response mechanisms are sufficiently broad to account for the full range of State responsibilities. (IMO 2004c, § 6.21)

The IMO has adopted specific measures for passenger ships. For instance, SOLAS Regulation V/7.3 adopted guidelines concerning additional exchange of information between these ships and interested coastal states before and during the passage of the vessel in certain areas (IMO 2003, 2006) and recommended the adoption of a more complete voyage passage plan for these vessels, compared to the "standard" documents required by the IMO Guidelines for Voyage Planning (IMO 1999, 2007). In addition, with regard to navigation in polar regions, the Polar Code offers a further tool to prevent accidents (Polar Code 2014/15). However, the impression remains that the existing rules and standards are limited in scope and unsatisfactory and that additional or improved solutions should be considered.

4.4 Tackling the Present SAR Challenges

Having briefly summarized how the SAR Convention works and what is required by contracting states for implementing its provisions, it is now relevant to consider the existence of cooperation schemes among neighbouring states to enhance the network of assets capable of offering organization, coordination or implementation of

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[12] Reference can be made to the IMO Basic Safety Guidance for Yacht Races or Oceanic Voyages by Non-Regulated Craft (IMO 2012), whose application is limited to the case of yacht races and oceanic voyages. But see note 14 above and the potential of Polar Code "Phase II".

SAR activities. Indeed, these cooperation schemes are in place in different sea areas, for instance, the agreement in place among Arctic Council members (Arctic Council 2011). As far as the Mediterranean is concerned, Italy, France and Spain have entered into a technical agreement (SARMEDOCC) for SAR of airplanes in distress (European Commission 2017). Bilateral agreements also exist between Mediterranean countries, such as the Italy-Croatia treaty for SAR in the Adriatic Sea. In general, these agreements provide for the establishment of joint operations to improve performance. These arrangements in the Mediterranean area and the Arctic are explored further below.

4.4.1 A Holistic Approach to SAR in the Mediterranean

Currently, SAR in the Mediterranean is largely a by-product of migrations. Shortcomings and tension have arisen when rescue of migrants has been dealt with exclusively using traditional SAR instruments. It has become clear that new approaches and solutions are needed. Since safety of human life in the Mediterranean is no longer a pure maritime affair, the matter is no longer confined to maritime law or law of the sea. Other sectors of law and policy come into play, such as immigration and refugee law, human rights and humanitarian law, criminal law, foreign and external policies, the fight against transnational criminality and terrorism, and national security.

For the European Union (EU), the changing legal environment for saving lives in the Mediterranean area is confirmed by the fact that the problems arising out of movement of persons at sea are no longer governed by autonomous legal instruments and implementing measures, and by no means are they exclusively maritime in nature. Rather, they are treated within a catch-all programme that was strengthened in June 2018 through the EU Maritime Security Strategy (EUMSS) Action Plan revision by the EU Council (i.e., the member states' governmental representatives) (Council of the European Union 2018).

The EUMSS Action Plan pulls together various EU policies and law, *inter alia*, the Common Security and Defence Policy; the EU Global Strategy and the Internal Security Strategy 2015–2020; maritime multilateralism and rule of law on the sea; cooperation with the United Nations, the IMO, the North Atlantic Treaty Organization, the Association of Southeast Asian Nations and other international organizations; information sharing on maritime security and surveillance, as per the EUCISE Project 2020; and mobilization of all financial facilities existing at the EU level (Council of the European Union 2018; Schiano di Pepe 2019; Ippolito and Trevisanut 2015). The ultimate goal of this new approach is to implement multipurpose surveillance of the seas that is capable of contemporaneously satisfying different, but converging, policy and legal priorities. While safety at sea and SAR are still implemented, they are only a portion of the much more encompassing policies and programmes involving "actors" and institutions beyond the SAR contracting parties and their maritime administrations. In this vein, new alliances and cooperation schemes are expected; partnerships are no longer (exclusively) between coast guards. Navies, other military forces, the European Border and Coast Guard Agency (EBCGA, formerly known as Frontex) and NATO are also participating. The modalities of SAR have changed, and the traditional agreements with neighbouring states have lost their importance vis-à-vis other forms of cooperation involving prevention of human trafficking and assistance by land-locked states where migration flows originate and satellite observations through the multipurpose Copernicus programme (European Commission n.d.). This improved strategy for coping with a "non-traditional" SAR problem suggests that there is a need and an opportunity to evaluate new legal and policy instruments in other areas of "new" SAR circumstances.

4.4.2 SAR in the Arctic Region

The example of migration in the Mediterranean can help us advance evaluation of proposals for coping with navigation in the Arctic. Of course, there are substantial differences between the two regions, but similarities exist and an analogous methodological approach might be considered. The main similarity has to do with an altered relationship between the coastal state and persons on board vessels in distress.

Arctic coastal states do not enjoy substantial benefits from international navigation in the Arctic; on the contrary, ships encroaching these delicate waters threaten both the environment and coastal communities (Anderson 2012). These threats can be justified when vessel traffic is domestic, but not when it is international. Merchant vessels considering the "trans-Arctic" use of the Northwest or Northeast Passage seek to save time and money to transport goods to destinations beyond the coastal Arctic states. Similarly, yachtsmen and cruise ships venturing into the Arctic do not serve any specific need of coastal residents. In fact, these vessels cause a free-riding problem, exploiting the reduced length of their voyage and enjoying the magnificent beauty of the Arctic without providing many advantages to the affected coastal states and people.

Whether commercial vessel traffic, yachtsmen, cruise ships or migrants by sea, neither solidarity nor reciprocity can be expected to play any role as far as SAR in the Arctic is concerned: the rationale of the SAR Convention obligations is thus not met. The business reasons for international navigation in the Arctic are the push factor for much traffic in this region; like in the case of migrants by sea, certainly merchant vessels would prefer a less risky alternative than polar navigation, if such an alternative would reduce voyage time as well. However, in general, commercial vessels in Arctic waters are crewed by experienced seafarers, which allows for the establishment of legal frameworks to regulate navigation in these remote areas.

Such being the background, it seems that a disproportionate and non-equitable burden for coastal states arises with respect to setting up and maintaining operations of an SRR in the Arctic vis-à-vis this new vessel traffic: "classical" SAR operations meant patrolling Arctic coasts for the benefit of coastal navigators and sporadic fishermen venturing in these waters for work reasons, but not much more. If this is true, it is appropriate to evaluate whether the current SAR schemes should be accompanied by other measures, along the lines of the holistic approach that is being pursued in the Mediterranean to cope with migration by sea.

Aside from the precautionary measures set out in the Polar Code (which is, however, limited to merchant ships), a first solution to be considered is the establishment of specific corridors for navigation in the Arctic, already anticipated in Canadian waters (Brooks 2018; Abou Absii 2018). This would limit the freedom of the seas, but would ensure more efficient SAR services and limit environmental risks. Such corridors might be the first step towards more ambitious goals to reduce or exclude altogether leisure or merchant navigation in some waters in order to preserve and protect delicate areas from human intrusion. From this viewpoint, it can hardly be contested that navigational constraints also can be imposed at the international level when the environment is at risk (Schiano di Pepe 2007). Such limitations are also in conformity with Article 25 of the UN Declaration on Rights of the Indigenous People (UNDRIP 2007; Idlout 2018).

A second focus should be on how to avoid the free-riding problem. While coastal states can be required to organize their SRR under equitable and reciprocal conditions with all contracting parties to the SAR Convention (or with regional agreements implementing it), the situation seems different when considering the extreme conditions of navigation that are willingly accepted by commercial vessels venturing into polar waters. In this case, coastal states should be somehow compensated for their increased efforts. Perhaps navigation should be conditional on ensuring that adequate economic or financial securities are put in place before passage through polar waters and that there is a contribution to the coastal state(s) providing SAR services. Both measures would require amendments to the SAR Convention; however, these amendments seem to be in line with the evolution of the current situation and with the changing patterns of SAR outlined above. At the least, requiring financial securities would satisfy other paramount needs such as environmental protection. For example, following the grounding of the *Clipper Adventurer* (TSBC 2012), the shipowner was ordered to reimburse the Canadian government for the costs and expenses incurred in dealing with the environmental damages. The Federal Court rejected the shipowner's claim to be reimbursed for alleged lack of information provided for by Canadian authorities.[13]

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[13] The Court of Appeals established that "[t]he Clipper Adventurer was the author of her own misfortune by recklessly proceeding at excessive speed in largely unknown waters" (Ryan 2018).

4.5 Conclusion

In maritime law and the international law of the sea, upgrading of international instruments is frequent, and an update of the SAR Convention to better cope with the new perils at sea should be carefully considered by lawyers and policy-makers. As long as we are not able to control and limit apparently unbeatable market forces, law should at least restore the balance of interests that – as shown – initially founded the international SAR regime.

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Chapter 5
Unmanned Remotely Operated Search and Rescue Ships in the Canadian Arctic: Exploring the Opportunities, Risk Dimensions and Governance Implications

Jinho Yoo, Floris Goerlandt, and Aldo Chircop

Abstract This chapter is a proactive risk exploration of hypothetical remotely operated search and rescue (SAR) ships in the Canadian Arctic. The harsh and remote environment in the region, combined with complicated coastlines and many uncharted or poorly charted traffic routes, makes it one of the most challenging SAR areas. Canada has committed itself to safety, environmental protection and sovereign presence in the area by maintaining joint SAR centres of federal government departments and mobilizing private volunteers. The characteristics of Canadian SAR response in the Arctic rest with its high dependency on heavy equipment such as aircraft, helicopters and icebreakers, entailing prolonged hours of response time. As recent climate change impacts and maritime traffic increase in the northern waters disclose safety gaps, innovation in SAR assets is anticipated. The safety gaps may be filled by state-of-the-art remote control technology. This chapter discusses remotely operated unmanned ships for SAR response, exploring their opportunities, risk dimensions and governance implications.

Keywords Canadian Arctic · Governance · Risk management · Risk prevention measures · Remotely operated search and rescue ships · Unmanned ships

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5.1 Introduction

Could we imagine a ship remotely controlled from a distance of 8000 km? This long-distance test has been successfully passed, and a vessel-borne sensor with machine learning has advanced to identify the brand name of beer cans in the water (Wärtsilä 2017; Baraniuk 2017). The *Yara Birkeland*, an 80 m-long autonomous cargo ship, is expected to be in service within a few years (Baraniuk 2017). Notably in May 2019, the first-ever remotely controlled cargo ship completed a 22 h-long voyage between the United Kingdom and Belgium with a maximum payload capacity of 2.5 tonnes (Amos 2019).

Drones have been tested in the Canadian Arctic for safety monitoring since the first remote trial at Alma, Quebec, in June 2017 (Transport Canada 2018). One Australian drone successfully searched and rescued persons at sea by dropping an inflatable life raft (Haddou-Riffi 2018). In line with these technical innovations, in May 2018, the International Maritime Organization (IMO) coined a new term, maritime autonomous surface ships (MASS), to describe these new technologies. MASS were categorized into four stages: (1) manual operation with automated processes and decision support, (2) manned remotely controlled ships, (3) unmanned remotely controlled ships and (4) fully autonomous ships (IMO 2018a).

Given the limitations of the present SAR response time (Chase 2013) and the safety risks to SAR responders in the Arctic, the authors anticipate the third stage of unmanned remotely controlled ships to be able to play a potential role as a breakthrough in SAR response. In particular, in parallel with the recent improvements of multitier communication systems, unmanned and remotely operated SAR ships (RO-SARS) could open a new phase of SAR operations, assisted by a tailored design for rescue operation in the Canadian Arctic. Considering wind, current and wave height effects, a preliminary conceptual design can feature a high-speed craft (HSC) of 24 m or more with a capacity of at least 12 passengers.

However, despite the probable benefits, unmanned RO-SARS would also face novel risks, raising safety concerns to various stakeholders (Aven and Renn 2010). This chapter aims at exploring the opportunities, risk dimensions and governance implications of unmanned RO-SARS in the Canadian Arctic context from the socio-technical and legal perspectives. The discussion is guided by two research questions. First, given the Canadian northern SAR context, what opportunities and risk dimensions are anticipated if and when unmanned RO-SARS are deployed? Second, what governance implications and risk prevention measures can be drawn, considering preliminary risk assessment of RO-SARS under the International Risk Governance Council (IRGC) framework? The outcome of this exploratory analysis will likely contribute to developing a conceptual design, risk characterization and regulatory model of RO-SARS in later research.

5.2 SAR in the Canadian Arctic Context

The International Convention on Maritime Search and Rescue, 1979 (SAR Convention), defines “search” as “an operation … to *locate* persons in distress” and “rescue” as “an operation to *retrieve* persons in distress, provide for their initial *medical* or other needs, and *deliver* them to a place of safety” (SAR Convention 1979, Annex, chap 1). These definitions are overarching principles in designing, manufacturing and operating RO-SARS.

5.2.1 *Navigational Complexity and Uncertainty in the Canadian Arctic*

The Canadian Arctic, and in particular the Northwest Passage (NWP), which extends 1450 km, is a uniquely complex navigational area consisting of multiple routes as shown in Fig. 5.1. Its characteristics include a combination of (1) a huge geographical area accounting for 40% of Canada’s land mass (Esri n.d.); (2) an extensive and complicated coastline with landfast ice in many areas; (3) an estimated 50,000 giant icebergs as well as drifting ice accompanied by strong winds,

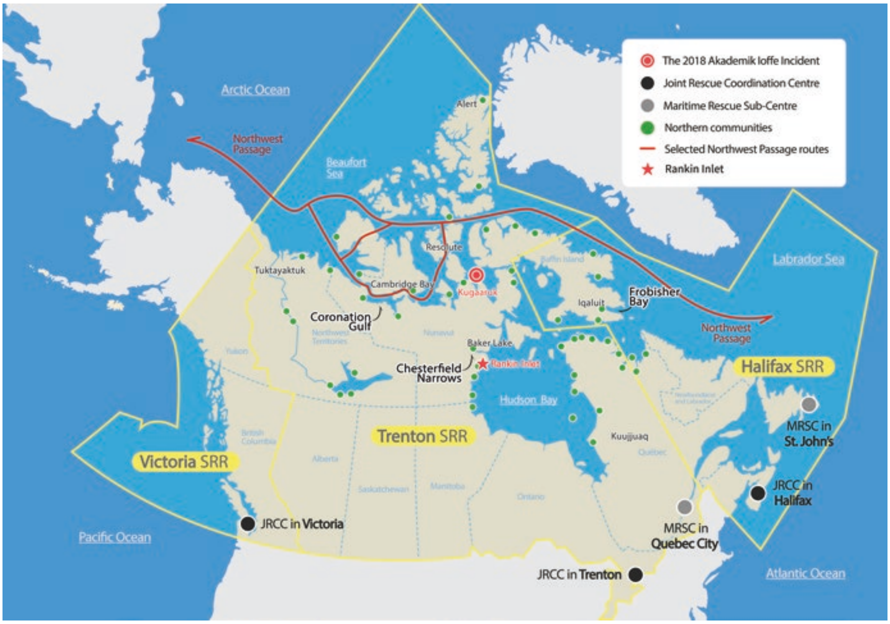

Fig. 5.1 SAR centres in the Canadian Arctic and the 2018 *Akademik Ioffe* incident (Office of the Auditor General of Canada 2013, 2014)

spray, fog and waves (Esri n.d.; Arctic Council 2009); (4) complicated sea routes through an archipelago consisting of over 90 major and 36,400 minor islands (World Atlas 2018); (5) the fact that only 10 per cent of the routes are considered adequately charted, although in some areas this figure has improved through recent surveys (Struzik 2018); (6) a complete lack of ports with any significant infrastructure; and (7) scarce emergency infrastructure for fuel, spare resources and trained personnel.

Most importantly, the Canadian Arctic is not only fundamental to Canada's national identity but is the homeland of Indigenous peoples across the Yukon, the Northwest Territories and Nunavut. Canada has maritime boundary disputes and incomplete boundaries with the United States in the Beaufort Sea and Denmark in the Lincoln Sea (Government of Canada 2010). Most significantly, under international law, Canada claims a historic title to the waters of the Canadian Arctic archipelago over which it exercises sovereignty (Chircop et al. 2018). Shipping in the archipelagic waters and the territorial sea and the exclusive economic zone seaward of the straight baselines enclosing the archipelago is governed by stringent national law, most especially the Arctic Waters Pollution Prevention Act, 1970 (AWPPA), its regulations and the regulations under the Canada Shipping Act, 2001 (Fisheries and Oceans Canada 2009; Chircop et al. 2018).

5.2.2 Multilevel Canadian SAR Resources in the Context of Increasing Demand

Canadian Arctic SAR is based on shared responsibilities of federal, territorial and municipal governments, as well as Indigenous communities, volunteers and commercial sectors (Senate of Canada 2018). SAR response entails reliance on heavy equipment, such as the dedicated 35 SAR aircraft (e.g., 17 fixed-wing and 18 rotary) operated by the Royal Canadian Air Force (2018), the 23 helicopters operated by the Canadian Coast Guard (2016) and the 15 icebreakers of the Canadian Coast Guard (2019) (Fisheries and Oceans Canada 2009; Senate of Canada 2018; Canadian Coast Guard 2019). These resources are mostly deployed in the three Joint Rescue Coordination Centres (JRCCs) and two Maritime Rescue Sub-Centres run by Canada's Department of National Defence and the Canadian Coast Guard (CCG) (part of Fisheries and Oceans Canada) (Fig. 5.1). Volunteer SAR organizations include the Canadian Coast Guard Auxiliary with about 4000 volunteers and 1100 vessels across 16 bases in the Arctic; the Civil Air Search and Rescue Association (CASARA); and the Search and Rescue Volunteer Association of Canada (SARVAC) (Office of the Auditor General of Canada 2013). Commercial vessel operators, such as Fednav and Groupe Desgagnés, have also provided assistance.

Although these SAR resources appear to be considerable, the increased SAR demands in the northern region are presumed to exceed existing capabilities. The SAR resources are expected to cover both land and sea areas. Covering 18 million km^2 of land and water, in 2017 the three JRCCs responded to about 10,000 air, marine and humanitarian incidents. Each JRCC addresses approximately 3000 incidents every year (Senate of Canada 2018; Office of the Auditor General of Canada 2013). Over 500 SAR missions were completed in the Canadian Arctic for the last 5 years immediately preceding 2019, compared with the yearly average of 29.3 accidents and incidents in the entire Arctic between 1995 and 2004 (Ward 2019; Arctic Council 2009).

In 2018, a CCG Arctic base was established in Rankin Inlet as part of Canada's Arctic strategy to involve 14 northern Indigenous communities in SAR operations (Government of Canada 2009; Crown-Indigenous Relations and Northern Affairs Canada 2019). The Rankin Inlet Inshore Rescue Boat station in Nunavut will provide maritime SAR support during the summer season and will be crewed by Indigenous peoples trained by the Canadian Coast Guard (Canadian Coast Guard 2019).

5.3 Opportunities of RO-SARS

5.3.1 Increasing Vessel Traffic and Precursors of Arctic Accidents

The number of ship voyages to the Canadian Arctic increased from 123 in the year 2005 to 347 in 2016, including 147 voyages for cargo ships, 131 fishing vessels and 20 cruise/passenger ships (Lasserre 2018). Furthermore, there were 6036 cruise passengers in 2016, compared with 1239 in 2005 (Lasserre 2018). In 2017 alone, 178 vessels made about 400 visits to the Arctic including 32 transits through the NWP (LeBlanc 2018a).

Although there have not been massive fatalities in Northern Canada since the 1990s, some incidents could serve as precursors of disasters in the near future, such as the *Hanseatic* which ran aground with 149 passengers on board in 1996, the *Clipper Adventurer* which hit underwater ledges with 128 passengers in 2010 (TSBC 2012) and the *Akademik Ioffe* with 126 passengers, which was grounded in 2018 (Fig. 5.1) (TSBC 2019). It is plausible to assume that in case of more traffic entering the Arctic, the number of incidents will also increase. The year 2017 saw 71 marine incidents in the entire Arctic, up 29% year-on-year, with 29 total losses in the Russian Arctic and Bering Sea between 2008 and 2017 (Allianz 2018). Accordingly, it is reasonable to prepare for machinery damage and failure when navigating the Canadian Arctic, the conventional biggest cause of incidents in the region (Arctic Council 2009).

5.3.2 Limitations of the Canadian Arctic SAR Response

Regardless of multilevel SAR resources, geographical remoteness and a complete lack of ports have created inherent limitations to the response time in the Canadian Arctic in the sense that how fast a response can be made depends on how close assets are located (Struzik 2018). Most importantly, the fact that all the JRCCs are located at the far south of the country (Fig. 5.1) has caused the average response time to be about 10 h under average ice conditions during the navigation season (Dalaklis 2019). In the *Akademik Ioffe* incident in 2018, the SAR flight took 9 h from the JRCC in Trenton, Ontario, to the grounding site (Fig. 5.1) (TSBC 2019; Struzik 2018). Similarly, SAR ships could take days to arrive at a site and rescue people (e.g., *Hanseatic* incident) due to the vast area and because the average speed of vessels on Arctic routes is known to be around 7 to 13 knots, compared with 21 to 25 knots in open sea (Plass et al. 2015). The number of people who can be delivered by helicopter is also extremely limited and helicopters need frequent refuelling stops.

Safety gaps and emerging risks have been mentioned at the federal level because of multifarious challenges: (1) the limited hydrographic survey and nautical charting of marine routes, (2) "dead zones" of radio communications, (3) the lack of trained SAR personnel, (4) ageing equipment, (5) insufficient icebreaking services, (6) the lack of land base connectivity through fibre optics, (7) the low bandwidth of satellite communications and (8) prolonged SAR time (Office of the Auditor General of Canada 2013, 2014; LeBlanc 2018a, b; Brown 2018). Given the financial burden of SAR amounting to over CAD 136.9 million (Canadian Coast Guard 2018), adding more aircraft, helicopters and icebreakers will not be a continuous and sustainable answer. Technical innovation in SAR is required.

5.3.3 The Changing SAR Technology: Remote Control and Unmanned RO-SARS

5.3.3.1 Communication Links Under Innovative Improvement

There have been multitier and hybrid approaches to improving marine communication technologies. Figure 5.2 provides a visual impression of some of these technologies: low earth orbit satellite services by 2022 (LeBlanc 2018b); Enhanced Satellite Communication Project, Polar (ESCP-P) (National Defence 2019); nano satellite and microsatellites called the "Gray Jay Pathfinder" (University of Toronto 2019; Boucher 2019; Cho 2019); and terrestrial systems by fibre-optic cables extending to the northern areas (Nuvitik Communications 2018). These developments are believed to gradually contribute to paving innovative foundations for effective SAR communication and response. For example, in May 2019, Canada

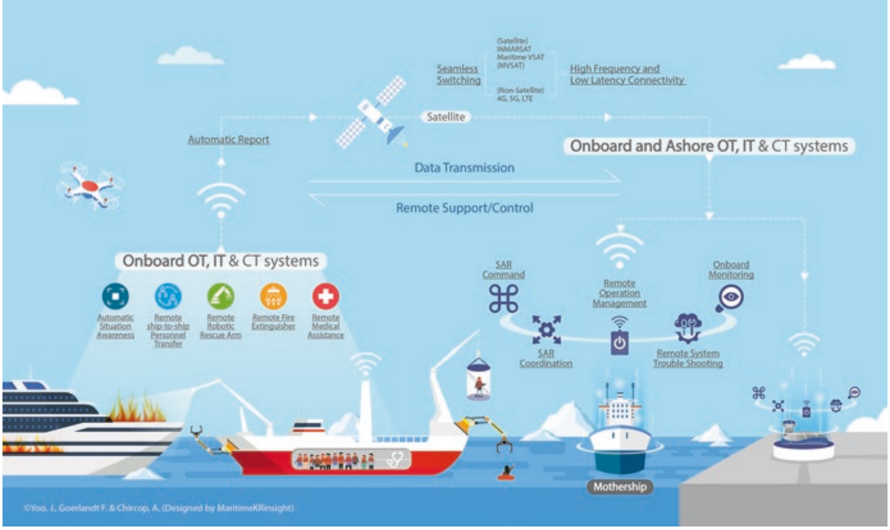

Fig. 5.2 Preliminary system concepts of RO-SARS (the authors' original concepts)

opened the Marine Communication and Traffic Services Centre (MCTS) in Iqaluit, which provided assistance to 112 public and private vessels in the Northern Canada Vessel Traffic Services Zone (NORDREG) between 15 May and 31 July 2019 (Canadian Coast Guard 2019).

5.3.3.2 Remote Control Technology and Unmanned RO-SARS

Among enabling communication technologies, drones are surfacing as an effective tool to *search* in the Canadian Arctic, saving a significant share of the CAD 14,000 per hour needed for the operation of C130 Hercules aircraft. Drones may be equipped with thermal imaging devices, audio transmitter/receivers and emergency supplies payloads and are capable of streaming real-time images to a control centre (Ward 2019). In addition, unmanned RO-SARS could be a game changer in *rescue* operations, being equipped with a remote ship-to-ship personnel transfer crane, a robotic rescue arm to save people from the water, a remote fire extinguisher and a remote medical assistance service system.

On the deployment of RO-SARS in northern communities, JRCCs, and other stations, safety risks to SAR personnel would be eliminated; the response time would be accelerated; and cost-efficiency compared with icebreakers, aircraft and helicopters would be enhanced. Furthermore, a complementary solution would be provided to the otherwise insufficient SAR infrastructure, a lack of trained personnel, many uncharted areas and ageing equipment.

5.4 Risk Dimensions of RO-SARS in the Canadian Arctic

5.4.1 Pre-assessment of Risks

Given that technology is strongly associated with risk, it should be noted that a technology-led society could turn into a risk-susceptible society (United Nations 2017). Technology-driven risks could increase when *organized irresponsibility* begins to take advantage of unclear boundaries between ethics, law and technology (Beck 1999; FTI Consulting 2018). Modern risk society features the paradoxical coexistence of economic progress and increased risk, as well as unintended consequences and hidden risks between systems (Jarvis 2007; Renn et al. 2011). Accordingly, more attention should be paid to neighbouring risk components and an adaptive and integrative risk governance combining top-down and bottom-up approaches (Renn et al. 2011). In the maritime domain, risk is commonly defined as the probability of a defined hazard and the severity of its consequences (IMO 2018b). However, risk has been getting more complicated and uncertain in the maritime sector due to increasingly interconnected sociotechnical issues and related governance concerns. As such, the importance of explicitly and systematically considering uncertainties in the risk characterization has been stressed in recent years (Goerlandt and Reniers 2018).

As there are no unmanned RO-SARS in service in the Canadian Arctic at this time, the probability and severity of accidents are unknown. However, the expected minimum functional components could allow the pre-assessment of risks by exploring risk dimensions that could function as problem-framing, early warning and risk screening under the IRGC risk framework (Renn et al. 2011). This pre-assessment is based upon pre-existing maritime regulatory regimes, sociotechnical systems of ships and seafarers, the present stage of remote technology and the status of Canada's SAR response. The functional heterogeneity of unmanned RO-SARS shown in Fig. 5.2 will likely define the nature of risks as systemic under the IRGC risk framework, meaning a risk of a high degree of complexity and uncertainty (Renn et al. 2011).

5.4.2 Five Risk Dimensions to and from RO-SARS

5.4.2.1 Legality as a Threshold Issue

A potential concern with the deployment of RO-SARS vessels is their legal status. Canadian maritime law takes a broad definition of a ship in terms of navigability and a shipowner's intent to use it as a ship (CSA 2001, s 2; Thibeault v. Canada 2015 FC 162). Unmanned and remotely operated submersibles have been considered as ships by Canadian courts (Cyber Sea Technologies Inc v. Underwater Harvester Remotely Operated Vehicle 2002 FCT 794). As such, it will not be difficult to have unmanned RO-SARS recognized as ships under Canadian maritime law with the usual consequences for safety, security, environment protection, insurability and liability. IMO has also defined MASS as a ship (IMO 2018b), and this characterization can thus be extended to unmanned RO-SARS. Again, the consequence of this definition is to bring MASS within the regulatory domains of international maritime safety, pollution prevention and security standards.

A further concern is whether the absence of a crew on board a SAR vessel might raise an issue of legality under the international law of the sea and international maritime law. The literature has explored possible solutions (Chircop 2017; Yoo and Shan 2019; IMO 2018c; Karlis 2018), which include amending regulatory provisions requiring seafarer presence on board, resorting to constructive treaty interpretation under the Vienna Convention on the Law of Treaties (VCLT 1969, art 61) or introducing new technology exemptions or equivalency under the International Convention for the Safety of Life at Sea (SOLAS) Convention (SOLAS 1974, regs I/4(b) and I/5). The effect of these solutions is to extend, to the extent appropriate, the full range of international rules and standards to MASS.

5.4.2.2 The Human Element in Seaworthiness

As in the case of all other ships, SAR vessels are required to be seaworthy. Pursuant to the definition of seaworthiness under the Canadian maritime law (Laing v. Boreal Pacific 2000 CanLII 16,313), RO-SARS as a ship should be reasonably fit in all respects, including SAR operations, to encounter the ordinary perils of the Canadian Arctic. "All respects" can be rephrased as the human and technical aspect of seaworthiness, which is a central principle in maritime law, to ensure the safety of ships under Article 94 of the United Nations Convention on the Law of the Sea (UNCLOS 1982).

The human element in seaworthiness emphasizes the role of a master and crew (SOLAS 1974, regs V/34–1; CSA 2001, s 109(1); Marine Personnel Regulations, s 215, 216). In particular, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 1978, Annex, chaps II and III) sets mandatory minimum qualification standards for masters, officers and watch personnel. With respect to RO-SARS, the assets deployed will not be crewed but will be operated by an onshore team or operators on board motherships. SAR remote controllers will be required to exercise command skills and make tough decisions in a SAR value chain (Aase and Jabour 2015), but without having the benefit of at-sea situational awareness. Because irreparable consequences could occur by any failure of remote controllers on a real-time basis to understand, direct and cooperate with people and ships in distress and other SAR units, it is imperative that remote controllers are appropriately qualified according to generally accepted training standards (Schmied et al. 2017). Among other things, remote controllers will have to be familiar with Volume III of the International Aeronautical and Maritime Search and Rescue Manual, 2000, as amended (IMO 2019). Moreover, remote controllers should be conversant with the rules of the road and ice navigation because 70% of navigational negligence worldwide is attributable to the violation of the rules of steering and sailing (Maritime News 2019). Indeed, remote technology and the human element are inseparable (Rothblum 2000), and it will be necessary to establish uniform standards for SAR remote controllers and simulator-based remote SAR training programs.

5.4.2.3 The Technical Element of Seaworthiness

Seaworthiness of unmanned RO-SARS should be verified for reliability of interconnectivity and interoperability between operation technology (OT) (e.g., sensors and software of situation awareness), information technology (IT) (e.g., data collection, storage and analysis) and communication technology (CT) (e.g., satellite and terrestrial communication systems) in Canadian Arctic operations. Any failure of these technical components of RO-SARS could cause serious and unanticipated hazards to the safety of the SAR operation. In addition to hull structure, engines, machinery, electrical systems and conventional ship equipment, special attention will need to be paid to remote technical elements, including sensor technology, communication links, cyber safety and cybersecurity, and the interface between RO-SARS and remote controllers. Each of these four elements is discussed immediately below. More significantly, practical rescue functionality should be added to the conceptual design of RO-SARS. After all, human and technical elements of RO-SARS will have to prove that their reliability is as capable as the ordinary practice of conventional maritime rescue responders in the Arctic (c.f., Yoo et al. 2019).

A sensor is a device that responds to biological, chemical or physical stimulus such as heat, light, sound and pressure, providing a measured response of the observed stimulus (ISO 2011). Sensor function is critical for situation awareness in a SAR operation. It is enabled by the collection and integration of information from on-board sensors (e.g., heat, sonar and sound detection sensors), cameras and the automatic identification system (AIS) through satellites (Perera and Murray 2019). Even the lookout requirement under the International Regulations for Preventing Collisions at Sea (COLREG) (COLREG 1972, rule 5) is expected to be fulfilled by sensor technology (Lloyd's Register 2017 Code, chap 4, s 4.1.5; Bruhn et al. 2014). However, the quality of data collected through sensors could be compromised by fog, rain, temperature, wind, freezing or harsh weather, which makes the resilience of sensor functions important when breakdowns occur (Bruhn et al. 2014; Lim 2019). As such, a system with a fail-safe design or sensor fusion has been suggested (Kim 2017).

The very recent development of communications technology and government efforts to improve coverage are enablers for unmanned RO-SARS in Canada's Arctic. Even if sensor technology functions well, the data created from the sensors must be seamlessly transmitted to remote controllers as pictured in Fig. 5.2. For this to function effectively, RO-SARS will likely rely on a combination of multitier and hybrid satellites and terrestrial communications for ship-to-ship and ship-to-ashore data exchange (Aase and Jabour 2015). This combination will allow remote controllers to perform remote SAR operations (Fig. 5.2).

In 2017 the ransomware called "NotPetya" attacked the Maersk shipping line's central computer system, halting operations at 76 port terminals and costing the shipowner about USD 300 million (Thomson 2017). Cyber incidents can be defined as an occurrence that results in adverse consequences to the entire OT, IT and CT of a ship and its related systems. For example, a virus could corrupt chart data held in an electronic chart display and information system (i.e., cybersecurity), and software controlling engines may malfunction due to a lack of compatibility with upgraded software (i.e., cyber safety) (Jorgensen 2018). Vulnerability may exist in virtual reality bridges, remote control centres and other communication systems. Accordingly, there needs to be stringent testing and certification of system safety and security, access control, security control, penetration testing and adoption of best practices for the protection of OT, IT and CT systems (Woo and Kim 2018; Bureau Veritas 2017, s 1, ss 2.6.2). In addition, a system of attack-safety will be necessary (Kim 2017). Recently, the IMO amended the requirements for an approved safety management system under the International Safety Management (ISM) Code (IMO 1993) to take into account cyber risk management (IMO 2017).

The work scope of SAR remote controllers will not be simple but will be comprehensive so as to include controlling, navigating, monitoring, searching and rescuing. These multifarious functions will require an ergonomic design of the physical and psychological work environment in remote control centres ashore or in motherships. Most importantly, a ship safety management system for RO-SARS and personnel ashore should be put in place as enjoined under the ISM Code (SOLAS 1974, chap 9), because there should be a strong link between the hazards of the actual operations of RO-SARS and the specific design of the safety management system (Valdez Banda et al. 2019).

5.4.2.4 Interaction with Ships in Distress and Other SAR Units

One probable concern of the stakeholders would be the interaction among remote controllers, ships in distress and other SAR units. First, to increase communication links, remote controllers and remote control centres could be stationed in motherships, northern communities or JRCCs (Fig. 5.2). Second, the operation of RO-SARS should be coordinated on-scene to ensure the most effective results with other SAR units engaged (SAR Convention 1979, Annex, chap 4, art 4.7). Third, to maximize the SAR performance and minimize communication error, remote controllers should be better trained and an experienced SAR personnel. Finally, for safer interplay with ships in distress and other SAR units, adaptive dynamic positioning (Witkowska and Śmierzchalski 2018), safe routeing systems (Lehtola et al. 2019), collision avoidance systems (Ozturk and Cicek 2019) and cooperative control algorithms (Almeida et al. 2010) are expected to be useful to RO-SARS.

5.4.2.5 Effective Design of RO-SARS

Finally, it is the design of unmanned RO-SARS that enables the rescue of people from waves, freezing temperatures and floating ice. At the design stage, depending on the nature of the voyages, the preliminary length of 24 m or more may entail meeting the requirements of the International Convention on Load Lines (ICLL 1966, Annex A, art 5). Further, having the capacity to carry more than 12 passengers will require RO-SARS of 15 tonnage or less to hold a "passenger vessel safety certificate" issued under the Vessel Certificates Regulations (2007, ss 3, 9, 10). As SOLAS defines a passenger ship to be a vessel carrying more than 12 passengers (SOLAS 1974, regs I/2 and II-1/1), the design of RO-SARS for an international voyage will have to factor in the requirements of SOLAS. Most importantly, an effective feasibility study on design should be made with respect to a ship-to-ship personnel transfer cranes, a robotic rescue arm to deliver people out of water, remote fire extinguishers and remote medical assistance. The authors of this chapter presume that unmanned RO-SARS could contribute to SAR response more likely with respect to *rescue* operations in coordination with other search equipment such as drones, satellites and aircraft. A further risk assessment of the conceptual design of RO-SARS should be made considering rescue-focused functionality, proper power systems for fast navigation comparable to a high-speed craft, energy sources available in the northern communities, the proper size and length of the asset for delivery of more than 12 persons, a reversionary mode of partly autonomous operation in communication dead zones and structural strength resistant to floating ice and heavy winds (Lee 2018).

5.4.3 Summary

Given the five risk dimensions of RO-SARS, most aspects of risk dimensions, except the risk of legality, are contingent upon sociotechnical developments and technical decisions. This complexity and uncertainty makes it difficult to characterize the risk of RO-SARS as being tolerable or not under the IRGC risk framework. Regardless, this problem-framing could at least serve as an early warning and as a basis for specifying design requirements. Moreover, the advantages of RO-SARS, especially in actual rescue operations, will not be easily outweighed by these risk dimensions. Adaptive designs of unmanned RO-SARS and standardization of operation will likely serve as an innovative solution to lagging SAR response time.

5.5 Governance Implications

Given the complexity and uncertainty of unmanned RO-SARS in the Canadian Arctic context, this risk-reducing SAR response mechanism necessitates close collaboration between multilevel governance systems ranging from international regulatory bodies to national institutions, to Indigenous peoples and to private volunteers (Renn et al. 2011). The human and technical risks of RO-SARS in Canadian Arctic waters will be controlled and managed by international and domestic regulatory regimes and include the engagement of Indigenous rights-holders and public and private stakeholders. In the near future, concern assessment and risk communication with rights-holders and stakeholders under the IRGC risk framework will be also needed.

5.5.1 RO-SAR and International Conventions

Under Article 98 of UNCLOS, every state is obliged to require ships registered under its flag to render assistance to people and ships in danger, and every coastal state has a duty to promote the provision of infrastructure for adequate SAR services, emphasizing mutual regional arrangements between coastal states and neighbouring states. In the same vein, the SAR Convention also requires rescue coordination centres to be established by states (SAR Convention 1979, Annex, chap 2.3). Moreover, the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (Arctic SAR Agreement), to which Canada is a party, obligates states parties to implement the most expeditious border crossing procedures and establishes a legally binding duty of cooperation, including mutual SAR cooperation (Arctic Council 2011, arts 8, 9). Cooperation encompasses information exchange including available SAR facilities and lists of available supply infrastructure (Arctic Portal 2011). The Agreement is intended to enhance the cross-boundary mobility of SAR assets. Accordingly, the regional development and deployment of RO-SARS could be seen as supporting states parties' duties under UNCLOS, the SAR Convention and the Arctic SAR Agreement.

5.5.2 Multilayered Regulatory Regimes Applicable to RO-SARS

Besides the existence of an international SAR regulatory regime to which Canada is a party, RO-SARS deployed in and navigating the Canadian Arctic will also be governed by Canadian maritime law concerning registration, safety, security, environmental protection, insurability, tort and liability as they will likely be defined as a ship under Canadian maritime law. As "naval auxiliaries and other ships owned or operated by" government and "used only on government non-commercial service" are not bound by the safety of navigation regulations under SOLAS (SOLAS 1974, reg V/1), the safe navigation of RO-SARS owned or operated by the Canadian government will be mostly governed by Canadian national law. Moreover, Section 7 of the Canada Shipping Act, 2001, also implies that RO-SARS owned by the government can avoid the Act by resorting to other new regulations and provides that

RO-SARS owned or operated by the Canadian Forces are outside of its application, as well as SOLAS and the Polar Code, which applies to ships certified under SOLAS. However, it should be noted that even state-owned RO-SARS will be subject to COLREG, which applies to all ships (COLREG 1972, rule 1). On the other hand, privately owned RO-SARS on international voyages carrying more than 12 passengers, which are more than 24 m in length, are subject to the construction, equipment and inspection requirements of SOLAS, as well as the watertight and stability requirements of ICLL (Canadian Supplement to the SOLAS Convention, s 2.1.1.1; ICLL 1966, Annex A, art 5).

5.5.3 Political and Social License from the Arctic States and Northern Communities

SAR operations in the Canadian Arctic have a probability of crossing land borders and maritime boundaries with the United States and Denmark (Greenland). Even if the federal government approves the operation of RO-SARS, other Arctic states might not welcome the novel technology in waters under their sovereignty or jurisdiction for safety and security reasons (Lee et al. 2018). Accordingly, political and social license in and between neighbouring Arctic states, territories, Indigenous peoples and northern communities is important (van der Vegt 2018). Without their support, the deployment of both RO-SARS and remote control centres in the North could face obstacles. Furthermore, for the effective governance of RO-SARS in the Canadian Arctic, the coordination among federal government departments, JRCCs, volunteer groups, northern communities and neighbouring states will be essential to obtaining full support from aeronautical, maritime and ground SAR units.

5.6 Risk Prevention Measures: Future Research Needs

Rapidly advancing remote technology for ships is poised to open new chapters for small cargo delivery (Amos 2019), oil spill response (Maritime Logistics 2019) and tugboat operations (Martine 2019), which also suggests new opportunities for SAR response in the Canadian Arctic. However, the following risk prevention measures which require further research and development are suggested because “risks are created and selected by human actors” (Renn et al. 2011).

First, a concept design for RO-SARS needs to be defined in terms of their size, length, structure, machinery and SAR functionality. Second, a more complete risk characterization should be made with regard to the technical design specification of RO-SARS, one which also accounts for stakeholder concerns and risk perceptions. Third, the Canadian government should develop uniform standards of qualification, training and certification for search and rescue remote controllers in Arctic waters (SQ-SARC) in the near future. Fourth, a prototype of RO-SARS should be repeatedly tested, inspected and surveyed through sea trials to verify their human and technical seaworthiness and effective interaction with ships in distress, other SAR units and relevant technologies, including drones. Fifth, remote controllers should be qualified, trained and licensed seafarers for SAR operation under new legal standards that would need to be developed, possibly by the IMO as well as under Canadian federal law. Sixth, stakeholders should increase multitier satellite and terrestrial supports and data transmitters so that the interconnectivity of OT, IT and CT can meet the ordinary practices of SAR responders in the Canadian Arctic. Seventh, a safety management system specifically for unmanned RO-SARS should be put in place with approved training simulators and mandatory procedures (Dasgupta 2017). Eighth, the contribution of northern communities to the practical operation of remote controllers and remote control centres is a key to the success in SAR response in the region (Ward 2019). As such, including these communities in the conception, planning and design of the centres, as well as the associated operating procedures, is highly recommended. Finally, knowledge-sharing and promotion of best practices of RO-SARS ought to be taken up by the Arctic Council through the Protection of the Arctic Marine Environment Working Group, perhaps through its Arctic Shipping Best Practice Information Forum, or the Emergency Prevention, Preparedness and Response Working Group or in collaboration with both Working Groups (Dalaklis 2019).

5.7 Conclusion

Given the Canadian Arctic context, unmanned and remotely controlled ships could considerably enhance and complement Canadian SAR capabilities, particularly rescue operations, by reducing response time, infrastructural costs and life risks to responders. However, there are complex and uncertain risks that can be identified under the IRGC risk framework: the qualification and certification of remote controllers, the technical reliability of sensor technology, the stability of communication links, the hazards arising from the breach of cyber safety and cybersecurity, the probable interface errors between RO-SARS and remote controllers and the new design requirements for remote rescue functions such as the remotely operated ship-to-ship personnel transfer crane. These risks should be addressed under multilevel governance systems comprising international and national and public and private stakeholders. Most significantly, it is clear that unmanned RO-SARS are in line with the international conventions concerning SAR operations, that there are multilayered regulatory regimes applicable to these novel ships and that these vessels and craft should gain political and social license from the Arctic states and northern communities.

Nonetheless, the risks of deploying unmanned RO-SARS in the region should not be treated as simple. These risks feature a combination of intrinsic heterogeneities such as remote technology, the SAR operation itself and the extreme environment, all of which are complex and uncertain in nature under the terms of the IRGC risk framework. Indeed, although the opportunities for RO-SARS look promising, the required technical reliability and actual SAR practicability are unproven in the Arctic context. Hence, it is premature to characterize overall risks as intolerable, tolerable or acceptable. However, the minimal exploration of the risk dimensions taken in the foregoing discussion might trigger feasibility studies and dedicated ship design approaches accounting for the different hazards originating from this novel technology concept, for which new design approaches for unmanned vessels could be applied.

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Chapter 6
Ambient Noise in the Canadian Arctic

Emmanuelle Cook, David Barclay, and Clark Richards

Abstract Numerous studies of ocean ambient noise and under-ice acoustic propagation and reverberation in the Canadian Arctic have been carried out since the 1960s. These studies, largely led by scientists at the Defence Research Establishment Pacific and Defence Research and Development Canada, have been motivated by the need to improve sonar performance prediction in the Arctic over the wide range of seasonal ice, oceanographic, and meteorological conditions at high latitudes. Aside from the valuable insight into the physics of noise generation by sea ice and sound propagation under sea ice, they provide a historical baseline for Arctic ambient noise against which modern measurements can be compared. In 2017, the Department of Fisheries and Oceans added passive acoustic monitoring to their Barrow Strait Real Time Observatory, reporting power spectral density over the acoustic band of 10–800 Hz in 2017–2018 and 10–6400 Hz in 2018–2019. Co-located measurements of ice draft, salinity, temperature, and current profiles, along with nearby meteorological measurements, provide time series of environmental forcing and conditions. An updated seasonal baseline for ambient noise in Barrow Strait is calculated and compared against historical measurements, along with a review of noise-generating mechanisms and transmission loss models in the Arctic.

Keywords Acoustic propagation · Ambient noise · Arctic soundscape · Under-ice propagation

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6.1 Introduction

The Arctic Ocean is the northernmost body of water in the world and features constant ice cover, causing temperature and salinity profiles unlike any other ocean basin. These unique profiles keep cool freshwater at the surface and, together, generate a unique sound speed profile which has a positive gradient with increasing depth causing horizontally propagating sound waves to be refracted towards the surface. This has the effect of creating a shallow sound channel, shown in Fig. 6.1, allowing sound to travel great distances where the primary loss mechanism is due to the sea ice itself (Hutt 2012).

Ice cover also makes the Arctic Ocean difficult to access. However, the low levels of anthropogenic noise make it ideal for studying the myriad of natural sound sources that contribute to underwater noise levels. With receding ice cover due to climate change, existing shipping channels are becoming accessible for greater periods of the year, and new channels will begin to open, allowing ship traffic to increase. In fact, shipping in the Arctic has tripled over the past 20 years (Giesbrecht 2018), and with this increase comes the growing concern of its effects on marine life, including the impact of ship-generated noise on the underwater soundscape (Stephenson et al. 2011).

Thus, quantifying the natural ambient noise levels of the Canadian Arctic Ocean is becoming increasingly important in order to establish a baseline for this environment. The mechanisms of natural ambient noise generation must be understood in order to accurately model and predict the background against which increasing the sounds of anthropogenic activity (noise pollution) will be added to the marine habitat. In order to model the temporal and spatial extent of both natural and human-generated noise, the transmission of underwater sound in the unique Arctic waters must be understood. Several models have proposed methods to capture the

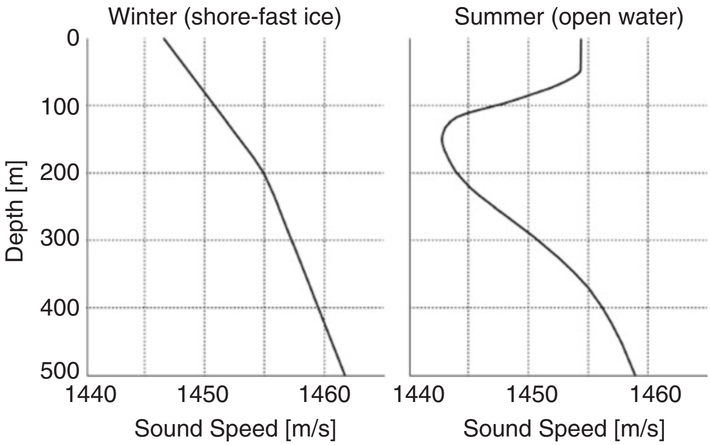

Fig. 6.1 Typical sound speed profiles in the Arctic, demonstrating the under-ice surface duct in winter and the shallow sound channel at 150 m in summer (Hutt 2012)

transmission losses associated with sea ice: shear energy conversion, rough water-ice interface scattering, and scattering and shadowing by large ice keels.

This chapter will give a brief summary on ambient noise studies that have been conducted in the Arctic with an emphasis on presenting research conducted in the Canadian Arctic. So far, studies have described a few dominant noise-generating mechanisms in the Arctic, ice combined with wind and temperature changes being the leading ones (Urick 1984; Carey and Evans 2011; Hutt 2012). Recent work on the use of permanent monitoring systems for the real-time reporting of ambient noise is presented.

6.2 Survey of Acoustic Measurements

A variety of techniques have been used for measuring ambient noise levels in the Arctic Ocean. They have ranged from single hydrophones to hydrophone arrays that are lowered from ice stations, drifting buoys, and moored or mounted to the sea floor. Experimental interest has been primarily focused on the effects of the shallow propagation channel and the rough ice surface on ambient noise properties. Consequently, measurements conducted in the Arctic have generally been made in the littoral zone (< 300 m) and over low-frequency bands (10–1000 Hz). In this section, a summary of ambient noise measurements in the Canadian Arctic is presented historically, by region and by experimental method.

6.2.1 Temporal Distribution of Measurements

Arctic ambient noise has been studied in Canada since the mid-1900s. Measurements before the 1990s were usually conducted in the spring and summer months due to both the difficulty of access caused by ice cover and the harsh weather conditions in the fall and winter. Over time, temporal coverage was improved by developing long-term monitoring systems that could be deployed one season and recovered the next. One of the earliest attempts at this was done in 1967 using five Remote Instrument Packages (creating the unfortunate acronym RIP) installed on the Arctic sea floor for a period of 1 year (Milne and Ganton 1971). When recovered, only 30% of the data was retrieved successfully. The main difficulties were that the data were not available until the retrieval of the system and the actual process of retrieval. Certain systems were even never retrieved due to ice conditions or recovery system failures. Furthermore, since the electronics were exposed to freezing temperatures, they may be prone to breaking and corrupting data before the systems could be recovered (Milne and Ganton 1971; Roth 2008).

More recently, Defence Research and Development Canada (DRDC) conducted a series of persistent monitoring experiments using persistent, multi-sensor observation systems with real-time reporting capability under the Northern Watch program (Heard et al. 2011a; Forand et al. 2008), deployed in Gascoyne Inlet, Devon Island, Nunavut. The difficult conditions in the Arctic initially caused hardware problems (Carruthers 2016) though preliminary results, including ambient noise and transmission loss data, have been reported (Heard et al. 2011b).

The Barrow Strait Real Time Observatory (BSRTO) was installed after a decade plus observation effort near Resolute, Nunavut, using long-term moorings by Fisheries and Oceans Canada (DFO) at the Bedford Institute of Oceanography (BIO) (Hamilton and Pittman 2015; Hamilton et al. 2013). The system records and transmits daily water property, ice thickness, currents profiles, and passive acoustic data year round. The observatory consists of an underwater network that communicates using acoustic modems to a main mooring, connected to a shore station (in fact, the Northern Watch camp established by DRDC) via an underwater cable.

To reduce the size of the transferred acoustic data, certain processing is done automatically before transmission, while the raw data is saved on the instrument, which is typically retrieved and serviced annually. To conserve battery power and to reduce data transmission bandwidth, the hydrophone is duty-cycled, recording for 1 min every 2 h. BSRTO has been reporting ambient noise data in near real-time over the band 10–800 Hz in 2017–2018 and 10–6400 Hz in 2018–2019. Measurements in 2017 often hit the hydrophone's noise floor of 57 dB ref 1 μPa; thus, a sensor with a higher sensitivity was deployed in September 2018. Figure 6.2 provides a spectrogram of ambient noise measured over fall and winter at BSRTO.

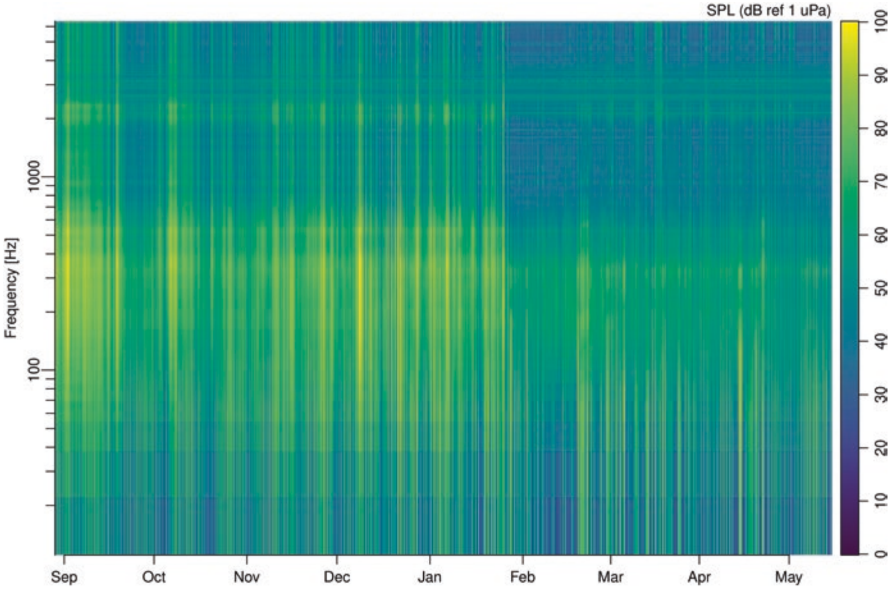

Fig. 6.2 Spectrogram of data collected at BSRTO between August 2018 and May 2019

6.2.2 Spatial Distribution of Measurements

To help distinguish the sources of noise that might contribute to the ambient noise, the Arctic Ocean can be divided into four different regimes (Carey and Evans 2011):

1. The central Arctic: permanently covered with pack ice
2. The coastal regions: covered in shore-fast ice in the winter and a mixture of pack ice and/or ice-free periods during the summer
3. The marginal ice zone: progression from a pack ice region to an ice floe region
4. Open waters: ice-free regions adjacent to the marginal ice zone

In this chapter, data has been divided into three geographical regions. These three regions were chosen to reflect the different regimes as well as to isolate the major study regions in the Canadian Arctic. Zone 1 in Fig. 6.3 is the region with the most ambient noise spectra. It represents the regions north of Alaska and the Yukon known as the Beaufort Sea, consisting of the deep Canadian Basin and wide Chukchi and Beaufort Shelves. The ice conditions vary with season, with the Beaufort Gyre driving first-year and multi-year ice in a clockwise direction. Zone 2 represents the Canadian Archipelago, characterized as a coastal region with seasonal shore-fast ice and shallow water. Finally, Zone 3 represents the central Arctic region, defined by

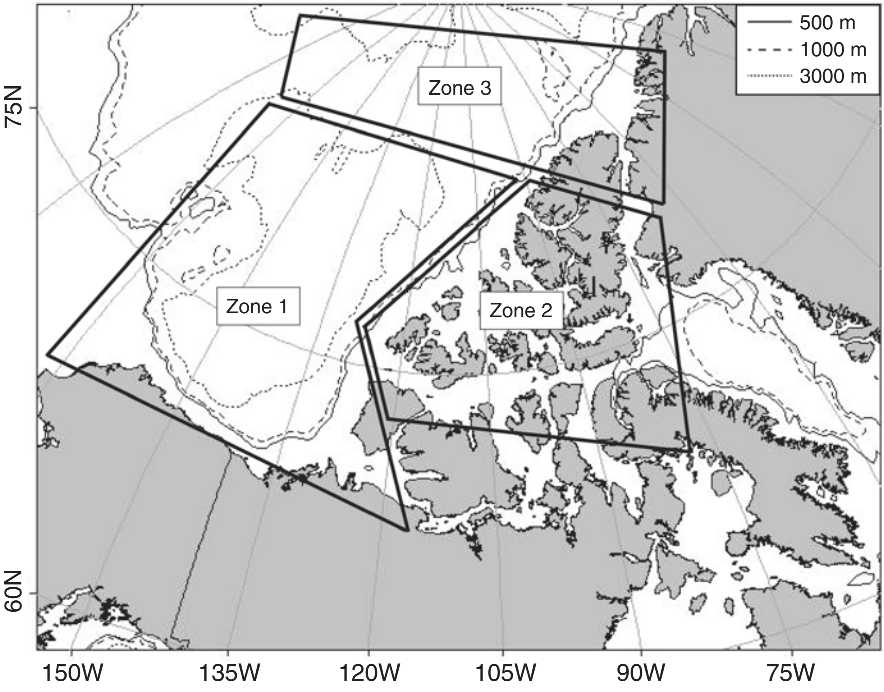

Fig. 6.3 Map defining different zones of collected data in Figs. 6.4, 6.5, 6.6, and 6.9

persistent multi-year ice. Regions for which no ambient noise spectra were found are the southern region of the Canadian Archipelago[1] and Baffin Bay. Table 6.1 shows the distribution of studies and the different equipment configurations used for the measurements presented in this chapter.

6.2.3 Notes on Measurement Quality and Compatibility

Ambient noise levels during quiet periods (e.g., sea state 0 in the open ocean), especially in the low-frequency bands, can be masked by electronic and mechanical system noise or fall below the sensitivity of the sensor (Milne and Ganton 1964; Insley et al. 2017). This can clearly be seen as very narrow band spikes in some spectra under Zone 1 of Fig. 6.4. The spectrum attributed to Chen et al. that has much higher values than the others in Fig. 6.4 was taken during an experiment in the Beaufort Sea in 1994. The study attributed these high-spectrum values to possible high array self-noise during the SIMI94 experiment (Chen et al. 2018).

Most early studies consider ambient noise in the Arctic to be analogous to ocean noise recorded in other basins, free of deterministic transient sources and with quasi-stationary statistics over an appropriate time window, typically greater than 1 min and less, than time scales associated with the changing environmental forcings. Once ice signatures such as thermal cracking were distinguished and identified, certain studies started removing these signals based off the NRC (2003) definition of ambient as noise originating from many indistinguishable sources. Kinda et al. (2013) used a statistical method to isolate and remove ice-generated transients to separate purely ocean-driven noise from ambient noise. Roth et al. (2012) removed transient events from their 2006 data but left them in their 2008–2009 measurements. It would be beneficial for the community to accept a definition of what transient events should be excluded from ambient noise measurements to make noise levels more comparable. The highest peak at 10 Hz in Zone 3 of Fig. 6.6 is due to transients unrelated to the environment, that is, airgun pulses occurring in the surrounding area (Ozanich et al. 2017).

Another factor that makes study inter-comparison difficult is the ambiguity of the units, particularly when considering third octave bands. Here, all measurements are presented as mean-square sound pressure spectral density in dB re 1 μPa^2, which is also known as power spectral density (PSD). All values converted to third octave band measurements were assumed, unless otherwise stated, to be averaged and not integrated over the bands. All measurements presented in dB re 1 μPa that were not integrated over frequency bands or stated as sound exposure levels were assumed to be equivalent to dB re 1 $\mu\text{Pa}^2/\text{Hz}$.

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[1] Measurements in Pond Inlet, Nunavut, were made in 2016 but have not been reported.

Table 6.1 Source description of experimental set-up for data shown in Figs. 6.4, 6.5, and 6.6

Source	Location	Frequency band (Hz)	Set-up	Collection dates	Hydrophone depth (m)	Bottom depth (m)	Notes
Chen et al. (2018)	Zone 1	~ 10–350	ICEX16 experiment (anchored vertical array)	March 2016	54	–	Pack ice conditions with a thickness of ~ 1 m
Chen et al. (2018)	Zone 1	~ 10–350	SIMI94 experiment (anchored vertical array)	Spring of 1994	62	–	Pack ice conditions with a thickness ≥ 2 m
Greene and Buck (1964)	Zone 1	25–1000	Measured from a hydrophone under an ice floe	April 1963	60.96	–	Wind speeds ranging between 0 and 15.4 m/s
Insley et al. (2017)	Zone 1	10–1000	Anchored hydrophones	May 2015 to July 2016	23.5	26.5–28.5	Coastal location, southwest of Banks Island
Kinda et al. (2013)	Zone 1	0–4100	AURAL-M2 autonomous underwater recorder attached to a mooring line	6 November 2005 to 23 June 2006	50	397	Marginal ice zone
Lewis and Denner (1988b)	Zone 1	10, 32, and 1000	AIDJEX experiment (from station 10 buoy)	February 1976	–	~ 1300	Winter pack ice
Mellen and Marsh (1965)	Zone 1	~ 10–1000	Measured with hydrophones at drift stations T3, Arlis 2, and Polar pack 1	September–October 1961 and May–September 1962	60–180	–	Variable conditions
Roth et al. (2012)	Zone 1	10–1000	Measured from autonomous acoustic recorder (HARP)	September 2006 to May 2009	235	~ 235	Variable conditions
BSRTO	Zone 2	0–6390.63	Measured with an anchored icListen AF hydrophone	September 2018 to present	159	162	Off the southwest coast of Devon Island

(continued)

Table 6.1 (continued)

Source	Location	Frequency band (Hz)	Set-up	Collection dates	Hydrophone depth (m)	Bottom depth (m)	Notes
Ganton and Milne (1965)	Zone 2	~ 10–10,000	Three bottom-mounted hydrophones with 106.68 m space between them	February 1964	~ 243.84	243.84	Shore-fast pack ice, 95% was old Arctic pack ice and 5% was 1.83 m-thick fresh lead ice
Milne and Ganton (1964)	Zone 2	20–10,000	Bottom-mounted hydrophone	September 1961	~ 485	485	Nearly 100% ice cover; 70% first year ice; wind below 7.8 m/s and temperatures ranging between −3 and −6 °C (ice pack 2)
Milne et al. (1967)	Zone 2	~ 16–5000	Bottom-mounted hydrophone	2–5 May 1966	~ 451	451	Shore-fast ice
Milne and Ganton (1971)	Zone 2	150–300	Remote instrument package installed on the sea floor	10 September 1967 to 10 October 1967	–	–	Moving ice floes of various sizes; winds below 11 m/s; temperatures ¡ −37 °C
Milne (1974)	Zone 2	400–20,000	Hydrophone lowered through ice	April 1972	30	–	Wind speed of 6.7−11.2 m/s and sea ice thickness of 0.03 m with a mean snow layer thickness of 0.1 m
Milne (1974)	Zone 3	400–20,000	Hydrophone lowered through ice	April 1972	30	–	Wind speed of 4.5–6.7 m/s and sea ice thickness of 1.37 m with a mean snow layer thickness of 0.04 m
Ozanich et al. (2017)	Zone 3	~ 1–976.56	Drifting array of 22 omnidirectional hydrophones	4 April to 20 September 2013	84.1 (for spectrum presented in Figs. 6.4, 6.5, and 6.6)	2500 to 4700	Ice concentrations ranged between 0 and 100%
Zakarauskas et al. (1991)	Zone 3	~ 2–1000	–	April 1987	55	500	Under pack ice in temperatures ranging between – 26.5 and – 32 °C and wind speeds of 1–9 m/s

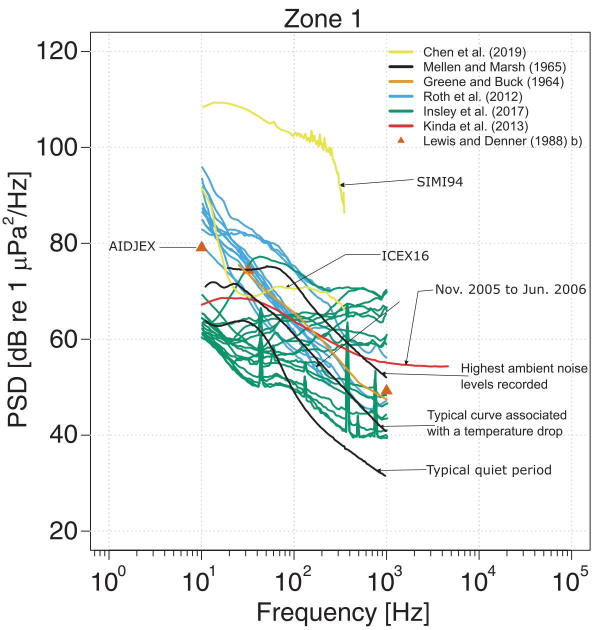

Fig. 6.4 Accumulation of recorded ambient levels in Zone 1 as defined in Fig. 6.3. Details on how the spectra were collected can be found in Table 6.1 (Greene and Buck 1964; Mellen and Marsh 1965; Lewis and Denner 1988a; Roth et al. 2012; Kinda et al. 2013; Insley et al. 2017; Chen et al. 2018)

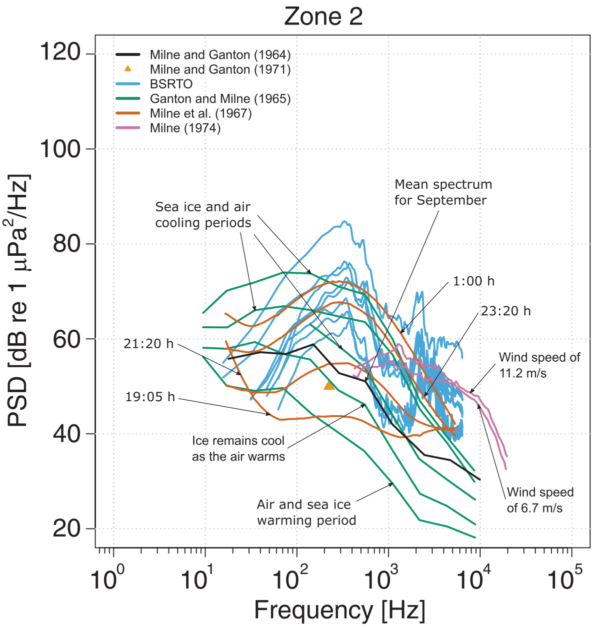

Fig. 6.5 Accumulation of recorded ambient levels in Zone 2 as defined in Fig. 6.3. Details on how the spectra were collected can be found in Table 6.1 (Milne and Ganton 1964, 1971; Ganton and Milne 1965; Milne et al. 1967; Milne 1974)

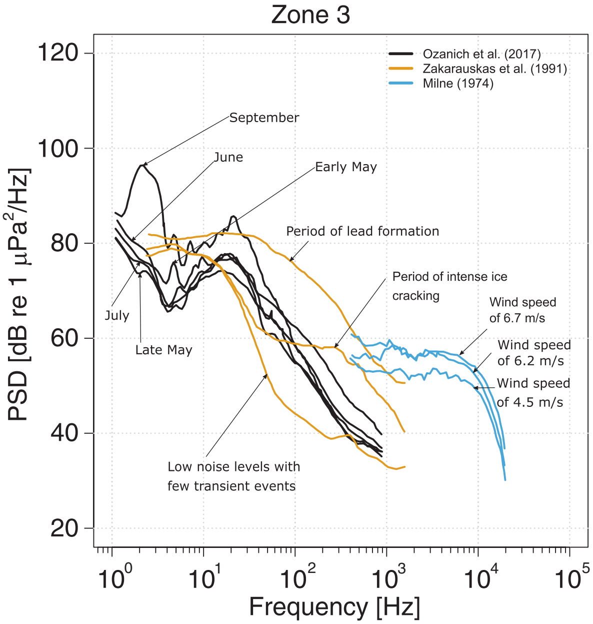

Fig. 6.6 Accumulation of recorded ambient levels in Zone 3 as defined in Fig. 6.3. Details on how the spectra were collected can be found in Table 6.1 (Milne 1974; Zakarauskas et al. 1991; Ozanich et al. 2017)

6.3 Environmental Sources of Noise

6.3.1 Ice

Sea ice cover in the Arctic Ocean produces a unique set of sounds related to various mechanical processes within the ice. The characteristics of ice (brittleness, thickness, surface roughness, ridging, and snow cover) along with the outside forces (wind stress, ocean currents, and tidal heave) and the thermodynamic forcing (air temperature) that act on it add new sources to the underwater environment that make predicting and understanding ambient noise in the Arctic more complex than in ice-free oceans, where wave height (or by proxy, wind speed) provides a stable estimate of noise levels (Knudsen et al. 1948; Barclay and Buckingham 2013a). Ice generates noise near the surface boundary under the influence of meteorological conditions, and the mechanisms will change depending on the season and ice cover type (Milne et al. 1967). During shore-fast ice conditions, surface cracks due to thermal gradients will dominate the soundscape. In floe pack ice, relative motion of the flows dominates the soundscape (Milne and Ganton 1964).

Generally, ice cover will skew noise level distributions to low frequencies, as higher frequencies are more readily scattered and absorbed by the ice canopy (Hutt 2012). Spectra dominated by ice noise also have a typical slope of −12 dB per octave although this can vary drastically depending on the dominant source mechanism (Yang et al. 1987). Low-frequency ice noise is generated by large-scale ice motion ridging, and higher-frequency (kHz −10's of kHz) noise is induced by particles impinging on the ice surface (Milne 1974) and bubbles bursting as the ice melts (Urick 1971; Hutt 2012).

6.3.1.1 Ice Cracking

Noise from the cracking of ice is usually thermally generated and is an effect observed in pack ice, shore-fast ice, and winter ice. As the air cools, the surface of the ice contracts and cracks; these cracks generate broadband impulsive noise underwater (Ganton and Milne 1965). Ice cracking occurs at the surface where thermal stresses are highest; therefore, these cracks are shallow (0.10–0.15 m deep) (Ganton and Milne 1965; Milne and Ganton 1969, 1971). Cracking is especially prevalent in multi-year ice since it contains less salt and is more brittle (Hutt 2012). As seen in Fig. 6.7, the dashed and dotted lines represent ambient noise levels when cracking is present. A flat spectral shape or a peak near the 100–500 Hz band is the distinguishing feature of a spectrum dominated by thermal ice cracking (Milne and Ganton 1969; Greening and Zakarauskas 1994; Greening et al. 1997; Mellen and Marsh 1965). As air temperature increases, cracking activity will be significantly lower due to the transition of tensile stress to compressive stress (Milne et al. 1967; Milne and Ganton 1969). The resonant frequency of the cracking noise has been hypothesized by Milne and Ganton (1969) to follow Eq. 6.1:

$$f = (2\pi d)^{-1} \left(\frac{E}{\rho}\right)^{1/2} (1+\mu)^{-1/2}, \tag{6.1}$$

where f is frequency, E is Young's modulus, d is the crack depth, ρ is the density of the ice, and μ is Poisson's ratio.

6.3.1.2 Ice Ridging

The formation of an ice ridge occurs when two different ice sheets collide, forming a relatively thicker section of ice comprising of a keel on the ocean side and a ridge on the air side. The noise source of this mechanism is from the bottom portion of the keel, which will generate noise at low frequencies and will have a louder sound pressure level (SPL) with thicker ice (Buck and Wilson 1986). According to Greening et al. (1997), spectral peaks centred at around 10 Hz usually represent a noise field dominated by ice-ridging noise. This may be attributed to propagation properties in the Arctic surface channel, which has the lowest attenuation in the band 10–30 Hz (Greening and Zakarauskas 1994; Dyer 1988). Greening and Zakarauskas (1994) demonstrated that source mechanisms with a spectral peak near

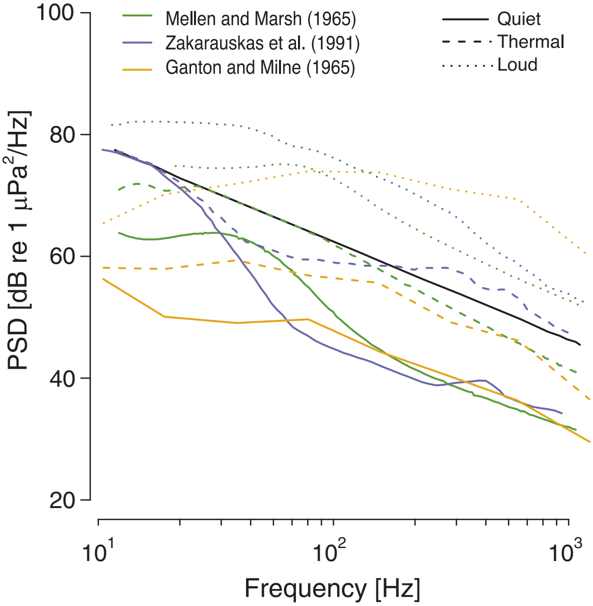

Fig. 6.7 Arctic ambient noise levels due to cracking using data from Mellen and Marsh (1965), Ganton and Milne (1965), and Zakarauskas et al. (1991) where the solid black line shows a typical ice-free wind-driven noise spectral slope of −19 dB/decade or $f^{-5/3}$

10–20 Hz are not required to reproduce observed ambient noise spectra. Broad peaks centred at 10 Hz can be observed in the purple and green curve of the quiet periods in Fig. 6.7 and are due to distant ice ridging.

A model to predict ridge noise was first developed by Pritchard (1984). By assuming that the energy dissipated during the ridging process was a proper measure of the noise source level, Pritchard (1984) was able to explain 46–64% of the noise between 10 and 32 Hz measured in the Beaufort Sea during the AIDJEX project. Another model for ice ridging noise was later developed by Buck and Wilson (1986). They considered the ridge to be a line source and assumed an active ridge spacing of 37 km. They were able to show that the 50 percentile noise levels measured were in good agreement with the model. This shows that ridging noise dominates the average low-frequency ambient noise field in the Arctic. Finally, Pritchard (1990) developed a low-frequency model that used the sum of interactions from ridging, microcracking, and mixed layer shearing to predict ambient noise in the Arctic. The system uses a sea ice dynamic model to predict the distribution and characteristics of the sources. This model generally successfully simulated longer-term trends (daily to weekly) in the CEAREX drift experiment data.

6.3.1.3 Other Ice-Related Mechanisms

Diachok and Winokur (1974) studied noise at the ice edge using a horizontal series of sonobuoys. They found that noise levels generated at the ice-water boundary dissipated faster under the ice sheet than in open water and that the difference in dissipation was larger when in the presence of a compact ice versus a diffuse ice edge. They determined that a primary noise-generating mechanism was related to interactions of waves and swells with the ice floes. Yang et al. (1987) determined that the source distribution was not uniform along the ice edge but that noise comes from "hotspots" that act as point sources. The observed distribution of the "hotspots" approximately followed the dimensions and distribution of eddies in the East Greenland Sea (Yang et al. 1987).

Ashokan et al. (2016) studied ice calving and bobbing noises in the Arctic. They observed that an increase in underwater noise under 500 Hz is associated with iceberg calving and bobbing. Tegowskia et al. (2011) also observed a calving event that increased levels at 80 Hz by approximately 17 dB. They compared a location with calving glaciers to a location covered by marine ice floes and found that the site surrounded by calving glaciers had generally lower levels at frequencies below 40 Hz but had levels that were 4–5 dB higher at frequencies above 1000 Hz. The location covered in ice floes had an increase in spectral slop above 5 kHz that was attributed to gas bubbles being released during ice floe collisions, disintegration, and melting (Tegowskia et al. 2011). So far, the overall contribution of calving and bobbing to the Arctic soundscape is unclear (Ashokan et al. 2016).

Ice noise is generally impulsive and can be categorized as a transient signal. A transient signal is short bursts of energy that deviates from a steady state. Kinda et al. (2015) studied local transient signals and divided them into three categories, broadband transients, frequency-modulated tones, and high-frequency broadbands, with centre frequencies ≥1000 Hz. Broadband transients are low-frequency signals that can range between seconds and several minutes (0.9 s and 7 min). Seventy-five percent of the time, their frequency peaks are below 50 Hz and the received levels average at 104 dB re 1 μPa. Kinda et al. (2015) associated these signals with the two first phases of the ice fracturing process. Frequency-modulated tones are signals that cover an even larger bandwidth than broadband transients and have several harmonics. They can repeat at regular intervals and have an average duration that ranges between 1 s and 420 s. These signals have frequencies between 500 Hz and 4 kHz and average receive levels of 95 dB re 1 μPa. Kinda et al. (2015) associated frequency-modulated tones with the reopening of a large lead. Xie and Farmer (1991) and Ye (1995) had observed similar signals, attributing them to friction between newly formed ice flows rubbing longitudinally due to wind and current forcing. High-frequency broadbands can have a continuous or pulsed pattern. They can be distinguished by their long durations and high recorded levels at frequencies above 1 kHz. Their levels have a narrow distribution with a mean of 92 dB re 1 μPa. Kinda et al. (2015) associated these signals with wind effects on frazil ice and did not see a significant link with any kind of precipitation.

6.3.2 Wind

Wind will typically generate underwater noise by producing a rough sea state. As the wind speed increases and sea state becomes rougher, the generated underwater noise will increase (Wenz 1962; Urick 1984). This also occurs in the Arctic, but with ice cover, wind will generate noise by crashing ice floes together and by blowing snow and ice over the ice sheets that cover the water. The relationship between wind and noise will change with ice cover and might even be indistinguishable depending on the state of the ice. As opposed to ice-generated noise, wind-generated noise has a Gaussian distribution. Consequently, it can be easily separated from ice ridging and cracking noise using the coefficient of excess. Ganton and Milne (1965) calculated coefficients of excess up to 100 in samples where ice cracking noise dominated. For regions with shore-fast ice cover, Ganton and Milne (1965) were able to identify wind saltation noise (Milne 1974), where ice and snow particles move along the topside of the ice canopy creating high-frequency noise in the water column. Ganton and Milne (1965) derived an empirical equation that related noise levels with wind speed to the power of 5.3. The onset of the relationship occurred at wind speeds between 1.3 and 2.2 *m/s*. Later, Milne (1974) concluded that noise increased with wind speed cubed using data from Ganton and Milne (1965) and Milne et al. (1967).

Milne (1974) also determined a method to calculate wind threshold speed using a model developed by Bagnold (1941) which depends on height, acceleration due to gravity, minimum grain diameter, grain density, density of air, and the aerodynamic roughness. Using data from the Robertson Channel, the theoretical threshold wind speed of 4.1 m corresponded closely to their observations. Milne (1974) also concluded that the shape of the spectrum tends to remain constant once saltation starts.

Milne and Ganton (1971) showed that moving ice flow noise was best correlated with a mean daily wind. In this case, noise was generated by breaking waves and the collision of ice floes. SPL increases with wind speed, and the effects of wind speed are less distinguishable as ice cover concentration and thickness increase (Insley et al. 2017). The relationships of wind speed to noise can be seen in Table 6.2. For Roth et al. (2012), correlations of ambient noise and wind were done for a wind with zero temporal lag.

6.3.3 Biological

Most of the detected biological signals are from the western Canadian Arctic and are from bowhead whales, walruses, bearded seals, beluga whales, and grey whales. All of these live year round in the Arctic, except for the grey whale which visits seasonally (Baumgartner et al. 2014). These mammals rely on sound to sense their underwater environments (communication, echolocation, and predator avoidance) (Moore et al. 2012). Bowhead whales make tonal frequency-modulated sounds in the 50–400 Hz range. Beluga whales create whistles, pulsed tones, and noisy

Table 6.2 Slopes of linear regressions between wind and ambient noise levels at different ice concentrations

Source	Wind effect coefficient (dB re 1 μPa)/(km/h)	Frequency Hz	Ice cover concentration
Insley et al. (2017)	0.43	250	Varying ice cover from dates ranging between May 2015 and July 2016
Insley et al. (2017)	0.14	250	100%
Roth et al. (2012)	0.28	250	0–25%
Roth et al. (2012)	0.14	250	75–100%
Milne and Ganton (1971)	0.6	150–300	Concentration not specified; moving ice floes observed

vocalizations between 0.4 and 20 kHz. Bearded seal songs will predominantly be in the 1–2 kHz band but may range between 0.02 and 6 kHz. Walruses will mostly produce clicks, rasps, a bell-like tone, and grunts between 0.4 and 1.2 kHz, and grey whales produce knocks and pulses in the 0.1–2 kHz range (Richardson et al. 1995).

All the animals listed have been detected in ambient noise recordings in the Canadian Arctic (Mellen and Marsh 1965; Richardson et al. 1995; Baumgartner et al. 2014). In fact, Clark et al. (2015) showed that, during spring, the chorus of bearded seals dominated the ambient noise levels in the 0.25–2.5 kHz frequency band between the Chukchi and Beaufort Seas. MacIntyre et al. (2013) recorded bearded seals year round and found that their calls coincided with the seasonal ice changes for two consecutive years. Calls increased in the winter with formation of pack ice and peaked in the spring for mating season and preceding the break-up of sea ice.

6.4 Anthropogenic Sources of Noise and Their Effect on Marine Mammals

Anthropogenic sources include transportation, dredging, construction, hydrocarbon and mineral exploration and exploitation, geophysical surveys, sonar, explosions, and ocean science studies. In the Arctic, common offshore sources include airgun surveys, pile driving, shipping, ice breaking, dredging, and small boat operations (Moore et al. 2012). Of these, the most widespread source comes from transportation (Giesbrecht 2018). Anthropogenic sources can affect marine mammals by masking important sounds, causing temporary or permanent hearing loss, cause physiological stress or physical injury, and reduce prey availability by causing changes in the ecosystem (Moore et al. 2012). To date, ship noise and airgun noise were of most concern in the Canadian Arctic, and findings have been described in the sections below. A list of studies that focus on the effects of anthropogenic sound on marine maps can be found in Moore et al. (2012), and a review of documented disturbance reactions can be found in Richardson et al. (1995).

6.4.1 Ships and Boats

Over the past 20 years, shipping traffic has tripled (Giesbrecht 2018), and with the receding ice cover, existing shipping routes are open longer while new shipping paths could be accessible by the mid-century. In fact, the shorter winter seasons are reducing access to winter roads and making increased boating traffic an even more likely prospect (Stephenson et al. 2011). With increased ship and boat traffic come increased noise and the potential for an increase in disturbance reactions (Moore et al. 2012; Richardson et al. 1995). Shipping traffic generally increases noise levels in the 10–1000 Hz range, which directly overlaps with the calling frequencies of bowhead whales, bearded seals, and ringed seals and could therefore mask their communications (Insley et al. 2017). Furthermore, predictions from the western Canadian Arctic show that loud vessels are audible underwater when they are within 100 km and could affect marine mammal behaviour when within 52 km depending on the vessel type (Halliday et al. 2017). A Monte Carlo simulation study driven by historical observations showed that when a vessel was within the study region, the Tallurutiup Imanga National Marine Conservation Area (TINMCA), the 24-h sound exposure level predicted that vessel noise would be audible to narwhals, belugas, and bowheads for 85%, 81%, and 88% of the time, respectively, but never above the National Oceanic and Atmospheric Administration's limit of temporary threshold shift, where temporary hearing loss will occur (NMFS 2018).

6.4.2 Airguns

Airgun pulses are generated by low frequency-controlled sources designed for sub-bottom imaging. Roth et al. (2012) and Ozanich et al. (2017), studies which were conducted in the western and eastern Canadian Arctic, respectively, measured increased SPL in between frequencies of 10 and 30 Hz. Roth et al. (2012) estimated that ambient noise levels in September and October were raised between 2 and 8 dB re 1 μP a2/Hz due to airgun pulses.

6.5 Characteristics of Variation

Arctic ambient noise is highly variable and impulsive due its major noise source and major contributor to transmission loss and wave suppression: ice. The wide ranges of ambient noise in the Arctic have been measured to be about 20 dB lower than sea state 0 and up to levels similar to the Knudsen sea state 4 (Urick 1984; Carey and Evans 2011). Ice cracking, ridging, melting, and bobbing will take turns dominating the ambient noise profile depending on the season or study region. Figure 6.8 shows how ice cover type and seasons affect ambient noise levels, based on Hutt's summary of observations from Canadian ice camps and from the BSRTO.

6.5.1 Temporal Variations

6.5.1.1 Short Time Scales

The most studied short time variations are due to thermal ice cracking. As the air cools at night, the ice sheet contracts and becomes more brittle making it more susceptible to cracking under tensile stress (Milne and Ganton 1969). This diurnal variation was also observed to be significantly reduced in the presence of snow cover. The snow acts as insulation and slows down the cooling of the ice with the atmospheric temperature (Hutt 2012).

6.5.1.2 Long Time Scales

Studies have shown that ambient noise variation does not necessarily follow seasons but is better correlated with month and ice cover type. Arctic seasons can be divided as done by Clark et al. (2015): summer to fall (August to November), spring to summer (April to July), and winter (December to March). In Insley et al. (2017), January to April had the lowest recorded levels, and sound pressure levels were highest between May and October. These trends are also reflected in Fig. 6.8.

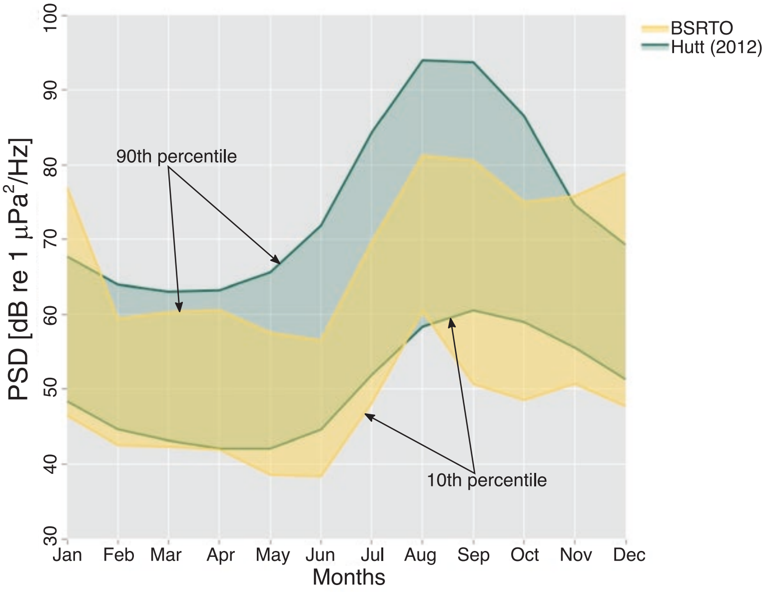

Fig. 6.8 Distribution of underwater ambient levels in the Arctic as a function of time of a calendar year for the 10–1000 Hz band, where the shaded region indicates the noise level between the 10th and 90th percentile, as computed by Hutt (2012) (green) and from observations from the BSRTO (yellow)

As seen in Fig. 6.8, July to October shows higher ambient levels due to open water and moving ice flows, which can create high noise levels through collisions. Between December and May, most of the Arctic is covered with pack ice and shore-fast ice, which, although this ice is a source of noise, has quieter ambient noise levels. This is due to increased transmission loss, reduction in biological and anthropogenic sources, and reduction of wind-generated waves by the ice cover. The BSRTO data follows the lower range values presented by Hutt (2012), while the highest values from both curves are recorded between August and September. In December, the noise level at BSRTO increases and widens, which is not seen in Hutt (2012). This difference could be attributed to the BSRTO's single year and sole location of data collection, while the data from Hutt (2012) is an accumulation of data collected at different sites, during various years. Local effects, such as the limited fetch in Barrow Strait and regular weather patterns (e.g., wind direction, ice conditions, freeze-up date), will define the observation, whereas the Hutt data will tend to smooth these effects.

These seasonal trends can also be observed in Fig. 6.9, especially after the 2000s when there were more permanent monitoring systems. Over the frequency band of 150–300 Hz, the PSD will be higher between August and December (blue shades) than January and May (red shades). The levels are also typically highest in August to September and will be lowest in March to May.

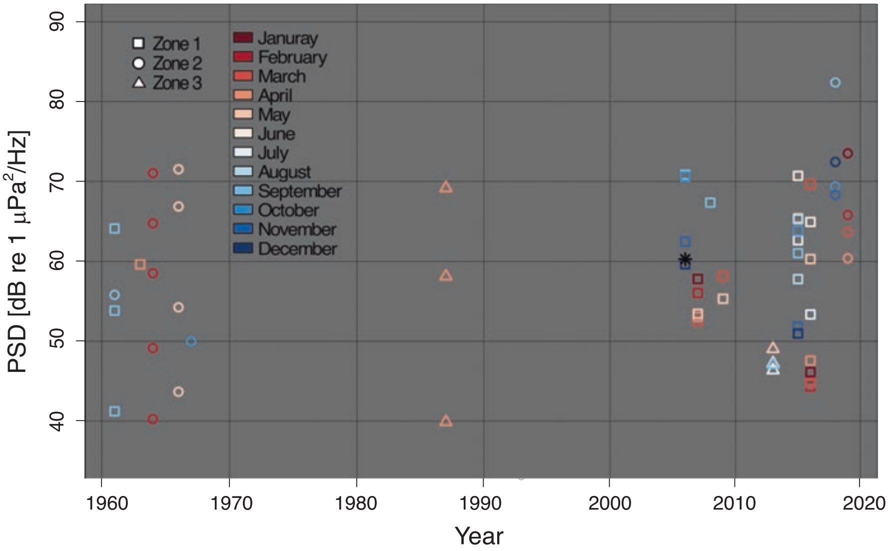

Fig. 6.9 PSD for the 150–300 Hz band as a function of year collected using the same data as in Figs. 6.4, 6.5, and 6.6. Shapes represent the location of the measurement and colours represent months. If data was collected over 2 months, then the first one was chosen to represent the data. The black star represents data from a year-long mean spectrum taken by Kinda et al. (2013) (Ozanich et al. 2017; Lewis and Denner 1988a, b; Milne and Ganton 1964, 1971; Chen et al. 2018; Zakarauskas et al. 1991; Mellen and Marsh 1965; Ganton and Milne 1965; Greene and Buck 1964; Insley et al. 2017; Roth et al. 2012)

During winter and spring, noise distributions are typically non-Gaussian due to the noise created by the ice, whether it is by cracking, forced collisions due to wind, or other mechanisms. If there are enough events over time and they are distributed evenly enough in space, relative to the recorder, the distribution will be Gaussian (Milne 1966; Zakarauskas et al. 1991; Kinda et al. 2013).

6.5.2 Spatial Variations

As seen in Figs. 6.4, 6.5, and 6.6, the PSD levels in each zone cover a wide range of values. All the measurements were made over the 10–1000 Hz band and have similar slopes. Two exceptions occur: a single spectrum in Zone 1 shown in Fig. 6.4. and those made by Insley et al. (2017), which were collected in very shallow water and are presumably more influenced by local surface ice noise and ice interactions with the bottom. The seminal measurements of Mellen and Marsh (1965) do a remarkable job in summarizing observations succinctly.

Spectra in Zone 2, with the exception of the BSRTO data, were all taken with the purpose of understanding the effect of ice cracking on ambient noise and thus were computed on short time scales. Measurements were taken at different times of day when cracking was known to be quiet or loud due to forcing by atmospheric heating and cooling. BSRTO data, shown as monthly averages, have a peak at 2.5 kHz, corresponding with the horizontal bands shown in Fig. 6.2. The source of this broadband noise may be due to mechanical noise generated by the mooring, though further study is required.

Spectra in Zone 3 have peaks between 10 and 50 Hz. All measurements in Zone 3 were taken at depths shallower than 85 m, which is within the shallow propagation channel created by the sounds speed profile. Distant airgun-generated noise is observable during the open water months, particularly in the September data of Ozanich et al. (2017).

6.5.3 Depth Dependence

Though the spatial properties of noise are important for predicting sonar performance, only Greene and Buck (1964) and Ozanich et al. (2017) have reported on the depth dependence of Arctic ambient noise. Greene and Buck (1964) determined that minimum noise intensity is at the bottom of the ice, increasing to a uniform depth dependence beyond a depth of one-half the wave length. Ozanich et al. (2017) replicated those observations using a drifting array and concluded that noise time series tends to become normally distributed as the sensor depth increases and the receiver effectively monitors a larger area of the surface, an effect also seen in the ice-free ocean (Vagle et al. 1990; Barclay and Buckingham 2013b). Close to the ice, local overpowering transients skew the noise signal towards non-Gaussianity.

6.6 Propagation

To both develop a model of natural ambient noise and quantify the effect of anthropogenic sources on the underwater soundscape in the Canadian Arctic, accurate knowledge of underwater sound transmission loss is required. Transmission loss in the Arctic is affected by mechanisms related to the ice canopy, as well as scattering and reflection from the seabed and volume scattering and absorption. Considerable experimental and theoretical efforts have been invested into understanding these mechanisms since the middle of the previous century, though an accurate model of a rough, elastic sea ice layer has yet to be demonstrated. The ice layer contributes to transmission loss through scattering from the rough underside layer, comprised of a local surface roughness as well as large keels (ridges), through the conversion of compressional energy to shear energy in the ice layer and interface waves and through the bulk acoustic wave properties within the ice itself, such as compressional and shear attenuation. The wave speed structure and attenuation within the ice layer depends on parameters such as temperature, salinity, and density (Rajan et al. 1993). Sea ice thickness can range from a fraction of a wavelength to multiple wavelengths, making these effects highly frequency dependent.

Due to the dynamic nature of atmospheric and oceanographic conditions in the Arctic, the material properties within the sea ice undergo significant seasonal changes and are subject to large spatial variability. Additionally, the measurement of the ocean ice roughness profile and the acoustic properties within the ice layer over long ranges is technically and logistically challenging. As a result, simplified analytical models and statistical methods are typically employed for predicting transmission loss in the Arctic. A range of propagation models have been developed, including empirically derived relationships, ray models, normal mode models, wave number integral models, and parabolic equation (PE) models of varying complexity. This section provides a brief overview of under-ice transmission loss measurements and modelling.

6.6.1 Measurements

Figure 6.1 shows that in both summer and winter, the upward refracting environment in the Arctic allows for very long-range transmission of sound that is either surface trapped or in a shallow sound channel centred at 150 m depth. In the ice-free ocean, the air-sea interface is perfectly reflecting, making a surface trapped waveguide an efficient propagation channel. Surface roughness due to wind waves and swell, and bubble layers due to breaking waves, can reduce the channels' efficiency through scattering and cause a deterministic signal to lose coherence as it repeatedly interacts with the surface.

Similarly, the underside of the sea ice layer adds losses due to scattering and reflection, phenomena quantified in early measurement by Buck and Greene (1964) who measured aircraft-deployed explosive sources at ranges of up to 200 km in the deep Arctic Ocean. The frequency-dependent effective attenuation of the ice layer was observed to begin at 50 Hz and increase with frequency (Fig. 6.10). During the same period, Marsh and Mellen (1963) conducted transmission loss experiments over a distance of 800 km and similarly demonstrated the strong frequency dependence caused by the ice layer.

At the time, Canadian defence researchers began studying sound propagation in Barrow Strait, a shallow water environment where both the ice layer and the seabed contribute to transmission loss. Milne (1960) observed a loss consistent with geometric spreading, in this case cylindrical, over a relatively short range of 18 km with an added 1 dB of loss in the 10–20 kHz band per 1.8 km (nautical mile) (Fig. 6.10). At these ranges, Milne noted that transmission times between fixed stations were more stable than in the open ocean (Ganton et al. 1969).

In order to estimate the importance of ice keels on transmission loss, observations of ice ridge densities and sail height were used to infer keel number densities and draft in the central Arctic (Zones 1 and 3) by Diachok (1976) and used as input parameters for a propagation model that treats the ice as a pressure release (perfect) scatterer. The results were used to estimate a frequency-dependent effective attenuation in two different regions of the Arctic, as shown in Fig. 6.10. During this time, a Canadian effort by Verrall and Ganton (1977) was focused on improving estimates

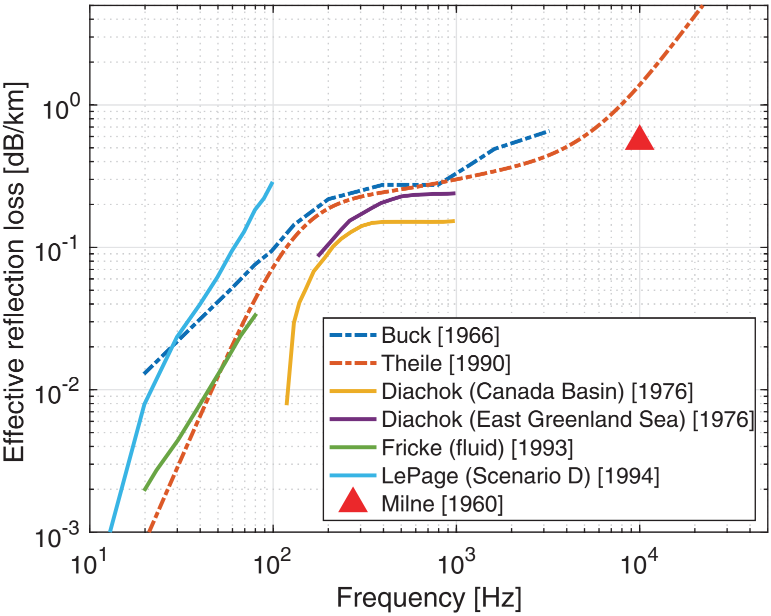

Fig. 6.10 Effective attenuation per unit distance due to ice cover as a function of frequency according to observations (solid red triangle) (Milne 1960), empirical relationships (dashed lines) derived by Buck and Greene (1964) and Thiele et al. (1990), and physics-based models by Diachok (1976), Fricke (1993), and LePage and Schmidt (1994)

of the reflection coefficient of shore-fast ice in the Canadian Archipelago. Further experiments were carried out to improve the sea ice reflection coefficient at low frequency (Livingston and Diachok 1989), and theoretical progress was made on rough ice scattering models (Kuperman and Schmidt 1986).

The next series of measurements began in the early 1990s and were planned as basin-scale tomographic experiments. By sending precisely timed tomographic signals across the Arctic basin, the travel times along various deep diving, shallow diving, and surface interacting acoustic paths can be used to compute the sound speed (thus temperature and salinity) in depth and range, as well as the ice thickness and roughness. The Transarctic Acoustic Propagation (TAP) experiment was planned as a demonstration project to measure the warming of the Arctic Ocean basin between a source placed north of Spitzbergen and two receivers, one near Barrow, Alaska, and a second near Alert, Nunavut (Mikhalevsky et al. 1995, 1999). The 6-day experiment successfully detected the intrusion of warm Atlantic Intermediate Water using a 20.5 Hz signal and led to improved scattering models for the ice-water interface (LePage and Schmidt 1994; Fricke 1993) (Fig. 6.10). This sets the stage for a year-long monitoring program, Arctic Climate Observations Using Underwater Sound (ACOUS), deployed in 1998. ACOUS used a similar geometry and source to TAP and successfully inferred the seasonal ice thickness and roughness, using a scattering inverse model by Kudryashov (1996) (Gavrilov and Mikhalevsky 2006).

Tomographic measurements in the Arctic have continued to the present day, with persistent monitoring and increasingly complex ocean acoustic-coupled models. A series of experiments monitored the Fram Strait during the previous decade (Sagen et al. 2016) resulting in studies of small- to large-scale processes (e.g., internal waves to global scale currents) (Dushaw et al. 2016a, b). In the Canadian Arctic, the Canada Basin Acoustic Propagation Experiment (CANAPE) recently concluded, with early results demonstrating the effect of the Beaufort Gyre throughout the year on propagation between the central Arctic and the Chukchi Shelf (Worcester 2015; Ballard et al. 2017). Analysis from these recent data sets will push the underwater acoustics community to advance low-frequency, under-ice propagation models (Collins et al. 2019), ocean acoustic-coupled models (Duda et al. 2018; Ballard et al. 2017), and three-dimensional propagation models. These advances will better allow the modelling of anthropogenic activity, namely, shipping and oil and gas exploration, in the Canadian Arctic.

6.6.2 Modelling

Buck (1966) used their early measurements of under-ice transmission loss to develop an empirical model that combines geometric spreading with a frequency-dependent effective reflection loss per unit distance term (Fig. 6.10). The model was fit to the data at nine frequencies in the band 20–3200 Hz, where the standard deviation for each fit ranged between ±5 and ± 9 dB. Empirically derived models, such as the more recent Thiele et al. (1990) equation, and data summaries, such as the one provided in Urick (1984), provide rapid estimates of transmission loss but fail to account for the spatial diversity in ice layer properties, as well as the seasonal and climate change-driven temporal variability. For this reason, a portable, physics-based model of under-ice propagation is desirable.

The early efforts of Marsh and Mellen (1963) and Milne (1960) both focused on ray models for quantifying the loss due to ice and worked on estimating reflection loss coefficients for the ice-water interface. Diachok (1976) continued this effort, incorporating scattering from semi-cylindrical ice ridges (keels) into a ray tracing model. The majority of modelling development was then directed at better scattering physics, ice-water reflection coefficients, and the incorporation of keels and roughness into ray tracing and normal mode models (Kuperman and Schmidt 1989; Fricke 1993; LePage and Schmidt 1994; Kudryashov 1996).

Kuperman and Schmidt (1986) implemented a full-wave solution to a horizontally stratified ocean waveguide with a random rough interface between any combination of fluid and elastic layers. This model was able to account for scattering at the ice-water interface and the conversion of compressional energy to shear energy, but only for range-independent problems. This model has provided accurate predictions of arrival times for recent tomography measurements in the Fram Strait (Hope et al. 2017).

Gavrilov and Mikhalevsky (2006) used a normal mode propagation code to demonstrate that the ACOUS tomographic signals likely contained information on the ice thickness, though the range-dependent environment added uncertainty to the result. In another study, a finite-difference numerical simulation showed both the elastic parameters and a rough interface have frequency-dependent effects on the propagated and scattered fields, though it was the simulation of fluid ice keels that best fits the observations (Fricke 1993).

In the preceding decades, PE propagation models had grown in capability, reliability, and accuracy and offered the advantage of accommodating range-dependent environments at low frequencies, where ray models tended to have difficulty computing transmission loss. Recent advances allowed a fully elastic seabed and ice canopy to be incorporated into a PE simulation (Collins 2012, 2015). Collis et al. (2016) benchmarked such a model against an elastic normal mode code and wave number integration solution and demonstrated the PE model's ability to compute transmission loss under a slowly varying range-dependent ice thickness. Collins et al. (2019) was further able to demonstrate scattering from a data-derived ice surface with keels using a fully elastic PE code over a model range of 40 km.

Diachok (1976) showed that a pressure release rough surface could do a good job of matching data, provided the statistics of the keels were well known. When scattering is the dominant loss mechanism, the same approximation may be applied to a range-dependent propagation model without the added computational complexity of a thin, elastic interface. Ballard (2019) implemented a three-dimensional hybrid PE-normal mode propagation code with a pressure release rough surface. She found that horizontal reflections from ice keels cause the predicted standard deviation of received levels over the model area, though the mean remained nearly constant.

The recent demonstration of a fully elastic PE code capable of roughness on the length scale of ice keels represents a significant advancement in under-ice sound propagation modelling (Collins et al. 2019). Careful model data comparisons are required to fully quantify the relative loss contributions of scattering due to roughness and ice keels and shear energy conversion. In some cases, range-independent elastic models may suffice, while in others, inelastic pressure release rough ice may capture the dominant physics relevant to predicting transmission loss.

6.7 Conclusion

The changing ice conditions in the Canadian Arctic will alter the underwater soundscape through spatial and temporal shifts in the natural noise-generating mechanisms, a reduction in ice-driven transmission loss, and an increase in the presence of industrial activity, including shipping. A review of historical measurements demonstrates that the power spectral density at any given frequency in the 10 Hz to 10 kHz band may vary by 30 dB in the deep water environment of the Beaufort Sea or Canada Basin (Zone 1), between 30 and 40 dB in the shallow Canadian Archipelago (Zone 2), and by 20 dB in the Lincoln Sea (Zone 3), where multi-year ice persists.

These large variations are driven by seasonal variations in forcings, with increased ice-generated noise occurring during freeze-up and break-up, increased wind noise during open water, and periods of quiet arriving with shore-fast ice. Contemporary measurements made by the BSRTO demonstrate this seasonality, shown in Fig. 6.8, which compares well with historical measurements made at locations throughout the Archipelago between 1962 and 1987 (Hutt 2012). In both data summaries, the noisiest time occurs during the open water season (August and September) when sound generated by wind wave dominates, and the quietest season (February to May) is when stable, shore-fast ice is present.

The year-round BSRTO acoustic data, along with concurrent oceanographic, ice draft, and meteorological data, presents a significant opportunity to advance the ability to predict and model natural ambient noise in the Canadian Archipelago and in ice-covered waters in general, using a physics-based and portable approach.

Accurate modelling of the natural noise field is a necessary component of a marine spatial planning tool capable of quantifying the potential noise impact of industrial activity, including shipping, and presenting useful and meaningful information to decision-makers. The other key component of such a tool is a high-fidelity transmission loss model capable of operating in a range-dependent, partially or fully ice-covered environment. Recent advances in under-ice sound propagation modelling appear to meet these requirements, though further validation is required, particularly in shallow water and over long ranges. The combination of a portable Arctic transmission loss model and ambient noise model, along with an understanding of the sensitivity of their accuracy to input data quality (such as per cent ice cover, ice draft, sound speed profile, and meteorological conditions), will allow the realistic prediction of the acoustic footprint of vessels, airguns, and other industrial sound sources. Once validated, such a tool could provide an accurate representation of the acoustic impact of future use and simulate the effect of management solutions.

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Part II
The Human Dimension

Chapter 7

Inuit Nunangat and the Northwest Passage: An Exploration of Inuit and Arctic Shipping Conceptualizations of and Relationships with Arctic Marine Spaces in Canada

Leah Beveridge

Abstract Historically, Inuit have not been participants in the governance of Arctic shipping, but efforts are underway to better account for their concerns with regard to the operations of vessels in their waters through partnerships and other forms of collaboration. To understand and address these concerns, there is a need to understand and appreciate the worldview within which they are based. To support cross-cultural dialogue on shipping matters, this chapter will discuss the worldview of Inuit and the worldviews that are implicit in the governance of Arctic shipping, as well as the challenges of and opportunities for integrating the two. By bringing the ethnographic and anthropological literature on Inuit worldviews into a discussion of shipping governance, this chapter offers insights for cross-cultural collaborations between Inuit and non-Inuit working on matters of Arctic shipping governance in Canada.

Keywords Arctic · Arctic shipping · Canada · Inuit · Marine space · Sea ice · Shipping governance

7.1 Introduction

Historically, Arctic voyages were figments of the imagination for most and reality for only a few. Even until recently, maritime activities have been minimal, with the majority of traffic in Canadian Arctic waters being associated with community

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resupply and mining projects. However, with changing environmental conditions, advancing technology, and a drive to explore and exploit new frontiers, commercial shipping across the circumpolar Arctic is growing. The greatest expansions seen in the Canadian North have been in the marine tourism sector, a trend that is expected to continue along with other forms of destinational traffic including the servicing of communities, mines, and, if permitted in the future, offshore oil and gas[1] (e.g., Lasserre and Pelletier 2011; Pizzolato et al. 2013). The governance of such Arctic shipping is a "complicated mosaic" (Arctic Council 2009, 50), which Inuit have not historically participated in. However, the Government of Canada has undertaken to better account for the concerns of Inuit with regard to the operations of vessels in their waters by collaborating with them, namely through the Low Impact Shipping Corridors and the Oceans Protection Plan, and by focusing on partnerships and the inclusion of Inuit knowledge.

Each and every person has a worldview: a set of underlying, intrinsic, and subconscious assumptions about the world. When someone speaks, the meaning of their words is tied to their worldview (Ingold 2000), which is particularly important to acknowledge when engaging across worldviews. If the differing points of departure are not acknowledged and/or respected, there is the risk that although the words used by the two interlocutors are the same, the meaning behind them may be different (Viveiros de Castro 2004). Therefore, to effectively communicate, collaborate, and partner with Inuit on matters of Arctic shipping governance, there must not only be the forums to speak to one another but also the willingness and commitment to understand the worldview of those involved in the dialogue so that the true meaning of their words can be understood. This subsequently demands an acknowledgement that the worldview of Inuit is an equally legitimate way of knowing and being in the world to that of shipping governance.

This chapter will discuss the worldview of Inuit and the worldviews that are implicit in the governance of Arctic shipping and the challenges of and opportunities for integrating the two. Herein, "shipping" will refer to vessels resupplying communities and mines and transporting bulk cargo and will not include fishing vessels, passenger (cruise) vessels, or pleasure craft. It is important to note at the onset that the understanding, articulation, and engagement with the Inuit worldview outlined in this chapter is based on a review of ethnographic and anthropological literature, supplemented with the author's own experiences. It does not attempt to speak on behalf of Inuit, but rather intends to bring literature on Inuit worldviews into a discussion of shipping governance, offering insights for cross-cultural collaborations between Inuit and non-Inuit working on shipping issues and opportunities in Canada's North.

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[1] A moratorium on offshore oil and gas development in Canadian Arctic waters was established in 2016 and will be reviewed every 5 years (Office of the Prime Minister 2016).

7.2 Governance of Arctic Shipping

The governance of Arctic shipping consists of interacting and interdependent instruments and decisions at the international, regional, domestic, and subnational scales, rooted in what will be referred to here as a "shipping governance worldview". Like any other, this worldview has its own belief system, inclusive of knowledge and the subconscious processes for thinking about and perceiving the world (Blaser 2009; Laidler 2007; Sable et al. 2006; Stephenson and Moller 2009; Trippett 2000). Insights into how shipping governance views the world can be drawn from the fields of geography (Bennett et al. 2016; Heyes 2007; Steinberg 1999) and anthropology (Aporta 2011; Ingold 2000; Tyrrell 2005; Whitridge 2004), as well as the key instruments of the governance regime itself.

The shipping governance worldview is rooted in a naturalist ontology, meaning there is an understanding that nature and culture can be divided (Blaser 2009; Ingold 2000); people are placed outside rather than alongside nature, that is, the marine environment. The United Nations Convention on the Law of the Sea (UNCLOS) positions nature—the marine environment—as something to be used by people, believing that through clear rules for this use, peaceful international relations and economic, social, and sustainable development can be achieved (UNCLOS 1982, Preamble). It acknowledges that marine issues (e.g., with respect to fishing, shipping, marine conservation, scientific research) are interrelated but introduces a number of divisions to support legal order for the seas and oceans. One inherent division underlying UNCLOS is that the land is separate from the sea, wherein the boundary lies at the low-water mark (Article 5). UNCLOS further subdivides ocean space into zones based on distances from this boundary and defines jurisdictions for marine management within each. Responsibility for managing various aspects (e.g., fishing, shipping, conservation, research) within the zones is also divided. These divisions, together with the understanding that the space and its issues are interconnected, demonstrate that there is an understanding that the whole can be rebuilt through a compilation of all the pieces.

Under UNCLOS, matters of international shipping are assigned to the "competent international organization", which is understood to be the International Maritime Organization (IMO). The IMO is a specialized agency of the United Nations that sets global standards for the safety, security, and environmental performance of international shipping. It has established a comprehensive regulatory framework that is universally adopted and uniformly implemented by its member states. The mechanisms through which the various topics of its work (e.g., safety of life at sea, protection of the marine environment, and training and certification) are advanced are divided across committees and subcommittees and implemented through a number of conventions, codes, and other standards.

A member state is expected to implement the IMO instruments to which it is a party within their jurisdiction, as defined by UNCLOS. In Canada, Transport Canada is the main department responsible for implementing IMO instruments to which Canada is a party and for regulating shipping activities in its waters; that is, it is Canada's maritime administration. The main mechanism through which this is achieved is the Canada Shipping Act, 2001 (CSA 2001), supported by various other maritime statutes, such as the Canadian Navigable Waters Act (1985; formerly the Navigation Protection Act). Environmental statutes also establish offences applicable to shipping, including the Canadian Environmental Protection Act (1999), the Oceans Act (1996), and the Migratory Birds Convention Act (1994). This regulatory regime recognizes the relationship between shipping and other ocean matters, such as those in the Oceans Act (e.g., fishing, conservation).

Under UNCLOS, within the IMO, and by Canada, there is recognition that there is a divide between the Arctic and the rest of the global ocean, including southern Canadian waters, due to its unique environmental sensitivities and operational requirements for ships. This is reflected in Article 234 of UNCLOS, which provides states the authority to develop "laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of [their] exclusive economic zone"; in the establishment of the International Code for Ships Operating in Polar Waters (the Polar Code 2014/2015), which addresses the aspects of safety of navigation, seafarer training, and marine environmental protection that are specific to the polar regions; and in the Canadian Arctic Waters Pollution Prevention Act (AWPPA 1970), which focuses on the safety of navigation and marine environmental protection and predates both UNCLOS and the Polar Code. Canada further subdivides its Arctic waters by historical ice regimes with the zone/date system, which is laid out in the Shipping Safety Control Zones Order (see Chap. 15 in this volume).

One of the key operational requirements for ships in Arctic waters is the need to cope with the presence of sea ice, which is a risk to ships and a barrier to marine transportation (Lasserre et al. 2016). Sea ice also introduces the need to be flexible and adaptable within an otherwise rigid regime. This has been achieved through the Polar Operational Limit Assessment Risk Indexing System (POLARIS) and the Arctic Ice Regime Shipping System (AIRSS) (Transport Canada 2018). These systems assess the risk posed by various ice conditions to a vessel based on its construction. Risk assessments are conducted throughout the duration of a voyage, and if it is determined that the pre-planned voyage will take a vessel through ice conditions outside its operational limits (i.e., unsafe conditions), the vessel is required to adapt its voyage plan to ensure the safety of navigation. This could mean taking a longer route, waiting for sea ice conditions to become lighter, or cancelling a voyage altogether. Sea ice thus represents not only a safety risk to vessels but a financial risk, as delays in transportation mean extra costs in fuel, wages, and sometimes penalties for late deliveries (Lasserre et al. 2016). The unpredictability introduced by the Arctic environment, namely sea ice, was found by Lasserre et al. (2016) to be the second most-cited operational challenge by shipping companies around the world; the environmental conditions more broadly were the most-cited.

In addition to the regulatory regime, there are a number of domestic policies and programs targeting the safety and environmental considerations of navigating in Canadian Arctic waters. One of the key programs is the Low Impact Shipping Corridors (the Corridors) initiative, which is co-led by the Canadian Coast Guard and Transport Canada. The aim of the Corridors is to inform the prioritization of federal investments in the northern marine transportation system and to develop a collaborative governance framework in partnership with Inuit (Chénier et al. 2017). The work on the Corridors is supported and complemented by the Oceans Protection Plan (OPP), which aims to develop a world-leading marine safety system, to preserve and restore marine ecosystems, to establish a stronger evidence base for decision-making, and to strengthen Indigenous partnerships (Government of Canada 2019). The implementation of the OPP is divided across a number of initiatives, with the understanding that, together, they will achieve the overarching goals of the Plan. Some of the initiatives that will contribute to the Corridors include investments in basic marine infrastructure, training programs, expanding Canadian Coast Guard Auxiliaries, and enhancing community search and rescue and environmental response capabilities. Other initiatives are exploring alternative approaches to decision-making regarding ship operations; for example, the Proactive Vessel Management initiative is providing the space for the Government of Canada and Indigenous peoples and coastal communities to explore solutions to marine issues and conflicts pertaining to shipping through six pilot projects across Canada, including one with Inuit in the Canadian Arctic (Transport Canada 2019a).

Although the regulatory framework of the Arctic shipping governance regime focuses on nature (safety, environmental protection), it is beginning to be recognized that culture is integrated with nature in Arctic marine spaces in particular. For example, in the "Methodology to Analyse Impacts of a Ban on the Use and Carriage of Heavy Fuel Oil as Fuel by Ships in Arctic Waters" developed by the Prevention, Preparedness and Response Subcommittee of the IMO, it is recommended that the "subsistence culture and lifestyle of Arctic indigenous and local communities" be taken into consideration when trying to understand the potential impacts of banning the use of heavy fuel oil by ships in the Arctic (PPR 2019, para 13). It is understood in the Methodology that subsistence is not simply a monetary matter or one of food security but that "subsistence activities are integrated more broadly in a cultural sense as an aspect of the underpinnings of social cohesion, language, public health and identity" (PPR 2019, para. 14).

Furthermore, the individuals that work in the governance and industry of shipping that regularly work on the ground and the waters may have different conceptualizations of marine spaces and the North than the regime itself. For example, Tyrell (2005) speaks of her own engagement and experience with the marine environment, and Steinberg and Peters note that "those who actually engage the ocean, like sailors … become one with the waves as the waves become one with them, in a blend of complementarity and opposition" (2015, 251). Heyes further suggests that for mariners and sailors in particular, the sea is "a domain comprised of divergent spaces [with] real and fanciful stories, memories, mythologies, events and place-names" (2007, 91). At the same time, though, there are many who within the shipping governance regime and Canada's maritime administration who have not been and are not actively or consistently interacting with marine spaces and even fewer with Northern places, for example, those working in Ottawa (Transport Canada headquarters), Winnipeg, and Edmonton (Transport Canada Prairie and Northern Region offices); that is, non-coastal and non-northern cities. Thus, it is far less likely these individuals would have the same conceptualization or relationship with the North or even marine spaces generally (Laidler 2006).

7.3 Inuit and Marine Spaces

Whereas the shipping governance worldview is based in a naturalist ontology, Inuit, like many other Indigenous peoples, have a worldview rooted in an animist or relational ontology (Blaser 2009; Heyes 2007). Through this lens, there is no nature-culture divide; people are not separated from the natural world, but rather all aspects of life are intertwined, with people a part of a network (Aporta 2002, 2010, 2011; Dowsley 2015; Ingold 2000; Tester and Irniq 2008; Tyrrell 2005). The relationships within this network are social, non-dominant, and respectful, as opposed to hierarchical wherein people are to use and manage the marine environment (Dowsley 2015; Ingold 2000; Laidler 2006, 2007). Furthermore, the network is holistic, extending beyond the environmental, geophysical, and biological features that often define disciplinary notions of marine spaces. In contrast, the world cannot be divided into such parts, subsequently meaning that it cannot be constructed because there are no parts to assemble (Ingold 2000; Tester and Irniq 2008). In their study of the historical and cultural context of Inuit knowledge, Tester and Irniq (2008) argued that the term "holistic" was not appropriate for describing the Inuit worldview because it represents exactly this concept of compiling pieces to form a whole. Instead, they offer the terms "seamless" or "avaluqanngittuq" (Inuktitut for "that which has no circle or border around it") as better options because it reflects the lack of boundaries that exist within the Inuit worldview. To contrast with "holistic", this chapter will adopt the term "wholistic", which was first heard by the author at an event in Halifax, Nova Scotia by Albert Marshall, a Mi'kmaw Elder (March 2017),[2] to represent this conceptualization of the indivisible whole of the world.

The seamless, borderless, and "whole" world within which Inuit are a part includes not only marine spaces but land as well. There are some authors who suggest there is a conceptual division between land and sea in the Inuit worldview, even if the worldview embraces continuity from one to the other. Heyes (2007), for example, found that the people of Kangiqsualujjuaq, a community in Nunavik (northern Quebec), see a division due to different terminology associated with land and sea. Tyrrell (2005) also noted that there is an understanding by Inuit of a functional boundary between land and sea, particularly when sea ice is not present. However, when sea ice is present, the "boundary" of the shoreline is blurred and the Arctic transforms into a network of trails that join the land to the sea (Aporta 2009),

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[2] There are examples of the use of "wholistic" outside an Indigenous perspective; according to the Merriam-Webster online dictionary, the term dates back to the 1920s philosophy.

connecting people with places and each other (e.g., Aporta 2011; Laidler 2007). The sea ice becomes home to Inuit (Aporta 2011), which expands and contracts as the sea ice develops and recedes (Heyes 2007; Tyrrell 2005). Aporta et al. (2018) suggest that the coastline thus be considered a continuum across the land-sea interface, rather than a dividing boundary, which better reflects the notion that the "land" is a single comprehensive whole, while also reflecting that there is a functional distinction between terrestrial and marine spaces. To support a discussion of the governance of Arctic shipping, an industry that only exists in the marine domain, I will proceed with an understanding that a division does exist between the land and the sea while also recognizing that within the Inuit worldview, marine spaces cannot be considered in complete isolation from the land.

The animist or relational ontology also aligns with Ingold's dwelling perspective. In exploring hunter-gatherer cultures, Ingold (2000) describes a dwelling perspective as a worldview wherein one comes to know the world by engaging with it. Given the wholistic nature of the Inuit worldview, this requires attention to the whole of the world through ongoing interactions with it and the active application of knowledge within it (Heyes 2007; Tyrrell 2005; Wisniewski 2010). Gibson (1979, as cited in Ingold 2000, 22) refers to this type of knowledge as borne of an "education of attention". Through a lifelong learning process, one is trained to be attentive and attuned to particular aspects of the world, depending on the activities with which the individual is engaged. Knowledge is not something one gains, stores, and transmits, it is discovered and lived through everyday practices; it is a process rather than a transaction. Inuit knowledge is therefore best understood as a way of being in the world (Rasing 2017; Tester and Irniq 2008) and subsequently is as much about being "Inuk" as it is about what one knows (Dowsley 2015; Searles 2009, 2010; Tyrrell 2005; Whitridge 2004).

"The interaction between people and their places is a lifelong conversation" (Tyrrell 2005, 118) that is personal (Laidler 2006) and intimate (Kielsen Holm 2010) and "brings many memories and emotions that tie people to the place and to each other" (Dowsley 2015, 543). A "place" is not static, nor is it something one can come to know everything about. Rather, it is dynamic and alive, changing in tandem with the rest of the wholistic environment (Aporta et al. 2018; Heyes 2007; Tyrrell 2005). Those who have discovered their world through the "lifelong conversation" of learning through an education of attention can come to predict these changes by understanding the relationality within the ever-changing world around them. For Inuit, the changes, or seasons, can be understood in the ebbs and flows of environmental conditions, with the formation and break-up of sea ice, the changes in animal distribution and behaviour, and subsequently the sequence of harvesting playing important roles (Laidler 2006; Wisniewski 2010). These seasons are closely associated with Inuit identity and the daily activities that make up the patterns of life (Aporta et al. 2018; Laidler 2006, 2007; Tyrrell 2005).

A key part of Inuit life is travel across the network of trails the sea ice reveals, be it to reach hunting grounds or to visit family and friends. But traveling is not simply a matter of moving from one location to another. The act of the journey itself, the movement along the trail, is an equally important facet of interacting with "home" (and thus discovering knowledge and being Inuk) as is the act of hunting or sharing the harvest or visiting with family and friends. These trails are not the static lines they are depicted to be through traditional cartographic methods, for this network unfolds across the landscape over time “just like musical performance” (Ingold 2000, 238). Just as with music, it is the movement from one place to the next, measured in time rather than space, that produces the meaning and significance of a trail. Through active engagement with the trail and the practice of applying knowledge along it (an education of attention), one develops a deeper understanding of and relationship with the wholistic world, which is often reflected in the richness and level of detail in the associated vocabulary. For example, Inuit have a vast vocabulary relating to sea ice, which demonstrates the importance of being able to describe the conditions and the functional implications of such detailed knowledge for travel and hunting (Huntington et al. 2010; Ingold 2000; Krupnik et al. 2010; Wisniewski 2010). Through this process, the trail becomes a journey, one that encompasses places, movements, memories, events, and social connections (Aporta 2002, 2004, 2009, 2011; Heyes 2007; Laidler 2007; Tyrrell 2005; Whitridge 2004).

Some authors have found the relationship between Inuit, particularly younger generations (Aporta 2004; Bennett et al. 2016), and the world to be changing. For example, Aporta and MacDonald (2011) found that distance of travel is described by some Inuit today less in terms of time and more so by the number of tanks of fuel required to traverse the distance by skidoo. Rasing (2017) also wrote of the changes in the relationship between Inuit and the environment as a result of the shift from the semi-nomadic lifestyle of living on the land to the more sedentary lifestyle of living in communities. Trippett (2000), however, understands these changes as examples of the close and dynamic relationship between all facets of life, including between Inuit and the land (Aporta and Higgs 2005; Dowsley 2015). Therefore, although the manifestation of the relationship and conceptualization of spaces may be changing, the existence and importance of the relationship may not necessarily be diminishing.

7.4 Implications of Considering Inuit and Shipping Worldviews for Shipping Governance

To reflect an Inuit worldview, the Arctic can be articulated as “Inuit Nunangat”, meaning homeland, all-encompassing of the land, water, and ice, and the interrelationships within that embodies the concept of “home”. From a shipping governance worldview, the Arctic can be understood as the “Northwest Passage”[3], signifying the space as one for transportation and trade and embodying the geographic aspects that delineate a way through the Arctic Archipelago. The Northwest Passage represents a conception of space defined by the boundaries of maritime zones according to UNCLOS, the Polar Code, the AWPPA, and the Shipping Safety Control Zones Order.

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[3] The Northwest Passage(s) only represents a component of Canadian Arctic waters—those that serve as transportation routes through the Arctic Archipelago—but here will represent Arctic marine spaces in Canada as a whole.

To begin to integrate the conceptualizations of the Arctic as Inuit Nunangat and the Northwest Passage would be to recognize that in the former, the elements that comprise the whole of the world cannot be isolated from one another, whereas in the latter, the ability to divide space, topic, and jurisdiction is a central tenant. Consequently, this would mean that discussions of marine issues (as it has been accepted that a division can exist between land and sea), cannot be focused on shipping alone, no matter how comprehensive the approach to the discussion. Inuit relationships to marine spaces cannot be understood in isolation, but by trying to have conversations on only shipping matters, they are being asked to isolate their concerns, that is, to create divides, circles, and borders around particular items within their conceptualization of the space as "home". The difference between wholistic and holistic thus represents a key challenge to integrating shipping governance with Inuit approaches, though it does not make it an impossible feat. Krupnik et al. (2010), for example, demonstrate that endeavours can be successful at bridging across the holistic and wholistic divide through their SIKU Project, an interdisciplinary and comprehensive study of the relationship between Inuit and sea ice. A key piece of this body of work is the participation and involvement of Inuit throughout.

For Transport Canada to encompass a wholistic approach would require the Department to consider far more than transportation policies and programs for the purpose of an efficient, clean, safe, and secure transportation system (Transport Canada 2017). For example, it would require greater consideration of marine biology and ecology (the mandate of Fisheries and Oceans Canada and Environment and Climate Change Canada) and natural resource development (Natural Resources Canada). It would also require considerations of "culture", for example, health and social and cultural well-being (Crown-Indigenous Relations and Northern Affairs Canada). Sea ice complicates this further by physically being of water and functionally being of land (Steinberg and Peters 2015) and furthermore by only being present for part of the year.

An alternative to the expansion of the mandate of a single department would be significantly greater interdepartmental collaboration. Support for such an approach can be found in UNCLOS, which recognizes that "the problems of ocean space are closely interrelated and need to be considered as a whole" (Preamble), as well as policies of the federal government, including the 2002 Oceans Strategy, which calls for integrated management, and, more recently, through the Oceans Protection Plan and its whole-of-government approach. Greater coordination of efforts within the Government of Canada would represent a holistic approach but would still be challenged by the concept of wholism. Not only is it based on an assumption that the summation of the parts (departments) produces the whole, but it does not and arguably cannot reflect the relationship Inuit have with marine spaces and the sea ice built on lifetimes of engaging with their home without their participation.

The sea ice is subject to particularly polarizing views between Inuit and the existing shipping governance regime. As a part of Inuit Nunangat, sea ice is a feature of home and one that expands territory, allowing for greater mobility and supporting the practice of living. In contrast, in the context of the Northwest Passage, it is an inhibitor of transit, a dangerous inanimate feature of Arctic navigation that represents a significant financial and operational risk (Aporta 2011; Bravo 2010; Lasserre et al. 2016; Tyrrell 2005). These opposing conceptualizations of ice and interactions with it—one living through engaging with it and the other conducting business through destroying or avoiding it—create a conflict between the freedom of mobility and the freedom of navigation. However, the emphasis on the risk posed by the sea ice in the shipping governance regime also represents a certain degree of respect for the feature. Although it may not be envisioned as "alive" as it is in the Inuit worldview, it is recognized as dynamic and outside the control of people. It has led the otherwise rigid shipping governance regime to adapt to provide flexibility through the zone/date system, AIRSS and POLARIS.

Flexibility in the management of ship traffic is also appearing elsewhere in Canada. For example, Transport Canada has introduced dynamic speed restrictions on traffic in the Gulf of St. Lawrence for the purpose of protecting the North Atlantic right whale. When the Government of Canada determines a whale is present in defined "dynamic zones", vessels over 13 m in length must reduce their speed (Transport Canada 2019b). This demonstrates a more general recognition that the world is dynamic, and therefore so too must be the approaches to shipping governance. This, in turn, opens the door for cross-cultural conversations about adaptability and flexibility based on a shared understanding that the world is ever-changing.

7.5 Conclusion

This chapter set out to support cross-cultural dialogues on matters of Arctic shipping governance through a discussion of the worldview of Inuit and the worldviews implicit in the governance of Arctic shipping, as well as the challenges of and opportunities for integrating the two. The conception of this work was the recognition that words come from a worldview, and subsequently there is a requirement to acknowledge and respect the worldview of Inuit if their concerns are to be truly heard and considered.

The Inuit worldview can be understood as conceptualizing Arctic marine spaces as part of Inuit Nunangat—their homeland—inclusive of the land, water, sea ice, and all facets of life. The shipping governance worldview, in contrast, conceptualizes Arctic marine spaces as the Northwest Passage, dividing nature from culture and further separating nature into jurisdictions and responsibilities that isolate facets of life from one another. Through efforts such as the Oceans Protection Plan's whole-of-government approach, the shipping governance regime is moving towards a holistic approach by advancing interdepartmental and multi-stakeholder collaboration. Inuit, though, have a wholistic worldview, which is premised on the notion that the world cannot be subdivided and isolated into parts, meaning it also cannot be reconstructed. The differences between a holistic and wholistic approach are not a barrier to collaboration and partnership but do need to be taken into consideration when working cross-culturally.

Although the Inuit and shipping governance worldviews do demonstrate differences, to state that all those involved in the shipping governance regime hold this same conceptualization of Arctic and/or marine spaces is to miss a potential opportunity, for just as "the cognized landscape of the Inuit was not less precise or rational for the immense cultural burden it bore, [neither are] Western geographies devoid of fantasy, emotion, and other subtexts" (Whitridge 2004, 228). Although unlikely to understand Arctic marine spaces as Inuit Nunangat (unless they are Inuk or spent significant time in the North with Inuit), there are individuals working within the regime that have come to know the Arctic and/or marine spaces through their own active engagement with the space. By leveraging the personal experiences of these individuals whom have discovered knowledge through interacting with the world, it is more likely that mutual understanding and respect of worldviews can be found and fostered. Such a foundation will support an understanding of the words spoken by Inuit and subsequently the consideration of Inuit concerns and interests with respect to shipping.

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Chapter 8

Knowledge and Data: An Exploration of the Use of Inuit Knowledge in Decision Support Systems in Marine Management

Claudio Aporta, Breanna Bishop, Olivia Choi, and Weishan Wang

Abstract In increasingly data-driven marine and coastal management practices, the issue of "data" is becoming central, resulting in the development of comprehensive data hubs and spatial data infrastructures. These data hubs are often composed of different types of datasets, from oceanographic to biological and socioeconomic. In the Canadian Arctic, and in the context of co-governance arrangements and participatory approaches, these data hubs include, prominently, Inuit knowledge. This chapter explores the ontological tensions of using Inuit knowledge as data in the context of marine and coastal management, and it discusses the nature of Inuit knowledge and the transformations that take place when the knowledge is rendered into data. The authors assess the ability of existing decision support systems and tools to incorporate Indigenous knowledge and propose a number of criteria to integrate Inuit ontological approaches in the design of these systems and tools.

Keywords Canadian Arctic · Decision support systems · Indigenous knowledge · Inuit · Marine spatial planning

8.1 Introduction

As semi-nomadic people, whose livelihood and residence patterns depended on seasonal variations, mobility is at the core of the Inuit approach to the environment and their identities. Though the Canadian government's policies prompted Inuit to move to permanent settlements in the 1960s and 1970s, the social fabric of the Arctic is still based on the timing of mobility and residence patterns. The implication of this

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is that, for Inuit, *home* is not only in today's settlements but also (and mostly) *on the land*, a generic expression used to describe activities that happen outside of the settlement, including the seasonal trails that Inuit travel periodically and the marine environment of which the sea ice is fundamental. This means that while government organizations, nongovernmental organizations (NGOs), and outsiders in general may look at the Arctic environment as wilderness, a shipping corridor, a marine protected area, or a park, to Inuit these environments are intertwined with their own historic and present senses of community and homeland. This sense of place is manifested in harvesting practices, social and economic arrangements, cultural identity, and in the knowledge that Inuit have developed, transmitted, and relied upon since time immemorial. Mobility is, therefore, at the core of Inuit ontologies (Aporta 2009) and is embedded in time-honored social and environmental relations.

In the broad policy and legal contexts within which Inuit have been called to be partners in co-management and co-governance arrangements, interactions between Inuit and government invariably involve ontological tensions, as the environment may be regarded as, on the one hand, an entity to be managed, protected, used, or exploited and, on the other, as a social space or homeland. These tensions are implicit (and often unnoticed) in negotiations, management, and decision-making. They can manifest in differing and sometimes conflicting ideas regarding conservation of the environment, the structure of governance arrangements, and the validity of scientific evidence and of Inuit knowledge.

In increasingly data-driven marine and coastal management practices, which include frameworks such as ecosystem-based management, integrated coastal zone management, integrated ocean management, and marine spatial planning (MSP), the issue of "data" is becoming central, resulting in the development of comprehensive data hubs and spatial data infrastructures. These data hubs are often composed of different types of datasets, from oceanographic to biological and socioeconomic. In the Canadian Arctic, in particular, these hubs, such as the Inuvialuit Settlement Region Online Platform (ISROP), include (predominantly) Inuit knowledge. The ontological tensions referred to above are also present in the making, composition, and integration of datasets.

Decision support systems (DSSs) and decision support tools (DSTs) are broadly understood as computer-supported systems or tools that can process different types of data, visualize uses and observations, analyze dynamics and interactions, and provide estimated outcomes of potential scenarios or decisions.[1] They include standard geographic information systems (GIS), collaborative planning platforms such as SeaSketch, and complex analytical tools such as Marxan (Table 8.1). Some visualization tools such as Esri's Storymaps and open-source Nunaliit are also used in the form of atlases or to convey stories. All these tools deal with a number of challenges, including how to integrate different datasets; how to account for and represent "cultural value"; how to account for changes, both social and environmental,

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[1] While these concepts may have had broader meanings when they were coined in the 1980s, DSSs and DSTs are increasingly understood today as involving information and communications technologies.

Table 8.1 Strengths and weaknesses of DSSs and DSTs

Examples	Short description	Strengths	Weaknesses
GIS platforms (e.g., ArcGIS, QGIS)	GIS are systems and tools designed to capture, store, manipulate, analyze, manage, and present all types of geographic data, including local knowledge, and to display and analyze interactions between datasets (Goodchild 2010). They provide users with access to regulatory, spatial, and temporal information outputs (Edwards and Evans 2017)	(1) GIS allows straightforward data integration including local knowledge through cartographic conventions	(1) Advanced skills and expertise are still required to use these tools in full capacity
		(2) GIS programs allow Indigenous users to work interactively with models and data, as well as to conduct spatial queries based on certain criteria and Indigenous priorities	(2) GIS platforms have very limited ways to deal with nonspatial data, such as narratives
		(3) GIS programs have tools that allow for defining and visualizing cultural values	(3) GIS platforms have limited capabilities in terms of dealing with dynamic/changing seasonal data, including representations of the sea ice dynamics
Marxan	Marxan contains a suite of spatial analysis tools, and it is the most widely used decision support software to help decision-makers find reasonably efficient solutions for conservation planning issues (Ardron et al. 2008). Marxan combines socioeconomic and ecological data, and has been widely used for designing marine protected areas (Van Kouwen et al. 2007)	(1) Marxan and Marxan with Zones can deal with a variety of data, including socioeconomic data and local knowledge	(1) The process of scenario building using algorithms is so abstract that it is often viewed as obscure and dismissed by nonexperts
		(2) They can enhance transparency in decision-making processes	(2) Marxan is limited in terms of incorporating data that cannot be quantified
		(3) They provide complex analytical and scenario-building tools based on management targets	

(continued)

Table 8.1 (continued)

Examples	Short description	Strengths	Weaknesses
SeaSketch	SeaSketch is a service-based online software platform (McClintock and Gordon 2015). It supports map-based discussions and has been used for marine spatial planning initiatives at various scales, for a variety of purposes, and for engaging all types of users and stakeholders (McClintock 2013)	(1) Easy for users to use through online platform	(1) Requires certain level of technical skills to use the online platform
		(2) Easy access to data	(2) Requires considerable funding for continued access and use
		(3) Incorporates diverse data and ideas from user groups and stakeholders	(3) Requires reliable Internet connection
		(4) Can provide immediate analytical feedback	
		(5) Advanced collaboration and engagement tools for users and stakeholders	
		(6) Allows for remote participation through the online platform	
DESYCO	DEcision support SYstem for COastal climate change impact assessment (DESYCO) is a DSS system developed in Italy for water resource management. DESYCO is a multidisciplinary DSS for analyzing risks and biophysical and socioeconomic impacts on a regional scale. It is designed particularly to facilitate engagement by means of end users' analysis and collection of preferences (Santoro et al. 2013)	(1) Recognizes users' or stakeholders' control of the decision-making process	(1) Large resources devoted to comprehensive stakeholder engagement
		(2) Integrated assessment and management on a regional scale	(2) Hazard scenarios are developed by numerical models and statistical analysis which require high degree of technical skill and research capacity
		(3) Multi-criteria decision analysis to balance differing priorities	

(continued)

Table 8.1 (continued)

Examples	Short description	Strengths	Weaknesses
Nunaliit Atlas Framework	The Nunaliit Atlas Framework aims to facilitate storytelling and participatory mapping, allowing for the use of different forms of information from a variety of sources, using maps as a central way to connect and interact with the data (GCRC 2018)	(1) Simple for users to use	(1) Acts as a visualization and data collection tool and is not a DST per se
		(2) Permits web-users to contribute additions and make changes	(2) Requires Internet access and basic software operational skills
		(3) Designed particularly for Indigenous knowledge	
		(4) Able to store text-based attributes	
		(5) Deals well with narratives by allowing multimedia objects on a map	

over time; how to deal with different views from diverse users and practitioners; and how to support participatory decision-making processes. In the case of the Canadian Arctic, an additional challenge is related to the documentation, processing, analysis, and integration of Inuit knowledge.

This chapter will explore the ontological tensions of using Inuit knowledge as data in the context of marine and coastal management. It will first discuss the nature of Inuit knowledge and the transformations that take place when the knowledge is rendered into data. It will then reflect on how some DSSs incorporate (or could incorporate) Inuit knowledge. Finally, it will propose a number of criteria to integrate Inuit ontological approaches in the design of DSSs. This chapter is exploratory, and its focus is conceptual rather than technical, with the main goals of (1) outlining some ontological tensions regarding the collection and use of Inuit knowledge in marine and coastal management in the Canadian Arctic and (2) exploring some potential ideas of designing DSSs that are culturally appropriate and informed by Inuit views and knowledge.

8.2 Inuit Knowledge as Data: Transformations and Contextualization

No experiential knowledge can be seamlessly represented and converted into data, as the process will always involve various levels of transformation and interpretation. Some information management models account for the differences between what they sometimes refer to as wisdom, knowledge, information, and data (e.g.,

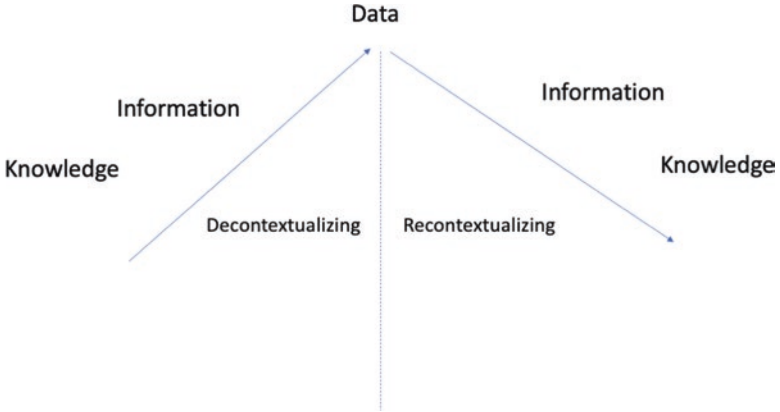

Fig. 8.1 The process of de- and recontextualization in the knowledge-information-data continuum. Wisdom has not been included in the diagram as the concept is not relevant for our discussion

Rowley 2007). Most models characterize wisdom as more abstract and contextual, while data is considered the least abstract and contextual (Cooper 2010; Aamodt and Nygård 1995). What demarcates the difference between each state is somewhat blurred, with transitions often characterized through varying degrees of ascribed meaning (Bates 2005).

For instance, we could reflect on a situation in which a decision is made on whether or not to cross a river in certain places based on the depth of the water. Wisdom may be defined as making a decision based on the knowledge of the parts of the river that are easier and those that are more difficult to cross, according to observations of depth. The depths that are good for crossing can be input into a dataset of measurements. The data itself is stripped of context and abstraction, while the decision to cross the river (or not) at a particular location will include both abstraction and context.

This model, as straightforward as it may seem, is complicated by the fact that in reality the continuum of wisdom-knowledge-information-data does not exist as a chain of discrete states in experiential observations or behaviours. Context and abstraction can be derived, for instance, from information and data. In essence, the river's depth can be used to make other assessments; for example, a biologist can use the data in defining the features of a particular ecosystem (instead of using it to make a decision about crossing). The data is decontextualized of its original meaning and practical use and recontextualized in other uses and interpretations. In other words, the data, separated from its original context, can be placed in other contexts and its meaning redefined, as illustrated in Fig. 8.1.

The process of documenting and the possible recontextualization of knowledge can potentially be a heavily loaded political process, whether intended or unintended, as Indigenous knowledge can be used to justify or inform certain decisions or claims. If the context of the knowledge is not retained, the recontextualization and subsequent uses of the data could no longer support the interests of the original knowledge holder. This problem has been identified by Indigenous groups who have introduced concepts such as Indigenous data sovereignty (Walter and Suina 2018; see also Tesar et al. 2019), guided by principles including OCAP™ (Ownership, Control, Access and Possession).

Inuit knowledge, as described in the Introduction, is intrinsically experiential and contextual. It is based on observations of states, dynamics, and relationships and is rooted in individual and collective memories and experiences. For example, knowledge related to sea ice safety is learned in the context of harvesting, traveling, and, in a broader sense, living. It is for this reason that documenting, for instance, places where harp seals can be harvested, will be invariably related to broader experiences of the environment and of others. It is possible to render the location of the harvesting site as information and eventually as data (a geographic coordinate, or *a point*, to use GIS terminology). If the context is not documented, such a point may become detached from its original context and meaning and recontextualized in different ways. This process is far from simple and straightforward. To a local hunter looking at the harvesting site on a map, the point may become reattached to its original context, but to a biologist, the point may become integrated to other knowledge, and a new context (e.g., presence of harp seals) may be created. On the other hand, if the original context is documented in relation to the point (this can be achieved, for instance, through the recording of the narratives that accompanied the documentation process and included as part of the metadata of that point feature), some contextual information of the original experiential knowledge may be retained.

The process of decontextualization and recontextualization is unavoidable,[2] but an understanding of Inuit ontologies could inform the paths through which knowledge is documented, managed, and (to a degree) interpreted, in order to avoid recontextualization practices that may substantially alter the original knowledge. The abovementioned harvesting site, for instance, can be associated (through a documented narrative) to seasonal variations, broader ecological understandings, wind directions, ice dynamics, seasonal camps, historical memories, family and community relations, place names on the shore, and open water or sea ice routes. Knowledge in this sense is embedded in a host of environmental and social experiences, making documentation of context integral to minimizing knowledge loss through decontextualization and recontextualization processes.

Inuit place names are appropriate examples of the relationships between knowledge and context. As Inuit are holders of an oral culture, place names are good indicators of collective knowledge, observations, memories, and experiences. Salliq (Fig. 8.2) is an island east of Igloolik. The name of the island refers to the fact that it is located “furthest from the mainland,” and its location can be rendered into a latitude and longitude in a geographic coordinate system (69.0994346; −78.8144168).

There are many places named Salliq or Salluit (plural) in the eastern Canadian Arctic (including the settlement formally known as Coral Harbor). Salliq in Fig. 8.2,

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[2] Semiologist Roland Barthes argued that any sort of “text” is actually produced through the reader’s engagement with the original writing/narrative (1973).

Fig. 8.2 The island of Salliq, east of Igloolik in northern Foxe Basin

however, was properly documented in the context of an Inuit-led place names project in the Igloolik area, and a narrative of the place provided by Noah Piugattuk in the 1980s was recorded. Piugattuk's narrative unveils significant contextual knowledge that would be lost if the documentation process had only included the location and meaning of the name:

> When Noah Piugaattuk was a boy, many caribou starved to death here [in Salliq] because it had rained in the winter. The whole island was covered with ice and, since then, no one camps here. Before the arrival of traders in the Igloolik area, some Inuit would camp here from autumn until spring, hunting polar bears for trade in Pond Inlet. (unpublished material, part of the Igloolik Oral History Project database)

It is clear that the context of Salliq is multifaceted, as it includes biological and ecological information, human use, weather events, personal memories, and lessons learned. The context is surely richer, as it is embedded in broader narratives and experiences possessed by Noah Piugattuk and others in Igloolik. A process of documentation informed by Inuit ontologies would include some level of reference to or understanding of the broader and comprehensive nature of Inuit knowledge, especially regarding the limitations of fragmenting that knowledge to make it fit within western scientific or management frames of reference. In other words, documenting one type of knowledge (e.g., presence of polar bears) will only have limited value unless some process of context keeping is established.

In practical terms, a data collection process of Inuit knowledge should consider the significance of other variables, such as seasonality and sea ice dynamics. Salliq is not just a point on a map, but it is knowledge of a place that is connected to other phenomena and events. In the case of MSP, such contextual dimensions can be accounted for in the form of documenting (a) narratives associated to the feature, (b) seasonal observations including sea ice as an extension of the land, and (c) a definition of "cultural value" that would allow for representation of a given place, such as Salliq, in connection to traditional travel routes. Salliq, therefore, will become a place within a network rather than an isolated indicator of human use (the harvesting of polar bears) or a species' habitat.

The concept of "cultural value" has been coined to identify places that are not immediately defined by a single discrete piece of information (e.g., the location of a harvesting site) and as a way to represent qualitative information in a world of quantitative data. In the context of defining spaces that reflect cultural value, this could include demarcating marine and coastal spaces that are distinguished not only by the presence of a harvesting site but also by other types of use and knowledge. As mobility is at the core of Inuit environmental and social relations, it should occupy a central role in defining "cultural value" spaces, allowing for a more comprehensive approach to data collection and interpretation that would include places within broader contexts.

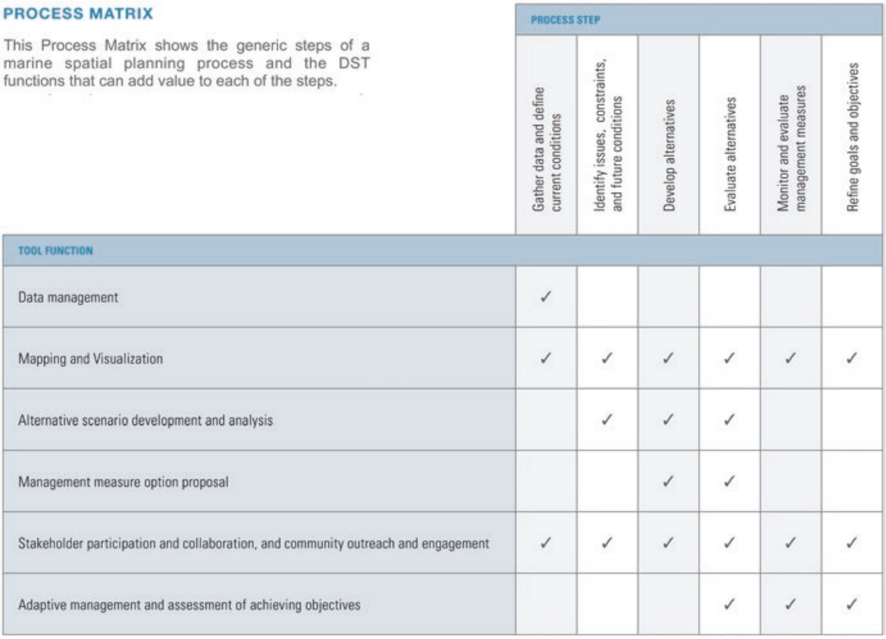
Data is often conceived as static states of knowledge, a conception which is contrary to the dynamic synergies between individual, community, and environment that shape core aspects of knowledge. In this sense, documenting seasonal or cyclical observations and change is another important method of contextualizing data. It should be understood that seasonal changes in the Inuit context do not necessarily follow western conceptions of the four seasons, as temporal boundaries are determined by interactions with environmental or ecological phenomena that are also in flux (Mackenzie et al. 2017; Aporta 2016). For example, throughout the year, sea ice acts as an extension of the land, allowing for mobility networks to expand or contract in response to changing sea ice conditions (Aporta 2002). Subsequently, as routes adapt, harvest patterns, ecological observations, and the social fabric of a community all respond to and revolve around such temporal changes. While accounting for all interactions may be beyond the scope of data documentation, considering seasonality or temporal cycles can provide a basis for deriving other relational contexts (e.g., through metadata).

Methodologies for mapping Indigenous knowledge in context have been extensively developed in the practice of participatory mapping, also referred to as "counter mapping" (Rundstrom 2009), as it provides cartographic representations of objects or events that otherwise would not appear on regular maps. Map biographies were fully developed in land use studies in the 1970s in Canada (see, for instance, Freeman 1976), and best practices for mapping of Indigenous knowledge have been clearly laid out (Tobias 2009). Public participatory GIS (PPGIS) are approaches to bring the academic practices of GIS and mapping to the local level to promote knowledge production by local and nongovernmental groups (Sieber 2006). The connection between counter mapping or participatory mapping and MSP, however, has been less explored, and it is certainly underdeveloped in concrete practices of marine management. While there are many examples of including Indigenous knowledge at different stages of a decision-making process (especially in situations involving co-management), the idea of adapting DSSs or DSTs according to Indigenous ontologies, such as concepts of the environment, is quite novel. It is often acknowledged that Indigenous knowledge is important for marine management, but the knowledge is usually collected and used in the context of scientific or western frames of reference, including theories, methods, and, ultimately, epistemology. The issues we will address in the next two sections are (1) how well-suited current DSSs and DSTs are in considering Indigenous ontologies and (2) criteria that could help to design culturally appropriate DSSs and DSTs that align with Indigenous approaches to knowledge production and sharing.

8.3 Indigenous Knowledge and Ontologies in Decision Support Systems and Tools

As mentioned above, DSSs and DSTs are broad concepts that involve a variety of programs and platforms (Kannen et al. 2016). Coleman et al. (2011) organized DSTs in relation to their functions and role in the different phases of the marine planning process, demonstrating that issues around knowledge documentation, data management, and community engagement are present in all stages of marine management and are embedded in DSTs (Fig. 8.3).

DSSs and DSTs have been used to support evidence-based decision-making for terrestrial, coastal, and marine management in places and on issues that often



PROCESS MATRIX

This Process Matrix shows the generic steps of a marine spatial planning process and the DST functions that can add value to each of the steps.

	PROCESS STEP					
TOOL FUNCTION	Gather data and define current conditions	Identify issues, constraints, and future conditions	Develop alternatives	Evaluate alternatives	Monitor and evaluate management measures	Refine goals and objectives
Data management	✓					
Mapping and Visualization	✓	✓	✓	✓	✓	✓
Alternative scenario development and analysis		✓	✓	✓		
Management measure option proposal			✓	✓		
Stakeholder participation and collaboration, and community outreach and engagement	✓	✓	✓	✓	✓	✓
Adaptive management and assessment of achieving objectives				✓	✓	✓

Fig. 8.3 DSTs organized by function and process within MSP. (Retreived from Coleman et al. 2011)

involve local and Indigenous communities. This section looks at three aspects of the intersection between DSSs and DSTs and Indigenous ontologies: (1) how the systems and tools deal with the process of data transformation and integration; (2) how they allow for the incorporation of Indigenous-informed decision-making; and (3) how they are suited for the implementation of cross-cultural procedures. Examples are drawn from tools and platforms that are often used in data-driven decision-making (GIS, Marxan, SeaSketch, and DESYCO), as well as from Nunaliit, an online atlas that allows for narratives and multimedia representations of knowledge.

Data integration involves pairing Indigenous knowledge data alongside other types of data, such as biophysical, oceanographic, atmospheric, geological, socio-economic, and non-Indigenous human uses (e.g., commercial shipping). In other words, Indigenous knowledge becomes one dataset among many others. In marine planning, such integration is often done through the spatial attribute (location) of the data. In addition, data integration also involves assembling quantitative and qualitative data from different sources, as well as dealing with different spatial and temporal scales, and collection methods. Hence, integrated databases (data hubs or data atlases) require dealing with datasets that are not only different in nature and composition but that also belong to different stakeholder groups or organizations. Once again, it is critical that the user understands the context of the data and that it is maintained when integrating different datasets. This often requires tiered levels of information access and flow.

As mentioned in the previous section, assigning cultural values to places is a way of rendering Indigenous knowledge into data. As shown in Table 8.1, while GIS software is not specifically designed for participatory approaches, it can be adapted to document knowledge and practices through a community-led process. Cultural values and relationships between places of importance can be assigned, visualized, and analyzed through methods such as *buffering* (identifying regions on a map within a specified distance of one or more features) and *network analysis* (examining the properties of natural and human networks in order to understand the behaviour and linkages of flows within and around them). Temporal indicators, such as seasons, can be also included in the data. GIS platforms, however, are poor at incorporating narratives and other forms of nonspatial qualitative information.

Spatial analysis tools such ArcGIS and Marxan are the most common DSTs, and they are used for visualizing, integrating, and analyzing data (Janßen et al. 2019). Marxan is also used for creating management scenarios and conservation targets based on data-driven evidence. They can combine socioeconomic and biophysical data and display complex interactions between datasets. These analytical tools can help conduct comprehensive spatial analysis to enhance transparency in the decision-making process, but they are heavily reliant on external expertise (particularly Marxan) and mostly based on quantitative and/or decontextualized data.

SeaSketch is a web-based planning tool, which is being used for MSP around the world (McClintock and Gordon 2015). It allows users to input local data and use cartographic tools to transform their knowledge into features in a way that is easily understood by other stakeholders. SeaSketch is a development of Esri's GIS platforms, and it allows participatory approaches, including online collaborative mapping by different stakeholders and users that may be situated in different parts of the world. As such, SeaSketch provides a user-friendly platform that can be used in cross-cultural settings, as long as clear parameters are set. For instance, a transportation agency could input shipping data, a conservation NGO could provide data on beluga whales' habitats, and an Indigenous organization may provide rolled-up (aggregated) data related to cultural significance. At the same time SeaSketch is costly, requires continuous expert input, and is limited in terms of including nonspatial data, such as narratives.

SeaSketch, however, is used by the Marine Planning Partnership for the North Pacific Coast (MaPP) for collaborative planning among the four subregions of British Columbia: Haida Gwaii, North Coast, Central Coast, and North Vancouver Island. MaPP has integrated Marxan outputs into SeaSketch projects to inform the design of protection management zones, which are used in discussion with stakeholders. MaPP draws upon and integrates different knowledge and data sources in planning initiatives, including traditional knowledge. For example, the Council of the Haida Nation documented cultural sites, ecologically important areas, harvesting sites, and marine species in the Haida Marine Traditional Knowledge Study through participatory mapping. To maintain the richness, complexity, and context of Haida traditional knowledge, interviews—both map-based and to record oral histories—were conducted to document spatial and temporal patterns of marine use and the stories behind their significance (Council of the Haida Nation 2011). The map in Fig. 8.4 illustrates the approach that was taken to present traditional knowledge in a holistic manner.

Some additional challenges for DSTs are the seasonal dynamics of Inuit knowledge and land/marine use patterns and the changing states and processes of the sea ice, which are difficult to represent and analyze cartographically. They are also not suited for the representation of nonspatial information, and they are challenged in their ability to account for expert opinion. Marxan and Marxan with Zones are useful analytical tools when properly incorporated into broader information and knowledge management systems.

Some of these challenges can be overcome through the use of PPGIS and participatory tools such as the atlas platform Nunaliit. The Nunaliit Atlas Framework, created by the Geomatics and Cartographic Research Centre at Carleton University, has been designed to store and display text-based attributes and "data objects" in a relatively simple way, allowing for multimedia tools to represent nonspatial dimensions of knowledge in a cartographic way. Nunaliit is open source and follows the principles of cybercartography proposed by D.R.F. Taylor. Taylor (2005) defined it as "the organization, presentation, analysis and communication of spatially referenced information on a wide variety of topics of interest to society in an interactive, dynamic, multisensory format with the use of multimedia and multimodal interfaces." Nunaliit allows users to create attributes and make changes through online platforms. However, the framework is a visualization and collaborative tool, and it has not been incorporated into broader DSSs or used in the context of decision-making in marine planning.

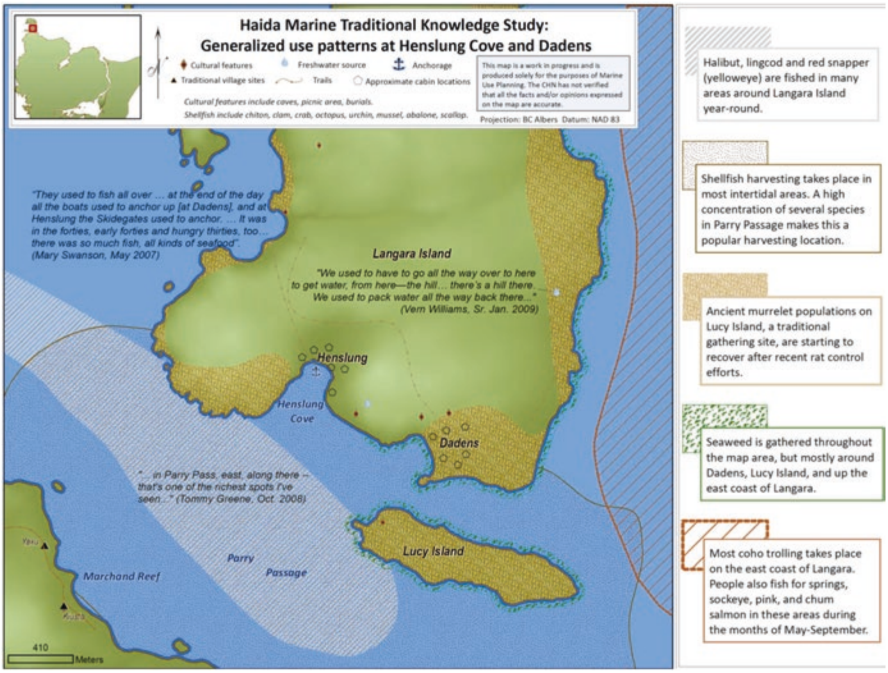


Fig. 8.4 Map showing cultural and ecological significance in Henslung Cove and Dadens (Council of the Haida Nation 2011)

Emerging data sovereignty concepts encourage Indigenous groups to play a key role in Indigenous data governance, including data collection, interpretation, management, application, and dissemination. Current DSSs and DSTs provide some opportunities for Indigenous peoples to input, analyze, edit, visualize, and share a variety of datasets but are limited in terms of reliance on outside expertise, limitations to include narratives and nonspatial data, and lack of participatory tools integrated into DSSs. Most DSSs and DSTs are not designed to focus particularly on Indigenous research needs, which results in limited functional ability of DSSs to interpret Indigenous knowledge. Furthermore, most DSSs and DSTs are highly technical, which remains an important factor preventing practitioners from using them (Janßen et al. 2019). For example, Marxan and Marxan with Zones have been accepted as the most commonly used DSTs, but they require a high level of expertise and strict data formats and lack user-friendly interfaces. In practice, these tools are not designed according to Indigenous communities and organizations' capacity. Ultimately, the outcomes of these tools could be misleading if they are not utilized properly (Janßen et al. 2019) or if they do not incorporate input by users and stakeholders. This can result in constraints and disadvantages for DSTs like Marxan to incorporate Indigenous data and knowledge.Table 8.1 summarizes some inherent strengths and weaknesses of the platforms described in this chapter, in regard to the documentation of integration of Indigenous knowledge and in terms of accounting for Indigenous ontologies. It is not a comprehensive table but rather an illustration of transformations and alignments (or misalignments) between DSSs/DSTs and Indigenous knowledge.

Some participatory DSTs and DSSs are attempting to support end users' continuous involvement throughout the decision-making process. For example, the DEcision support SYstem for COastal climate change impact assessment (DESYCO) is a participative DSS that recognizes end users' control of the entire decision-making process. It was designed particularly for involving user groups and stakeholders by means of end users' analysis and collection of preferences (Santoro et al. 2013). Within DESYCO, comprehensive engagement is conducted in each decision-making process; users and stakeholders are able to detect and check the overall usefulness of this DSS. However, involving end users in the development of DSSs is not yet common practice (Bolman et al. 2018). Most DSSs and DSTs are designed and/or used by planners, academics, and programmers and are often distrusted or little understood by Indigenous peoples (Stelzenmüller et al. 2013). Indeed, incorporating traditional knowledge into decision-making must go beyond simply integrating scientific and traditional knowledge systems and methods. Holistic approaches to coastal and marine management require power sharing and the capacity to participate in decision-making. Necessarily, tools and approaches to linking knowledge systems must ensure protections against the misuse and exploitation of traditional knowledge and that the source communities maintain control of access and use of the knowledge.

8.4 Criteria for Incorporating Inuit Ontologies in Decision Support Tools

Article 32.2 of the UN Declaration on the Rights of Indigenous Peoples (UNDRIP) stipulates:

> States shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free and informed consent prior to the approval of any project affecting their lands or territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources.

Through the ratification of UNDRIP, its intention to act upon the findings of the Truth and Reconciliation Commission,[3] and the creation of institutions and initiatives such the Inuit-Crown Partnership Committee, the Government of Canada is increasingly engaging Indigenous peoples in matters of governance. Community engagement in marine and coastal management is also clearly articulated in ocean policy, particularly in the Oceans Act (1996). Canada has committed to establishing

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[3] The Truth and Reconciliation Commission was established by the Government of Canada in 2008 with the goal of documenting the history and lasting impacts of the Canadian Indian residential school system on Indigenous students and their families.

partnerships and collaborating with Indigenous communities in initiatives under the Oceans Protection Plan (Transport Canada 2016). In 2018, the Reconciliation Framework for Bioregional Oceans Management and Protection was signed by Canada and 14 First Nations on the North Pacific Coast, which establishes co-governance structures for marine planning initiatives in the Northern Shelf Bioregion (DFO 2019). However, a major gap persists on how to effectively and practically facilitate and enable this engagement.

Since marine management today inevitably involves data collection and integration, it is clear that not only governance arrangements but also data protocols must follow the principles of free, prior, and informed consent. The premise in this chapter is that true engagement will involve taking the appropriate steps to ensure that Indigenous knowledge is properly transformed into data and that the process of data integration will be done in a respectful and intercultural manner. This involves assuming that Indigenous cosmologies will inform the design of DSS and that the processes of data collection, analysis, and integration will take place in a cross-cultural setting.

The involvement of end users is fundamental in developing a DSS that meets users' needs (Santoro et al. 2013). In a context of co-governance and genuine participation, DSSs in the Canadian Arctic should be developed in partnership with Inuit organizations and communities, opening doors for Inuit ontologies to shape the design of the decision-making process and DSSs in accordance to Inuit practices and understandings.

Inuit Tapiriit Kanatami (ITK) recently released a policy paper entitled "National Inuit Strategy on Research" in which it emphasizes that Inuit involvement in research is a matter of self-determination (ITK 2018). The ITK document articulates Inuit expections for how research in their territories should be conducted, providing guidelines that cover the whole research process, from identifying research priorities to communicating research outcomes. The document's value extends beyond the limits of academic research, and it can be taken as a guide for defining the criteria for the improvement of DSSs and DSTs in Arctic coastal and marine planning. The criteria listed below do not constitute a comprehensive list, but an exploration of potential ways in which the issue of data can be better approached in the context of coastal and marine management. Definite criteria, in fact, would require Inuit engagement, but the ideas suggested in this policy paper align with participatory approaches and our interpretation of Inuit ontologies.

Among the preconditions for the design and applications of these decision-making systems are (a) a comprehensive engagement process with Inuit communities and organizations; (b) a clear and balanced co-governance framework and legislation; (c) appropriate funding to support initiatives, training, and implementation; and (d) consideration that, in an intercultural setting, building capacity is a two-way process involving social learning from all relevant actors. In essence, the preconditions of an Inuit-informed DSS involve a process of empowerment. An Inuit-informed DSS could/should therefore involve the following:

1. A comprehensive data management plan (DMP), which would include data sharing and data ownership agreements. The DMP must establish clear rules for access, collection, protection, integration, and use of all datasets, with special provisions for Indigenous knowledge. In the Canadian Arctic, data collection protocols should include provisions for accounting for temporal/seasonal variability and for the specific nature of the sea ice as a recurrent and dynamic feature. The DMP must also recognize the oral and experiential nature of Inuit knowledge, providing guidelines for documenting contextual information and narratives.
2. Cultural values as defined by Inuit mobility and other ontological considerations. Any Inuit-informed DSS should recognize the relationships between people and the environment and connectivity between places and between environmental phenomena. Further, such recognition must circumscribe practices of compartmentalization or data disaggregation that do not adequately support an Inuit ontological approach. It is important to sustain representations of the interconnectivity and interdependency of social-environmental relations to strengthen how cultural values are incorporated, whereby such cultural values are rooted in mobility and seasonality, and which intersect with subsequent social and environmental relations.
3. Contextualization of data. As data integration within a DSS is inevitable, ensuring that Inuit-sourced data can remain contextualized is imperative to supporting an Inuit-informed DSS. While incorporation of "cultural value" data achieves this, additional methods such as including narratives or accounting for temporal changes can help avoid knowledge loss through decontextualization processes (e.g., through data aggregation in a DSS). It could be assumed that all planners or managers interacting with a DSS may not have a deep understanding of Inuit ontological approaches. However, through creating a DSS that supports context keeping, key ontological aspects may be retained.
4. PPGIS in the planning and management process. Combined with visualization and analytical tools, PPGIS can allow Inuit users to enhance data control, share knowledge and experiences, express different perspectives, collaborate with other stakeholders, and facilitate participatory learning. PPGIS in this context is strengthened by acquiring the consent of Inuit prior to the decision-making process, recognizing Inuit priorities in decision-making and implementation, and reflecting Inuit priorities throughout planning and management processes.
5. An integrated and user-friendly DSS. Given the comprehensive nature of Inuit knowledge, and complex interactions with the environment, an integrated and user-friendly DSS is suggested, to avoid additional fragmentation of knowledge and to empower Inuit communities and organizations. This DSS would be conceptualized in consultation with Inuit, but it could involve the following features: a well-defined data hub, allowing for interoperability of datasets; a user-friendly interface, combining visualization, PPGIS, and analytical tools; web-based, allowing for remote access to enable Inuit communities and other actors to participate in decision-making; and conceptualization of the decision-making process where data-driven analysis and expert opinion could coexist.

6. Continuous funding and capacity building. Developers should create a user-friendly DSS according to research capacity of Inuit communities and organizations to support their proactive involvement in planning and management, and to increase their access to and control of data. Also, tenable funding should be provided to balance financial sustainability and technical stability of the DSS (Pınarbaşı et al. 2017). It should also be designed to facilitate participatory learning and research capacity building among Inuit and non-Inuit stakeholders. Non-Inuit stakeholders can learn about Inuit ontologies, while Inuit can learn about western science and research approaches to improve communication and understanding between those involved in decision-making.
7. Co-governance friendly systems. Ultimately, an Inuit-informed DSS should support not only decision-making but co-governance arrangements. In this sense, usership of the DSS should increase the applicability of its outputs in policy formulation and support the implementation of policies and decisions. Through the use of an Inuit-informed DSS, such outputs can perhaps reduce some of the ontological tensions that arise between Inuit and other levels of government in decision making while strengthening co-governance legitimacy by overcoming issues of policy inertia.

8.5 Conclusion

This chapter has highlighted the ontological tensions of using and integrating Inuit knowledge into DSSs and DSTs, as well as approaches to overcome some of the challenges inherent in converting Indigenous knowledge into information and data. As collaborative approaches—whereby power is redistributed to enable local communities to influence planning and decision-making processes—are becoming more prevalent as principles and processes of good governance, preservation of the context and the stories behind the ecological and sociocultural significance of Indigenous knowledge are often overlooked. Many applications of DSSs and DSTs fall short of dealing appropriately with quantitative and qualitative data of varying spatial and temporal scales, as well as narratives, seasonal changes, and broader experiential contexts. The preconditions of integrating Inuit knowledge into decision-making tools include a comprehensive data infrastructure for storage and visualization of spatial and nonspatial information, recognition of the relationship between Inuit and the environment, participatory approaches to the collection and use of data, and user-friendly systems that promote capacity building. These criteria address some of the challenges of integrating science and Indigenous or local knowledge in DSSs and DSTs to ensure information is presented in a holistic manner and ultimately to advance co-governance goals. Inuit ontological approaches to the environment should inform not only governance frameworks in the Canadian Arctic but also the design of the data and information systems and tools through which decisions are made.

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Chapter 9
Seafarers and Arctic Cruise Shipping: Protecting Those Who Work While Others Explore and Sightsee

Joseph Anthony Loot

Abstract Arctic cruise shipping is a growing niche in the highly globalized cruise shipping industry. The service workers in the hotel operations of expedition cruise ships are beneficiaries of Arctic cruise tourism. They provide leisure, tourism, travel, and hospitality services to the increasing number of international cruisers who are motivated to experience the "last frontier" tourism, including the changing and disappearing Arctic landscape and wildlife. The Maritime Labour Convention, 2006 considers these service workers as seafarers and ensures the protection of their rights to decent work and living standards.

The global cruise shipping industry operates within an international market system governed by the neoliberal policies of privatization, liberalization, and deregulation. The neoliberal market system creates an imbalance in the power relations in favour of corporations over the state. There are three actors with contending interests that operate the global cruise shipping industry: states, shipowners, and seafarers. Considering the contentious tripartite relations, the neoliberal globalization of the industry moves shipowners to register their ships in flags of convenience and gain access to cheap seafarer labour, labelled as "crew of convenience" on the global seafarer labour market. The treatment of seafarers as "crew of convenience" is a labour and human rights concern. Nevertheless, there are international standards that protect the labour and human rights of seafarers. Mechanisms to implement these standards exist for the three industry parties to use. The mechanisms reconcile the contending interests, address the problems of globalization, and serve as a framework for research.

Keywords Arctic cruise shipping · Arctic cruise tourism · Global cruise shipping industry · Expedition cruise shipping · Neoliberal globalization · Flag of convenience · Cruise ship service workers · Crew of convenience · International labour standards · International human rights · Tripartite industry relations

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9.1 Invisible Beneficiaries

Environmental changes are making the navigable waters in the Canadian Arctic archipelago accessible to international shipping and simultaneously opening economic opportunities for people external to the region. One cohort of people are the seafarers who work on commercial passenger vessels engaged in Arctic cruise tourism. These seafarers are the invisible workers on board the expedition cruise ships, and they benefit through their employment from the tourism activities in the Arctic. As the expedition cruise traffic in the Canadian Arctic continues to dramatically increase with more travel routes and destinations becoming viable for exploration and sightseeing (Manley et al. 2017; Lajeunesse 2012; Dawson 2018), more seafarers will be recruited to serve the growing number of cruising passengers.

The seafarers, particularly those working in the hotel section of cruise ships, comprise a distinct but essential and invisible group[1] of workers who contribute to the growth of the broader tourism, travel, leisure, and hospitality industries. They are a significant component of the service supply chain that supports the growth of the expedition cruise shipping's niche in the Arctic tourism market (Véronneau and Roy 2009). This industry growth is advantageous to Canada's economic development and contributes to the on-going increase in the larger and highly global cruise shipping industry (Dawson 2018; Innovation, Science and Economic Development Canada 2018).

Despite their contributions to the cruise shipping industry revenue and state national income, the seafarers providing the services in the different types of cruise ships are discriminated, exploited, and abused. In the same manner as the seafarers in the marine section of cruise ships, the service workers are treated as "crew of convenience." This treatment is the result of the neoliberal policies governing international shipping and the contentious relations between the three actors—the state, shipowners, and seafarers—that operate the global industry (Dimitrova and Blanpain 2010). To address this labour concern, the United Nations maritime, labour, and human rights organizations enacted international standards aimed at protecting the employment and social rights of all seafarers in all segments or sectors of international shipping. There are various mechanisms available for the industry actors to implement these standards. These mechanisms ensure the protection of the rights of seafarers and enable these workers to act on their rights.

This chapter presents theoretical propositions on the protection of the rights of seafarers working in the global cruise shipping industry. The focus of discussion is on the protection of the rights of the seafarers who provide the tourism and hospitality services in the hotel operation of cruise ships, particularly in those vessels

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[1] Seafarers are the invisible workers who operate both the marine and hotel functions of cruise ships. They live and work on ships that most of the time are at sea and away from shore. Their living and working places on board the ship are not easily accessible to people. Passengers may have access to go on board, but only on limited unrestricted spaces and only during the duration of travel. Moreover, the overall living and working conditions of seafarers on board are hidden from public view and scrutiny.

engaging in Arctic expeditions. These service workers comprise the non-traditional seafarers who are not trained and certificated in safe and efficient vessel navigation, but they directly engage with the passengers for whom the safe and experiential expedition cruises are designed. However, they are trained in specific hotel operation services, including providing safety assistance during emergencies. The sequence of discussion centres on three points. The first point describes the growth of Arctic expedition cruise shipping as a segment of the growing and globalized cruise shipping industry. Second, an examination of the labour and social conditions of employment on board the cruise ships raises the need for protection of the rights of seafarers. Third, there are existing international maritime labour standards and implementation mechanisms that protect the rights of seafarers and provide these workers with the means to protect their rights.

9.2 Expedition Cruise Shipping

An expedition cruise is a form of ecotourism activity on board specially designed small expeditionary ships operated by specialized companies that offer an exclusive educational experience to a small group of passengers-customers-tourists (Walker and Moscardo 2006; Faber and Saltzman 2019). Expedition cruising is closely related to adventure cruising in terms of small ship size, low number of passengers and crew, and remote destinations intended for exploration and adventure. However, the key distinction is the learning experience in expedition cruising through educational activities (onboard lectures, on-site tours and guided walks, snorkelling and diving, zodiac boat trips in areas inaccessible by ship, and wildlife/scenery photography) conducted by an expedition team comprising natural and social scientists who are experienced in the various settings (ecology, culture, geography, anthropology, politics, biology, among others) of the destination (Smith 2006).

Expedition cruise shipping in the Arctic is a rapidly expanding industry. Although a small segment with just less than 1% of the global cruise market (Jarvis 2017), the expedition cruise market will experience a 4-year boom between 2019 and 2023 according to the *2019 Expedition Market Report* published by the Cruise Industry News. The highlights of this growth are:

- 41 new generation expedition ships with strong ice-class hulls and longer fuel and provision space are set to be delivered to 17 cruise operators.
- Introduction of over 8500 berths that are projected to double the 2018 capacity.
- Potential growth of four to five dozen ships and their market entry within 6 years.
- Smaller ships with an average orderbook size of 214 guests.
- Established players and new market entrants expected to contribute to the projected number of new ships.
- Antarctica and the Arctic as new frontiers for niche and luxury cruise brands in order for tour operators to keep their customer base of affluent cruisers (Mathisen 2019).

Smaller ships built for rough operating environments are considered more rewarding for cruisers given their flexibility in reaching remote areas that allow more shore landings. After two voyages of the 1000-passenger non-ice-class cruise ship *Crystal Serenity* through Canada's Northwest Passage in 2016 and 2017, Crystal Cruises is shifting to a smaller 100-guest purpose-built Polar-Code compliant megayacht by 2020 (The Maritime Executive 2017). This shift in ship size is indicative of the growth prospects of expedition cruises in Canada's Arctic. The small size expedition cruise ships that sailed the Northwest Passage in 2019 include the *RCGS Resolute* (146-passenger capacity), *Ocean Endeavour* (198), *Ocean Adventurer* (215), *Silver Cloud* (240), *L'Austral* (264), *MS Fram* (317), and *MS Roald Amundsen* (500).

Another aspect of the growth prospect that supports the increase in the number of ships is the consumer demand for the distinct expeditionary experience in the Arctic. Demand is created by two interrelated factors: the innovative marketing of tour operators and the change in cruiser motivation. Both tour operators and cruisers share an interest in the new niche tourism market labelled as the "last chance" or "last frontier" tourism, which refers to the Arctic as a tourism destination with its unique and iconic but changing and disappearing landscape and wildlife (Dawson et al. 2014; Dawson 2018). Thus, tour operators are building business portfolios and developing programs that include ice-class vessels, new year-round itineraries, and luxury expedition cruising (Mathisen 2019). Further, the increasing accessibility to geographically remote areas due to the decline of sea ice and the availability of ice-strengthened vessels enhance the motivation of the growing base of affluent and retired baby boomers to experience and learn the novelty of the Arctic landscape, particularly in Canada (Dawson et al. 2014; Manley et al. 2017).

The growth in the number of expedition cruise ships implies an increase in the number of staff and crew who will provide the services of the ship's hotel operation. The small ship size explains the fact that expedition cruise ships do not have the resort amenities and services of the larger cruise ships. The essentials on board a polar expedition cruise include the luxury passenger cabins and suites, lounging and dining rooms (separate from cabin and suite services), exercise rooms, library with a significant collection of polar books, ship-to-shore communication room, boutique, and multi-purpose presentation room. The services to maintain and operate these amenities and attend to passenger needs are performed by the ship's service crew 24 h every day throughout a cruise itinerary (between 2 and 3 weeks, mainly during the summer cruise season). Generally, the service ratio (crew–passenger) onboard is low (e.g., *MS Fram* capacity is 318 passengers and 75 crew) to enable a complete, personalized, distinctive, and high-quality service that reflects the luxury of an expedition cruise.

Despite the unique experience offered by expedition cruises in the Arctic, there are risks to navigation in the region. Two expedition cruise ships ran aground while cruising through Canada's Arctic: the *Clipper Adventurer* in 2010 and the *Akademik Ioffe* in 2018. The passengers and crew of both ships were rescued and evacuated. During maritime accidents and in the rescue and evacuation procedures, the cruise ship's trained service crew is required to provide the extended assistance of ensuring passenger safety.

9.3 A Global Industry

The various shipping sectors of international shipping have the characteristics indicating the global condition of the industry. The following characteristics are common to all the sectors, especially cruise shipping and its different segments:

- High vessel mobility through non-territorial spaces and cross jurisdictions (DeSombre 2006).
- Maritime operations in a complex system of worldwide shipping networks of ports and navigational routes (maribus gGmbH 2010).
- International demand for maritime transport and the consequent technological advancement to increase cargo tonnage and enhance travel and migration of people to international destinations (Williams and Armstrong 2010).
- Shipping operations occurring in a global free-market system that is governed by the neoliberal policies of privatization, liberalization, and deregulation.
- Registration of ships in open and second registers located away from national control.
- Multinational ownership and management of ships, regulatory control, and crew composition.

Compared with the other sectors of shipping that are engaged in global trade and operation, cruise shipping is the most globalized (Terry 2011; Weaver and Duval 2008). Cruise ship technology steadily improves (size, carrying capacity, facilities, and amenities), and ship deployment and tourism destination and itineraries increase. The cruise shipping sector operates within a market-driven global port system (Rodrigue and Notteboom 2013), transnational flagging and management practices of shipowners (Chin 2008a; Wood 2000), and the multinational crewing of ships by transnational shipping companies (Chin 2008a; Gibson 2008). Cruise ships, in particular, are floating resorts and deterritorialized touristic destinations of multinational clientele who converge on board the vessel and in geographical areas that are detached from the passengers' communities and countries (Chin 2008a; Wind Rose Network n.d.).

The global characteristics of cruise shipping exist in the smaller expedition cruise segment. As an example, the *Crystal Serenity*, which cruises in various international destinations, is legally owned and managed in the United States by two corporations (Serenity Holdings Inc. and Crystal Cruises LLC, respectively), is beneficially owned in China (Genting Hong Kong Ltd. 2015), is flagged in the Bahamas, and is manned by Asian, European, and North American officers and crew (Equasis 2019a; Genting 2015). Another expedition ship that frequents the Northwest Passage, *MS Fram*, cruises in the Arctic and Antarctica, and is owned and managed by the Norwegian Hurtigruten Cruise AS, is flagged in Norway, and is manned by Norwegian and Filipino officers and crew (Equasis 2019b).

In addition to its international reach, cruise shipping operates within an international market governed by neoliberal policies. Neoliberalism is the dominant ideology in the process of globalization. It is built around two core ideas: (1) the superiority of the market and the efficacy of market mechanisms in allocating resources and (2) the distrust with governments in intruding into economic affairs, thereby allowing the shift of power to market forces through policies of deregulation, privatization, and market competition (Wood 2006; Harvey 2005; Bowles 2008). When the neoliberal ideology is translated into a policy doctrine, market-based economic growth processes are accelerated through technological advances and the policies of privatization, liberalization, and deregulation (Scholte 2005). The market-based growth processes are working in the cruise shipping industry as demonstrated by the advancements in ship technology, industry-led productivity, the cross-border movement of cruise ships, and the regulatory limitations on government interference in the market dynamics and efficacy of cruise ship operations. The regulatory limitations on government authority are manifest in the unrestricted ship registration practices and the flexibility of the seafarer labour market.

9.4 Tripartite Labour Relations

Within the industrial relations system, there are three principal actors with individual interests expressed through specific means to achieve specific goals (Bellemare 2000). In the tripartite system of the International Labour Organization (ILO), these actors are represented by employers' organizations, workers' organizations, and member states (ILO n.d.-a). In the cruise shipping industry, there are three primary actors with specific interests: the seafarers who seek to protect their economic and social rights, the shipowners who pursue the advancement of capital, and states that seek to balance human rights and market gains.

With the neoliberal globalization of world markets today, the focus is on multinational corporations (MNCs) or transnational corporations (TNCs) because of the impact of the power they possess on human rights conditions and state action. As global actors, TNCs wield significant power to the extent that corporate financial investments influence critical state's actions: relax its monitoring of corporate behaviour; use corporate resources in abusing human rights; and lose control in implementing regulations (Ratner 2001). With the state retreating in the face of the advances of corporations, this imbalance gives the power of capital the advantage to seek labour and use it to maximize economic self-interest at the expense of human rights (Strange 1996). While TNCs indeed create jobs, bring in fresh capital and new technology, and provide employees with health care, they actually exploit workers, particularly those from the global South, by placing them in sweatshops characterized by low pay, hazardous working conditions, absence or limited fundamental worker rights and benefits, and racial discrimination (Ratner 2001; Wood 2006; Chin 2008a; Terry 2011).

The power imbalance between the actors and its negative impact on the protection of workers' rights exist in the cruise shipping industry. The practice of ship registration and the treatment of seafarer labour across the various segments of cruise shipping show the influence of shipowners on state action and seafarer employment and social well-being.

9.5 The Global Seafarer and the "Crew of Convenience"

A "seafarer" as defined in Article II, paragraph 1(f) of the Maritime Labour Convention, 2006 refers to "all persons who are employed or are engaged or work in any capacity on board a ship to which the Convention applies." This definition includes the crew who navigate or operate the ship and the personnel who provide the services in the hotel section of the ship. In cases of doubt as to whether a category of workers shall be regarded as "seafarer" covered by the Convention, the national competent authority must make a determination on the question in consultation with the shipowners' and seafarers' organizations (Article II, paragraph 3).

There are two types of seafarers working in two separate operations on board a cruise ship: the traditional seafarers who navigate and operate the ship and the service workers who provide the leisure, tourism, travel, and hospitality services as part of the hotel operations of cruise ships. Unlike the traditional seafarers who are required to complete rigid maritime education, training, and certification for employment, the service workers' basic qualifications for work on cruise ships are skills-based for entry-level positions and work-related experience for higher-level positions in the various hotel departments. An additional employment requirement for service workers is the completion of cruise ship safety training before joining a ship.

Cruise ship crew composition is highly diverse in terms of nationality, racial origin, gender, and culture—a "mini-United Nations"—on board a large modern sailing vessel (Chin 2008a). On the smaller expedition cruise ships, the diversity is less intense. However, diversity is more intense in the hotel section of the cruise ship than the marine section. There are more varieties of hotel operation services performed by the crew from various nationalities. The presence of diversity, regardless of intensity, reflects the flexibility of maritime labour in favour of capital, a consequence of the application of the neoliberal policy of deregulation (Chin 2008a). The unregulated practice by cruise shipowners and operators of employing seafarers from different countries is in response to market conditions and aims at boosting customer service and corporate profit.

The neoliberal globalization of the cruise shipping industry moves shipowners and managers to register their ships in open registers, commonly labelled as flags of convenience or FOCs,[2] in order to gain access to cheap seafarer labour, a “crew of convenience,” on the global seafarer labour market. FOCs offer minimal restrictions on seafarer’s nationality, pay, and working conditions. As a result, shipowners and operators employ seafarers from less developed countries who are willing to accept low contract compensation and work in inferior and exploitative conditions (Alderton and Winchester 2002; Dimitrova and Blanpain 2010). These seafarers are oftentimes subjected to expensive third-party recruitment requirements, discriminated against on the basis of nationality, gender, and race, contracted to work for specific periods with no guarantee for continued and future employment opportunities, provided with limited access to communication and information, provided with inconvenient accommodation, required to work long hours without a vacation or day off, and denied access to full health protection (Chin 2008b). The Bahamas is a FOC where expedition cruise ships such as the *Ocean Adventurer* and *Ocean Endeavour* are registered (ITF n.d.; Equasis 2019c; Equasis 2019d).

Maintaining the practice of FOCs, nonetheless, has significant economic benefits to the cruise shipowners, the FOC and labour supplying state, and the seafarer. Shipowners incur lower operating costs through the liberal conditions, which include minimal regulation, cheap registration fees, low or no taxes, and freedom to employ cheap labour from the global labour market (Tolofari et al. 1986). For states, the FOC practice is a source of national income through either ship registration or labour export, respectively. Also, for the labour supplying state, particularly developing countries, the export of seafarer labour fulfils the state obligation of providing employment, and seafarer remittances are essential revenue for domestic production and spending (Dimitrova and Blanpain 2010). As a crew of convenience, seafarers benefit from overseas employment that is not available in their home country. The reality is that seafarers endure the cost of exploitative employment on board the ship because of the assurance of the economic benefit that is far more difficult to acquire at home.

Considering the economic benefits of FOCs, an overriding question is: if the three industry actors benefit from the FOC and crew of convenience, how would an international maritime labour and human rights standard, and its implementation, protect the seafarers? There are at least two answers to the question. First, it is necessary to cushion the impact of FOC practice on seafarer well-being. Under the FOC system, seafarers are an easy target for extreme physical, economic, and social abuse by dishonest shipowners (Dimitrova and Blanpain 2010). Seafarers, particularly those coming from the global South, are placed in “sweatships” characterized by low pay, hazardous working conditions, absence or limited fundamental worker rights and benefits, and racial discrimination (Chin 2008b; Walker 2016). The ability of the seafarer to endure such abuse is limited and, thus, could lead to loss of employment and an income source. Second, the presence of regulatory standards

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[2] The term “FOC” is used less today because of the stigma attached to the term (Mukherjee and Brownrigg 2013). However, the International Transport Workers’ Federation continues to use the term and lists the countries that it has declared FOCs (International Transport Workers’ Federation n.d.).

will empower seafarers to act on their rights. The seafarer is the weakest in the tripartite relationship in terms of economic and political power. When shipowners advance through abuse and the state retreats on its obligation to protect labour and human rights, seafarers will be rendered unable to defend themselves.

9.6 International Maritime Labour Standards

There are three interconnected international legal standards on the protection of seafarers in the global maritime industry: the protection of seafarers' rights under the ILO conventions, the protection of human rights under the United Nations' (UN) human rights treaties, and the enhancement of maritime safety under the International Maritime Organization's (IMO) conventions. This set of interconnected legal guarantees establishes the integration of seafarers' rights and human rights and their comprehensive legal protection sanctioned by states. Seafarers have, under international law, human rights and fundamental freedoms that cannot be removed, overridden, or waived by contracts of employment (Seafarers' Rights International 2016).

The core treaty law on the protection of seafarers' rights is the Maritime Labour Convention 2006 (MLC 2006) that became binding on state parties on 20 August 2016, a year after the requirements for entry into force under Article VIII were fulfilled. An ILO maritime labour standard, MLC 2006 is an international "bill of rights of seafarers" and "a global response to a global problem" (McConnell et al. 2011). The MLC 2006 consolidated numerous ILO conventions and recommendations. Seafarers' rights are categorized into fundamental rights and principles (Article III) and seafarers' employment and social rights (Article IV); globalization and competition issues are addressed in the MLC 2006 with the goal of creating a "level playing field" to benefit stakeholders in the maritime community through fair competition (McConnell et al. 2011; Blanck Jr 2006). Designed as the fourth pillar of the international maritime regulatory regime, the MLC 2006 mainstreams maritime labour standards and compliance and enforcement, thereby complementing and completing the IMO's approach of developing and maintaining a comprehensive regulatory regime for quality shipping established in the three IMO core conventions on marine pollution, ship safety, and seafarer competency (Blanck Jr 2006) (see further below).

The human rights of seafarers are provided for in two human rights instruments of the United Nations: the 1948 Universal Declaration of Human Rights (UDHR) and the 1966 International Covenant on Economic, Social, and Cultural Rights (ICESCR). These two instruments proclaim the social and economic rights that workers are entitled to enjoy and set the standards of state behaviour in protecting human rights. The UDHR is "soft law," but its universalist foundation and the broader benefits from membership in this instrument, even under diminished or minimal obligation, are key reasons for states to sign the declaration (R.K. Smith 2009; Hathaway 2007). The UDHR provides the essential principles of equality

(Section 1) and non-discrimination (Section 2) for the protection of the employment (Section 23) and social rights (Sections 22, 24, and 25) of seafarers. On the other hand, ICESCR is a binding covenant that identifies the "second generation" rights requiring state action for enforcement (Vasak 1977; van Boven 1982; Ssenyonjo 2009). The 2008 Optional Protocol to the Covenant on Economic, Social, and Economic Rights (OP-ICESCR) provides for an inter-state complaint mechanism and individual complaint procedure, and the Committee on Economic, Social and Cultural Rights (CESCR) monitors its implementation.

The regulatory standards for safety at sea set by the IMO do not create rights for seafarers since they cover only the technical aspects of maritime safety, navigation, equipment, training, certification procedures, and marine pollution, but they recognize the importance of the human element in maritime safety, security, and marine environmental protection (Seafarers' Rights International 2016; Christodoulou-Varotsi and Pentsov 2008; Dimitrova and Blanpain 2010). The three pertinent IMO international conventions are the International Convention on Standards of Training and Watchkeeping for Seafarers (STCW) 1978, the International Convention for Safety of Life at Sea, 1974 (SOLAS) and, under it, the International Safety Management Code (ISM Code) as amended, and the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL). These standards address the multidimensional issues that involve human activities and their effect on maritime safety and pollution prevention (IMO n.d.-a). The effective and consistent global implementation and enforcement of these conventions are covered in the IMO Instruments Implementation Code adopted in 2013, which enhanced the standards on maritime safety and security and protection of the marine environment through the review and identification of the rights and obligations of states and the implementation of the mandatory IMO audit scheme (IMO n.d.-b).

9.7 Implementation Mechanisms

Implementation and enforcement are often understood as synonymous and used interchangeably. However, the terms are distinct from each other. Implementation refers to the broad application of the law to improve policy and increase support for the improvement (Mazmanian and Sabatier 1989). It is one of the processes in the function and execution of policy or law (Satterlund et al. 2009). Enforcement, on the other hand, involves specific actions that include sanctions intended to compel compliance (Brunnée 2005). Distinguishing implementation from enforcement allows better contextualization of the specific processes related to the function and execution of policy.

Table 9.1 lists the various mechanisms available for shipping industry actors to implement maritime labour standards. The free online *Black's Law Dictionary* defines a mechanism as a component, an element, or a part that enables a process or system to achieve an intended result. From this definition, the list of mechanisms serves two purposes. First, it provides information about the

Table 9.1 Mechanisms to implement maritime labour standards

		Mechanisms			
Actors		Organizational–structural–functional	Systemic–procedural	Social–political	Corporate
Public-traditional/Conventional	States	International multilateral Regional organizations National departments, competent authority	Flag state and ROs Port state Labour supplying state Domestic judicial procedures	Maritime education and training Social dialogue	
Private-alternative	Seafarer	Unions and associations Legislative representation	Domestic judicial remedies	Social dialogue	
	Shipowner	Shipping associations		Social dialogue	CSR, industry self-regulation
	Other actors (public interest groups)	International NGOs, civil society organizations		Investigations, research, advocacy Maritime ministry	

strategies and activities relevant to policy formulation and reform. The mechanisms are drawn from the labour and human rights treaties and the practices of the actors involved in the operation of the general global shipping industry or a particular shipping sector (such as cruise shipping) and the smaller segments of the shipping sector (such as expedition shipping). Second, the list identifies specific actions that can lead to the reconciliation of the contending interests of industry actors, realize the protection of seafarers' rights, and empower seafarers to act on the protection of their rights. The mechanisms identified are aimed at addressing the labour problems arising from globalization, the contentious interests of the actors, and violations of the legally recognized rights of the seafarers.

9.7.1 Organizational–Structural–Functional Mechanisms

Organizational mechanisms are international and domestic organizations that engage in methods to ensure the observance of human rights established under existing laws (Vasak 1982). Organizations at the inter-state level are international governmental organizations (IGOs), which implement member state labour standards. Structurally, the link between the international organization and the state is a prerequisite for the former to successfully carry out its functions of implementing regulatory standards on the latter (Vasak 1982; Knudsen and Hassler 2011). Functionally, IGOs perform supervisory, monitoring, and information processing and reporting activities to ensure compliance of states with their treaty obligations and to allow workers' and employers' organizations and international NGOs (INGOs) to examine state compliance and pursue mechanisms for improvement in the application of international convention standards (ILO 2014). Private and voluntary non-state organizations (INGO and NGO) comprising individuals or their associations also contribute to the protection of human rights.

At the domestic level, the organizational mechanism includes national government departments and agencies, with their structures, functions, and interconnections a critical element in formulating laws and policies that implement the state's treaty obligations. The presence of workers and employers' associations complete the tripartite structure and function within the state. The tripartite system that functions at the international level is not a functional mechanism within the state in the absence of worker and/or employer representation.

9.7.2 Systemic–Procedural Mechanisms

Flag and port state responsibilities and jurisdictions are the primary systems of implementation under ILO's maritime labour and IMO's safety of navigation standards; labour supplying state responsibilities are an innovation in the MLC 2006 that highlight the state's important role in maintaining labour standards on seafarer recruitment, employment agreement, and social security (McConnell et al. 2011). Although the flag and/or port state may not be the home nation of a seafarer, the system and procedure of inspection and certification comprising the flag and port state responsibilities reinforce the measures adopted to regulate substandard ships, facilitate ships' timely port entry and exit, and improve the seafarers' bill of rights and the shipowners' ability to retain and recruit qualified seafarers amid existing global maritime labour market conditions (Lilie 2008; Blanck Jr 2006; Piniella et al. 2013), as well as complementing any shortcomings in the control measures of either the flag or port state (Christodoulou-Varotsi and Pentsov 2008). The onboard and onshore complaint mechanisms are additional complementary flag and port state inspection functions (Politakis 2013). The system of inspection, including monitoring and legal proceedings for breaches of MLC 2006 operational requirements, is particularly vital for the labour-supplying state because it links the state to the chain of responsibility to protect seafarers, especially those who are its nationals, resident, or domiciled in its territory (Christodoulou-Varotsi and Pentsov 2008; Lilie 2008).

States enter into regional arrangements for port state control (PSC) known as the port state control memorandum of understanding (PSC MOU) to address more effectively the concerns about sub-standard vessels and their danger to maritime safety. The arrangements also address the differences in the extent that port states apply their national laws. Fundamental to this cooperation is the application by port state authorities of a common and uniform set of laws and standards to vessels that visit the ports within a region (McDorman 2000). Structurally, a regional PSC MOU establishes a committee comprising representatives of the member state's national maritime administration and acts as the MOU's executive body. Such MOUs, however, have specific limitations, such as lack of binding effect, territorial jurisdiction, and authority to detain ships in the context of technical standards; however, these limitations do not hinder the function of MOUs in resolving the anomalies that clearly risk the safety and health of seafarers and in contributing to the realization of PSC (Christodoulou-Varotsi and Pentsov 2008; McDorman 2000).

Since the responsibility of implementing seafarer rights and human rights standards rests primarily with the state, the national legislative, judicial, and executive branches of government examine, formulate, revise, and adopt national legislation and policies in order to give effect to the standards in the treaties that a state ratifies. In the context of the law and policy formulation process under MLC 2006, government agencies are expected to produce consensus through the tripartite social dialogue system in order to bring legislative and policy frameworks closer to the international labour standards set by the maritime industry. Thus, in the development, promulgation, and review of domestic laws, the political branches of government are required to follow the consultative process. With regard to ICESCR, although the formulation of legislation is left to the legislature without mentioning specific procedures, the state is expected to comply with the obligation to take the appropriate steps to adopt legislative measures that include judicial remedies for the human rights that under the national legal system are considered justiciable. This gives the judiciary an essential role, and judicial remedies are necessary for the promotion of social and economic rights, especially of vulnerable groups that have minimal options to protect themselves. Arbitration is one accessible alternative judicial process accepted by the parties in a proceeding and encouraged by the judicial system as a tool to resolve maritime (including labour) disputes (Cortazzo Jr. 2012). Arbitration, whether voluntary or compulsory, is a dispute settlement procedure provided for in the ILO Voluntary Conciliation and Arbitration Recommendation, 1951 (No. 92) and may also be explicitly provided for in domestic legislation (ILO n.d.-b).

9.7.3 Social–Political Mechanisms

Socio-political activities comprise the third type of mechanism to implement maritime labour standards. Social dialogue, generally done in a tripartite arrangement, is common to the three industry actors. However, the ILO defines social dialogue as either a tripartite or bipartite (between labour and management with or without government involvement) process of negotiation, consultation, or exchange of information (ILO n.d.-c). The ILO requires that workers' and employers' organizations have the technical capacity and access to information to enable them as primary stakeholders to engage in consensus building, particularly as regards work-related social and economic issues within the ILO principles and standards. In a bipartite social dialogue, the state plays an active supporting role, establishing legal, institutional, and other frameworks that ensure productive engagement between the involved actors. Tripartism and social dialogue are significant in reconciling the parties' (as equal social partners) contending interests and addresses the imbalances in their power relations and global labour issues.

The ILO labour standards recognize the importance of human resource development through vocational guidance and training in order to improve employability and competitiveness, gain access to decent work, and increase labour productivity (ILO n.d.-d). For cruise ship service workers who are not required to have IMO certification, cruise line pre-departure and on-the-job training requirements align with the ILO standards. Interestingly, there is no emphasis at ILO on the education of seafarers about their labour rights so that they will be empowered to act on those rights and adequately protect themselves against any abuse.

The UN Office of the High Commissioner on Human Rights (OHCHR) highlights, in accordance with the 2011 United Nations Declaration on Human Rights Education and Training (UNDHRET), the importance of education and training in building values, beliefs, and attitudes that encourage individuals to understand their everyday responsibilities, uphold their rights, and contribute to the long-term prevention of human rights abuses (Office of the High Commissioner on Human Rights n.d.). Moreover, the UNDHRET stresses the role of human rights education (HRE) as a mechanism to protect the main categories of rights provided in the UN declarations and conventions, and for compliance to obligations and responsibilities outlined in these instruments (Struthers 2015). HRE is an encompassing approach that includes acquiring a basic understanding of factual human rights information and possessing a more profound knowledge of the cultural and contextual settings that present the concept and reality of human rights as an integral aspect of human life (Struthers 2015). Although the UNDHRET is non-binding soft law, it reaffirms the importance of the HRE provisions in international human rights instruments that member states are obligated to comply with. Thus, states are expected to develop a comprehensive and effective national strategy for HRE that includes the development of a curriculum on HRE in educational institutions.

An innovative aspect of UNDHRET is the tripartite framework that mandates the implementation of HRE by governments, UN organizations and agencies, and NGOs (excluding business organizations). The role of human rights NGOs in the framework is especially appropriate, because the expanded initiatives of these organizations—investigative research, policy development, and advocacy (Robinson 2004)—complement HRE. Some INGOs and NGOs engage in political activities that challenge the interest of states violating human rights treaties. NGO advocacy that names and shames offending states holds them accountable for their violations and often leads to remedies through punitive action or policy reform (Roth 2004).

The maritime ministry of faith-based INGOs and NGOs is essential in the implementation of the MLC 2006 welfare provisions and human rights guarantees. The strength of this mechanism is demonstrated by at least three key commitments of maritime missions and societies: (1) providing port facilities and services that promote seafarers' spiritual, physical, moral, and social welfare; (2) establishing solidarity and identification with seafarers; and (3) facilitating links with other government and private organizations committed to or essential for seafarer welfare (Mooney 2005).

9.7.4 Corporate Mechanism

A corporate mechanism refers to the method by which corporate entities engage in forms of self-regulation (e.g., Association of Arctic Expedition Cruise Operators), which entails changes in corporate behaviour in order to comply with public policies. Cruise shipping corporations and their crewing or manning agencies, while potentially contributing to global seafarer labour market stability, can also directly disregard labour standards and abuse seafarers' rights in the process of supplying shipping companies with cheap maritime labour (Dimitrova and Blanpain 2010). For this reason, both corporate entities are essential in the implementation of international maritime labour standards.

Corporate social responsibility (CSR) is a form of self-regulation that private businesses voluntarily perform to address public shipping regulation implementation and to improve the negative impact of shipping corporations and their supply chains to, among others, safety and quality management and transparency (Yliskylä-Peuralahti and Gritsenko 2014). CSR enhances performance and reputation, which are vital advantages for a highly globalized cruise shipping industry. However, two factors challenge these CSR strengths: first, the effect of CSR on financial performance, particularly on the sustainability of the company's competitive advantage and the transactional costs of compliance to the regulatory standards amid intense industry competition; and second, the nature of voluntarism in self-regulation whereby voluntary commitments are highly vulnerable to the level and extent of business actors' commitment and motivation (Vogel 2010; Yliskylä-Peuralahti and Gritsenko 2014).

9.8 Conclusion

Arctic cruise shipping is a booming niche segment in the growing cruise shipping industry, the most globalized sector of international shipping. The invisible seafarers who provide the tourism, travel, and hospitality services in the large luxurious hotel operations of cruise ships are beneficiaries in the cruise industry's use of Canada's Arctic for tourism. There is scant information about this smaller group of service workers other than their inclusion as part of the generic notion of seafarers on board the more popular mainstream and mega cruise ships.

The cruise ship service workers are global seafarers in a highly globalized industry. Since cruise shipping operates within a market system governed by neoliberal policies, seafarers are treated as the crew of convenience, and their rights are not protected. Further, since the well-being of seafarers is essential for the sustainability of meeting growing passenger demand, it is necessary for the three industry actors to collectively or individually engage in the implementation of the existing international labour and human rights standards. This chapter presented a list of existing mechanisms that implement international standards.

With expedition cruise shipping growing in Canada's Arctic, research data are necessary, initially, on two problem areas: first, a profile on the global characteristics of the service workers on cruise ships with itineraries in the Canadian Arctic, and second, an assessment of the labour, employment, and social issues and the implementation of the labour and human rights standards in Canada. Additional data about the expedition cruise shipping segment will enhance the existing literature on the broader cruise ship seafarers' rights.

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Chapter 10
Mapping the Maritime Occupational Health and Safety Challenges Faced by Canadian Seafarers

Desai Shan

Abstract This chapter explores the occupational health and safety challenges faced by Canadian seafarers. Maritime occupations continue to be among the most dangerous occupations in the world. Technological development and climate change, as well as the increasing level of Arctic shipping opening driven by oceanographic changes together with technological innovation, lead to significant health and safety challenges for mariners in Canada. Drawing on findings from two research projects on seafaring occupational health and safety (OHS), including qualitative semi-structured interviews with 25 Canadian seafarers and a preliminary legal review of Canadian maritime OHS law, this chapter presents some common OHS challenges confronted by Canadian seafarers and the gaps existing in the current Canadian maritime OHS law. These challenges include increasing Arctic shipping activities led by the climate change, intensified work-related mobility, and insufficient legal protection.

Keywords Canada · Occupational health and safety · Seafarers

10.1 Introduction

Maritime occupational health and safety (OHS) has attracted increasing research attention in recent years, but most studies focus on the OHS of international seafarers (Roberts et al. 2014; Sampson et al. 2017; Walters and Bailey 2013). Maritime OHS challenges faced by Canadian seafarers are underexamined in the current peer-reviewed academic literature, particularly in coastal and inland shipping. To fill this

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research gap, this chapter draws on and extends recently published findings from a study of Canadian seafarers working on the Great Lakes and St. Lawrence Seaway (Shan and Lippel 2019; Shan and Neis 2019), and from a legal analysis of current international and Canadian occupational health and safety law to explore the health and safety challenges in the context of Canadian short-sea shipping and Arctic shipping. The related studies were conducted between 2017 and 2018.

Maritime occupations continue to be associated with a high risk for injuries and fatalities. According to Lefkowitz (2013), the injury rate of global shipping was estimated at 850 per 100,000 seafarers. A transnational study found that 8.5% of seafarers suffered an injury during their most recent tour of duty (Jensen et al. 2004), and a Danish study found that the fatal accident rate in merchant shipping is ten times that in shore-based industries (Hansen et al. 2002). The fatal accident rate among seafarers in the United Kingdom was 14.5 per 100,000 workers between 2003 and 2012, which was 21 times that in the general British workforce and 4.7 times that in the construction industry (Roberts et al. 2014). The fatal accident rate in Canada among seafarers was 22 per 100,000 workers between 1996 and 2005, which was higher compared to the United Kingdom (Roberts et al. 2014). In Canada, taking the seafarers (tug, barge and other water transport) in the water transport industry in British Columbia as an example, the injury rate is about 400 per 100,000 seafarers, which is about half compared to the global rate (WorkSafe BC 2019). However, considering the provincial average injury rate is 200 per 100,000 workers, seafarers' injury rate is still high relative to the primarily land-based workforce in British Columbia (WorkSafe BC 2019).

The relative higher workplace injury and fatality rate at sea can be attributed to various occupational hazards. The occupational hazards faced by maritime workers can be divided into two types: occupational accident and occupational disease, including both physical and mental health. Occupational accidents can be divided into three categories: firstly, accidents related to maritime disaster, for example, accidents or incidents involving ships, such as collision, foundering and explosion; secondly, on-duty accidents, namely, personal accidents involving seafarers on duty, such as a fracture caused by snapping mooring lines; and thirdly, off-duty accidents, such as injuries caused by slips, trips and falls when seafarers are off duty on board (Roberts et al. 2014).

10.2 Canadian Maritime Sector and Occupational Hazards at Sea

Canada has the world's longest coastline at 243,042 km (Statistics Canada 2016). As a maritime nation, Canada's economy, culture and security have been closely connected with merchant shipping (CCA 2017). The *2018 Review of Maritime Transport* shows that Canada has the world's 31st largest fleet with 220 Canadian flagged vessels and 149 vessels registered overseas (UNCTAD 2019). Canada has approximately 14,680 registered seafarers (Roussel 2018). Canadian export and import trades heavily rely upon foreign-flagged vessels for non-U.S. marine trade, but Canadian-flagged vessels carry about 98% of domestic tonnage, as well as trade between Canada and the United States (Minister of Transport 2015). This is mainly because of the cabotage protection contained in the Coasting Trade Act (1992). With this cabotage protection, in principle, only Canadian-flagged vessels are allowed to operate transport between Canadian ports (Coasting Trade Act 1992, s. 3.1). In addition, only Canadian citizens and permanent residents can serve on these ships. These vessels are also active in the Canada–United States marine trade, which was valued at $216 billion over the 2006–2015 period (Statistics Canada 2015; Transport Canada 2015). Foreign vessels, only with a special license issued by Transport Canada, can carry domestic tonnage, which are of a very small proportion.

Domestic marine shipping activities are concentrated in four areas of the country: British Columbia, the Great Lakes and St. Lawrence Seaway, Atlantic Canada, and northern Canada (CCA 2016; Transport Canada 2015). From 2004 to 2011, the Pacific region accounted for 54% of all commercial vessel movements in Canada, followed by the Great Lakes and the St. Lawrence Seaway (29%), Atlantic Canada (16%), and northern Canada (1%) (CCA 2016).

In British Columbia, Vancouver is the largest port for domestic marine trade, comprising mainly agriculture and food products, forest products and minerals, such as wheat, canola, limestone, stone and sand. In the Great Lakes and St. Lawrence Seaway, iron ore, fuel oils and wheat constituted the majority of marine transport. In Atlantic Canada, crude oil was the major commodity transported between the ports of Saint John, Come by Chance, and the Newfoundland offshore in 2011 (Statistics Canada 2012). Domestic marine trade in northern Canada includes the transport of most of the food, fuel, construction materials and other goods used in the North. These are essential supplies for Arctic communities (CCA 2017).

Canada's marine environment, and its domestic shipping design, patterns and activities, are very diverse; and the occupational hazards faced by seafarers are therefore also varied. According to an analysis conducted by the Council of Canadian Academies (2016), northern Canada has the highest rate of maritime accidents and incidents, including both ship accidents and accidents on board vessels, with 10.26 per 1000 vessel movements (Table 10.1). Shipping in northern Canada is

Table 10.1 Incident and accident rates based on vessel movements for different regions in Canada (2004–2011) (adapted from CCA 2016)

Region	Total number of vessel movements (2004–2011)	Total number of incidents and accidents (2004–2011)	Incidents and accidents per 1000 vessel movements
Northern Canada	3607	37	10.26
Atlantic Canada	114,543	174	1.52
Great Lakes and St. Lawrence Seaway	206,235	1055	5.12
British Columbia	380,472	456	1.19

subject to severe weather and ice conditions. In addition, the lack of port and terminal infrastructure increases the risk of accidents and incidents. The Great Lakes and St. Lawrence Seaway have the second highest rate of incidents and accidents. This reflects the abundance of narrow waterways, canals and locks, which increase the risk of grounding, allision and collision. British Columbia and Atlantic Canada have significantly lower rates of incidents and accidents compared to northern Canada and the Great Lakes and St. Lawrence Seaway.

As pointed by Roberts et al. (2014), maritime accidents contribute 5% of the fatalities of seafarers in the United Kingdom, while occupational accidents and off-duty accidents on board are the cause of 70% of the fatalities of seafarers. Suicide and undetermined intent (including alcohol, drug intoxication, drowning and missing at sea) contribute 25% of the fatalities of seafarers. Occupational hazards related to general shipping labour processes include watchkeeping during the voyage, piloting through narrow waterways, mooring and anchoring at terminals, loading and discharging cargo, cargo handling, and trimming, marine engineering, and vessel-sourced pollutant processing (Larson 1997; Walters and Bailey 2013). Canadian seafarers confront additional risks related to landing boom operations, that is, operation of a boom to swing crew members ashore to handle mooring lines on tie-up walls (The St. Lawrence Seaway Management Corporation 2019). This practice is unique to the Seaway. Frequent calls to ports in the near coastal regions will also require seafarers to be on call and shorten their rest hours (Pauksztat 2017). Short-sea seafarers are more vulnerable to fatigue compared to deep sea seafarers, which is a recently recognized workplace hazard (Shan and Neis 2019). The remainder of this chapter will explore three aspects of the OHS challenges faced by Canadian seafarers: challenges caused the climate change, in particular, the increase of Arctic shipping activities; challenges related to commuting and intensive work-related mobility; and challenges arising from insufficient OHS rights.

10.3 Methods

This chapter draws on findings from two research projects: (1) On the Move: Occupational Health and Safety Regulations and Management on Canadian Vessels on the Great Lakes and St. Lawrence Seaway (2017–2018); and (2) Regulating Maritime Occupational Health and Safety in the Canadian Arctic Gateway (2018–2020). The first project adopted qualitative research methods, which are recognized as valuable instruments to obtain insights into the experiences and views of stakeholders (Silverman 2011), including 25 semi-structured in-depth interviews with seafarers with working experiences on the Great Lakes and St. Lawrence Seaway, safety managers, human resource managers, representatives from unions and charities, and key informants from Canadian maritime authorities. The research was approved by the University of Ottawa Research Ethics Board. The research methods also included legal doctrinal analysis, documentary analysis drawing on legal sources, to provide a technically accurate portrait of the applicable regulatory framework (Lippel et al. 2016). The author conducted legal research using both international conventions and Canadian acts and regulations collected from the official websites of the International Maritime Organization (http://www.imo.org/en/KnowledgeCentre/Pages/Default.aspx) and Transport Canada (https://www.tc.gc.ca/eng/acts-regulations/menu.htm). "Health", "safety" and "seafarers" are used as keywords in the legal research. A selection of collective bargaining agreements provided by the interviewees was also analysed to understand contractual rules applicable to the working conditions of Canadian seafarers on the Great Lakes and St. Lawrence Seaway. The second project is an on-going research project, and the findings reported in this chapter are mainly from legal analysis results. Similar to the first research project, in the second project, the author is collecting and analysing both international conventions and Canadian acts and regulations related to Arctic shipping from the official websites mentioned above.

Between them, the two projects cover two of the main maritime regions in Canada, the Great Lakes and St. Lawrence Seaway, and northern Canada, including those with the highest accident/incident rates. This chapter examines the challenges faced by Canadian maritime workers from the perspective of empirical accounts of seafarers, as well as conducting legal analysis of current maritime regulations. In addition, the gaps existing in Canadian maritime OHS law are discussed.

10.4 Occupational Health and Safety Challenges Faced by Canadian Seafarers

Occupational health and safety challenges include both risk factors related to weather, environment and marine operations, and those related to institutional and regulatory factors. This section presents study findings related to OHS risk factors faced by Canadian seafarers related to climate change, work-related mobility and insufficient legal protection.

10.4.1 Climate Change

Maritime activities in Canada have been affected by climate change, in particular the opening of the Arctic. The increasing loss of sea ice in the Arctic is expected to result in significant growth of various forms of maritime activities in this region. In 2014, Arctic shipping comprised 9.3% of the world's shipping traffic (Eguíluz et al. 2016). The Arctic has been used as a transit route between the Pacific and the Atlantic for the international shipping industry, in particular the Northern Sea Route (NSR) on Russia's side of the Arctic between North Cape and the Bering Strait. Compared to traditional route sailing through the Panama or Suez Canals, it has been suggested that the NSR offers a 40% shortcut in terms of distance (Lasserre and Faury 2020). The Northwest Passage (NWP) is a sea corridor through Canada's

Table 10.2 Number of voyages in the Canadian Arctic (adapted from Laserre 2019)

	2005	2007	2009	2011	2013	2015	2017
Total number of ship voyages	121	181	185	317	349	315	416
Cargo ships or barges	65	101	100	126	127	120	188
Fishing vessels	20	39	44	136	137	129	138

Arctic Archipelago and along the northern coast of North America. It has remained little utilized for international traffic, mainly because of complicated natural conditions and environmental concerns (Lasserre and Faury 2020).

However, there has been an increase in destinational shipping connected to Arctic communities and resource extraction in the Canadian Arctic (Lasserre and Faury 2020). The number of voyages in the Canadian Arctic almost tripled between 2005 and 2017 (Table 10.2). On the one hand, the increased number of ship voyages (Table 10.2) in the Arctic creates new commercial and job opportunities for the Canadian shipping industry. On the other hand, it will also place Canadian seafarers in an extreme, remote, low-temperature and risky working environment. Extratropical cyclone weather conditions are identified as a major risk factor in the maritime working environment at sea (Rezaee et al. 2016).

The growth of Arctic shipping activities brings an increasing number of seafarers to the polar navigation environment, which has extraordinary risks that affect both maritime safety and occupational health. Adopted by the International Maritime Organization (IMO) in 2014, the International Code for Ships Operating in Polar Waters (Polar Code 2014/2015) identifies ten sources of hazards for polar maritime activities. Section 3.1 of the Polar Code identifies eight hazards that are directly related to health and safety of seafarers:

1. Ice, which may affect hull structure, stability, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems
2. Topside icing, with potential reduction of stability and equipment functionality
3. Low temperature, as it affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems
4. Extended periods of darkness or daylight as it may affect navigation and human performance
5. Remoteness and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential or groundings compounded by remoteness, limited search and rescue facilities, communication capability, and delays in emergency in emergency response
6. Potential lack of ship crew experience in polar operations, with potential for human error
7. Potential lack of suitable emergency response equipment
8. Rapidly changing and severe weather conditions, with the potential for escalation of incidents

In the Northwest Passage, as mentioned above, destinational shipping plays a major role, a significant portion of which consists of domestic shipping activities carried out by Canadian ships and considered as cabotage. In principle, these vessels should be crewed by Canadian citizens and permanent residents. Increasing maritime activity in the Arctic means a growing number of Canadian maritime workers face the occupational hazards of the polar marine environment.

Additionally, noise caused by ice breaking operations affects the quality of sleep and worsens the fatigue experienced by seafarers (Sillitoe et al. 2010). Ship motion and noise are also challenging for seafarers to cope with at sea. Fierce swells in storms, machine noise on board, as well as ice-breaking noise seriously affect the sleep quality and patterns of seafarers on board a vessel. The motion of ships also increases the risk of slips, trips and falls for seafarers.

A finding of this research is that the lack of port infrastructure in the Arctic region is reported to make discharge operations more difficult and may create additional occupational hazards related to port operations. In the Canadian Arctic, except at the port of Churchill, seafarers have to conduct discharge operations without support from a port terminal. The lack of nautical charts also increases the unpredictability of Arctic navigation and increases the risk of maritime incidents, such as groundings. Working in the Arctic in a low-temperature environment may also create additional risks for individual seafarers, including numbness, frostbite and hypothermia (Mäkinen and Hassi 2009). Long-term working in the cold may also cause musculoskeletal disorders (Pienimäki 2002). Cooling also worsens the symptoms of many diseases, including respiratory and heart diseases (Pienimäki 2002).

10.4.2 Commuting and Intensive Work-Related Mobility

In addition to the challenges brought by the increase of Arctic shipping activities, long commuting and employment-related geographical mobility also impact Canadian seafarers' occupational health conditions. However, limited attention has been paid to Canadian maritime transport workers, although the excessive and complex work-related mobilities within seafaring jobs are well-recognized (Borovnik 2004). Taking Canadian seafarers working on the Great Lakes and St. Lawrence Seaway as an example, the work-related mobility includes both commuting from the east Pacific and west Atlantic coasts to the ports, and the intensive mobility on the waterway, which stretches 3700 kilometres from Duluth (United States) to the Atlantic Ocean. According to empirical studies conducted in 2017 and 2018 (Shan and Lippel 2019; Shan and Neis 2019), a commute of more than 5 h is common among Canadian seafarers working on the Great Lakes and St. Lawrence Seaway. In addition, every 6–12 weeks, many seafarers are placed directly on shifts after overnight commuting, which increases the risks associated with fatigue. Due to the complex system of canals and locks on the Great Lakes and St. Lawrence Seaway, some Canadian seafarers report that they have to work 12 h, in particular on the Welland Canal, continuously after a 6–8 h commute (Shan and Neis 2019). As a result, they have no chance to take a proper sleep break within 18–20 h. Fatigue risk arising from long commutes also creates challenges for safety management on board the vessel. It is challenging for captains to supervise exhausted crew, because tired crew are not able to conduct safety-critical tasks on board (Shan and Neis 2019).

The Seaway system is connected by five canals, which include 15 locks. This means that seafarers must confront the challenges of navigating into and out of these canals and locks. To pass the locks safely, intensive manoeuvring of the vessel is required, and mooring may also be required during transit through the locks. Of the five canals on the Seaway system, navigating the Welland Canal with eight locks is reported to be the most fatiguing part of this system. Irregular working hours may break the circadian rhythm of seafarers, even though many human resource managers and captains try their best to maintain the minimum hours of rest required by law. In addition, the reduction of crew size increases the difficulty for Canadian seafarers to address intensive mobility, in particular the time-consuming vertical mobility across the locks and canals on the Great Lakes and St Lawrence Seaway (Shan and Neis 2019).

Seafarers work intensive shifts while navigating the locks including extended working hours and reduced and broken rest hours. Furthermore, quick turnarounds at the port mean seafarers may have to travel back down through the Welland Canal or the Montreal to Lake Ontario system again fairly soon afterwards. In our empirical study, one captain highlighted ways this work pattern, combined with a reduction in crew size (from 30 to 17 on some ships, and from 24 to 12 on other ships), contribute to fatigue on the downbound and upbound voyages. The only time to have some rest is during the 5-h sail on Lake Ontario (Shan and Neis 2019).

Intensive mobility, in particular the increasing competition in loading and discharging operations, restricts shore leave opportunities for seafarers. Some seafarers may not get ashore even once for the whole sailing season on the Great Lakes and St Lawrence Seaway. Seafarers' shore leave may create "unnecessary delay" in the highly competitive transport market (Shan and Neis 2019).

10.4.3 Insufficient Occupational Health and Safety Rights

Legal instruments that enshrine occupational health and safety rights are the primary tool used to protect seafarers from occupational hazards. Canadian seafarers' occupational health and safety rights are provided for under international conventions, including the Maritime Labour Convention, 2006 (MLC 2006), and Canadian domestic laws, including Canada Labour Code, Part II, Maritime Occupational Health and Safety Regulations, Canada Shipping Act, 2001, and Marine Personnel Regulations (MPR). Canada ratified the Maritime Labour Convention, 2006 in 2010, but implementation and enforcement of the standards takes time, and gaps between Canadian law and the Maritime Labour Convention, 2006 still can be identified. For example, under Section 319 of the MPR and Regulation 2.3 of the MLC 2006 concerning hours of work and rest, Canadian standards are lower compared to the international ones (International Labour Organization 2018). In addition, ships that navigate exclusively in inland waters or waters within, or closely adjacent to, sheltered waters are not subject to the provisions of the MLC 2006 (Article II.1 (i)). With respect to ships of less than 200 gross tonnage not engaged in international voyages, competent authorities, in consultation with the shipowners' and seafarers' organizations concerned, can determine the Codes of the MLC 2006 that are not applicable (Article II.6). Canadian seafarers are mainly involved in domestic shipping, and many work on ships that are not subject to the MLC 2006. For these seafarers, the Canada Labour Code and Canada Shipping Act, 2001 are the primary legal sources of their occupational health and safety rights, which have not been amended to an equivalent level to the international maritime labour standards.

To address the occupational health and safety hazards faced by seafarers, it is necessary to ensure there is sufficient protection of occupational health and safety rights in the regulatory framework. However, a legal analysis of Canadian maritime health and safety regulations identifies several gaps in maritime labour protection. These gaps pose challenges for seafarers because the weaker legal protection makes it more difficult for workers to voice their safety concerns and to participate in the control of the occupational hazards they face.

Canadian occupational health and safety law has adopted the internal responsibility system, which means although the employer has primary responsibility, all workplace stakeholders, including supervisors and workers, have statutory duties to ensure compliance. In the maritime industry, due to the total institutional nature of the ship as a working environment, many seafarers' occupational health and safety rights are restricted in order to adapt to the nature of the competitive transport market (Shan and Lippel 2019). The current protection of Canadian seafarers is relatively lower compared to land-based workers, and in some cases, there are gaps between Canadian maritime occupational health and safety standards and international ones.

The first gap is related to maximum working hours and minimum hours of rest. Canadian seafarers are exempted from the maximum hours of work stipulated in Section 171 of the Canada Labour Code, which are 48 h/week, under the East Coast and Great Lakes Shipping Employees Hours of Work Regulations (s. 5) and the West Coast Shipping Employees Hours of Work Regulations (s. 3). Instead, the MPR stipulate the minimum hours of rest for crew on federally regulated ships. There are two patterns of working hours adopted on Canadian ships, one is 4 h on 8 h off, and the other is 6 h on 6 h off. In both patterns, seafarers are required to take two work shifts of 4 or 6 h in 24 h (Shan and Neis 2019). When working on board, seafarers are required to work 7 days a week, which means regularly working between 56 h and 84 h per week. Working hours on board are much higher compared to land-based work, which is also a common practice in the international shipping industry (Sampson 2013).

Under Section 320 of the MPR, for Canadian vessels engaged on sheltered water voyages or near coastal voyages or vessels that are in any waters other than those of a foreign state that has ratified the MLC 2006, the master and the crew have (i) at least six consecutive hours of rest in every 24-h period, and (ii) at least 16 h of rest

Table 10.3 Application of minimum hours of rest standards

	Canadian vessels engaged on sheltered water voyages	Canadian vessels engaged on near coastal voyages in any waters other than those of a foreign state that has ratified MLC 2006	Canadian vessels engaged on near coastal voyages in waters of a foreign state that has ratified MLC 2006	Canadian vessels engaged on unlimited voyages	Foreign vessels in Canadian waters
MPR, s. 320	x	x			
Regulation 2.3 of MLC 2006 (MPR, s. 321)			x	x	x

in every 48-h period. These standards allow seafarers to work continuously 16–18 h in a 24-h period. Even compared to international maritime labour standards, seafarers working on Canadian domestic water are subject to a lower standard of rest hours. Under Regulation 2.3 of the MLC 2006, minimum hours of rest shall not be less than (i) 10 h in any 24-h period and (ii) 77 h in any 7-day period. Canada adopts the equivalent standards for ships engaged on near coastal voyages while the ship is in the water of a foreign state that has ratified the MLC 2006 for ships engaged on unlimited voyages and for foreign ships in Canadian waters (Table 10.3) (CSA 2001, ss. 319 (2), 321, 324).

On a Canadian vessel on the Great Lakes and St. Lawrence Seaway, Section 320 of the MPR is applicable to Canadian seafarers. However, on a foreign vessel, Regulation 2.3 of the MLC 2006 would be applicable. As a result, during a 14-day period, Canadian domestic seafarers would be entitled to a minimum 112 h of rest, which is 42 h less compared to international seafarers' 154 h of rest, even though they are working in a same region. Considering the demanding nature of navigation in Canadian waters, including the constant irregular working hours on the Great Lakes and St. Lawrence Seaway and complicated ice navigation in Arctic waters, lower labour standards for minimum hours of rest applicable to Canadian domestic seafarers may exacerbate the risk of fatigue-related incidents and accidents in Canadian waters.

The second gap between standards is marine workers' right to participate in safety management. The workplace health and safety committee is a key institution under Canadian occupational health and safety law, but mandatory establishment of a workplace health and safety committees is not applicable to ships. According to Section 135 (1) of the Canada Labour Code, "for the purposes of addressing health and safety matters that apply to individual work places, and subject to this section, every employer shall, for each work place controlled by the employer at which twenty or more employees are normally employed, establish a workplace health and safety committee and … select and appoint its members." However, an employer is not required to establish such a committee for a workplace that is on board a ship in respect of employees whose base is the ship. Canadian ships are, however, required to have health and safety representatives. As per Section 136 (1) of the Code, every employer shall, for each workplace controlled by the employer that is not required to establish a workplace committee, appoint a person as the health and safety representative (Shan and Lippel 2019).

This exemption for a workplace health and safety committee makes Canadian maritime workers' right to participate in health and safety management lower compared to land-based workers. In addition, this exemption may also place Canada, as a party to the MLC 2006, not fully able to comply with its obligations to provide minimum health and safety protection standards. According to the MLC 2006 Standard A4.3.2(d), a ship's safety committee shall be established on board a ship on which there are five or more seafarers and seafarers should be appointed or elected as safety representatives to participate in meetings of the ship's safety committee. However, the current Canadian health and safety regulations allow a ship with more than 20 seafarers to operate with a safety representative, selected from the crew, rather than with a properly established health and safety committee on board. This gap in seafarers' occupational health and safety rights between the Canada Labour Code and the MLC 2006 should be filled to ensure sufficient protection of Canadian seafarers. Further, it is necessary to require a mandatory workplace health and safety committee on board a vessel with more than five seafarers and to remove the exemption provided by the Canada Labour Code in order to ensure that Canadian domestic seafarers have equivalent rights to international seafarers, as well as domestic land-based workers.

The third gap is related to the right to refuse dangerous work (Shan and Lippel 2019). As a general rule provided by Section 128(1) of the Canada Labour Code, an employee may refuse to work if he/she has reasonable cause to believe that a condition exists in the workplace that constitutes a danger to the employee or other employee, unless the refusal may put another person's life or safety in danger. On board ships, the exercise of the right to refuse dangerous work is more complicated. As per Section 128(3) of the Canada Labour Code, once a danger is identified at the workplace on a ship in operation (casting off from a wharf in a Canadian or foreign port until it is next secured alongside a wharf in Canada), the employee has a primary obligation to notify the person in charge of the ship (usually the captain), and that person should decide whether or not the employee may discontinue the work. If the person in charge commands the employee to continue their work, then the employee shall not discontinue the work. The extra conditions for seafarers to exercise their rights may restrict their capability of self-protection and expose them to greater risks (Shan and Lippel 2019).

Although there are certain gaps in the Canadian maritime occupational health and safety legal system, Canada does have a communication platform, the Canadian Marine Advisory Council. With representatives from industry, labour and government, the Council enables the government to keep improving Canadian maritime OHS standards together with the industry, trade unions and other non-governmental organizations (Transport Canada 2019).

10.5 Conclusion

The high risk of a fatal accident in the maritime sector indicates that additional regulatory efforts are required to ensure the health and safety of workers at sea. In addition, considering the expansion of Arctic maritime activities due to climate change, intensive work-related mobility in Canada, and the existing gaps in occupational health and safety protection standards between Canadian domestic seafarers, international seafarers and land-based workers, how to protect Canadian seafarers is an important question to address.

This chapter, based on findings from empirical studies and legal analysis, sets out some of the health and safety challenges facing Canadian seafarers. In the current literature on seafarers' health and safety issues, major attention has been paid to international deep-sea seafarers, while domestic short-sea seafarers are under-examined. However, with the opening of the Arctic, as well as increasing international regulatory efforts to ensure decent working conditions at sea, the necessity to examine the health and safety challenges faced by Canadian seafarers, particularly in the Arctic, is becoming prominent. Maritime occupational health and safety challenges are not restricted to hazards related to the environment at sea; technical challenges and labour process on board, commuting and high-level work-related mobility, limited rights and insufficient legal protection are also significant challenges, making seafarers more vulnerable.

Canada has a relatively comprehensive occupational health and safety legal framework for seafarers, which is a good start to ensure health and safety protection, although there are still some gaps to be bridged to ensure sufficient legal protection for domestic seafarers. The Canada Labour Code, Maritime Occupational Health and Safety Regulations, *Canada Shipping Act,* 2001, and Marine Personnel Regulations are the primary legal instruments that provide protection for seafarers. The Canadian Marine Advisory Council also provides a communication platform between the industry, labour and government. The OHS challenges facing seafarers can be addressed with more concerted efforts from government, industry and labour organizations. To ensure Canadian seafarers can access sufficient legal rights to participate in health and safety is important for the healthy development of Canadian shipping, as well as the ocean economy.

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Chapter 11
Insights from the History of Fishing Safety: Preparing for Increased Fisheries and Shipping in the Canadian Arctic

Barbara Neis, Joel Finnis, Ronald Pelot, and James Shewmake

Abstract The opening Arctic means not only expanding shipping but also expanding fisheries. On an industry basis, fishing is one of the most hazardous industries in the world, even more hazardous than shipping. Both sectors are vulnerable to the effects of weather and require travelling significant distances into and through a range of environments and changing marine contexts, while workers complete complex tasks on moving platforms. Fishing relies on many of the same resources that other maritime industry sectors rely on to reduce and mitigate occupational health and safety (OHS) incidents, including public forecasting services, search and rescue (SAR), and the Coast Guard. This chapter provides an overview of selected fishing safety research highlighting (1) historical analogues relevant to expanding traffic in the Canadian Arctic and (2) insights from fishing on ways to reduce risk and mitigate OHS outcomes in this context. It draws on relevant fishing OHS literature to highlight lessons from history, illustrating ways that changes comparable to expanded fishing and shipping in the Arctic resulted in spikes in fatalities and injuries and identifying steps eventually taken to address these impacts. At least some of these fatalities and injuries may have been prevented with proper and careful hazard recognition and planning prior to, or early on, in the period of change. The chapter takes stock of some weather forecasting, governance, and SAR resource initiatives with the potential to reduce the risk of injuries and fatalities during the transition to increased traffic in the eastern Canadian Arctic.

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11.1 Introduction

As marine traffic through the Canadian Arctic increases, it is inevitable that the number of related occupational health and safety (OHS) incidents will also rise. Anticipating, reducing, and mitigating the effects of hazards and incidents requires that we identify factors that either contribute to incident occurrence or influence outcomes and take steps to address them before and during traffic increase. Literature on OHS in the fishing industry offers a wealth of relevant information and cautionary examples to help address these challenges. Fishing OHS is more relevant than it may initially seem to the current treatment of Arctic shipping. As a dynamic and diverse activity, fishing encompasses the full range of tasks across marine occupations. Indeed, distinctions between fishing and other forms of marine transport are treated as negligible by some agencies (e.g., Canada's Transportation Safety Board (TSBC 2019), includes fishing in their 'shipping incident statistics'). In this sense, fishing has effectively served as a 'pioneer' shipping sector in the Arctic with a long history of subsistence fishing and, more recently, of commercial fishing in the Canadian eastern Arctic and an even longer history (going back to the sixteenth century in some regions) of commercial fishing in the northeast Arctic off Norway, Iceland, and Russia (Hurtubise 2016; Aglen et al. 2004; Standal 2003; Townhill et al. 2015). This chapter provides an overview of selected fishing safety research highlighting (1) historical analogues relevant to expanding traffic in the Canadian Arctic and (2) insights from fishing on ways to reduce risk and mitigate OHS outcomes in this context. It draws on relevant fishing OHS literature to highlight lessons from history, illustrating the ways changes comparable to expanded commercial fishing and shipping in the Canadian and European Arctic, but excluding the Central Arctic, resulted in spikes in fatalities and injuries, identifying steps eventually taken to address these impacts and taking stock of some recent weather forecasting and search and rescue (SAR) initiatives in terms of their potential to help reduce the risks associated with the Arctic shift.

Fishing is recognized as one of the most dangerous occupations globally (Hasselback and Neutel 1990; Lincoln and Conway 1999; TSBC 2012). Shipping has a somewhat better safety record, but retains 'a high potential for catastrophes' (Hetherington et al. 2006). Both sectors are vulnerable to the effects of weather and take place while travelling through varying regions and marine contexts. Both require task completion on moving platforms. Fisheries and shipping are also diverse (in the Arctic, as elsewhere): they encompass small-scale, short-haul, close to shore operations as well as medium- and large-scale operations that take place farther offshore and sometimes far from home ports and can last for weeks or months.[1] Activities on board vessels in both sectors can vary considerably and may include maintenance of vessels and gear, steaming, docking, as well as loading and unloading (at dock and at sea). Fishing often also includes varying degrees of processing and stowage of the catch. Efforts to reduce OHS incidents in both sectors make use of similar instruments including regulation (equipment design and safety equipment requirements, certification requirements for captains and crew, licensing), establishing professional safety organizations, and improving communication (radio, satellite links) and location (radar, GPS) services. Most incident mitigation measures such as search, rescue, towing, and monitoring apply equally to shipping and shipping traffic.

Perhaps even more than other maritime workers, fish harvesters are by necessity adaptable, changing gear, shifting fishing grounds, and refitting vessels in response to changes in fish stocks (such as species abundance and range shifts, and fisheries management (licences, quotas, closures), evolving safety regulations, etc.). Unable to avoid risk, they are risk navigators (e.g., Eggert and Martinsson 2007; McDonald and Kucera 2007; Thorvaldsen 2015) and adopt a variety of strategies and tools to address the diverse hazards associated with fishing and 'keep themselves safe'. These include vessel and gear design, monitoring weather and forecasts, work practices such as maintaining communication with other vessels and careful management of physical shipboard hazards like rope (Finnis et al. 2019; Power 2008). However, many of these strategies and tools (notably vessel/gear design, local knowledge) are somewhat context-specific and do not necessarily transfer safely following significant changes in activities, geography, or working conditions. As discussed below, history has shown that in the absence of careful planning, incident rates often spike at times of significant change, such as those associated with the development of new fishing vessel designs, switching target species, and fishing in unfamiliar areas and weather and climate conditions. Expanding commercial fishing in the Arctic combines several such changes, including potentially targeting new species in previously under-used or inaccessible ocean regions that are poorly charted and where knowledge of navigational, weather, and vessel/gear design-related hazards is very limited. As in the past, it therefore has the potential to result in high incident rates, and, with limited search and rescue (SAR) resources (Goegebeur 2014) and untested marine forecast reliability in the Arctic (Jung and Matsueda 2016), incident severity is also liable to be greater than in more traditional fishing areas.

The 2015 sinking of the *Atlantic Charger* in Frobisher Bay illustrates the combination of factors that can come together to trigger a major incident in this context. The 65-foot vessel had recently acquired a fishing quota near Baffin Island, far from its normal fishing grounds. Originally intending to land their catch in Pangnirtung, the skipper was forced to adjust his plan when sea ice blocked the entrance to

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[1] At the time of writing, there are large fishing vessels operating in Baffin Bay (e.g., operated by the Nunavut Fisheries Association), in addition to the smaller vessels engaged in subsistence activities, including traditional vessels (kayaks and umiaks).

Pangnirtung Harbour. The vessel instead headed back to Newfoundland with a hold full of fish and was soon found to be taking on water. In the words of the *Charger*'s skipper, Byron Oxford, 'we were fishing out of our element; 200–250 miles from the coast where it was rare to see another fishing vessel' (Oxford 2018; Adey 2015). This statement captures the crew's lack of experience with the area, including what sea state to expect at the mouth of Frobisher Bay entering the Labrador Sea, given the forecasts for a storm on their journey. Other elemental variations in the region for this vessel would include differences in communication and rescue options during the long steam back to Newfoundland.

The *Atlantic Charger* incident is, unfortunately, not an isolated event. In 2016, the FV *Saputi* ended up racing against rough weather while taking on water near the Davis Strait following a collision with sea ice. Four days later, the *Saputi* reached port in Nuuk, Greenland, under its own power, but much of the voyage was through high winds (up to 50 knots), significant swells (>5 m), and low visibility, all while listing dangerously (TSBC 2017).

Neither the *Atlantic Charger* nor *Saputi* incidents resulted in fatalities, but, given harsh weather conditions and their remote positions at the time of the incidents, they should be considered significant 'near misses'. Both are part of a trend towards increased fishing in the eastern Canadian Arctic. Since the 1970s, the region has gradually (if intermittently) moved from subsistence to combined subsistence and small exploratory fisheries, to (most recently) larger commercial operations (Hurtubise 2016). Although limited data make it difficult to fully assess the impact of fishing on eastern Canadian Arctic marine traffic, available estimates suggest fishing vessels are responsible for the greatest increase in Arctic traffic (measured as kilometres travelled) of any monitored class of vessels (Dawson et al. 2018). The geographic extent of this increase is largely limited to Baffin Island and Davis Strait, in contrast with the broader expansion of shipping traffic through the Canadian Arctic Archipelago. However, fishing traffic has been steadily moving north since 2000 and is now occurring along Devon and Ellesmere Islands. Although Canada recently ratified a ban on commercial fishing in the Central Arctic Ocean beyond national jurisdiction (Canadian Press 2019), activity will likely continue to expand within the 200 nm limit excluded from this agreement.

The next section of this chapter draws on relevant fishing OHS literature, highlighting a handful of lessons extracted from historical periods of shifting fishing activity roughly analogous to current developments in Arctic fishing and shipping. These past events resulted in spikes in fatalities and injuries before steps were taken to reduce newly encountered hazards. It is likely that some of these fatalities and injuries could have been prevented with proper, careful hazard recognition and planning prior to, or early into, the period of change. To some degree, the chapter seeks to do for Canadian Arctic shipping what a similar Norwegian analysis sought to do for Norwegian Arctic shipping and other activities (McGuinness et al. 2013): to learn from the longer-term experience with fishing in Arctic and sub-Arctic waters about how to plan for and mitigate related health and safety risks. As argued there, based on a regulatory review and interviews with fishing industry representatives regarding maintenance and safety management regimes and requirements devised by the Norwegian fishing fleet, safe operation in the Arctic requires, 'adequate preplanning of the activities, understanding of the operational environment and development of barriers against undesired events' (McGuinness et al. 2013, 1). Preplanning of core vessel requirements, maintenance, and spare part availability are required in order to deal with Arctic-related challenges such as short operating seasons, remoteness from service and help resources, as well as hazards such as the threat of marine ice accretion (a well-known fishing-related hazard associated with cold marine environments) (Shipilova et al. 2012). Here, particular attention is given to potential lessons to be learned from previous periods of rapid change in fisheries, including expansion into regions with marine environments that are at least seasonally comparable to the Arctic Ocean (cold water, presence of sea ice, potential for icing, etc.) and that feature similar, sparsely distributed populations and key resources (e.g., SAR, Coast Guard). These regions include northeast Newfoundland and Labrador (Reid and Finnis 2019), Greenland, Iceland, and the seas off of North Norway (e.g., Serreze and Barry 2014; McGuinness et al. 2013). These subpolar and low Arctic seas also currently serve as prominent entries to the Arctic Ocean proper and are already active sites of fishing activity. This historical discussion is followed by a description of some of the resources and factors that have proven effective in mitigating OHS fishing incidents during periods of fisheries change, including prior expansion into the Arctic that might also be relevant for shipping (McGuinness et al. 2013).

11.2 Fishing Safety

Marine commercial fishing is generally understood to be the world's most hazardous industry. Fishing is an ancient trade, global in scope and highly diverse that has, until recently, received limited attention from OHS researchers. A recent scoping review of the literature on OHS and fisheries in industrialized countries since 1966 found only 200 articles and reports, 131 (65%) of them published since 2000 (Shewmake et al. 2018). The review captured a diverse body of research that encompasses engineering and the natural, social, and health sciences. The review showed that multiple factors interact to affect fishing safety. These include biophysical factors such as fishing location, species, season, and weather; education and training; workplace culture and perceptions of risk; technological factors such as vessel, gear, and equipment design; weather forecasting, communications, and SAR infrastructure; social-organizational factors such as work organization, payment systems, and labour force composition; and, regulatory frameworks including those related to workplace safety inspection, safety awareness cultivation, workers' compensation and return to work, and fisheries management and conservation (Shewmake et al. 2018; Windle et al. 2008). The next section draws on this review, supplemented by relevant historical documents, and focuses on three moments in the history of fisheries where spikes in incidents (1) have been documented; (2) provide insights into the OHS implications of expanding vessel traffic into the

Arctic (i.e. vessels operating ‘out of their element’); and (3) offer insights into ways similar spikes might be avoided/mitigated in future Arctic shipping and fishing.

11.2.1 Lessons from Fishing Safety History: Incident ‘Spikes’ Following Fleet Shifts to Colder Waters and More Remote Locations

A recurring theme in OHS literature is that significant change in the location/type of fishing activity is liable to bring an increase in injuries and fatalities. These changes can arise from ‘pull’ (e.g., the opening of new fishing grounds or a draw towards more lucrative catch species) or ‘push’ factors (e.g., fisheries management initiatives, declining catch rates/quotas, or closing of existing fisheries). They may be driven (or enabled) by technological innovation, technology transfer, regulation related to fisheries management, and, in the past, loss of fishing grounds in foreign jurisdictions as a result of EEZ claims by coastal states. Regardless of the reason, when harvesters, vessels, and/or safety resources move substantially ‘out of their element’, the risk of incidents, injuries, and fatalities often increases. Past work has partially attributed spikes in OHS incidents following these kinds of changes to several features of fisheries work that do not always transfer smoothly to new contexts, including local knowledge, vessel design, and fishing gear. Risks posed by moving to new environments are hardly specific to the fishing industry; any vessel on its first voyages through the Arctic could experience similar concerns with vessel design and operational gaps, lack of local knowledge and related familiarity with a range of marine hazards, poorly developed infrastructure for hazard identification (including weather forecasting), and hazard mitigation (including ports of refuge and SAR resources). Consequently, literature on fishing OHS implications of shifts comparable to a territorial expansion into the Arctic can provide useful insights and context for Arctic shipping broadly. Three examples are provided in this chapter: (1) the advent of iron, and later steel, deep-sea side trawlers that supported a northward shift of trawler fleets from the United Kingdom (UK) and elsewhere into the Arctic; (2) the northward shift of Newfoundland and Labrador trawlers from the Gulf of St. Lawrence and Southern Grand Banks to fish off the northeast and Labrador coasts; and (3) the reorganization and related species and spatial shifts in the Newfoundland and Labrador fisheries following the 1990s’ groundfish moratoria and allocation of permits to fish for snow crab to small-scale enterprises.

11.2.1.1 Post-industrial Expansion of UK Trawler Fisheries into the Arctic

The introduction of larger iron and then steel steam side trawlers was associated with the development of distant water fisheries, enabling fleets from locations such as the UK to harvest remote locations (including the European Arctic) starting in the 1890s. These vessels were not designed for activity in cold ocean environments, leading to several decades of effort to document resulting hazards and address the various technological, design, infrastructure, and other gaps that led to high injury and fatality rates in these fisheries (Holland-Martin 1969). According to author David Butcher in *The Trawlermen* (1980), a book based on interviews with Lowestoft fishermen:

> [a]ll fishing is a dangerous business and trawling has the highest accident and mortality record of all. As the steam trawler fleets pushed further northwards into Arctic waters, so the risks multiplied. Beyond the normal hazards of the job were added the freezing temperatures, black frost, the long periods of winter darkness, the long steam to and from the grounds and the relentless round-the-clock routine of shooting, gutting and hauling to make the trip worthwhile. (115)

Between 1958 and 1967, fatality rates were highest on board distant water side trawlers including those fishing near Iceland, Greenland, Norway, and Newfoundland and Labrador. Three British trawlers were lost in 1968, including two off of Iceland during bad weather. The Holland-Martin final report on trawler safety (1969) shows that problems with icing were well-known and experiments were being conducted to find ways to reduce the risk it posed, including changing vessel design. However, concrete changes had not been widely implemented. The report acknowledged that the best solution was for skippers to stop fishing and seek refuge when icing conditions were present. At this time, the Board of Trade was experimenting with stationing a support trawler (the *Orsino*) for the fleet, outfitted to deliver meteorological, medical, and rescue services – a common practice of other European countries fishing in the region. The report notes that the *Orsino*'s local weather forecasts 'were especially valuable since they were much more detailed than the forecasts normally available to trawlers in the area from Iceland or from the United Kingdom' (Holland-Martin 1969, 21). The report concluded that weather forecasting and other support services required an international initiative. Around this time, the trawler fleet was converting to stern trawlers. Stern trawlers were quickly shown to have a better safety record in terms of vessel losses and injuries than side trawlers: 'Of eight major trawler casualties in 1968, the only vessel not lost was a stern trawler…. It was gradually recognized that safety depended on the state of vessels as well as the competency of seamen' (Capes and Robinson 2008, 304).

Unfortunately, unsafe side trawlers were not necessarily decommissioned or removed from cold ocean service as they were phased out in Europe. Rather, some British side trawlers were sold to fishing operations in areas such as Newfoundland and Labrador. The icing up and disappearance of two of these vessels (the *Blue Wave* and the *Blue Mist*; 1959 and 1966 respectively) resulted in the loss of a total of 29 lives (Stoodley 2017a, b), highlighting that OHS lessons often are not shared efficiently or effectively between countries.

11.2.1.2 Manoeuvring for Control: Spatial Shifts in Canada's Trawler Fisheries After 1977

The starting point for fishing safety research in Newfoundland and Labrador was a 1986 report published by Memorial University's Institute of Social and Economic Research (ISER), funded by the Canadian government (Neis et al. 1986). While the focus of the study was the social impact of technological change in Newfoundland and Labrador fisheries, a section of the report dealt with OHS issues in deep-sea fishing. The trigger for the report was concerns about injuries and fatalities on trawlers associated with a government-supported initiative after 1977 to secure Canadian access to offshore fisheries in new areas. Prior to 1977, Newfoundland and Labrador's offshore fishery was concentrated in the ice-free Gulf and Grand Banks areas. With the extension of the 200 mile exclusive economic zone (EEZ), vessels designed for fishing in these largely ice-free environments were sent to fish off northeast Newfoundland and Labrador where some of the fishing took place in the ice and where there was a high risk of icing. Vessels were not ice reinforced, so there was high risk of ice damage. In addition, on the Newfoundland and Labrador trawlers, fishing in the ice led to a practice of 'chaining off the warp' (placing a chain around the metal warps connecting the net to the boat and manoeuvring them down onto the ramp) in order to ensure nets went under versus onto the ice. Chaining off the warp was associated with a serious risk of injury and fatality due to the risk of chains snapping. This practice was eventually eliminated with the introduction of hydraulic ice davits used to steer the warps or wires linking the trawl to the boat into the open water area behind the ship.

11.2.1.3 Atlantic Canada Groundfish Moratoria

After dramatic post-WW II increases in commercial groundfish landings (notably cod) off the Newfoundland and Labrador coasts, a moratorium on cod fishing was implemented for three of 31 Northwest Atlantic Fisheries Organization management divisions ('zones') in July 1992. Motivated by sharp declines in both catch rates and estimated biomass, cod moratoria were implemented in an additional four zones by 1996, effectively ending the single most critical commercial fishery for the inshore fleet in Newfoundland and Labrador. Widespread moratoria on other groundfish species followed, limiting the inshore fleet from pursuing comparable alternative species (DFO 2019). In the mid-1990s, the federal government decided to allocate snow crab fishing permits to small-scale fishermen. With limited disposable income following the abrupt groundfishery collapse, existing fishing enterprises felt significant pressure to quickly gain and hold any licences they could for these new target species. Crews found themselves pursuing a very different catch with very different equipment in deeper waters further offshore, using the same vessels, safety equipment, and knowledge that had been employed in nearshore cod fishing.

The result was a burst of fisheries SAR incidents and accidents within Newfoundland and Labrador (Pelot et al. 2000; Binkley et al. 2008). Interviews and focus groups with harvesters indicated that during the initial years, they often used vessels designed for fishing other species and steamed offshore without the radar and other equipment essential to survival. They were ‘out of their element’, and it took some years for them to adjust in terms of their knowledge of the area and the fishery, their vessel design, navigation and safety equipment, and gear management (Brennan 2008; Macdonald et al. 2008; Power 2008).

11.3 Mitigating Risk in Times of Change: Taking Stock

This section takes stock of existing and emerging resources for mitigating the OHS hazards associated with expanding shipping and fishing in the eastern Canadian Arctic that might help to reduce the risk of high rates of fatalities and injuries in the short and longer terms.

11.3.1 Marine Forecasting and Sea Ice Resources

Marine forecasts and sea ice services are critical risk management resources applied in decision-making across all marine industry sectors. Studies of forecast use in fisheries emphasize that the application of these resources is nuanced, involving the interpretation of multiple forecast sources with peers and through the filter of accrued local knowledge and working experience (Finnis et al. 2019; McDonald and Kucera 2007). When harvesters adjust their activity or move into new fishing grounds, forecasts become critical tools for anticipating dangerous conditions and ‘learning’ an unknown environment or working context (e.g., different gear). However, while some form of forecast information will be immediately available for any new fishing ground, the peer networks and local knowledge necessary to best implement these resources take time to develop. This presents a significant limit to the utility of forecasts; harvesters report referencing multiple forecast resources in their operational decision-making and interpret these in an informal, yet collaborative manner via continuous weather discussions with peers. Forecasts are approached in an inherently probabilistic manner, as harvesters synthesize data products with very different scales, formats, and strengths with an awareness that forecasting is a difficult, uncertain process (Finnis et al. 2019). This stresses the fact that while marine forecast availability and reliability matter when managing fishing risk, experience and peer networks are equally as important.

Marine forecasts and expanded sea ice services are becoming available as the Arctic opens to increased traffic. New areas of marine forecasting responsibility (METAREAs) were established by the International Maritime Organization (IMO) and World Meteorological Organization (WMO) in 2010 in anticipation of increased Arctic traffic as sea ice continues to retreat (ECCC 2015). Marine forecasts are now seasonally available for portions ('zones') of Canadian Arctic METAREAs (XVII and XVIII), with additional forecast zones planned as sea ice recedes and traffic increases. However, it is important to note that forecasting in the Arctic poses unique technical challenges that limit the reliability of Arctic marine forecasts relative to lower latitudes. The region suffers from a sparse observational network, with relatively few surface stations (Casati et al. 2017) and upper air sounding (radiosonde) sites (Inoue et al. 2013). Satellite observations can partly fill this gap, but coverage is again limited relative to lower latitudes, which benefit from perpetual coverage by geostationary satellites (e.g., Trishchenko et al. 2011). Forecast models often struggle to capture key atmospheric processes (e.g., Jung et al. 2016; Jung and Matsueda 2016), and it has been suggested that Arctic predictability is effectively limited to 48 hours (Nakashima et al. 2012). Indeed, forecast skill across most of the Arctic remains somewhat uncertain, as traditional verification is limited to existing observing sites (Casati et al. 2017; Jung and Matsueda 2016). It has been suggested that verification schemes need to be adjusted to meet Arctic conditions (Casati et al. 2017). The outlook for forecast reliability is consequently uncertain; responsible agencies are just beginning to provide forecasts for a dynamic, under-observed region impacted by a wide range of navigational hazards (e.g., winds, waves, sea ice, icing, ice shelves, and fog). These products must be approached with caution. There is, fortunately, reason to believe the situation will improve. Novel satellite observing systems that will focus on the Arctic are being actively pursued (Trishchenko et al. 2011); nontraditional observation and communication networks are emerging to partially fill gaps in observation and communication networks (Knol et al. 2018; Bell et al. 2014); and, as air and sea traffic in the Arctic increases, so will the volume the 'observations of opportunity' provided by many aircraft and marine vessels. Still, vessels currently operating in the Arctic do so with relatively limited forecast resources.

There are already vessels operating in the Arctic with crews that are unfamiliar with the region (e.g., the *Arctic Challenger* incident). Others may have crew members that have been active in the region for many years, especially those operating in high traffic areas with existing commercial fisheries, for example, Davis Strait and Baffin Bay (Dawson et al. 2018). Deficits in crew experience may be partially alleviated by hiring crew members from within Arctic communities, building some local and indigenous knowledge into within-crew weather discussions. Still, it is unclear whether this knowledge (often developed during land-based, near-shore, or on-ice activities) will translate to the context of commercial fishing or shipping. There is also concern that the reliability of traditional weather knowledge is being eroded by such changes as reduced reliance on country foods (George et al. 2004; Aporta and Higgs 2005; Ford et al. 2008; Laidler et al. 2008) and by climate changes (George et al. 2004; Gearheard et al. 2007; Durkalec et al. 2014).

Due to the limits placed on Arctic prediction, as well as key gaps in relevant local weather knowledge, marine forecasts are likely to remain a limited OHS mitigation tool in the early period of Arctic shipping expansion. There is reason to believe the situation will gradually improve as rising traffic inevitably adds observing capacity and relevant local knowledge accrues, although the time frame for such 'passive' improvement may be unconscionably prolonged. Jeuring et al. (in press) present a strong argument that the forecasting outlook will improve faster and to a greater degree if forecast producers and end users proactively adopt a concerted model of knowledge co-development. This requires routine exchanges between forecast producers and end users, in which forecast utility is assessed; gaps in knowledge, data, or infrastructure are identified; practices of forecast use are explained; and weather-related OHS incidents are reviewed. Such an approach partially addresses the need for observations and forecast validation, builds local knowledge and forecast expertise among end users, educates producers on practices of forecast application, and encourages holistic perspectives on relationships between weather, behaviour, technology, and OHS. Past knowledge co-production efforts with fish harvesters have proven successful in both Europe (Jeuring et al. in press) and Atlantic Canada (Finnis et al. 2019). Such approaches are likely to be particularly valuable in the context of expanded fishing/shipping in a changing Arctic, reflecting the need to treat adaptation as a continuous, collaborative process between OHS stakeholders and service providers. One potential avenue for encouraging this process is through direct reporting of hazardous conditions by fishing/shipping vessels to Environment and Climate Change Canada's marine forecasting centres; this builds on reporting required under the Northern Canada Vessel Traffic Services Zone Regulations (NORDREG 2010) while establishing rapport between forecast producers and end users. There are emerging precedents for this type of collaboration in forecasting/verification for Arctic communities, including the development of online platforms for mobilizing disparate environmental observations (e.g., SIKU.org; SmartICE.org) and community-level collaboration on events of particular concern (e.g., Eerkes-Medrano et al. 2019).

11.3.2 SAR Resources

Maritime SAR in Canada is led through collaboration between the Canadian Coast Guard (CCG) and the Department of National Defence. Their capacity is bolstered through other means such as volunteers (CCG Auxiliary), CASARA (Civil Air Search and Rescue Association), and marine industry assets. The Canadian Arctic is a relatively high-risk environment for fishing, shipping, and cruise ship operations, and this reality extends to the SAR function. While the great distances from most response resources, the harsh environment, and some communication limitations make this region challenging for SAR operations, there are several plans underway to help mitigate this risk.

One way to improve response in the Arctic is to shorten the search time. This can be reduced to a negligible amount by tracking vessels and people on the water. Significant advances have been made in the past decade on marine tracking devices and systems, and these improvements are ongoing. A key enabler is the Automatic Identification System (AIS), borne by all ships and some smaller vessels,[2] which transmits location information and some ship attributes (Fournier et al. 2018). While relaying AIS signals from ships in the Arctic to government authorities was problematic due to signal strength, the increasing number of custom satellites that can capture AIS signals and the recent installation of the first land-based AIS receiver stations in the Canadian north are alleviating this problem. Efforts are ongoing to develop smaller, cheaper AIS units in order to encourage increased voluntary carriage by smaller vessels. The Long Range Identification and Tracking (LRIT) system is another global system for satellite-based ship tracking specifically designed to enhance safety and security.

On another front, many advances are being made in the capacity to respond to incidents in the north. Canada's icebreaking fleet has been ageing and by some accounts is inadequate to deal with the changing environment and demands in the north. However, recent acquisitions by the CCG of vessels to be refitted for Canadian needs, planning for a new CCG icebreaker over the next few years, and the ongoing construction of several Arctic and Offshore Patrol Ships (AOPS) for the Canadian Navy will provide a significant boost to the emergency response capability in the Arctic (Wikipedia 2019). This increased readiness is complemented by the Canadian Rangers, a cadre of part-time, non-commissioned members of the Canadian Armed Forces Reserves, comprising about 5000 individuals distributed across 200 northern communities. The government recently committed to expand and enhance their functional capabilities, including in SAR (Lackenbauer 2018). While their rescue equipment may be somewhat limited, their potential proximity to maritime incidents can be an invaluable asset. Technological advances in autonomous vehicles are also beginning to penetrate the marine world, with many prototype vessels and devices under development in various countries, including some dedicated to SAR. Capabilities such as autonomously reaching an immersed victim, communicating with them, scooping them out of the water, and many other features are being explored. This type of equipment could be particularly useful in the Arctic both because it could be pre-positioned in locations suitable for quick response and/or operated in a hostile environment while awaiting more powerful SAR resources to arrive (Dalziel and Pelot 2018).

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[2] In Canada, the following vessel categories must carry AIS: (i) every vessel carrying more than 12 passengers, or carrying passengers and greater than 8 metres in length; (ii) every ship, other than a fishing vessel, of 300 tons or more that is engaged on an international voyage; and (iii) every ship, other than a fishing vessel, of 500 tons or more that is not engaged on an international voyage (DFO 2014). While owners and operators of vessels to whom mandatory carriage requirements do not apply are encouraged to outfit their vessels with AIS, issues such as personal privacy or concealment of fishing effort information counter such compliance.

Finally, a more customized risk-based approach to SAR planning allows the acquisition, deployment, and usage of response resources to result in the most efficient and effective assistance. Each region of the country has significant differences in terms of geography, weather, maritime activities, and types of traffic. Thus, the CCG has developed a new method of risk-based analysis of maritime search and rescue delivery (RAMSARD) to support a more systematic approach to evaluating maritime SAR delivery in Canada (DFO 2017). A few of the 40 SAR areas nationwide are assessed each year and reassessed on a 5-year cycle. The methodology is currently being implemented, with the Arctic as one of the pilot areas. The area-specific evaluation will better capture the specific SAR needs in the Arctic, and the periodic updates will accommodate dynamic situations, such as the rapidly evolving north.

SAR resources are improving, but will always be somewhat constrained by remoteness, cost, and weather. Two key questions include: (1) how much of this infrastructure needs to be in place before major increases in traffic are allowed to happen, ensuring effective support for different types and scales of traffic (Indigenous, small, and larger-scale fishing and hunting; coastal and international shipping; tourism-related marine traffic), and (2) how to develop the resources/capacity in a way that maximizes efficiency and effectiveness in the context of changing ocean conditions, diverse and changing patterns of vessel traffic and activities in the region, and emerging documentation of navigational, weather, and other hazards.

11.3.3 Regulation, Safety and Maintenance Management, and Safety Organizations

Regulation is an essential part of reducing the risk of injuries and fatalities as traffic increases in the Arctic. Past experience with fisheries highlights the need for active regulation of vessel design, training requirements, safety management, and vessel/gear maintenance capabilities, pursued with advance consideration of hazards and risk mitigation options. The IMO has now adopted the Polar Code for international regulation of Arctic shipping (Polar Code 2014/2015). Canada played a key role in its development and, in 2017, the Polar Code was implemented by Canada through the Arctic Shipping Safety and Pollution Prevention Regulations (ASSPPR 2017; Chircop et al. 2018). The history of Canada's engagement with the Polar Code and safety requirements in the new regulations suggest a strong focus on the need for vessel and equipment designs, specialized training for Arctic conditions, and particular attention to maintenance. These initiatives are consistent with some of the priorities identified by McGuinness et al. (2013) in their earlier study of insights from fisheries for marine shipping in the Norwegian Arctic and should be helpful in managing and mitigating Arctic hazards. However, Polar Code Phase I encompasses only SOLAS vessels, excluding fishing vessels, and the ASSPPR also do not apply to fishing vessels, although some provisions may apply to fishing vessels including, for example, Section 14 regarding waste management. If fishing vessels are part of a proposed Phase 2 Polar Code, this situation could change, and if the regulations are fine-tuned for fishing in its diverse forms, they could help support a safer transition in this sector, although provincial and territorial health and safety agencies would need to be involved (Antarctic and Southern Ocean Coalition 2019; personal communication, Desai Shan, 24 July 2019).

Multi-stakeholder fishing sector safety organizations have been established in several Canadian provinces including Newfoundland and Labrador (NL Fish Harvesting Safety Association), Nova Scotia (Fisheries Safety Association of Nova Scotia), and British Columbia (Fish Safe BC). Focused and ideally cooperative interventions are believed to be a more constructive approach to safety, and such associations can both contribute to more effective discussion of policy and play a major role in improving the scope and direction of safety research and interventions (Finnis et al. 2019). These organizations have the potential to bring together representatives from fishing fleets, including industry unions and companies, organizations responsible for professionalization, safety training, and workers' compensation, with federal and provincial agency representatives and representatives from Indigenous groups and organizations. The net effect can be improvements to policy and safety culture through a more grounded understanding among government and forecasters and others of how diverse types of harvesters navigate environmental and regulatory risk and, among harvesters, of often shared hazards and resources for mitigating them.

Given the diversity in traffic, sectors, and groups involved and given that Arctic fishing and shipping will inevitably necessitate navigating risk (Kaplan and Kite-Powell 2000; Thorvaldsen 2015), the development of industry led, multi-stakeholder safety organizations could play a key role in helping to more safely manage the transition to the Arctic. Such organizations can play a critical role in enhancing dialogue and communication around safety hazards, mitigation, and safety infrastructure needs and gaps. Some of the fishing vessels and companies operating in the Arctic are from the Canadian provinces of Newfoundland and Labrador and possibly Nova Scotia and British Columbia, but others are from Indigenous organizations and territories. It is unclear the extent to which Indigenous representatives are actively engaged in the existing safety associations, but such engagement would be critical in the context of the Arctic. If adequately resourced and supported, the development of an Arctic-based fishing safety association with cross-cutting representation from the fishing groups engaged in Arctic fishing, including Indigenous organizations, as well as other stakeholders, might be an effective way to help support the Arctic transition. Given the potentially international and inter-regional origins of fishing activity in the Arctic and the very limited SAR and other resources, such an association would ideally encompass all active organizations and agencies engaged with fishing in the Canadian Arctic.

11.4 Conclusion

There is a strong case for looking to the history of fishing OHS in subpolar and low-Arctic seas in order to anticipate impending OHS concerns in the Arctic. As a particularly hazardous subsector within broader shipping concerns, fishing represents a ‘worst-case scenario’ for OHS shipping impacts. Fishing also has a long history of pioneering vessel traffic in new regions; this has certainly been the case in the Arctic, and fishing has previously been used to anticipate shipping needs in the European Arctic (Dypvik 2013; McGuinness et al. 2013). As the Arctic Ocean increasingly comes to resemble subpolar seas (at least seasonally), comparisons to these lower latitudes make increasing sense. As Eicken (2013) highlights, Arctic communities have already noted that ‘the key to adapting to increasingly dynamic ice is to learn from those to the South … the charge to the scientific community is to help create a foundation for such mutual learning to occur’ (433).

The historical examples explored here present a few key repeating themes; change (which can take many forms, from geography, target catch species, vessel design, and regulatory/management regimes through to fishing gear) has the potential to increase fishing risk. This is due to limited transferability of many OHS risk mitigation strategies to new contexts, from local knowledge through to vessel design and gear use. History suggests resulting increases in OHS incidents are transitory; experience gradually fills gaps in local knowledge, while vessel and gear replacement eventually removes equipment poorly suited to new contexts. However, given the consequences of poorly managed transitions in terms of human life and injury, and the relationship between environmental and safety hazards clearly evident in the context of vessel foundering and capsizing, everything possible should be done to prevent or minimally mitigate the risk of major spikes in incidents through effective planning, regulation, training, governance, and response.

It is important to note that expanding marine traffic into the Arctic presents a uniquely hazardous set of circumstances; Arctic waters integrate many severe ocean hazards in a region that is particularly difficult to predict and sparsely covered by SAR and communication infrastructure. Sea ice in particular presents a concern and may rapidly shift access to key ports of refuge (as in the example of the *Atlantic Charger*). These complicating factors are expected to gradually improve, albeit slowly, but will likely never be completely ameliorated. Consequently, OHS concerns in Arctic shipping are likely to remain high in the absence of active regulatory intervention, direct investment in improving resources (forecasting, communication, SAR, etc.), and pursuit of active knowledge co-development strategies between support agencies and the workers they serve.

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Part III

Regulating Shipping and Ocean Use

Chapter 12
The IMO Regulatory Framework for Arctic Shipping: Risk Perspectives and Goal-Based Pathways

Anish Arvind Hebbar, Jens-Uwe Schröder-Hinrichs, Maximo Q. Mejia, Heike Deggim, and Sascha Pristrom

Abstract The International Maritime Organization (IMO), in its capacity as a specialized agency of the United Nations, is the global regulator to ensure safety, security, environmental standards, efficiency and sustainability of international shipping. The current regulatory framework of IMO, which is developed and maintained on a continuous basis, includes over 50 international instruments and numerous codes, guidelines and circulars that cover every aspect of international shipping ranging from design, construction, equipment, manning and operation to ship recycling. The safety net of the universally adopted IMO regulations currently covers approximately 1.5 million seafarers and more than 60,000 ships. With declining ice cover leading to an increasing spiral of traffic despite the many hazards, safety of shipping in polar waters and, in particular, the Arctic and its fragile environment is a current focus area of IMO and purported to be addressed by the Organization through a set of goal-based regulatory standards. This chapter provides an overview of the IMO framework and process of shipping regulation and maps the transition from prescriptive to goal-based approach. Risk-based approaches to safety are discussed in the context of the Canadian Arctic. The chapter further reviews the IMO instruments relevant to the Arctic, including the Polar Code, and discusses the approaches to implementation at the flag state, coastal state and regional level, lending new insights and future pathways on tiered implementation of the IMO goal-based framework.

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Keywords Arctic · Canada · Goal-based standards (GBS) · Goal-based standards-safety level approach (GBS-SLA) · International Maritime Organization (IMO) · IMO regulation · IMO regulatory framework · Maritime safety · Polar Code · Risk · Shipping

12.1 Introduction

The Arctic is uniquely distinctive in nature owing to its extreme milieu of low temperatures, high geographic latitude, the special magnetic phenomena and extraordinary light conditions. The many hazards of polar shipping, especially in the remote Arctic regions (Fig. 12.1), are perhaps without any parallel. In terms of meteorology, the Arctic is among the world's most poorly observed regions. Environmental conditions are generally quite harsh. Ice cover is variable and dynamic, and climate change is expected to have even further impacts. Bathymetric information is scant or outdated, and navigational chart information is not available for all polar waters. For example, only 10% of the Canadian Arctic is charted, and less than 25% of the charts are deemed to be of an adequate standard. Infrastructure to support ships in transit in terms of aids to navigation or ports and reception and

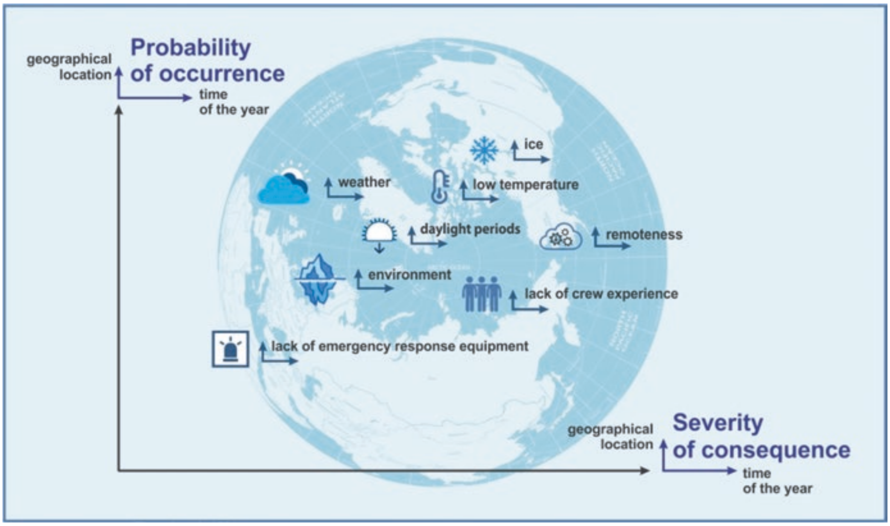

Fig. 12.1 Graphical representation of sources of hazards in the Arctic
Note: (1) The twin dimensions of geographical location and time of the year associated with each variable add to the complexity and multidimensional nature of the hazards. (2) The position of each hazard in the graph does not represent its probability of occurrence or severity of consequence

repair facilities is rather limited. Remoteness implies lower capability for search and rescue, and lack of adequate resources implies limited capacity for post-incident response. Then there is emerging consideration of hazards to navigation due to inadequacies of navigational risk assessments and marine spatial planning (Schröder-Hinrichs et al. 2013; Mehdi et al. 2019).

Regardless of the adverse climate and severe challenges, the Arctic is known to have been traversed since olden time, although the earliest documented transit of the Northwest Passage (NWP) dates to 1906. While trans-Arctic voyages in the past were few and far between, declining ice cover in more recent times is leading to an increasing spiral of shipping traffic with attendant concerns for maritime safety and the fragile marine environment. Between 1980 and 2018, the minimum extent of Arctic ice declined sharply from 7.7 to 4.71 million square kilometres (NSIDC 2019). Of the eight nations bordering the Arctic (Canada, Denmark (Greenland), Finland, Iceland, Norway, Sweden, Russian Federation, and the United States), the Canadian Arctic, for example, encompasses more than 150,000 kilometres of coastline and provides habitat for a majority of the world's beluga and bowhead whales, narwhals, and polar bears and witnesses some of the greatest marine mammal and seabird migrations on the planet (The Pew Charitable Trusts 2016). Given the slow rate of recovery of the natural environment in those areas, any shipping accident could potentially have very serious consequences for the vulnerable Arctic ecosystems, alongside other safety implications.

When it comes to shipping incidents, the Arctic presents unique risks. An early example is the cruise liner *Maxim Gorky* who collided with an iceberg in June 1989, with nearly 1000 passengers, in the Greenland Sea north of Norway and listed heavily having sustained two gaping holes in her side. Grounding of ships at frequent intervals is of particular concern. The *Hanseatic* ran aground twice, breaching two of her fuel tanks in August 1996 and sustaining a 5-meter hole in her hull on the second occasion in 2005. The *Clipper Adventurer* grounded in 2010, and less than 2 years later, in 2012, the tanker *Nanny*, carrying 9.5 million litres of diesel, was the fifth to be grounded since 2007, threatening environmental disaster in an area that allows little margin for error. The more recent August 2018 grounding of the research vessel *Akademik Ioffe* in the Gulf of Boothia, Canada, passed without danger although it was a harrowing experience for the 102 passengers and 24 crew members on board (Struzik 2018).

It is, however, remarkable that the response efforts in each incident met with success. Passengers who abandoned the *Maxim Gorky* into lifeboats were rescued by the Norwegian Coast Guard vessel *Senja* that arrived on scene within 4 hours of the incident (Lohr 1989). One hundred fifty-three passengers aboard the *Hanseatic* were evacuated by helicopter. One hundred twenty-eight passengers from the *Clipper Adventurer*, along with 69 crew, were safely rescued (Struzik 2018). Concerns remain nevertheless, and, therefore, when the *Crystal Serenity* ferried the largest ever number, about 2000 passengers and crew, through the NWP on her maiden voyage in the Arctic in August 2016, several questions arose about the availability and capacity for response in the region, especially for mass rescue operations to the extent that it is described as a "wicked" cross-cutting policy problem that challenges many policy structures (Waldholz 2016; Pincus 2015).

Recognizing the fact that cooperation is an excellent way to overcome challenges, consequent to the *Maxim Gorky* incident, Finland actively engaged with the Arctic states regarding protection of the Arctic environment and organized the Rovaniemi meeting in September 1989 and followed up with three more meetings, which concluded in June 1991 with the adoption of a multilateral nonbinding agreement, the Arctic Environmental Protection Strategy (AEPS) (Arctic Council 1991). The AEPS was a first step to the 1996 Ottawa Declaration, which established the Arctic Council (Arctic Council 1996). This circumpolar forum currently promotes proactive cooperation, coordination and interaction among the Arctic states to address the risks of shipping and related issues of environmental protection in the Arctic. Two working groups of the Council are of particular interest – the Emergency Prevention, Preparedness and Response (EPPR) Working Group, which works for the protection of the Arctic environment from the threat or impact of an accidental release of pollutants as well as considering search and rescue-related issues, and the Protection of the Arctic Marine Environment (PAME) Working Group, which serves as the focal point for activities related to the protection and sustainable use of the Arctic marine environment (PAME 2018).

However, recurring incidents underscore the need for a well-rounded perspective on the risks associated with polar shipping and for innovative ways and means of addressing the identified risks. This chapter focuses on the goal-based regulatory framework of the International Maritime Organization (IMO) for enhancing maritime safety and prevention and control of marine pollution. Section 12.2 touches upon the key role of IMO in setting global standards and discusses the transition from the prescriptive to goal-based approach with reference to the Arctic. Section 12.3 discusses the implementation of the IMO goal-based standards (GBS) for Arctic shipping, with focus on the case of Canada. The chapter concludes with new insights and future pathways to a tiered implementation of the IMO GBS framework in Sect. 12.4.

12.2 IMO Goal-Based Standards and the Arctic Context

12.2.1 IMO as a Global Regulatory Authority

As regards global standards for ensuring safety and security of international shipping and the protection of the marine environment, it is IMO in its capacity as a specialized agency of the United Nations which serves as the global regulatory authority. IMO develops on a continual basis and maintains an effective framework of universally adopted and implemented regulations that cover every aspect of international shipping, from design, construction, equipment, manning, and operations to environmental protection and ship recycling. Indeed, when it comes to advancement of international maritime safety standards, IMO plays a key role having adopted over 50 international instruments and numerous codes, guidelines and circulars.

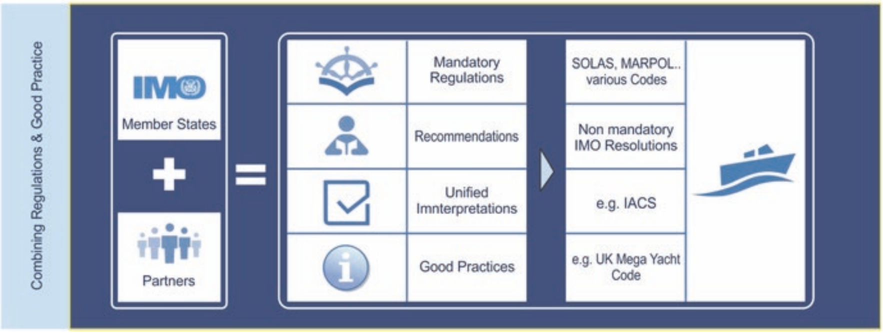

Fig. 12.2 IMO framework and process of shipping regulation (Schröder-Hinrichs 2018)

Figure 12.2 is a simplified depiction of the rather complex framework of the IMO system of regulations and its basis in compromises agreed to by the international maritime community.

12.2.2 IMO's Transition to Goal-Based Standards

Rules and regulations for international shipping adopted at IMO are organic in nature and require periodic refining based on research and experience and the level of risk deemed acceptable to the member states. Adoption of prescriptive rules and regulations was the classic approach to standard setting. The emerging focus at IMO on a goal-based regulatory framework marks a significant cultural shift from a culture of compliance, governed by a complex system of prescriptive statutory international and national regulations, classification rules, and industry standards to a culture of benchmarking, supported by functional risk-based requirements. According to IMO (2019a), GBS are goals and functional requirements that should be met through regulations, rules, and standards. The guiding principle is to establish clear, demonstrable, and verifiable goal-based standards such that the risk to the cargo, crew, and the environment from a properly built, operated and maintained ship is as low as reasonably practicable during its specified design life. The International Code for Ships Operating in Polar Waters (Polar Code 2014/2015), which is elaborated on below, the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code) (IMO 2015a), and the goal-based ship construction standards for bulk carriers and oil tankers (IMO 2009a) are examples of IMO instruments based on the GBS approach. It is intended that overarching goals and their related functional requirements will allow for novel designs that meet the required level of safety which, when applying prescriptive regulations, would have to be treated under the existing provisions for alternative design arrangements (see SOLAS regs II-1/55, II-2/17, and III/38) which may not achieve a globally harmonized implementation as such alternative arrangements are subject to individual flag state interpretations. A goal-based approach, however, provides not only a global standard but also promotes new technology and greater innovation within the shipping industry.

The transition to risk-based considerations and the change in the basis for rule-making at IMO are in keeping with demands for objective evidence of the need to develop new regulations or to amend existing ones. The formal safety assessment procedure (IMO 2018) for the evaluation of risks signifies the transition, and Schröder-Hinrichs (2018) cites the elements of risk-based considerations that are to be found in several IMO instruments. For example, under the International Convention for the Safety of Life at Sea (SOLAS 1974), the position of aids to navigation is to be determined on the basis of risk assessments, while alternative designs and arrangements such as for oil tankers or fire safety are required to demonstrate that the suggested design deviations from prescriptive regulations meet the required safety levels (IMO 2001, 2003, 2006a). Similarly, both designation and decisions on requests for places of refuge involve two independent risk assessments. Another example is the designation of Particularly Sensitive Sea Areas for which a cause relationship must be demonstrated when suggesting associated protection measures. After having implemented risk-based approaches, a further transition to goal-based standards with its safety level approach in five hierarchical tiers was the logical next step.[1]

As per the IMO (2019a) goal-based standards framework in Fig. 12.3, risk assessment is integral to the development of a GBS, which may be for new regulations or based on existing prescriptive ones. When developing GBS, the goals or high-level objectives to be achieved are defined at the very outset. A hazard identification (HAZID) process, possibly guided by the IMO Formal Safety Assessment Guidelines (IMO 2018), is the first step and the basis for a risk analysis and the formulation of risk mitigating functions. The HAZID itself may be system- or process-based and conducted in varying degrees of detail leading to varying degrees of detail of the functions developed consequentially. Functions are supplemented by the expected performances that specify the effectiveness to be achieved. These performance requirements provide the criteria for verifying compliance with the goal and form part of the functional requirements (IMO 2019b).

12.2.3 Risk-Based Approaches and Maritime Safety in the Arctic

In terms of risks for operations in the Arctic, the harsh marine environment presents unique and significant challenges to a vessel and its crew. The risks of frostbite and hypothermia are drastically accelerated in sub-zero temperatures (Transport Canada

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[1] The UK Health and Safety Regulation is believed to be one of the longest running applications of a goal-based approach to regulations and traces its origins to the 1972 Robens Report (UK HSE 1972).

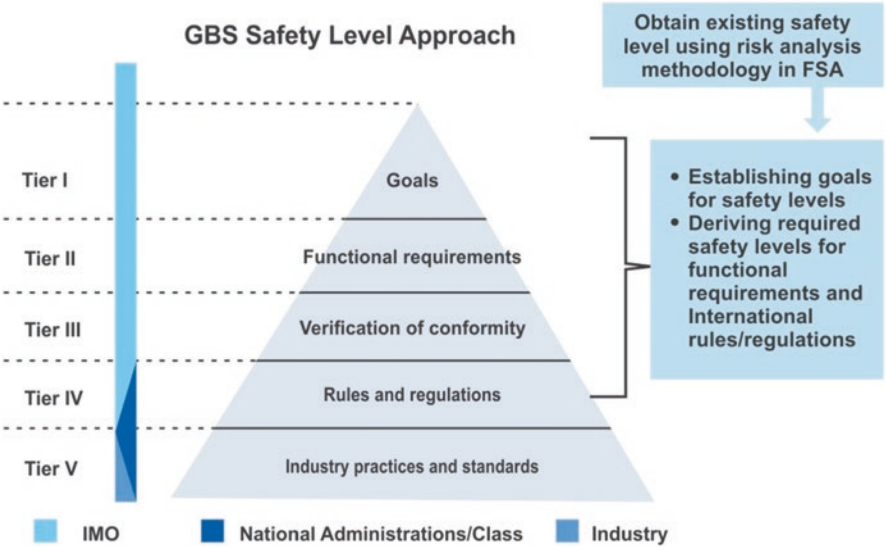

Fig. 12.3 IMO safety case goal-based standards framework (IMO 2019a)

2011). Extreme cold and the use of heavy gloves affect tactile sensitivity and manual dexterity (Parsons 2014; Islam et al. 2017). Compared to navigation in calm water conditions, ice passage can increase whole-body vibration exposure by a factor of 11 (Bekker et al. 2017). Icicles overhead can break off and fall on seafarers, and snow and ice underfoot can cause them to slip and fall. All these, together with accidental immersion, excessive ultraviolet light, extreme contrasts in the length of day or night, and unusual weather conditions that affect both visibility and the sea state, influence performance and decision-making in seafarers. The conditions associated with navigation in the polar regions present physical and cognitive risks to seafarers that can affect not only their personal safety but also their ability to control the vessel and its systems (Sillitoe et al. 2010).

Materials used for the hull structure and equipment may not be suitable in terms of class or design service temperature in polar regions. Contents of tanks for fresh water, ballast, and fuel oil will be susceptible to freezing. Vent pipes, valves, and suction lines may suffer blockages. The bow will be particularly vulnerable to sea spray and ice accretion. Vessel stability could be impaired by ice build-up on the hull. Cold air could have unintended effects on systems and machinery. Engines may not fire because of low combustion air temperature. The ship's anchoring system and navigational systems such as the radar would suffer from icing. Some navigation and communication systems do not work in high latitudes. Safety systems such as life-saving appliances and firefighting and protection systems may fail to perform due to freezing. The presence of ice on the sea surface may even inhibit deployment of life boats. Some ship types, such as tankers, bulk carriers, and liquefied natural gas (LNG) carriers, may require further special consideration of design and operational features. Indeed, in Arctic conditions, many systems and components could be operating at or near their design limits (ABS n.d.).

The management of risks for ships plying the Arctic begins with the owner defining the operational limitations for the ship by selecting the ice class, design temperature or rather the polar service temperature (PST), working latitude of the navigation and communication equipment, and the expected time to rescue based on the operating area (Hindley 2017). The IMO Polar Code includes risk management as part of ice class selection (Operational Assessment), by way of requirements for voyage planning, as part of tactical ice navigation (Polar Operational Limit Assessment Risk Indexing System (IMO 2016a)), operational limitations as reflected in the Polar Ship Certificate, and the Polar Water Operational Manual guiding operational decision-making on board.

From a design perspective, in the context of the Arctic, a failure mode and effects analysis (FMEA) on machinery and systems or any other suitable risk-based technique is imperative early on in the design stage.[2] Risk assessment is indeed *de rigueur* to the evaluation of new conceptual designs, particularly for Arctic operations. The goal is to identify hazards and failure modes applicable to a novel concept application vis-à-vis the control of these hazards and failure modes so as to verify the novel aspects not covered by any of the existing rules, codes, and standards. A qualitative risk assessment comprising HAZID (hazard identification), What-if, or HAZOP (hazard and operability study) is generally the first step. It will usually involve a brainstorming session with structured discussions on the proposed concept together with a consideration of the risk ranking methodology or risk matrix. The qualitative assessment will be followed up with a more detailed quantitative risk assessment such as fault trees and event trees to verify that the identified risks are properly managed.

Several projects underway are devoted to the concept of risk-based design. An integrated risk-based design framework is being developed as part of the SEDNA research project of the European Union's Horizon 2020 program. The project includes an analysis of the key parameters affecting the risk level of ships in ice together with the possible risk control options that will allow ships designed for the Arctic to be measured against the actual risks that they will experience in operation (SEDNA n.d.). Classification societies are partnering with the industry to develop holistic, risk-based design and the concept of mission-based design is being explored to address the challenges of navigating in the Arctic (ISSC 2015). Apart from risk-based design, scholars are also investigating accident models specific to the Arctic, such as the collision risk factors analysis model for icebreaker assistance in ice-covered waters (Zhang et al. 2018).

There are advantages of risk- and goal-based approaches in the context of the Arctic. However, risk-based design for the Arctic is challenging as the ice environment, together with all the possible ship-ice contact scenarios, is complicated

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[2] FMEA is a useful tool to not only identify design changes to equipment or systems or possibly provide additional features, but also to prevent failures from occurring or to mitigate consequences if a failure were to occur.

and difficult to define properly, especially in proper probabilistic terms. The main challenge is still how to describe the ship-ice interaction parameters such as ship-ice contact characteristics, pressure distributions, and load levels in all the various ice conditions. The possible environmental consequences of accidents also need further research, and human factors need to be incorporated in risk analysis techniques (Kujala et al. 2019).

Theoretical analyses identify many contextual factors that could impact the effectiveness of GBS and regulations. The GBS approach depends on interpretative practices and whether or not it is possible to develop a shared understanding of the goals and concepts; therefore, their effectiveness could be impaired by any deficit of trust between the regulator and the regulated. A major practical challenge is to monitor and assess achievement of goals and identify the desired levels of performance or, rather, the precise point at which a goal may be deemed to have been satisfied (Decker 2018). As regards the risk-based approaches in maritime safety, some of the impending challenges are varying levels of risk acceptance, varied approaches, requirement of new resources, and new competences within maritime administrations to evaluate and approve risk-based designs and possible alienation of some stakeholders (Schröder-Hinrichs 2018).

12.2.4 IMO Instruments for Arctic Shipping

Owing to the unique nature of risks in the Arctic, the IMO is paying particular attention to these polar waters, also including the Antarctic area. Among the first attempts at the IMO to provide common baselines of requirements for polar shipping was an Arctic-focused document by Germany in the early 1990s. In keeping with the two-pronged approach adopted by consensus thereafter, the IMO developed broad Guidelines for Ships Operating in Arctic Ice-covered Waters in 2002 (IMO 2002b, 2009b) that were recommendatory in nature, while the International Association of Classification Societies (IACS) developed detailed Polar Class Unified Requirements (IACS 2016), which in turn were accepted by IMO. In 2007, taking note of the growing popularity of the Arctic and the Antarctic as an exotic destination for cruise ships, IMO (2007, 2006b) adopted Guidelines on Voyage Planning for Passenger Ships Operating in Remote Areas as additional non-mandatory standards for the operation of passenger ships (Deggim 2010). However, diverse national and regional regulations governing polar shipping continued to prevail in the absence of a clear and mandatory international standard applicable to ships of all member states, leading eventually to the adoption of the mandatory Polar Code (IMO 2014/2015b)[3] supplementing requirements mandatory

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[3] The Polar Code consists of two parts: Part I Safety Measures, of which Part I-A covers mandatory measures in 12 chapters and Part I-B recommendatory Additional Guidance to Part I-A, and Part II Pollution Prevention Measures (Environmental Protection Measures), of which Part II-A covers mandatory measures in five chapters and Part II-B recommendatory Additional Guidance.

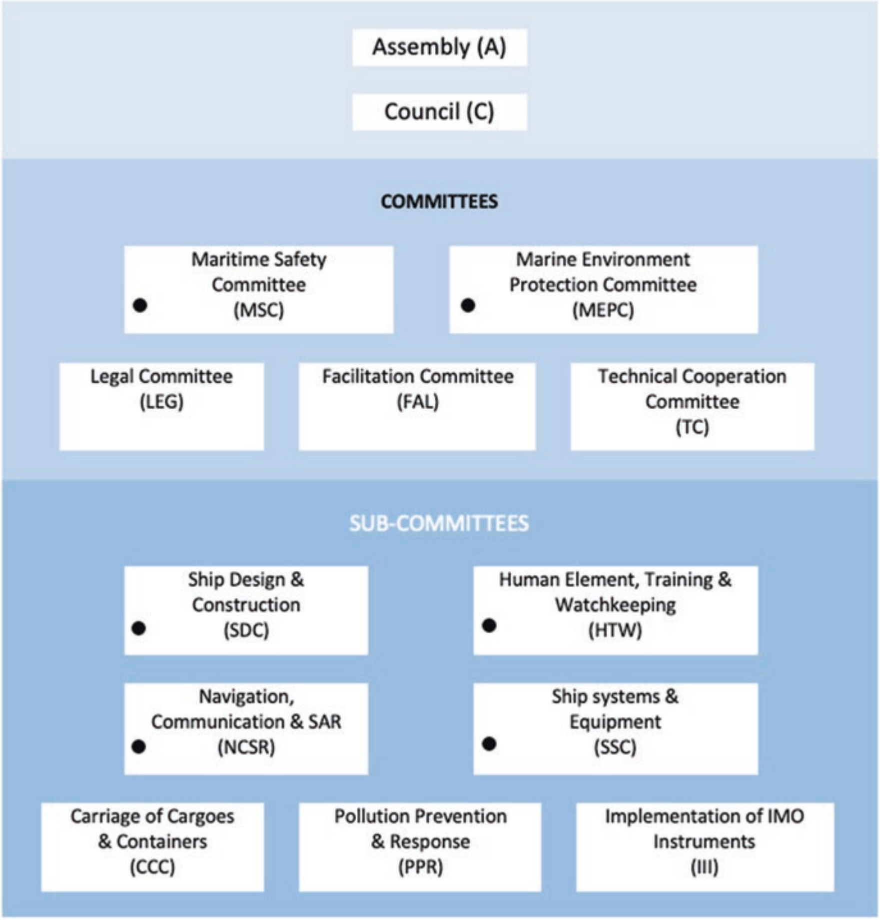

Fig. 12.4 IMO organizational structure and work on the Polar Code (● denotes Committees or Sub-Committees with Polar Code work items)

under IMO instruments such as SOLAS, the International Convention for the Prevention of Pollution from Ships (MARPOL 1973/78), and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) for ships operating in the polar regions. Figure 12.4 depicts the extensive work across the committees and sub-committees at IMO which resulted in the adoption of the Code.

The IMO Polar Code consists of mandatory safety and pollution prevention (environmental protection) measures as well as recommendatory additional guidance for each set of measures. The Polar Code is risk-based, containing functional requirements and prescriptive provisions. The key principles for developing the Polar Code were the use of a risk-based approach in determining the scope and the adoption of a holistic approach in reducing identified risks. The goal of the Code is to provide for safe ship operations and the protection of the polar environment by addressing risks present in polar waters and not adequately mitigated by other IMO instruments. The Code not only regulates navigation in Arctic and Antarctic waters in legal terms, but also aims at mitigating risks in the polar areas through the identification of hazard sources and institutionalization of procedures for risk assessment (Deggim 2018).

The safety measures mandated by the Polar Code cover structure, sub-division and stability aspects of design and construction as well as specifications for machinery, fire safety, life-saving appliances and communications. A Polar Water Operational Manual, required to be carried on board, provides information regarding the ship's operational capabilities and limitations in order to support the decision-making process. A Polar Ship Certificate is required by the Code stating, *inter alia*, the ice class of the ship, which defines the limitations for operations in ice. Additional training and certification requirements for masters and deck officers on ships operating in polar waters have been made mandatory through amendments to the STCW Convention and Code, 2010 (IMO 2016b, c).

While the Polar Code encourages ships not to use or carry heavy fuel oil (HFO) in the Arctic, a regulation providing for a ban on HFO is under discussion at IMO in the Marine Environment Protection Committee (MEPC) and its Sub-Committee on Pollution Prevention and Response (PPR) with the aim of protecting the fragile polar environment from increasing shipping emissions. The ban would eventually be inevitable, given the fact that the traffic of cruise ships fuelled by HFO has increased nearly 35% between 2005 and 2017 and HFO combustion produces high levels of black carbon emissions which, among other impacts, accelerate melting when deposited on Arctic snow and ice, aggravating the climate crisis.[4]

Nevertheless, there is scope for improvement and several areas within the IMO regulatory framework for the Polar waters may merit further work. For example, extremely low temperatures could adversely affect certain dangerous goods while being transported through the Arctic. In this context, the International Maritime Dangerous Goods Code (IMO 2002a) and the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk Code (IMO 2014b), both mandatory under Chapter VII of SOLAS, would require a review to address this aspect (Arctic Council 2009, 55–56). Meanwhile, recognizing that over a third of the shipping in the Arctic comprises non-SOLAS vessels, a discussion is underway at IMO's Maritime Safety Committee (MSC) on follow-up work to the adoption of the Polar Code, identifying safety measures that would be applicable to vessels outside the remit of the SOLAS Convention, such as fishing vessels, small cargo ships and pleasure yachts. Similarly, the mandatory ship reporting system currently applicable to the Barents Area (IMO 2012) could be extended to the NWP, although the need is currently fulfilled by Canada's national legislation which mandates ship reporting (see below).

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[4] Three related points of interest: a HFO ban is already implemented in the Antarctic; a global limit of the sulphur content of fuel oil enters into force on 1 January 2020; and a probably bigger environmental issue is the risk of HFO spills in polar waters (IMO 2015c).

12.3 Implementation of IMO Safety Case Goal-Based Standards Framework in the Arctic

12.3.1 The Role of Classification Societies in Implementation

Traditionally, in the prescriptive framework, it would suffice for the national maritime administration to develop a clarification of the intent and application of the IMO convention regulations and IMO resolutions, particularly on those matters in the convention which are left to the satisfaction of the flag administration or where more precise wording is found to be necessary. Such clarifications are found as either regulations issued by an administration or Unified Interpretations applied by IACS member societies to ships whose flag administration has not issued instructions on the interpretation of the regulations concerned (IACS 2011).

In contrast to the rigorous prescriptive framework, the IMO GBS establish broad, overarching safety, environmental, and/or security standards which are "clear, demonstrable, verifiable, long standing, implementable and achievable, irrespective of ship design and technology and specific enough in order not to be open to differing interpretations" (IMO 2011). It is thereafter the responsibility of the national administration of each IMO member state to develop national complementary regulations that may be required to meet the goals, functional requirements, and associated regulations of an IMO instrument. An administration may task a Recognized Organization (RO), often class societies, to develop detailed requirements that will allow industry to meet the safety objective. Thus, for example, IMO (2010) adopted goal-based ship construction standards for bulk carriers and oil tankers (the Standards) requiring these ship types to be designed, built, and maintained in accordance with the Standards which are, for the time being, solely met by class societies' individual rule sets and their Common Structural Rules (CSR). The CSR form the core of the rule set required to meet the functional requirements of the Standards.

In respect of the traditional role played by classification societies, the stipulation in 1881 by Det Norske Veritas (DNV) requiring sufficient additional strengthening in the extreme forepart of the vessel by closer frame spacing than directed in the rules or the adoption of some alternative means is the earliest known classification society rule for vessels having to steam through ice (Snider and Jamieson 2015, 2). Thereafter, the first special requirements for ships intended for operation in ice-covered waters were introduced in 1932, also by DNV. These rules required increased scantlings of frames, plates, and stringers given as a percentage increase (15–25%) above normal class rules. The Finnish-Swedish Ice Class Regulations, which have been elaborated and issued since 1971, were instrumental for the Polar Code. In 2006, IACS developed detailed Polar Class Unified Requirements (UR) as amplification of the then prevailing IMO Guidelines for Ships Operating in Arctic Ice-covered Waters. The descriptions and application (UR I1), structural requirements (UR I2), and machinery requirements (UR I3) which comprise the Polar

Class UR have since undergone several rounds of revisions.[5] The IACS Polar Class set out seven classes of construction (lowest class 7, to highest class 1) based on whether the vessel is intended to operate seasonally or year-round and the ice conditions in which the vessel is expected to operate in as defined by WMO (World Meteorological Organization) Sea Ice Nomenclature.

The winterization requirements of the classification societies for hull construction, machinery equipment, and operational parts also supplement the IMO's goal-based standards for the Arctic. The Russian Maritime Register of Shipping (RS) requirements for ship equipment serve to ensure long-term operation at low temperatures. DNV Ice Class Rules Sections 6 and 7 relate to winterization and design ambient temperature (DAT) requirements.

12.3.2 Implementation by Member States: The Case of Canada

Whereas flag states have traditionally had the responsibility to transpose instruments adopted at the IMO into their national legislation, when it comes to implementation of IMO regulations, such as the Polar Code, administrators will require a different level of knowledge and skill sets including good knowledge of the various design elements. From a coastal state viewpoint, Article 234 of the United Nations Convention the Law of the Sea (UNCLOS 1982) grants Arctic state parties the right to adopt and enforce nondiscriminatory laws and regulations for the prevention, reduction, and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone (EEZ) (Chircop 2012). From either perspective, Canada makes for an excellent case study for member state implementation given its significant influence in Arctic waters and jurisdiction over large swathes of the NWP (see also Chap. 15 in this volume).

Canada implemented comprehensive special ship construction, equipment, and crewing requirements together with stringent pollution prevention standards through the Arctic Waters Pollution Prevention Act (AWPPA) in 1970, long before their introduction in MARPOL (AWPPA 1970; AWPPR 1978). The legislation, which is regarded as a pioneer at addressing the hazards facing Arctic shipping (Struzik 2018; Jensen 2007), originally applied to a 100-nautical-mile pollution prevention area, but recent amendments extend the application to the 200-nautical-mile EEZ (Arctic Council 2009, 66–67). Additionally, Shipping Safety Control Zones adopted under the AWPPA stipulate the areas and time period for operation of ships based on their ice classification. Vessel traffic services zones implemented as a voluntary vessel reporting and clearance system in the Arctic shipping safety control zone are a mandatory requirement with effect 1 July 2010 for ships entering the Canadian Arctic waters north of 60°N under the Canada Shipping Act, 2001 (CSA 2001;

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[5] Prevailing UR are as follows: UR I1, Rev.2 Apr 2016; UR I2, Rev.3 Apr 2016; and UR I3, Rev.1 Corr.1 Oct 2007.

NORDREG 2010; Arctic Council 2009, 66–67). Canada also led the Working Group established by the IMO Sub-Committee on Ship Design and Equipment (now the Sub-Committee on Ship Systems and Equipment (SSE)), the work of which culminated in the adoption of the Polar Code.

The Polar Code, Sect. 12.3, stipulates a requirement of advanced training for the master and chief mate and basic training for officers in charge of a navigational watch in other than open and ice-free waters. Canada developed the IMO model courses on basic and advanced training for ships operating in polar waters. Canada's national legislation (the Arctic Shipping Safety and Pollution Prevention Regulations (ASSPPR), s 10) requires vessels other than a cargo vessel of 500 gross tonnage or more, or a passenger vessel certified under SOLAS, to have an ice navigator on board if the master or person in charge of deck watch does not hold a certificate in advanced training for ships operating in polar waters in accordance with Regulation V/4 of the STCW Convention. A person qualifies to be recognized as an ice navigator if he or she has served in the capacity of master or person in charge of the deck watch for at least 50 days, with a minimum 30 days in Arctic waters, in ice conditions (ASSPPR 2017).

The good work being done by Canada is not without critique though. The Pew Charitable Trusts report (2016) notes that Canada, owing to a lack of a cohesive vision for Arctic shipping policy and insufficient funds, has been unable to implement recommendations for policy improvement, including recommendations for reforms by several key government studies. Based on its research and taking a cue from the Canadian Coast Guard Northern Marine Transport Corridors Initiative, the Trusts proposed an Integrated Arctic Corridors Framework, a system of shipping corridors according to assessed risk that would implement targeted routeing and site-specific management strategies.

It may also be argued that while Canada is among the eight nations that border the Arctic, all states involved in Arctic shipping share responsibility for navigational safety and environmental protection as per Article 194 of UNCLOS. Moreover, while national regulation is best suited to serve as a complement, especially towards elaboration of goal-based regulation, it has its fair share of limitations, and, consequently, regional cooperation initiatives in the Arctic are desirable and also recommended by the IMO. In this context, the Arctic Council's 2011 Arctic Search and Rescue Agreement and 2013 Agreement on Cooperation on Marine Oil Pollution Preparedness, Response and Cooperation in the Arctic serve as excellent examples of cooperation in the Arctic.

12.4 Future Pathways in Risk-Based Approaches and Goal-Based Standards for the Arctic

As regards future pathways, like any another instrument developed at the IMO, the Polar Code will need further work in view of the experience gained with its implementation (Jensen 2007). For example, icing of lifeboats and launching equipment impinges on safety of life at sea. There is scope for elaborating measures to prevent, mitigate, and avoid sea spray icing of vessels. Further, reference could be made to factors such as wind speed, air temperature, and ship speed that determine the potential for such icing. Provision could also be made for alternative ice removal equipment. Measures could also be specified for protection of vital components on deck. In fact, several areas for further development of the Polar Code have been identified in the literature. These include risk assessment of operational capabilities and limitations in ice, additional performance and test standards for the equipment and systems on board ships, ship routeing measures and reporting systems, polar-specific rules on the use of antifouling paints and ballast water management, and a ban on the use and carriage of heavy fuel oil in Arctic waters (Sun 2018).

It is recognized that strengthening regulations is a continuing process at IMO. Even as this chapter is penned, the MSC approved two guidance circulars at its 101st session addressing communication equipment de-icing/ice accretion (IMO 2019c) and life-saving appliances and arrangements for ships operating in polar waters (IMO 2019d). Further, relevant sub-committees at the IMO (see Fig. 12.4) continue working on the output “Consequential work related to the new International Code for Ships Operating in Polar Waters”. The SSE Sub-Committee is also reviewing the International Life-Saving Appliance Code and the relevant IMO resolutions to adapt current testing and performance standards to the Polar Code provisions or develop additional requirements, develop guidance on extinguishing media at polar service temperatures, and also consider any necessary amendments to current standards for firefighters’ outfits.

Given the fact that the regulations adopted at the IMO represent the minimum common standard for shipping agreed upon by the collective member states, such “one-size-fits-all” prescriptive regulations may not be adequate to meet all the considerations of safety, security, and environmental protection of international shipping in particularly harsh climates such as the Arctic. A supplement to the principal safety legislation such as the Polar Code may specify enhanced requirements for ships, but even this GBS approach purports to partly meet safety requirements for ships operating in the polar regions while expecting member states to fill in at lower tiers of the GBS framework. In this context, the risk-based approach bears immense potential and utility in development of the future regulatory framework at the IMO. While regulations would be justified by risk analysis based on agreed risk acceptance criteria, the regulations themselves could be simple requirements that do not refer to risk and may even be prescriptive. Nonetheless such a risk-based framework would be open for risk-based design and thereby suited for implementation in all climes and jurisdictions with due diligence by flag administrations.

In conclusion, it may be said that the IMO safety case goal-based standards framework provides an advantageous synergy of “risk-based” efforts at all levels for enhancing safety of ships. While the IMO continues to establish and maintain a complex global legal regime for safety of ships and environment protection, including standards for navigation and protection of the marine environment, the inadequacies, if any, in the IMO’s global legal regime present an opportunity for the coastal states to supplement or fill in with their own set of regulations. In the context of the Arctic, the array of unmitigated hazards provides coastal states such as Canada with ample opportunities to play an important role in undertaking mitigation measures such as enhancing navigation aids, collecting bathymetric information and updating charts, augmenting vessel traffic services, diversifying ship repair facilities, designating places of refuge, strengthening the capacity for search and rescue and pollution response, and extending the applicability of regulations in equal measure to non-conventional vessels and fishing vessels. Of course, as the expenditure exceeding CDN$500,000 consequent to the grounding of the *Akademik Ioffe* highlights, there is always the question as to what extent should a coastal state invest towards fulfilment of its obligations. Lastly, while the Polar Code and other instruments may be regarded as among the first steps, initiatives such as joining the Arctic Council as an official observer in May 2019 are testimony to IMO's continuing endeavours at working closely with Arctic states, regional organizations, and the international maritime community to build an effective and efficient regime to reduce the risks associated with Arctic shipping.

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Chapter 13
The Regulation of Ship Emissions in Canadian Northwest Atlantic and Arctic Waters: Is There a Need for Consistency and Equity?

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Abstract Since the adoption of Annex VI of the International Convention on the Prevention of Pollution from Ships, 1973/78, the International Maritime Organization has gradually expanded the scope of ship emission regulation to include VOCs, SOx, NOx, particulate matter and, more recently, greenhouse gas emissions. This regulatory effort has not been integrated and displays some inconsistency and even fragmentation, resulting in different levels of environment protection for different regions and even potential conflicts between standards. The regulation of use and carriage of heavy sulphur fuel oil may lead to increase of clean fuel use and thereby produce more CO_2 emissions. Designation of emission control areas under Annex VI has benefitted public health in the Baltic, North Sea and North American waters, but not Arctic waters and coastal communities adjacent to international trade routes elsewhere. This chapter discusses the prospects and pitfalls of ship emissions regulation and argues for the development of an integrated approach consistent with the IMO's own principles of regulation and enhancement of air emission standards in Arctic waters.

Keywords Air pollution · Emission control area · MARPOL · Public health · Indigenous peoples · International Maritime Organization (IMO) · North American Emission Control Area (NAECA) · Ship emissions · Truth and Reconciliation Commission (TRC) · United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

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13.1 Introduction

Shipping has long carried the bulk of global trade efficiently and with the lowest emissions per tonne mile of any transportation mode. Nevertheless, shipping still produces substantial atmospheric emissions harmful to public health and the environment and contributes to climate change (ICCT 2007). The regulated ship emissions consist of a range of harmful substances such as nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs), ozone-depleting substances and particulate matter (PM) (MARPOL 1973/78, Annex VI). Ship emissions include substantial carbon dioxide (CO_2) releases, among other greenhouse gases (GHGs), and are also the subject of a long-term regulatory plan (IMO 2014, 2018). Air pollution from ships received initial international policy attention in the International Maritime Organization (IMO) in 1991, and since 1997 ship emissions constitute a topic for systematic and ongoing regulation (IMO 1991; Protocol 1997; Chircop et al. 2018a). While efforts to curb the emission of various harmful substances have grown incrementally, the increase of international trade has meant consequential increases in emissions (IMO 2014).

Although the IMO adopted standards for ship emissions applicable at the global level, the highest levels of protection are contingent on the designation of an emission control area (ECA) for particular substances (MARPOL 1973/78, Annex VI). Generally, the Canadian waters of the Northwest Atlantic (including the St Lawrence Seaway) and Pacific regions, as well as their ports and their coastal communities, enjoy some of the highest levels of protection from ship emissions of any marine area. This is the case because the North American Emission Control Area (NAECA) was designated by the IMO in 2010 to control the emission of SOx, NOx and PM in North American waters up to a northernmost limit of 60 degrees north in Canadian waters (IMO 2011). The effect of the ECA is to prescribe the highest emission standards for these harmful substances for the Northwest Atlantic and Pacific marine areas of Canada, as well as the United States and its Caribbean area. However, because the northernmost limit of the NAECA in Canadian waters is 60 degrees north, the sensitive Arctic environment and Indigenous communities do not enjoy the same clean air standards for ship emissions as other Canadian marine regions. The differentiated treatment should be of concern to Canada as shipping in the Arctic is increasing with enhanced seasonal accessibility due to loss of sea ice cover and as a matter of environmental justice towards Indigenous peoples.

This chapter argues for scaling up standards for ship emissions in Arctic waters with respect to NOx, SOx and PM, similarly to other Canadian waters. The purpose is to challenge differences in regulatory approach and consequences for the Northwest Atlantic and Arctic through which there are continuous transportation corridors. The focus is on these substances because of their harmful nature and the NAECA, which was designated to scale up their regulation. The discussion starts with an explanation of the nature of the harmful substances in ship emissions and why they need regulation. Next, the regulation of ship emissions through MARPOL Annex VI and the designation of ECAs is explained. The discussion then moves to the regulation of ship emissions in the Northwest Atlantic, with a focus on the NAECA, and in Arctic waters, followed by consideration of policy concerns and possible options for Canada. The chapter concludes with an overall assessment and argues for an integrated approach to ensure that human health and environmental concerns are appropriately, uniformly and equitably addressed throughout waters under Canadian sovereignty and jurisdiction.

13.2 Rationale for Ship Emissions Regulation

Ship emissions are regulated because they contribute to the ambient concentration of air pollution, resulting in adverse impacts on human health and the environment (ICCT 2007; IMO 2009a). The vast majority of shipping relies on fossil fuels for motive power and onboard operations while at sea, in the navigation of inland waterways and even when in port. The combustion of such fuels produces the range of substances of concern in this chapter. Moreover, incineration activities on board a ship may also produce harmful substances to human health and the environment and hence are largely banned (MARPOL 1973/78, Annex VI, reg III/16).

From a human health perspective, the elevated ambient concentrations of PM, ground-level ozone, NOx and SOx are known to contribute to air pollution and to have adverse public health impacts, including premature mortality, cardiopulmonary disease, lung cancer and chronic respiratory ailments (Barregard et al. 2019; IMO 2009a; MARPOL 1973/78, Annex VI, Appendix III). $PM_{2.5}$ and ozone due to ship emissions have the largest concentrations near the coasts, thus affecting human settlements. The fine particles of $PM_{2.5}$ tend to reduce visibility, linger longer in the atmosphere and are carried over great distances (IMO 2009a). The particles can go deep into the respiratory tract and reach the lungs, worsening medical conditions such as asthma and heart disease. Long-term exposure can lead to premature mortality, including from lung cancer (NY Department of Public Health, 2018). A study submitted to the IMO in 2009 by the United States and Canada in support of the NAECA forecasted the impact of regulating $PM_{2.5}$ from ship emissions on reduced premature mortality, a range of illnesses and hospital visits (Table 13.1) (IMO 2009a, Annex I). The study concerned densely populated areas in the vicinity of major shipping lanes on the Atlantic and Pacific coasts and clearly identified the public health imperative.

SOx is known to be harmful to marine and terrestrial ecosystems by affecting biogeochemical cycles through the deposit on land, soils, vegetation and surface waters (IMO 2009a). Ecosystem impairment from SOx and NOx includes nutrient overloading and eutrophication and acidification. NOx and precursor gases create smog and reduce visibility (IMO 2009a). Some areas display greater sensitivity than others, and this is a factor to be borne in mind with respect to emissions in Arctic waters where black carbon from PM may help accelerate sea ice loss (Comer 2019). For coastal and marine areas that have multiple stressors, the ship emissions may exacerbate the problem, such as through increased acidification from sulphuric and

Table 13.1 Estimated $PM_{2.5}$ and ozone-related human health impacts associated with ship emissions in the United States and Canada (adapted from IMO 2009a)

Mortality/illness	2020 Annual ship-related incidence without NAECA	2020 Annual reduction in ship-related incidence with NAECA
Premature mortality	5100–12,000	3700–8300
Hospital admissions	8400	3300
Emergency room visits	4100	2300
Chronic bronchitis	4600	3500
Acute bronchitis	13,000	9300
Acute respiratory symptoms	6,500,000	3,400,000

nitric acids. Moreover, ship emissions using hydrocarbon-based fuel contain harmful GHGs which are a major contributor to climate change and associated human and environmental impacts (IMO 2014). Carbon dioxide (CO_2) from the burning of fossil fuel alone accounts for the bulk of GHG emissions from ships, and as noted earlier, black carbon accelerates loss of sea ice (IMO 2014; Comer 2019).

The rationale for regulating ship emissions by the IMO includes the need for a multilateral approach to regulating standards for international shipping. In their NAECA proposal, Canada and the United States argued that a global approach to regulating ship emissions reduces the pressure for unilateral regulation of substances harming public health and the environment (IMO 2009a). In exercising sovereignty over the terrestrial, inland and internal waters, states have the right to regulate emissions at the national and subnational levels. If they do so, a fragmented approach to this aspect of ship regulation could arise, which in turn could affect the pursuit of vital uniform standards for shipping to support international trade. This is an option for Canada because it claims that the waters of the Arctic archipelago are internal waters subject to a historic title, and therefore those waters are subject to its sovereignty and entail consequential exclusive jurisdiction and control (House of Commons 1985; AWPPA 1970).

13.3 The Regulatory Framework

13.3.1 The Global Approach to Ship Emissions Regulation

The regulation of international shipping occurs, first and foremost, at the global level. The imperative of international regulation through the IMO, a UN specialized agency expressly established for the governance of international shipping, reflects the global and transnational nature of the industry. The general belief has always been that this is the optimal regulatory level which produces necessary controls while ensuring the continuing flow of maritime trade (IMO Convention 1948). The regulation of pollution from ships is primarily governed by the International

Convention for the Prevention of Pollution from Ships, 1973/78 (MARPOL), a comprehensive IMO instrument addressing a broad range of wastes generated during the operation of ships (MARPOL 1973/78). Other IMO conventions concerning pollution prevention from ships, such as from antifouling systems and ballast waters, are not a concern of this chapter. Through six annexes, MARPOL addresses pollution from oil (Annex I), noxious liquid substances carried in bulk (Annex II), noxious liquid substances carried in packaged form (Annex III), sewage (Annex IV), garbage (Annex V) and air pollution (Annex VI), the concern of this chapter.

Annex VI was adopted in 1997 to regulate a growing list of harmful substances in ship emissions, including NOx, SOx, VOCs, ozone-depleting substances and PM, and to regulate onboard incineration (Protocol 1997). Its provisions apply to all ships, except where stated otherwise in particular regulations (MARPOL, Annex VI, reg 1.1). The targets for NOx emissions rules are marine diesel engines with a power output of more than 130 kW built after specified dates for Tier I, II and III, each of which has more stringent standards (MARPOL, Annex VI, reg 13). The SOx rules apply to all fuel oil, combustion equipment (main and auxiliary engines) and equipment on board (e.g., boilers, inert gas generators) (MARPOL, Annex VI, reg 14).

Of particular interest to this chapter is that Annex VI makes provision for the designation of ECAs for specific substances in identified marine regions on the basis of requests from the region’s coastal states. An ECA is defined as “an area where the adoption of special mandatory measures for emissions from ships is required to prevent, reduce and control air pollution from NOx or SOx and particulate matter or all three types of emissions and their attendant adverse impacts on human health and the environment” (MARPOL, Annex VI, reg 1.1.8). An ECA helps “reduce the stresses on a large number of sensitive ecosystems, including numerous forests, grasslands, alpine areas, wetlands, rivers, lakes, estuaries, and coastal waters” (IMO 2009a; MARPOL, Annex VI, Appendix III). The emission standards in an ECA are substantially higher: NOx emissions are subject to Tier III and SOx with a sulphur limit of 0.10% (since 1 January 2015) compared to the current 3.5% and 0.50% by mass (as of 1 January 2020) for all other areas. Proponent states must demonstrate the need to prevent, reduce and control the emission of any or all three harmful substances in a clearly designated area (MARPOL, Annex VI, Appendix). The need must be evidenced. In particular, because of the public health concern, there should be a description of the human populations at risk. There must be assessment of the emissions contributing to ambient pollution and environmental impacts in the areas concerned, including “a description of the impacts of the relevant emissions on human health and the environment, such as adverse impacts to terrestrial and aquatic ecosystems, areas of natural productivity, critical habitats, water quality, human health, and areas of cultural and scientific significance, if applicable” (MARPOL, Annex VI, Appendix). Scientific information on relevant meteorological conditions, such as prevailing wind patterns, topographical, geological, oceanographic, morphological and other conditions that contribute to pollution concentration or environmental impact, has to be submitted. This information has to be accompanied by data on ship traffic and density, measures already undertaken at the national level to curb ambient pollution from NOx, SOx and PM in the areas concerned, as well as the estimated relative costs of reducing ship emissions through the ECA, compared with national measures for land-based sources of those substances, and the economic impact on trade (MARPOL, Annex VI, Appendix). The ECA criteria underscore the need for a demonstrable probable cause-effect nexus, disclosure of sources of data and methodologies used for the assessment and the anticipated burden for shipping and trade to enable a generalized cost-benefit assessment by the Marine Environment Protection Committee (MEPC), the key structure within the IMO responsible for overseeing MARPOL.

The designation of an ECA entails an amendment to Annex VI, resulting in an express mention in Regulations 13 and 14 of Annex VI. To date, ECAs have been designated by the IMO for the Baltic (NOx and SOx), the North Sea (NOx and SOx), the Atlantic and Pacific waters off Canada and the United States (NOx, SOx and PM) and the US Caribbean Sea area off Puerto Rico and the US Virgin Islands (NOx, SOx and PM) (MARPOL, Annex VI, regs 13.6 and 14). The consequence is that ships on voyages that include ECAs as well as other marine areas will need to take into account the different fuels they have to carry (to be evidenced by the bunker delivery notes), to keep them separate, to know when and where to use them and to maintain detailed log book records that will be subject to inspection in port.

It is interesting to observe that while there is a substantial case to be made by the proponent states, the ECA criteria do not require those states to evaluate and report back to the IMO on the functioning of the ECA. Concern has been expressed within the IMO about the absence of mandatory review or reporting requirements for area-based management tools designated and adopted by the IMO to determine lessons learned and ensure ongoing relevance (IMO 2016).

In addition to the general rules concerning emissions and ECAs, Annex VI also regulates ships' energy efficiency through an Energy Efficiency Design Index (EEDI), mandatory for new commercial vessels of 400 gross tonnage or more,[1] and the Ship Energy Efficiency Management Plan (SEEMP), applicable to all ships, for the purpose of enhancing efficiency in engine and ship design as well as the overall energy use on board ships to curb GHG emissions (MARPOL 1973/78, Annex VI, chap IV).

13.3.2 NAECA Emission Standards in the Northwest Atlantic

The NAECA was adopted on 26 March 2010, entered into force on 1 August 2011 and came into effect on 1 August 2012 (IMO 2010a). It entailed amendments to Annex VI Regulations 13.6 and 14.3 and introduced a new appendix containing the full

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[1] Bulkers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo carrier, combination carrier, ro-ro cargo ships (vehicle carriers), ro-ro cargo ship, ro-ro passenger ships, liquefied natural gas carriers and cruise passenger ships without conventional propulsion.

Fig. 13.1 North American Emission Control Area (IMO 2009a)

coordinates of the navigational area regulated (MARPOL 1973/78, Annex VI, regs 13, 14 and Appendix VII). Figure 13.1 describes the area covered, which includes, up to the limits of the exclusive economic zone (EEZ), the sea areas located off the Pacific coasts of the United States and Canada; the Atlantic coasts of the United States, Canada and France (Saint Pierre and Miquelon) and the Gulf of Mexico coast of the United States; and the coasts of the Hawaiian Islands, but not the waters off the Aleutian Islands chain (MARPOL 1973/78, Annex VI, Appendix VII). In 2011 there was further definition of the NAECA boundaries to include the waters off the coast of the Commonwealth of Puerto Rico and the US Virgin Islands (IMO 2011). The northernmost limit of NAECA in Canadian waters is 60 degrees north. At the time of adoption of the NAECA, Canada had not yet become a party to Annex VI, which is a voluntary annex of MARPOL. The Canadian Minister of Transport at the time provided the IMO Secretary-General with the "highest assurances" that it would become a party, which it did on 26 March 2010 with effect as of 26 June 2010 (IMO 2010b, 44; IMO 2019).

The NAECA was designated for the purpose of preventing, reducing and controlling air pollution from the designated substances in incremental stages. It entered into force specifically for NOx in 2011 and for SOx and PM in 2012. Temporary exemptions were adopted for certain ships in 2011 (IMO 2011). As of 2015, the fuel of all vessels cannot exceed 0.10% fuel sulphur (1000 ppm), which is aimed at reducing PM and SOx emissions by more than 85% (IMO 2010a). Ships can comply with the SOx and PM standard by using low sulphur fuel or alternative fuels or by installing a scrubber or adopting procedures to ensure compliance. Prior to 2016, marine diesel engines constructed on or after 1 January 2011 were required to comply with the Tier II standard for NOx. As of January 2016, new engines are required to employ emission controls that achieve a Tier III outcome, namely, an 80% reduction of NOx.

13.3.3 Ship Emission Standards in Canadian Arctic Waters

The international standards for ship emissions while navigating Arctic waters are lower than those in the NAECA. Atmospheric emissions did not feature in the pollution prevention provisions of the International Code for Ships Operating in Polar Waters, 2014/2015 (Polar Code), and amendments to MARPOL Annexes I, II, IV and V adopted by the MEPC in 2015 (Polar Code 2014/2015). The Polar Code geographical area of application is described in Fig. 13.2. Annex VI was not part of the negotiation agenda, and while there were proposals to regulate the use of heavy fuel oils (HFOs), there was no agreement on the introduction of a mandatory rule. The voyage planning requirements in the mandatory safety section, while referring to environmental considerations, make no reference whatsoever to the fuel to use to minimize emission impacts (Polar Code 2014/2015, Part I-A, chap 12). Instead, the only provision relevant for ship emissions while navigating polar waters is in the form of additional guidance, not a mandatory standard, in Part II-B of the Polar Code: "Ships are encouraged to apply Regulation 43 of MARPOL Annex I when operating in Arctic waters" (Polar Code 2014/2015, Part II-B, para 1.1). With the exception of vessels used in search and rescue, Regulation 43 establishes a ban in

Fig. 13.2 Geographical area of the Polar Code (Polar Code 2014/2015)

the Antarctic area on the carriage of HFOs in bulk as cargo, for use as ballast, or carriage and use as fuel (MARPOL, Annex I, reg 43).[2]

Accordingly, the currently applicable international ship emission standards for Arctic waters generally consist of the basic rules of Annex VI concerning SOx at 3.5% until 31 December 2019 (and 0.5% as of 1 January 2020) and consequential PM reduction from the lower sulphur (rather than the 0.10% for ECAs), NOx at the Tier I level and other generally applicable standards for other harmful substances such as ozone-depleting substances and VOCs.

Canada implemented the Polar Code in 2017 through a new set of regulations, the Arctic Shipping Safety and Pollution Regulations, under the authority of the Arctic Waters Pollution Prevention Act, 1970 (AWPPA) and the Canada Shipping Act, 2001 (ASSPPR 2017; AWPPA 1970; CSA, 2001). The new regulations make no mention of ship emissions. All emissions in Canadian waters are regulated by the Vessel Pollution and Dangerous Chemicals Regulations (VPDCR) under the Canada Shipping Act, 2001 (CSA 2001). Thus NAECA standards are implemented under these regulations (VPDCR 2012, ss 110, 111). The NOx Tier III standard for marine diesel engines does not apply to a Canadian or foreign vessel pleasure craft operating in Arctic waters, including Hudson Bay, James Bay or Ungava Bay (ibid, s 110.3(3)). The maximum sulphur content standard for Arctic waters (including Hudson Bay, James Bay and Ungava Bay) for Canadian and foreign vessels and pleasure craft remained in step with the general Annex VI standard, rather than the NAECA. Accordingly, the 3.50% limit before 1 January 2020 and thereafter the 0.50% limit apply (ibid, s 111(1)). The NAECA 0.10% limit applicable after 31 December 2014 does not apply to Canadian Arctic waters (ibid). In addition to the sulphur content standard, PM is also addressed in the rules on smoke. Arctic waters appear to be covered by the rule concerning density of smoke applicable to all other waters under Canadian jurisdiction, namely, that a vessel must not operate fuel-burning installations that do not utilize hand-fired boilers and that emit smoke of a density greater than density number 1 (20% of box space on Transport Canada's Smoke Chart) (ibid, ss 117(1), 119 (1)).

Short of scaled-up emission standards for Canadian Arctic waters, the Transport Canada Guidelines for Passenger Vessels Operating in the Canadian Arctic contain recommendations with respect to cruise ships (Transport Canada 2017). The Guidelines state, in discretionary language, that "where possible, operators should use distillate fuel oil during all operations in the Arctic. Lower emission outboard engines are also encouraged" (ibid, 60). With respect to the use of HFOs, the Guidelines simply remind operators of the recommendatory Part II-B provision in the Polar Code encouraging ships to apply Regulation 43 of MARPOL Annex I (ibid, 22). Accordingly, apart from the discretionary nature of the recommendations, the hope is that cruise ships will attempt to minimize harmful emissions when in Canadian Arctic waters.

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[2] These include crude oils having a density at 15 °C higher than 900 kg/m^3; oils, other than crude oils, having a density at 15 °C higher than 900 kg/m^3 or a kinematic viscosity at 50 °C higher than 180 mm^2/s; and bitumen, tar and their emulsions.

13.4 The Argument for Scaling Up Emission Standards in Polar Waters

It might come across as ironic that Arctic waters, which are among the most fragile ocean spaces, are receiving only the basic minimum protection from ship emissions, rather than the heightened protection equivalent to an ECA. This observation is particularly pertinent considering that the pollution prevention provisions for oil, noxious liquid substances, sewage and garbage adopted with the Polar Code and related amendments to MARPOL Annexes I, II, IV and V, while not designating the Arctic as a special area, actually provide equivalent protection. A major reason for eschewing special area designation in the Polar Code was the paucity of ports to provide reception facilities for the regulated ship wastes in the region's states, a condition of that status (Chircop et al. 2018b).

The Canadian Northwest Atlantic is an integral part of potential new navigation routes through the Northwest Passage, which arguably ought to be subject to equivalent safety and environmental standards because the navigation occurs continuously through waters under Canadian sovereignty or jurisdiction. A counter argument is that, for the sake of consistency, polar shipping standards should then extend to navigation in the Northwest Atlantic. For this to occur, Canada would need to propose to the IMO the designation of its Northwest Atlantic waters as a special area under MARPOL Annexes I, II, IV and V. To do so, Canada would need to meet another set of criteria for special designation, which will also entail amendment of the parent instrument and would likely be a lengthy process (IMO 2013). The case for such an initiative has as yet to be made and scientifically supported to meet the MARPOL Annex VI Appendix III criteria. Hence, it would be more fruitful at this stage for Canada to focus on equivalency of emissions to ensure that Canada's Indigenous peoples in the Arctic receive the same level of protection as their counterparts in the other Canadian coastal regions.

Canada can be expected to face challenging policy choices in the regulation of ship emissions in the Arctic. Canada played a critical role in the development of the Polar Code, and its initial proposal set out what could be described as a comprehensive first draft of the code (IMO 2009b; Chircop et al. 2018b). Canada argued for the strongest possible environmental standards, but was unsuccessful in securing the inclusion of mandatory rules for ballast water management and antifouling systems in polar waters (Chircop et al. 2018b). Despite the strong environmental mission, the Canadian "comprehensive" proposal was silent on ship emissions. Much has transpired since that initial submission, most especially with respect to the report of the Truth and Reconciliation Commission (TRC), whose recommendations were endorsed by the federal government (TRC 2015). In the light and spirit of the TRC findings, it is arguable that the federal regulator ought to be concerned about the harmful emissions from the growing shipping traffic in the Arctic and the impacts on Indigenous coastal communities. While some might argue that the population densities in the Arctic are nowhere comparable with the Northwest Atlantic, the fact is that the thinly populated areas of the coastal regions of the Atlantic provinces received the NAECA protection. It is further arguable that the navigational chokepoints in Canadian Arctic waters, such as straits and low-impact navigational corridors proposed by the Canadian Coast Guard to facilitate the delivery of its services (see Chap. 7 in this volume), can be expected to concentrate the smaller shipping tonnage in localized geographical areas and surrounding coastal communities, thus raising concerns (Carter et al. 2018). The notion of low-impact corridors should include potential impacts from emissions as shipping increases.

Canada has policy choices in terms of whether it should proceed with scaling up ship emission standards in Arctic waters to elevate them to the same level as those applicable in the NAECA. One route is to proceed unilaterally by invoking the power granted by Article 234 of the United Nations Convention on the Law of the Sea, 1982 (UNCLOS 1982). Article 234 provides:

> Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.

According to this provision, Canada has international legal authority to legislate and enforce pollution prevention standards for shipping in the 200-nautical mile EEZ in the Arctic as an ice-covered area for most of the year. This unique provision was specially negotiated at the behest of Canada and is widely regarded as providing unilateral power to regulate vessel-source pollution prevention to a higher standard than the international norm and without a requirement to proceed through the IMO first. Such a move would apply only to Canadian Arctic waters as defined in the AWPPA (AWPPA 1970, s 2).[3] Canada could exercise this power to raise emission standards in the Arctic in a speedy manner.

There are policy and legal issues that arise with this approach. Article 234 applies to the EEZ, defined as having a breadth of 200 nautical miles from the baselines of the territorial sea in a seaward direction (UNCLOS 1982, art 57). Article 234 has drafting ambiguities, such as whether the territorial sea is included "within" the EEZ (Bartenstein 2011). Since the territorial sea is technically not part of the EEZ, Canada could be constrained in its ability to regulate construction and design standards required to control ship emissions in relation to vessels exercising the right of innocent passage without applying generally accepted international standards or proposing to the IMO to scale up the international standards applicable to ship

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[3] Section 2 of the AWPPA defines Canadian Arctic waters as "the internal waters of Canada and the waters of the territorial sea of Canada and the exclusive economic zone of Canada, within the area enclosed by the 60th parallel of north latitude, the 141st meridian of west longitude and the outer limit of the exclusive economic zone; however, where the international boundary between Canada and Greenland is less than 200 nautical miles from the baselines of the territorial sea of Canada, the international boundary shall be substituted for that outer limit".

emissions in the Arctic (UNCLOS 1982, art 21). Further, and with respect to the internal waters in the Arctic claimed on the basis of historic title, while Canada can exercise its sovereign right to regulate emissions without applying generally accepted international standards or resorting to the IMO, it would mostly likely attract protest or criticism from states that do not recognize the historic title, such as the United States. It could be further argued that a Canadian unilateral approach would be geographically limited when ship emissions concern the entire region and probably also inconsistent with and even counterproductive to the Polar Code which, after all, was a largely successful attempt at raising polar shipping standards in a multilateral manner and to facilitate their uniformity. Another criticism could be policy hypocrisy, because Canada is perceived to be dragging its feet on regulating the use and carriage of use of HFOs in the Arctic ostensibly to protect Indigenous interests (Clean Arctic Alliance 2018), another matter under consideration at the IMO (Sun 2019) and discussed in a separate chapter in this book (see Chap. 14 in this volume).

The alternative is for Canada to proceed through the IMO with a coordinated submission involving other Arctic states assuming they, and most especially the Russian Federation as the largest regional state with the longest coastline, are all supportive. The proposal would build on the Polar Code and entail amendments to MARPOL Annex VI through the designation of the Arctic area defined in the Code as an ECA. This is not unprecedented, and in fact since the adoption of the Arctic Marine Shipping Assessment report of 2009, the region's states have used the Arctic Council to consult on shipping matters and support initiatives at the IMO (Arctic Council 2009; Chircop et al. 2018b). Most recently, the Arctic Council member states made a joint submission concerning the adoption of a regional approach for the provision of port reception facilities, entailing amendment of MARPOL, and which is currently under consideration by the MEPC (IMO 2017).

It is possible some IMO members and organizations having consultative status might argue that not only are population densities low in the Arctic (especially along the Northwest Passage), but at this time there is relatively little international shipping whose emissions could pose public health and environmental impacts. The counter argument is that the Polar Code may be seen as a proactive and precautionary form of regulation as the region is expected to become more accessible to international shipping. And, as argued earlier, the NAECA benefits also sparsely populated areas of the Canadian Atlantic region.

Scaling up pollution prevention from all sources in the Arctic is more likely to contribute to the sustainability of polar shipping. Major shipping companies appear to be increasingly ready to act on their corporate social responsibilities. It is instructive to note the recent decision of CMA CGM, one of the world's largest container operators based in France, to avoid using the Northern Sea Route for its trade between Asia and Europe, citing environmental concerns, including the threat of pollution (gCaptain 2019a). Similarly, President Emmanuel Macron of France called upon container shipping companies to avoid using the Arctic route for the same reason (gCaptain 2019b).

13.5 Conclusion

This chapter has advanced the argument that Canadian Arctic waters, if not even the entirety of Arctic waters as defined for the purposes of the Polar Code, should receive protection from ship emissions at least equivalent to those applicable in the NAECA and possibly be designated as an ECA. The argument is based on the need to protect the especially sensitive Arctic environment that is subject to multiple stressors and the imperative of protecting the health of Indigenous peoples. It draws on, by analogy and rationale, with the scaled-up standards for pollution prevention in the Polar Code, in which Arctic waters (as well as Antarctic waters) receive a level of protection comparable to that provided for MARPOL special areas in Annexes I, II, IV and V. Since the Arctic is deemed worthy of special protection from oil, noxious liquid substances, sewage and garbage, why not also from ship emissions, given the public health concerns and the multiple stressors the region is experiencing? This author acknowledges current IMO efforts at regulating the use and carriage of use of HFOs, a significant concern for SOx and NOx, but further observes that such an initiative would not equally address harmful NOx.

Canada has fundamental obligations towards its Indigenous peoples in redressing historic injustices in the process of reconciliation (TRC 2015). Canada has embraced the UN Declaration on the Rights of Indigenous Peoples which, among other, obliges it to obtain the free, prior, and informed consent of Indigenous peoples with respect to decisions that affect their rights, interests and well-being (UNDRIP 2007, art 19; see Chap. 8 in this volume). The federal government is to be commended in taking steps in engaging Indigenous communities on shipping matters, but the extent to which these efforts concern the impacts of atmospheric emissions from shipping is not clear (OPM 2016). Considering the multiple public health concerns experienced by Indigenous peoples, especially in remote areas where access to health services is especially challenging, Canada should endeavour to prevent, control and mitigate an additional stressor from ship emissions. Pollution prevention from all sources is not only a matter of good maritime administration but also a matter of environmental justice. An integrated approach to the regulation of ship emissions ensures that human health and environmental concerns are uniformly and equitably addressed throughout waters under Canadian sovereignty and jurisdiction.

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Chapter 14
The Regulation of Heavy Fuel Oil in Arctic Shipping: Interests, Measures, and Impacts

Jiayu Bai and Aldo Chircop

Abstract Since the International Maritime Organization's (IMO) ban on the use and carriage for use of heavy fuel oil (HFO) for ships operating in Antarctic waters came into effect in 2011, the international community has been engaged in a discourse on whether to adopt a similar standard for ships operating in Arctic waters. The issues are complex as, in addition to reducing the environmental risks posed by HFOs, there are economic and social consequences, including dependence on such fuels by Indigenous peoples. The discourse has involved the IMO, the Arctic Council, industry associations, environmental nongovernmental organizations, and Indigenous peoples. The issue was first raised during the development of the Polar Code and is considered unfinished business of the Code. This chapter discusses the nature of the problem and the challenges to explore a possible regulatory strategy. The chapter will consider the issue in the larger context of the public and private maritime law conventions to consider how an HFO regulatory strategy complements and remains consistent with other elements of maritime regulation.

Keywords Arctic Council · Civil liability · Heavy fuel oil (HFO) regulation · International Maritime Organization · MARPOL · Polar Code · Regulation implementation · Regulatory strategy · Stakeholders' interests

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14.1 Introduction

Anthropogenic activities have accelerated the speed of global warming and increased sea ice melting in polar areas. Reports from the Intergovernmental Panel on Climate Change and an Arctic Council working group, the Arctic Monitoring and Assessment Programme, have noted that the Arctic Ocean may become ice-free during the summer season by mid-century (IPCC 2013, 2019; AMAP 2012). While, on the one hand, climate change is having fundamental adverse impacts on polar environments, on the other hand it may provide opportunities for destinational and transit shipping in the Arctic. Shipping economics and natural resources exploitation are drivers for the increase in Arctic shipping (Lasserre et al. 2016). There are findings indicating that the total distance travelled by all vessels in Canada's Arctic tripled between 1990 and 2015 (Dawson et al. 2018). On the Northern Sea Route, the volume of cargo transported increased more than fourfold between 2013 and 2018 (Astapkovich 2018). The potential increase of volume of maritime traffic in the Arctic has raised the issue of specific concern in this chapter, namely, the use and carriage for use of heavy fuel oil (HFO) and carriage as bulk cargo. The burning of HFO emits black carbon, sulphur oxides, nitrogen oxides, and greenhouse gases (GHGs), which could aggravate global warming. Black carbon is considered the second largest contributor to climate warming after carbon dioxide (Bond et al. 2013). Further, HFO spills could cause far-reaching harm to the Arctic environment (AMSA 2009).

Regulation 43 of MARPOL Annex I has banned the carriage of HFO as cargo, ballast, or carriage and use as fuel in the Antarctic since 2011 (MARPOL). However, there is no similar ban in the Arctic. Unlike in the Antarctic, Arctic shipping has a wider range of rights holders and stakeholders, littoral Arctic states (including subnational levels of government), user states, Indigenous peoples, and diverse nongovernmental organizations (NGOs). There are many complex issues to be balanced with shipping, including respect and protection of Indigenous peoples and the very sensitive environment that is warming at twice the global rate. These factors make the regulation of HFO in Arctic shipping much more complicated than Antarctic shipping, and, not surprisingly, the proposed ban of HFOs in polar shipping is not uniformly supported at the International Maritime Organization (IMO).

On 1 January 2017, the International Code for Ships Operating in Polar Waters (Polar Code) entered into force following tacit acceptance in 2014 and 2015 of amendments to the International Convention for the Safety of Life at Sea and MARPOL (Polar Code 2014/2015). Separate amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers entered into force on 1 July 2018 (IMO 2016a). The only reference to HFOs in the Polar Code is with respect to a recommendation in Part II-B encouraging ships to apply Regulation 43 of MARPOL Annex I when operating in Arctic waters (Polar Code 2014/2015). This means that the hazard posed by HFOs has not yet been resolved.

From a civil liability perspective, the International Convention on Civil Liability for Oil Pollution Damage (CLC 1969) and the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Fund Convention) (FUND 1992) cover pollution damage in the territorial sea and exclusive economic zone (EEZ) from a spill from HFO carried as cargo. In addition, the International Convention on Civil Liability for Bunker Oil Pollution Damage (Bunkers Convention) covers pollution damage from HFO fuel spills, but again within zones of national jurisdiction (Bunkers Convention 2001). A vessel registered in a CLC state carrying more than 2000 tons of HFO as bulk cargo must carry a certificate of insurance cover or financial security. The Bunkers Convention requires ships over 1000 gross tonnage to maintain insurance or other financial security to cover the liability of the registered owner for pollution damage caused by HFO used or carried as fuel. The CLC provides the shipowner with limitation of liability. Where the claims exceed that limit, the Fund Convention applies, but again to a ceiling, to address losses not covered by the CLC. The shipowners' limit of liability under the Convention on Limitation of Liability for Maritime Claims also applies (LLMC 1976). This regime does not cover all potential damages. Spills on the high seas are not covered by the CLC, Fund and Bunkers regimes. The funds available are limited and might not cover all economic losses and environmental clean-up costs, let alone reverse what would likely be irreversible damage to the vulnerable and fragile Arctic environment. Furthermore, spill costs in Arctic conditions are highly uncertain, because, compared to other sea areas, there is no data and earlier studies on spill costs for use in IMO decision-making may not apply (Kontovas et al. 2010).

Given the threat posed by HFOs in Arctic shipping and the limitations of the civil liability regimes to recover losses, it is arguable that the protection of the Arctic from this threat requires proactive measures. This chapter explores what, how, and when proactive measures, most especially regulation, could be designed and applied to address the hazard posed by HFOs in Arctic shipping. It analyses the related interests, feasible measures, and corresponding impacts.

14.2 The HFO Work of the Arctic Council

14.2.1 The Generative Role of the Arctic Council

The effects of HFO in Arctic shipping were first realized by the Arctic Council, which is the most influential regional governance body for the region. Established by the Ottawa Declaration in 1996 as a political body to promote cooperation, the Arctic Council has no authority to adopt legally binding instruments (Arctic Council 1996). However, the Council has the capacity to identify emerging issues, frame them for further consideration of policy-makers, and formulate the issues as matters of policy priority. Oran Young categorized this function of Arctic Council as a "generative" role, which means that it mainly helps shape the decisions but not make decisions itself (Young 2016). It plays this role through scientific research via six working groups and subsidiary task forces and expert groups. The working groups produce cutting-edge environmental, ecological, and social assessments.

The Working Group on the Protection of Arctic Marine Environment (PAME) and Sustainable Development Working Group (SDWG) are the most relevant for the HFO ban. PAME released the Arctic Marine Shipping Assessment (AMSA) in 2009, and the report is considered the biggest contribution to the cooperative approach to enhancing Arctic marine safety, protecting Arctic people and the environment, and building Arctic marine infrastructure (AMSA 2009; Basaran 2017). AMSA provided a comprehensive assessment of Arctic shipping risks and supported the negotiation of the Polar Code under the auspices of the IMO. AMSA mentioned HFOs, but left the issue for future consideration. Thereafter, the PAME commissioned four multi-phase reports associated with the use and carriage of HFO as fuel in Arctic shipping from 2011 to 2016 (DNV 2011, 2013a, b; PAME 2016; Henaug 2016).

14.2.2 Findings of the Arctic Council Reports

Phase I of the PAME report relied upon the satellite-based automatic identification system (AIS) data provided by the Norwegian Coastal Administration for the period from August to November 2010 (DNV 2011). Det Norske Veritas Petroleum Services offered the fuel sample data to identify vessels most likely to use HFO and Arctic ports where HFO bunkering operations occur. Based on these data, Phase I identified risks associated with both use and carriage of HFOs in the Arctic, after which mitigation strategies were proposed. Phase I found that although fishing vessels, followed by service vessels, community support vessels, and passenger vessels, accounted for the greatest percentage of vessels navigating within the Arctic region, the typical vessels using HFO as fuel mainly were larger cargo, tanker, and passenger ships. The report concluded that the most severe threat from HFO is oil spills in ice-covered waters; therefore, prevention measures should mitigate the risks posed by HFO, and distillate oil was suggested as a substitute oil. The report predicted that along with the increase of global commercial transits in the Arctic and petroleum exploration, the number of larger cargo and tanker vessels using HFO as fuel will also increase.

Phase II of the PAME report collected AIS data for 2012, through which vessel composition, geographical distribution, sailed distances, and operating hours throughout the year were identified (DNV 2013a). In view of the data, the report found that larger ocean-going vessels relied on HFO and other vessels were more likely to use distillate fuels. Two risk control methods were emphasized, speed reductions and area-based vessel management such as vessel restrictions during certain times of year, establishment of traffic channels, and designation of areas to be avoided. The Phase II(b) report focused on the areas of Bering Sea south and beyond the geographical area of the Polar Code and analysed AIS data from August 2012 to August 2013 (DNV 2013b). The report found that grounding of tankers could result in the greatest risk of accidental oil spills occurrence likelihood, also a finding of Phase II.

Phase III(a) of the PAME report analysed the shipping incidents encompassing HFOs and other fuels in the Arctic and near-Arctic marine environment between 1970 and 2014 (PAME 2016). It found that the majority of incidents occurred in near-Arctic waters and outside the geographical area of the Polar Code. The report identified the relevant factors to assess the damage caused by HFOs and other oil, namely the properties of HFOs, characteristics of the Arctic ecosystem and its inhabitants, and the nature of the clean-up and remediation process. Phase III(b) of the report further compared the rate of engine or fuel system failures for ships using HFO and the rate of similar failures for ships using other fuel types in similar Arctic conditions (Henaug 2016). With respect to engines, the key risk factors identified related to the disruption of fuel supply, quality, and switchover.

PAME also made progress on four other HFO projects under its 2017–2019 work plan (PAME n.d., 3). The projects continued research on mitigation of risks associated with the use and carriage of HFO in Arctic shipping. Currently, PAME is collaborating with SDWG in a project to assess the use of HFO in Indigenous communities (Phase IVb). The project will build an integrated knowledge base in consideration of Indigenous Arctic communities and help achieve UN Sustainable Development Goal 14 to conserve and sustainably use the oceans, seas, and marine resources. Indigenous peoples' interests are driving the discourse on HFO usage in Arctic shipping as well as marine environment protection concerns. In summary, the PAME reports influenced the Arctic states' understanding about HFO regulatory arrangements and were reflected in their proposals at the IMO (IMO 2018a).

14.3 The HFO Work of the IMO

14.3.1 The Relationship Between the Work of the IMO and the Arctic Council

Under the United Nations Convention on the Law of the Sea Convention (UNCLOS), the IMO is the "competent international organization" to make "generally accepted international rules and standards" for safety, security, and environment protection in international shipping (DOALOS 1996). The IMO's regulatory mandate complements the Arctic Council's knowledge generation work. Central Arctic Ocean coastal states acknowledged the significance of cooperation with the IMO in the Ilulissat Declaration (Arctic Ocean Governing Conference 2008). Subsequently, AMSA stressed the necessity of cooperation between Arctic Council states and the IMO in order to strengthen, harmonize, and regularly update international standards for vessels operating in the Arctic (AMSA 2009). The cooperative relationship between the IMO and Arctic Council can be expected to be consolidated after IMO was granted observer status at the Arctic Council in 2019. The policy shaping function of the Arctic Council provides a valuable input into the IMO's exercise of its regulatory mandate with respect to Arctic shipping. For instance, AMSA helped inform the need for mandatory standards for polar shipping and provided valuable background information during the negotiations of the Polar Code. Similarly, whereas the Arctic Council provided background information on HFOs in Arctic shipping, the IMO provided the negotiation platform (the Marine Environment Protection Committee or MEPC) for HFO regulation in Arctic shipping.

14.3.2 MEPC Deliberations on HFO Regulation

The discussion of HFO regulation in Arctic shipping at the IMO can be divided into three stages. These are (1) the period from the development of the Polar Code until its adoption, (2) the period following adoption and until the Polar Code came into effect, and (3) the period since the date of effectivity. During the first stage in 2010, there was debate on whether to ban the use and carriage of HFO in the Arctic at the former IMO Sub-Committee on Ship Design and Equipment (DE) (IMO 2010). Thereafter, in 2013, some NGOs submitted a proposal to the DE concerning HFO use by vessels in Arctic waters and further supported the inclusion of a provision in the draft Polar Code banning the use of HFO on ships operating in Arctic waters (IMO 2013a).[1] In that same year, MEPC 65 referred the document for consideration and advice, although the majority of delegations felt that it was premature to regulate the use of HFO on ships operating in Arctic waters (IMO 2013b).

During the second stage, which encompasses MEPC 69 and 70, several Arctic states and NGOs mooted the necessity to regulate HFO use by vessels in Arctic waters.[2] At MEPC 69, the NGOs' proposal analysed the significant hazards that HFO use could pose to the Arctic marine environment and invited the reassessment of current IMO measures to reduce the increasing risk of HFO use in Arctic waters (IMO 2016b). At MEPC 70, the NGOs submitted a proposal (MEPC 70/17/4) concerning heavy fuel oil use by vessels in Arctic waters (IMO 2016c) that contained extracts from PAME work on a strategy to address the use of HFOs, carriage of bunkers and as ballast and weighed the threats of HFO use to the food security of coastal Indigenous communities (IMO 2016d). The Russian Federation also submitted a commentary on MEPC 70/17/4 and expressed the view that a clear, balanced, and science-based approach was necessary instead of relying on assumptions and proposed prevention and mitigation measures (IMO 2016e). Canada and the United States also submitted a commentary on MEPC 70/17/4 that emphasized the necessity of further work on the regulation of HFO use in the Arctic and called for collaboration with other interested member states and observers through the IMO

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[1] At DE 57, the NGOs submitting the proposal about HFO use by vessels in Arctic waters, as discussed at DE 54 (IMO 2010), included the Friends of the Earth International (FOEI), Clean Shipping Coalition (CSC), International Fund for Animal Welfare (IFAW), World Wide Fund for Nature (WWF), and Pacific Environment.

[2] The NGOs that submitted proposals about HFO use by vessels in Arctic waters at MEPC 69 and 70 are the same as those making a proposal at DE 54 except IFAW.

(IMO 2016f). During the second stage, MEPC 69 and 70 recognized the necessity of continuing work on the HFO use in Arctic waters (IMO 2016g, 2016h).

During the third stage since 2017, several Arctic states and observer organizations have submitted proposals to MEPC concerning measures to reduce the risks of use and carriage of HFOs in the Arctic. The emerging HFO regulatory strategy has gained clarity. At MEPC 71, Canada, Finland, Germany, Iceland, the Netherlands, Norway, and the United States proposed a new output for HFO measures with the consideration of economic impacts of the measures (IMO 2017a). As they had at MEPC 69 and 70, a group of NGOs highlighted the future increase in the volume of Arctic shipping and compared the cost of the alternative fuels, including distillate and liquefied natural gas (LNG), which could offer an economically viable short-term solution (IMO 2017b). They also observed that the prohibition of any petroleum-based fuel oil would offer the greatest long-term protection from the environmental and economic risks of HFO spills and black carbon emissions (IMO 2017c). The Russian Federation felt that information in the NGO proposal could be used as the basis to ban HFO on ships and affirmed that it would instead focus on mitigation measures to prevent spills and other negative impacts (IMO 2017d). MEPC 71 agreed to include a work item on the development of measures to reduce risks of use and carriage of HFO as fuel by ships in Arctic waters proposed by Canada and other states on the 2018–2019 Committee agenda while tasking the Sub-Committee on Pollution Prevention and Response (PPR) to complete the work, and invited further concrete proposals (IMO 2017e).

MEPC 72 was a turning point for the discussion since a group of Arctic and non-Arctic states (Finland, Iceland, Norway, Sweden, the United States, together with Germany, the Netherlands, and New Zealand) jointly proposed a mandatory ban on HFO use as fuel in Arctic shipping and urged MEPC to consider an appropriate timeline (IMO 2018b). In light of the implementation of a global sulphur limit of 0.50% by 2020 (IMO 2016h), it was recommended that the HFO ban commence by the end of 2021, which would encourage switching to marine distillate fuels. While Canada and Marshall Islands felt the objectives of the ban were consistent with their desire to protect the Arctic, they argued that the impacts on Arctic communities and economics should be taken into account when developing HFO measures (IMO 2018c). NGOs supported the mandatory ban and further sought clarity in the definition of HFO and the geographical area of the ban (IMO 2018d, 2018e).[3] The Russian Federation proposed several measures, other than a ban on HFO use as fuel, including navigational measures, ship operational measures, infrastructure and communication, emergency preparedness and early detection of oil spills, and training (IMO 2018f). It viewed the ban as significantly impacting maritime trade and negatively affecting the balance between economic development and environmental protection (IMO 2018g). In summary, MEPC 72 approved PPR's continued work to develop a

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[3] At MEPC 72, CSC, FOEI, Greenpeace, Pacific Environment and WWF submitted the proposal to ban HFO use and carriage as fuel by ships in Arctic waters. The Cruise Lines International Association submitted the comments on the proposal to ban HFO use and carriage as fuel by ships in Arctic waters.

definition of HFO taking into account Regulation 43 of MARPOL Annex 1, prepare guidelines on mitigation measures to reduce risks identified by the Russian Federation, and develop a ban on HFO for use and carriage as fuel by ships in Arctic waters within a rational timeline and premised on an impact assessment (IMO 2018h). MEPC was advised to develop an appropriate impact assessment methodology to enable the PPR to proceed with this work.

There were several new proposals introduced at MEPC 73. Canada and the Russian Federation jointly submitted the report of the informal correspondence group on the determination of an appropriate impact assessment methodology, especially with respect to impacts of an HFO ban on Arctic communities and economies (IMO 2018i). The United States proposed a cost-benefit methodology to determine impacts on Arctic communities and industries (IMO 2018j). In commenting on the Canadian and Russian proposal, Finland proposed a five-step approach for further consideration (IMO 2018k). France further suggested considering the impact of the ban on HFOs carried as cargo in addition to bunker use. In searching for consensus, MEPC 73 instructed PPR to finalize the impact assessment methodology on the basis of the suggestions made by Canada, the Russian Federation, and Finland (IMO 2018l).

PPR 6 established a working group to report on the HFO issues and develop a working definition of HFO. What emerged was a much narrower definition than the one about the HFO ban in the Antarctic in Regulation 43 of MARPOL Annex I. PPR defined HFO as follows: “Heavy fuel oil means fuel oils having a density at 15°C higher than 900 kg/m^3 or a kinematic viscosity at 50 °C higher than 180 m^2/s” (IMO 2019, para. 12.26). PPR 6 also agreed with the working group’s suggestion to introduce the ban in MARPOL Annex I (IMO 2019, para. 12.30f). This represented a big step forward for HFO regulation in Arctic shipping.

14.3.3 The Interests Underscoring the Debate

There are various interests at play in MEPC during HFO deliberations. All state and non-state actors found consensus on the potential hazards posed by HFO use as fuel in Arctic shipping, but there was significantly less agreement on risk mitigation measures because of the complicated interests involved.

First, the NGOs are the primary and prominent driving force promoting the development of mitigation measures for HFOs in Arctic shipping. Their central concern is the importance of environment protection in the Arctic and the imperative on a ban on HFO use or carriage as fuel in those waters. They also point out the potential economic risks resulting from HFO use as fuel in Arctic shipping.

Second, some non-Arctic states, such as France, contributed to the development of mitigation methodologies and even recommended extending consideration to HFO use and carriage as fuel and as cargo, thus appearing to support the environment protection concerns espoused by NGOs. However, these non-Arctic states constitute a small number of actors, while other non-Arctic stakeholders with major shipping interests, such as China, Japan, and Korea, did not clarify their positions on the use of HFO in Arctic shipping. Undoubtedly, the ban of HFO use and carriage as fuel will increase the cost of Arctic shipping. However, if the global cap on sulphur emissions in 2020 is also considered, the influence of the ban on HFO on key shipping stakeholders may need further detailed analysis (Bai and Wang 2019).

Third, Arctic states other than the Arctic coastal states support the ban on HFO use and carriage as fuel by ships in Arctic waters. Such agreement among them is not surprising if the PAME work is considered, also bearing in mind the central theme to protect the Arctic environment and promote sustainable development. Moreover, some of those Arctic states, such as Finland and Sweden, are both member states of the European Union and may share the similar strong environmental mission as the European Union. Sweden and Finland both made environmental protection a priority theme during their two-year chairmanship beginning in 2011 and 2017, respectively (Arctic Council 2011, 2017).

Fourth, among the Arctic states, Canada and the Russian Federation, as the states with the longest coastlines, may be impacted the most by an HFO use ban. An HFO use ban would be beneficial from environment protection and public health perspectives, but at the same time a ban might decrease the attractiveness of new shipping routes, thus affecting local economic development. In the case of Indigenous peoples, a key concern for Canada, the ban might adversely affect the resupply of northern communities by sealift and potentially increase the cost of living. Canada drew attention to these concerns in the analysis on the impact of an HFO ban (IMO 2018m).

The Russian Federation, concerned about the possible impact on northern development and the benefits to national shipowners and refining industries, underlined the need for balance between economic development and environmental protection (IMO 2018n). Although the Russian Federation opposed the mandatory ban of HFO use in the Polar Code during its negotiation, in 2018 Russian President Vladimir Putin and Finnish President Sauli Niinisto issued a joint statement on the need to move to cleaner ships' fuel, such as LNG, in the Arctic (The Maritime Executive 2018). Taking all the interests into consideration, a step-by-step responsive regulatory strategy is necessary to respond to the identified risks of HFOs in Arctic shipping.

14.4 The IMO Regulatory Strategy

14.4.1 The Rule-Making Strategies for HFO in Arctic Shipping

As mentioned above, the IMO has regulatory authority relating to the protection of the marine environment from vessel source pollution and maritime safety. Historically, the IMO adopted rules and standards using a prescriptive approach, which is to specify precisely the standard or conduct respected by the regulatee and which flag states applied to their ships (Chircop 2017). Goal-based standards (GBS) were developed and approved by the Maritime Safety Committee in the form of official guidelines at its 89th session (IMO 2011) and revised at its 95th session (IMO 2015a). For the application of GBS, the IMO only states what is intended to be achieved and leaves the goals to be achieved by various methods (Bai 2015). Regarding the regulatory strategies under the IMO on HFO use in Arctic shipping, the prescriptive approach and GBS could form a staged approach, informed by the principles of necessity, consistency, proportionality, fit for purpose, resilience, and clarity.[4]

14.4.2 Short-Term Measures

At PPR 6 it was clear that there was no absolute guarantee about the exact approval time of an HFO ban for Arctic shipping. The scope and application of the ban will be likely clear and definite before 2021 and could be phased in before 2023 as called for by the Clean Arctic Alliance at PPR 6 (HFO-Free Arctic 2019). Thus, interim and proportionate measures may be necessary to mitigate the potential threats posed by HFOs.

The most severe threat posed by HFOs in Arctic shipping is an oil spill. Navigational and operational measures could help reduce the risks associated with vessel source oil pollution. The available measures at the IMO include ship routeing measures (including areas to be avoided) and particularly sensitive sea areas (PSSAs). For instance, IMO has approved the Bering Strait and Bering Sea ship routeing measures proposed by the United States and the Russian Federation, which has six two-way routes and six precautionary areas taking effect 1 December 2018 (IMO 2018o). These measures are the first approved ship routeing measures in Polar Code waters by IMO and could play a precautionary role to mitigate the risks caused by an HFO spill from Arctic shipping by promoting greater maritime safety. In addition, under Article 211(6) of UNCLOS, Arctic states may seek IMO assistance in adopting a special mandatory measure with respect to HFOs in Arctic shipping (UNCLOS 1982).

A PSSA designation is also an option. However, in practice PSSAs cover particular areas and even large areas such as EEZs, but it is unlikely that all Arctic waters covered by the Polar Code could be encompassed by such a measure. Rather, this area-based management tool is useful for particular areas in the Arctic, for example where there are endangered species and very sensitive habitats. Only one criterion from clusters of ecological, social-culture-economic, and scientific-education criteria needs to be satisfied to meet the threshold for PSSA designation. A PSSA is useful where the appropriate measure adopted under it helps address the risk of pollution from HFOs (IMO 2015b). In the case of the Western European

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[4] The prescriptive principles for drafting IMO instruments are required to be considered by the IMO Resolution A.1103(29), entitled as Principles to be Considered when Drafting IMO Instruments.

Waters PSSA, the only measure adopted was mandatory reporting for tankers before entering EEZs. This could be a useful measure in Arctic waters to enable coastal state authorities to track the movements of such vessels.

The establishment of emission control areas (ECA) in the Arctic may help control vessel source pollution, such as sulphur and nitrogen emissions caused by the use of HFO as fuel. The detailed regulations of emissions from vessels are discussed in Chap. 13 of this volume.

14.4.3 Medium-Term Measures

Short-term measures are provisional as they are only applicable to specific risks in particular areas until an HFO ban is eventually adopted. Permanent and unified rules for the entire Arctic region are necessary to prevent pollution from HFOs used as fuel in Arctic shipping. An HFO ban seems the simplest and most effective approach to reduce the risks from the use and carriage of HFO as bunkers. As reflected in discussions at MEPC and PPR, and at the time of writing, a ban on the use and carriage of HFO as fuel in Arctic shipping is supported by most stakeholders (with concerns expressed by the Russian Federation and Canada) on the premise of the consideration of its impacts on, including but not limited to, Indigenous peoples and economic development.

If MARPOL Annex I is considered the most appropriate option to introduce the ban on HFO in Arctic shipping, the ban would come into effect following the adoption of an amendment to the Annex accepted “by two thirds of the Parties, the combined merchant fleets of which constitute not less than 50 per cent of the gross tonnage of the world’s merchant fleet” (MARPOL 1973/78, art 16(2)(f)(ii)–(iii)). However, there has been no consensus on possible amendment options through MARPOL Annex I. There may be three possible approaches to amend MARPOL Annex I to ban HFO in Arctic shipping. The first approach is to extend the application of Regulation 43 of MARPOL Annex I to both Arctic and Antarctic waters. The second approach is to add a new regulation in Chapter 9 of MARPOL Annex I that is only applicable to the ban on the HFO use and carriage as fuel for ships’ operations in the Arctic. The third approach is to add another chapter under MARPOL Annex I to prohibit the use and carriage of HFO as fuel in the Arctic. After a ban on HFO in Arctic shipping is included in MARPOL Annex I, the Polar Code could be updated subsequently, if needed, which would mean that the use and carriage of HFO as fuel in areas covered by the Polar Code would be restricted accordingly.

Since the construction and equipment of most vessels currently are designed for the use of HFO as fuel, a staged application, such as a one- to two-year grace period, could be applied when a ban is adopted. The Polar Code included similar arrangements for safety and training requirements. After a certain period, the ban could be applied to all ships, with the exception of vessels engaged in securing the safety of vessels or in search and rescue operations as stipulated in Regulation 43 of MARPOL Annex I.

14.4.4 Long-Term Measures

Does an HFO ban under the MARPOL Annex I and embodied in the Polar Code resolve all the risks posed by HFOs in Arctic shipping? The short answer is no. First, the carriage of HFO as cargo poses even greater risks than the carriage of HFO as fuel due to the volume of HFO in the tanker holds. However, the ban under MARPOL Annex I only relates to HFO as fuel in Arctic shipping. Second, the PAME Phase III(a) report indicated that the majority of incidents happened near the Arctic, but not in the area covered by the Polar Code (PAME 2016). The HFO spill risk outside the Polar Code area is much higher than within those waters. Hence the ban under MARPOL Annex I applicable only to the Polar Code area cannot prevent an HFO spill beyond that area. Third, the substitute for HFO as fuel in Arctic shipping mainly includes distillate fuel and LNG, which still cause GHG emissions and accelerate sea ice melting. IMO has adopted its GHG reduction strategy to encourage the development and provision of zero-carbon or fossil-free fuels in the shipping sector in order to realize decarbonization in the long term (IMO 2018p). The medium-term measures suggested for HFOs in Arctic shipping may not decrease GHG emissions, or contribute to decarbonization. Obviously, additional measures are necessary to completely resolve the issues caused by the use of HFOs in Arctic shipping. Existing measures such as routeing and reporting measures and any PSSA designated near the Arctic would reduce the risks of an HFO spill as cargo and fuel beyond the limits of application of the Polar Code (Polar Code area). The designation of ECAs in and near the Arctic could decrease the emission of GHGs and black carbon. Bio-fuels, ammonia, hydrogen fuel cells and electric batteries could help realize the decarbonization challenge and get to the root of the problems brought about by HFOs in Arctic shipping.

14.5 Assessment of the Impacts of the Regulatory Strategies for HFOs in Arctic Shipping

The response to the risks posed by HFOs cannot be accomplished with one stroke, and it is insufficient to only assess the impact on the ban of HFOs. A comprehensive assessment of the environmental, economic, and social impacts of the regulatory strategies as a whole is necessary before the final decision on HFO regulation is made.

14.5.1 Environment Impacts

When the environmental impacts of an HFO regulatory strategy for Arctic shipping are considered, the prevention principle and the precaution principle might be considered as the prominent criteria. The prevention principle emphasizes the obligation of states to prevent damage to the environment in general. The precaution principle stresses the precautionary approach where there are threats of serious or irreversible damage but there remains lack of full scientific certainty. In light of the environmental impacts of the HFO regulatory strategies discussed above, the short-term strategy focuses on the protection of the environment per se and adopts remedial measures to mitigate the effects of hazards brought by the use of HFO in the Arctic. The medium-term strategy highlights the precautionary approach and takes measures anticipated to minimize the generation of the risks no matter whether it is based on a true hypothesis. The long-term strategy implements a more progressive mixed measure that applies the precautionary approach in the fragile Arctic and preventive measures near the Arctic.

14.5.2 Economic Impacts

When economic impacts of the regulatory strategies on HFO in Arctic shipping are analysed, cost-benefit criteria should be applied to assess whether the benefits would satisfy the costs brought by the ban (Abbasov et al. 2018). Limited data are available for considering the economic impacts of the short-term regulatory strategy and long-term regulatory strategy. Thus, the discussion here will focus on the economic impacts of the medium-term regulatory strategy based on impact assessment reports submitted to IMO.

The additional costs for shipowners (e.g., per ship costs differentiated by ship type), the potential impact on consumer prices, and the clean-up costs that could be saved in case of an oil spill should be considered. First, because the global cap on sulphur emissions will come into effect in 2020, ships could meet the standards if they choose to use low-sulphur heavy fuel oil. The ban on HFO would increase the cost associated with the switch to distillate fuels. Under such a scenario, there would be additional costs for the medium- and long-term regulatory strategy.

Second, commercial cargo vessels would be affected more than cruise ships by an HFO ban in the Arctic (Bannon 2018). Vessels that seasonally sail in the Polar Code area would be influenced more than international vessels, because a higher volume of the fuel would need to be switched. Under such a scenario, there could be negative economic impact on the local communities in the Arctic with the medium- and long-term regulatory strategies because of their reliance on the sealift supply.

Third, the increased cost for shipping non-perishable food items to communities in the Arctic would be relatively small (Nelissen and Tol 2018, 24). So there would be a slight difference for consumer prices between the short-term and medium-term strategies. However, if the ban not only included the use and carriage of HFO as fuel, but also the carriage of HFO as cargo, the price of supplying oil in the Arctic would be heavily influenced, which means the long-term regulatory strategy has the most impact on local communities and oil companies in the Arctic.

Fourth, the ban on the use and carriage of HFO as fuel and cargo would significantly reduce the associated risks and clean-up costs of an oil spill of ban-compliant fuel, although a study shows that there is no direct causation linkage between the prevention of an oil spill and the HFO ban (Government of Greenland 2018). Thus, there would be more benefits under the medium- and long-term regulatory strategies with the lowering of the possibility of an oil spill.

14.5.3 Social Impacts

The social impacts of the regulatory strategies for HFO in Arctic shipping mainly refer to the influence on local communities in the Arctic. The HFO ban is a double-edged sword for local communities. On the one hand, a ban would protect the environment, which could be affected by the increasing transits by a large volume of commercial vessels; on the other hand, a ban would potentially increase the cost to resupply local communities and reduce the attraction of foreign investment in oil exploitation in the Arctic, particularly in the Russian Federation. In other words, the ban on HFO use and carriage as fuel would benefit the local communities and secure the marine food chain, but it could increase the cost of living for local communities, although this would be minimal, as indicated by the study mentioned above. The ban on HFO carriage as cargo would impact foreign investment opportunities in those states that have signficant oil resources. Therefore, the medium- and long-term regulatory strategies could safeguard local communities, but at the same time pose other challenges.

14.6 Conclusion

The hazards brought by HFOs in Arctic shipping urges their regulation. Initially considered and discussed by NGOs and Arctic states through the platform of the Arctic Council, HFO use and carriage as fuel has been discussed for a few years at IMO diplomatic conferences. Before a mandatory ban is adopted under MARPOL Annex I, various regulatory strategies offer a valuable reference to considering the impacts on various interests. From the perspective of a short-term regulatory strategy, the existing fragmented regulations could provide an expedient arrangement to minimize the damage resulting from the potential hazards posed by HFOs in the Arctic. From the perspective of a medium-term regulatory strategy, the holistic HFO ban as fuel under MARPOL Annex I applies a precautionary approach that could cover the Polar Code area, but still has some limitations on the efficient control of the threats posed by HFOs beyond the current IMO regulatory regime. From the perspective of a long-term regulatory strategy, the progressive decarbonization goal approach in the Polar Code area could maximally protect the vulnerable Arctic environment, especially together with the establishment of ECAs and PSSAs in and near the Arctic.

These regulatory strategies reflect various environmental, economic, and social impacts. The ultimate goal is environmental protection, but flexible measures are needed to deal with existing vessels and the specific needs of Indigenous peoples. Successful realization of the HFO regulatory strategies relies on good implementation and coordination among flag states, coastal states, and port states. Through such staged regulatory strategies, the Arctic will be conserved and sustainably used for the interests of Indigenous peoples and all the other stakeholders.

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Chapter 15
A Change in the Ice Regime: Polar Code Implementation in Canada

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Abstract In 2017 Canada implemented the Polar Code into domestic legislation, marking the most significant update to Arctic shipping safety and pollution prevention in over 20 years. While much has been written about the events leading to its creation, this chapter will instead focus on the steps taken by Canada *after* Polar Code adoption, in particular the domestic considerations that culminated with the creation of the Arctic Shipping Safety and Pollution Prevention Regulations. Changes made by Canada to certain Polar Code provisions during implementation are highlighted, as are ongoing efforts at the International Maritime Organization to further advance standards for ships operating in polar waters.

Keywords Arctic · Antarctic · Equipment · Guidelines · International Maritime Organization · Marine pollution prevention · Operations · Polar Code · Regulations · Safety · Sea ice · Shipping · Training · Vessel design

15.1 Introduction

On 1 January 2017, the International Code for Ships Operating in Polar Waters (the Polar Code) entered into force internationally. The product of years of negotiations at the International Maritime Organization (IMO), the primary objective of the Polar Code is to address the unique hazards confronted by ships operating in the Arctic and Antarctic through the introduction of a variety of safety and pollution prevention measures, including those related to design and equipment, operations, crew training, and the protection of the marine environment.

Canada played an instrumental role in the development of the Polar Code, leveraging over 40 years of experience in the oversight of Arctic shipping. As a result of

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this active engagement, the content of the Polar Code—from the hazards addressed, to how a ship should operate in ice, to the restrictions placed on certain discharges—is influenced significantly by Canadian safety and environmental standards.

The Polar Code is not a new IMO treaty or convention. Rather, it is a technical code implemented through amendments to the existing International Convention for the Safety of Life at Sea, 1974 (SOLAS 1974) and the International Convention for the Prevention of Pollution from Ships, 1973/78 (MARPOL) by way of tacit acceptance (Polar Code 2014/2015). Under this process, states that are signatories to these conventions automatically become bound by amendments unless an intention to object is formally submitted to the Secretary-General of the IMO.

Following the adoption of the final text of the Polar Code, Canada initiated a technical review of its content and the enabling amendments to both SOLAS and MARPOL. A comparative analysis was also undertaken to determine the extent to which these newly adopted international measures differed from the prevailing domestic ones, and whether any reasonable grounds existed to warrant formal objection. The results of this technical review are highlighted below, along with the various regulatory incorporation options and unique amendments considered by Canada to make the Polar Code applicable domestically. The chapter concludes by noting the ongoing work at the IMO to develop guidance material to supplement the Polar Code's goal-based safety standards, as well as its possible expansion to others types of vessels not originally considered (e.g., fishing vessels and pleasure craft).

15.2 Technical Review of the Polar Code

Drawing on operational and technical expertise from across the Government of Canada, every goal, functional requirement, and regulation contained in Part I-A (Safety Measures), and every prescriptive regulation contained in Part II-A (Pollution Prevention Measures) of the Polar Code, as well as the entirety of SOLAS Chapter XIV and the related amendments to MARPOL Annexes I, II, IV, and V, were subject to review and analysis. To facilitate this exercise, a concordance table was developed whereby the dissected and itemized contents of the Polar Code were individually identified as being either "higher" (e.g., more stringent), "lower" (e.g., less stringent), or on par with the closest equivalent standard across the suite of acts, regulations, and guidance material that constitute Canada's Arctic shipping regulatory regime. Any specific considerations unique to Canada and not directly captured by the adopted text of the Polar Code (e.g., Canadian ice class notations, ice navigator requirements) were highlighted and assigned a provisional location for regulatory incorporation. Moreover, to assist with the overall tacit acceptance review, a recommendation on whether or not an objection should be made to each provision was also indicated.

The safety portions of the Polar Code are established through the addition of a completely new chapter to SOLAS—Chapter XIV (Safety Measures for Ships Operating in Polar Waters). Comprised of four regulations that contain universal definitions (e.g., Arctic waters, Antarctic area), that set out application and certification criteria, and that make allowances for the use of alternate design arrangements, this chapter provides an overarching framework under which the specific safety features of the Polar Code are organized.

Regulation 2 of Chapter XIV contains language concerning the rights and obligations of states under international law. This is particularly noteworthy for Canada as its inclusion guarantees that the contents of the Polar Code established through SOLAS do not in any way prejudice or infringe upon rights enshrined elsewhere, in particular Article 234 of the United Nations Convention on the Law of the Sea (UNCLOS 1982), which allows coastal states the ability to adopt and enforce laws for the prevention of pollution from ships operating in ice-covered areas:

> Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.

Canada’s Arctic Waters Pollution Prevention Act (AWPPA 1970) and Northern Canada Vessel Traffic Services Zone Regulations (NORDREG 2010) were both enacted to protect the Arctic marine environment via more stringent pollution prevention measures and are directly linked to Article 234.

It is worth noting that at the time of its accession to the 1978 Protocol to MARPOL, Canada deposited a declaration to the IMO asserting its “right in accordance with international law to adopt and enforce special non-discrimination laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered arctic waters … within or adjacent to Canada” (IMO 1992). This declaration was also based on Article 234 of UNCLOS and was later reaffirmed when Canada formally accepted the Polar Code-related amendments to MARPOL in 2018.

After careful review, all four regulations contained in SOLAS Chapter XIV were accepted. Similarly, with respect to the various amendments to regulations contained in MARPOL Annexes I, II, IV, and V that consequentially amend existing text to include appropriate references to Part II-A of the Polar Code and that add new Polar Code-specific chapters to each of the identified annexes, no reasonable grounds to object were identified.

As for the mandatory text of the Polar Code itself—that is, the 12 safety chapters, five pollution prevention chapters, and the related introductory text (all enabled by the aforementioned SOLAS and MARPOL amendments)—no objections to its content were raised upon the completion of the technical review. Indeed, with a precautionary and pollution prevention-focused domestic regime for Arctic shipping in place since the early 1970s, much of this content was already applicable to ships operating in Canada.

15.3 Regulatory Incorporation Options

Despite the absence of any formal objection, certain administrative concerns were identified with respect to the length of time required by Canada to discharge its international law obligations under both conventions through the introduction of new or the update of existing regulations by the 1 January 2017 international entry into force date.

In response to these concerns, several regulatory incorporation options were considered. The option ultimately chosen was to use IMO mechanisms made available under both conventions to delay entry into force, thus formally providing Canada with additional time to complete its necessary domestic processes. Under SOLAS, contracting parties have up to 1 year from the international entry into force date to delay, meaning that Canadian regulations concerning the safety provisions of the Polar Code would need to be in force no later than 1 January 2018. No specific time limit exists under the MARPOL Convention concerning delayed entry into force.

Accordingly, a formal process was soon set in motion authorizing the Government of Canada to accept amendments adding Chapter XIV to SOLAS, adopted by the Maritime Safety Committee (MSC) of the IMO on 21 November 2014, and the amendments to Annexes I, II, IV, and V of MARPOL, adopted by the Marine Environment Protection Committee (MEPC) of the IMO on 15 May 2015. In addition, the High Commission of Canada in the United Kingdom sent notice to the Secretary-General of the IMO, in accordance with Article VIII(b)(vii)(2) of SOLAS, exempting Canada for a period of not more than 1 year from giving effect to the amendments that introduce the provisions of the Polar Code into that Convention on account of national procedural requirements. The High Commission also notified the Secretary-General that, in accordance with Article 16(2)(f)(ii) of MARPOL, and also due to national procedural requirements, Canada's express approval would be necessary before the amendments to that treaty entered into force.

15.4 The Arctic Shipping Safety and Pollution Prevention Regulations

Subsequent to landing on the delayed entry into force approach, and after much internal consultation and review, it was agreed that a single regulation that incorporated the Polar Code into Canadian law be pursued, and that this was both feasible and likely to be in place during 2017, thereby meeting the 1 January 2018 delayed implementation deadline. The single regulation approach was chosen over the more piecemeal alternative that would involve making amendments to a variety of individual regulations subject to their own unique and potentially lengthy regulatory timelines.

Canada therefore proposed to capture the Polar Code domestically through the creation of a completely new regulation: the Arctic Shipping Safety and Pollution

Prevention Regulations (ASSPPR 2017). At the same time it would also make a variety of consequential amendments to avoid conflict or duplication with other regulations relevant to Arctic operations, in particular a full repeal of the Arctic Shipping Pollution Prevention Regulations (ASPPR 2006).

Central to incorporating the Polar Code domestically via the ASSPPR was ensuring that existing levels of safety and pollution prevention applicable to ships operating in Canadian Arctic waters were not eroded, and that only those international standards adopted by the IMO that further strengthened safety and pollution prevention would be introduced. Accordingly, Canada proposed that this new regulation fully incorporate by reference the safety provisions (Part I-A) of the Polar Code and that the environmental provisions be drafted so as to take into consideration existing discharge prohibitions made under the AWPPA. Additional Canadian modifications not contained within the adopted text of the Polar Code were also introduced.

The concordance table developed during the previous technical review served as a guiding document in the drafting of the ASSPPR, ultimately informing the extent to which the Polar Code should be replicated in full and the degree to which Canada-specific amendments should be introduced. This review was complemented by further consultations with key stakeholders across all levels of government, industry, academia, and the non-governmental organization community, the views and opinions of which were critical in shaping the final regulatory draft.

Without context or familiarity with the interrelationship between the ASSPPR and other pieces of Canadian legislation, reading the regulations in isolation can be limiting. Therefore, to facilitate a greater understanding of its application and intent, certain illustrative features of the ASSPPR and the chapters of the Polar Code incorporated by reference are highlighted below.

15.4.1 General Provisions

The general provisions section of the ASSPPR contains terminology applicable throughout both the safety and pollution prevention parts of the regulation, as well as definitions not contained within the adopted text of the Polar Code though required to be included in order to reflect certain Canadian modifications. For example, to make the distinction between the application of the regulations to Canadian flagged ships outside Canadian Arctic waters (though still within polar waters), and all ships within Canadian Arctic waters, the term “shipping safety control zone” is used to refer to the latter.

15.4.2 Safety Measures

The entirety of the introduction and Part I-A of the Polar Code is incorporated by reference, meaning that rather than replicate this content in full in the body of a regulation, the ASSPPR instead simply indicates that applicable ships must conform fully to the requirements of SOLAS Chapter XIV. In turn, SOLAS Chapter XIV makes separate reference to the introduction and the 12 safety-related chapters of the Polar Code.

15.4.2.1 Introduction

The introduction contains the primary goal of the Polar Code, definitions to be used in both the safety and pollution prevention sections, a list of hazards to consider during polar operations, and a brief description of the document's structure. The introduction provides definitions that establish context for the Polar Code, many of which are similar to definitions used in the Canadian regime prior to incorporation.

15.4.2.2 General

Chapter 1 provides the overall structure and framework for Part I-A of the Polar Code, as well as additional definitions not noted in the introduction, requirements for the issuance of Polar Ship Certificates and surveys, and the general criteria for determining ship performance standards and operational assessments. Where they exist, definitions of terms shared between this chapter and those within the Canadian regime prior to incorporation are largely similar or equal to one another. This chapter also requires that a Polar Ship Certificate reference a methodology to assess operational capabilities and limitations of a ship in ice. Under Canada's longstanding regime, the Zone/Date System (ZDS) and the Arctic Ice Regime Shipping System (AIRSS) are examples of this methodology.

15.4.2.3 Polar Water Operational Manual

Chapter 2 describes content to be included in the Polar Water Operational Manual (PWOM), a mandatory ship-specific document designed to support decision-making through the identification of procedures for operations under routine and emergency conditions. Prior to incorporation, no direct PWOM equivalent was required under the Canadian regime, although the PWOM must contain references to methodologies used to determine operational capabilities and limitations of a ship in ice (e.g., AIRSS).

15.4.2.4 Ship Structure

Chapter 3 includes provisions to ensure that the materials and scantlings of ships with or without ice strengthening retain their structural integrity under certain environmental loads and conditions. This chapter seeks to provide assurance that a ship's structure is suitable for the environmental conditions by requiring that design plans be made to a recognized standard, such as Polar Class or the Finnish-Swedish (Baltic) Class, and that all materials be suitable if the ship intends to operate at low air temperatures. The contents of this chapter are generally equivalent to measures contained in the Canadian regime prior to incorporation.

15.4.2.5 Subdivision and Stability

Chapter 4 identifies requirements for ensuring adequate subdivision and stability for both damaged and intact ships at risk of ice accretion or ice-related damage. Provisions contained in this chapter are generally similar to those in the Canadian regime prior to incorporation.

15.4.2.6 Watertight and Weathertight Integrity

Chapter 5 contains requirements to maintain the watertight and weathertight integrity of all closing appliances and doors on board a ship. Prior to incorporation of the Polar Code, the Canadian regime had few specific requirements to address the maintenance of watertight and weathertight integrity of certain spaces on board ships operating in the Arctic.

15.4.2.7 Machinery Installations

Chapter 6 identifies requirements for ensuring that the machinery installations used on board ships operating in polar regions are capable of functioning under low air temperatures and in anticipated environmental conditions. Provisions contained in this chapter are generally broader and less prescriptive than related provisions in the Canadian regime prior to incorporation.

15.4.2.8 Fire Safety/Protection

Chapter 7 includes measures to ensure that fire safety systems and appliances are effective and operable, and that means of escape remain available under expected environmental conditions and at low air temperatures. Fire safety and protection requirements for ships operating under the Canadian regime are described in the

Vessel Fire Safety Regulations and are generally equivalent, though less tailored to Arctic operations than requirements made under the Polar Code.

15.4.2.9 Life-Saving Appliances and Arrangements

Chapter 8 contains requirements that provide for safe escape, evacuation, and survival under various operating conditions. The Canadian regime prior to incorporation had no specific provisions for lifesaving appliances and arrangements unique to Canadian Arctic operations.

15.4.2.10 Safety of Navigation

Chapter 9 sets out measures for safe navigation, including with respect to ships involved in icebreaker escort operations, and requires the addition of certain navigation safety equipment. The Canadian regime had previously required that navigation safety equipment be present when operating in certain shipping safety control zones depending on the size of the ship. Polar Code measures still require additional navigation safety equipment for certain ships, though requirements for this equipment are less prescriptive (e.g., the option of one echo sounding device with two separate independent transducers) than previously contained in Canada's regime.

15.4.2.11 Communications

Chapter 10 sets out regulations for effective communications for ships and survival craft during normal and emergency situations. This chapter's contents are generally equivalent to the Canadian communication regime for ships operating in the Arctic prior to incorporation, though more explicit requirements for search and rescue (SAR) and telemedical assistance communications are included.

15.4.2.12 Voyage Planning

Unlike previous chapters, Chapter 11 does not include specific regulations that must be met. Instead, this chapter contains only requirements designed to ensure that the company, master, and crew are provided with sufficient information to enable operations to be conducted with due consideration for the safety of ships, persons on board, and awareness of local environmental conditions. With the exception of the requirement for a PWOM, all the contents of this chapter are generally equivalent to those contained within a variety of Canadian government publications (e.g., Notices to Mariners, Ice Navigation in Canadian Waters) prior to incorporation.

15.4.2.13 Manning and Training

Chapter 12 includes provisions to help ensure that ships operating in polar waters are crewed by qualified, trained, and experienced personnel. While regulations concerning manning and training are noted in this chapter, the details—including various transitional provisions—are ultimately made pursuant to amendments to Chapter V of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended (IMO 2016a).

Similar in concept to that of a Canadian ice navigator, the Polar Code recognizes a person, other than a ship's officer, who is suitably qualified and experienced to operate in Arctic (or Antarctic) areas. Overall, provisions contained within this chapter are generally higher than those in the Canadian regime prior to incorporation, including additional training and qualifications requirements for certain personnel on board ships operating in open water (e.g., less than 1/10th ice concentration).

15.4.2.14 Canadian Additions

Certain provisions of Part 1 of the ASSPPR are not contained in the Polar Code, though are included in order to maintain as closely as possible key features of Canada's Arctic shipping regime prior to incorporation. In wanting to reflect consistency of application with other Canadian Arctic regulations (e.g., NORDREG), these additions are applicable in Canadian Arctic waters only and generally apply to all ships 300 GT or more (including fishing vessels and pleasure craft), all ships engaged in towing or pushing another ship (if combined weight is 500 GT or more), and all ships carrying a pollutant or dangerous good as cargo.

Ships that fit within the above criteria are required to follow one of two methodologies to assess operational capabilities and limitations in ice when operating outside prescribed periods in a shipping safety control zone: either AIRSS or the Polar Operational Limit Assessment Risk Indexing System (POLARIS) (IMO 2016b). Specifically, if the ship in question is of Polar Class or built after 1 January 2017, POLARIS must be used. The implied preference for POLARIS use under the ASSPPR rests on it being the more current and global of the two methodologies, as well as it having a built-in review period of 4 years set by the IMO to evaluate its efficacy.

The ASSPPR continues to require the presence of an ice navigator on board ships above 300 GT not certified in accordance with SOLAS. An ice navigator is a qualified master or deck watch officer who has served in this capacity on board a ship for a minimum of 50 days, 30 of which are to be in ice-infested Arctic waters.

Finally, Canadian ships built after 1 January 2017 must also be assigned a specific low air temperature notation in addition to the Polar Service Temperature. This notation is to ensure that systems and equipment not covered by the Polar Code or other IMO instruments remain functional at this temperature (e.g., deck machinery, hydraulic systems).

15.5 Pollution Prevention Measures

The pollution prevention provisions of the ASSPPR were developed with an understanding that, under the AWPPA, a complete prohibition on the discharge of waste from ships exists except when authorized by regulations. Therefore, the ASSPPR assume this complete prohibition as a baseline and only introduce select operational and structural pollution prevention measures as found in Part II-A of the Polar Code, rather than fully incorporate by reference. Unless provided otherwise, Part 2 of the ASSPPR is applicable to all ships operating in Canadian Arctic waters and all Canadian ships operating in polar waters.

15.5.1 Prevention of Pollution by Oil

Concerning the prevention of pollution by oil, the Polar Code sets out both operational and structural requirements. Operationally, all discharges into the water column of oil or oily mixtures are completely prohibited, essentially aligning Arctic standards with measures already in place in the Antarctic area (after its designation as a Special Area under MARPOL Annex I on 16 November 1990), and thereby prohibiting even the trace amounts of discharge (e.g., 15 ppm) permitted under the MARPOL Convention.

Structurally, all ships built on or after 1 January 2017 that have been designed for operations in thin to medium first-year ice, and with an aggregate oil fuel capacity of less than 600 m^3, require the separation of oil fuel tanks, oil cargo tanks, and sludge tanks from the outer shell. In addition, smaller oil tankers of less than 5000 tonnes, built on or after 1 January 2017, and also having been designed for operations in thin to medium first-year ice, require cargo tanks to be constructed with added protection, including double bottom tanks. In doing so, the structural provisions currently applicable under MARPOL Annex I to larger ships are essentially extended down to ships of all sizes operating within the polar regions.

Maintaining Canada's prohibition on the discharge of oil in Canadian Arctic waters therefore required prohibiting Polar Code allowances for the discharge of clean ballast (that may contain up to 5 ppm of oil) and the discharge of oily water from machinery spaces of Category A ships operating for more than 30 days in the Arctic.

15.5.2 Control of Pollution by Noxious Liquid Substances in Bulk

Under MARPOL Annex II, ships (e.g., chemical tankers) are permitted the controlled discharge of certain noxious liquid substance (NLS) residues, as well as the discharge of ballast water or tank washings that contain NLS. The Polar Code, however, completely prohibits these discharges, though in the Arctic region only, as regulations already exist prohibiting similar discharges in the Antarctic area (pursuant to its designation as a Special Area under MARPOL Annex II on 30 October 1992).

In addition, under section 2.1.2.3 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), ships built on or after 1 January 2017 designed for operations in thin to medium first-year ice that carry NLS deemed to have "sufficiently severe" environmental and safety hazards now require approval by their flag state administration to carry these substances. "Sufficiently severe" is third in rank in the IBC Code behind "severe" and "appreciably severe," and unlike these other two categories is not subject to prescribed location requirements for cargo tanks. Accordingly, the goal of this provision is to limit the carriage of NLS against the side shell of ships operating in polar regions by requiring extra discretion through flag state approval.

As the AWPPA already prohibits the discharge of NLS, the ASSPPR does not duplicate this Polar Code prohibition. However, the remaining operational requirements contained within the Polar Code with respect to modifying ship documentation (e.g., Cargo Record Books and Manuals) are incorporated in the ASSPPR.

15.5.3 Prevention of Pollution by Sewage from Vessels

The Polar Code sets out operational requirements allowing for the release of sewage only when done in accordance with specific provisions, including at a range of specified distances based upon whether or not the sewage has been ground and disinfected. Whereas MARPOL Annex IV establishes discharge distances from land, the Polar Code's primary difference here is that it also considers discharges from the ice shelf, fast ice, and areas exceeding 1/10th ice concentration.

For ships operating with an approved sewage treatment plant, discharge distances set out under the Polar Code are less prescriptive, though they must still occur as far as practicable from the ice shelf, fast ice, and areas exceeding 1/10th ice concentration. Indeed, all ships designed for operations in thin to medium first-year ice and all passenger ships constructed on or after 1 January 2017 must have an approved sewage treatment plant on board; otherwise sewage is to be retained. These new rules are similar to those currently applicable under MARPOL Annex IV, Regulation 11, paragraph 3, which prohibits the discharge of sewage from passenger ships operating in Special Areas except if using an approved sewage treatment plant certified by the Administration, and provided that the effluent does not produce visible floating solids or cause discoloration of the surrounding water.

The AWPPA and the ASPPR previously allowed for the release of untreated sewage into Canadian Arctic waters (AWPPA 1970; ASPPR 2006). Recognizing the advancements in sewage treatment technology, the ASSPPR replace this allowance with the Polar Code's requirement for the discharge of treated sewage from ships 400 GT or more or certified to carry more than 15 persons. Additionally, the ASSPPR incorporate modified versions of the Polar Code's various other operational discharge requirements not currently included within the Canadian regime, including minimum discharge distances from ice. For ships not subject to MARPOL Annex IV though more than 15 GT but less than 400 GT, the discharge of sewage will be subject to certain distance and speed considerations. For ships of not more than 15 GT, untreated sewage will remain permitted.

15.5.4 Prevention of Pollution by Garbage from Vessels

The disposal of garbage generated on board ships is also addressed by the Polar Code. As MARPOL Annex V already covers the Antarctic area and sets out strict discharge provisions, the Polar Code's regulations on garbage are primarily limited to the Arctic region, thereby making it a de facto Special Area. Therefore, in both the Arctic and Antarctic, the discharge of garbage (including animal carcasses) is prohibited with the exception of food wastes, provided such wastes are ground and comminuted, and disposed of at set distances from land and ice. Regardless of area of operation, MARPOL Annex V, Regulation 3, already prohibits the disposal of all plastics within the water column, including synthetic ropes, synthetic fishing nets, plastic garbage bags, and incinerator ashes from plastic products.

Only certain operational requirements contained in the Polar Code pertaining to garbage are incorporated into the ASSPPR. As with other discharges, the AWPPA prohibits the release of waste except as provided by regulations. Accordingly, the Polar Code's allowances for the discharge of cargo residues, while subject to certain conditions, nevertheless remain prohibited under the ASSPPR. For ships operating in Canadian Arctic waters, only food waste subject to certain criteria (e.g., comminuted or ground) is permitted to be discharged and, similar to sewage discharge requirements, is also subject to minimum distances from ice.

15.6 Consequential Amendments

To avoid conflict, duplication, and to reflect internationally agreed upon standards, a variety of consequential amendments were made to several other regulations upon entry into force of the ASSPPR. In addition to repealing the Arctic Shipping Pollution Prevention Regulations, sections of both the Navigation Safety Regulations (2005) and Ship Station (Radio) Regulations, 1999 (2000) pertaining to additional navigation safety equipment while operating within Arctic shipping safety control zones were also removed in lieu of those requirements identified within the Polar Code. Further, modifications to sections of the Vessel Pollution and Dangerous Chemical Regulations (VPDCR 2012) were made to remove any conflict with the pollution prevention measures contained within the ASSPPR.

15.7 Regulatory Publication

The ASSPPR were published in Part I of the Canada Gazette on 1 July 2017 (Government of Canada 2017) and were accompanied by a 75-day comment period. During this time, comments from 10 separate stakeholders were received. These comments generally included requests for the inclusion of additional content considered to be outside the scope of the regulations (e.g., a ban on heavy fuel oil use by ships in the Arctic) and requests for clarity of interpretation.

A consequence of the ASSPPR's primary focus on incorporation of the Polar Code is that the regulations are non-exhaustive in their treatment of other environmental concerns facing the Arctic, including many raised by stakeholders that remain unaddressed at both the domestic and international levels. However, their omission does not reflect their level of importance, nor does it preclude the possibility of them being addressed within Canada's Arctic shipping regime at a later date. Rather, as these issues would have required further consideration and consultation that could have delayed the domestic implementation of the Polar Code, Canada made the decision to address them separately.

Overall, no objections to the regulations were received and no substantive changes were made as a result of stakeholder input. Only minor amendments for purposes of added clarity were introduced. The ASSPPR were then published in Part II of the Canada Gazette (Government of Canada 2018) and registered on 19 December 2017, thereby meeting the delayed entry into force window set at 1 January 2018.

Accordingly, on 8 February 2018, the High Commission of Canada in London advised the Secretary-General of the IMO that with respect to MARPOL amendments, Canada had completed its national procedural requirements for bringing them into force. In doing so, Canada approved, under Article 16(2)(f)(ii) of MARPOL, the entry into force of these amendments. With respect to SOLAS, Canada's view was that in accordance with Article VIII(b)(vii)(2) of SOLAS, these amendments automatically entered into force on 1 January 2018, and that no additional express notification was required.

15.8 Conclusion

Inasmuch as the Polar Code marked a sea change in the international order for ships operating in the Arctic and Antarctic, its adoption and entry into force did not bring to a conclusion discussions on how to further reduce risk or fully confront the unique hazards ships encounter in these regions. Indeed, the comments received during regulatory pre-publication of the ASSPPR provide evidence of this. Further, for all its deserved praise in effectively replacing the otherwise inconsistent regulatory environment for ships transiting high latitudes, the Polar Code's less prescriptive goal-based approach to standard setting for safety measures (representative of a new direction within the IMO) has resulted in certain open interpretations.

To address this, the IMO Sub-Committee on Ship Systems and Equipment (SSE) has developed Interim Guidelines on Life-Saving Appliances and Arrangements for Ships Operating in Polar Waters (IMO 2019a) in an effort to further mitigate polar hazards and to facilitate compliance with Chapter 8 (Life-Saving Appliances and Arrangements) of the Polar Code. Meanwhile, the IMO Sub-Committee on Navigation, Communications and Search and Rescue (NCSR) also developed Guidance for Navigation and Communication Equipment Intended for Use on Ships Operating in Polar Waters (IMO 2019b) that provide recommendations on general requirements as well as specific performance standards.

In parallel to these efforts, the IMO's MSC is considering the extent to which additional safety measures related to navigation safety and voyage planning should be made mandatory for non-SOLAS ships operating in polar waters. Complementary Guidelines for Safety Measures for Fishing Vessels 24 Meters and Over Operating in Polar Waters and Guidelines for Safety Measures for Pleasure Yachts of 300 GT and Above not Engaged in Trade Operating in Polar Waters (IMO 2018) are also in the process of being developed at the request of MSC by the IMO's Sub-Committee on Ship Design and Construction.

Efforts to provide further regulatory clarity concerning polar ship operations are not restricted to the IMO. Indeed, since the entry into force of the ASSPPR, Canada has updated or developed a range of new bulletins, guidelines, and standards, all of which are intended to facilitate the implementation and harmonized interpretation of the Polar Code in Canada. For example, the Arctic Ice Regime Shipping System Standard (Transport Canada 2018) has been updated to reflect the use of POLARIS as an official methodology for ships to assess operational capabilities and limitations in ice. Additionally, the AIRSS Pictorial Guide (Transport Canada 2003) and User Assistance Package (Transport Canada 1998) have both been replaced in lieu of the more comprehensive Guidelines for Assessing Ice Operational Risk (Transport Canada 2019) which describe, in practical terms, the application of parts of the ASSPPR and other regulations relevant to reducing the risks for vessels navigating in Arctic waters under Canadian jurisdiction.

The Polar Code remains a comparatively new international instrument and as such continues to contend with a paucity of experience in application. The same is also true of the ASSPPR. Aided by various clarification and guidance material, invaluable practical experience will accumulate over time to further inform interpretations, providing the needed justification for regulatory fixes or improvements to the safety and pollution prevention standards of both regimes.

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Chapter 16
Integrated Ocean and Coastal Zone Management in France: Some Perspectives

Annie Cudennec

Abstract French integrated ocean management takes place in the framework of the Integrated Maritime Policy (IMP), the European policy whose aim is to foster coherent decision-making. France has to respect the European commitments imposed by the IMP and especially the Marine Strategy and the Maritime Spatial Planning Directives. On this basis, France has adopted a National Sea and Coast Strategy. The Strategy defines four maritime façades. For each façade, a strategic document, under development, will be the reference framework, taken into account by all maritime actions. The scheme set up by the French maritime strategy is ambitious and complex. Let's hope that it will be a suitable manner to develop a real integrated ocean management policy in France.

Keywords Blue economy · Coastal zone management policy · Coastline · European Integrated Maritime Policy · European Union · French law · Law of the sea · Maritime affairs · Marine environment · Marine policy · Maritime spatial planning

16.1 Introduction

Around 10 years ago (Legislation 2010), France initiated a process for managing its marine and coastal waters in what turned out to be a rather long and progressive procedure that has not yet been successfully achieved (Trouillet et al. 2011). One important step in this process is the National Strategy for the Sea and Coast, which was launched and adopted in 2017 (Legislation 2017a; Ministry for an Ecological

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and Solidary Transition 2017). It sets out the necessary steps to be carried out before French integrated ocean and coastal zone management is set to become a reality in 2022 (Legislation 2017b). While France is learning from other national experiences, especially existing European measures, it is worthwhile examining the process it has launched for managing and developing its national policy for ocean and coastal zones.

For a better understanding of how this policy is being developed in France, it is necessary to grasp the importance of the sea and the maritime economy to the country. France has the second largest maritime domain in the world with an exclusive economic zone (EEZ) of 11 million square kilometres and a shoreline of more than 5800 kilometres (shoreline not including the overseas territories). The French blue economy represents 1.5% of France's GDP, 460,000 jobs and 30 billion euros of added value. The main activity is tourism, representing over half of the added value and over half of the jobs.[1]

France has had a long interest in maritime activities and policies, as shown by the adoption of the Great Ordinance of Marine in 1681, under the reign of Louis XIV, which is the first text to codify the uses of the sea in France. Much has changed since this period, and today, in addition to its national legislation, France is a signatory to the major international maritime instruments such as the United Nations Convention on the Law of the Sea, 1982 (UNCLOS). It must be emphasized that France is mostly party to these agreements alongside the European Union (EU) of which it is a Member State.

Marine and maritime affairs were not really addressed in the first EU treaties, but they are becoming an increasingly crucial topic for the EU. By adopting the Blue Growth Strategy in 2012, the European Commission highlighted the importance of marine affairs in Europe, especially the blue economy that represents 5.4 million jobs and a gross added value of just under 500 billion euros per year (European Commission 2012). As a European state, France must respect European regulations.

Since the founding of the European Economic Community (EEC) in 1957, the progressive recognition of the importance of the sea and sea-related activities has led to the development of European maritime regulations (Paasivirta 2017). These regulations cover all aspects of maritime activities such as the exploitation of marine resources, living resources (Cudennec and Curtil 2015) or minerals, maritime transport (with important rules on maritime safety) and preservation of the marine environment. To ensure coherence between all of its actions, the EU adopted the Integrated Maritime Policy (IMP) in 2007 (European Council 2007). It is defined as a

> [EU] policy whose aim is to foster coordinated and coherent decision-making to maximise the sustainable development, economic growth and social cohesion of Member States, and notably the coastal, insular and outermost regions in the Union, as well as maritime sectors, through coherent maritime-related policies and relevant international cooperation. (European Union 2014, art. 3)

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[1] The other major French maritime activities are offshore oil services (17% of added value), maritime transport (8% of added value) and sea products (8% of added value) (Ifremer 2017).

The objective of the IMP is to connect all maritime activities, for example, maritime transport, marine environmental protection and fisheries (Koivurova 2009). Under the IMP, the EU sets out a strict framework that must be respected by all Member States when developing their domestic marine policies, in particular integrated ocean management (IOM). France's action falls within this framework, and as such, domestic IOM policy must comply with European commitments, especially the EU IMP.

16.2 France's Integrated Ocean Management Policy: Part of the European Maritime Framework

One of the IMP's main commitments is an environmental obligation prescribed by the Marine Strategy Framework Directive (MSFD) adopted in 2008 (European Union 2008).[2] Under the MSFD, Member States must take all necessary measures to achieve or maintain good environmental status (GES) in the marine environment by 2020 at the latest (art 1). Article 3.5 defines GES as

> the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.

To adapt to the needs of each specific European marine region and thus ensure that this objective can be respected, the MSFD defines several subregions along Member States' coasts. Four French subregions have been defined: Channel-North Sea, Celtic Sea, Bay of Biscay, and West Mediterranean. For each of these subregions, France has been required to establish an Action Plan for the Marine Environment (PAMM – *Plan d'action pour le milieu marin*). Each Action Plan consists of specific measures adapted to the subregion's particularities in order to get a GES for the marine environment by 2020.[3]

More precisely, the elaboration of the Action Plan observes several stages defined by the EU in the MSFD. The first one is the definition of the initial assessment. This assessment comprises an analysis of the essential features and characteristics of the

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[2] Under European law, a directive "shall be binding, as to the result to be achieved, upon each Member State to which it is addressed, but shall leave to the national authorities the choice of form and methods" (TFEU 2016, art 288). If national authorities do not take sufficient measures to reach the objective assigned by the Directive, the Member State concerned can be prosecuted before the Court of Justice of the European Union (CJEU) and be required by the Court to fulfil its obligations. The CJEU can impose a lump sum or a penalty payment on the Member State.

[3] For example, for the Channel-North Sea, this subregion is particularly concerned with maritime transport due to the importance of commercial harbours such as Le Havre. The Channel-North Sea Action Plan includes several measures that limit the introduction of exotic species in the marine environment from ships.

current environmental status of marine waters[4] and an analysis of the predominant pressures and impacts including human activity on the environmental status of its marine waters (art 8.1). On the basis of this initial assessment, France has established a set of environmental targets for its marine waters including preservation of biodiversity and non-disturbance of the ecosystem by non-indigenous species. These targets provide a crucial guide to achieve GES in the marine environment. Subsequently France adopted some monitoring programs, including programs of measures, in several inter-prefectoral orders in April 2016.

The approach enforced by the European Marine Strategy shows that the EU has prioritized the environmental dimension in its definition of European IOM: the MSFD makes all maritime policies and actions coherent because they are all linked by the same objective, that is, to achieve GES for the marine environment by 2020. To comply with this rather complex process (Cavallo et al. 2019), France and all other EU Member States have undertaken several types of actions.[5] More specifically, and as set out in the MSFD (art 13.4), the French programs of measures include spatial protection measures such as special areas of habitat conservation or special bird protection areas, in accordance with European regulations pre-dating the MSFD, such as the Habitat Directive (European Council 1992; European Commission 2018).

The EU has given prominence to this spatial approach, and, after giving priority to the environmental dimension, formalized by the MSFD, the integrated approach is now being extended (Gilbert et al. 2015) to the spatial dimension. Spatial integration has been developed by adopting a new legal tool, a text that supplements environmental integration and that must be respected and implemented by all Member States, namely, the Directive establishing a framework for maritime spatial planning (Directive 2014/84/EU European Union 2014). As stated in Article 1 of the Directive, this text has been adopted because of “the high and rapidly increasing demand for maritime space for different purposes” that has made it ever more crucial to organize the sharing of space in European waters (Ansong et al. 2019). Therefore, to limit and prevent conflicts between maritime activities and uses, the EU decided to establish an integrated planning and management approach (Cudennec 2015).

Under Directive 2014/89/EU, maritime spatial planning is defined as a “process by which relevant Member State’s authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives” (art 3.2). The objective of the Directive is significant: maritime spatial planning aims “to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and

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[4] Article 3.1 of the MSFD (European Union 2008) defines marine waters as the “waters, the seabed and subsoil on the seaward side of the baseline from which the extent of territorial waters is measured extending to the outmost reach of the area where a Member State has and/or exercises jurisdictional rights”.

[5] Due to this complexity, it may be difficult for Member States to comply with the MSFD. As underlined by the European Commission in 2018, “not all the pressures on the marine environment are covered properly through the measures adopted by Member States” (European Commission 2018, 21).

improvement of the environment, including resilience to climate change impacts" (art 5.2). To achieve these objectives, France faces a real challenge: to establish maritime spatial plans as soon as possible and at the latest by 2021 (art 15.3).

Directive 2014/84/EU underlines Member States' responsibilities (Friess and Grémaud-Colombier 2019). Under this Directive, the French authorities are accorded considerable responsibilities to develop maritime spatial planning in French marine waters. To do so, they must identify the spatial and temporal distribution of relevant existing and future activities and uses in France's marine waters. These activities and uses can include aquaculture or fishing areas, installations for the exploration, exploitation and extraction of energy resources, minerals and aggregates, for the production of energy from renewable resources, maritime transport routes and traffic flows and for nature and species conservation sites and protected areas (art 8). Land-sea interactions must be taken into account to promote coherence between maritime spatial planning and other formal or informal processes, such as integrated coastal management. France must cooperate with other Member States and also with third countries.

France also has to satisfy some transversal commitments. First, national authorities must ensure the involvement of all stakeholders and guarantee public participation at an early stage in the development of maritime spatial plans (art 9). Then, using the best available data (environmental, social, economic and marine physical data), national authorities decide how to organize knowledge sharing, a necessary part of maritime spatial plans (art 10). Therefore, under Directive 2014/89/EU, France is required to replace its existing sectorial approach of zoning – for instance, determining areas of fishing, water quality, marine renewable energies and marine protected areas – with an integrated vision of all uses of marine space to give coherence to all previous actions (Boillet 2019).

Up until this point, it can be seen how the EU defines environmental and spatial integration commitments that France must respect when developing domestic integrated marine policy. Under this framework, it is now possible to specify the current French policy for the marine environment and the way chosen to define the French Integrated Ocean and Coastal Zone Management Policy.

16.3 Implementing European Requirements Through the French Integrated Ocean and Coastal Zone Management Policy

16.3.1 The Cornerstone of France's Action: Strategy for the Marine Environment

France's Integrated Ocean and Coastal Zone Management Policy is part of the French Marine Environment Policy, which is based on two laws. The first is the Law on National Commitment for the Environment adopted in 2010, which is at the origin of the Marine Environment Policy (Legislation 2010). This instrument has been supplemented by the Law on the Recovery of Biodiversity adopted in 2016 (Legislation 2016). Both of these texts have been codified in the French Environment Code (*Code de l'environnement*), which dedicates an entire chapter to marine environmental policy. This policy is divided into two aspects: integrated ocean and coastal management that reflects the spatial approach as prescribed by Directive 2014/89/EU and the protection and preservation of the marine environment that reflects the environmental approach prescribed by the MSFD.

The synthesis between the environmental and the spatial approach stems from the adoption in 2017 of the National Strategy for the Sea and Coast (Legislation 2017a; Ministry for an Ecological and Solidary Transition 2017), which aims to provide a reference framework for all public sea- and coast-related policies. The Strategy sets out the following objectives: ecological transition of the sea and coastline, development of the sustainable blue economy,[6] GES of the marine environment and the preservation of an attractive coastline, as well as France's influence internationally. To achieve these objectives, the National Strategy for the Sea and Coast has defined four cross-cutting areas: reliance on knowledge and innovation, development of sustainable and resilient maritime territories and coastal territories, support for and enhancement of initiatives and promotion of the French vision, and stakes within the EU and in international negotiations. The Strategy then sets out 26 priority actions, each one extremely different from the other, of which the following are noteworthy: training for maritime jobs, developing marine spatial planning that balances all maritime uses, determining 100 "zero net energy" territories, preserving maritime heritage, establishing maritime jurisdictions dedicated to maritime litigations and developing the maritime energy sector.

Under this framework and in order to create a strategy that is well adapted to each of its maritime regions, France has designated four coastlines: East Channel-North Sea, North-Atlantic-West Channel, South Atlantic and Mediterranean Sea. Figure 16.1 shows that the perimeter of each coastline is different from the perimeter of each subregion defined by the MSFD. Of course, this could potentially increase the complexity of the process and impact its coherence. Further, this hinders the development of the measures that implement the MSFD prescriptions.

16.3.2 A Strategy Adapted to Each Maritime Subregion

For each coastline, a Sea Basin Strategy Document (*Document Stratégique de Façade* – DSF) must be prepared (Environment Code, art R219-1), and at present (June 2019), there are four in progress. The DSF is regarded as the reference framework, the integrated tool that must be taken into account and be observed by all maritime policies and actions (fisheries, transport, environment, etc.).[7] More specifically, with the integration of the MSFD-related European commitments and

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[6] As stated by the Decree, blue economy means the sea-related maritime and coastal economy.

[7] Each DSF will be adopted by a decree in the Council of State (*Conseil d'État*).

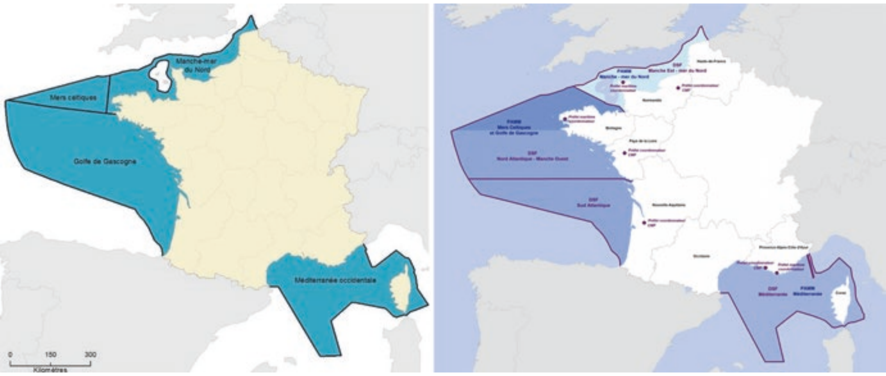

Fig. 16.1 The four coastline designations under the Marine Strategy Framework Directive (left) (Ifremer 2012) and the National Strategy for the Sea and Coast (right) (Ministry of Environment, Energy and the Sea 2017)

Directive 2014/789/EU (Legislation 2017b), these documents will constitute the main IOM instruments in France.

There are two components for each DSF: strategic and operational. The strategic component must be adopted in 2019[8] and the operational component in 2022. In order to develop the strategic component, national authorities must determine the initial situation by identifying existing activities, activity-environment interactions, land-sea interactions and planning actions that have already been adopted. This strategic component must provide details about the main issues and an assessment of their evolution, such as the environmental situation and new needs.

The determination of the original situation is needed in order to formalize the key objectives by 2030. These objectives are all-encompassing: environmental (resulting from the MSFD), economic and social. The strategic component must then justify the spatial coexistence of the uses and determine coherent areas in terms of issues and objectives. Finally, all of these elements form a "vocation map" that needs to be established to enable the operational component to be developed.

As required by the Environment Code (art R 122-17) and according to the environmental objectives, the strategic component is based on a strategic environmental assessment that must make sure all definitive choices are relevant. The assessment may propose measures to avoid, reduce or offset the potential environmental impacts of the activities carried out.[9]

Several steps are required in operationalizing the DSF. The first is to determine some assessment procedures that include a set of relevant criteria and indicators. To do so, the previously mentioned MSFD monitoring programs must be referred to.

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[8] See, for example, the project adopted in February 2019 for the North Atlantic-West Channel coastline (Ministry for the Ecological and Inclusive Transition 2019).

[9] For example, see the environmental evaluation for the North-Atlantic-West-Channel sea coastline (DGALN 2018).

The final step of the DSF involves establishing and implementing an action plan. It must be noted that the MSFD Action Plan will form a part of the adopted DSF Action Plan.

By analysing the DSF's two components, it can be seen that the documents include previous actions, especially the actions carried out in an environmental approach through the MSFD. In fact, as stated in the Environment Code, all actions adopted before the launch of the National Strategy for the Sea and Coast must "be compatible with the objectives and provisions of the Sea Basin Strategy Document…" (art L219-4-I). This means that the actions adopted under the MSFD (monitoring programs, Action Plans, etc.) and the maritime spatial planning directive must be coherent with the DSF.

16.3.3 An All-Inclusive Strategy

In analysing the development of the DSF, it is clear that French authorities want to maintain control of the process. The DSF is developed by the State (Environment Code, art L219-2), more precisely by the Minister for the Sea (Environment Code, art L219-1-2).[10] National consultation is ensured by the National Council for the Sea and Coastlines (*Conseil National de la Mer et des Littoraux* – CNML). This Council is the competent national strategic forum for all questions on the sea and the coastline. Its president is the Prime Minister, and it is composed of 52 members representing all public and private stakeholders involved in maritime issues. The Council acts in an advisory role for the main texts (decrees) on maritime issues. It can be consulted on any questions concerning the sea and the coastline and is a real source of proposals to the government. This national council has a local-level guidance role represented by the consultative body, the *Conseil maritime de façade*.

More precisely, at the local level, the development of the DSF is also the responsibility of state representatives, mainly the maritime prefect (who represents the state on sea matters), the region's prefect and coordinating prefects. These prefectural authorities rely on the Maritime Council for the Coast, which is under the guidance of the aforementioned CNML, and it is the discussion forum for all regional maritime stakeholders. It is composed of public authority representatives and professional activity representatives (fishers, shipowners, port authorities, employee representatives, marine environment protection associations, sea user associations). The Maritime Council for the Coast makes recommendations to the national authorities on the use, preservation and enhancement of the shoreline and sea.

All citizens can express their views in a prior consultation organized by the National Commission for Public Debate (*Commission Nationale du débat public*

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[10] At present (June 2019), this is the Ministry for the Ecological and Inclusive Transition (*Ministère de la transition écologique et solidaire*).

– CNDP). This is an independent administrative authority and a major participatory democracy instrument in France whose objective is to provide information to citizens and to ensure that their point of view is taken into account effectively during the decision-making process. However, the jury is still out on whether this happens in reality.

Actually, this system of governance places the national authorities at the core of French maritime strategy. According to the national authorities, this is the price to pay to achieve coherence between all the actions undertaken in the various French maritime regions. In this context, national authorities must take care to effectively consider all stakeholders' interests.

16.4 Conclusion

It is clear that the scheme set up by France's maritime strategy within the European framework is ambitious and complex. In comparison to its European counterparts (Friess and Grémaud-Colombier 2019), France is not ahead of other Member States in determining its ocean strategy and especially its maritime spatial planning. However, the increase in maritime activities and uses around French coasts requires an effective global and integrated action. As the DSF process is still under construction, it is, of course, too early to say if the National Strategy for the Sea and Coast is a suitable means of developing a truly integrated ocean management policy in France. There are questions that remain unanswered such as, does this process really take into account all maritime stakes and stakeholders? Are citizens being listened to? Is their participation effective? We will return in a few years to answer these questions and to analyse the enforcement and reality of French integrated ocean management!

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