Commercial Marine Shipping Accidents: Understanding the Risks in Canada

Workshop Report

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

COMMERCIAL MARINE SHIPPING ACCIDENTS: UNDERSTANDING THE RISKS IN CANADA

Workshop Report

THE COUNCIL OF CANADIAN ACADEMIES
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This workshop report was prepared for the Clear Seas Centre for Responsible Marine Shipping (Clear Seas) and results from a two-day expert workshop informed by a survey and a review of the literature. Any opinions, findings, or conclusions expressed in this publication are those of the authors, the workshop Steering Committee, and do not necessarily represent the views of their organizations of affiliation or employment, or the sponsoring organization, Clear Seas.

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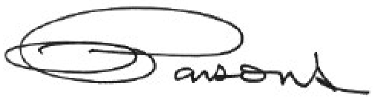
Message from the Chair

The Steering Committee wishes to thank the Clear Seas Centre for Responsible Marine Shipping for asking the Council to undertake this workshop. This report would not have been possible without the expertise and engagement of workshop participants, and all those who took the time to give critical input into the report through the peer-review process and the survey. We would also like to thank Erik Lockhart from the Executive Decision Centre at the Queen's School of Business for facilitating the workshop. Finally, the Steering Committee would like to thank the Council's project team for its excellent work throughout this process.



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Report Review

This report was reviewed in draft form by the five individuals listed below — a group of reviewers selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations.

The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Steering Committee, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the Steering Committee and the Council.

The Council wishes to thank the following individuals for their review of this report:

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Executive Summary

Over the past few decades, commercial marine shipping has benefited from a number of developments ranging from improved traffic control technology and better ship designs, to a strengthened regulatory regime and enhanced industry safety procedures. These and other changes have all helped contribute to a notable drop in marine shipping accidents, ship losses, and marine oil spills. Though efforts continue to further improve marine safety, public scrutiny of shipping has been heightened in recent years. The risks associated with opening the Arctic to greater ship traffic, increasing marine shipments of oil from Canada's oil sands, and the growth in vessel size, especially of container ships, have all contributed to this awareness.

Amidst these developments, this study seeks to contribute to a national dialogue about acceptable levels of risk. It identifies the risks of commercial marine shipping accidents across Canada's regions and for different cargo types, while highlighting gaps in understanding and areas for further research. To this end, *risk* is characterized in terms of two central elements: the likelihood that accidents will occur, and the magnitude and severity of resulting impacts. The study was commissioned by the Clear Seas Centre for Responsible Marine Shipping and is the outcome of a workshop process and survey that sought input and consensus from a diverse group of experts from across Canada with backgrounds in academia, industry, and government.

LIKELIHOOD AND IMPACT OF COMMERCIAL MARINE SHIPPING ACCIDENTS IN CANADA

This study makes clear that Canada's waters as a whole have been getting safer over the past decade, with fewer commercial marine shipping accidents. Accidents nonetheless do occur yet typically do not result in large impacts. Indeed, for a commercial shipping accident to occur and result in an impact of significance, multiple factors (e.g., weather, type of cargo, vessel age, timing of accident) must coalesce against a backdrop of a large body of regulations, safety protocols, and practices in place, which serve to mitigate risks. An accident such as a grounding or collision may damage the vessel, but not necessarily lead to any wider negative social, economic, health, or environmental effects. Further, the statistics show that most marine accidents occur in confined waters (harbours, rivers, canals) where response regimes are in place to react quickly.

With few accidents in Canada, much of the evidence on the environmental, economic, social, and health impacts of marine shipping accidents comes from elsewhere. This evidence underscores the fact that large oil spills, because of the severity of their impact, present a significant risk to Canada. Environmental impacts, both immediate and longer term, can lead to a number of subsequent social, economic, and health impacts that increase the overall degree of risk associated with oil spills. The evidence also makes clear, however, that shipment of certain hazardous and noxious substances (HNS) such as pesticides may pose as significant a risk (if not greater) as oil — not least because of Canada's underdeveloped HNS spill response system, as noted by Transport Canada's Tanker Safety Expert Panel in 2014. In the absence of further research on how substances classified as HNS behave in a marine environment, as well as public data on the frequency of HNS shipments, it is difficult to further qualify this risk.

REGIONAL VARIATIONS IN RISKS OF ACCIDENTS

Different regions face very different risk profiles owing to variances in main types of cargo, risk prevention policies such as moratoriums or pilotage zones, and waterway characteristics, including the degree of ecological sensitivity or the number of constrained waterways. Local economic, social, and cultural contexts further contribute to the diverse risk profiles across regions.

Although **British Columbia** (Pacific region) experiences the highest level of shipping activity, the accident rate and the nature of the cargo shipped, together with current and planned moratoriums, suggest it has a relatively low risk profile compared to other regions. Sensitive marine ecology and geography, a tourism industry heavily tied to marine resources, and the potential impacts on First Nations coastal communities, however, elevate the possible consequences of any accident. Tanker shipments of oil and petroleum products could increase with proposed pipeline projects, which would in turn increase the risk profile of the region.

The risk profile of the **St. Lawrence River** and the **Great Lakes** (Central region) is quite different. The St. Lawrence River experiences the highest level of commercial marine incidents and accidents in Canada and the second highest accident rate, after Northern Canada. However, accidents in this region are the least likely to lead to fatalities or serious injuries, potentially because many are minor events such as strikings along canals, where ships are moving at lower speeds. The proximity of major shipping routes to densely populated cities, the potential economic disruption, and the fact that the St. Lawrence River and Great Lakes provide drinking water for millions would add to the impact should a major accident occur. Increased shipment of crude and petroleum products would in turn increase the risk profile in the region.

The **Maritimes** and **Newfoundland and Labrador** (Atlantic region) as a whole ship more crude oil than any other region in Canada. Though harsh weather conditions and the presence of ice increase the likelihood of an accident in this region, accident rates are relatively low. Nonetheless, the reliance on fisheries (including aquaculture) and tourism, would heighten the social and economic impacts of a significant accident.

In **Northern Canada** where traffic levels are currently low, the factors that can potentially lead to a shipping accident are several and include inadequacy of navigation aids and port infrastructure, ice, and harsh weather conditions. This likely explains why the Arctic experiences a disproportionate number of accidents. There is wide consensus on the sensitivity of the environment and the potential seriousness of impact should a pollution event occur. Furthermore, the Arctic's remoteness can compromise response efforts, and with the absence of a dedicated spill response organization, the potential for impact is elevated.

RESEARCH AND DATA GAPS

Current gaps in data and research limit the degree to which Canada's commercial marine shipping risks can be fully understood and measured. For risks to be better characterized by stage of shipping or by cargo type, data are needed on the causes, the stages at which incidents or accidents occur, and the frequency of shipments by cargo type and region. This latter data on commercial marine traffic are now much more difficult to acquire since Statistics Canada terminated its publication of marine shipping statistics after releasing 2011 data. Publicly available Canadian statistics on spills, in particular, are found wanting, lacking in the completeness and consistency necessary to understand the breadth of pollution events across Canadian waters.

As for impacts associated with commercial marine shipping accidents, more research is needed on the environmental impacts of HNS, diluted bitumen, and spills in freshwater and cold environments. This research will allow for a better understanding of the extent of their impacts, which in turn can provide a better account of their risk and help improve preparedness and response.

There are also gaps in the understanding of social, economic, and health risks directly associated with major accidents, such as potential disruptions to industry supply chains. More insight into these impacts will come with the completion of the Council's expert panel assessment on the social and economic value of commercial marine shipping in Canada, also commissioned by the Clear Seas Centre for Responsible Marine Shipping and due for release in 2017.

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Introduction

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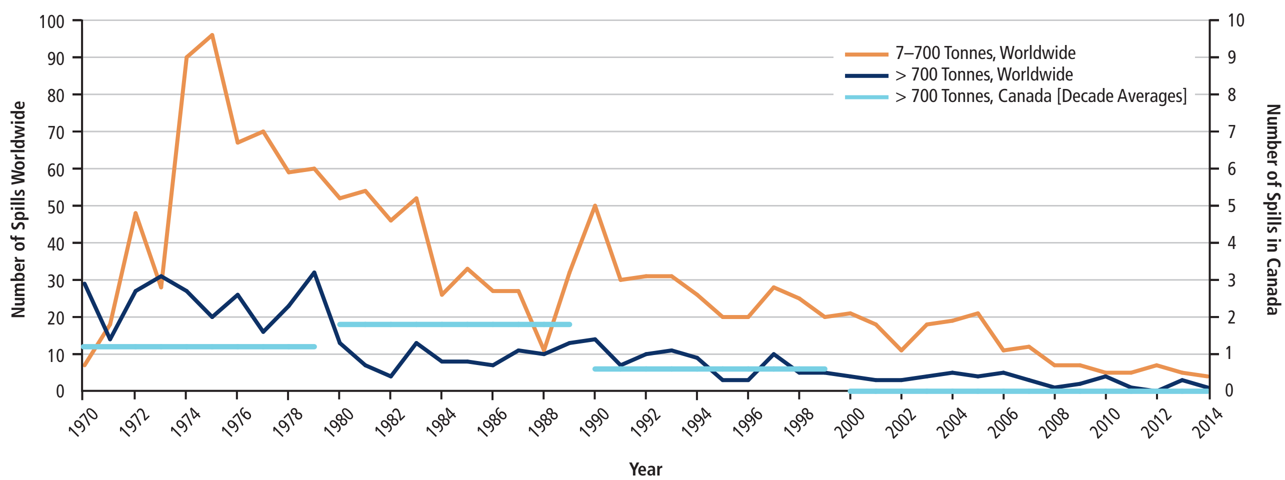
1 Introduction

Canada's economic and social development has benefited immensely from centuries of marine shipping. Since the time the country was a colonial outpost engaged in the fur trade and cod fishery to its current standing as an advanced economy embedded in global production networks, marine shipping has been central to Canada's prosperity. Marine shipping's current importance, however, could not have been realized without the significant changes that have occurred within the industry itself, particularly over the last half-century. Major shipping innovations, notably the introduction of containers in the late 1960s and, more recently, advanced navigation aids and the development of very large vessels, have revolutionized the ways in which cargo is moved. Safety too has improved with new regulations, more robust ship design codes, enhanced emergency preparedness and response systems, and better self-regulated guidelines and procedures. These developments have coincided with a notable drop in marine shipping accidents and ship losses worldwide and in Canada (Allianz, 2012, 2015), fewer oil spills (Figure 1.1), and a major increase in the amount and type of cargo traded globally over the past half century (Bernhofen *et al.*, 2016). Indeed, the value of marine trade shipped to and from Canada nearly doubled between 2003 and 2014 (TC, 2014a, 2015a).

Shipping's growing prominence is made visible to the general public by an increasing number of large cargo vessels and tankers in close proximity to major population centres. Globally, carrying capacity of the largest container vessels has increased by some 1200% since 1968 and by 80% in the last decade alone (Allianz, 2015). The largest ships are now capable of holding over 19,000 shipping containers — equivalent to 39,000 cars or 117 million pairs of shoes. This introduces new issues such as the concentration of risk, salvage challenges, and potential losses of over US$1 billion in the event of a major accident (Allianz, 2015). There are also increasing concerns over the growth of commercial shipping in the Arctic, as well as the potential impacts of a changing climate on shipping. Further, in western Canada, the development of the oil sands together with proposed pipeline projects could increase shipments of hazardous cargo. Collectively, these concerns have heightened public scrutiny of marine shipping to the point where the shipping industry itself is now realizing that it must continue to improve its safety reputation if it is to maintain public acceptance for the marine transportation of solid and liquid cargo.

For its part, the federal government has taken a number of steps towards helping reduce marine shipping risks. Most recently, it has called on the Ministers of Transport, Environment and Climate Change, and Fisheries and Oceans and the Canadian Coast Guard to work together to improve marine safety, and to formalize a moratorium



Data Source: Huijer, 2005; WSP Canada Inc., 2014a; ITOPF, 2015

Figure 1.1

Trends in Oil Spills from Tanker Ships, Worldwide and Canada

Oil spills have been on the decline over the past four decades, both worldwide and in Canada. In the 1970s there was an average of 24.5 spills of over 700 tonnes per year, compared to 3.4 for the 2000s and 1.8 for the current decade (2010 to 2014). In Canada, the number of spills dropped from an average of 1.2 spills of over 700 tonnes in the 1970s to 0 in the 2000s and first half of the 2010s. Note that the volume of oil spilled accounts for all oil lost, including oil that burned or remained in a sunken vessel.

on crude oil tanker traffic on British Columbia's North Coast (Office of the Prime Minister, 2015). This follows Transport Canada's funding of the Network of Expertise on Transportation in Arctic Waters (NEXTAW) and its commissioning of the Tanker Safety Expert Panel (TSEP, 2013, 2014), the latter of which produced two reports. One of these reports reviews and makes recommendations for improving Canada's ship-source oil spill preparedness and response regime south of the 60th parallel, and the other focuses on requirements for Arctic waters and establishing a formal ship-source HNS (hazardous and noxious substances) incident preparedness and response program.

In 2015, the federal government also helped establish the Clear Seas Centre for Responsible Marine Shipping (Clear Seas), an independent centre of expertise on safe and sustainable marine shipping in Canada. A non-profit operating out of Vancouver, British Columbia, Clear Seas has been given a national mandate to "facilitate research, analyze policies, identify best practices for safe and sustainable shipping worldwide, share information broadly, and create open dialogue with communities, starting with those along our coasts" (Clear Seas, 2015).

In support of its national mandate, Clear Seas asked the Council of Canadian Academies (the Council) to review the breadth of risks associated with marine shipping across Canada's regions, reflecting the views of a multisectoral group of experts. With a broader expert account of the environmental, economic, and social risks, Clear Seas aims to build consensus on the scope and character of risks that can be used to lay the groundwork for future assessments and research, and which can be made accessible to all those involved in, or affected by, decision-making related to commercial marine shipping. This workshop report complements a second expert panel assessment being conducted by the Council on the value of commercial marine shipping due to be released in 2017. Together, these reports could contribute to a national dialogue about acceptable levels of risks of shipping in Canadian waters.

1.1 CHARGE TO THE WORKSHOP

Specifically, Clear Seas asked the Council to organize a workshop that could respond to the following questions:

> *What are the main areas of social, environmental, and economic risk associated with key stages of marine shipping of goods in Canadian waters? Are these risks commonly agreed upon? To what extent are they measurable?*

In responding to the charge, the Council brought together 19 experts with backgrounds in industry, academia, and the public sector for a two-day workshop held in Toronto on the 29th and 30th of October, 2015. To assist in preparing for the workshop, the Council struck a steering committee of four experts to provide guidance in drafting a detailed review of relevant peer reviewed literature, reports, and statistics, and in developing a survey on marine shipping risks in Canada. The survey was administered by the Council in September 2015 and sought input from marine shipping stakeholders across Canada with expertise in the field of commercial marine shipping and knowledge of the impacts of shipping accidents. At the workshop, participants were asked to consider the results of the literature review and survey, as well as other issues that arose as they worked towards a consensus on identifying and characterizing the main risks by region. More information on the workshop and survey can be found in Appendix B.

Canadian waters was defined as the coastal waters within the 200 nautical mile Exclusive Economic Zone of six regions: British Columbia, the Maritimes (Nova Scotia, New Brunswick, Prince Edward Island), Newfoundland and Labrador, and Northern Canada (including Churchill, Manitoba), plus the inland waterways of the Great Lakes and the St. Lawrence River (Figure 1.2). For the purpose of some types of analyses, the Great Lakes and St. Lawrence River were considered together and referred to as the Central region. Similarly, in some instances, the Maritimes and Newfoundland and Labrador were merged and referred to as the Atlantic region.

Workshop participants were asked to consider the risks associated with the following stages of marine shipping:[1] a) cargo operations alongside (at berth)/cargo operations at anchor; b) bunkering operations alongside (at berth)/ bunkering operations at anchor; c) underway with and without pilot; and d) underway with tugging/escort. They were also asked to take into account the following categories of goods: i) crude oil; ii) refined hydrocarbons; iii) liquefied natural gas (LNG); iv) HNS (other than LNG, crude oil, and refined hydrocarbons); v) dry bulk (grain, iron ore, coal, etc.); and vi) container.

1 Definitions for shipping terms included in the report are provided in the Glossary of Terms (Appendix A).

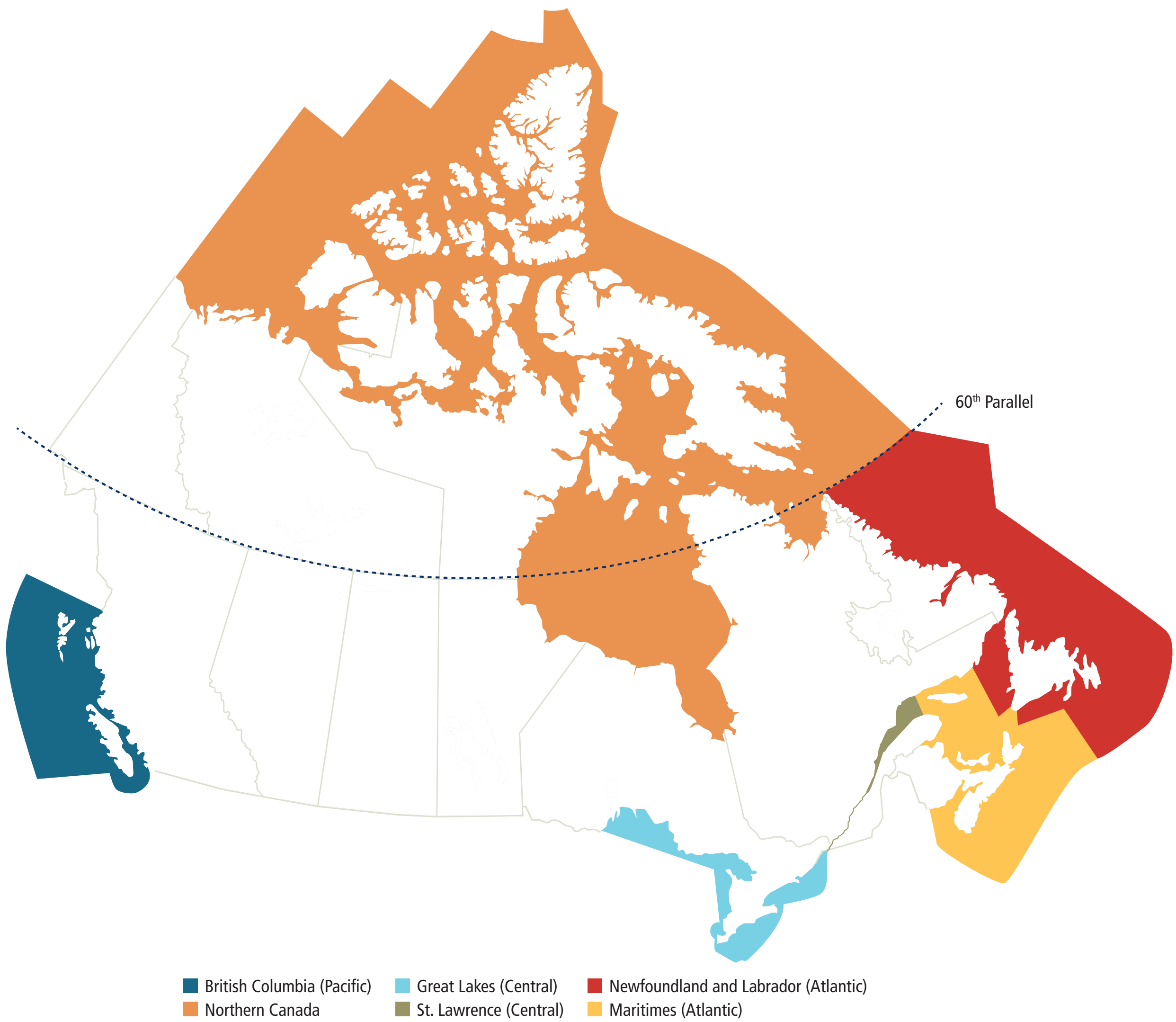


Figure 1.2
Commercial Marine Shipping Regions

1.2 SCOPE

At the request of Clear Seas, the focus of this workshop report is to identify the risks stemming from commercial marine accidents at the different stages of shipping, for different cargo types and across six Canadian regions. The report is therefore not a complete risk assessment, nor does it seek to measure risk. It was also requested that the emphasis be on risk characterization rather than on risk management and mitigation measures. However, in recognition of the important role that the regulatory system and the various safety protocols and practices have in mitigating risk, workshop participants agreed that there be a review of the various components of the marine safety system now in place.

In keeping with the mandate of Clear Seas, this report is concerned with commercial marine shipping and therefore excludes the risks of accidents involving fishing and passenger vessels despite their significance, including the potential for loss of life. Also, with a focus on risks of accidents, the report does not examine the risks that stem from routine shipping activity. These risks from routine shipping activity, however, warrant recognition given the range of impacts that shipping, in the absence of any incident or accident, can have on marine ecosystems as well as port regions (Box 1.1). Finally, workshop participants agreed that health risks should be considered separately from social risks. Thus, this report looks to identify and characterize environmental, economic, social, and health risks.

Box 1.1
Some Risks from Routine Shipping Activity

Workshop participants acknowledged that routine shipping can have many types of negative impacts that are beyond the scope of this report. These include water pollution, toxic contamination by antifouling paints, seabird collision and behaviour changes, ship strikes of whales, underwater sound, and air pollution. The latter three are elaborated upon below.

Ship strikes: Records of ship strikes with whales date back to the advent of steam-powered ships. They began to increase, however, between the 1950s and 1970s with the growth in the number and speed of vessels (Laist *et al.*, 2001). While data limitations make it difficult to assess frequency, analyses of stranded whales in the United States from 1975 to 1996 and from 1980 to 2006 suggest ship strikes are responsible for about 15% of observed mortalities, with some species, such as fin whales (33%), more affected than others (Laist *et al.*, 2001; Douglas *et al.*, 2008). Speed is recognized as a critical yet controllable factor in strikes, with most severe and lethal injuries resulting from strikes with vessels travelling at or above 14 knots (Laist *et al.*, 2001). Location of shipping lanes and implementation of marine-protected areas can mitigate the risk of strikes.

Underwater sound: With ships now a dominant and growing source of underwater low-frequency sound (Chapman & Price, 2011), there is increasing concern over the impact of such noise on any marine life that depends on sound for communication, foraging, and predator avoidance (NRC, 2005). Documented responses of fish include: physiological effects such as elevated heart rate; secretion of stress hormones; and increased metabolism and motility (Logan *et al.*, 2015). For marine mammals, impacts include: behavioural changes (avoidance, diving pattern changes); displacement from habitats; and masking or interfering with vocalizations made for communication and sensation (which can disrupt feeding) (Jasny *et al.*, 2005; NRC, 2005; Lacy *et al.*, 2015). For the beluga population, strong and prolonged behavioural responses have been linked to the sound of icebreakers some 50 kilometres away (NRC, 2005). In recognition of these impacts, the National Oceanic and Atmospheric Administration in the United States has introduced interim guidance on sound pressure thresholds as it develops comprehensive guidance on sound characteristics likely to cause injury and behavioural disruption (NOAA, 2015).

Air pollution: Although marine shipping is an efficient mode of freight transport, marine engines have been responsible for sizeable quantities of air pollutants, notably $PM_{2.5}$ (fine particulate matter), SO_2, and NO_x. This is due to the lack of pollution control requirements and the ships' use of low-quality, high-sulphur bunker fuels consisting mostly of residual oil (ICCT, 2007; IMO, 2015e). Such pollutants have been shown to affect air quality across entire shipping regions (BC Chamber of Shipping, 2007; Matthias *et al.*, 2010) and can result in higher health risks and costs in port regions where concentrations are highest (Chatzinikolaou *et al.*, 2015). In the Arctic, black carbon particles, which are formed from incomplete fuel combustion and emitted in the form of $PM_{2.5}$, pose additional ecological and health risks. As the most strongly light-absorbing component of PM black carbon reduces the ability of ice and snow to reflect sunlight, thereby accelerating the retreat of Arctic sea ice (Arctic Council, 2009; EPA, 2015). Air pollution from ships is, however, improving as a result of a 2010 amendment to the *International Convention for the Prevention of Pollution from Ships* (MARPOL), which has designated significant portions of North American waters (excluding the Arctic) as Emission Control Areas (ECAs). Ships entering ECA waters must now meet new stringent emissions standards for NO_x, $PM_{2.5}$, and SO_x levels (EPA, 2010).

Though this report focuses on the risks of marine shipping, other alternatives, such as rail or trucking for inland shipment of cargo, also have risks that can be even greater. Marine shipping, for example, has been shown to produce lower emissions of CO_2, PM, and NO_x on a per tonne basis, and to generate lower levels of noise than truck, rail, or air transport (John, 2011; NCFRP, 2012). Evidence also indicates that marine shipping has fewer incidents and accidents compared to other modes of transport, and fewer fatalities (NCFRP, 2012; RTG, 2014).

1.3 APPROACH TO RISK

Characterizing risks associated with marine shipping is a complex undertaking. In simple terms, risk is understood as "the potential for suffering harm or loss" (Hightower *et al.*, 2004). In a marine shipping context, this potential for harm is determined by the *probability* of an incident or accident occurring, together with the nature and severity of the *resulting impacts*.[2]

The complexity arises from the fact that both the probability of an incident or accident occurring *and* the nature and severity of impacts depend on a multitude of factors — some controllable, such as voyage planning and onboard safety protocols, and others less so, such as the characteristics of a region (e.g., saltwater vs. freshwater) or severe weather events (which could become more frequent and intense in a changing climate). This is especially relevant in the Canadian context given the varied geographies, populations, ecosystem characteristics, and climates of the different waterways where marine shipping takes place, including the Arctic.

To identify and characterize risk for all the different stages and types of commercial shipping, workshop participants agreed to approach risk as it is commonly measured. In so doing, *risk* is understood as being defined by the likelihood that an accident will occur (which is mitigated by accident prevention regulations and practices) and the significance of the resulting impacts. The factors that influence these aspects, such as safety culture, the condition of the vessel, the type of cargo spilled, and spill response systems, are also taken into account (Figure 1.3).

Note that in focusing on Canada, this study is limited by not considering the likelihood of accidents on the U.S. side of Canada's shared waterways, which include the Strait of Juan de Fuca, the Great Lakes, and the St. Lawrence River. It is recognized that accidents on the U.S. side of these waterways could result in impacts on the Canadian side and therefore would need to be accounted for in a full risk assessment, which is beyond the scope of this study.

1.4 REPORT STRUCTURE

The three basic elements of marine shipping risk identified in Figure 1.3 provide the organizational framework for this report: accident prevention, incidents/accidents, and impacts. Chapter 2 describes the type and level of shipping activity in Canada and the various ways in which risk is mitigated through regulation, safety protocols, and technology. Chapter 3 looks at the events themselves, reviewing Canadian incident and accident data for each of the six regions, along with the factors that influence the likelihood of an event occurring. Chapter 4 characterizes the potential impacts following a marine shipping event, focusing on cargo types and the factors that can increase or decrease the severity of impact. Chapter 5 concludes the report with a summary framework that identifies the important aspects of risk, a review of how risk factors and the potential nature of impacts vary by region, and an appraisal of research and data gaps.

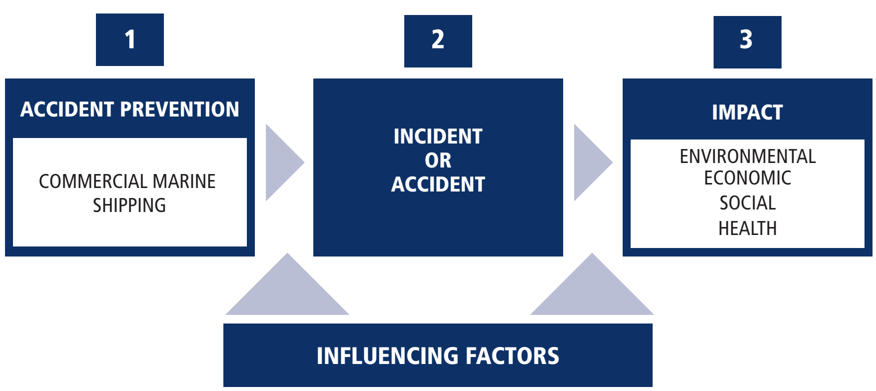


Figure 1.3

Approach to Understanding Commercial Marine Shipping Risks

To identify and characterize the risks of commercial marine shipping, workshop participants focused on three components: 1) accident prevention, including safety regulations, 2) the likelihood of an incident or accident, and 3) the impact(s) that may result from this incident or accident. Influencing factors that increase or decrease the likelihood of an event or impact from occurring are also recognized.

2 This reflects a common approach to quantifying risk by way of a simple equation based on probability and potential impacts. Transport Canada's Tanker Safety Expert Panel defines an Environmental Risk Index as the product of the probability of an adverse event occurring along with the type and magnitude of any resulting impacts (TSEP, 2013).

2

Commercial Marine Shipping Activity and Accident Prevention in Canada

- **Overview of Canadian Commercial Marine Traffic**
- **Regulatory Regime Mitigating Marine Shipping Risk in Canada**
- **The Role of Safety Culture in Reducing Marine Shipping Risks**
- **Accidents, Trust, and Social Licence**
- **Conclusion**

2 Commercial Marine Shipping Activity and Accident Prevention in Canada

Key Findings

From 2004 to 2011, the Pacific region accounted for 54% of all commercial vessel movements in Canada, followed by the Great Lakes (15%), the St. Lawrence River (14%), the Maritimes (9%), Newfoundland and Labrador (7%), and Northern Canada (1%). Tanker traffic is predominantly concentrated in Atlantic Canada while solid cargo traffic is more prevalent in the Pacific and Central regions.

Marine safety is a shared responsibility that spans multiple levels of governments and involves a broad range of domestic and international organizations, government departments and agencies, and the shipping industry itself. The result is a multitude of regulations, conventions, codes, and practices — many of which are adopted from the International Maritime Organization (IMO) standards — administered by multiple government authorities and put into practice by ship owners and operators.

Beyond regulations, a strong safety culture can further reduce the risks of marine shipping. Safety culture can be fostered within a vessel, across a fleet, and by clients and service providers.

The shipping industry relies on a certain degree of community support (a social licence) to conduct its business. Challenges in obtaining a social licence in British Columbia are particularly prevalent due to widespread concerns about the risks of tanker traffic.

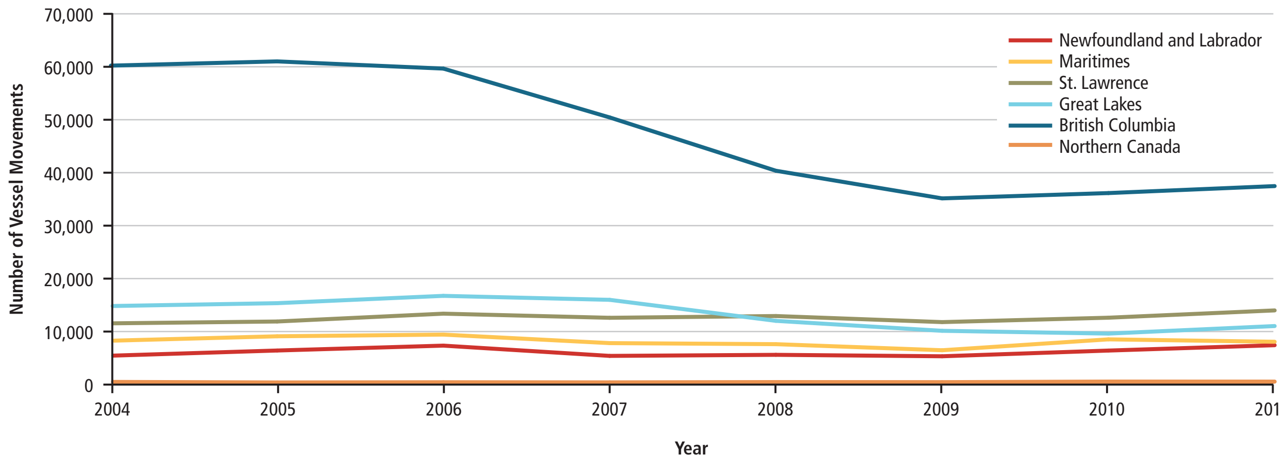
On Canada's waters, commercial ships carry a diversity of cargo, from dry bulk to liquid to containers of consumer and other goods. The vast majority of shipping activity is now carried out without incident, owing in part to a well-developed regulatory and operational environment, and industry-developed guidelines and best practices. In order to better understand both the nature of the shipping industry in Canada, and the systems in place to ensure it runs safely, this chapter i) establishes basic facts about the amount, type, and location of shipping activity in Canada and ii) sets out the scope of regulations and practices in place to prevent incidents and accidents from occurring. All of these factors together provide essential context for an informed understanding of marine shipping risks in Canada.

2.1 OVERVIEW OF CANADIAN COMMERCIAL MARINE TRAFFIC

Commercial marine traffic activity is highly variable across the country and reflects regional differences in economic strengths. Most of this activity, as measured by each vessel arrival and departure from a Canadian port (i.e., vessel movements),[3] occurs in the Pacific region and comprises mainly vessels carrying solid cargo.[4] The East Coast, however, experiences the highest levels of tanker traffic.

3 Vessel movement data were acquired from Statistics Canada (StatCan 2007, 2008, 2009, 2010a, 2010b, 2011, 2012a, 2012b); the last year for which Statistics Canada published these data is 2011. Each arrival at and departure from a Canadian port is counted as a vessel movement. The data include cargo movements, which involve loading or unloading of commercial cargo, and ballast movements, which do not. Movements are broken down by region and include solid and liquid cargo ships, barges, and tugs. Because the numbers are not separated by vessel type, it was not possible to remove barges and tugs from the data (StatCan, 2012b). Ships passing through or near to Canadian waters but not arriving at or departing from a Canadian port (e.g., ships transiting the Great Lakes and St. Lawrence River to or from U.S. ports, or ships travelling to or from Washington through the Strait of Juan de Fuca) are excluded.

4 Vessels carrying solid cargo are bulk carriers, container ships, general solid cargo ships, heavy load carriers, and ro-ro cargo ships. This terminology is used here to be consistent with Transport Canada's Marine Occurrence Data (TSB, 2015c).



Data Source: StatCan 2007, 2008, 2009, 2010a, 2010b, 2011, 2012a, 2012b

Figure 2.1

Commercial Cargo Vessel Movements by Canadian Region, 2004 to 2011

From 2004 to 2011, British Columbia accounted for more than half (54%) of the commercial vessel movements in Canadian waters, reaching a peak of approximately 61,000 in 2005. Traffic levels in Northern Canada remained low, but did climb to over 500 in 2010 (StatCan, 2012b). This figure includes movements for solid and liquid cargo vessels, barges, and tugs.

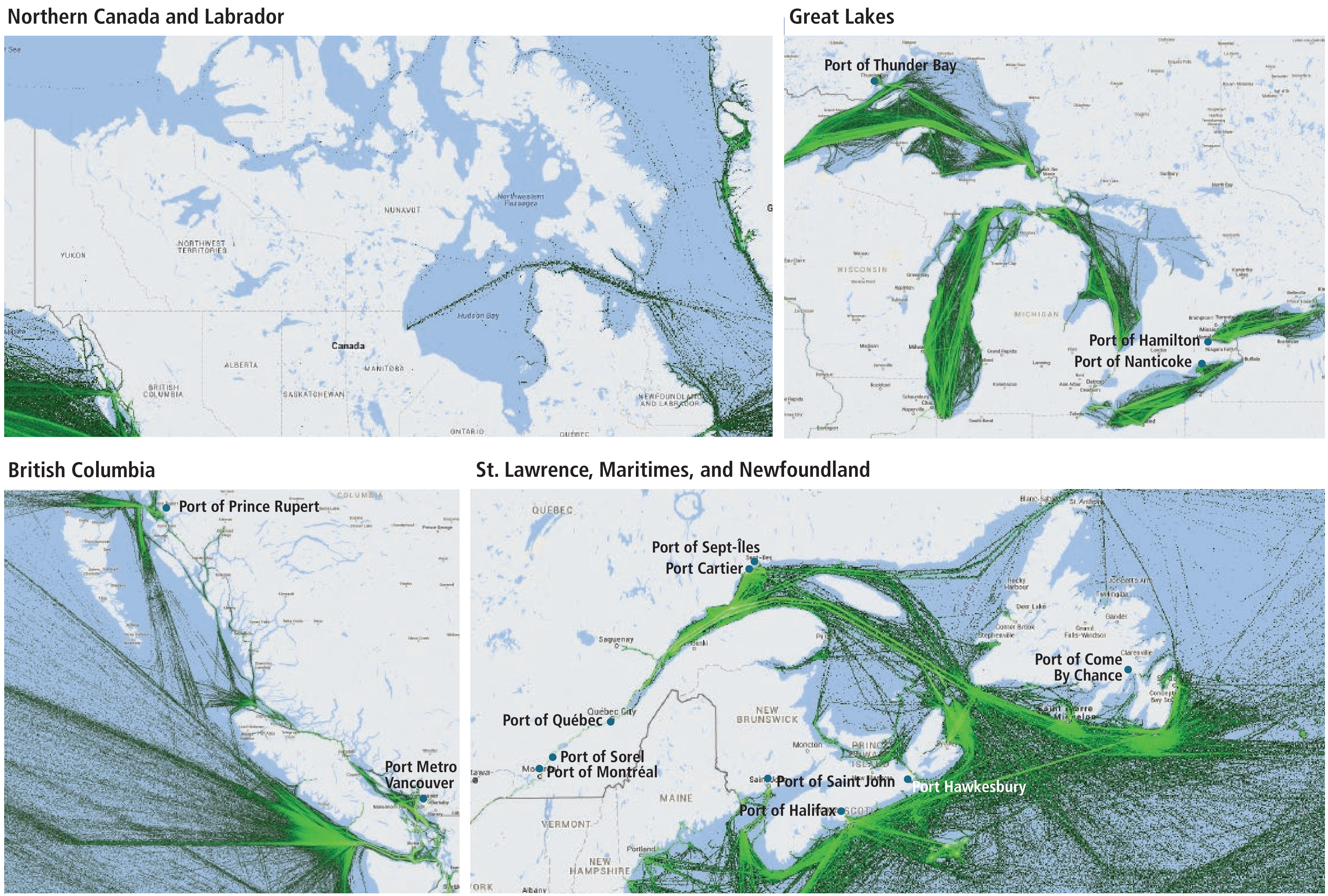
2.1.1 Commercial Marine Traffic Is Highest in the Pacific Region and Comprises Predominantly Solid Cargo

Between 2004 and 2011, commercial cargo ships made approximately 88,000 movements per year in Canadian waters. The Pacific region accounted for 54% of all commercial vessel movements in Canada, followed by the Great Lakes (15%), the St. Lawrence River (14%), the Maritimes (9%), and Newfoundland and Labrador (7%) (Figure 2.1). Northern Canada accounted for 1% of all traffic, having registered 547 vessel movements in 2011, up from 388 in 2004 (StatCan, 2012b).

Regional variation of traffic density is also evident from Automatic Identification System (AIS) data[5] from 2014. In Canada, cargo vessels — those carrying solid cargo, whether unpackaged bulk or containers — accounted for more activity than tankers, which include all vessels transporting liquids or gases in bulk (as illustrated in Figures 2.2 and 2.3). In 2014, 94% of all tanker movements in Canada were on the East Coast (TC, 2015b).

Figures 2.2 and 2.3 show that commercial marine shipping in the Arctic is currently minimal. Though this activity could increase as Arctic sea ice continues to retreat and thin as it has in the second half of the 20th century (Vaughan *et al.*, 2013) and as is predicted by climate models (Kirtman *et al.*, 2013), recent research indicates that increased marine access and a longer navigation season alone may not bring about large-scale changes in activity (Pizzolato *et al.*, 2014). Furthermore, any shipping in the region may still face the risks associated with variable and unpredictable ice cover (Arctic Council, 2009). Key drivers of future Arctic marine activity include natural resources development (e.g., hydrocarbons, hard minerals, and fisheries) and intra-Arctic regional trade, which may involve multiple users and new non-Arctic stakeholders (Arctic Council, 2009).

5 Automatic Identification System (AIS) data automatically broadcast static and voyage-related information (e.g., a ship's identity, the type of cargo it is carrying, its destination) as well as dynamic information (e.g., a ship's position coordinates, course, speed) (IMO, 2015g; MarineTraffic, n.d.-a, n.d.-b). As of December 31, 2004, the IMO requires that AIS transponders be "fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size" (IMO, 2015g).



Data Source: StatCan, 2012b; MarineTraffic, 2015

Figure 2.2

Solid Cargo Vessel Traffic in Canada (2014)

Density maps were generated from accumulated AIS data on cargo ship positions in Canadian and some U.S. waters during 2014. The location and intensity of the green markings indicate overall vessel movement patterns and concentrations. Cargo ships include bulk carriers, container ships, heavy load carriers, ro-ro cargo ships, cargo barges, and others (MarineTraffic, n.d.-c). Blue circles mark top Canadian ports by tonnage (based on 2011 data).

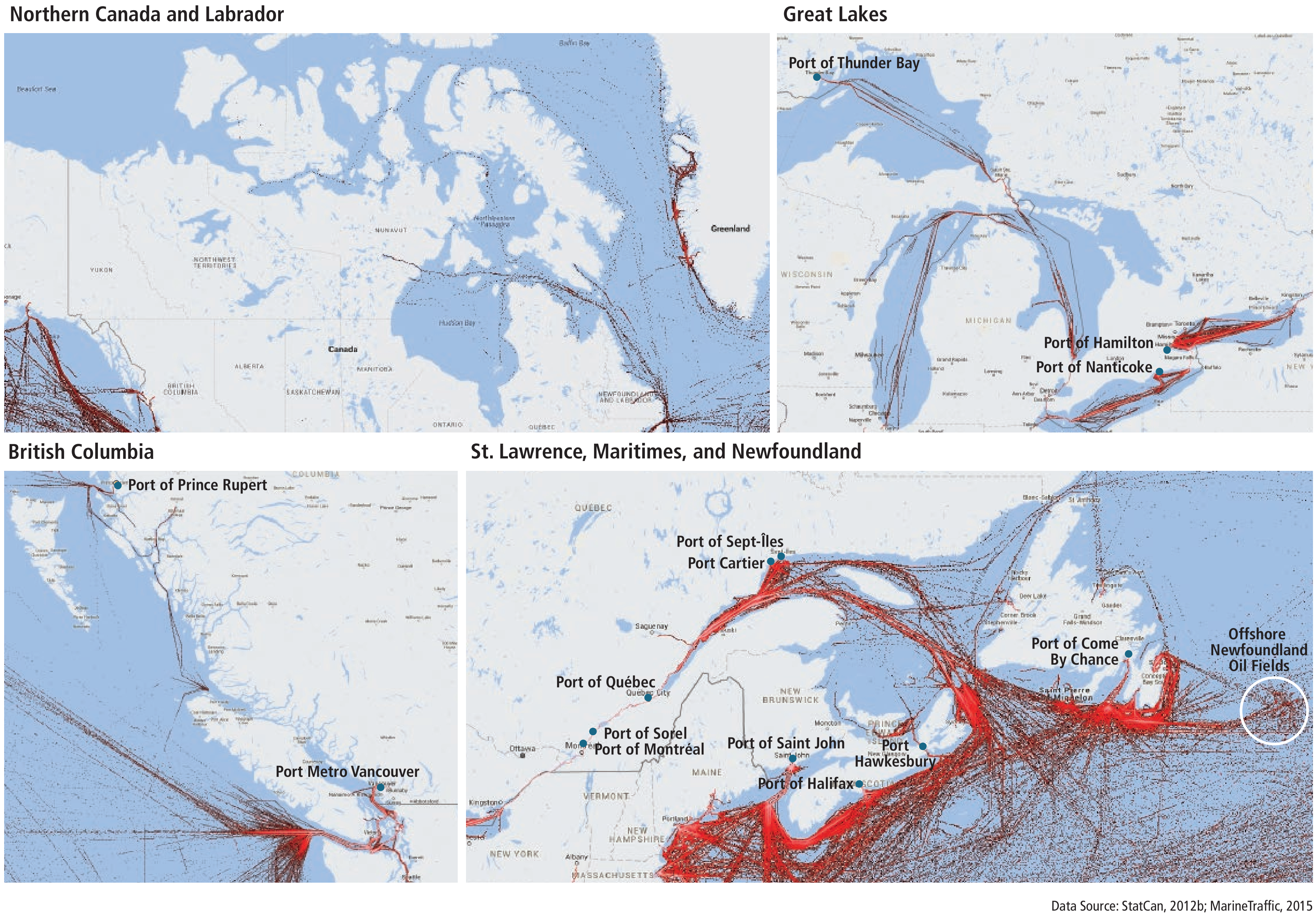


Figure 2.3

Tanker Traffic in Canada (2014)

Density maps were generated from accumulated AIS data on tanker positions in Canadian and some U.S. waters during 2014. The location and intensity of the red markings indicate overall vessel movement patterns and concentrations. Tankers include asphalt/bitumen tankers, crude oil tankers, chemical tankers, liquefied gas tankers, and others (MarineTraffic, n.d.-c). Blue circles mark top Canadian ports by tonnage (based on 2011 data).

2.1.2 Atlantic Canada Handles Most of Canada's Crude Shipments

In 2011, regions varied considerably in the type and amount of commodities they shipped (Table 2.1). The West Coast was the top region for outbound shipping of coal, wood products, agriculture and food products, and pulp and paper products, whereas the main cargo type shipped on the East Coast was crude petroleum and fuel products, of which some 82 million tonnes were shipped in and out of ports in Atlantic Canada. Though Central Canada was predominant in minerals, it also supported 25 million tonnes of crude oil and other petroleum fuel products, which moved in and out of Quebec ports (TC, 2015b).

Table 2.1

Top Canadian Regions for International Shipping of Various Cargo Types (2011)

Cargo Type	Top Region (in terms of total tonnes loaded)
Agriculture and food products	**Pacific**
• Wheat	Pacific
• Colza seeds (canola)	Pacific
Minerals	**St. Lawrence River**
• Iron ores and concentrates	St. Lawrence River
• Salt	Great Lakes
Fuels and basic chemicals	**Atlantic**
• Crude petroleum	Atlantic
• Fuel oils	Atlantic
• Gasoline and aviation turbine fuel	Atlantic
• Potash	Pacific
Coal	**Pacific**
Forest and wood products	**Pacific**
Pulp and paper products	**Pacific**

Data Source: StatCan, 2012b

Table shows top Canadian regions in 2011 for international shipping of various cargo types, based on loaded cargo only (i.e., outbound cargo loaded at a port of origin in Canada and heading to an international destination).

A number of recent proposals could affect the amount of crude oil and other petroleum products shipped in various parts of Canada in the future. Export of LNG or diluted bitumen from Alberta's oil sands using ships on the West Coast could increase current tanker traffic leaving the Port of Metro Vancouver. With the rejection of Keystone XL by the American government and with the lifting of the U.S. embargo on oil exports, there is also the potential for increased marine movement of oil through Central Canada and the East Coast. For example, the reversal of Enbridge's Line 9B pipeline allows for up to 300,000 barrels/day of Alberta oil to flow into Montréal, increasing tanker traffic on the St. Lawrence River as some of this crude is shipped to a refinery in Lévis, near Québec (CBC News, 2015c). In the Maritimes, the proposed TransCanada Energy East project, if approved, would carry 1.1 million barrels of crude oil per day to a New Brunswick refinery destined for subsequent marine export (Marotte, 2015).

2.1.3 Port Activity Reflects Regional Diversity in Commerce and Trade

In 2011, the four busiest ports, as measured by total tonnage handled, were located in the Pacific, Maritimes, and St. Lawrence River regions (Table 2.2). Port Metro Vancouver was by far Canada's busiest port, handling the most tonnes of cargo and highest number of containers (as measured by Twenty-Foot Equivalent Unit (TEU)), while also managing the greatest number of vessel movements.

For most ports, a single commodity dominated (Table 2.3). Coal, for example, accounted for the largest share of tonnage for the Port Metro Vancouver, while Come By Chance dealt almost exclusively with crude petroleum and petroleum products (StatCan, 2012b). Other ports, such as Montréal, handled a larger variety of cargo, including lighter containerized cargo, which was reflected by its position among the top ports by TEUs.

Table 2.2

Top Canadian Ports by Tonnage (2011), TEUs* (2014), and Vessel Movements (2011)

Tonnage

Port (ranked 1 to 15)	Tonnes Handled (x1,000)
Metro Vancouver (BC)	107,575
Saint John (NB)	31,469
Québec (QC) (incl. Lévis)	28,962
Montréal (QC) (incl. Contrecœur)	27,856
Come By Chance (NL)	27,387
Sept-Îles (QC) (incl. Pointe-Noire)	25,786
Hawkesbury (NS)	23,738
Prince Rupert (BC)	18,780
Port-Cartier (QC)	17,603
Newfoundland Offshore (NL)**	13,663
Hamilton (ON)	10,016
Halifax (NS)	9,930
Thunder Bay (ON)	7,609
Sorel (QC)	6,396
Nanticoke (ON)***	6,186

TEUs

Port (ranked 1 to 5)	TEUs Handled (x1,000)
Metro Vancouver (BC)	2,913
Montréal (QC) (incl. Contrecœur)	1,402
Prince Rupert (BC)	618
Halifax (NS)	400
Saint John (NB)	90

Vessel Movements

Port (ranked 1 to 15)	Number of Movements
Metro Vancouver (BC)	17,306
Montréal (QC) (incl. Contrecœur)	3,898
Halifax (NS)	2,657
Québec (QC) (incl. Lévis)	2,215
Crofton (BC)	2,034
Saint John (NB)	1,649
Nanaimo (BC)	1,528
Sept-Îles (QC) (incl. Pointe-Noire)	1,425
Newfoundland Offshore (NL)**	1,425
Prince Rupert (BC)	1,330
Hamilton (ON)	1,140
Sault Ste. Marie (ON)	945
Windsor (ON)	918
Thunder Bay (ON)	781
Port-Cartier (QC)	747

Data Source: StatCan, 2012b; CNLOPB, 2014; NATS, 2014; AAPA, 2015

*TEU: Twenty-Foot Equivalent Unit, a standard linear measurement used in quantifying container traffic. For example, one 40-foot long container is two TEUs (Brodie, 2013). TEU data are for total loaded and empty containers handled in domestic and international trade.

**Newfoundland Offshore includes the Hibernia, Terra Nova, and White Rose/North Amethyst Oil Fields.

***As of 2012, the port of Nanticoke was listed as one of 211 deproclaimed harbours (TC, 2012a).

Table 2.3
Cargo Handled by Top Five Canadian Ports (2011)

Port	Top Cargo Types (in terms of total tonnes handled)	Total Tonnes Handled (x1,000)	Crude Petroleum, Fuel, and Fuel Oils (total tonnes handled x1,000 and % of total tonnage)
Metro Vancouver	Coal	32,278	5,563 (5.2%)
	Potash	7,196	
	Wheat	5,969	
	Colza seeds (canola)	5,843	
	Wood chips	4,996	
	Lumber	4,825	
Saint John	Crude petroleum	15,415	26,956 (85.7%)
	Fuel oils	6,543	
	Gasoline and aviation turbine fuel	4,998	
	Other refined petroleum and coal products	3,190	
Québec (incl. Lévis)	Crude petroleum	9,874	14,567 (50.3%)
	Iron ores and concentrates	5,968	
	Wheat	2,815	
	Fuel oils	2,685	
	Gasoline and aviation turbine fuel	2,009	
Montréal (incl. Contrecœur)	Gasoline and aviation turbine fuel	5,275	9,883 (35.5%)
	Fuel oils	4,492	
	Other manufactured and miscellaneous goods	3,207	
	Iron ores and concentrates	1,244	
Come By Chance	Crude petroleum	23,732	27,241 (99.5%)
	Fuel oils	2,378	
	Gasoline and aviation turbine fuel	1,131	

Data Source: StatCan, 2012b

Table includes cargo handled by the top five Canadian ports in terms of total tonnes handled, based on both international and domestic shipping, and including loaded (outbound) and unloaded (inbound) cargo. Data are from 2011.

2.2 REGULATORY REGIME MITIGATING MARINE SHIPPING RISK IN CANADA

The numerous rules and regulations that govern marine shipping activity are often complex and span multiple jurisdictions. As a result, accident prevention cannot be achieved by any one regulatory body or jurisdiction (provincial, national, or international). In the absence of a central coordinating body for marine affairs in Canada, coordination among governments, international regulatory bodies, port authorities, and industry is required to help mitigate the risk of negative marine shipping events occurring in Canada.

2.2.1 Marine Safety Is a Shared Responsibility with the Greatest Concentration of Authority Residing in Transport Canada

A starting point for understanding the breadth of regulations that govern marine shipping in Canada is the United Nations' International Maritime Organization (IMO) of which Canada, along with 170 other countries, is a member. The IMO, which is dedicated to "safe, secure, environmentally sound, efficient and sustainable shipping through cooperation," serves as a forum for the negotiation of dozens of conventions and over 1,000 codes and recommendations regarding maritime safety and environmental protection (IMO, 2013, 2015d) (Box 2.1). While the IMO has no power to enforce these regulations, these codes and recommendations govern diverse facets of shipping, from prevention to liability regimes, including standards for ship construction and equipment, distress communications, and oil pollution preparedness and response (IMO, 2013).

Box 2.1
Marine Risk Prevention: An International Perspective

A number of international conventions are particularly important for mitigating the risks of marine shipping. The IMO's *International Convention for the Prevention of Pollution from Ships* (MARPOL), for example, is the "main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes" (IMO, 2015c). The *International Convention for the Safety of Life at Sea* (SOLAS) is the most important instrument regarding the safety of commercial ships (IMO, 2015b), and the *International Convention on Standards of Training Certification and Watchkeeping for Seafarers* (STCW) sets out minimum standards for all signatories (IMO, 2015a). A fourth code of major importance, the *International Safety Management Code* (ISM), covers ship management, operations, and pollution prevention, requiring the establishment of safety management systems (IMO, 2016c).

Flag states — the country in which a vessel is registered — are responsible for implementing IMO rules and regulations in their jurisdictions (IMO, 2016b). Canada, through Transport Canada's Port State Control authority, monitors compliance through boarding and inspection.[6] Port State Control activities include expanded inspection for chemical tankers, gas carriers, oil tankers, bulk carriers, and ships over 12 years of age (TC, 2015b). In 2015, for example, Canada inspected 981 vessels as reported under the Paris MOU, finding deficiencies in 485 inspections (49%), with 3% classified as high risk. This led to the detention of 22 vessels (2%) (PSC, 2014).

Under the *Constitution of Canada*, the federal government has authority over shipping, navigation, and fisheries in both Canadian ocean waters (i.e., out to the 200 nautical mile Exclusive Economic Zone) and navigable inland waters (Becklumb, 2013). Thus, the federal government can regulate shipping routes, vessel emissions and discharges, and safety (Becklumb, 2013). Foremost among the various Canadian laws and policies that apply to marine shipping is the *Canada Shipping Act, 2001*, which establishes, for example, licensing requirements and safety standards. The Act applies to all vessels in Canadian waters, as well as Canadian vessels internationally (TC, 2012c). Table 2.4 provides a list of several federal acts that govern marine shipping.

Table 2.4
Canadian Acts Governing Marine Shipping

Act	Notes
The Oceans Act	Highlights the various zones of Canadian oceans, the Arctic included, as well as describing the Ocean Management Strategy within which power to create and regulate marine protected areas in Canadian oceans is given. The Act also outlines the regulations relating to Marine protected areas.
Arctic Water Pollution Prevention Act (AWPPA)	Provides measures to prevent pollution from ships, and in particular, the deposit of waste into Arctic waters. Includes regulations to deal with navigating including the need for ice navigators and a Zone/Date System (Z/DS) identifying safety zones and opening and closing dates for those zones for ships of different ice classes.
Canada Shipping Act (CSA)	Represents Canada's principal legislation for marine shipping and recreational boating in all Canadian waters including the Arctic.
Marine Liability Act (MLA)	Requires that the owners and/or operators of vessels are responsible and liable for their vessels and the consequences of their operation.
Marine Transportation Security Act (MTSA)	Provides for the security of marine transportation and applies to marine facilities in Canada and Canadian ships outside of Canada.
Navigation Protection Act (formerly Navigable Waters Protection Act)	Protects the public right to navigate and ensures a balance between public right and need to build works which may obstruct navigation.
Coasting Trade Act	Supports domestic marine interests by reserving the coasting trade of Canada to Canadian registered vessels. The legislation provides a process to temporarily import a foreign vessel under a coasting trade licence when a suitable Canadian registered vessel is not available or in the case of transportation of passengers. In this case duty taxes under *Customs Tariff and Excise Tax Act* apply.

Table taken from Dawson, 2014

6 Port State Control is an internationally agreed authority held by countries who are signatories to the UN Convention on the Law of the Sea (UN, 2013). Through ship inspection, the Canadian government exercises its rights to ensure vessels entering Canadian waters are not substandard. Upon entering national ports, foreign vessels are boarded and inspected to verify adherence to international conventions (TC, 2013c). Port State Control acts as a safety net to avoid substandard ships, with the ability to record deficiencies and detain ships (IMO, 2015h; TC, 2015b). Transport Canada is responsible for these inspections in Canadian ports. Canada is a signatory to the Paris MOU (an Atlantic Port State Control agreement) and the Tokyo MOU (a Pacific Port State Control agreement). These MOUs allow for the coordination of Port State Control activities between signatories (TC, 2013c; IMO, 2015h).

Table 2.5

Departments and Agencies with Responsibilities for Different Aspects Related to Marine Shipping

Department/Agency	Areas of Responsibility or Participation										
	Ship Safety	Port/Facility	Emergency Response	Navigation Aids	Ice Breaking	Dredging/Water Levels	Environment	Safety and Health of Personnel	Licensing/Pilotage	Class/Design of Ships	Security/Search and Rescue
Canada Border Services Agency											x
Canadian Coast Guard			x	x	x	x	x				x
Canadian Port Authorities		x				x		x			
Employment and Social Development Canada								x			
Environment and Climate Change Canada			x				x				
Fisheries and Ocean Canada				x			x				
Labour Program		x						x			
Local Governments		x	x				x				
National Defence											x
Provincial Governments		x	x				x				
St. Lawrence Seaway Management Corporation*	x	x	x				x				
Transport Canada	x	x	x			x	x		x	x	
Transportation Safety Board of Canada	x							x			

Adapted from RTG, 2014

*The Saint Lawrence Seaway Development Corporation maintains similar responsibilities on the U.S. side of the Seaway.

These acts are implemented by a range of government departments, agencies, and organizations; no one central organization is tasked with coordination across the Canadian marine sector. Table 2.5 demonstrates the range of actors at the federal, provincial, and municipal levels involved in marine shipping oversight. Transport Canada plays a principal role as a regulator, making regulations and confirming compliance (TC, 2015b). Among other duties, this includes a National Aerial Surveillance Program to detect and help prosecute illegal discharges of pollution at sea, and certification of local marine pilots for vessels in designated hazardous waterways (TC, 2014c). The Canadian Coast Guard plays a prominent role in enforcement, provides a network of navigational aids, runs Marine Communications and Traffic Services centres (which share safety information and monitor distress and safety calls), provides icebreaker assistance, and gives advice to manage marine traffic movement (CCG, 2008, 2015).

2.2.2 Regional Variations to the Marine Safety Regime Exist and Reflect Differences in Operating Environments

Within the wider national marine safety regulatory framework, there are a number of important differences that correspond to realities or conditions of a given region. Within the St. Lawrence River and Great Lakes regions, along with Canadian authorities, American agencies are involved in regulating the safety of marine shipping including, most notably, the U.S. Coast Guard and the Saint Lawrence Seaway Development Corporation, adding to the regulatory complexity and to the need for coordinated activities (RTG, 2014). For example, all foreign flagged vessels, including those that are Canadian-owned but registered under foreign flags are subject to enhanced inspections prior to entering the seaway through a coordinated United States–Canada effort. This is in response to the *International Ship and Port Facility Security Code* that introduced additional inspection requirements following the 2001 terrorist attacks. Also, the Great Lakes and St. Lawrence River waters are designated as a compulsory pilotage zone, requiring either Canadian- or American-certified pilots to assist in the navigation with reciprocity established in the *Boundary Waters Treaty* of 1909 (RTG, 2014).

Regulations can be supported by the use of marine spatial planning to reduce risk and prevent conflict among uses. For example, shipping lanes can be shifted away from sensitive areas where risks from routine shipping activities, such as ship strikes and noise, are of particular concern. Marine spatial planning is not limited to environmental factors and objectives, and can include social and economic considerations (The White House Council on Environmental Quality, 2010). In the Pacific region, a voluntary Tanker Exclusion Zone off the British Columbia coast has been in place since 1985 for loaded oil tankers travelling between Alaska and Washington, but it does not apply to tankers travelling to or from British Columbia ports (TC, 2015b). Furthermore, tankers carrying over 40,000 tonnes of deadweight transiting the Haro Strait and Boundary Pass are required to use two pilots and a tug escort. Similar requirements are in place for all loaded tankers that enter the Burrard Inlet and Indian Arm (TC, 2015b). There is also a size limit on tankers permitted at Port Metro Vancouver; tankers cannot exceed 120,000 tonnes, thereby excluding very large crude carriers (PMV, 2014).

Northern Canada is subject to additional regulations through the *Arctic Waters Pollution Prevention Act* (GOC, 2014c). Arctic-bound vessels must be designed, built, and equipped for Arctic conditions, in keeping with the IMO's *Guidelines for Ships Operating in Polar Waters* and design standards from the International Association of Classification Societies' *Unified Requirements for Polar Class Ships* (TC, 2013b). The IMO's recently adopted *International Code for Ships Operating in Polar Waters* (the Polar Code) should come into force in January 2017. It includes requirements relating to ship design and construction, equipment, and operations and manning, which will support international harmonization (IMO, 2016a). While it is prudent to develop specific standards for the North, legislation is only part of the wider system needed to ensure safety. Furthermore, there has been criticism that the Polar Code does not go far enough in terms of environmental protection (Cressey, 2014).

2.3 THE ROLE OF SAFETY CULTURE IN REDUCING MARINE SHIPPING RISKS

Though the marine safety regulatory regime is necessary for reducing risks, workshop participants viewed this as being insufficient. Regulations reflect the minimum agreed-upon standards and, without an internal culture that has "the ability and willingness […] to understand safety, hazards and means of preventing them, as well as ability and willingness to act safely" (Berg, 2013), risks cannot effectively be minimized. Indeed, it is argued that safety culture makes a material difference in improving outcomes (Berg, 2013; ISF, n.d.). Chauvin *et al.* (2013) examined accident reports for 39 ships involved in 27 collisions reported by the United Kingdom and Canada that took place between 1998 and 2012. The authors used the Human Factors Analysis and Classification System (HFACS)[7] to identify the factor(s) that contributed to each accident. Overall, unsafe leadership was a factor in 59% of collisions, primarily due to inappropriate scheduling and planning. Organizational influences factored into 54% of collisions, primarily attributed to incomplete Safety Management Systems (Chauvin *et al.*, 2013). Both leadership and organizational influences are strongly shaped by safety culture. Reason (1998) presents a Swiss cheese model where each slice of cheese is "shown as intervening between the local hazards and potential losses." Essentially, a safety system is composed of multiple layers, each representing a single defence strategy. For an accident to occur, gaps in each layer must align. However, these gaps are continuously shifting with circumstances. As safety culture is overarching, it applies to each layer of defences, helping to close gaps in safety and reduce the chance of an accident (Reason, 1998).

Since 2002, the IMO has required all international ship owners and operators to adhere to the *International Safety Management* (ISM) *Code* (Chauvin *et al.*, 2013). The ISM Code calls for the implementation of a safety management system, development of safeguards against risk, fostering of safety management skills development, and improvement of environmental protection (IMO, 2002). According to the IMO (2015f):

> Effective implementation of the ISM Code should lead to a move away from a culture of "unthinking" compliance with external rules towards a culture of "thinking" self-regulation of safety — the development of a "safety culture." The safety culture involves moving to a culture of self-regulation, with every individual — from the top to the bottom — feeling responsible for actions taken to improve safety and performance.

7 HFACS is used to support accident investigations by categorizing contributing factors as *outside factors, unsafe acts of operators, preconditions for unsafe acts, unsafe supervision*, and *organizational influences* (Chauvin *et al.*, 2013).

Shipping companies demonstrate a commitment to safety through the adoption of new technologies on their vessels (Box 2.2). Company leaders and their clients are also involved in improving safety by supporting various industry initiatives, some of which represent a form of private sector regulatory oversight (Walters & Bailey, 2013). For example, major oil companies conduct extensive oversight of the shipping companies they contract, and the threat of losing business encourages tanker transport companies to comply (Walters & Bailey, 2013). The Oil Companies International Marine Forum (OCIMF), an industry association of oil companies, runs two such initiatives: the Ship Inspection Report Programme (SIRE) and the Tanker Management and Self Assessment (TMSA) programme. Members of SIRE commission vessel inspections to examine activities such as cargo handling, safety procedures, and pollution control measures, and then post inspection reports to the SIRE database (OCIMF, 2015). Roughly 20,000 such reports were added to the database in 2014, and an average of more than 10,000 reports are viewed each month by database users who can benefit from the inspection reports to assess vessel performance (OCIMF, 2015). The TMSA Programme encourages self-regulation and the measurement and improvement of safety management systems (OCIMF, n.d.), providing guidance to meet performance objectives for a number of areas of management practice, and encouraging participants to identify and work to resolve areas of weakness. One of the areas of management practice is incident investigation and analysis, wherein firms learn from all incidents to develop and refine prevention measures. The TMSA sets out an approach to incident reporting, investigation, and sharing of lessons learned across vessels, and highlights the importance of training and supporting incident investigators (NEPIA, 2012). This program is used by 90% of tanker operators (OCIMF, n.d.). OCIMF also developed the Marine Terminal Information System, which includes a Marine Terminal Management and Self Assessment guide and Marine Terminal Operator Competence and Training Guide (OCIMF, 2014).

The insurance industry can further encourage safety by offering incentives or imposing requirements on holders of insurance policies (Faure, 2014). Insurance policies can reward good performers with favourable insurance rates and can use deductibles so that policy-holders have a strong incentive to avoid accidents. Insurers may choose to evaluate the policy-holder's risk management program to assess existing procedures (Faure, 2014).

There are limits to what can be achieved through self-regulation, as companies with weaker safety culture may "game" some of these systems by, for example, applying for membership to multiple classification societies (which validate the appropriate construction and operation of vessels) before ultimately being accepted by one. However, when these self-regulating strategies are imposed in addition to government regulations, they can further enhance overall safety.

Box 2.2

Technologies That Support Safe Marine Shipping

Over the last 100 years, the safety of shipping has improved dramatically with the integration of new navigation technologies. The bridge of a modern-day vessel bears little resemblance to those from a century ago, with several different technologies available to enhance safety. These include: depth finders based on echo sounding that provide warning of potential groundings; radar that provides advanced warning of hazards well before they can be identified visually; weather monitoring and forecasting to aid planning; and very high-frequency (VHF) radio that enables contact between a ship and authorities ashore at all times. Navigation, in particular, has been completely changed as technology has removed the need for estimation. The Global Positioning System (GPS), which became fully operational in the early nineties, provides accurate location information to ensure safe passage and can be used regardless of location, time of day, or weather. GPS was revolutionary, but navigational technology continues to evolve and improve safety. Today, AIS allows instant identification and tracking of ships, including information about course and speed, by other vessels and authorities ashore. Furthermore, the Electronic Chart Display and Information System (ECDIS) updates charts with AIS information instantly and can be interfaced with radar, providing crews with the best possible situational awareness to avoid accidents. Though these technologies, which continue to improve, are increasingly important for marine safety, they remain only one component within the broader marine safety environment.

(Allianz, 2012)

2.4 ACCIDENTS, TRUST, AND SOCIAL LICENCE

Safety depends on a sound regulatory regime coupled with a ship owner's strong safety culture. Yet, in order to keep earning public trust, the marine shipping industry, in the view of workshop participants, must strive to improve further on its safety and environmental protection performance.

Like all industries, the shipping industry relies on a certain degree of community support, or *social licence*, to conduct its business.

Social licence to operate reflects an increasingly popular notion that industry activities require the tacit consent of those affected, and signals growing expectations by the public that industry compliance with regulations is necessary but insufficient when satisfying concerns over planned or existing operations. While the concept has its origins in the mining sector, it has been applied to a growing number of non-mining sectors, from agriculture to tourism (Koivurova *et al.*, 2015). Companies and industries are awarded a tacit social licence when they are viewed as legitimate by society, when they gain the trust of stakeholders, and when affected parties consent to their operations (Morrison, 2014). Ircha (2012) notes that "[a] social license is based on the beliefs, perceptions and opinions of the local community; it is granted by the community (in other words, a network of stakeholders); and is intangible, dynamic and non-permanent." In order for the public to grant a social licence, there must be a common understanding of key facts — what is being granted and the nature and risks of the activity (House, 2013). For shipping, this could include a clear understanding of the likelihood and potential impacts of spills of different types of cargo in different marine environments. Furthermore, social licence requires that, before an accident occurs, communities trust that a shipping company's response will be sufficient and promptly carried out.

In the shipping industry, and particularly in port communities, social licence may be particularly challenging to secure when some of the benefits of shipping (e.g., trade, tax revenue) are widely dispersed but the negative impacts (e.g., traffic congestion, pollution) may be locally concentrated. Ports employ a range of strategies to secure a social licence. For instance, Port Metro Vancouver (PMV) has developed a First Nations Engagement Strategy that has improved PMV's understanding of how First Nations historically used the port lands and developed a formal consultation process (Ircha, 2012). Underlying this consultation process is the acknowledgement of treaty lands and asserted traditional territories, and an understanding that Indigenous consultation is a separate endeavour from public consultation (PMV, 2016). Ircha (2012) encourages ports to proactively address equity concerns and to foster their reputation in calm times, as this will create a foundation for managing conflict in the event of a crisis.

The ease with which social licence can be gained will depend not just on the risk level, but also the broader risk perception of a given community. The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) points out that the public's acceptance of risk depends on risk characteristics such as degree of personal control, the potential for catastrophe, the distribution of benefits, and the extent to which risk exposure is voluntary, in addition to the level of trust in the institution managing the risk (IALA, 2013). Risk perception is influenced by a wide variety of factors beyond risk characteristics, however, including culture, and demographic and social characteristics (e.g., age, gender) (Slovic, 2000). Therefore, the public or government view on the acceptability of a given risk may be very different for different communities, despite the risk level being the same.

Shipping companies may perceive enhancing their safety culture as one of the key ways they can acquire social licence to operate. Commitment to gaining and maintaining a social licence may enhance regulatory compliance and even motivate firms to go beyond compliance, particularly in the environmental arena, as shipping companies seek to address public concerns about the environmental impacts of routine shipping operations and the risks of spills (Bloor *et al.*, 2013). Furthermore, companies may seek out certification programs to demonstrate their commitment to the environment. One such organization relevant for Canada is Green Marine, a North American environmental certification program that provides recognition for ship owners, ports, Seaway corporations, terminals, and shipyards that make yearly improvements in reducing their environmental footprint (Green Marine, 2014).

Morrison (2014) encourages "organizations to think about all their social relationships with the same seriousness that they already [use to] approach health and safety." Events such as the tanker traffic protests in British Columbia (Box 2.3), the BP *Deepwater Horizon* blowout in the Gulf of Mexico, the *Exxon Valdez* oil spill, and public opposition to Shell's proposed disposal at sea of the *Brent Spar* offshore oil drilling installation underscore the risks to the shipping industry when social licence is not sufficiently established prior to a negative event or is revoked following such an event.

Box 2.3
The Challenges of Securing a Social Licence for Tanker Ships in British Columbia

In British Columbia, some types of shipping have recently received negative attention (CBC News, 2015a). Concerns about tankers have been heavily tied to reservations about resource development, including increasing export opportunities for Alberta's oil sands and associated climate change impacts. Proposals for the Northern Gateway pipeline to Kitimat and the Trans Mountain pipeline to Burnaby, both of which are intended to transport diluted bitumen from Alberta, have been met with protest due, in large part, to the associated tanker traffic (Stueck, 2013). In particular, there are worries about the potential impacts of a marine spill of diluted bitumen. In its January 2016 submission to the National Energy Board, the Government of British Columbia cited concerns about the quality of a marine spill response as a key factor behind its decision not to support the proposed Trans Mountain pipeline expansion (GBC, 2016). Concerns were exacerbated by the recent bunker fuel spill in Vancouver's English Bay, where the Canadian Coast Guard response was perceived as poor and questions were raised about oil spill preparedness (Editorial Board, 2015).

Environmental concerns are particularly significant in British Columbia because residents place high value on the natural environment. The Council's survey revealed that respondents from the Pacific coast were generally more concerned than those from Atlantic, Central, or Northern Canada about the environmental impacts of a shipping accident involving cargo release in their region. Survey responses indicated that the degree of environmental impacts expected from a spill were somewhat greater for the Pacific coast than for the rest of Canada. This may be partially explained by the results of another national survey, which found that British Columbians were more likely than other Canadians to have chosen their residence, in part, for access to nature (biodivcanada.ca, 2014). Moreover, average annual expenditures on nature-related activities were among the highest in the country (biodivcanada.ca, 2014).

Competing demands for coastal access can further erode support for shipping. In port cities the waterfront is valued for many uses — commercial, residential, and recreational (OECD, 2014). When the community does not perceive a sufficient benefit from shipping-related activities, they may prefer that other waterfront uses be prioritized. These concerns may be exacerbated in an area like Metro Vancouver where land prices are high.

A planned moratorium on tanker traffic in Northern British Columbia demonstrates what is at stake when social licence for resource development and transportation is absent (CBC News, 2015a). There is widespread opposition to the Northern Gateway's proposed transportation of diluted bitumen across ecologically sensitive land and waters, including among Coastal First Nations. Coastal First Nations determined that the risks to health and livelihood posed by the project far outweighed the benefits (CFN, n.d.).

2.5 CONCLUSION

Canada's shipping industry is important to domestic commerce and international trade, and the cargo moved is highly diverse. International agreements backed by national laws, regulations, and industry standards are part of a comprehensive but complex governance structure to mitigate the risks of commercial marine shipping. The regulatory and safety framework that governs marine shipping in Canada is well developed and continues to evolve. Together with ongoing efforts to support a safety culture, it is critical to the continued reduction of risks at all levels.

3

Incidents and Accidents

- Incidents and Accidents by Vessel Type and Region
- Incidents and Accidents by Stage of Shipping and Type of Waterway
- Bringing It All Together: The Importance of Frequency and Severity
- Factors That Influence the Likelihood of an Incident or Accident
- Conclusion

3 Incidents and Accidents

Key Findings

For Canadian ships and Canadian waters, the total number of marine shipping accidents involving solid cargo vessels and tankers has been declining since 1998.

Incident and accident rates vary across Canada. Using publicly available data from 2004 to 2011, the rate on a per-vessel movement basis was highest in Northern Canada followed by the St. Lawrence River and Great Lakes. Further research is needed to better understand these findings.

Over the past 10 years, almost half of the marine occurrence reports involving cargo vessels described minor incidents rather than serious accidents. Accidents in restricted waterways (e.g., harbours, rivers, canals) were less likely to lead to serious injury than those in open water and, accordingly, the St. Lawrence River region had the lowest fatality and injury rate.

Fewer than 2% of commercial marine incidents and accidents in Canadian waters involved a known release of pollutants into the environment.

Though shipping incidents and accidents usually have multiple causes, the most commonly cited ones are human and organizational factors.

Insight into the risks associated with commercial marine shipping begins with an understanding of i) the frequency, types, and locations of incidents and accidents;[8] and ii) factors that influence the probability of these events occurring. Together, these elements help determine the overall likelihood of an accident and provide insight into where, when, and why different types of incidents and accidents are occurring. The marine shipping risk characterization process is dependent on accurate, complete data on incidents and accidents, which can facilitate the development of regulations that reflect the realities of the marine shipping industry (Psarros *et al.*, 2010; Hassel *et al.*, 2011).

This chapter relies on Canadian data to determine the most common incident and accident types and locations for commercial cargo ships. Although these data are useful for helping understand shipping risks, it should be noted that they do not provide insight into catastrophic (Black Swan) events, which are characterized by their rarity, low predictability, and extreme impact (Taleb, 2010). A Black Swan event is an outlier because "nothing in the past can convincingly point to its possibility" (Taleb, 2010); thus, it falls outside the realm of risk models, which use existing data to predict the future.

The Transportation Safety Board (TSB) maintains Canada's most comprehensive data set, which is generated by mandatory reporting of incidents and accidents by a ship's crew (GOC, 2014a). Under the *Canada Shipping Act*, 2001, these reporting requirements apply "to Canadian vessels operating in all waters and to all vessels operating in Canadian waters" (TC, 2012c). The TSB data has proven superior to national data from other countries in terms of completeness — it includes approximately three-quarters of the estimated true number of incidents and accidents in Canadian waters (Hassel *et al.*, 2011). However, unlike its American equivalent, the TSB database does not report on the stage of shipping during which an incident or accident occurred.

Crews are also required to inform the owners of their vessels of any incidents or accidents (Lappalainen *et al.*, 2011). Owners, in turn, are expected to report damage or deterioration to the classification society under which they are certified, and may report to a marine insurance agency if they decide to make a claim (IACS, 2011; Allianz, 2012). Data from all of these sources may be analyzed to help characterize marine shipping risks. However, as Box 3.1 explains, the data suffer from numerous issues that make accurate analyses of marine incidents and accidents difficult.

8 There are no universally accepted definitions for the terms *marine incident* and *marine accident*. Some organizations divide adverse events into accidents and near misses (ABS, 2014), whereas others categorize an event as either a casualty or an incident (EMSA, 2014). In Canada, the Transportation Safety Board uses accident and incident. Accidents are events such as collisions, sinkings, groundings, or fires/explosions that may result in death, serious injury, ship damage, or total loss of a ship. Incidents are events that pose safety threats but do not result in consequences (e.g., mechanical failure, bottom contact without going aground) or events that could have resulted in more severe consequences under different conditions (e.g., intentional grounding to avoid an accident) (TSB, 2015a). See Appendix C for the full list of the events that are considered marine incidents or accidents.

Box 3.1
Marine Shipping Incident and Accident Data

The usefulness of marine shipping incident and accident data is limited by several issues:

Under-reporting: Marine incident and accident databases may be incomplete due to under-reporting, particularly for minor incidents or injuries (Ellis *et al.*, 2010; Psarros *et al.*, 2010; Hassel *et al.*, 2011; Lappalainen *et al.*, 2011). A number of reasons for under-reporting have been identified including a reluctance to report incidents to managers for fear of being blamed or punished; the belief that reporting is a poor way to learn from incidents; and the existence of too much paperwork with insufficient resources to complete it (Lappalainen *et al.*, 2011).

Incomplete or poorly categorized records: Records are often incomplete with information missing on, for example, the accident location, the type of ship involved, or the suspected cause of an accident. Causal information in particular can be problematic due to the practices of i) failing to record any causal information or ii) mixing causes and outcomes together in the same database field (Devanney, 2009; Psarros *et al.*, 2010). For example, the TSB includes technical failure (a cause), grounding, ship damage, and death or injury (all outcomes) in the same category called *accident/incident subtype*. These types of categorization inconsistencies make it difficult to correlate data from different sources.

Comparisons of accident data: On its own, accident database information can be used to establish the total number of accidents by parameters, such as vessel type or region. Comparing these data in a more meaningful way through accident rate calculations is more difficult, however, due to the lack of suitable baseline data for the denominator. For this report, rates are calculated on the basis of vessel movements and the number of registered vessels, neither of which allows for a detailed portrayal of incident and accident rates by vessel type.[9]

3.1 INCIDENTS AND ACCIDENTS BY VESSEL TYPE AND REGION

Shipping accident statistics are reported in various ways by different organizations. For example, insurance organizations generally report numbers of total losses, which refer to situations in which ships are lost, destroyed, or damaged beyond repair (Allianz, 2015; Lloyd's, 2016). From a risk perspective, less serious events, including marine incidents, are also important, since they could have been major accidents under different conditions. Furthermore, incidents such as near misses may share the same underlying causes as accidents (IMO, 2008). Both incidents and accidents are recorded in the TSB database; workshop participants generally did not distinguish between the two in their data analyses, since both contribute to the overall understanding of risk.

3.1.1 Shipping Accidents Involving Commercial Vessels Are Declining

Worldwide, insurance statistics indicate that total losses for ships have declined significantly since the early 1900s (Allianz, 2012). For Canadian ships and Canadian waters, accidents involving commercial cargo vessels (e.g., tankers, bulk carriers, container ships)[10] dropped by 40% from 1998 to 2014 (Figure 3.1).

3.1.2 Tankers and Solid Cargo Vessels Have Similar Incident and Accident Rates

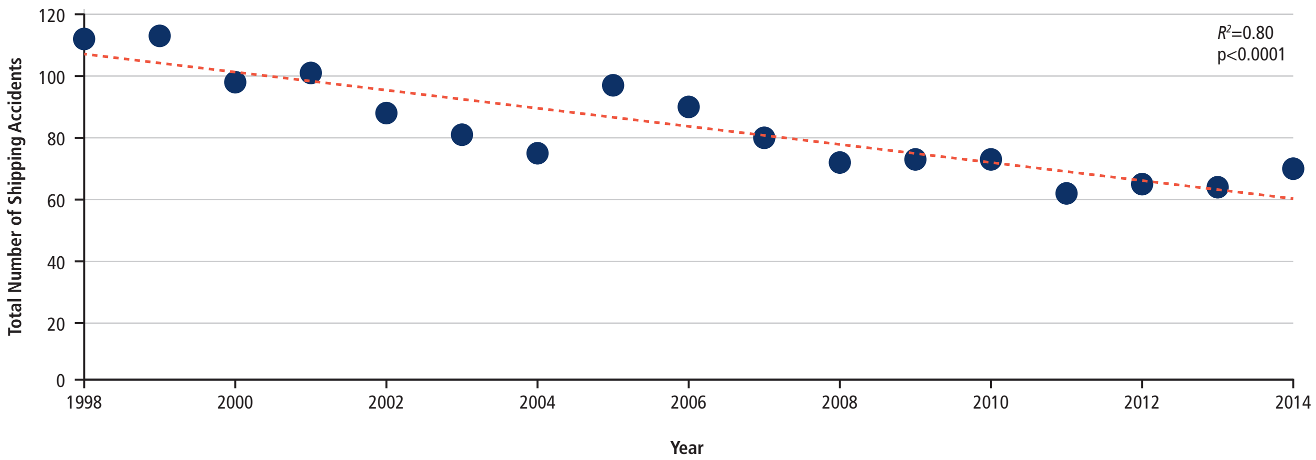
Between January 2004 and October 2015, 1,819 incidents and accidents involving cargo ships in Canadian waters were reported to the TSB — 274 for vessels carrying liquid cargo and 1,545 for those carrying solid cargo (Figure 3.2). These accounted for 21.7% of all incidents and accidents in Canadian waters, with tankers responsible for 3.3% and solid cargo ships for 18.4%.

Though solid cargo vessels were disproportionately represented in the total number of reported incidents and accidents, data on Canadian flagged vessels suggest this is largely because there are more solid cargo vessels operating in Canadian waters than there are tankers. Indeed, in proportion to vessel registry numbers from Transport Canada, the five-year average incident and accident rates for Canadian-registered solid cargo vessels and tankers were similar.[11]

9 See Appendix C for a description of the data used in this report and an explanation of analysis limitations.

10 Most data analyses only include commercial vessels carrying solid and liquid cargo. Other vessel types (e.g., fishing vessels, service ships, barges, tugs, and passenger ships) are excluded unless indicated. Please see Appendix C for a note about barges and tugs and more discussion of data analysis parameters.

11 From 2010 to 2014, there was an average of 175 solid cargo vessels and 35 tankers registered in a given year in Canada. During this same time period, solid cargo vessels and tankers experienced an average of 0.39 and 0.31 incidents and accidents per registered vessel, respectively (TC, 2013a; TSB, 2015c). Appendix C explains why the number of registered vessels was used to calculate the incident and accident rate.

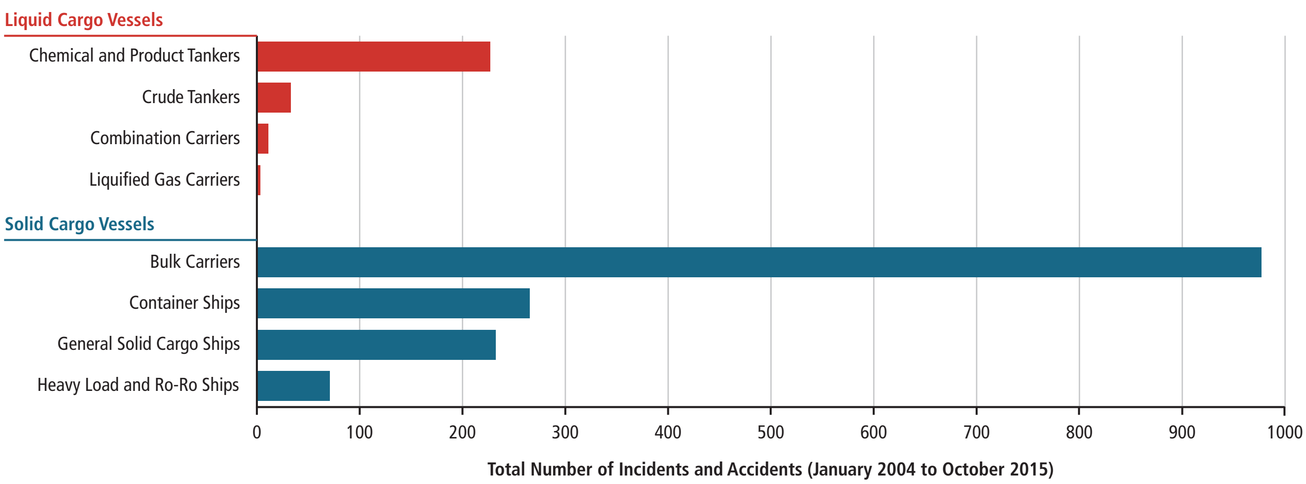


Data Source: TSB, 2008, 2015c

Figure 3.1

Total Number of Reported Shipping Accidents in Canadian Waters or Involving Canadian Ships, Solid and Liquid Cargo Vessels (1998 to 2014)

Data include all reported shipping accidents involving solid and liquid cargo vessels in Canadian waters (for Canadian and foreign vessels) and in foreign waters (for Canadian vessels only) from 1998 to 2014. Only shipping accidents (and not accidents aboard ship or incidents) are included (see Appendix C for definitions of these terms).



Data Source: TSB, 2015c

Figure 3.2

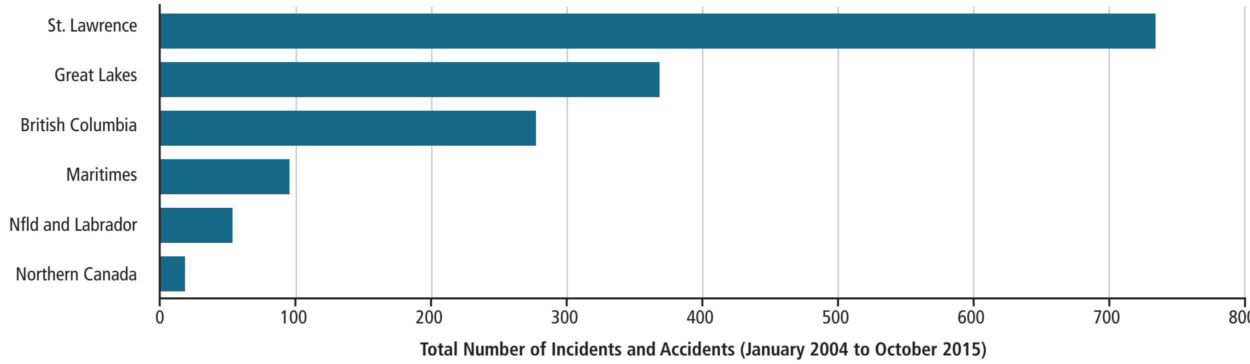
Total Number of Reported Incidents and Accidents by Vessel Type, Solid and Liquid Cargo Vessels (2004 to 2015)

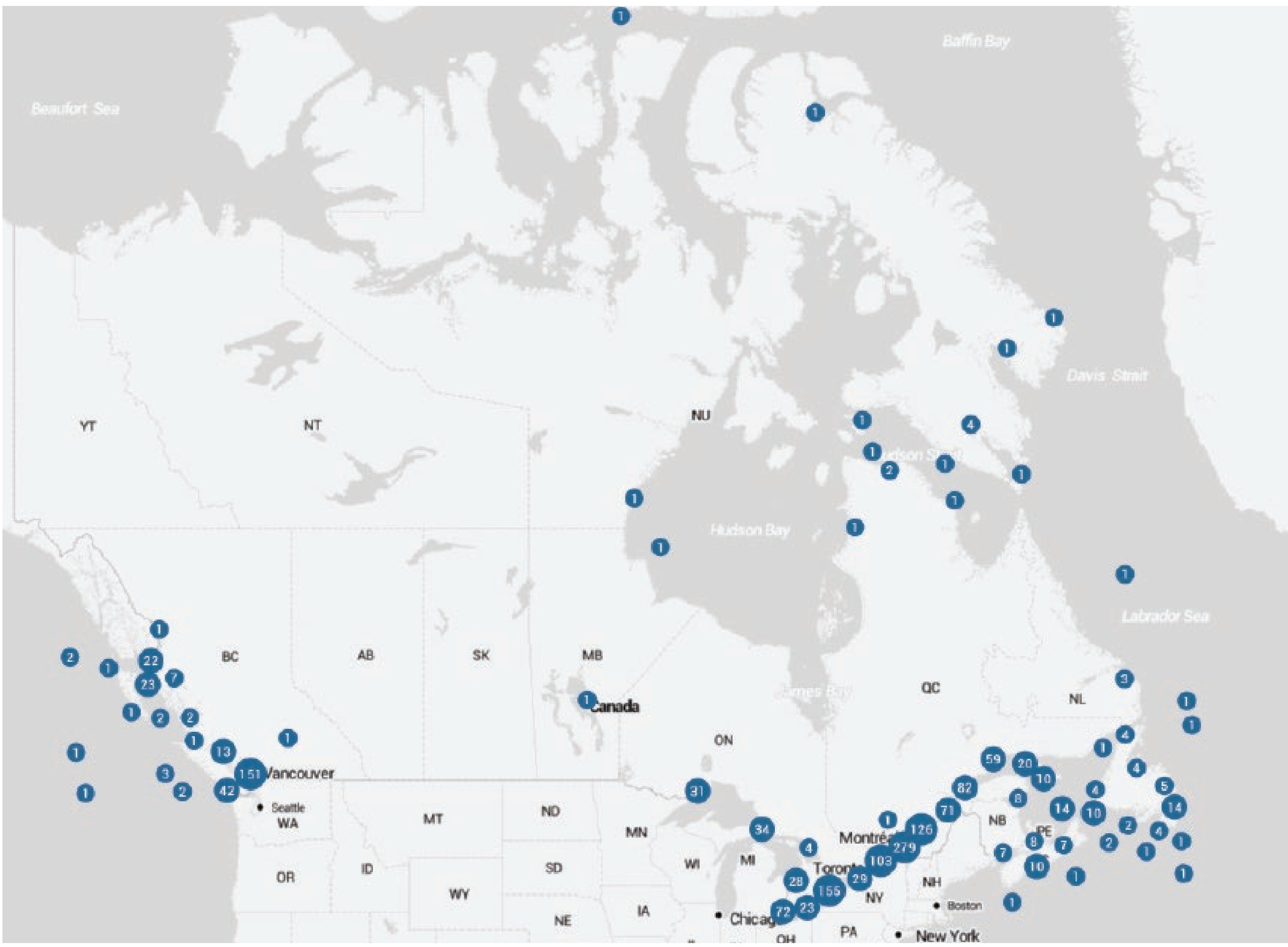
Data include all reported incidents and accidents involving solid and liquid cargo ships in Canadian waters (for Canadian and foreign vessels) from January 2004 to October 2015.

3.1.3 The Likelihood of an Incident or Accident Varies Considerably by Region

From 2004 to 2015, 72% of all reported incidents and accidents involving solid and liquid cargo ships occurred in the Central region of Canada, with 50% along the St. Lawrence River and 22% in the Great Lakes (Figures 3.3 and 3.4). This is despite the fact that, each year, British Columbia experiences almost twice as many vessel movements as the St. Lawrence River and Great Lakes combined (Figure 3.5). When incidents and accidents were considered as a proportion of vessel movements, both the St. Lawrence River and Great Lakes regions had higher incident and accident rates than British Columbia (Figure 3.5). Northern Canada stood out as having the highest rate, though one that is based on far fewer vessel movements (and thus fewer overall incidents and accidents). Some potential reasons for the high rates in Central and Northern Canada are discussed in Sections 3.3 and 3.4, respectively. Caution is required in comparing rates between regions. While accident data include all incidents and accidents occurring in Canadian waters, vessel movements only record vessels arriving at or departing from a Canadian port. In the Central region and British Columbia, this excludes vessels traveling through Canadian waters that do not stop at a Canadian port.

Solid Cargo





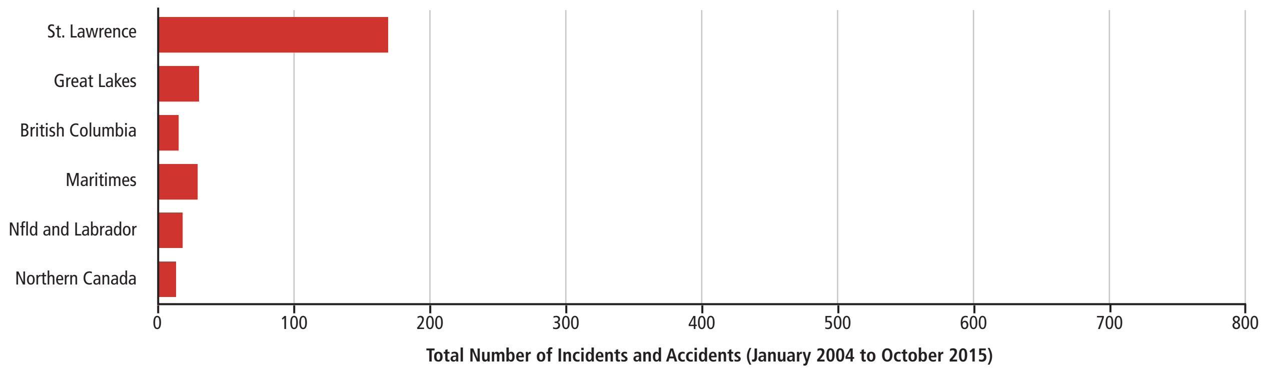
Data Source: TSB, 2015c

Figure 3.3

Location of Reported Incidents and Accidents in Canadian Waters, Solid Cargo Vessels (2004 to 2015)

Cluster map generated from latitude and longitude data included in each TSB record (TSB, 2015c). Mapping tool: Inquiron (2013). Histogram shows total number of incidents and accidents involving solid cargo ships in Canadian waters from January 2004 to October 2015.

Liquid Cargo



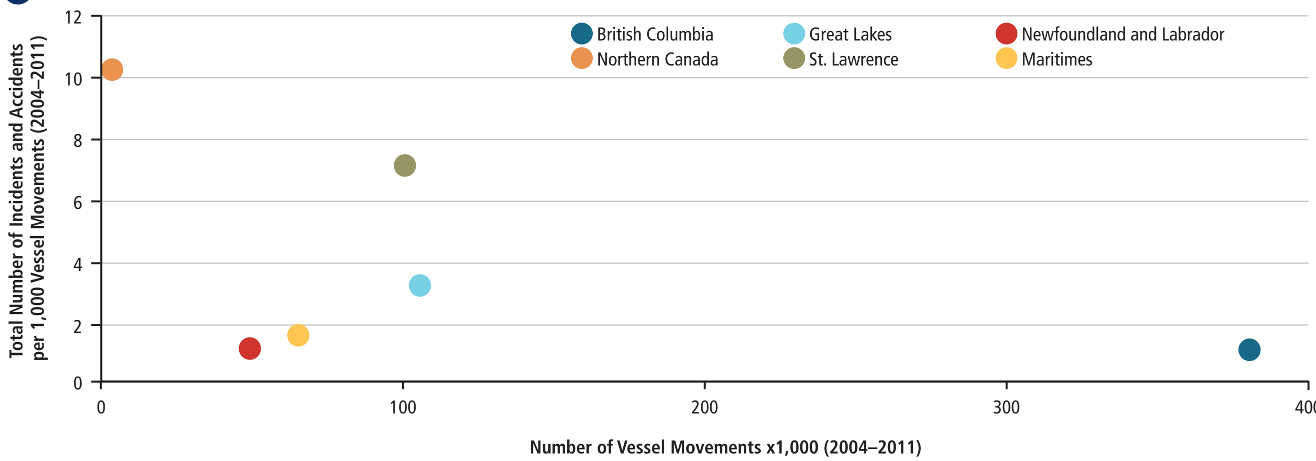
Data Source: TSB, 2015c

Figure 3.4

Location of Reported Incidents and Accidents in Canadian Waters, Liquid Cargo Vessels (2004 to 2015)

Cluster map generated from latitude and longitude data included in each TSB record (TSB, 2015c). Mapping tool: Inquiron (2013). Histogram shows total number of incidents and accidents involving liquid cargo ships in Canadian waters from January 2004 to October 2015.

A



B

Region	Total Number of Vessel Movements (2004–2011)	Total Number of Incidents and Accidents (2004–2011)
Northern Canada	3,607	37
Newfoundland and Labrador	49,246	61
Maritimes	65,297	113
St. Lawrence	100,629	720
Great Lakes	105,606	335
British Columbia	380,472	456

Data Source: StatCan 2007, 2008, 2009, 2010a, 2010b, 2011, 2012a, 2012b; TSB, 2015c

Figure 3.5

Incident and Accident Rates Based on Vessel Movements for Different Regions in Canada

The relationship between marine traffic (vessel movements) and incident and accident rates for each Canadian region is shown in Panel A. Data include all reported incidents and accidents involving solid and liquid cargo ships, barges, and tugs in Canadian waters (Canadian and foreign vessels) from 2004 to 2011. Vessel movements include vessels arriving at or departing from a Canadian port but not vessels traveling through Canadian waters that do not stop at a Canadian port. Analysis could not go beyond 2011 because Statistics Canada's vessel movement numbers are only available up to that year. In addition, the vessel movement numbers include barges and tugs; because data are not separated by vessel type, it was not possible to isolate movement numbers for specific types of vessels. Thus, tugs and barges could not be excluded from this calculation. The table in Panel B shows the total number of vessel movements and the total number of incidents and accidents in each region for the eight-year period indicated. These data were used to calculate the incident and accident rate.

3.1.4 The Most Common Incident and Accident Types Are Consistent Across Regions

Although more incidents and accidents were reported in certain regions of Canada than others over the past 10 years, the most common types for solid and liquid cargo vessels appeared to occur in similar proportions across all regions (Table 3.1). Strikings were more variable between regions than any other accident type. Their higher likelihood in the St. Lawrence River and Great Lakes likely reflects the abundance of narrow waterways such as canals in these regions (see Section 3.2.1). The top incident and accident types provide some indication of the potential associated impacts. For instance, groundings could impose economic costs associated with delays and supply chain disruptions and, in severe cases, could lead to cargo spills that impact the environment. In contrast, fires could contribute to air pollution and casualties, and necessitate costly ship repairs. Impacts of marine incidents and accidents are explored in detail in Chapter 4.

As discussed in Box 3.1, the field within the TSB database describing incident or accident type contained a mix of causes (e.g., technical failure) and outcomes (e.g., serious injury). Workshop participants were aware of this and acknowledged that many accidents involve multiple causes and outcomes. For example, technical issues and poor visibility could lead to a collision, followed by an explosion, a grounding, and subsequent loss of life (Devanney, 2009). This level of detail is difficult to codify in a database. While recognizing the shortcomings of the data in Table 3.1,

Table 3.1

Top Incident and Accident Types for Solid and Liquid Cargo Vessels, by Region (2004 to 2015)

Type of Incident or Accident	British Columbia n=292 total		Great Lakes n=398 total		Maritimes n=125 total		Nfld and Labrador n=71 total		Northern Canada n=31 total		St. Lawrence River n=902 total		Canada n=1,819 total	
	% of All Incidents and Accidents in Region (Ranking)													
Total failure of any machinery or technical system	22.3	(1)	24.4	(1)	30.4	(1)	19.7	(1)	22.6	(1)	31.6	(1)	27.8	(1)
Striking (allision)	12.3	(4)	22.9	(2)	6.4	(5)	9.9	(5)	None		18.2	(2)	16.8	(2)
Serious human injury or death	12.7	(3)	12.8	(3)	10.4	(3)	15.5	(2)	22.6	(1)	7.4	(4)	10.2	(3)
Sustained damage to ship, rendering it unseaworthy or unfit for purpose	4.1	(9)	8.3	(5)	16.0	(2)	12.7	(3)	16.1	(3)	11.1	(3)	9.8	(4)
Grounding	5.5	(7)	9.5	(4)	9.6	(4)	11.3	(4)	12.9	(4)	7.0	(5)	7.8	(5)
Risk of striking (near allision)	14.4	(2)	3.5	(8)	2.4	(11)	2.8	(8)	None		6.7	(6)	6.7	(6)
Bottom contact	1.4	(11)	5.8	(6)	4.0	(8)	5.6	(6)	12.9	(4)	4.1	(7)	4.2	(7)
Fire	3.4	(10)	5.0	(7)	5.6	(7)	5.6	(6)	3.2	(7)	2.5	(10)	3.6	(8)
Other	24.1		7.8		15.2		16.9		9.7		11.4		13.1	
Total	**100%**		**100%**		**100%**		**100%**		**100%**		**100%**		**100%**	

Data Source: TSB, 2015c

The TSB database was used to establish the top 8 incident and accident types reported in Canada (from January 2004 to October 2015), and their rankings were then determined for each region of Canada. In most cases, the types contained within the top 8 for all of Canada were within the top 10 for each region. The only exceptions were: i) in British Columbia and the Maritimes, bottom contact and risk of striking, respectively, were outside the top 10; and ii) in Northern Canada, no striking accidents or risk of striking incidents were reported. Some accident types for a region have the same ranking because they occurred at equal frequencies.

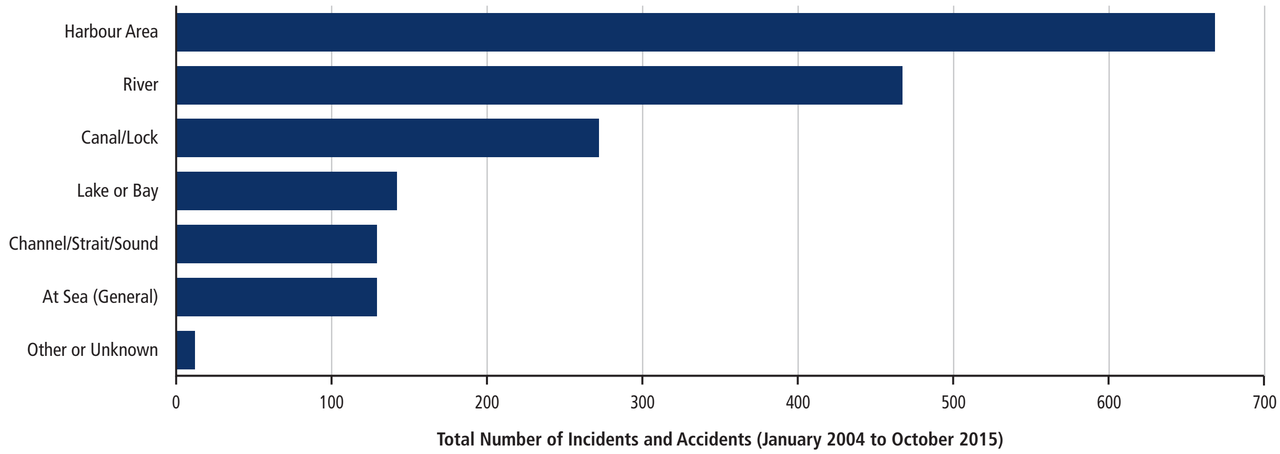
workshop participants still felt that it was useful to convey the message that different regions of Canada have experienced various accident types in similar proportions over the past 10 years.

3.2 INCIDENTS AND ACCIDENTS BY STAGE OF SHIPPING AND TYPE OF WATERWAY

There is a lack of publicly available Canadian data on incidents and accidents related to stages of shipping. As such, it was not possible to adequately characterize risks in terms of the numbers and types of incidents and accidents that take place when a vessel is, for example, undergoing cargo or bunkering operations, being assisted by a tug or pilot, or traversing the open sea. The TSB data did, however, give some insight into the type of waterway in which the incident or accident occurred, such as a harbour, river, or lake (see Figure 3.6 for waterway types defined by the TSB). If some assumptions are made (e.g., cargo operations are carried out in harbour areas; vessels out at sea are not under pilotage), these can be used to provide at least some information on the types of activities that are more likely to trigger an incident or accident. For reports submitted to the TSB over the past 10 years, restricted waterways (harbours, rivers, canals) emerged as areas with the largest number of incidents and accidents.

3.2.1 Harbour Areas Account for the Largest Percentage of Incidents and Accidents

From 2004 to 2015, 37% of the incidents and accidents reported in Canadian waters occurred in harbour areas (Figure 3.6), suggesting that they may be taking place during cargo loading or unloading, or when a vessel is under pilotage. The top three areas (harbours, rivers, canals/locks), where 77% of the incidents and accidents involving commercial cargo ships took place, are all restricted waterways as compared to the open sea. Incidents and accidents in very narrow waterways appear to be common — for example, 21% of the reported incidents and accidents in the St. Lawrence River and Great Lakes regions occurred at canals or locks, and of these, 41% occurred along the Welland Canal (TSB, 2015c).

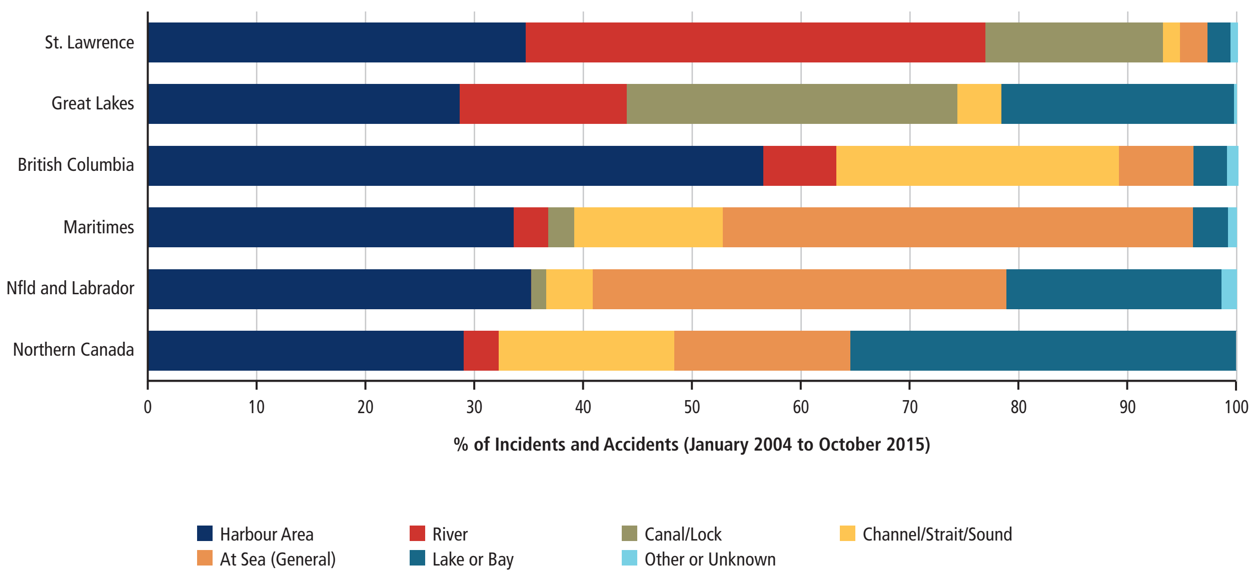


Data Source: TSB, 2015c

Figure 3.6

Total Number of Reported Incidents and Accidents by Type of Waterway, Solid and Liquid Cargo Vessels (2004 to 2015)

Data include all reported incidents and accidents involving solid and liquid cargo ships in Canadian waters (Canadian and foreign vessels) from January 2004 to October 2015.



Data Source: TSB, 2015c

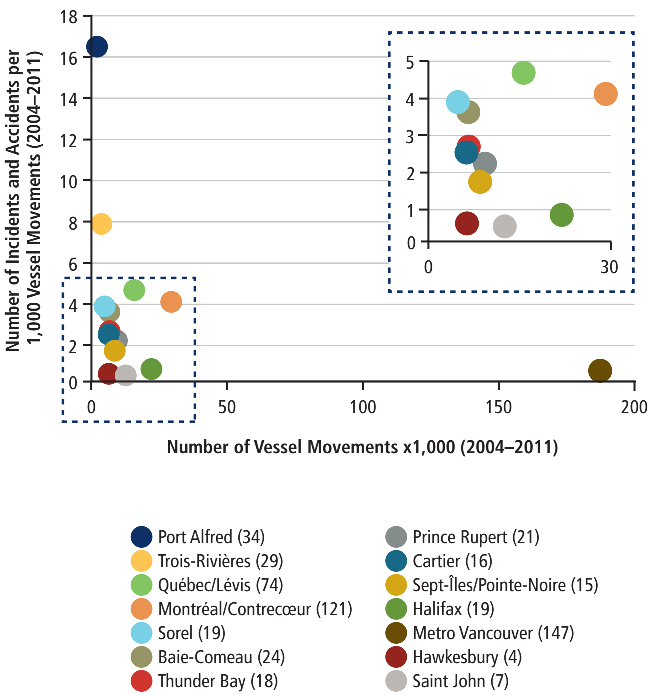
Figure 3.7

Percentage of Reported Incidents and Accidents by Type of Waterway, Solid and Liquid Cargo Vessels (2004 to 2015)

Data include all reported incidents and accidents involving solid and liquid cargo ships in Canadian waters (Canadian and foreign vessels) from January 2004 to October 2015. For each region, bars are subdivided to indicate the proportion of incidents or accidents that occurred in each type of waterway.

In terms of the incident and accident types that occurred in different waterways, a division was apparent between open or moderately open and restricted areas. Total failure of any machinery or technical system was the top type in all areas, except along canals, at locks, and in harbour areas, where striking was the most common type. This was especially apparent at locks, where 64% of reported incidents and accidents were strikings (TSB, 2015c).

Certain regional differences were expected given the types of waterways that are present in different parts of Canada (Figure 3.7). Of note, the profiles of the Pacific (British Columbia) and Atlantic (Maritimes and Newfoundland and Labrador) regions were different, despite the fact that they are both coastal areas. In British Columbia, 57% of the incidents and accidents occurred in harbour areas and 7% occurred at sea. In contrast, for both the Maritimes and Newfoundland and Labrador, approximately 35% occurred in harbour areas and 40% at sea (TSB, 2015c).



Data Source: StatCan 2007, 2008, 2009, 2010a, 2010b, 2011, 2012a, 2012b; TSB, 2015c

Figure 3.8

Incident and Accident Rates for a Sampling of Canadian Ports

The relationship between marine traffic (vessel movements) and incident and accident rates at different ports in Canada. Data include all reported incidents and accidents involving solid and liquid cargo ships, barges, and tugs in Canadian waters (Canadian and foreign vessels) from 2004 to 2011. In the legend, ports are listed in order from highest (top) to lowest (bottom) incident and accident rate. Total numbers of incidents and accidents at each port from 2004 to 2011 are stated in parentheses. Analysis could not go beyond 2011 because Statistics Canada's vessel movement numbers are only available up to that year. In addition, the vessel movement numbers include barges and tugs; because data are not separated by vessel type, it was not possible to isolate movement numbers for specific types of vessels. Thus, tugs and barges could not be excluded from this calculation.

Given the large number of incidents and accidents reported in harbour areas throughout Canada, the TSB data were analyzed by port. In absolute terms, three of the four busiest ports, Metro Vancouver, Montréal, and Québec (Table 2.2) had the highest number of incidents and accidents, but relative to the number of vessel movements, they were not the most incident- or accident-prone (Figure 3.8). In fact, Port Metro Vancouver — the busiest Canadian port from 2004 to 2011 — had the highest number of incidents and accidents, but the third lowest incident and accident rate of the ports that were examined.

3.2.2 Canadian Data on Incidents and Accidents by Stage of Shipping Are Lacking

As mentioned, there are no readily available Canadian data on the stages of shipping during which incidents and accidents occur. Studies from other countries provide some insight, but information on this aspect of marine shipping risk is generally limited.

A broad range of incident and accident types can occur at various stages of shipping (e.g., during cargo operations, bunkering, and tugging). For example, with containerized cargo, a box may fall from a crane and smash into a solid structure or fall in the water (CBC News, 2015b). When transferring liquid cargo, spills may occur if a tank overflows or if a discharge hose becomes disconnected or damaged (Skura, 2015). Certain types of wet and dry bulk cargo may pose specific issues (e.g., flammable liquid cargo such as fuel may ignite; offloading of dry material such as coal or salt can generate significant quantities of dust) (Johnson & Bustin, 2006). If a vessel is being aided by an icebreaker or a tug, the two vessels involved may collide. Other potential events during icebreaker or tug assistance include damage from ice fragments or parting of tug lines, respectively.

An American study assessing the risk of a proposed marine terminal on the Pacific coast determined that incidents[12] in the study area were least likely to occur while vessels were anchored. Incidents were approximately twice as likely when vessels were docked, more than three times as likely when vessels were underway, and approximately 20 times as likely when vessels were manoeuvring (e.g., moving in and out of anchorages or berths) (Kirtley *et al.*, 2014). Given that marine pilots are often required to manoeuvre through busy, complex waterways, which already provide a greater opportunity for accidents, it may be inferred that the chance of an accident while under pilotage is higher than the chance while underway without a pilot

12 In this study, an incident was defined as "an event or circumstance deemed by the U.S. Coast Guard and/or the State of Washington Department of Ecology to have the potential for an oil spill. A spill may or may not have occurred" (Kirtley *et al.*, 2014).

(i.e., in open water) (Anbring & Grundevik, 2012). The communication and cooperation needed between a pilot and master to safely guide a vessel add another layer of complexity to the pilotage process (TSB, 1995). However, this is not to imply that pilots increase the chance of an accident; a Swedish study that analyzed navigation-related accidents (i.e., groundings and collisions with objects or other vessels) from 1985 to 2009 suggested — though did not confirm — that the opposite is true. The number of navigation-related accidents declined after mandatory pilotage criteria were introduced in 1983, and most of these accidents (approximately 80%) occurred without a pilot onboard. However, the authors were careful not to conclude that pilotage was responsible for these results, clarifying that other factors may have contributed (Anbring & Grundevik, 2012).

3.3 BRINGING IT ALL TOGETHER: THE IMPORTANCE OF FREQUENCY AND SEVERITY

Thus far, Chapter 3 has analyzed reported cargo ship incidents and accidents in Canadian waters for the past 10 years, in terms of the categories of vessels involved, the location of occurrence (by region and type of waterway), and the most common incident and accident types. To get a complete picture of the marine shipping risk environment in Canada, it is also important to consider whether any of these incidents or accidents have had significant consequences such as loss of life, serious injury, or pollution. Although 1,819 incidents and accidents involving solid and liquid cargo vessels were recorded in the TSB database from January 2004 to October 2015, only 23 records (1.3%) included fatalities (some accidents involved multiple fatalities, for a total of 29), and only 31 records (1.7%) indicated that pollution was released into the environment. Furthermore, almost half of the entries in the database were classified as incidents (Table 3.2), suggesting that, while many posed safety threats, they did not have serious consequences. Nonetheless, under different conditions, incidents could have been major events involving casualties or large spills. Thus, it is still important to determine why certain geographical regions or types of waterways have higher incident and accident rates, no matter how minor these events may be.

Most (96%) of the serious injuries and fatalities involving cargo ships in Canadian waters were categorized as accidents aboard ship rather than shipping accidents (see Appendix C). No further information is provided in the TSB database about the nature or cause of the injury or death, other than to indicate whether it involved contacting part of the ship or its contents, or falling overboard. The eight shipping accidents that resulted in serious injury or death were categorized as capsizing, collision, fire, or sinking. This small sample size makes it difficult to relate specific shipping accident types to injuries or fatalities; of note, however, only three instances of capsizing were reported between 2004 and 2015, and all three involved fatalities. In contrast, only 3 to 4% of the reported collisions, fires, or sinkings led to serious injury or death (TSB, 2015c).

Table 3.2

Number of Fatalities, Serious Injuries, and Pollution Events in Canadian Waters for Solid and Liquid Cargo Vessels, by Region (2004 to 2015)

Region	Number of Incidents	Number of Accidents	Number of Accidents with at Least 1 Fatality	Number of Accidents with at Least 1 Serious Injury	Number of Incidents or Accidents Involving Pollutant Release
St. Lawrence River	451	451	8	58	9
Great Lakes	149	249	2	45	9
British Columbia	165	127	6	32	4
Maritimes	53	72	2	12	1
Nfld and Labrador	27	44	4	10	2
Northern Canada	14	17	1	6	6
Total (Canada)	**859**	**960**	**23**	**163**	**31**

Data Source: TSB, 2015c

3.3.1 The St. Lawrence River Region Has the Lowest Fatality and Injury Rate

Depending on the way they are presented, fatality statistics can be misleading. One accident may lead to many fatalities and this detail is hidden when data are reported as a fatality rate (Devanney, 2009). Because there were no mass casualties involving cargo ships in Canadian waters from 2004 to 2015, this is not an issue for the TSB data set. Of all the accidents that led to fatalities, each caused one or two fatalities with the exception of one: in 2008, the *Cap Blanc*, a small French cargo vessel loaded with salt, capsized in Placentia Bay, Newfoundland, resulting in the loss of four lives (The Canadian Press, 2008). The same is true for injuries — no more than three serious injuries were reported for any individual cargo ship accident except for one in 2010 involving the German vessel *Hermann Schoening*. Sixteen crew members became ill after fumigation pellets applied to grain that was loaded onto the vessel became moist and produced phosphine gas (Johnson, 2010; The Canadian Press, 2010).

Fatality and injury rates[13] for each region suggested that accidents along the St. Lawrence River were the least likely to lead to fatalities or serious injuries. A corresponding trend emerged when the data were analyzed by type of waterway. Although there were many accidents in rivers, canals/locks, and harbours, accidents in the open sea, lakes, or bays were approximately three times as likely to result in serious injury (TSB, 2015c). This finding qualifies the elevated incident and accident rate in the St. Lawrence River (Figure 3.5) by suggesting that, while it may be high, accidents that do occur are less likely to have serious outcomes, potentially due to the fact that ships are moving at lower speeds in these narrow waterways. This finding also makes clear that more incidents and accidents in a given region do not necessarily imply greater risk.

3.3.2 Large Oil Spills and HNS Spills Are Rare in Canadian Waters

As shown in Table 3.2, most of the reports submitted to the TSB from 2004 to 2015 indicated that pollutants were not released. The low number of pollution events made it difficult to perform any meaningful analyses. For commercial vessels, the type of accident that most often led to pollution was capsizing. Given that only three cargo ships capsized from 2004 to 2015, with one of these events (33%) leading to pollution, this is not a reliable statistic. Nonetheless, when all vessel types in the TSB database were analyzed, the statistic was similar — 30 of 117 (26%) instances of capsizing resulted in pollutant release (TSB, 2015c).

Tracking marine pollution is not a major focus of the TSB database. In 2001, the Canadian Coast Guard implemented the Marine Pollution Incident Reporting System (MPIRS) for this purpose (OAG, 2010). Unlike the TSB database, there is no official mandate for the MPIRS database to exist and it has not been made public. Information is entered by Canadian Coast Guard officials after they receive and investigate a report of marine pollution and the database is housed at Fisheries and Oceans Canada. The database suffers from some quality issues — fields such as region of occurrence, type of pollutant, and volume of spill are left blank for many records and estimates of spill volume vary significantly from year to year (OAG, 2010). In some cases, the full volume onboard the ship is reported, rather than the volume that is spilled. In its report prepared for the Tanker Safety Expert Panel, WSP Canada Inc. scrutinized the MPIRS database for the years 2003 to 2012, removed entries that could not be verified, and determined the following statistics for ship-source oil spills[14] in Canadian waters:

- There were no spills greater than 1,000,000 litres.
- For spills of 100,000 to 1,000,000 litres, the average number of spills per year was 0.7.
- For spills of 10,000 to 100,000 litres, the average number of spills per year was 2.5.
- For spills of 100 to 10,000 litres, the average number of spills per year was approximately 48, but most of these (approximately 70%) were fewer than 1,000 litres. Overall, 67% of ship-source oil spills in Canadian waters from 2003 to 2012 were between 100 and 1,000 litres.

(WSP Canada Inc., 2014a; MPIRS, 2015)

Of the larger spills (those 10,000 litres or greater), 78% involved fuel oil (e.g., Bunker C fuel oil, diesel) rather than oil being carried as cargo (WSP Canada Inc., 2014a). In accordance with this, oil tankers were not the source of most of these spills. Data available from the MPIRS on HNS spills was not verified, making it impossible to calculate a reliable spill rate. Nonetheless, it was still evident that HNS spills were rare. The database indicated that cargo vessels were the source of 10 chemical spills greater than 100 litres from 2004 to 2014. These involved compounds such as sulphuric acid and ethylbenzene (MPIRS, 2015).

Although some incidents and accidents were noted in both the TSB and MPIRS databases, they are in no way connected. A 2010 report by the Office of the Auditor General, which was undertaken to examine how Transport Canada, the Canadian Coast Guard, and Environment Canada have managed oil and chemical spills, noted that "there is no

13 Rate was calculated by dividing the number of accidents involving at least one fatality or one injury by the total number of accidents for each region.

14 Data include all vessel types. Workshop participants' own analysis of the MPIRS database showed that many oil spills smaller than 10,000 litres were from fishing vessels (MPIRS, 2015). Thus, if commercial cargo ships were considered on their own, the spill rate for this category would be lower.

central repository where all pertinent information related to an incident, including environmental or socio-economic damages, is documented" (OAG, 2010). A single data repository that included information on causes, types, and impacts of incidents and accidents would be valuable for trend analyses and risk assessments (OAG, 2010).

3.4 FACTORS THAT INFLUENCE THE LIKELIHOOD OF AN INCIDENT OR ACCIDENT

Accident investigations point to a wide range of factors that contribute to shipping accidents. Together, all of these factors constitute the complex risk environment within which shipping operates. A risk environment is the physical, socio-economic, and policy space "in which a variety of factors interact to increase the chances of harm occurring" (Rhodes, 2009). For marine shipping, the physical risk environment includes factors such as confined waterways and storms; the socio-economic risk environment may be influenced by inadequate vessel upkeep or poor safety culture; and factors within the policy risk environment include insufficient provision of maps, charts, and navigation aids.

For an individual accident, it is rarely possible to pinpoint a single causal factor. The process for determining all contributing factors is complex and resource-intensive. As a result, not all incidents and accidents are formally investigated by the appropriate authority, and contributing factors often remain unidentified. For example, between 2004 and 2015, there were just over 8,600 incidents and accidents in Canadian waters, and the TSB published 120 marine investigation reports (TSB, 2015b, 2015c). Although each report includes a section on contributing factors, the TSB database does not contain any causal information. Thus, it was not possible to analyze the factors contributing to commercial cargo vessel incidents and accidents in Canada.

Some databases attempt to include a field for the suspected cause of an accident, despite the difficulty of this task. In this case, the most obvious cause (i.e., the triggering factor) is often the only one that is recorded (NMD, 2011). Internationally, human error is the documented triggering factor for at least 75% of marine incidents and accidents (see numerous citations referred to in papers by Özdemir and Güneroglu (2015), Chauvin (2011), and Celik and Cebi (2009)). Research using hierarchical decision tools is finding that human factors are composed of *active failures* (unsafe acts such as errors or violations) and *latent conditions* (existing conditions such as poor ship design; poor management and organization, leading to overworked crews; and a poor safety culture). After lying dormant for a while, latent conditions may combine with active failures and local triggers, such as unfavourable weather, to cause an accident (Reason, 2000; Celik & Cebi, 2009; Chauvin *et al.*, 2013). Box 3.2 uses a case study to show how multiple factors, including active failures and latent conditions, can lead to a shipping accident.

Box 3.2
How Multiple Factors Contributed to a Tanker Grounding in Nunavut

On October 25, 2012, an oil tanker carrying 2893 m^3 of diesel ran aground in darkness on a shoal while outbound from Qamani'tuag (Baker Lake), Nunavut. The tanker was equipped with an ice-strengthened hull and a complement of navigational aids including two radars, two electronic chart systems, and two GPS systems. Though the accident resulted in neither injuries nor pollution, it illustrates how multiple risk factors can be at play. In this case, various human errors, inadequate channel navigation aids, and confined waterways all played a part.

At 110 metres in length, *M/T Nanny* is one of two tankers that transfers fuel to Qamani'tuag from a larger tanker, anchored 20 nautical miles east of the Chesterfield Narrows, to meet demands of the community and the Meadowbank gold mine located north of Qamani'tuag. The Chesterfield Narrows, through which the tankers must pass, is a challenging, confined passageway that is subject to tidal currents of up to four knots. The narrows can only be navigated within a 30 to 60 minute window during high water slack tide. A TSB investigation found a number of factors that contributed to the accident. *M/T Nanny* ran aground in darkness after having deviated from the charted route from the outset and then failing to return to it. Due to poor bridge resource management, the route deviation was not discussed by the bridge team, who were therefore unaware of the extent to which the vessel was off the charted course while entering the narrows. Furthermore, at the time of the grounding, the master had been focused on the engine controls and thrusters rather than on monitoring the navigation of the vessel. The TSB also found that onboard navigation aids were not configured with audible alarms. In addition, although calls for range beacons to be fitted with lights had been made and were considered a high priority by the Arctic Marine Advisory Board Sub-Committee in 2011, the range beacons remained unlit at the time of the accident.

TSB (2014a)

Table 3.3

Factors That Increase the Likelihood of an Incident or Accident

Factor	Ranking of Factor in Region				
	Atlantic	Central	North	Pacific	Canada
Human and organizational issues: inadequate crew training, exhaustion of watch-keeping personnel, poor bridge resource management, poor communication	2	1	4	3	1
Safety culture: failure of shipping companies to take ownership of safety (i.e., failure to promote a culture that goes beyond complying with regulations by doing the "bare minimum")	4	7	7	6	2
Age and condition of vessel: poor vessel design or maintenance	5	5	9	6	3
Ocean and weather conditions: unfavourable tides, currents, weather (including increased frequency or intensity of storms from climate change), and presence of ice	1	8	3	5	4
Regulatory complexity: interaction of a multitude of federal, provincial, and state regulations (particularly environmental) that can be overlapping and confusing (e.g., Canada shares waters with the United States)	–	4	–	–	5
Maps, charts, aids to navigation: physical and electronic aids to navigation, sailing directions, bathymetry maps, other maps or charts, or weather information may be poor, out-dated, or lacking	8	8	1	9	6
Shipping, port, and ice-breaking infrastructure and capacity: infrastructure may be lacking or poorly maintained	8	5	1	–	7
Geographical constraints: confined waterways, including narrow passages such as canals	5	1	6	2	8
Traffic density and volume: increased traffic and changes in traffic patterns or routes, leading to congestion	5	1	7	1	9
Cargo declarations: incorrect declarations due to loading errors or misstated manifests (inaccurate cargo type or weight)	10	10	–	6	10
Presence or abundance of marine animals or marine protected areas: poor traffic management to avoid sensitive species and environments	3	–	4	4	11

After coming to a consensus on the top 11 factors that increase the likelihood of a marine shipping incident or accident, workshop participants were asked to independently choose the top 4 factors for Canada as a whole and the top 4 factors for each of the indicated regions. The most important national factors were chosen independently of the top regional factors; therefore, the rankings for Canada do not reflect an average of the rankings for each region. Cells are shaded blue to highlight rankings that ranged from 1 (dark blue) to 4 (light blue). For a given region, note that some factors have the same ranking because they received the same number of votes. If for example, three factors for a region tied for a first place ranking, the next factor was assigned a fourth place ranking. Factors that did not receive any votes for a region were not assigned a ranking and are marked with a dash.

While acknowledging that a single accident has multiple causes, workshop participants sought only to develop a list of key factors that can work together in various combinations to increase the likelihood of an accident. These factors were ranked by their importance for Canada overall and for each indicated region (Table 3.3).

In line with existing data from around the world, workshop participants ranked human and organizational issues as the factor most likely to contribute to an incident or accident in Canada. Some notable regional trends emerged during this exercise. For example, the top two factors in the North (lack of maps, charts, and navigational aids, and lack of shipping, port, and ice-breaking infrastructure) were ranked much lower for all other regions. Their high ranking in Northern Canada reflects the lack of knowledge and capacity in this region, which was identified as a knowledge gap by those with northern expertise who participated in the survey. Ocean and weather conditions were viewed as very important for Atlantic and Northern Canada, but less so for other regions.

Detailed TSB investigation reports are readily available for a handful of the shipping accidents that have occurred north of the 60th parallel in Canada, and the contributing factors discussed in these documents corroborate the workshop findings. For example, lack of navigational aids was a factor in the *M/T Nanny* grounding discussed in Box 3.2. In a separate accident in 2010, the passenger vessel *Clipper Adventurer* ran aground in Nunavut on an uncharted shoal. In addition to navigating a route that had not been subjected to a complete hydrographic survey, the vessel was travelling at full sea speed without a functional forward-looking sonar (TSB, 2012). Vessel damage by multi-year ice — extremely hard, thick ice that has survived multiple melting seasons (Arctic Council, 2009) — was one causal factor in the sinking of the *FV Northern Osprey* off the coast of Northern Labrador in 1990 (TSB, n.d.). Thus, the harsh, inadequately charted waters of Northern Canada contribute to a risk environment that increases the likelihood of a shipping accident.

Geographical constraints and traffic density and volume were both ranked within the top two factors for Central and Pacific Canada, highlighting the abundance of restricted waterways (rivers, channels, canals) and areas with dense shipping traffic in these regions. Finally, although regulatory complexity and overlap were seen as moderately important for Canada overall, this was entirely due to their significance in the Central region, which contains several bodies of water that are shared with the United States. Ongoing uncertainty about managing ballast water in the St. Lawrence River and the Great Lakes provides an example of regulatory complexity. Canada signed onto the IMO's *Convention for the Control and Management of Ships' Ballast Water and Sediments*, which is likely to come into force soon (pending ratification by a sufficient number of member states) (EC, 2015b). The United States does not support the IMO's approach but has not solidified its own, with the U.S. Coast Guard yet to specify any acceptable treatment technology (BIMCO, 2015). Various shipping companies, governments, and other stakeholders are calling for a unified approach (Tanker Operator, 2015; CSA, n.d.). In the meantime, shipping companies may be forced to decide whether to install expensive equipment in the hopes of complying with the IMO regulations, but with no guarantee of meeting future U.S. requirements (Tanker Operator, 2015).

3.5 CONCLUSION

Canada's waters as a whole have been getting safer over the past decade, with fewer commercial marine shipping accidents. Much of the commercial marine traffic in Canada can be attributed to solid cargo vessels rather than tankers and, accordingly, solid cargo vessels accounted for most of the commercial shipping incidents and accidents in Canadian waters between 2004 and 2015. On a per-vessel-movement basis, Northern Canada, the St. Lawrence River, and the Great Lakes had the highest incident and accident rates. For the latter two regions, one factor contributing to these higher rates may be the abundance of restricted waterways in these areas — Canadian data for the past 10 years suggest that incidents and accidents are more likely to occur in confined waterways (harbours, rivers, canals). However, the data also suggest that accidents in restricted waterways are less likely to lead to serious injury than those in the open sea, lakes, or bays. In agreement with this finding, the St. Lawrence River region had the lowest fatality and injury rate. The reasons for higher incident and accident rates in certain regions are not fully understood.

It was difficult to correlate the likelihood of marine pollution with parameters such as region or type of accident, in part because Canadian pollution data suffer from some quality issues, but also due to the rarity of spills (particularly for HNS). There were no oil spills larger than 1,000,000 litres in Canadian waters from 2003 to 2012. Of the oil spills greater than 10,000 litres, just over three-quarters involved fuel oil rather than oil carried as cargo and, accordingly, oil tankers were not the source of most of these spills.

The data analyses in this chapter provide some indication of common incident and accident types and locations in Canada. However, key information, which would have allowed workshop participants to make more definitive statements on the likelihood of an oil or HNS spill, was not easily accessible. For example, the number of yearly vessel movements made by oil tankers and ships carrying HNS in Canadian waters was not readily available. Without this information, discussion of oil spills is mainly restricted to Chapter 4, which deals with the impacts of commercial marine shipping accidents. Because both likelihood *and* impact are important for understanding risk, this missing data hindered the overall characterization of marine shipping risks in Canada.

Determining the causal factors for a marine incident or accident is usually only possible if an investigation is conducted. Certain factors may be more likely to play a role in specific regions of Canada. For example, two factors with a regional bias that workshop participants identified were lack of navigation information and shipping infrastructure (most relevant to the North) and regulatory complexity and overlap (primarily relevant to Central Canada).

Many of the analyses in Chapter 3 raise questions and point to research gaps. For example, could better reporting practices be affecting the elevated number of incidents and accidents in the St. Lawrence River and Great Lakes regions, perhaps due to a strong safety culture among companies operating in the region? Is the fatality rate lower along the St. Lawrence River because ships are travelling slower as they navigate through this busy, restricted waterway? Does the lack of deepwater ports in Northern Canada, which forces many operations to be performed at anchor, contribute to the higher incident and accident rate in this region? Are accidents at sea more likely to happen in Newfoundland and Labrador because of dangerous conditions such as fog and ice? Are accidents more likely to occur at a certain time of day (e.g., night-time) or a certain time of year when weather conditions are more extreme? To answer these questions, better data, particularly causal information, will be needed.

4

Impacts

- Environmental Impacts
- Social, Cultural, Health, and Economic Impacts
- Factors That Influence the Impacts of an Accident
- Conclusion

4 Impacts

Key Findings

Shipping accidents involving the release of cargo can create a series of environmental impacts, which can in turn create social, cultural, health, and economic impacts.

The impacts of oil spills have been subject to extensive research and are likely to be significant. Spills of some HNS have not been well studied but have the potential to create major impacts.

The nature and extent of impacts from any pollution event is a function of many factors, including time of year, location, cargo type, volume spilled, weather and environmental conditions, and the ways in which nearby communities use the marine environment.

The speed and efficacy of the response to a pollution event are critical for reducing its impacts. Overall, Canada has a well-developed oil spill response regime, though recent developments have identified areas for improvement. Gaps include a lack of response organizations and support infrastructure in the North and remote areas, and the lack of an HNS preparedness and response regime across Canada.

The overall risk of a marine shipping accident[15] is determined by the probability that an accident will occur and by the potential type and magnitude of any resulting impacts. Chapter 3 dealt with the first part of the risk equation (the likelihood of an accident and the likelihood of resulting casualties or pollution) while this chapter considers the second element (the consequences — the potential impacts of an accident and factors that can influence impact).

The great majority of accidents primarily involve damage to property (e.g., hull damage, damage to cargo) and/or crew injury. These health and economic impacts can be significant (as with a crew fatality), and tend to involve the ship, crew, and related families and communities, often without affecting the natural environment. While recognizing that serious injuries and deaths have a great toll, these impacts are not specific to shipping and nor are they particularly elevated in marine shipping relative to other modes of transportation. This report does not attempt to offer insights into the nature of these impacts. Other types of accidents, although far less frequent, could include environmental impacts as a result of cargo and/or fuel spills, which then also lead to impacts on human health, societies, cultures, and economies. This suite of impacts associated with these types of accidents has been the subject of significant research and is central to current debates about the future of marine shipping in Canada; it is thus the primary focus of this chapter. Other potential impacts such as supply chain disruptions are acknowledged briefly in this report and this limited discussion reflects the availability of research in this area.

4.1 ENVIRONMENTAL IMPACTS

Environmental impacts of marine shipping accidents have been subject to extensive research, primarily tied to a few major oil spills (e.g., the 1989 *Exxon Valdez* spill in Prince William Sound, Alaska). Accidents in which pollutants are released into the environment have impacts on air quality, individual species, habitats, and the ecosystem, among others (Peterson *et al.*, 2003). Lessons from previous incidents are used to inform oil spill risk assessments, typically factoring in three components that influence environmental impacts: physical sensitivity (e.g., type of substrate, depth); biological sensitivity (e.g., species, habitat); and human and socio-economic sensitivity (e.g., economic activities) (DNV, 2011; Reich *et al.*, 2014). The potential environmental impacts of a spill vary by location, time of year, and amount and type of cargo spilled. Both the nature and degree of environmental impact heavily depend on whether a ship is carrying petroleum products, HNS, or less hazardous cargo. There is also a risk of a ship losing its own fuels — in fact, fuel oil is the type of oil that is most frequently spilled from ships in Canadian waters (WSP Canada Inc., 2014a). The potential impacts of oil spills discussed below are also

15 Although shipping data classify incidents and accidents separately, for simplicity this chapter nevertheless uses *accident* to refer to the kinds of major events likely to lead to significant impacts beyond the ship itself.

relevant when a fuel spill occurs. This section offers a brief summary of the key potential environmental impacts of spills of different types of cargo but is by no means comprehensive.

4.1.1 The Impacts of Oil Spills on the Natural Environment Can Be Significant and Persist over Long Periods

Most oils, when spilled, start by floating on the surface of the water, because oil products tend to have a lower density than water (Lee *et al.*, 2015). But, depending on the type of oil and environmental conditions, it can quickly begin to change its behaviour and chemical and physical properties. The Royal Society of Canada's Expert Panel on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments notes that, for each oil:

> [its] chemical fingerprint is a key predictor of not only the physical properties of the oil (e.g., how heavy or thick it is), but also its behaviour in the environment (e.g., how it spreads, sinks or disperses in water), its toxic effects on aquatic organisms and humans, and its susceptibility to degradation by 'weathering' (i.e., changes to the oil caused by the sun, waves, weather conditions and microorganisms in the environment).
> (Lee *et al.*, 2015)

Three groups of oils are commonly considered: heavy (e.g., crude oil, including diluted bitumen), light oil (e.g., diesel, refined), and fuel oil (e.g., bunker oil). Each exhibits different behaviours, and these behaviours must be considered when evaluating the potential impacts of a spill and determining the most appropriate spill response. For example, diluted bitumen from Alberta's oil sands combines heavy bituminous oil with diluents — used to facilitate transportation — which are primarily lighter oils. In the event of a spill, diluents may evaporate, leaving behind heavy oils that in some instances may be denser than water and thus may sink. If they sink to the ocean floor, they may pose risks to benthic habitat and wildlife (NOAA, 2014; Lee *et al.*, 2015). However, some of the weathered oil turns into tar balls, which stabilize at a certain depth and are then sometimes transported by currents for tens or hundreds of kilometres until they reach and subsequently contaminate a shore (Hostettler *et al.*, 2004; Lee *et al.*, 2015). Diluted bitumen also forms residues on which chemical dispersants are less effective (Lee *et al.*, 2015; Committee on the Effects of Diluted Bitumen on the Environment, 2016).

In general, this complex physical and chemical transformation that oil undergoes when spilled in the ocean, along with its toxicity, is better understood in the case of conventional crude oil. Research gaps remain in the case of newer oil types, including diluted bitumen, and further study will help reveal such oils' fate and effect on the environment (Lee *et al.*, 2015).

Impacts of oil spills on plants and animals are well documented (e.g., NRC, 2003; Lee, 2015; Peterson, 2003), though more is known about impacts in saltwater and temperate environments relative to freshwater and cold environments including the Arctic and Subarctic (Fitzpatrick *et al.*, 2015; Lee *et al.*, 2015). Marine mammals and seabirds are particularly vulnerable to floating oil because they come in frequent contact with the sea surface (NRC, 2003). When fur and feathers become covered in oil, they lose the ability to provide insulation, thus leaving animals susceptible to hypothermia (WSP Canada Inc., 2014a). Mortality and reduced reproduction can result from contact with contaminated sediments, ingestion of contaminated prey, and disruption of functions such as caregiving (Peterson *et al.*, 2003; WSP Canada Inc., 2014a; Lee *et al.*, 2015). Mortality may also be caused by ingestion of oil during excessive preening (WSP Canada Inc., 2014a). Indeed, the *Exxon Valdez* spill led to the deaths of an estimated 2,650 sea otters, 250,000 seabirds and 300 harbour seals (Garrott *et al.*, 1993; Loughlin, 1994 as cited in Peterson *et al.*, 2003; Piatt & Ford, 1996). Along with birds and marine mammals, invertebrates, fish, amphibians, and reptiles may all be affected at multiple life stages: mortality of eggs or larvae, reduced reproductive success, slower growth, lower survival rates, developmental defects, and behavioural changes have all been documented (WSP Canada Inc., 2014a). Oil can significantly alter shoreline habitats and, when those habitats are primarily composed of plants and animals (as in marshland), the entire habitat structure may be lost and can in turn limit the biological cycle of organisms (NRC, 2003). The use of chemical dispersants in oil spill response can change the ways the oil impacts the environment, and the dispersants themselves can cause additional impacts (Lee *et al.*, 2015). Dispersants are used to break the oil into smaller components that can more easily submerge in water and degrade, but there is a trade-off between exposing surface and sub-surface resources to oil. Lee *et al.* (2015) observe:

> Dispersants themselves are moderately toxic to aquatic species when free in solution, but appear to be unavailable and non-toxic when mixed with oil. Thus, dispersant toxicity will depend on how accurately it is applied to oil, whether it is completely mixed with oil, and the concentration of "free" dispersant in surface water if applications by spraying from aircraft miss the target.

Lee *et al.* (2015) call for additional research into the impacts of chemical dispersants on marine life under various conditions.

In the long term, the overall impact of oil on the ecosystem is more difficult to measure. The response of an ecosystem to oil exposure involves large spatial and temporal scales. Some of the impact of the *Exxon Valdez* spill was only detected years after the spill occurred. A study of harlequin duck populations in the years following the spill projected a recovery timeline of 24 years, and suggested that "cumulative mortality associated with chronic exposure to residual oil may actually exceed acute mortality" (Iverson & Esler, 2010). Sea otter populations also exhibited elevated mortality rates for nine years following the spill, even for otters born after the spill, likely as a function of acute oil exposure and indirect impacts like maternal influences or ongoing exposure to oil residues (Monson *et al.*, 2000). In a review of the literature, Peterson *et al.* (2003) note that "oil persisted beyond a decade in surprising amounts and in toxic forms, was sufficiently bioavailable to induce chronic biological exposures, and had long-term impacts at the population level." Workshop participants observed that, although these longer-term impacts may be less dramatic, less visible, and less studied, they are much more detrimental to the environment and population dynamics than the immediate acute mortality.

4.1.2 LNG Spills Pose Limited Environmental Risks

Little information on the impacts of a spill of LNG exists due to the lack of spills of this product worldwide (Hightower *et al.*, 2004). Still, experimental studies have evaluated LNG spill effects, mostly at a small scale (Hightower *et al.*, 2004). Overall, an LNG spill is likely to have minor impacts on the natural environment since natural gas will mix with the air and become diluted (DFO, 2013). However, in the immediate aftermath of a spill, gases may be concentrated in a vapour cloud, which could be flammable under certain conditions (DFO, 2013). The risks associated with this are concentrated in the area closest to the spill site (Hightower *et al.*, 2004). A cooling or freezing effect (air and water) will be observed under LNG exposure, but an LNG spill is unlikely to have large-scale consequences (DFO, 2013). If a container leaks underwater, LNG may dissolve and displace dissolved oxygen, leading to hypoxic or anoxic conditions that can harm aquatic organisms (WSP Canada Inc., 2014b). A better understanding of the fate and behaviour of LNG in both air and water would be helpful if this commodity were to be shipped in new areas (which is being contemplated in the Pacific region) or in larger volumes (which is being contemplated in the Maritimes) (NRCan, 2015; GBC, n.d.).

4.1.3 The Environmental Impacts of HNS Are Highly Variable and Sometimes Poorly Understood

HNS represent a class of substances with a wide range of chemical properties (from inert to very reactive) and toxicity. The behaviours of HNS in the environment vary widely: they may sink, float, evaporate, or dissolve, etc. (Neuparth *et al.*, 2011). HNS that are highly soluble, persistent, bioavailable, toxic, able to float to other sensitive coastal areas, or able to sink pose the greatest threats (Neuparth *et al.*, 2011; Häkkinen & Posti, 2014). HNS that sink can deposit on the sea floor, potentially smothering sediments or poisoning wildlife (WSP Canada Inc., 2014b).

In order to capture HNS diversity, sub-classes may be considered for organic and inorganic substances. A recent HNS risk assessment study conducted by WSP Canada Inc. included five categories: coke and asphalt; liquefied and compressed gas; organic substances (e.g., solvents like methanol and xylene); inorganic substances (e.g., fertilizers); and animal and vegetable oils.

The impacts of HNS on wildlife are generally poorly understood, but some of these substances may affect growth and reproduction (Rocha *et al.*, 2016). Despite being less toxic, spills of edible oils can have some of the same impacts as crude oil spills; in particular, they can cause smothering and oiling of feathers (Fingas, 2015). Of all the HNS transported by marine shipping, pesticides are thought to represent one of the greatest threats to the marine environment (Häkkinen & Posti, 2014).

As a consequence of the large diversity of HNS and a lack of statistics on these spills, few risk assessments exist to date. However, the Tanker Safety Expert Panel was informed by WSP Canada Inc.'s HNS risk assessment study (TSEP, 2014). It considered 26 products factoring in volumes moved, an index of hazard,[16] and environmental sensitivity across regions, and concluded that, overall, the risk of HNS spills was low (TSEP, 2014; WSP Canada Inc., 2014a). This risk profile does vary by region and by HNS, generally reflecting the relative tonnage of different products moved in different regions. WSP Canada Inc. (2014b) found that the greatest risks lie in the Great Lakes/St. Lawrence Seaway for spills of coke, asphalt, and organic substances, followed by the St. Lawrence Gulf and Estuary for those same substances (WSP Canada Inc., 2014b). Neuparth *et al.* (2011) prioritize 23 HNS that are most likely to create hazards for marine life in the event of a spill in European Atlantic waters, factoring in transport volumes, reported incidents, physio-chemical properties, and toxicity.

16 This was informed by the IMO's hazard profiles developed by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). Their profiles factor in the way in which each substance interacts with the aquatic environment, human health, and other uses of the marine environment.

4.1.4 Spills of Dry Bulk and Container Cargo Typically Have Limited Environmental Impacts, Though Some Seemingly Benign Substances Can Cause Significant Damage

The behaviour of dry bulk and containers in the marine environment is also highly variable. In general, spills of these cargo types are relatively benign. However, as with HNS, the impacts are dependent on the exact type of cargo. Even substances that might be presumed innocuous can actually be hazardous, making it challenging and misleading to draw a clear line between HNS and dry bulk and containers. For example, in 1996, the cargo ship *Fenes* grounded on the Lavezzi Islands in France and spilled 2,600 tonnes of wheat (Marchand, 2002; Mamaca *et al.*, 2009). As the wheat decomposed, it created conditions that favoured sulphate-reducing microbes, which fermented the wheat to produce hydrogen sulphide, a toxic gas. As a result, response crews were required to wear protective respiratory equipment (Marchand, 2002; Mamaca *et al.*, 2009).

When container cargo is not recovered it can contribute to marine debris, which can negatively impact wildlife through entanglement, ingestion, habitat destruction, and other pathways (Sheavly & Register, 2007). Indeed, plastic pollution in the ocean is a major problem for many marine organisms (Sheavly & Register, 2007).

4.1.5 Invasive Species Introduced by Ships Have Caused Substantial Damage to Canadian Marine Ecosystems

Introduction of invasive species is not related to a particular cargo type, but workshop participants still viewed this as a significant environmental impact of shipping accidents. Most aquatic invasive species originated from ballast water exposure (voluntary or not), and most of the close to 200 invasive species in the Great Lakes came via marine shipping along the St. Lawrence River (Ricciardi, 2006). Efforts to control the spread of invasive species have been ongoing since the 1980s, and include federal regulations for ballast water management established in 2011 (Bailey *et al.*, 2011; GOC, 2011). Bailey *et al.* (2011) demonstrate the efficacy of these policy reforms, with declining Great Lakes invasion rates since the early 1990s and no new invasive species introduced between 2006 and 2011. As a result, current invasive species introduction is more likely to occur due to an accident or illegal activity rather than routine shipping activity.

Invasive species can cause extensive ecosystem disruption by altering habitats, competing with native species for food, or directly feeding on native species. This may subsequently cause large impacts on fisheries and other local economies. For example, zebra mussels introduced to the Great Lakes in the 1980s are filtering out large amounts of phytoplankton and therefore increasing water clarity and moving nutrients from the water column to the bottom substrates (Hecky *et al.*, 2004). This shift caused changes in algal and bacterial growth, impacts on species relying on plankton as a food source, and changes in lake heat, among others (Hecky *et al.*, 2004; Higgins & Vander Zanden, 2010). In addition to threatening native species, the introduction of zebra mussels to the Great Lakes has led to increased algae growth and diminished enjoyment of the Great Lakes (e.g., by cutting swimmers' feet and causing a foul odour when decaying onshore).

4.1.6 The Quality of Evidence on the Environmental Impacts of Spills Is Highly Variable, and Is Largely a Function of the Events That Have Been Experienced to Date

Workshop participants developed a matrix to summarize the degree to which each type of cargo would impact various aspects of the environment. The extent and level of certainty of impacts for six different categories of cargo were reviewed. Table 4.1 reflects the current understanding of workshop participants, who were informed by their research, experience, reading of the literature, and analysis of survey results. The greatest impacts tend to arise from oil spills and there is significant research in this area. At the other end of the spectrum are dry bulk and container cargo types, which are unlikely to cause significant impacts. The survey revealed consistent views on the cargo types that would be most likely to have a high vs. low environmental impact. Respondents across all of Canada felt that crude oil would have the highest impact, followed by HNS and refined hydrocarbons. The impact from LNG was expected to be moderate. Dry bulk and, lastly, containers were rated as low-impact cargo types.

Table 4.1

Type and Degree of Environmental Impact for Various Cargo Types

Environmental Impacts	Cargo Types					
	Crude Oil	Refined Hydrocarbons	LNG	HNS	Dry Bulk	Container
Decrease in air quality	***	***	***	*	***	***
Decrease in water quality	***	***	**	*	**	***
Alteration of physical habitat	***	***	**	*	**	***
Impact on ecosystem structure and function+	*	**	***	***	***	***
Acute and chronic effects on plants	**	**	***	***	***	***
Acute and chronic effects on invertebrates	***	**	***	***	***	***
Acute and chronic effects on fish	***	**	***	***	***	***
Acute and chronic effects on birds	***	***	***	***	***	***
Acute and chronic effects on marine mammals	***	***	***	***	***	***
Acute and chronic effects on marine reptiles and amphibians	***	***	***	***	***	***

+E.g., impact on predator-prey relationships, changes in thresholds and tipping points

High Impact Medium Impact Low Impact ***High Certainty **Medium Certainty *Low Certainty

Workshop participants developed this table to summarize the evidence of how spills of various cargo types create different environmental impacts. The colour of each cell represents the level of impact on the environment (high, medium, or low) and the star rating indicates the degree of certainty in assigning each impact rating, with one or two stars as evidence that this analysis could be further enhanced through additional research. Although LNG, crude oil, and refined hydrocarbons are technically HNS, they were considered separately, while all remaining HNS were grouped together. To deal with the diversity of HNS, all of the environmental impacts in Table 4.1 were assigned a moderate rating. In reality, each substance would need to be dealt with separately, and its impacts would range from low to high.

4.2 SOCIAL, CULTURAL, HEALTH, AND ECONOMIC IMPACTS

Marine shipping accidents can create a range of social, cultural, health, and economic impacts. These impacts can arise directly, such as injury from a collision or economic loss from supply chain disruptions, or indirectly as a result of environmental impacts. For example, an oil spill can have impacts that reach beyond the environment, and may include economic impacts (e.g., loss of tourism revenue), social impacts (e.g., disruption in community relationships), and health impacts (e.g., illness from exposure to chemicals during clean-up efforts). Workshop participants noted the importance of separating human health and socio-economic impacts, but recognized that in some cases, the two may be intimately related. For example, closure of fisheries will result in lost income for communities that rely on fishing and lost revenue for the fishing industry, potentially leading to psychological stress for those who are financially affected.

4.2.1 Spills Can Contaminate Not Only the Physical Environment but Also the Social and Cultural Environment

Studies conducted in the wake of the *Exxon Valdez* spill provide insights into the potential social and cultural impacts of large-scale shipping accidents in which pollutants are released into the environment. Palinkas *et al.* (1993b) eloquently observe "[w]hen the *Exxon Valdez* ran aground in Prince William Sound, it spilled oil into a social as well as a natural environment." Shaw (1992) catalogues some of the social impacts of the *Exxon Valdez* spill: a widespread loss of social licence for the oil industry at large as public trust was undermined; economic and social dislocation stemming from an influx of clean-up workers and availability of short-term, high-paying employment; and a temporary interruption of two of the region's key economic industries — tourism and commercial fishing. A population-based survey provides further insights into the social and cultural impacts of the spill (Palinkas *et al.*, 1993a). Respondents reported reductions in traditional social relations, reduced subsistence activities, and perceived increases in alcohol consumption, drug abuse, and domestic violence. Conflict arose over the environmental impacts of the spill, the assigning of blame, and the uneven distribution of employment and compensation following the spill (among other things). Employment in spill clean-up activities reduced the time available for family and community relationships. Many communities lived in the areas most impacted by the spill, including Alaska Natives. Palinkas *et al.* (1993a) note that each Alaska Native community has its own cultural traditions, but common among them is "a set of social relations and values based on practices of subsistence production and distribution." The impacts of reduced subsistence activities were most pronounced in Alaska Native villages. Palinkas *et al.* (1993a) reported that "[t]he disruptions to maintaining Native culture raised pervasive fears and increased fundamental concerns about cultural survival for many in the affected Native villages." Social and cultural impacts can go beyond the timeframe of the spill and its clean-up, and can be felt for decades (Picou & Martin, 2007; Picou, 2009).

4.2.2 Human Health Impacts Can Arise in the Immediate Aftermath of an Accident but Can Also Develop and Persist over Time

Shipping accidents can directly result in crew casualties. Between January 2004 and October 2015 there were 29 fatalities and 183 serious injuries on cargo ships in Canadian waters (TSB, 2015c). Human health impacts can also arise as a result of a spill and its environmental consequences. In the immediate aftermath of an accident involving HNS, air pollution is a key concern, particularly for emergency response personnel (Häkkinen & Posti, 2014). The HNS that are likely to present the greatest risk to human health beyond the population onboard the ship or involved in clean-up operations are those that are volatile or gaseous and thus could be transported to onshore populations (Harold *et al.*, 2014).

Health risks are particularly acute for crews involved in oil spill clean-up operations due to their direct exposure to pollutants in the immediate aftermath of a spill. The U.S. National Institute for Operational Safety and Health catalogued injury and illness data from workers' compensation claims submitted in 1989 related to the *Exxon Valdez* oil spill; there were 1,811 claims including 264 relating to respiratory issues (Gorman *et al.*, 1991). An investigation into the health of clean-up workers following the *Prestige* spill off the coast of Spain found that this kind of work can result in persistent respiratory symptoms that last one to two years (Zock *et al.*, 2007; Rodríguez-Trigo *et al.*, 2010). Spills can also create longer-term health risks through contamination of food supplies (Solomon & Janssen, 2010; Chang *et al.*, 2014).

Mental health impacts can also be significant. A survey of 13 Alaskan communities found substantially higher rates of generalized anxiety disorder (3.6 times as likely), post-traumatic stress disorder (2.9 times as likely), and depressive symptoms (1.8 times as likely) in communities directly affected by the *Exxon Valdez* spill than in communities with similar demographic and economic characteristics that were not located near the spill (Palinkas *et al.*, 1993b). Incidence of all three of these symptoms was particularly pronounced among women, while incidence of depressive symptoms was elevated among Alaska Natives (Palinkas *et al.*, 1993b).

4.2.3 A Single Shipping Accident Has the Potential to Cause Significant Economic Disruption

The increased size of container ships creates the potential for greater environmental and economic impacts in the event of a single accident (i.e., the risk is concentrated among fewer larger vessels). While today's largest ships can already transport 18,000 TEUs, this could grow to 24,000 TEUs (Millman, 2015). A 2013 sinking of an 8,000 TEU ship with 4,328 containers onboard resulted in costs of over $500 million for the insurance industry, providing some indication of the potential cost of an accident involving the largest of cargo ships (The Maritime Executive, 2013; Millman, 2015). The costs of disruptions to a port or canal could also be considerable (Millman, 2015). Michigan's Soo Locks provide an example of the potential for disruption: these locks connect Lake Superior to the lower Great Lakes. There is currently only one lock that is wide enough to accommodate large ships, and organizations such as the U.S. Army Corps of Engineers and the Great Lakes Maritime Task Force have underscored the potential costs of a disruption at this lock (O'Bryan, 2015; GLMTF, 2016). However, these costs are challenging to appraise overall, as they are highly contingent on alternative transportation options for a particular cargo type and in a specific locality.

Spills undoubtedly create economic disruptions and wealth redistributions, but in the case of the *Exxon Valdez* spill one empirical investigation found that the new economic activity generated by the spill exceeded the loss of commercial fishing incomes in the year following the spill (Cohen, 1993). Other research finds that the fishery has still not rebounded more than two decades later. The herring fishery has been closed for 19 of the 25 years since the spill occurred, and is classified as *not recovering*, though the role of the spill in this collapse is unclear and the subject of ongoing research (Incardona *et al.*, 2015; EVOSTC, n.d.).

Introduction of invasive species has also imposed a major economic toll. As of 2002, Ontario Power Generation had spent tens of millions of dollars to deter zebra mussels and reported their yearly operating costs had increased by more than a million dollars as a result of the species (OAG, 2002). A more recent survey-based analysis of electric power generation and drinking water treatment facilities estimated total costs of US$267 million between 1989 and 2004 (Connelly *et al.*, 2007).

4.2.4 Concerns Vary by Region, Reflecting the Ways in Which Communities Engage with the Marine Environment

Workshop participants identified the socio-economic impacts of a marine incident or accident involving pollutant release by region (Table 4.2). For two regions, the top impact pointed toward an industry that is known to be particularly important to that region. For example, Nova Scotia, New Brunswick, and Newfoundland and Labrador are Canada's first-, second-, and fourth-largest exporters of fish and seafood, respectively, which would make disruption of commercial fisheries particularly impactful on the Atlantic coast (DFO, 2015). In British Columbia, sport fishing accounts for almost half the GDP of the fisheries and aquaculture sector, generating nearly as much as all three of the other activities combined (fish processing, commercial fishing, and aquaculture) (Stroomer & Wilson, 2013). Thus, any pollution that interfered with this recreational activity would have a significant effect in the Pacific region. In other cases, the top impact underscored the relationship between waterways and food and water, with an incident or accident creating problems for drinking water or food security. Impacts on shipping and port operations were mentioned for all regions except Northern Canada. Disruptions at large ports could i) result in shortages of essential goods for individual consumers (e.g., heating oil), and ii) interrupt business continuity by hindering the supply chain. Reduced tourism was a concern for Pacific and Atlantic Canada, since the marine environment is a major attraction for visitors to these regions.

4.3 FACTORS THAT INFLUENCE THE IMPACTS OF AN ACCIDENT

Certain general factors are at play in every pollution accident. These include variables such as cargo type; spill volume, rate, location, and timing; and mitigating variables such as speed and efficacy of spill response (Chang *et al.*, 2014). These factors all form part of the marine shipping risk environment. The potential impacts of an accident are heavily influenced by regional characteristics, including weather conditions, physical features of the landscape and waters, as well as social, economic, and cultural activities and traditions. Each time an accident occurs, a myriad of factors in the risk environment combine to determine the ultimate outcome.

4.3.1 Regional Features Determine the Nature and Extent of Impacts of a Shipping Accident

Survey respondents were asked to list features that most increase or decrease the environmental impacts of a shipping accident involving cargo release. The top seven response categories for each question by region are shown in Figure 4.1.

Table 4.2

Workshop Appraisal of Socio-Economic and Human Health Impacts of an Accident by Region

Rank	Atlantic	Central	North	Pacific
1	Disruption of commercial fisheries	Impacts on municipal water	Reduced food security	Disruption of recreational activities (sport fishing, kayaking)
2	Disruption of shipping and port operations*	Disruption of shipping and port operations*	Human health effects (due to consumption of contaminated food)*	Reduced tourism (short-term loss of revenue or jobs; long-term damage to reputation)
3	Disruption of aquaculture*	Calls for more regulations or shipping restrictions*	Disruption of cultural fabric*	Reduced catch for subsistence fishing*
4	Reduced tourism (short-term loss of revenue or jobs; long-term damage to reputation)	Increased costs (insurance, compliance, legal, safety)	Increased costs (clean-up very expensive in Arctic)	Disruption of commercial fisheries*
5	Human health effects (due to direct exposure to pollutants and emotional stress)	Modal shift (from marine to rail or road) Cause for a reassessment of risk	Changes in regulations that could deter local economic development Changes in regulations that could lead to a shipping prohibition or other expensive requirements	Disruption of shipping and port operations

Workshop participants were divided based on their geographical region of expertise. Each group generated a list of 11 to 18 socio-economic impacts that might occur in their region following a marine shipping accident involving pollutant release. All workshop participants were then invited to independently choose the top four impacts for each region; the top responses are shown.

*Indicates that multiple choices were tied in the ranking; when two choices were tied for 5th place, both were listed.

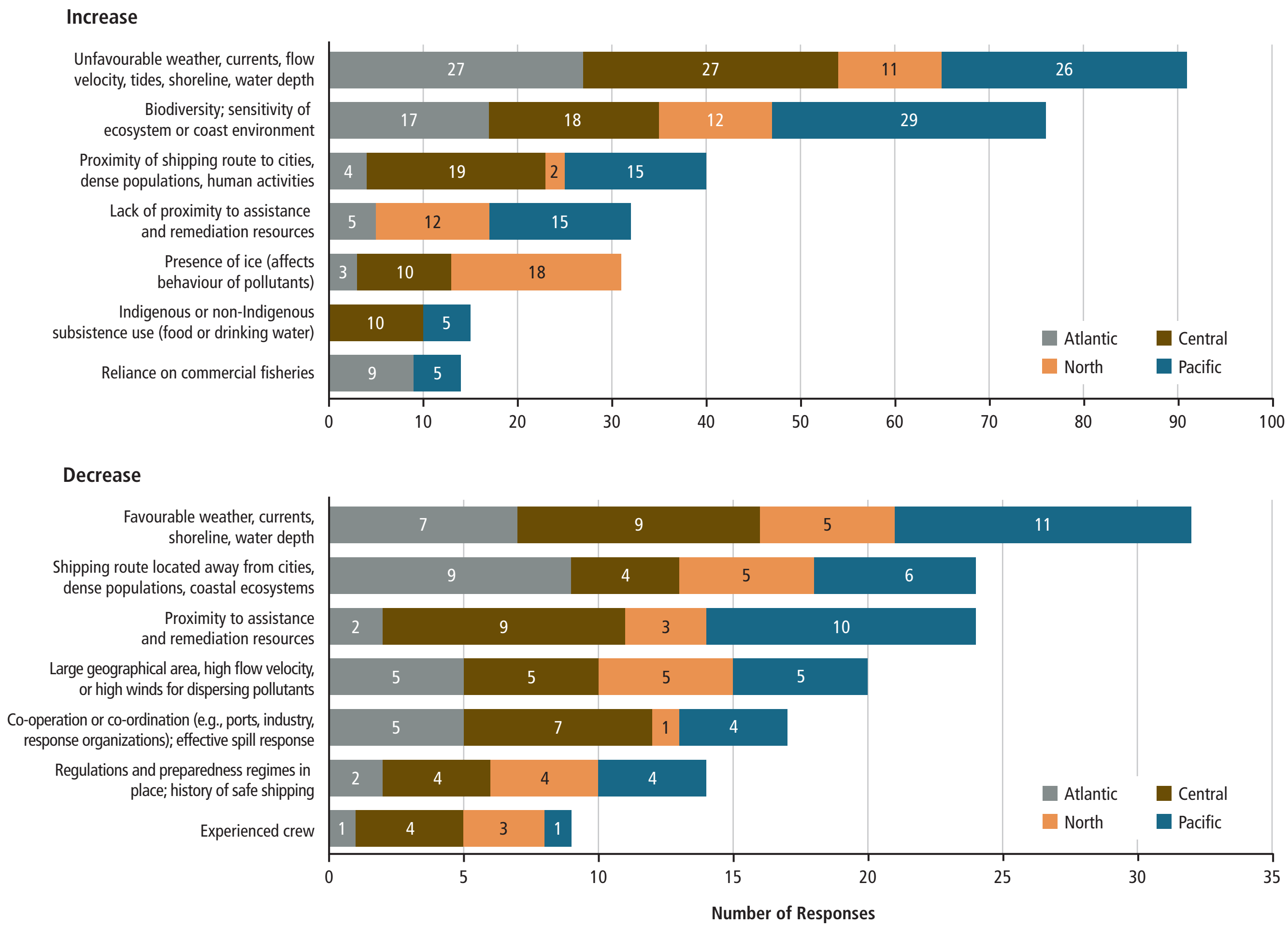


Figure 4.1

Features That Increase or Decrease the Degree of Environmental Impacts

Survey respondents were asked to provide features of their chosen region that most increase or decrease the degree of environmental impacts of an accident involving release of a pollutant. The top seven features are shown. For instance, the figure indicates that unfavourable weather and physical conditions (e.g., shoreline) are most likely to shape the overall degree of environmental impacts.
Increase: n=299 [Atlantic: n=65, Central: n=84, North: n=55, Pacific: n=95]
Decrease: n=140 [Atlantic: n=31, Central: n=42, North: n=26, Pacific: n=41]

Across all regions, the physical environment and conditions at the time of a spill rank among the most important factors for determining overall impacts. The Royal Society of Canada's Expert Panel on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments reached the same conclusion in the case of oil spills (Lee *et al.*, 2015). For features that might increase impact, respondents from the Pacific mentioned biodiversity and ecosystem sensitivity most frequently. More than half of the concerns about the presence of ice were in relation to Northern Canada. Ice affects the behaviour and fate of oil and is therefore a key factor in determining the impact of an oil spill in the Arctic, as well as the most effective response strategies (Lee *et al.*, 2011, 2015). The proximity of shipping routes to cities could also increase the impacts of an accident. The 2015 oil spill in Vancouver's English Bay raised significant concerns because it took place in a densely populated area where the water and coastlines have multiple users (Butler, 2015). Recent high-profile oil spills have occurred in less densely populated areas so there is little evidence of the potential societal impacts that would occur in the event of an urban spill. Respondents from Central Canada indicated reliance on fresh water from the Great Lakes for municipal water supplies could exacerbate negative impacts. Indeed, 90% of Ontario's population live in the Great Lakes basin, and the lakes are the source of drinking water for 8.5 million Canadians (EC, 2013).

The features that may lessen the environmental impacts of a pollution spill appear to vary less between regions. The most common responses were favourable weather and physical environment conditions, and shipping routes situated away from dense population areas. Response capacity was also a central theme; survey respondents highlighted regulations and preparedness regimes, cooperation and coordination to enable an effective response, and proximity to assistance and remediation resources as key elements for reducing environmental impacts.

In addition to these features, research has also identified the importance of the season in which a spill occurs in shaping the environmental impacts. Oil spills that directly precede or coincide with breeding periods can cause greater damage than spills that occur at other times of year (Mendelssohn *et al.*, 2012). Experiments conducted on saltwater grasses found that the impact of oil is lower when plants are dormant or have a reduced metabolism (Alexander & Webb, 1985). Seasonal variability informs spill response in the United States; Environmental Sensitivity Index maps used by the National Oceanic and Atmospheric Administration's Office of Response and Restoration catalogue seasonal sensitivity of various marine environments, noting features such as breeding and spawning patterns by species (NOAA ORR, 2016). Jensen *et al.* (1998) note that early versions of these Environmental Sensitivity Index maps were used to inform the spill response following the *Exxon Valdez* spill.

Survey respondents were also asked about regional features that could increase the socio-economic impacts of a pollution incident. Many of the features were the same as those cited for environmental impacts (e.g., proximity to dense populations for Central Canada, reliance on commercial fisheries for Atlantic Canada, and subsistence use of aquatic resources for Northern and Pacific Canada). However, one novel feature was highlighted by respondents from Pacific and Central Canada, predominantly, and by a handful of respondents from the North: negative views of shipping in these regions lead to greater discontent and unrest following a pollution spill. Survey responses indicated that robust political attention and media coverage of shipping accidents, along with varying perceptions of the risks and benefits of the shipping industry, may contribute to these views.

Socio-economic impacts may be caused not only by pollution, but also by shipping incidents or accidents that do not result in any release of pollutants but still disrupt shipping (e.g., by causing backlogs at ports). Survey participants were thus asked about features of their region that would exacerbate the socio-economic impacts of a shipping disruption. Respondents' answers highlighted both features that would make their region more susceptible and features that would make a disruption in their region more likely to have far-reaching effects on the shipping industry in Canada or even North America (Figure 4.2). Responses brought several regional differences to light. Atlantic and Northern Canada would be

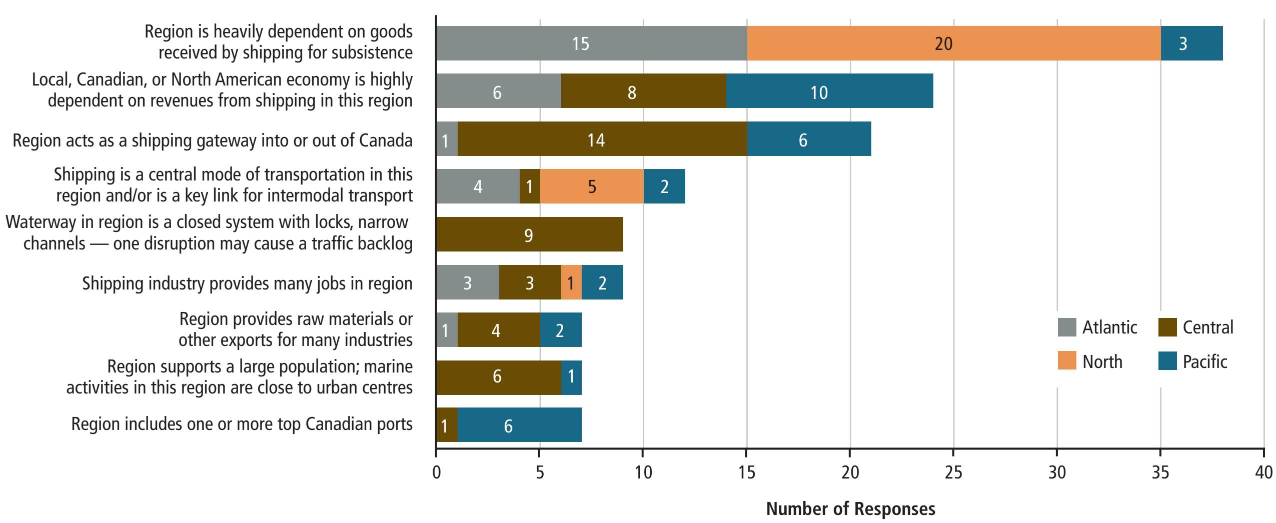


Figure 4.2

Features That Increase the Degree of Socio-Economic Impacts of a Shipping Disruption

Survey respondents were asked to provide features of their chosen region that most increase the degree of socio-economic impacts of a shipping disruption. Features that were mentioned by at least seven respondents are shown.

n=134 [Atlantic: n=30, Central: n=46, North: n=26, Pacific: n=32] particularly vulnerable following a shipping disruption due to their dependence on cargo shipped for food security, and their reliance on shipping as a central mode of transport for both people and cargo. Respondents highlighted the role of Central and Pacific Canada as busy shipping regions with major ports that function as key shipping gateways into and out of Canada, thereby generating revenue for the Canadian economy. Respondents from Central Canada also drew attention to a feature that makes the St. Lawrence River more vulnerable: this waterway is a closed system with locks and narrow channels, with the potential for a traffic backlog even after a single disruption at a single point.

4.3.2 Canada Has Well-Developed Oil Spill Response Protocols and Compensation Provisions but Important Gaps Remain

If a pollution spill occurs, the speed and efficacy of the response are key factors in determining the level of impact it will have. In recognition of the risks posed by oil spills, Canada has a well-developed oil spill response system that covers the southern parts of Canada's coastal waters. Canada's marine oil pollution response system is based on a partnership between government and industry (TC, 2012b). Transport Canada governs the Ship-Source Oil Spill Preparedness and Response Regime, which involves developing and enforcing regulations for oil-handling facilities and response organizations (TSEP, 2013). Canada has four private oil spill response agencies that are certified every three years by Transport Canada. Ships that carry oil through Canadian waters must have an agreement with one of these organizations, which will respond to a spill on their behalf (though this does not guarantee a prompt response in remote locations). Ship owners pay an annual fee to their response organization, an arrangement that adheres to the polluter pays principle (i.e., polluters must pay their own spill response and damage costs) (OAG, 2010; TC, 2014b). The Canadian Coast Guard is responsible for ensuring that an appropriate spill response has been carried out (TSEP, 2013). It may also act on site to manage a pollution spill if the polluter is unwilling or unable to fulfill its obligations, if it feels that the response is inadequate, or if the spill source is unknown. To help fulfill these roles, the Coast Guard has more than 80 depots of equipment located across the country. Overall, Canada's approach to ship-source oil pollution has been characterized as comprehensive (TSEP, 2013). However, the 2015 *M/V Marathassa* oil spill in Vancouver's English Bay raised some concerns in terms of timeliness of response, clarity of roles, and communication protocols (Butler, 2015). Butler's independent review of the spill response makes the point that "the Canadian Coast Guard and its partners rarely respond to real life events due to the infrequency of persistent oil spill events in Canadian waters" (Butler, 2015). He recommends that further efforts are needed to test and enhance the spill response system to ensure it performs well.

The situation in the Arctic and Labrador is more challenging (TSEP, 2014). The Coast Guard plays a particularly active role in spill preparedness and response in the Arctic, partly because there are no certified response organizations located north of the 60th parallel (TSEP, 2014). Coast Guard vessels that sail in the Arctic carry pollution response equipment (CCG, 2011). More than twenty of the Coast Guard's clean-up equipment depots are located in the Arctic. However, given Canada's vast coastline, the closest depot may still be far from a spill location, hindering a prompt response. One Arctic equipment depot is designed for airlift for that reason (TSEP, 2014). In 2013, Canada signed a legally binding treaty to work with seven other Arctic countries to improve response to oil spills in the region. Activities include monitoring, training, information exchange, and providing assistance following a spill (EC, 2015a).

The insurers of shipping companies that have experienced a spill are also likely to seek advice from the International Tanker Owners Pollution Federation Limited, which can provide observers to review and assist in the response (ITOPF, n.d.). Although responsible parties are required to be prepared for potential spills, many decisions involved in the response strategy will need to be made as the spill unfolds, taking into account the specifics of each situation.

Those seeking compensation for oil pollution damage may make claims against the ship owner (GOC, 2014b). Owners' insurance plans can provide funds that may be required in the event of an accident (Box 4.1). If the owner is unable to pay the full amount, or if the amount exceeds the limit that the owner is liable for (which is based on gross tonnage of the ship), the claimant may apply for compensation from another source (GOC, 2014b). Two international funds and a domestic Ship-Source Oil Pollution Fund exist for these purposes (GOC, 2015).

Box 4.1
Insurance in the Shipping Industry

Shipping firms hold multiple types of insurance including *hull and machinery* for damage to a ship itself; *collision liability*; *loss of hire* for loss of earnings that arise from vessel damage; and *protection and indemnity* (P&I) (Allianz, 2012). P&I insurance covers liability that arises beyond the physical impacts of a vessel collision. This could include the costs of dealing with a pollution spill, clearing wreckage, or liability related to damaged crew and cargo (though the cargo itself is insured by the cargo owners) (Allianz, 2012). Unlike the other more traditional forms of insurance, P&I is mutually provided within clubs where participants pool their risk together. Due to the nature of the coverage provided, P&I insurance claims are arguably the most relevant when contemplating large-scale accidents that have impacts beyond the ship and its crew. Table 4.3 below shows Canadian P&I insurance claims made to the Shipowners' Mutual Protection & Indemnity Association for 2007 to 2015, illustrating that there have been few major claims during that period.

Table 4.3

Protection and Indemnity Fees and Insurance Claims in Canada (C$) (2007 to 2015)

Type	2007 ($)	2008 ($)	2009 ($)	2010 ($)	2011 ($)	2012 ($)	2013 ($)	2014 ($)	2015 ($)	All Years
Breach of Regulations	0	0	0	20,774	0	0	0	0	0	20,774
Hydrocarbon Spill or Pollution	2,556	4,238	0	884,982	0	45,355	1,853	3,843	308,227	1,251,054
Vessel Damage or Loss	145,895	1,125,871	16,678	0	0	0	159,933	38,805	12,709	1,499,890
Total	**148,451**	**1,130,109**	**16,678**	**905,756**	**0**	**45,355**	**161,785**	**42,647**	**320,936**	**2,771,717**

Data source: SMPIA, n.d.

Table includes data for ships registered in Canada that are part of the Shipowners' Mutual Protection and Indemnity Association. Small claim amounts represent fees charged by accident investigators (e.g., professional fees, travel, hospitality) for incidents that did not materialize into losses.

The 2013 Tanker Safety Expert Panel identified a number of areas that could be improved to enhance levels of oil-spill preparedness and response, including regional identification and mitigation of risks; ensuring potential polluters (through their response organizations) have the capacity to respond to a worst-case scenario discharge; improving timeliness of responses; expanding response planning to encompass techniques beyond often inefficient mechanical recovery strategies; and guaranteeing that the oil cargo industry is responsible for the entire cost of spills it creates — with no financial liability for Canadians (TSEP, 2013).

In comparison to oil, there is much less HNS and LNG transported in Canadian waters. However, Canada's Tanker Safety Expert Panel recognized the importance of implementing a system for preparedness and response related to HNS and LNG transportation in Canada.[17] Since no formal requirements currently exist, the Panel acknowledged that it would take time and resources to implement a mature HNS program (TSEP, 2014).

4.3.3 A Convergence of Factors Typically Influences Ultimate Impacts

Just as many factors usually converge to cause a marine shipping accident, the same is true for factors that act to determine its impact. For instance, multiple small spills that occur in the same region can have consequences that are at least as significant as the consequences of a single large spill. Research conducted in Newfoundland highlights the harmful impacts of chronic oil pollution on sea birds, noting the high rate of oiled bird mortality in this region (Wiese & Ryan, 2003; Wiese *et al.*, 2004).

17 The Tanker Safety Expert Panel considered LNG under the umbrella of HNS.

Box 4.2
Factors That Influence Impacts: The Explosion and Fire of *PETROLAB*

On July 19, 1997, the crew of a 41m tanker named *PETROLAB* was washing the ship's cargo oil tanks in preparation for a loading of stove oil while alongside Newfoundland's St. Barbe wharf. At about 7:30 p.m., an explosion of accumulated petroleum vapours occurred below deck, resulting in two deaths. Two other crew members were seriously injured. This accident was made worse by the subsequent fire and is illustrative of how the degree of impact can be influenced by factors that arise after the accident itself. According to the TSB (2013), "[t]he ensuing fire was limited to the ship's stores burning in the 'tween-deck until, some two to three hours after the explosion, the paint on the outer hull began to burn and spread fire to the creosote impregnated dock pilings." The fire would continue to burn for another 60 hours, during which time part of the town of St. Barbe was evacuated out of concern that the fire might spread from the wharf to the adjacent tank farm. In the end, in addition to the onboard deaths and injuries, the entire wharf, ferry ramp, and pipelines were destroyed.

In their investigation report, the Transport Safety Board found that, while the wharf served both oil tankers and passenger vessels, the local volunteer fire department had neither shipboard firefighting training nor the necessary foam to fight petroleum fires. Despite these inadequacies they were being relied upon for emergencies by the terminal operator, Ultramar, as set out in their own contingency plan. Thus, when several local volunteer fire departments responded, they were reluctant to fight the fire with water. As for onboard firefighting equipment, although in compliance with regulatory requirements, much of it was left inoperable after the explosion disabled the ship's service generator. Thus, for two to three hours, no effort was made to fight the fire while it was contained below deck. It took the arrival of the Canadian Coast Guard in the morning of July 20th before a major firefighting effort began, at which point the dock was ablaze and the mooring lines had burned through, casting the ship adrift before it grounded across the harbour. The impacts could have been greater. A passenger ferry had been sharing the wharf for 90 to 135 minutes on the day of the explosion, with passengers embarking and disembarking, all while *PETROLAB* was conducting hazardous operations and with minimal precautions to separate such activities from ferry passengers.

(TSB, 2013)

Box 4.2 discusses a particular accident that occurred at a wharf in St. Barbe, in northwest Newfoundland, in 1997. The impact of the accident was worsened by an inadequate contingency plan set out by the terminal operator, insufficient training and resources for local firefighters, damage of onboard firefighting equipment during the accident, and a delayed response. Some of the regulations and voluntary initiatives described in Chapter 2 have led to improvements since this time.

4.4 CONCLUSION

The potential environmental impacts of a spill are heavily dependent on the nature and volume of the cargo, the local physical and social environment, the time of year, the location, and the response capacity. Marine spills can create significant challenges for respondents due to both the volume of cargo being moved by ships today and the challenges of conducting clean-up operations.

Oil dominates the marine pollution landscape in Canada in many ways: it is the most common type of pollution spilled in Canadian waters; it is the substance for which environmental impacts — and the resulting social, cultural, health, and economic impacts — have been most heavily documented and studied; and the potential impacts of an oil spill are great. Most impacts have been reported as the consequence of large spills, although smaller spills occurring much more frequently may be associated with cumulative chronic impacts. There are gaps in understanding the behaviour and impacts of oil spills in cold and freshwater environments. In addition, little is known about other potentially dangerous cargo types such as HNS. Other types of impacts (socio-economic and health) have been subject to less analysis, and these are more likely to depend on the activities that are important to the region's economy or survival (e.g., commercial fishing in Atlantic Canada and subsistence fishing in the North). Overall, there are many knowledge gaps surrounding the potential impacts of spills resulting from marine shipping accidents.

5

Conclusions

5 Conclusions

Workshop participants chose to analyze marine shipping risk in terms of its two basic elements: i) the likelihood that an accident will occur and ii) the severity of resulting environmental, social, health, and economic impacts. To the extent that the data and research allowed, these elements were assessed in the context of different types of cargo, stages of marine shipping, and Canadian regions. What follows are six main findings in response to the charge that stem from the workshop participants' expertise and assessment of the evidence.

Commercial marine shipping risks are mitigated by a large body of regulations, safety protocols and practices, and navigation technologies, which have made marine shipping, in Canada and globally, much safer in recent decades.

Commercial marine shipping in Canada, as with any other mode of transport, is not without risks. There is however a significant body of regulations, safety protocols, and practices now in place and overseen by numerous government and non-government bodies to help mitigate these risks. Ship design standards, mariner training programs, systematic vessel inspections, insurance requirements, and advanced navigation technologies, for example, all play a role in reducing the likelihood that an accident will occur. In addition, shipping companies also play a role by improving their safety culture which in turn can foster a social licence for the industry. These developments have collectively made commercial marine shipping safer over the past decade, as evident from the trend of fewer commercial marine shipping accidents.

Despite these precautions, accidents will likely continue to happen. Yet, as the evidence makes clear, most are unlikely to result in any significant impact. Indeed, groundings or collisions may damage the vessel, but not necessarily lead to any wider social, economic, health, or environmental impact. Further, the statistics show that most marine accidents occur in confined waters (harbour areas, rivers, canals, and locks) where response regimes are in place to react quickly.

Commercial marine shipping operates in a complex risk environment where a variety of factors interact to increase or decrease the likelihood of an accident and the severity of its impact.

For commercial shipping accidents to occur and result in an impact of significance, several factors must come together, some controllable — such as the condition of a vessel or safety practices — and others less so — such as strong currents or harsh weather conditions. These factors come into play first in the likelihood that an accident will occur and, second, in the extent to which impacts will be realized after the accident. The effect is a high level of complexity in characterizing commercial marine shipping risks. In recognition of this complexity, workshop participants developed a framework that summarizes the many factors that characterize commercial marine shipping risks (Figure 5.1).

The framework illustrates the range of factors that increase or decrease the likelihood of an accident, and the degree of its impacts before, during, and after an incident or accident. For instance, it recognizes the importance of risk prevention measures including safety regulations, inspections and training, and pollution response systems. It also acknowledges feedback that may come from investigations, incident reports, the public, or from the quality of response post-event. This feedback can result in improved safety protocols or can influence the public's perception and acceptance of marine shipping risks.

The nature of commercial marine shipping risk varies by region due to differences in cargo, regulation, physical traits of the marine environment, and economic, social, and cultural uses of waterways and coastlines.

Different regions face very different risk profiles owing to differences in main types of cargo, risk prevention policies such as moratoriums or pilotage zones, and waterway characteristics, including the degree of ecological sensitivity or the extent of constrained waterways. Varying economic, social, and cultural contexts further contribute to the differences in risk profiles across regions.

Pacific Region

Although the Pacific Region experiences the highest level of shipping activity, the accident rate and the nature of the cargo shipped, together with current moratoriums, suggest a relatively low risk profile compared to other regions. Sensitive marine ecology and geography, a tourism industry heavily tied to marine resources, and the potential impacts on the livelihoods of First Nations coastal communities, however, elevate the potential impact of any accident. Tanker shipments of oil and petroleum products could increase with proposed pipeline projects, which would increase the level of risk in the region. Public perceptions and dialogue on the potential risks of oil spills highlight how those affected by marine shipping risks seek a greater role in defining acceptability and tolerance levels in specific ports or regions.

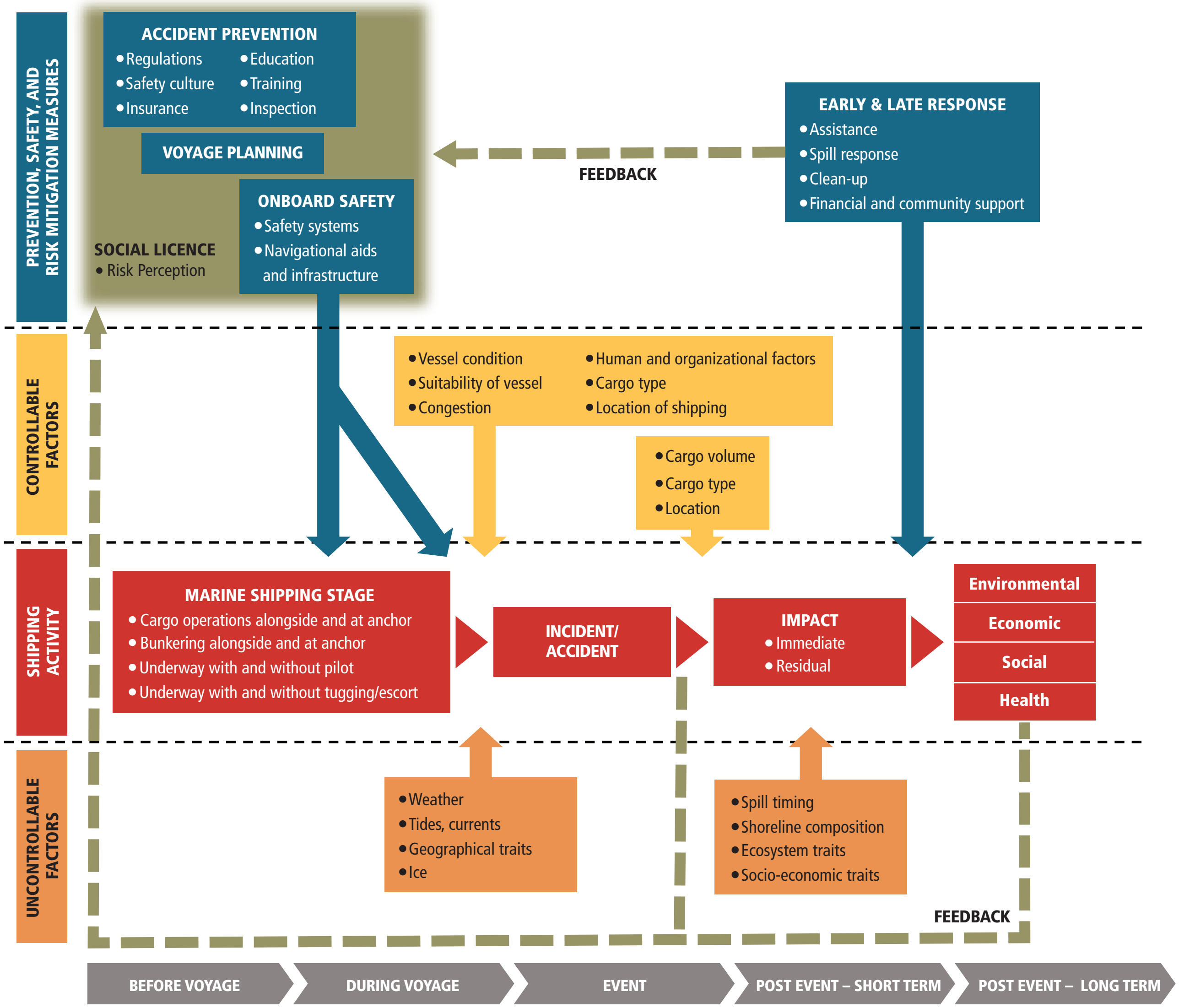


Figure 5.1

Summary Framework for Characterizing Risks of Marine Shipping Accidents

Risk is determined by the probability that an adverse event will occur, and the type and magnitude of any resulting impacts, both of which are influenced by a range of factors, controllable and uncontrollable. Prior to the voyage itself, prevention and mitigation measures (blue boxes), for example, are critical to reducing the likelihood of an event. When events occur, however, they can happen at one of several stages of shipping (be it piloting a vessel through a busy harbour or unloading cargo) and can be one of several types, including a grounding or collision. The nature of the event, the physical and social environment in which it occurs, and the quality and speed of response will all shape the type(s) and magnitude of impact(s) that result immediately from the event and following accident response efforts. Examples of controllable factors that influence the nature of the event and degree of impact are indicated in yellow boxes; examples of those that cannot be controlled or only partially controlled are identified in orange boxes. The figure also acknowledges feedback influencing social licence (green box) to operate: the level of satisfaction with response measures and the type/magnitude of environmental, economic, social, and health impacts can either help or hinder the degree of public support and social licence.

Central Region

The St. Lawrence River has extensive risk mitigation strategies in place, including a mandatory pilotage designation and an extended ship inspection program. Despite this, the St. Lawrence River experiences the highest level of commercial marine accidents in Canada and the second highest accident rate, after Northern Canada. However, accidents in this region are the least likely to lead to fatalities or serious injuries, potentially because many are minor events such as strikings along canals, where ships are moving at lower speeds. The reasons for this elevated rate are unclear and require further research. Constrained waterways together with currents, traffic density, and ice are among the factors that can increase the likelihood of an accident in the central region. Workshop participants noted that differences in reporting practices could also be a factor. The proximity of major shipping routes to densely populated cities, the potential economic disruption, and the fact that the St. Lawrence River and Great Lakes region is an important source of drinking water for millions would add to the impact should a major accident occur. Increased shipment of crude and petroleum products would in turn increase the level of risk in the region.

Atlantic Region

The Maritimes and Newfoundland and Labrador regions share a similar risk profile. The region as a whole ships more crude oil than any other region in Canada. Harsh weather conditions and the presence of ice increase the likelihood of an accident but, overall, accident rates are relatively low. Nonetheless, the region's reliance on fisheries (including aquaculture) and tourism would heighten the social and economic impacts of a significant accident.

Northern Canada

Although traffic levels are low, the factors that can potentially lead to a shipping accident are several and include inadequate navigation aids and port infrastructure, charting deficiencies, ice, and harsh weather conditions. This likely explains why the Arctic experiences a disproportionate number of accidents despite low vessel numbers. There is wide consensus on the sensitivity of the environment and the potential seriousness of impact should a pollution event occur. Furthermore, the Arctic's remoteness can compromise response efforts, and with the absence of a dedicated spill response organization, the potential for impact is elevated. Marine shipping risks in the Arctic will likely increase if there is a growth in traffic levels.

Risks associated with major oil spills are significant and well documented, and they underscore how resulting environmental impacts can bring about social, economic, and health impacts.

The risks presented by marine oil spills are relatively well understood. A series of major oil spills outside of Canada, including the *Exxon Valdez* spill, have enabled significant research in this domain. Initial impacts can include deaths of oiled birds and marine mammals, contamination of a range of marine species, and damage to coastal vegetation. Research demonstrates how an oil spill's environmental impacts can create social and cultural impacts through community disruption and contamination of subsistence foods, health impacts on clean-up workers and those in the immediate vicinity of a spill, and economic impacts through interruptions to tourism and commercial fisheries. A spill of diluted bitumen can pose particular environmental challenges as components of the heavy oil may sink in water.

Response to an oil spill influences the impacts of the spill. Canada's oil spill response regime includes industry initiatives plus government regulation and oversight of response protocols. This regime also includes provisions for clean-up, insurance, and compensation. However, as identified by the Tanker Safety Expert Panel, gaps exist. Response organizations are certified to respond to spills below the 60th parallel, but response capacity in Northern Canada is limited by remoteness and a lack of response organizations.

Better-quality marine shipping data are needed if the likelihood of incidents and accidents is to be better understood and measured for different cargo types, stages of shipping, and types of impacts.

Characterizing and measuring the likelihood of commercial marine shipping accidents is dependent on accurate and complete data on incidents and accidents, including resulting casualties and cargo releases. Canadian incident and accident data are comprehensive and generally well regarded. Although under-reporting may be an issue, evidence suggests that Canada's reporting performance for incidents and accidents is superior to that of other countries. However, these data do not include causal information and they do not allow for risks to be characterized by stages of shipping.

In contrast to incident and accident data, Canadian data on spills are found wanting. They are available from multiple sources, such as the Canadian Coast Guard, spill response organizations, and the insurance industry. However, each entity collects different data and there is no consistency in the categorizations used, making it difficult to harmonize across data sets. Further, as noted by the Auditor General, the Canadian Coast Guard database is incomplete and of questionable quality. As a result of these deficiencies, the data do not provide an adequate understanding of pollution events in Canadian waters. A single data repository that brings together the causes, types, and impacts (including types and volumes of pollutants released, injuries, and fatalities) of marine shipping incidents and accidents would allow for better risk characterization, as would ongoing updates to marine shipping traffic statistics that were last published by Statistics Canada for 2011.

Further research would address gaps in the understanding of Canada's marine risk environment, particularly with respect to impacts of HNS and diluted bitumen, spills in freshwater and cold environments, and on the multi-agency system that oversees marine safety in Canada.

Understanding the risks associated with HNS spills is challenging due to the diversity of substances and the behaviours these substances exhibit when released into water. Past experience suggests that the likelihood of an HNS spill is low, but the potential impacts associated with some HNS (e.g., pesticides) are high. Canada does not currently have a comprehensive HNS response plan in place. Further work is needed to better understand the risks presented by HNS and to establish appropriate preparedness and response regimes. Research into the impacts of oil spills has often occurred opportunistically at the site of an existing spill. As a result, most research focuses on saltwater spills in temperate environments; there is less research examining the impacts of oil spills in freshwater or Arctic and Subarctic environments. In addition, experience with spills of diluted bitumen is very limited. Research into how diluted bitumen behaves in water and appropriate mitigation and response strategies would allow for a better understanding of associated risks.

There are also gaps in the understanding of social, economic, and health risks directly associated with major marine shipping accidents, such as disruptions of industry supply chains that depend on shipping. More insight into these impacts will come with the completion of the Council's expert panel assessment on the social and economic value of commercial marine shipping in Canada, also commissioned by the Clear Seas Centre for Responsible Marine Shipping and due for release in 2017.

In recognition of the number of different organizations and jurisdictional authorities involved in the safety of marine shipping, workshop participants stressed the importance of stakeholders having a clear understanding of respective roles and responsibilities so as to avoid the risks associated with regulatory confusion prior to or at times of accidents. Further research into the various marine safety actors would help clarify potential areas of overlap, or gaps in their roles and responsibilities.

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Appendices

Appendix A – Glossary of Terms

Accident	Marine *accidents* are events such as collisions, sinkings, groundings, or fires/explosions that may result in death, serious injury, ship damage, or total loss of a ship.
Ballast movement	Ballast is "heavy weight, often sea water, which gives a ship stability and improves handling when she is not carrying cargo" (Brodie, 2013). An arrival at or departure from a port without any unloading or loading of cargo, respectively, is counted as a ballast movement (StatCan, 2012b).
Barge	A flat-bottomed vessel that is used primarily on rivers or canals. Some are self-propelled and others, which are not, must be pushed or pulled (usually by a tug) (Brodie, 2013).
Bunker fuel	"Fuel to be used by the vessel's engines for power during voyage but not fuel loaded onboard the vessel as cargo" (AMUSF, 2002). There are four general categories of bunker fuel, each with a different viscosity. The heaviest is Bunker C, also known as Fuel Oil No. 6 (Brodie, 2013).
Bunkering alongside/ at anchor	The process of supplying fuel to a vessel while the vessel is docked at port or anchored.
Cargo operations alongside/at anchor	The process of loading and unloading cargo onto a vessel while the vessel is docked at port or anchored.
Container	A container is a box, typically made of steel, which may be transferred from one mode of transport to another (e.g., ship, rail, truck) during a single voyage. Several standard sizes are used worldwide (Brodie, 2013). Non-bulk items, such as consumer goods (e.g., toys, personal technologies, clothing) and, increasingly, agricultural products, are shipped in this manner.
Dry bulk	Unpackaged (i.e., unsegregated) dry commodities, such as grain, coal, or salt, which are carried loose in cargo holds and can be loaded/unloaded by dumping, shovelling, sucking, or pumping at specialized terminals (GlobalSecurity, 2011).
Hazardous or noxious substances (HNS)	For survey purposes, HNS includes substances *other than* crude oil, LNG, and refined hydrocarbons, which may harm humans or marine life. Examples include: organic substances (e.g., methanol, xylene), inorganic substances (e.g., fertilizer, sulphuric acid), and vegetable/animal oil (WSP Canada Inc., 2014a).
Heavy load carrier	A cargo vessel specifically designed to carry heavy or oversized individual cargoes, either on deck or in holds. Such vessels may have ro-ro ramps for loading.
Incident	Marine *incidents* are events that pose safety threats but do not result in consequences (e.g., mechanical failure, bottom contact without going aground) or events that could have resulted in more severe consequences under different conditions (e.g., intentional grounding to avoid an accident) (TSB, 2015a).
Liquefied natural gas (LNG)	Natural gas that has been chilled to -160°C at atmospheric pressure and becomes a liquid.
Pilotage	The act, carried out by a pilot, of assisting the master of the ship in navigation when entering or leaving a port or in confined waters (Brodie, 2013).
Refined hydrocarbons	Refined crude oil (e.g., propane, diesel).
Risk	"The potential for suffering harm or loss" (Hightower *et al*., 2004) where potential for harm is determined by the probability of a marine shipping incident or accident occurring, together with the nature and severity of the resulting impacts.
Ro-ro carrier	A ship designed to handle cargo that can be driven on and off on-ramps (Brodie, 2013).
Safety culture	Refers to the ways that safety issues are perceived and addressed in a workplace, such as a shipping company.
Social licence	Companies and industries are awarded a tacit social licence when they are viewed as legitimate by society, when they gain the trust of stakeholders, and when affected parties consent to their operations (Morrison, 2014).
Twenty Foot Equivalent Units (TEUs)	"Unit of measurement equivalent to one 20-foot shipping container…. Thus a 40-foot container is equal to two TEUs" (Brodie, 2013).
Tug	A vessel "designed for the towing and pushing of ships or other floating structures. Additional activity may include salvage, fire-fighting and work duties of a general nature" (TSB, 2014b).
Vessel movement	Each arrival at and departure from a Canadian port is counted as a vessel movement. In this report, vessel movements include movements that involve loading or unloading of cargo and those that do not (see *ballast movement*).
Vessel underway with and without pilot	The stages at which a vessel is navigated through a port or busy waterway with the aid of a pilot or is outside of a compulsory pilotage area and is navigated by a captain.
Vessel underway with tug	The stage at which a vessel is escorted or towed by a tug.

Appendix B – Workshop Process and Survey Methodology

The two-day workshop held October 29-30, 2015 in Toronto aimed to foster consensus on the risks of commercial marine shipping (in terms of their significance and measurability) and on a framework for characterizing these risks. Day 1 was facilitated by Erik Lockhart of Queen's University School of Business Executive Decision Centre, who used Group Decision Support System (GDSS) technology to engage workshop participants in a brainstorming and prioritization exercise. GDSS is an interactive, computer-based system that allows groups to share ideas simultaneously by way of a computer network, and to prioritize and support decisions through the use of decision tools developed to reflect theory of group decision support. For more information see Frey & Cissna (2009).

Workshop sessions were based on questions put to participants, who were asked about the factors that contribute to shipping accidents, the types of environmental impacts, the types of social and economic impacts, and the types of risks associated with different stages of shipping. Results of the survey, described below, were provided in advance of the workshop and were drawn upon in each of the sessions. On Day 2, workshop participants, led by the Chair, sought consensus on a framework for characterizing risk and identified a range of issues that influence risk and risk measurement. Following the workshop, a report was drafted under the guidance of the Steering Committee and with input from participants and five peer reviewers.

Survey Purpose and Reach

The survey was designed to reach out to the broader marine-shipping stakeholder community across Canada to gather their views on risks related to commercial marine shipping. Its goal was to inform the workshop and give participants a better sense of concerns related to marine shipping on a regional basis and other variables of interest (e.g., stages of shipping, cargo type). The survey ran over a four-week period from September 2nd to October 9th, 2015. The Council invited over 600 experts from academia, government (including port authorities), industry, and non-profit sectors to complete an online survey (in English or French) on the risks of marine shipping in Canadian waters. A reminder email was sent in mid-September.

The survey received a total of 218 responses. This total includes complete and partially complete responses from the English and French versions of the survey; each regional response was counted as a separate response (i.e., if a respondent answered the survey for two regions, two survey responses were tallied). Table B.1-A depicts a percentage breakdown of responses by sector; Table B.1-B depicts a percentage breakdown of responses by subject area of expertise. Results were compiled by Council staff. Open-ended survey questions were categorized to reflect common themes.

Table B.1
Survey Responses

A – Survey Responses by Sector of Expertise

Responses by Sector of Expertise	% of Responses
Academia	28
Industry	25
Government	22
Other (e.g., consultant, international marine organization, non-governmental organization, service sector)	8
Port Authority	2
No response	15
Total	**100**

B – Survey Responses by Subject Area of Expertise

Responses by Subject Area of Expertise	% of Responses
Economics	8
Engineering	8
Environmental Sciences	18
Marine Shipping Governance	12
Marine Shipping Industry	18
Marine Shipping Service Sector (e.g., insurance, law)	10
Other Social Science	5
Other (e.g., Indigenous relations, human resources, navigation)	10
No response	11
Total	**100**

Appendix C – The Transportation Safety Board Marine Occurrence Dataset

The TSB publishes an annual report on marine occurrence statistics. The oldest report available online contains aggregated statistics for as far back as 1998 (TSB, 2008). These were used to produce Figure 3.1. The TSB also provides a public database with selected raw data on marine accidents and incidents from 2004 to the present (TSB, 2015c). These were used to produce Figures 3.2 to 3.8. The database is updated each month and includes all marine occurrences in Canada, as well as those involving a ship registered or licensed in Canada, even if they occurred in foreign waters. A *marine occurrence* is defined as "any accident or incident associated with the operation of a ship; and any situation or condition that the [TSB] has reasonable grounds to believe could, if left unattended, induce an accident or incident" (TSB, 2015a).

Marine occurrences include:

Accidents aboard ship: Accidents in which a person sustains a serious injury or is killed as a result of i) boarding, being onboard the ship, or falling overboard from the ship; or ii) coming into contact with any part of the ship or its contents.

Shipping accidents: Accidents in which the ship i) sinks, founders, or capsizes; ii) is involved in a collision or striking; iii) sustains a fire or explosion; iv) goes aground; v) sustains damage that affects its seaworthiness or renders it unfit for its purpose; or vi) is missing or abandoned.

Marine incidents: Incidents in which a ship i) sustains total failure of navigation equipment, propulsion, steering, deck, main, or auxiliary machinery if the failure poses a safety threat; ii) makes bottom contact without going aground; iii) fouls a utility cable, pipe, or underwater pipeline; iv) is anchored, grounded, or beached to avoid an occurrence; v) is involved in a risk of a collision; vi) releases cargo and/or dangerous goods; as well as incidents in which a crew member i) falls overboard or ii) is unable to perform his or her duties, posing a safety threat.

(TSB, 2015a)

The following vessel types are included in the database:

- Liquid cargo vessels (chemical, product, or chemical and product tankers; crude tankers; combination carriers; liquefied gas carriers)
- Solid cargo vessels (bulk carriers; container ships; general solid cargo ships; heavy load carriers; ro-ro cargo ships)
- Barges
- Ferries
- Fishing vessels
- Naval ships
- Passenger and passenger/cargo ships
- Research or survey vessels
- Sailing vessels
- Service ships (cable ships; pilot boats; salvage ships; workboats; dredgers or hoppers; buoy tenders or re-supply vessels; icebreakers; vessels for coastguard duties, environmental response, firefighting, search and rescue, offshore support, and patrol duties)
- Ship's boats (e.g., lifeboats)
- Tugs

(TSB, 2015a)

Data Analysis Parameters

The following parameters were used when analyzing TSB incident and accident data:

- All three types of marine occurrences (accidents aboard ship, shipping accidents, and incidents) were included. The single exception is Figure 3.1, which incorporated older data (from 1998 to 2003) that were only available in aggregated form; this limited the way in which these data could be analyzed.
- Only solid and liquid cargo vessels were included. Although tug and barge combinations may be used for shipping cargo, the TSB data did not specify whether a barge or tug occurrence involved either vessel being used in this configuration; thus, incidents and accidents involving these vessels were excluded, except when accident rates were calculated using vessel movements. As explained throughout Chapter 3, vessel movement

numbers were only available in aggregated form, and tugs and barges were included in the data. To match Statistics Canada's criteria for vessel movements, incidents and accidents involving tugs and barges less than 15 gross register tonnes were excluded.
- Only incidents and accidents in Canadian waters were included, except in Figure 3.1, which involved aggregated data that did not allow occurrences in foreign waters to be excluded. Incidents and accidents in Canadian waters were identified using latitude and longitude data included with each record and verified with mapping of each point.
- Vessels of all flag states that experienced an incident or accident in Canadian waters were included. Workshop participants did not perform any analyses by flag state, since a vessel owned by one country can be registered under the flag of another. This practice makes it difficult to comment on the marine safety of a given country based on flag states.

Challenges Associated with Data Analysis

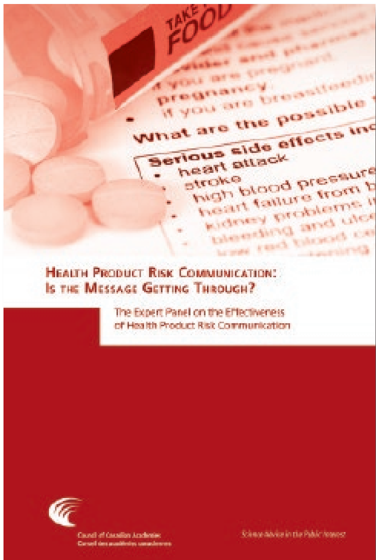
As discussed in Box 3.1, inconsistencies in the categories used for partitioning data from different sources hindered the calculation of incident and accident rates. The following limitations were encountered when analyzing the TSB data:

1) Vessel movement numbers are available from Statistics Canada (only until 2011), broken down by region, but not by vessel type.
2) Vessel registry numbers are available from Transport Canada, broken down by vessel type, but these data are for Canadian-registered vessels only.

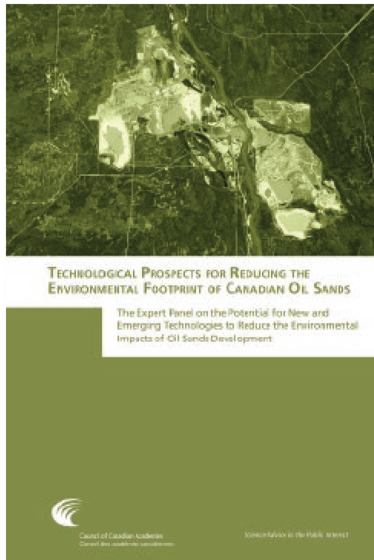
Because of these limitations, the data analyses were restricted in the following ways:
- To compare the incident and accident rate between different regions, it was necessary to use vessel movement numbers as the denominator and therefore to include both Canadian and international vessels. Because the incident and accident data were available from 2004 onwards and the movement data were only available until 2011, any incident and accident rate calculations using movement data as the denominator were restricted to 2004 to 2011.
- To compare the incident and accident rate between different vessel types, it was necessary to use vessel registry numbers as the denominator and therefore to include Canadian vessels only. In this case, number of registered vessels was assumed to be a surrogate for vessel activity.

Council of Canadian Academies's Reports of Interest

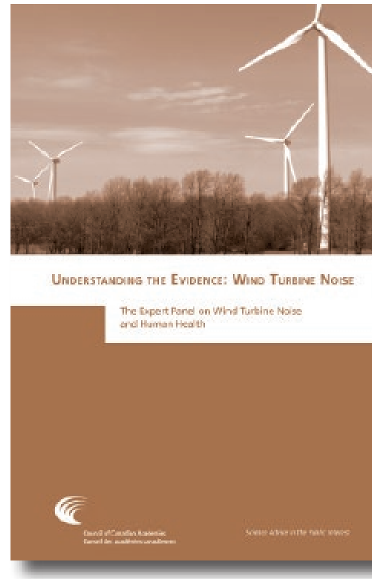
The assessment reports listed below are accessible through the Council's website (**www.scienceadvice.ca**):



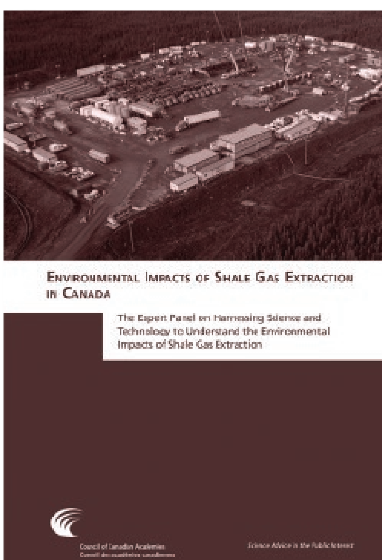
Health Product Risk Communication: Is the Message Getting Through? (2015)



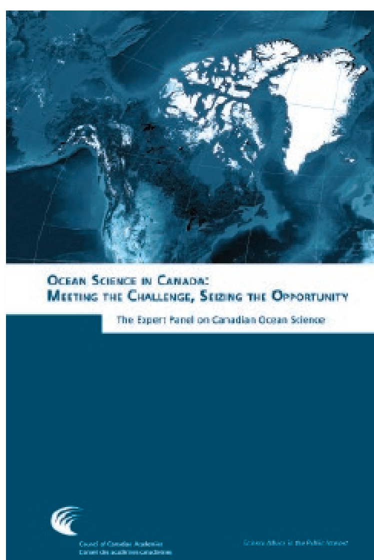
Technological Prospects for Reducing the Environmental Footprint of Canadian Oil Sands (2015)



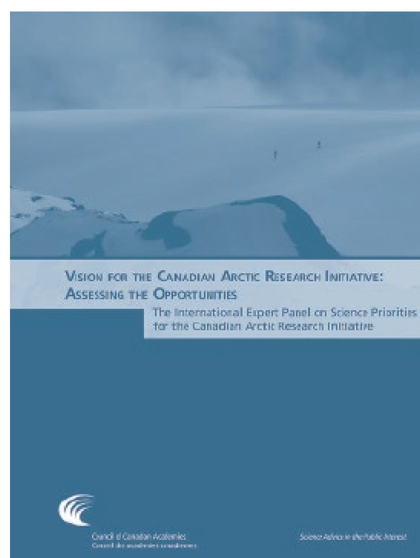
Understanding the Evidence: Wind Turbine Noise (2015)



Environmental Impacts of Shale Gas Extraction in Canada (2014)



Ocean Science in Canada: Meeting the Challenge, Seizing the Opportunity (2013)



Vision for the Canadian Arctic Research Initiative: Assessing the Opportunities (2008)

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