Chapter 11

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

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

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11.1 Introduction

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

Fishing is recognized as one of the most dangerous occupations globally (Hasselback and Neutel 1990; Lincoln and Conway 1999; TSBC 2012). Shipping has a somewhat better safety record, but retains 'a high potential for catastrophes' (Hetherington et al. 2006). Both sectors are vulnerable to the effects of weather and take place while travelling through varying regions and marine contexts. Both require task completion on moving platforms. Fisheries and shipping are also diverse (in the Arctic, as elsewhere): they encompass small-scale, short-haul, close to shore operations as well as medium- and large-scale operations that take place farther offshore and sometimes far from home ports and can last for weeks or

months.¹ Activities on board vessels in both sectors can vary considerably and may include maintenance of vessels and gear, steaming, docking, as well as loading and unloading (at dock and at sea). Fishing often also includes varying degrees of processing and stowage of the catch. Efforts to reduce OHS incidents in both sectors make use of similar instruments including regulation (equipment design and safety equipment requirements, certification requirements for captains and crew, licensing), establishing professional safety organizations, and improving communication (radio, satellite links) and location (radar, GPS) services. Most incident mitigation measures such as search, rescue, towing, and monitoring apply equally to shipping and shipping traffic.

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

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

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

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

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

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

The next section of this chapter draws on relevant fishing OHS literature, highlighting a handful of lessons extracted from historical periods of shifting fishing activity roughly analogous to current developments in Arctic fishing and shipping. These past events resulted in spikes in fatalities and injuries before steps were taken to reduce newly encountered hazards. It is likely that some of these fatalities and injuries could have been prevented with proper, careful hazard recognition and planning prior to, or early into, the period of change. To some degree, the chapter seeks to do for Canadian Arctic shipping what a similar Norwegian analysis sought to do for Norwegian Arctic shipping and other activities (McGuinness et al. 2013): to learn from the longer-term experience with fishing in Arctic and sub-Arctic waters about how to plan for and mitigate related health and safety risks. As argued there, based on a regulatory review and interviews with fishing industry representatives regarding maintenance and safety management regimes and requirements devised

by the Norwegian fishing fleet, safe operation in the Arctic requires, ‘adequate pre-planning of the activities, understanding of the operational environment and development of barriers against undesired events’ (McGuinness et al. 2013, 1). Preplanning of core vessel requirements, maintenance, and spare part availability are required in order to deal with Arctic-related challenges such as short operating seasons, remoteness from service and help resources, as well as hazards such as the threat of marine ice accretion (a well-known fishing-related hazard associated with cold marine environments) (Shipilova et al. 2012). Here, particular attention is given to potential lessons to be learned from previous periods of rapid change in fisheries, including expansion into regions with marine environments that are at least seasonally comparable to the Arctic Ocean (cold water, presence of sea ice, potential for icing, etc.) and that feature similar, sparsely distributed populations and key resources (e.g., SAR, Coast Guard). These regions include northeast Newfoundland and Labrador (Reid and Finnis 2019), Greenland, Iceland, and the seas off of North Norway (e.g., Serreze and Barry 2014; McGuinness et al. 2013). These subpolar and low Arctic seas also currently serve as prominent entries to the Arctic Ocean proper and are already active sites of fishing activity. This historical discussion is followed by a description of some of the resources and factors that have proven effective in mitigating OHS fishing incidents during periods of fisheries change, including prior expansion into the Arctic that might also be relevant for shipping (McGuinness et al. 2013).

11.2 Fishing Safety

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

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

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

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

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

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

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

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

Unfortunately, unsafe side trawlers were not necessarily decommissioned or removed from cold ocean service as they were phased out in Europe. Rather, some British side trawlers were sold to fishing operations in areas such as Newfoundland and Labrador. The icing up and disappearance of two of these vessels (the *Blue Wave* and the *Blue Mist*; 1959 and 1966 respectively) resulted in the loss of a total

of 29 lives (Stoodley 2017a, b), highlighting that OHS lessons often are not shared efficiently or effectively between countries.

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

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

11.2.1.3 Atlantic Canada Groundfish Moratoria

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

with very different equipment in deeper waters further offshore, using the same vessels, safety equipment, and knowledge that had been employed in nearshore cod fishing.

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

11.3 Mitigating Risk in Times of Change: Taking Stock

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

11.3.1 Marine Forecasting and Sea Ice Resources

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

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

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

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

11.3.2 SAR Resources

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

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

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

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

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

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

11.3.3 Regulation, Safety and Maintenance Management, and Safety Organizations

Regulation is an essential part of reducing the risk of injuries and fatalities as traffic increases in the Arctic. Past experience with fisheries highlights the need for active regulation of vessel design, training requirements, safety management, and vessel/gear maintenance capabilities, pursued with advance consideration of hazards and risk mitigation options. The IMO has now adopted the Polar Code for international regulation of Arctic shipping (Polar Code 2014/2015). Canada played a key role in its development and, in 2017, the Polar Code was implemented by Canada through the Arctic Shipping Safety and Pollution Prevention Regulations (ASSPPR 2017; Chircop et al. 2018). The history of Canada's engagement with the Polar Code and safety requirements in the new regulations suggest a strong focus on the need for vessel and equipment designs, specialized training for Arctic conditions, and particular attention to maintenance. These initiatives are consistent with some of the priorities identified by McGuinness et al. (2013) in their earlier study of insights from fisheries for marine shipping in the Norwegian Arctic and should be helpful in managing and mitigating Arctic hazards. However, Polar Code Phase I encompasses only SOLAS vessels, excluding fishing vessels, and the ASSPPR also do not apply

to fishing vessels, although some provisions may apply to fishing vessels including, for example, Section 14 regarding waste management. If fishing vessels are part of a proposed Phase 2 Polar Code, this situation could change, and if the regulations are fine-tuned for fishing in its diverse forms, they could help support a safer transition in this sector, although provincial and territorial health and safety agencies would need to be involved (Antarctic and Southern Ocean Coalition 2019; personal communication, Desai Shan, 24 July 2019).

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

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

11.4 Conclusion

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

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

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

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