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ARTICLE

Review of fishing safety policies in Canada with respect to extreme environmental conditions and climate change effects

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Abstract Fishing is one of the most dangerous occupations in the world. Numerous research studies have been carried out to improve fishing safety from many different perspectives. Several of these studies focused on the relationship between environmental factors, climate change effects, and fishing safety. This paper aims to suggest a knowledge mobilization structure that translates findings of this type of research into input of evidence-based decision making and consequently improve and update fishing policies with respect to fishing safety and environmental conditions. Significant safety factors extracted from related literature are stability of vessels, fisheries management, safety equipment, communication, insurance, training, safety information and culture, weather forecasts, fatigue, and search and rescue planning. The paper then reviews policies related to these factors to examine if they address extreme environmental conditions and climate change effects. The paper presents recommendations to improve general fishing safety with respect to short- and long-term environmental considerations.

Keywords Fishing safety · Fishing policies and regulations · Extreme environmental factors · Climate change

1 Introduction

Fishing has been identified as the deadliest occupation in Canada. The fatality rate for fish harvesters is 0.831 per 1000 persons per year, which is 19 times higher than any

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other industry in the country. In addition to the risk of life loss, fish harvesters are at danger of serious or minor injuries during their work at sea. In the province of Nova Scotia, approximately 4 % of fish harvesters have experienced at least one serious injury while fishing. It is important to note that these numbers only represent incidents reported to Workers' Compensation Boards (WCB) in Canada; hence, not all injuries or fatalities of small fishing operations may appear in these statistics (WCBNS 2012).

An overview of incidents reported to the Canadian Coast Guard (CCG) in Atlantic Canada (i.e., Canadian waters around Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and New Brunswick; 40° to 60° N latitude and 73° 20′ to 45° 50′ W longitude) showed that 8650 incidents occurred in this region during the period 2000–2010 and that 15 % of these incidents were classified as severe incidents (i.e., life loss or total vessel loss) (Rezaee et al. 2016a). Hard labor, long working hours, hazardous working conditions, and the competitive nature of the work are the elements of commercial fishing that contribute to the risks associated with the industry. Harsh environmental conditions combined with any of these factors could lead to a disaster. Several studies show that there is a correlation between various weather factors and fishing incidents (Jin et al 2001; Jin and Thunberg 2005; Chatterton 2008; Wu et al 2005, 2009; Wu 2008; and Niclasen et al. 2010). Rezaee et al. (2016a, b) studied the relationship between extreme environmental factors (i.e., air temperature, sea surface temperature, wind speed, ice concentration, precipitation, and Laplacian of pressure) and fishing incident rates and fishing incidents' severity levels, respectively. The local Laplacian of pressure, or simply Laplacian of pressure, is the indicator of pressure difference between the center of a cyclone and its frontiers that shows the cyclone's intensity. The results of these studies showed that there is a statistically significant relationship between these factors and fishing incidents and that these relationships and the degree of correlation between predictor factors and incidents are different for various fishery types. Another important issue that should be taken into account when studying the effects of environmental conditions on fishing safety is climate change. Global warming leads to short- and long-term changes in weather patterns, and this may also affect fishing safety. Rezaee et al. (2016c) proposed a framework to estimate fishing risk with respect to potential climate change scenarios. The results of these studies will be explained in detail in Sect. 2.2.

It is concluded from cited literature that, generally, harsh environmental factors can increase the risk of fishing incidents and worsen the situation during the period of recovery after an incident happens. Findings from the literature indicate that environmental factors and climate change are important elements to consider in formulating policies to improve fishing safety. This paper uses a knowledge mobilization structure to link the outcomes of different research efforts to safety policies and regulations. Knowledge mobilization is commonly defined as "getting the right information to the right people in the right format at the right time, so as to influence decision making" (ONF n.d.). Knowledge mobilization can be challenging for many reasons including differences in priorities of researchers and end users, a lack of a common language between them, uncertainty around use of research, lack of mutual trust, different understandings of policy and practices, time-related challenges, and so on (Shantz 2012). Therefore, it is very important to find a proper way to present knowledge in a readily understandable language for all the users and strengthen the connection between research, policy, and practice as much as possible. Levin (2008) refers to knowledge

mobilization models as "product models" with three main elements: input (evidence and research), outcome (practice and decisions), and a process that links input to output. The knowledge mobilization structure proposed in this paper has the following elements:

1. Input: Input to the framework comprises significant fishing safety factors in Canada extracted from related literature (along with a review current Canadian policies related to these factors) and findings of the studies related to the effects of extreme environmental conditions on fishing safety (Sect. 2);
2. Process: To build a bridge between the input items, relationships between research findings and the management of safety factors are determined (Sect. 3);
3. Outcome: Recommendations to modify regulations and policies in an attempt to make commercial fishing a safer occupation with respect to weather considerations are presented as the output of this framework (Sect. 4).

Before the knowledge mobilization structure approach can be used, the bodies within Canada responsible for fishing safety policies and regulation are introduced.

Many federal and provincial organizations are involved in fishing safety in Canada. Federally, Transport Canada (TC) and the Department of Fisheries and Oceans (DFO) are responsible for setting regulations and policies. Generally speaking, TC establishes policies on construction and stability of vessels, navigation and fishing equipment, lifesaving appliances, licensing, and the vessel-related training of fish harvesters. DFO is responsible for fisheries management, such as the setting of fishing seasons, fishery location, and species that may be caught and the catch limits (i.e., size and/or legal number of fish that can be caught). The Canadian Coast Guard (CCG), located within DFO, provides safety services for mariners and also regulates radio-communication and ice navigation in Canadian waters. After a fishing incident, search and rescue in Canada is a shared responsibility across government departments; for Atlantic Canadian waters, that responsibility is housed within the Joint Rescue Coordination Centre (JRCC) located in Halifax, one of three Canadian JRCCs. Other governmental or non-governmental organizations such as the Nova Scotia Fisheries Safety Council, the National Research Council, and various fishers' associations mainly work on research, training, and increasing safety awareness among fish harvesters. All of these departments and policies can directly or indirectly affect fishing safety in Atlantic Canada, the geographic location for this research.

2 Input

Input items for the knowledge mobilization framework are classified into two categories: fishing safety factors and the effects of extreme environmental conditions on fishing incidents. Fishing safety factors involve a review of fishing safety literature to provide a list of safety factors that may need improvement in Canada and examine current Canadian polices related to each factor.

The second part of this section summarizes findings of several research studies on the effect of extreme environmental factors on fishing incidents and determines which environmental factors are significant for fishing safety in Atlantic Canada.

2.1 Fishing safety factors

Kaplan and Kite-Powell (2000) indicated that fish harvesters find policies on reducing the maximum number of crewmembers, short fishing seasons, and restricted areas to be the main safety-related policies implicated in fishing incident levels. Loughran et al. (2002) concluded from a study on fishing vessel safety that safety culture is not very strong in fishing industries. Piniella (2007) focused on the use of safety equipment in a Spanish fishing fleet and showed that there is a need for training on the proper use of this equipment; he also highlighted the lack of safety culture among fishing communities. Windle et al. (2008) compared regulatory regimes and fishing safety outcomes in six countries (including Canada) and recommended improvements in policies with respect to safety training, safety equipment, inspection and enforcement, communication, search and rescue, weather forecasting resources, and fisheries infrastructure. Håvold (2010) showed that fish harvesters' safety attitude, safety training, and management's safety attitudes have significant influence on fishing safety policies and practices. An investigation of small fishing vessel incidents that occurred in Canadian waters during 1999–2010 showed that the main safety issues in Canada are as follows: vessel stability, fisheries resource management, lifesaving appliances, regulatory approach to safety, training, safety information, cost of safety, fatigue, fishing accident statistics, and safe work practices (Transportation Safety Board of Canada (TSB) n.d.).

Adopting the findings of the preceding studies, a list of factors for which related policies and regulations may need improvement is created. The list comprises the following:

- Factors related to incident occurrences:

– Stability: The stability of a vessel is defined as its ability to deal with strong winds, high waves, loading, and other forces resulting from the vessel's operations. Loss of stability is one of the main factors leading to fishing incidents. TC requires that every new fishing vessel to go through a stability inspection on, or near, the completion of construction. The inspection should include loading conditions (half load and full load), departure and arrival situations, and worst-case operating conditions and, when applicable, consider the worst operating conditions with ice accumulated on topside and rigging. If a vessel is larger than 150 gross tons, it needs to have a stability booklet on board that specifies the limits of that particular vessel's stability (Minister of Justice 2007a, b).
– Fisheries management strategies: The Department of Fisheries and Oceans Canada (DFO) aims to ensure sustainable fishing. It also contributes to maintaining and improving fishing safety by providing infrastructure, information, products, and services necessary to promote safe navigation and the protection of life and property in Canadian waters. Maintaining a balance between strategies that are most likely to achieve the objective of sustainable fishing and strategies that are designed to increase safety is an ongoing effort. Several studies have investigated different aspects of fisheries management and their effects on fishing safety culture (Kaplan and Kite-Powell 2000; Kaplan and MacCay 2004; Brooks 2005; Emery et al. 2014) in related literature. In Canada, fisheries management strategies and

their role in fishing safety decisions vary among different fishery types and fishery locations.

– Weather forecasts: Environment Canada (EC) provides marine weather forecasts for shippers, boaters, and fish harvesters through their website and radio stations. There are no stated policies or regulations on how fish harvesters get the weather forecast and no explicit link to agencies that provide additional safety guidance for fish harvesters in cases where weather warnings are issued.
– Fatigue: "Hours of work" is not included in polices or regulations, but fatigue has been determined to be one of the main causes of fishing incidents. Harsh weather conditions can have a significant effect on levels of fatigue. It is not hard to imagine that working in strong winds, heavy rain, and low temperatures can be exhausting and mentally frustrating.

• Factors related to incident consequences

– Safety equipment: Fishing vessels are required by TC to carry lifesaving appliances, vessel safety equipment, visual signals, navigation equipment, and firefighting equipment (TC n.d.).
– Communication: The CCG is responsible for fishing vessel radio communication regulations. Radio communication service is mainly used to exchange messages for safety and navigation. Fishing vessels that are 20 m or more are required to have a search and rescue transponder (SART) in their vessels under Canada's lifesaving regulations (Minister of Justice 2014). DFO also requires certain fisheries to carry vessel monitoring system (VMS) devices on their vessels for fisheries management purposes (DFO n.d.b). Automatic Identification System (AIS) is another transponder, which is mandatory for every ship operating in Canadian waters, which is 500 t or more and not a fishing vessel (TC 2007).
– Search and rescue: While search and rescue can be conducted via air or ocean, the JRCC Halifax coordinates maritime search and rescue operations in emergencies carried out by the CCG and Canadian Coast Guard Auxiliary (CCGA) and the Canadian armed forces assist with airside support. A search and rescue resource may have its own operational limits, and consequently, a search mission could be affected (or delayed) due to poor weather conditions in some situations.
– Insurance and Workers' Compensation Boards: Insurance is not mandatory for fishing vessels; however, some provincial governments require proof of insurance coverage before issuing permits for some fisheries. WCB coverage is only mandatory for certain size vessels (with possible variations across provinces), and the premium is relatively high compared to other occupations (for example, in 2012, Nova Scotia's average assessment rate was equal to $2.65 per $100 payroll. However, the rate for the fishing industry was equal to $7.85 per $100 of payroll) (WCBNS 2012).

• Factors related to fishing safety in general

– Safety information and culture: There is no policy on fishing safety culture; however, TC, DFO, and the TSB can effectively increase awareness of safety

issues among fish harvesters, which may potentially foster a culture of safer practices among fishing communities (Johannes et al 2000; Levin et al 2010)
– Training: Training can have a considerable effect on fishing safety. Currently, training is only compulsory for Masters and watchkeeping officers (TC 2011). The Master of the fishing vessel should also make sure that all the crewmembers know how to use safety equipment. Several federal and provincial organizations such as the Canadian Council of Professional Fish Harvesters, Professional Fish Harvesters Certification Board, Nova Scotia Fisheries Sector Council, and Prince Edward Island Fishermen's Association attempt to increase awareness among fish harvesters and provide training courses for them.

Fishing safety is a complex system, and there is a dynamic relationship between its elements. In other words, safety-related factors are not independent of each other and any change in one factor can affect others. For example, fishing management strategies may lead to competitive fishing during a short season (Emery et al. 2014) which, according to Gander et al. (2008), can add to the fatigue factor. Proper training on use of safety equipment may be assumed to decrease the severity level of fishing incidents, and all other things being equal, a decreased number of severe fishing incidents could eventually lead to lower insurance rates.

To study the relationship between safety factors and environmental conditions, the results from Rezaee et al. (2016a, b, and c) will be described in the following section.

2.2 The effects of extreme environmental conditions on fishing safety

Rezaee et al. (2016b) focused on the relationships between fishing incident rates (i.e., number of fishing incidents over related fishing traffic) and extreme environmental factors in Atlantic Canada. The environmental factors, chosen based on the related literature and experts' opinions, comprise wind speed, air and sea surface temperature, precipitation, ice coverage, and Laplacian of pressure. Several statistical methods were applied to the data sets, and the following results were obtained:

- On stormy days, lower air temperature, higher ice coverage, and strong winds will increase fishing incident rates.
- Low sea surface temperature and high wind speed are critical weather factors in winter.
- Low sea surface temperature, high ice coverage, and heavy rain are significant weather conditions for fishing incident rates in spring.
- Wind speed is the main weather factor that affects safety in summer.
- Wind speed and high Laplacian of pressure may lead to risky situations for fishing incidents in the fall.

Rezaee et al. (2016a) investigated the effects of environmental conditions after a fishing incident happens (i.e., incident consequences which can be severe or non-severe) in Atlantic Canada.

The results are summarized as follows:

- High Laplacian of pressure, low sea surface temperature, and strong wind speeds are significant weather factors in severe incident occurrences (i.e., life loss and/or total damage to the vessel)
- Shrimp and herring roe fisheries are more vulnerable to intense storms (i.e., high Laplacian of pressure).
- Strong wind speeds and low sea surface temperature are significantly correlated to severe incidents for groundfishing fishers.
- Ice coverage is the critical environmental factor in seal fishing incidents' severity levels.
- Scallop fishing and lobster fishing are at danger of severe incidents when the Laplacian of pressure is high (i.e., intense storms) (Rezaee et al. 2016a).

These results indicate that the effects of environmental conditions are different for various fishery types. These differences are likely related to the situational differences in fishery types such as the location of fisheries (geography and/or weather), their distance from shore (inshore and offshore fishing) with its associated remoteness, length of their fishing trip (1 day or multiple days), the fishing vessels' characteristics (size and age), and the fisheries management system for the fisheries (individual quota, limited traps, or competitive).

Rezaee et al. (2016c) proposed a general framework to study the effects of climate change on fishing safety. Intensity and frequency of storms hitting Atlantic Canada were chosen as predictors of fishing incident rates. Comparing the estimated fishing incident rates in 2081–2100 to the historical records from the years 1980–2000 in the area of interest showed a great of deal of similarity between the spatial distributions of incident rates in these two periods. Figure 1 compares these two periods: Blue shows no change, horizontal lines indicate risk reduction by one class (i.e., medium to low or high to medium), diagonal lines imply risk increase by one class, and dense dots show risk increase by two classes (i.e., low to high) in 2081–2100 compared to 1980–2000. Based on this figure, one can conclude that, generally, the shorelines around New Brunswick and the Gulf of St. Lawrence could experience an increase in fishing risk due to climate change effects. However, it must be noted that this study only adopts frequency and intensity of storms as fishing safety predictors, whereas including more determinants, such as air and sea surface temperature, vessel characteristics, and fisheries location, may result in more accurate estimations of impacts.

When climate change is studied, it is also necessary to consider annual variations in the frequency and intensity of storms. These factors differ for each individual year in that period and some years may be particularly harsh. This dynamic characteristic of storms can lead to high fishing incident risks in some years despite the average over longer periods remaining steady.

3 Process of linking research findings to safety factors

This step attempts to reveal relationships between safety factors and significant environmental conditions in fishing safety. These relationships will be employed to recommend improvements in fishing policies and regulations.

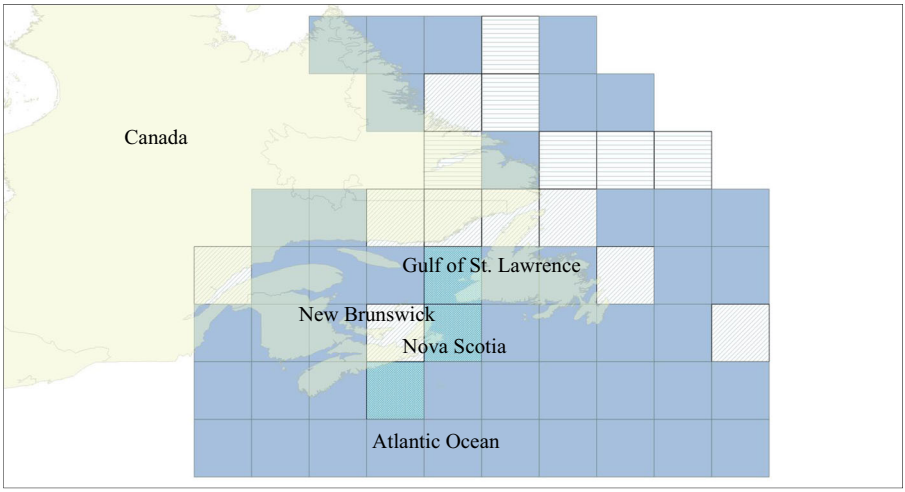

Fig. 1 Differences between incident rate classes in 1980–2000 and 2081–2100 based on ERA-Interim Reanalysis product storm simulation. *Blue*: no difference, *horizontal lines*: risk reduction by one class (i.e., medium to low or high to medium), *diagonal lines*: increase by one class (low to medium, medium to high), and *dense dots*: increase in risk by two classes (low to high) (Color figure online)

Each of the significant environmental factors in fishing incidents (listed in Sect. 2.2) might affect safety factors (listed in Sect. 2.1) directly or indirectly. For example, strong wind speed can affect stability, complicate search, and impede timely rescue. Working in strong winds can be stressful and add to fatigue. Low temperature can worsen the situation of a person in the water and lead to serious injuries; this brings attention to the importance of appropriate insurance for risky fisheries (smoothing the recovery phase if an incident happens). Low sea surface temperature causes cold shock, and drowning would be inevitable for a person in the water without a personal flotation device, even in calm seas. Ice coverage can trap vessels and cause damage to the hull, which signifies the importance of communication, search and rescue, and insurance. Precipitation lowers visibility, may affect communicating devices, and may add to the fatigue of crewmembers.

Weather patterns may alter due to climate change. All the relationships listed in Table 1 should be reviewed periodically due to short-term and long-term climate change considerations and revised if necessary.

In the following section, recommendations are presented with respect to results from Rezaee et al. (2016a, b, c) to modify Canadian policies in a way that general fishing safety is improved.

4 Output (fishing safety policies)

Stability Extreme environmental conditions and the resulting poorer operating conditions are different in each part of the country and each fishery type (see Table 1); therefore, inspections should be customized based on the particular environmental characteristics of each location/fishery. However, these

Table 1 Relationships between environmental and safety factors

Environmental factor	Season	Fishery type	Safety issue (direct effect)	Safety issue (indirect effect)
Wind speed	• Winter • Summer	• Groundfish • Scallop • Lobster	• Stability • Search and rescue	• Fisheries management • Safety information and culture • Weather forecast • Fatigue • Training
Air and sea surface temperature	• Winter • Spring	• Groundfish	• Insurance • Safety equipment	• Fisheries management • Safety information and culture • Weather forecast • Fatigue • Training
Ice coverage	• Spring	• Seal	• Stability • Search and rescue • Communication • Insurance	• Safety information and culture • Weather forecast • Fatigue • Training
Precipitation	• Spring	• –	• Communication • Fatigue	• Safety information and culture • Weather forecast • Training
Laplacian of pressure	• Fall	• Shrimp • Herring roe	• Stability • Safety equipment • Search and rescue • Communication • Insurance	• Safety information and culture • Weather forecast • Training

Source: summary of results from Rezaee et al. (2016a, b)

considerations should be periodically updated due to short- and long-term climate change effects. It is also important to increase awareness among fish harvesters about the role of stability in fishing vessel incidents and inform them about factors that may affect stability. Currently, there are training courses on stability such as the Fish SAFE Stability Education Program (Fish SAFE n.d.) and Fishing Vessel Stability Simulator (CCPFH n.d.). The role of these programs in improving fishing safety shows the importance and necessity of providing a more comprehensive and consistent training on stability. These could be offered by TC and/or Fishers' Associations, particularly for fishery types that are more vulnerable to strong winds (e.g., Lobster fishing). Vessel modification may have an impact on the weight of the vessel or on the watertight integrity of the hull and the superstructure, which consequently affects the stability (TC n.d.). Therefore, if a vessel is modified, or the location/target species of fishing has changed significantly since the previous inspection, spot checks of fishing vessels' stability by TC can improve safety.

Fisheries management Including safety of fish harvesters in general, and extreme environmental conditions in particular, fisheries management

infrastructure can reduce fishing risk (Pinkerton 2011). DFO's regulations indirectly affect many safety-related issues. Short fishing seasons may lead to overloaded vessels (thus decreasing stability) and/or cause fish harvesters to stay out in harsh weather conditions (Kaplan and Kite-Powell 2000). Adopting quota-based fishing programs instead of tightly specified fishing seasons gives more flexibility to fish harvesters and may improve safety (Hughes and Woodley 2007) particularly because each fishery can be affected by different weather conditions (as shown in Table 1). Involving fish harvesters in decision-making processes from the outset, and considering the specific environmental conditions for each location in decision making, as well as updating this information periodically based on climate change effects, can also help manage fishing risk. For instance, the opening date of the snow crab fishery in the Southern Gulf of St. Lawrence is determined by an industry-led committee, which assesses and recommends a targeted opening day based on DFO's operational requirements and weather conditions (DFO n.d.a). The advisory committees for various Lobster Fishing Areas (LFA) comprise DFO and industry representatives for each area. These committees meet before each season and establish opening- and ending-day protocols (personal communication, 2016 June 24). For example, according to the opening-day protocol (2015–2016) for Lobster Fishing Area (LFA) 34 in Southwest Nova Scotia, if the wind speed exceeds 26 knots, the opening of the season will be postponed. The End of Season (2014) Protocol for LFA 36 states that when unforecasted extreme weather occurs in the last days of the spring Lobster season that prevents fishermen from safely retrieving their fishing gear before the season ends, harvesters must contact their local Conservation and Protection (CandP) office as soon as possible (prior to the end of the season) to discuss the situation. CandP will consider the available options to allow fishers to legally retrieve their gear after the season ends. These types of risk reduction efforts should be practiced for fisheries all over Canada, with ongoing efforts to continue to improve dialogue between fishers and DFO to address critical issues in fishing safety and fisheries management.

Weather forecasts Governmental agencies' (e.g., TC, EC, DFO, and CCG) support of research on more accurate weather forecasts, and research on the most effective ways to share forecasts with fish harvesters, would improve fishing safety (Roberts 2004; Fulsås 2007). It is assumed that additional regulations toward better adherence to good safety practices in case of storm warnings may also improve fishing safety.

Fatigue Increasing awareness about fatigue through public engagement programs and training courses provided by TC and Fishers' Associations will better prepare fish harvesters for critical environmental conditions (Gander et al. 2011).

Safety equipment Several studies show that life-saving appliances may not be very easy for fish harvesters to use (Piniella 2007; TSB n.d.), so training courses offered by CCG, TC, and Fishers' Associations on how to use this equipment in case of storms and improvements in lifesaving appliance designs to increase the efficiency and ease of use would improve safety. More frequent and extensive inspections of this equipment

by TC or provincial Fishers' Associations are another action that can increase safety; however, there should be a cost-benefit analysis to find a balance between the cost of these inspections and the value that they may add to safety. Furthermore, the issue of who would bear the cost is also another challenge for such policy changes. Increasing awareness of fish harvesters on the critical role of the safety equipment in case of incidents, particularly in stormy and cold weather, can also save lives (Brooks 2005).

Communication Encouraging all fishing vessels to carry radio communication devices (SART, VMS, or AIS), even when it is not required by law, and training all crewmembers on how to use these devices in case of an emergency (offered by CCG and Fishers' Associations) may improve fishing safety (Morel and Chauvin 2006). It is important to maintain the efficient performance of the equipment in extreme weather conditions; this goal can be supported by TC's periodic inspection of equipment.

Search and rescue CCG's support of research to determine hotspots of incidents based on short- and long-term weather patterns (research similar to that presented in Fig. 1) and planning and allocating search and rescue resources based on the findings of related fishing safety research studies would save lives, time, and money.

Insurance and Workers' Compensation Boards Despite the fact that insurance and WCB coverage are not directly related to safety, encouraging all fish harvesters (particularly, the ones that are more vulnerable to extreme weather) to have proper insurance would alleviate the potentially harsh consequences of incidents. The need for insurance is also an important consideration in case of climate change, since factors such as weather conditions and locations of fisheries may change and fish harvesters may encounter unfamiliar situations, which can contribute to the risks associated with the industry.

Safety information and culture Knowledge mobilization, involving fish harvesters in decision-making processes from the early stages of developing new policies and practices, and encouraging research programs on safety culture in all governmental and provincial fishing-related organizations can improve overall fishing safety (Johannes et al 2000; Levin et al 2010)

Training Training courses on the stability of the vessels (Gudmundsson 2009) and the use of safety equipment in case of extreme environmental conditions (Brooks 2005) can improve fishing safety effectively. TC, DFO, and provincial Fishers' Associations could offer these training courses. To encourage all the fish harvesters to attend, the fee for these courses should be kept as low as possible. It is also important that fisheries associations provide a platform to facilitate knowledge transfer among universities and fishing communities and to initiate and maintain dialogue between marine researchers and fishers. Strong knowledge mobilization structures between research organizations (i.e., universities and NGOs) and the fishing industry can decrease the reliance on government for training and foster a relevant partnership to continue to address such issues.

5 Moving forward

5.1 Implications for managerial practice

Fishing safety literature demonstrates that there is a correlation between environmental factors and fishing incidents. To improve fishing safety and lower the consequences of incidents, it is of great importance to consider environmental factors and potential climate change scenarios in the context of fishing safety-related policies and regulations. This study identifies different fishing vessel safety issues in Canada and discusses relationships between these safety factors and environmental conditions (see Table 2). However, this research examines the policies from a general point of view as it does not investigate all the details, exemptions, vessel characteristics, fishery types, regional infrastructures, and cost-benefit considerations. In this section, we demonstrate how decision makers can utilize these recommendations to address safety issues, customized as needed for different fishing fleets, vessel types, and so on.

The following list presents some of the key questions that should be answered through ongoing research about each safety factor with consideration of weather conditions:

Vessel stability Wind speed and wave heights directly affect vessel stability and may lead to an incident. Hence, consideration of weather factors in stability inspections is a must; however, it should be clarified whether:

- Is it necessary to update stability inspection procedures with respect to changing weather patterns in the particular area of interest? If yes, how often?
- Is there already sufficient training for fish harvesters to periodically inspect the stability of their own vessels? If not, is it economically and technically possible to train them to do periodic inspections of their vessels with respect to weather considerations? Is there any local organization other than TC (e.g., Fishers' Association) that can help them on this matter?

Fisheries management Individual quota-based management system allows fish harvesters to catch a specific amount of fish (measured by weight) in a given period of time. This management strategy would give flexibility to fish harvesters in choosing a good time for fishing (avoiding trips in harsh weather conditions). However, it is necessary to conduct a multi-stakeholder study that compares the advantages and disadvantages of quota-based management from both ecological and safety perspectives for each fishery type. It is also important to create a comprehensive stakeholder engagement plan to involve fish harvesters in an evidence-based decision-making process about fishing safety-related strategies for each aspect of interest.

Weather forecast New research studies show that people prefer probabilistic forecasts to deterministic forecasts in extreme weather conditions (LeClerc and Joslyn 2012, 2015). There should be specific survey-based studies to investigate what the best ways are to circulate weather forecast information to fish harvesters to support their decision-

Table 2 Summarizes key safety-related policies and recommendations (responsible agencies)

Safety issue	Current policy	Recommendations
Stability	• Inspection at the time of (or close to) completion of a new vessel • Safety Booklet for large vessels	• Inspection based on updated extreme environment conditions and climate change effects (TC) • Training courses on stability (TC and Fishers' Associations) • Spot checks (TC)
Fisheries management	• Time, location, and effort intensity regulations in alignment with protection of fish stocks • Limitation on vessel sizes for some fisheries	• Quota-based fishing programs (DFO) • Involvement of fish harvesters in decision-making process from the early stages (DFO) • Extreme weather consideration for individual fisheries, temporally and spatially (DFO)
Weather forecasting	• Weather forecast information is provided by EC as "Marine Weather Forecast" • Weather warning such as Small Craft Warning is issued by TC for mariners and can be applicable to fish harvesters as well.	• Support research on weather forecast improvements (TC, DFO, CCG, and EC) • Support research on sharing forecast information among fish harvesters (TC, DFO, CCG, and Fisheries' Associations) • Increasing reliability and effective use of weather forecasts and warnings (EC)
Fatigue	• –	• Increase awareness (Fisheries' Associations) • Training courses (Fishers' Associations)
Safety equipment	• Mandatory for all fishing vessels to carry safety equipment with respect to the number of crewmembers	• Training courses on how to use the equipment in case of extreme weather (TC, CCG, and Fisheries' Associations) • Improvements in design of the equipment (TC) • Periodic inspection of the equipment (TC) • Increasing awareness among fishing communities (TC and Fishers' Associations)
Communication	• Mandatory for large vessels	• Periodic inspections (TC) • Training for all crewmembers (CCG and Fisheries' Associations) • Encourage use of radio communication (SART, VMS, and AIS) for all vessels (Fishers' Association and DFO)
Search and rescue	• Responsibility of Canadian Coast Guard and Canadian Coast Guard Auxiliary with support from the Department of National Defense (DND)	• Support research on operational and tactical resource planning with respect to extreme environmental conditions and climate change (CCG)
Insurance and Workers' Compensations Boards	• Mandatory for certain fisheries	• Encourage having proper insurance coverage for all vessels (Fishers' Associations and TC)
Safety information and culture	• –	• Knowledge mobilization (TC, DFO, and Fishers' Associations)

Table 2 (continued)

Safety issue	Current policy	Recommendations
		• Support research on safe work practices (TC, DFO, and Fisheries' Associations) • Involvement of fish harvesters in decision-making processes from the early stages (TC, DFO, and Fishers' Associations)
Training	• Mandatory for Masters and watchkeeping officers	• Consistent training courses on stability of the vessels and use of safety equipment in case of extreme environmental conditions for all crewmembers (Fishers' Associations, TC, and DFO)

making process for different fishery types, length of fishing trips, and fishing communities.

Fatigue Extreme weather factors can add to fatigue; it is not hard imagine that it is harder to work in strong winds than calm weather, but it is necessary to measure these effects scientifically. Experimental studies can quantify the effects of weather factors in each region on fatigue, and subsequently crew work plans might be revised accordingly. Here are some sample questions:

- Does precipitation increase fatigue? Would it be safer to get to shelter as quickly as possible or would it be better to take more frequent breaks, depending on fishing location and distance to shore?

Safety equipment There are numerous studies on how safety equipment can affect fishing safety. However, there are still issues to be investigated regarding training fish harvesters on safety equipment such as the following: Is it beneficial (economically and practically) to train fish harvesters to inspect their equipment periodically? Is there any local organization other than TC or CCG (e.g., Fishers' Association) that can help them on this subject?

Communication There is a gap in the policy literature on how communication can affect fishing safety. There are some key questions to be answered in this respect:

- Is there any statistical change in fishing incident rates (and/or consequences) before and after usage of a communication device on specific vessel types or sizes or by fishery locations? The same questions can be posed particularly for incidents related to weather conditions.
- Will training crewmembers about communication devices improve safety considerably? What are the cost-benefit results in this regard?

Search and rescue Search and rescue stations are mainly built to maximize the availability of various response resources and accessibility to incident hot spots. A comprehensive spatiotemporal study that tries to answer the following questions would benefit fishing safety:

- Where are the new locations of fish stocks for different fisheries? And, does this affect CCG resource allocation?
- What are the potential weather patterns in different areas due to climate change? What are the effects of changing weather patterns on fishing safety?

Insurance An empirical study should be conducted to examine the effects of insurance on fishing safety in an attempt to answer the following questions:

- How a fishing vessel's insurance premium is calculated? What are the important factors affecting the insurance market? How do fish harvesters evaluate insurance rates?
- Does having insurance encourage fish harvesters to assume more risk in extreme weather conditions as they may become less concerned over dealing with the adverse consequences of incidents?
- What are the different types of insurance? What is the best insurance plan for each type of vessel or fishery? Should insurance be obtained through large companies or small community-based groups?

In conclusion, it is important to recognize the research gaps in different aspects of fishing safety-related policies and ascertain whether these policies are in alignment with fishing safety research findings. Different entities (e.g., TC, CCG, DFO, NGOs, fishing communities, etc.) could be involved in addressing these research gaps to mitigate fishing risk. The methodology proposed in this paper can be customized and applied by these entities as needed.

5.2 Contributions to scholarly knowledge

This study used a knowledge mobilization structure to translate fishing safety research findings into recommendations for Canadian fishing-related policies with respect to short- and long-term weather considerations. Knowledge mobilization should not be considered just as transfer of research results, but it must also act as a mechanism for continually revising the research focus to address key problems. Achieving this objective requires a deep understanding of the industry and national and local capacity. Using this knowledge mobilization structure, this study investigates the relationship between commercial fishing safety policies and extreme weather and climate and highlights the gaps between the research areas and implications of regulations and policies. The output of this structure provides recommendations on how the relationship between policies and weather research factors can be built and strengthened. This structure also points out the areas for research capacity building to better address the critical issues in fishing safety.

The input for knowledge mobilization in this study is a data-driven statistical analysis based on historical data, and the quality of the data obtained and the methods to process the data impose limitations on the results from the study in terms of data availability and data accuracy. Collecting more detailed and accurate real-time data would be very helpful to pursue more work in this regard. Adding other environmental factors like fog and wave heights, human factors like years of experience, and vessel-related factors like size and age may also help to obtain a better understanding of fishing safety with respect to extreme climate. This study did not distinguish among different locations of fishing and individual fisheries due to data limitations. Addressing these factors in reviewing fishing policies would provide better links between understanding these policies and the impacts of extreme environmental conditions.

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