Taking stock: strengths, weaknesses and opportunities for improving fishing occupational health and safety research and resources in Newfoundland and Labrador

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DRAFT Background Paper Prepared for the Ocean Frontier Institute Module I Taking Stock Dialogue
September 17-19, 2018, St. John's NL.

Acknowledgements: Research funding was provided by the Ocean Frontier Institute, through an award from the Canada First Research Excellence Fund.

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Introduction

Multiple factors interact to affect fishing occupational health and safety (OHS). These factors include fishing location and species; season, weather and weather forecasting; vessel, gear and equipment design; education and training; work organization; workplace culture and perceptions of risk; fisheries management; and OHS governance (including search and rescue resources, workplace safety inspection, safety awareness cultivation, workers' compensation, and return to work). This background paper takes stock of strengths and gaps in fishing OHS research as it relates to these broad areas. It situates Atlantic Canada within a broader critical review of themes, methods, and findings from relevant international research on OHS in commercial marine fisheries in industrialized countries since 1980. The paper pays specific attention to existing research on: 1) the relationship between OHS and fisheries governance, including transitions in fisheries (such as after the Atlantic Canadian groundfish moratoria in the 1990s and subsequent shift to crab and shrimp); 2) OHS policies and frameworks; 3) fatality, accident, injury and incident rates within and across fisheries and related data sources and gaps; 4) the relationship between weather, weather forecasting and safety; and 5) the relationship between vessel design, stability, and noise across fleets/fisheries. It links to Module I's broader governance concerns, as these factors are either the subject of explicit government regulation or the purview of specific governmental (e.g. Coast Guard, Environment and Climate Change Canada) and non-governmental (e.g. unions) institutions or have the potential to interact with regulation and policy to affect health and safety (Windle et al., 2008).[6]

Methods

The background paper was developed from a scoping review of the literature. The goal was to collect and inventory as much of the relevant literature as possible in the time available. Identified sources were organized chronologically, by theme, and by citation count. We began by extracting references from existing international bibliographies on fishing safety and related literature reviews. These were supplemented using citation tracking in Google Scholar, through consultation with peers (18 sources) and from resources acquired by scanning abstracts from the International Fishing Industry Safety and Health Conference 5 held in June 2018 (IFISH abstracts were however excluded from the network analysis). Two bibliographies were used to seed the current list. The first was the National Institute for Occupational Safety and Health (NIOSH) Literature on Fishing Industry Safety, which contained 169 references up to 2012. Of these, only 135 were accessible using public and university access. An updated version of the list by Lucas et al. (2014) provided more recent sources. An additional 11 references on vessel stability were provided by fellow researchers, along with 7 references on work on moving platforms. Once the references were assembled, Google Scholar was used to identify how often the selected references were cited, which papers from the seed list had cited them, and to identify other potential sources. Two hundred and six sources (23 from Atlantic Canada) were processed for themes and citation linking in the production of this draft paper. An additional 58 were identified through Google Scholar but have not yet been processed due to time constraints. A

[6] M. J. S. Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries," *Marine Policy* 32, no. 4 (2008): 701–10, https://doi.org/10/ck386x.

digital version of the full database of references will be available on the OFI Module I Taking Stock website or by request to bneis@mun.ca.

References for studies done outside of industrialized countries of the North and South, and those on subsistence, freshwater and tropical fisheries were excluded from the analysis used for this paper. This ensures any international literature considered in the review aligns with our focus on commercial fisheries in a Canadian North Atlantic context. Sources in the final list of 206 sources were scanned to extract research questions, methods and findings. Bibliographic software was used to connect sources based on citations and common themes. Themes were identified at two scales: a) the publication/journal source and b) at the article level. Publication themes covered 14 broad areas, the largest of which were medicine/health and safety (60% of sources), marine policy and governance (10%), risk (6%), and ergonomics (6%). Journals were assigned to each group based on general themes addressed in each publication's description. In addition, each reference was assigned anywhere from one to five more specific themes, with most receiving at least three. These themes were based on article keywords, research disciplines and methods, and key findings. Citation counts and publication themes were mapped using Gephi, an open source network visualization program, to identify research clusters (strengths) and gaps within the larger international literature and between the Atlantic Canadian literature and international work.

Scoping Review Results

International Literature

Since the 1980's the body of global research on fishing OHS has grown substantially and spread across disciplines and thematic areas of focus. The existing body of research is still very small relative to the global scale of commercial fishing, its diversity, very high injury and accident rates and the engagement of millions of people. To date, we have identified just over 200 sources dealing with various aspects of OHS in commercial fisheries in industrialized contexts. Most are peer-reviewed publications, but some are technical reports and graduate theses. These publications span a time frame from 1966 to the present (2018). Nearly half of these (97) were published between 2000 and the end of 2009; 34 have been published in the last 5 years (2014 – 2018). Early research efforts often focused on documenting incident/accident/fatality rates in fishing relative to other sectors, and on extreme events associated with multiple vessel losses and multiple deaths. Many of these events were tied to weather phenomena such as major storms.[7]

Over the past few decades, fishing OHS research has expanded to encompass a wide array of disciplines and subject areas. Internationally, fishing OHS research now encompasses risk analyses, epidemiological and ergonomics studies, as well as physics, engineering and social science research. Study topics include: the relationship between fisheries management and

[7] M. S. Reilly, "Mortality from Occupational Accidents to United Kingdom Fishermen 1961-80," *British Journal of Industrial Medicine* 42, no. 12 (December 1985): 806–14.

fishing safety,[8] injured fishers,[9] and community-engaged fishing safety initiatives[10]; tracking and understanding SAR incident rates;[11] weather and climate;[12] vessel design;[13] stability;[14] work on moving platforms and ergonomics;[15] noise exposures;[16] the design and use of personal protective equipment (PPE);[17] socio-cultural factors such as gender; and perceptions of risk,[18] etc.

Some recent topics discussed in international research include improving adoption and functionality of PPE,[19] studies of weather and marine hazards, including impacts on vessel stability,[20] research on cold water submersion survival and fatal falls overboard,[21] and theoretical approaches to safety based on resilience and adaptation,[22] among others. Of the 206 sources drawn upon for this paper, 124 were published in journals or other outlets that fall broadly under the banner of Medicine/Health and Safety. These are primarily epidemiological papers dedicated to counting and compiling numbers of injuries, accidents, and fatalities for particular regions of the world. Roughly a quarter of papers use participatory approaches through surveys, interviews,

[8] Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries."
[9] Michael Murray and Theresa Heath-Rogers, "Injured Fish Harvesters," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/library/Fishery/IF.pdf.
[10] Michael Murray and Neil Tilley, "Promoting Safety Awareness in Fishing Communities through Community Arts: An Action Research Project," *Safety Science* 44, no. 9 (2006): 797–808, https://doi.org/10/b7kprj.
[11] Sara Rezaee, "Risk Analysis of the Effects of Extreme Weather Conditions on Commercial Fishing Vessel Incidents" (Dalhousie University, 2015).
[12] Yue Wu, Ronald Pelot, and Casey Hilliard, "The Effect of Weather Factors on the Severity of Fishing Boat Accidents in Atlantic Canada," *Risk Management* 7, no. 3 (2005): 21–40, https://doi.org/10/dr97nj.
[13] C. G. Loughran et al., "A Preliminary Study of Fishing Vessel Safety," *Journal of Risk Research* 5, no. 1 (2002): 3–21, https://doi.org/10/fsmq6c.
[14] J. Wang et al., "An Analysis of Fishing Vessel Accidents," *Accident Analysis & Prevention* 37, no. 6 (2005): 1019–24, https://doi.org/10/csg9xr.
[15] Carolyn A Duncan et al., "Effect of Simulated Vessel Motions on Thoracolumbar and Centre of Pressure Kinematics," *Occupational Ergonomics* 7, no. 4 (2007): 265–274.
[16] Jeffrey L. Levin et al., "Hearing Loss and Noise Exposure Among Commercial Fishermen in the Gulf Coast:," *Journal of Occupational and Environmental Medicine* 58, no. 3 (March 2016): 306–13, https://doi.org/10/f8kvhh.
[17] Tore Christian Bjorsvik Storholmen et al., "Design for End-User Acceptance: Requirements for Work Clothing for Fishermen in Mediterranean and Northern Fishing Grounds," *International Maritime Health* 63, no. 1 (2012): 32–39.
[18] N.G. Power, "Occupational Risks, Safety and Masculinity: Newfoundland Fish Harvesters' Experiences and Understandings of Fishery Risks," *Health, Risk and Society* 10, no. 6 (2008): 565–83, https://doi.org/10/b7vz93.
[19] Zheng Liu et al., "Enhancing Thermal-Moisture Comfort of a Chest Wader with Lining for Fishermen," *Textile Research Journal* 87, no. 17 (October 1, 2017): 2133–45, https://doi.org/10/gch6fb.
[20] Eirik Mikal Samuelsen, "Ship-Icing Prediction Methods Applied in Operational Weather Forecasting," *Quarterly Journal of the Royal Meteorological Society* 144, no. 710 (2018): 13–33, https://doi.org/10/gc4mgt.
[21] Devin L. Lucas et al., "Factors Associated with Crewmember Survival of Cold Water Immersion Due to Commercial Fishing Vessel Sinkings in Alaska," *Safety Science* 101 (January 1, 2018): 190–96, https://doi.org/10/gcqf9d.
[22] Tarsila Seara, Patricia M. Clay, and Lisa L. Colburn, "Perceived Adaptive Capacity and Natural Disasters: A Fisheries Case Study," *Global Environmental Change* 38 (May 1, 2016): 49–57, https://doi.org/10/f8m496.

or time onboard vessels.[23] Studies on prevention, management, and policy began to emerge slowly in areas as the research advanced and diversified.[24]

Research Central to the Literature

It was not possible to review all 200 plus sources we've identified in any depth for this paper, so our review of the international literature focuses on papers that help to coalesce the body of literature as a whole. This is where mapping the literature becomes useful, as it identifies the papers that have been cited most frequently while showing how these papers connect to the research that came before and after. Using this approach, each source becomes a "node" or point of connection in the network, or body of literature. These nodes are then pushed/pulled based on their connection to each other (in this case citations) to create clusters within the network. The more a node is connected to other nodes, the more it gets drawn towards the network center (See Appendix A). Unconnected nodes are pushed to the outside. The graph emphasizes how interconnected and tightly clustered the literature on fishing OHS is, particularly within publications broadly defined under the field of medicine. There are a few subject areas that are not as well connected to the other bodies of research, such as the research on working on moving platforms and vessel stability, and a few sources have no direct connection to the other literature (i.e. are not cited by others working in the broad field of fishing OHS). These unconnected nodes cover a variety of topics, including history,[25] risk governance,[26] and vessel design.[27] Using metrics built into Gephi makes it easier to identify which papers connect the literature.[28]

Based on this mapping exercise, the two papers most central to the fishing OHS literature reviewed here are, not surprisingly, both literature reviews. Lucas et al. (2014) evaluated the

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[23] Håkan Eggert and Peter Martinsson, "Are Commercial Fishers Risk-Lovers?," *Land Economics* 80, no. 4 (2004): 550–60, https://doi.org/10/csrxpf; I. M. Kaplan and H. L. Kite-Powell, "Safety at Sea and Fisheries Management: Fishermen's Attitudes and the Need for Co-Management," *Marine Policy* 24, no. 6 (2000): 493–97, https://doi.org/10/cmbg4w; G. Morel, R. Amalberti, and C. Chauvin, "Articulating the Differences between Safety and Resilience: The Decision-Making Process of Professional Sea-Fishing Skippers," *Human Factors* 50, no. 1 (February 2008): 1–16, https://doi.org/10/cf45c8; J. Poggie, R. Pollnac, and Stephen Jones, "Perceptions of Vessel Safety Regulations: A Southern New England Fishery," *Marine Policy* 19, no. 5 (1995): 411–418, https://doi.org/10/dt785w.

[24] Wang et al., "An Analysis of Fishing Vessel Accidents"; J. Lincoln and G. A. Conway, "Preventing Commercial Fishing Deaths in Alaska," *Occupational and Environmental Medicine* 56, no. 10 (October 1999): 691–95, https://doi.org/10/bztbmk; Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries"; Kaplan and Kite-Powell, "Safety at Sea and Fisheries Management: Fishermen's Attitudes and the Need for Co-Management"; Lise H. Laursen, Henrik L. Hansen, and Olaf C. Jensen, "Fatal Occupational Accidents in Danish Fishing Vessels 1989-2005," *International Journal of Injury Control and Safety Promotion* 15, no. 2 (2008): 109–17, https://doi.org/10/cnkbg9.

[25] Sarah Dry, "Safety Networks: Fishery Barometers and the Outsourcing of Judgement at the Early Meteorological Department," *British Journal for the History of Science* 42, no. 152 (March 2009): 35–56, https://doi.org/10/b6mz2b.

[26] Debra M. Lambert et al., "Guidance on Fishing Vessel Risk Assessments and Accounting for Safety at Sea in Fishery Management Design.," 2015, https://doi.org/10/gdtgxq.

[27] Marta Pedišić Buča and Ivo Senjanović, "Nonlinear Ship Rolling and Capsizing," *Brodogradnja: Teorija i Praksa Brodogradnje i Pomorske Tehnike* 57, no. 4 (2006): 321–331.

[28] Gephi provides a means for measuring graph distance based on how many connections it takes to move between all nodes. A statistic for "betweenness centrality" measures how often a node falls on the shortest path between any two nodes in the network. For a full description see https://www.sci.unich.it/~francesc/teaching/network/betweeness.html

fishing OHS literature using translational research criteria developed initially by the National Institutes of Health (NIH).[29] The NIH approach categorizes research based on its contribution to population health. At one end of the scale are outcomes that describe health problems and identify potential risk factors (T0). At the other end are studies that demonstrably improve health at a population level (T4). The steps in between deal with scaling up the research from theory to practice by moving from individual cases to solutions that improve safety outcomes for populations at risk. Lucas et al. found that a majority of fishing OHS studies fell into the T0 category of categorizing problems and risk factors. This means that a key gap in the literature is the "[testing of] hypotheses regarding risk factors" for which they recommend a stronger focus on doing more detailed "fishery-specific" studies (p. 79). Lucas et al. did find that there was an increasing trend in more recent studies towards translational research, defined as "a process for developing evidence-based interventions and implementing them in practice", but there is still a lot of work to be done in disseminating and evaluating population level health improvements.

The second literature review (Windle et al., 2008) is part of the Canadian North Atlantic literature review and is discussed in more detail below.[30] It has been cited 72 times according to Google Scholar, and effectively connects the literature across a wide range of disciplines.

The next paper central to the literature was an address to the Royal Society of Medicine by RS Schilling in 1966.[31] In that address Schilling lays out what has become the basic blueprint for first level fishing OHS research. He details the work processes of the UK trawler fleet, describing landings, technology, work tasks and time, accidents, worker populations, mortality, morbidity, legislation, and avenues for future research.

Reilly (1985) is another landmark paper in fishing OHS research.[32] This paper examined fishing accidents in the UK from 1961 to 1980 and was motivated by the Hull deep sea trawler disaster of 1968, where three fishing vessels sank at sea. The Hull disaster triggered an investigation by the Committee of Inquiry in Trawler Safety (CITS). Reilly wanted to compare accident rates among two cohorts, inshore harvesters (vessels < 24.4m) and deep sea fishermen (vessels > 24.4m), both before and after the regulatory changes brought about by the CITS findings. Neither group showed significant improvements in accident mortality rates over the 1961-1980 period.

Similarly, Thomas et al. (2001) examined fatal and non-fatal injuries in the Alaska commercial fishing fleet in the wake of regulatory changes to fishing safety training and equipment from 1991 to 1998.[33] During that time, 64% of all fish harvester fatalities were caused

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[29] Devin L Lucas et al., "Application of a Translational Research Model to Assess the Progress of Occupational Safety Research in the International Commercial Fishing Industry," *Safety Science* 64 (2014): 71–81, https://doi.org/10/gdwp45.

[30] Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries."

[31] R. S. Schilling, "Trawler Fishing: An Extreme Occupation," *Proceedings of the Royal Society of Medicine* 59, no. 5 (May 1966): 405–10.

[32] Reilly, "Mortality from Occupational Accidents to United Kingdom Fishermen 1961-80."

[33] Timothy K. Thomas et al., "Is It Safe on Deck? Fatal and Non-Fatal Workplace Injuries among Alaskan Commercial Fishermen*," *American Journal of Industrial Medicine* 40, no. 6 (2001): 693–702, https://doi.org/10/chhsmv.

by vessel loss and vessel loss fatality rates were on an 8 year decline. Workplace related fatalities failed to decline during the same period. Thomas et al. also looked at injury deaths by species targeted. They found the Alaska herring fishery to be the most dangerous, along with being one of the smallest fleets. Shellfish was another dangerous fishery with a high rate of deck-related injury deaths (44% of all man overboard deaths). They also found that drowning was the primary cause of death outside of vessel loss, and their paper outlines strategies for preventing "man overboard" events. Other recommendations include strategies for preventing falls and avoiding machine-related injuries on board the vessels.

Citation counts offer an additional measure for identifying papers key to the literature, and are a metric easily pulled from search engines like Google Scholar. Based on citation counts the most cited paper was by Morel, Amalberti, and Chauvin (2008) (cited 100 times).[34] They approach fishing health and safety from a resilience of complex systems standpoint by looking at decision-making processes. Using interactive simulations of fishing campaigns, they evaluated the expert knowledge of fish harvesters who were asked to navigate choices and trade-offs along the way. Each campaign was a simulated fishing trip (from dock departure, fishing, and return to port) where harvesters were presented with text scenarios that involved trade-offs between safety and productivity.

Other heavily cited papers include Bos et al. (2005) (91 citations & discussed in the CNA review below) and Törner et al. 1988 (90 citations) which was not accessible online. The latter is important because it dealt with musculo-skeletal symptoms in the Swedish fishing fleet, and provides a key bridge to the work on moving platforms which cite this source, and to the rest of the fishing OHS literature.[35]

Canadian North Atlantic Research

This section provides a chronological and thematic overview of fishing safety literature focused on the Canadian North Atlantic (CNA), with references to research conducted in or relevant to Newfoundland and Labrador. The starting point for fishing safety research in Newfoundland appears to have been a 1986 report published by Memorial University's Institute of Social and Economic Research (ISER), funded by the Canadian government and authored by the Fishery Research Group (lead researcher was Barb Neis) with support from the United Food and Commercial Workers, Fishermen's Union Local 1252 (now FFAW-Unifor)[36]. While the focus of the study was the social impacts of technological change in NL fisheries, a section of the report dealt with OHS issues in deep-sea fishing as well as in fish processing. 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, NL'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

[34] Morel, Amalberti, and Chauvin, "Articulating the Differences between Safety and Resilience: The Decision-Making Process of Professional Sea-Fishing Skippers."
[35] M. Törner et al., "Musculo-Skeletal Symptoms as Related to Working Conditions among Swedish Professional Fisherman," *Applied Ergonomics* 19, no. 3 (September 1, 1988): 191–201, https://doi.org/10/dfw5ts.
[36] Fishery Research Group, "The Social Impact of Technological Change in Newfoundland's Deepsea Fishery," *ISER-Memorial University of Newfoundland et Travail Canada*, 1986.

fishing in these largely ice-free environments were sent to north-east Newfoundland and Labrador where some of the fishing took place in the ice. Vessels were not ice reinforced, so there was high risk of ice damage. In addition, on the NL trawlers, fishing in the ice led to a practice of 'chaining off the warp' in order to ensure nets went under versus onto the ice. Chaining off the warp was associated with a risk of injury and fatality due to chains and warps breaking.

During the early 1990's, Marian Binkley authored three key publications on fishing safety in the CNA. The first was on safety awareness and perceptions of risk (1991)[37] where she concluded that future work should focus on broadening the understanding that fish harvesters have about risk and safety, to "heighten [their] consciousness of safety" in order to "redefine their situation". She followed this work up in 1994 with her book *Voices from Offshore: Narratives of Risk and Danger in the Nova Scotia Deep-Sea Fishery.*[38] In this book she details the offshore work of the Nova Scotian fleet and chronicles the "tales" of harvesters and family members as they talk about their own OHS-related experiences. In 1995 she published a second book based on a substantial program of social science research that took a more structured and rigorous look at commercial offshore fishing in Nova Scotia and the high rates of death and injury.[39] In the introduction, she provides a snapshot of the early research on fishing OHS in the North Atlantic (both US and Canadian). At this point research had focused on three key areas: the impact of technological change on work; job satisfaction and other socio-economic factors affecting work; and the socio-economics of perceptions of risk. Only one paper at the time had tried to link physical and socio-economic drivers of risk. On a similar theme to the work of Binkley, Murray et al. (1997) published a paper exploring the potential influence of fatalism, anxiety, and worry on injury rates among Newfoundland fish harvesters.[40] They worked with inshore harvesters to explore perceptions of risk and safety culture. Their key finding was that individuals with high anxiety had higher rates of reported injuries and took fewer precautionary safety measures.

These early publications laid the foundation for another round of research into fishing OHS in the CNA carried out in the early 2000's. This round had two converging lines of research: i) quantitative risk assessment focused on traffic, SAR, and weather that originated largely from Dalhousie University, and ii) research that was more interdisciplinary in nature focused particularly on OHS in the small scale fisheries in Newfoundland and Labrador. These are discussed below.

The research on traffic analysis, SAR, and weather starts with Shahrabi (2004), who used spatial-temporal analysis techniques to study fishing activity and relative incident rates in the

[37] Marian Binkley, "Nova Scotian Offshore Fishermen's Awareness of Safety," *Marine Policy* 15, no. 3 (1991): 170–82, https://doi.org/10/cpp26d.
[38] Marian Elizabeth Binkley, *Voices from off Shore: Narratives of Risk and Danger in the Nova Scotian Deep-Sea Fishery*, 53 (St. John's, Nfld.: Institute of Social and Economic Research, 1994).
[39] Marian Binkley, *Risks, Dangers, and Rewards in the Nova Scotia Offshore Fishery* (McGill-Queen's Press-MQUP, 1995).
[40] Michael Murray, Donald Fitzpatrick, and Colleen O'Connell, "Fishermens Blues: Factors Related to Accidents and Safety among Newfoundland Fishermen," *Work & Stress* 11, no. 3 (1997): 292–97, https://doi.org/10/d6smqv.

North Atlantic.[41] The study area focused on waters adjacent to Nova Scotia, New Brunswick, Prince Edward Island, and southwest Newfoundland (40N 67.5W to 50N 57.5W). Shahrabi showed that most incidents happen near land where vessel traffic is more regular, but the relative incident rate increased with distance from shore. Wu et al. (2005) delved into the issue of risk analysis, providing one of the first attempts to link weather factors to accidents in the fishing fleet.[42] They used Canadian Coast Guard SAR reports for the Canadian North Atlantic to classify accident response codes on a binary scale (0 = Not Severe, 1 = Severe). Severe incidents were considered to be ones in which there was potential or actual distress. Non-severe incidents were ones where a distress call was received but the issues were resolved without the deployment of SAR resources. Using logistic regression, they compared weather factors at the time of incident to severity of response. Wu et al. found that significant wave height (SWH) and ice presence were the strongest predictors of severe fishing incident rates. Wu et al. (2009) extends this SAR response analysis in 2009 to include a spatial analysis component, accounting for the location of the incident, traffic paths, and weather scenarios encountered along the way.[43] They used this dataset to create a regression tree explaining how fishing vessel traffic conditions deteriorate as certain weather conditions worsen, increasing the likelihood that incidents will become severe. Once again high ice concentrations and maximum wave height were the dominant factors increasing the likelihood of a severe SAR incident.

In 2015 Sara Rezaee further updated and expanded this research in her dissertation titled *Risk Analysis of the Effects of Extreme Weather Conditions on Commercial Fishing Vessel Incidents.*[44] Rezaee's dissertation focused particularly on extreme weather events, primarily extratropical cyclones, and SAR incident occurrence and severity. This research led to four publications between 2016 and 2017. The first, by Rezaee, Pelot, and Finnis (2016), analyzed the relationship between extratropical cyclone conditions and incident severity using logistic regression.[45] Incident severity was binned into binary categories (0 = Not Severe, 1 = Severe) based on Canadian Coast Guard (CCG) response data. They found that ice concentration, wind speed, sea surface temperature, and darkness were the most important factors impacting fishing incident severity. During storms, cyclone intensity became the leading factor in determining incident severity. In addition, they examined how fishery types (targeted species) factored into risk outcomes, changing the dynamics between environmental factors and incident severity. Controlling for changing contexts is important since targeted species change throughout the year as seasons open and close, and the prevalence and severity of weather factors change spatially and seasonally. In most fisheries Rezaee et al. (2016) found that sea surface temperature (SST) and wind speed were most closely related to incident severity, particularly in the seal hunt (where sea ice concentration was also a major factor). Only in the crab fishery were weather factors not significantly correlated to incident severity.

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[41] Jamal Shahrabi, "Spatial and Temporal Analyses of Maritime Fishing and Shipping Traffic and Incidents." (2004).
[42] Wu, Pelot, and Hilliard, "The Effect of Weather Factors on the Severity of Fishing Boat Accidents in Atlantic Canada."
[43] Yue Wu, Ronald Pelot, and Casey Hilliard, "The Influence of Weather Conditions on the Relative Incident Rate of Fishing Vessels," *Risk Analysis* 29, no. 7 (July 2009): 985–99, https://doi.org/10/c3hzmb.
[44] Rezaee, "Risk Analysis of the Effects of Extreme Weather Conditions on Commercial Fishing Vessel Incidents."
[45] Sara Rezaee, Ronald Pelot, and Joel Finnis, "The Effect of Extratropical Cyclone Weather Conditions on Fishing Vessel Incidents' Severity Level in Atlantic Canada," *Safety Science* 85 (2016): 33–40, https://doi.org/10/gdwp46.

The second paper, by Rezaee, Pelot, and Ghasemi (2016), looked at how extreme weather conditions affect fishing activity and the rate of vessel incidents.[46] Here vessel incidents were defined as any record in the CCG SAR database, regardless of cause or severity. They relied on a broad range of regression models in their assessment, finding that fishing activity was impacted by weather factors overall and that some factors impacted activity relative to vessel size. Wind was a major factor in determining small vessel (< 45') activity while vessels larger than 45' were only impacted by sea ice concentration. Relative incident rates positively correlated to low air temperatures, high sea ice concentrations, high winds, and storm intensity. They also identify other factors at play, including the seasonality of both weather and fishing in the North Atlantic, vessel size, harvester experience and preparedness, and the role of fisheries management structures in contributing to risk.

Building on this work, Rezaee, Seiler, Pelot, and Ghasemi (2016) crafted a framework for quantitatively forecasting the future risk of fishing incidents based on how climate change model assumptions will alter extreme weather events.[47] They used classification trees, the historical spatial distribution of storm tracks, and future shifts in storm tracks to understand changes in risk over time, finding that relative risk is not likely to change significantly by the end of the century for the North Atlantic.

Finally, within this subset of weather-related risk analysis research in the CNA, Rezaee, Brooks, and Pelot (2017) apply lessons learned from their work to suggest knowledge mobilization strategies for developing OHS policies in Canada relevant to climate change and extreme marine weather conditions.[48] In their outcomes they identify 10 policy themes with recommendations on how policies could be modified to improve fishing safety. These themes included stability, fisheries management, weather forecasting, fatigue, protective equipment, communication, SAR, insurance, safety culture, and training.

The second body of CNA research was carried out at Memorial and focused on the Newfoundland and Labrador small scale fisheries. A series of technical reports and publications from the SafetyNet Centre for Health and Safety Research's SafeCatch project (jointly funded by CIHR and by the Search and Rescue Secretariat New Initiatives Fund) illuminate issues in fish harvester OHS and fishing vessel safety in Newfoundland and Labrador. The 114 page report is a wealth of information on fishing OHS in Newfoundland and Labrador. There were 6 linked components to the multi-disciplinary program of research: 1) a comparative analysis of regulatory regimes (CARR); 2) a fishing vessel safety longitudinal analysis (FVSLA); 3) a study on perceptions of risk (POR); 4) a study on vessel motion and safer fishing vessel seakeeping

[46] Sara Rezaee, Ronald Pelot, and Alireza Ghasemi, "The Effect of Extreme Weather Conditions on Commercial Fishing Activities and Vessel Incidents in Atlantic Canada," *Ocean & Coastal Management* 130 (2016): 115–127, https://doi.org/10/gdwp4z.
[47] Sara Rezaee et al., "Will Commercial Fishing Be a Safe Occupation in Future? A Framework to Quantify Future Fishing Risks Due to Climate Change Scenarios," *Weather and Climate Extremes* 13 (2016): 73–85, https://doi.org/10/gdwp48.
[48] Sara Rezaee, Mary R. Brooks, and Ronald Pelot, "Review of Fishing Safety Policies in Canada with Respect to Extreme Environmental Conditions and Climate Change Effects," *WMU Journal of Maritime Affairs* 16, no. 1 (2017): 1–17, https://doi.org/10/gdwp49.

(SFVS); 5) a study of the psycho-social impacts of long term disability in injured fishers (IF); and 6) an arts driven approach to encouraging community healthy fisheries programs (CHFP).[49]

The CARR component included an extensive review of the literature on fishing OHS, and examined regulatory frameworks from six countries (Canada, US, UK, Iceland, New Zealand, and South Africa).[50] From these case studies Windle et al. (2008) developed a single conceptual framework for understanding fishing risk that emphasized multi-scale governance and ways regulations could both directly and indirectly affect safety. They also found a "widespread lack of consistency" surrounding how nations collect, count, and categorize fishing OHS outcomes, "making it virtually impossible to generate meaningful international comparisons."

Binkley et al. (2008) examined the feasibility and challenges associated with linking datasets from multiple governmental agencies as part of the Fishing Vessel Safety Longitudinal Analysis.[51] The FVSLA was an attempt to explore fishing OHS risks by developing a linked database containing DFO catch and effort data, SAR records, and Newfoundland and Labrador compensation claims data. The task was undertaken in response to an increase in severe incident rates in vessels under 65ft in the late 1990's, and proved to be difficult given the differences between dataset variables and problems with data completeness/integrity.

The goal of the POR component was to explore how harvesters experienced high risk situations. This information was considered to be "vital to interpreting data captured in other components". There were two major publications that came out of this component. Nicole Power (2008) examined safety through a gender lens of masculinity.[52] Her research demonstrates the complexity of OHS as something "negotiated in specific, gendered contexts." In addition, Sandra Brennans's thesis "*In God's Pocket": Accidents, Injuries, and Perceptions of Risk among Contemporary Newfoundland Fish Harvesters,* sought to create a multi-dimensional perspective of risk perception among Newfoundland fish harvesters.[53] She argues for the notion of "cascading effects", or the rapid accumulation of factors that can impact risk and the chance of

[49] M J S Windle et al., "Fishing Occupational Health and Safety: A Comparative Analysis of Regulatory Regimes," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/projects/fisheryrelproj/safecatch/1carr.php; Marian Binkley, Barbara Neis, and Stephen Bornstein, "Fishing Vessel Longitudinal Analysis: 1989 - 2001," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/library/Fishery/FVSLA.pdf; Nicole Power et al., "Newfoundland and Labrador Fish Harvesters' Perceptions of Risk," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/library/Fishery/POR.pdf; D Bass et al., "Safer Fishing Vessel Seakeeping (Safecatch)," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/projects/fisheryrelproj/safecatch/4sfvs.php; Murray and Heath-Rogers, "Injured Fish Harvesters"; Michael Murray and Neil Tilley, "Promoting Safety Awareness in Fishing Communities Through Community Arts," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/library/Fishery/CHFP.pdf.

[50] Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries."

[51] M. Binkley et al., "Lessons from Offshore: Challenges and Opportunities in Linking Data to Promote Understanding of Accidents and Injuries among Newfoundland and Labrador Fishers 1989â€"2001," *Marine Policy* 32, no. 6 (2008): 905–12, https://doi.org/10/cff934.

[52] Power, "Occupational Risks, Safety and Masculinity: Newfoundland Fish Harvesters' Experiences and Understandings of Fishery Risks."

[53] Sandra Lee Brennan, "In God's Pocket: Accidents, Injuries, and Perceptions of Risk among Contemporary Newfoundland Fish Harvesters" (2008), https://collections.mun.ca/u?/theses4,134217.

accident, injury, or death. She also points out that biophysical factors are "a constant concern" and "that severe weather plays an important role in fishing safety." Two related papers were published in 2010 as part of a special edition of *Policy and Practice in Health and Safety*.[54] In their article on "Bodies at Work", Power et al. (2010) seek to bridge how the body is treated in two unconnected areas of social science literature (sociology of the body and OHS social sciences) drawing from research in NL fish harvesters and processors. Power and Baqee (2010) critically examined the concept of "culture of safety" by analyzing OHS curricula delivered to fish harvesters and high school students. They found that curricula was largely based on the assumption that accidents are the result of poor OHS knowledge, presenting fish harvesters as risk takers or "at risk" while ignoring the knowledge and practices that harvesters rely on to stay safe in a high risk work environment.

The fourth component of SafeCatch (SFVA) dealt with vessel motion and "motion induced interrupts" (MII) or loss of balance that requires "special effort to avoid 'tipping and slipping'". Bass et al. (2006) studied MII using sea trials to develop motion profiles of vessels in the Newfoundland and Labrador fishing fleet[55]. These observations were then fed into a motion simulating model. They found that it was hard to predict motion profiles for smaller vessels, but note that vessels in 35 – 45ft range are more susceptible to MII. This makes fishing in the spring and fall a difficult, dangerous, and sometimes impossible task given typical sea state conditions during those seasons.

The Bass et al. research paved the way for further work on ergonomics of work on moving platforms beginning in 2005. Bos et al. (2005) used a ship motion simulator to study the effects of motion sickness symptoms under different visibility scenarios and their effect on task performance.[56] They found that motion sickness had minimal impact on task performance in subjects. Bos et al. also found less motion sickness in subjects who had an open view of the surrounding environment.

In 2007, Matthews et al. studied lifting 10 and 15kg loads under controlled and simulated scenarios to assess the impacts on trunk muscles and thoraco-lumbar kinematics[57]. In their study, lifting did not significantly affect the former, but it did affect the latter. Further work by Duncan et al. looked at working on moving platforms, the resulting impacts on lower back kinetics and contributions to strain and long term back disorders. The first paper (2007) used a motion simulator and lifting/holding tasks.[58] The second and third papers (2010 and 2012) were based

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[54] Nicole Gerarda Power et al., "Bodies at Work: Insights from Marine and CoastaL OSH Research," *Policy and Practice in Health and Safety* 8, no. 1 (January 1, 2010): 25–41, https://doi.org/10.1080/14774003.2010.11667740; Nicole Gerarda Power and Sumaiya Baqee, "Constructing A 'Culture of Safety': An Examination of the Assumptions Embedded in Occupational Safety and Health Curricula Delivered to High School Students and Fish Harvesters in Newfoundland and Labrador, Canada," *Policy and Practice in Health and Safety* 8, no. 1 (January 1, 2010): 5–23, https://doi.org/10.1080/14774003.2010.11667739.

[55] Bass et al., "Safer Fishing Vessel Seakeeping (Safecatch)."

[56] Jelte E Bos, Scott N MacKinnon, and Anthony Patterson, "Motion Sickness Symptoms in a Ship Motion Simulator: Effects of Inside, Outside, and No View," *Aviation, Space, and Environmental Medicine* 76, no. 12 (2005): 9.

[57] Julie D. Matthews et al., "Effects of Moving Environments on the Physical Demands of Heavy Materials Handling Operators," *International Journal of Industrial Ergonomics* 37, no. 1 (January 1, 2007): 43–50, https://doi.org/10/c77h5p.

[58] Duncan et al., "Effect of Simulated Vessel Motions on Thoracolumbar and Centre of Pressure Kinematics."

on measurements taken onboard vessels under different sea state conditions while standing/ holding a load and while lifting/lowering a load (respectively).[59] A fourth paper on the topic examined the concept of "sea-legs", or workers' ability to adapt to work on moving platforms through learning and retention (2014).[60] They found that over multiple simulations participants did indeed adapt, retain, and more efficiently transition into "corrective strategies" for minimizing the impacts of wave induced ship motion.

The Injured Fishers (IF) component of SafeCatch consisted of four main research objectives.[61] These were to describe and develop: 1) common work practices and accidents and injuries; 2) injury impact on the everyday lives of harvesters; 3) experiences with support services; 4) ways of improving these services. These were important issues to address given how tied most rural NL communities are to fishing. Harvesters who were injured to the point of having to leave fishing were found to be deeply affected by the "disorienting experience". Similarly, injured harvesters experienced difficulty and dissatisfaction when dealing with workers compensations claims. [62]

The last component of SafeCatch dealt with community participation in raising awareness of safety issues. Murray and Tilley (2006) addressed safety culture among fish harvesters by taking an approach developed around local arts and cultural traditions.[63] They found that there was strong potential for community arts to serve as a tool for raising awareness and engage not just harvesters, but the community at large.

In a follow-up SafetyNet-supported project, Jackson et al. (2013) examined safety on fishing wharves using qualitative methods. Their research delved into this high risk but understudied work environment, looking at intersections in wharf activities, risk perceptions, and observed incidents (full report accessible by request, bneis@mun.ca).[64]

Other CNA specific research has focused on issues of fishing vessel stability and moving platforms. In 2007, David Molyneux published a National Research Council Canada technical report on small vessel capsizing.[65] He highlighted the difficulty involved in simulating wave states for testing vessel stability and identified opportunities for future research. The paper contains valuable information on the regulatory approaches to reducing the risk of capsizing,

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[59] C. A. Duncan, S. N. MacKinnon, and W. J. Albert, "Changes in Thoracolumbar Kinematics and Centre of Pressure When Performing Stationary Tasks in Moving Environments," *International Journal of Industrial Ergonomics* 40, no. 6 (November 1, 2010): 648–54, https://doi.org/10/cs87f4; Carolyn A. Duncan, Scott N. MacKinnon, and Wayne J. Albert, "The Effects of Moving Environments on Thoracolumbar Kinematics and Foot Center of Pressure When Performing Lifting and Lowering Tasks," *Journal of Applied Biomechanics* 28, no. 2 (May 2012): 111–19, https://doi.org/10/f33hm8.

[60] Carolyn A. Duncan et al., "The Habituation of Human Postural Responses to Platform Perturbations," *International Journal of Industrial Ergonomics* 44, no. 6 (November 1, 2014): 874–81, https://doi.org/10/gdk35k.

[61] Murray and Heath-Rogers, "Injured Fish Harvesters."

[62] Michael Murray, "Fish Harvesters with Injuries' Accounts of Their Experiences with the Workers' Compensation System," *Work* 26 (2006): 11.

[63] Murray and Tilley, "Promoting Safety Awareness in Fishing Communities through Community Arts: An Action Research Project."

[64] B. Jackson et al., "Safety on Newfoundland's Fishing Wharves," *Safety Science* 60 (2013): 1–12, https://doi.org/10/gdwp44.

[65] David Molyneux, "The Safety of Small Boats (Including Fishing Boats) Against Capsize: A Review," 2007.

mainly through International Maritime Organization standards. Ongoing SafetyNet research, funded in part by MITACS and the Newfoundland and Labrador Fish Harvesting Safety Association (NL-FHSA) and now by the Ocean Frontier Institute (OFI), carried out by Bryan Davis and supervised by Bruce Colbourne and David Molyneux, is exploring dynamic or operational stability and capsizing by focusing on NL small scale fish harvesters' understanding of stability and how it can be impacted by the decisions they make.[66]

Some recent CNA research is seeking to aid with SAR resource allocation and marine hazard communication. Akbari's 2017 dissertation deals with SAR effectiveness using scenario planning, location-allocation modelling, and spatial analysis techniques.[67] In regards to weather and fishing safety-related research, Reid and Finnis (2018) aimed to develop a marine hazard climatology using spatial and temporal clustering of metocean weather factors.[68] The purpose behind using a climatological approach is "to explore the joint spatial and temporal variability of multiple metocean risk factors." While there has been some research on individual weather hazards (as outlined in previous sections), this study is unique in its linked spatial-temporal approach. The result is a grid of seasonally grouped hazard categories (or clusters) with each cell in a cluster being similar in risk with respect to multiple weather conditions. Some clusters, such as ones dominated by ice coverage, are highly seasonal or spatially specific in nature. Other clusters are found throughout most of the year, with their extents shifting as the seasons change. Mapping hazard clusters seasonally in this way is useful for quickly communicating and comparing expected conditions across large spatial areas. Another innovative aspect of this research is its use of weather warning thresholds as the basis for categorizing weather factors and communicating hazard climatologies. This ties into another area of ongoing research, that of marine forecast production and communication.[69]

James Shewmake has been conducting mixed methods research on weather and fishing safety as part of broader research projects on fishing safety that were funded by the Marine Environmental Observation Prediction and Response Network (MEOPAR) and MITACS and carried out through SafetyNet.[70] Qualitative aspects of the research include conducting interviews with Newfoundland fish harvesters. These interviews cover a range of topics on themes of fishery mapping, weather and decision-making (including forecasting), ports of refuge, and safety training/SAR activation. In order to improve fishing safety it is important to understand how harvesters make decisions that allow them to navigate risk throughout the

[66] Bryan Davis, Bruce Colburne, and David Molyneux, "Recommendations to Reduce Fishing Vessel Capsizing in Newfoundland and Labrador." (June 13, 2018).
[67] Amin Akbari, "MULTI-CRITERIA APPROACH TO MARITIME SEARCH AND RESCUE LOCATION ANALYSIS" (2017), https://DalSpace.library.dal.ca/handle/10222/73101.
[68] Heather Reid and Joel Finnis, "Summarizing Metocean Operating Conditions as a Climatology of Marine Hazards," *Theoretical and Applied Climatology*, 2018, 1–11, https://doi.org/10/gdwp47.
[69] Joel Finnis and Barbara Neis, "Marine Forecast Production and Applications in Atlantic Canada" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018); Devon Telford, "Impact Based Indices: Dangerous Seas, Initial Work to Develop a Dangerous Sea Index" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018).
[70] James W Shewmake, Barbara Neis, and Joel Finnis, "Studying Weather and Fishing Safety Using Mixed Methods" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018).

process of fishing.[71] Those interviewed were constant consumers of weather information from a broad array of public and private forecasting services and employed an array of strategies for managing the complexities of fishing, weather, and forecasting. Quantitative analysis includes measuring vessel traffic responses to marine weather conditions and warnings.[72] This analysis was useful for visualizing how vessel traffic (measured by vessel monitoring systems) responds to weather warning criteria within the context of expected seasonal variability. While fishing traffic is highly variable from day to day and season to season, there is evidence that hazards such as wind and wave height do impact traffic over large spatial scales.

In addition to weather and stability, a third component of the SafetyNet/NLFHSA MITACS research on fishing safety includes engineering research assessing noise exposures in different NL small scale fisheries and short- (minor structural changes and appropriate PPE) and longer-term (designs for future vessels) strategies for reducing exposures that exceed limits laid out in OHS regulations in NL. In recent years, hearing loss among fish harvesters in Newfoundland has become a high profile issue because of the rising costs associated with increased workers compensation claims. The research on noise-induced hearing loss involves measuring noise levels during fishing trips on a variety of vessels and targeting different species to see how exposures vary by fleet and vessel size.[73] The onboard data is being enhanced by scenario modelling of noise source and how it attenuates through a vessel with the hope of making vessels quieter through design changes.[74]

Another area of active research in fishing OHS in Newfoundland is the study of exposures to bioaerosols and chemicals in fishing vessel holds.[75] This is a particularly important issue in the Snow Crab and Northern Shrimp fisheries of Newfoundland, where shellfish allergens and their effects have been well-studied in onshore processing but no research had, until recently, been done onboard fishing vessels. To address this gap, Guernsey et al. (2018) interviewed captains and measured key allergens, toxic gases, and other air quality conditions on vessels. They found that further work was needed to improve vessel ventilation and reduce harmful exposure to these airborne dangers.

OFI postdoctoral fellow Desai Shan is embarking on research comparing marine and fishing safety law/governance in Canada. Research to date indicates that safety of fishing crew is

[71] James W Shewmake and Barbara Neis, "Navigating Risk" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018).
[72] James W Shewmake and Joel Finnis, "A Climatology of Marine Weather Hazards and Fishing Traffic" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018).
[73] Giorgio Burella, Lorenzo Moro, and Barbara Neis, "Noise Exposures of Fish Harvesters in Newfoundland and Labrador" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018); Giorgio Burella, Lorenzo Moro, and Barbara Neis, "Short-Term and Long-Term Methods and Procedures for the Reduction of Hazardous Noise Exposures on Newfoundland and Labrador Small Fishing Vessels" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 10, 2018).
[74] Mohamed Auf and Lorenzo Moro, "Effective Methods for Reduction of Noise Vibration in Fishing Vessel Design" (June 11, 2018); Md. Mahmudul Hassan, Jacopo Fragasso, and Lorenzo Moro, "An Innovative Design Solution to Mitigate Noise Levels on Fishing Vessels" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 11, 2018).
[75] Judith Read Guernsey et al., "Snow Crab and Northern Shrimp Aeroallergens and Toxic Gases in Holds and on Decks of Newfoundland and Labrador" Presentation to the International Fishing Industry Safety and Health Conference 5, St. John's, (June 12, 2018).

governed by both federal and provincial regulations in Canada. The *Constitution Act 1867*, to a large extent, places labour jurisdiction, including Occupational Health and Safety in the fishing industry under the provincial jurisdiction. On the other hand, the structural and operational safety of fishing vessels is subject to the federal jurisdiction. Transport Canada Marine Safety provides fishers with a national regulatory framework that applies to the structural and operational safety of the vessel. Canadian domestic law prescribes technical standards for vessels, including Fishing Vessel Safety Regulations,[76] Large Fishing Vessel Inspection Regulations[77] and Collision Regulations.[78] The technical standards include stability criteria of ship, safety equipment standards and navigation safety standards. In terms of qualification and competency of the fishing crew, Marine Personnel Regulations[79] provide skill and experience requirements for fishing masters.

Provincial governments have the responsibility to ensure that the fishing business is conducted in a safe manner. This authority was granted under the *Constitution Act, 1867*. However, provincial regulatory frameworks, regarding fishing safety, are not consistent across the country. Some provinces do not have fishing-sector-specific provisions in place.[80] Transportation Safety Board of Canada reports that close to half of Canada's fishermen have been left without any provincial safety oversight or workers' compensation coverage.[81]

In Atlantic Canada, Newfoundland and Labrador, Prince Edward Island, Nova Scotia and New Brunswick work is underway to develop a new guideline for the fishing industry, with the assistance of Transport Canada's marine safety branch. In Newfoundland and Labrador, the *Occupational Health and Safety Act* and the *Occupational Health and Safety Regulations* provide a general framework of rights and responsibilities of employers, workers, contractors, and suppliers. In addition, the *Workplace Health, Safety and Compensation Act* includes the assessment, compensation payment, and injury reporting procedures for commercial fishers. In Nova Scotia, except for fishing businesses established before 1970, employees in the fishing sector are covered by workers compensation.[82]

Prince Edward Island requires that fishing boat captains have the same responsibilities as employers under the *Occupational Health and Safety Act*. However, the fishing industry is excluded from workers' compensation.[83] Fishing employers are not required to provide Workers' Compensation benefits for their employees and therefore other employers who contribute to the Workers' Compensation Fund have not been willing to agree to support fishermen's safety

[76] Fishing Vessel Safety Regulations — Can. Reg. 1486 (Canada Shipping Act, 2001), C.R.C., c. 1486, applicable to fishing vessels that are Canadian vessels and that are not more than 24.4 m in length and not more than 150 gross tonnages.
[77] Large Fishing Vessel Inspection Regulations — Can. Reg. 1435 (Canada Shipping Act, 2001), C.R.C., c. 1435, applicable to new fishing vessels over 24.4 m in length or 150 tons, gross tonnage, that are not sailing ships.
[78] Collision Regulations — Can. Reg. 1416 (Canada Shipping Act, 2001), C.R.C. 1978, c. 1416
[79] Marine Personnel Regulations — Can. Reg. 2007-115 (Canada Shipping Act, 2001), SOR/2007-115, s. 1
[80] Transport Safety Board of Canada, *Reassessment of the Response to Marine Safety Recommendation*, No. M99-02, (Gatineau, 2017) at 1.
[81] Transport Safety Board of Canada, *Marine Investigation Report: Safety Issues Investigation into Fishing Safety in Canada*, No. M09Z0001, (Gatineau, 2012) at 51
[82] See Workers' Compensation General Regulations — N.S. Reg. 22/96 (Workers' Compensation Act) N.S. Reg. 22/96, s. 3
[83] See Section 2 of the Workers Compensation Act R.S.P.E.I. 1988, Cap. W-7.1:

programs. In the New Brunswick, workers' compensation coverage is required only when an employer has more than 25 employees in the fishing industry.[84]

By 2015, the Atlantic Provinces had developed various measures to address commercial fishing health and safety concerns raised by the Transportation Safety Board, but these varied across provinces. Newfoundland and Labrador revised its Occupational Health and Safety Regulations significantly in 2009, in particular with regulations specific to diving and marine operations. The province has also developed strategies for dealing with fish harvesting hazards and conducted intensive inspections since January 2012. More recently, the NL Fish Harvesting Safety Association, an industry-led, not-for-profit fisheries safety association (https://www.nlfhsa.com) was established in 2012. Its main focus is injury prevention. In addition to publishing a handbook for commercial fishing and aquaculture called *Fish Safe*, with the provinces of New Brunswick, Prince Edward Island and Transport Canada, Nova Scotia also developed an industry-led action plan to reduce fatalities and improve safety in collaboration with the provincial Workers Compensation Board, Department of Fisheries and Aquaculture, Department of Labour and Advanced Education, the Fisheries Safety Association of Nova Scotia and Nova Scotia Fisheries Sector Council.

The legislation regarding fishing occupational health and safety standards is still unbalanced in Atlantic Canada. Newfoundland and Labrador has workplace health and safety legislation specific to fishing vessels, and workers' compensation coverage for commercial fishers. Although New Brunswick and Prince Edward Island have taken certain efforts to develop awareness tools, access to workers compensation is still not compulsory for the general fishing industry.[85]

Fishing OHS research in Atlantic Canada and globally has advanced and diversified considerably since the initial study by the Fishery Research Group in 1986. More information is available today on diverse topics including SAR incidents, accidents and injuries, and drivers of risk and more diverse kinds of hazards. That said, there are still important gaps including in the areas of research on fish harvester decision-making, and how they navigate changes in governance and environment at multiple scales, as well as in other areas. A key area of neglect in the region and perhaps globally is OHS in the deepsea sector. To our knowledge, no research in Atlantic Canada has focused on this sector since the 1990s. Some OFI funding in Module I has been set aside to support work in the offshore sector including in the area of noise exposures (Moro).

Discussion and Conclusions

There were 5 key areas of interest identified at the beginning of the background paper that are important both to the broader body of literature and to taking stock of the existing CNA research in relation to international work. Those five key areas include:

[84] See the Exclusion of Workers Regulation — Workers' Compensation Act — N.B. Reg. 82-79 (Workers' Compensation Act) N.B. Reg. 82-79, s. 3

[85] Transport Safety Board of Canada, Reassessment of the Response to Marine Safety Recommendation, No. M99-02, (Gatineau, 2017) at 18 and 19.

1. the relationship between OHS and fisheries governance, especially during periods of transition;
2. OHS policies and frameworks;
3. fatality, accident, injury, and incident rates within and across fisheries;
4. the relationship between weather, weather forecasting, and safety;
5. the relationship between vessel design, stability, and noise across fleets/fisheries.

In this section we locate the CNA within the international literature on fishing OHS in these five areas and use this exercise to develop a roadmap of CNA research strengths, weaknesses, and pathways for future research.

Strengths and Weaknesses and Future Opportunities

For the purposes of this paper, governance is defined as " [the] mechanisms, processes and institutions through which public and private sectors articulate their interests, exercise their rights, meet their obligations, and mediate their differences in order to make decisions affecting society" (Rosenau in Finkelstein, 1995).[86] Governance as a topic of research makes up a relatively small portion of the international literature (58 sources) identified here, but has always been at the forefront of research in the CNA. Most of the international research on governance and fishing safety done in industrialized countries is the result of research and funding from the United States Center for Disease Control – National Institute for Occupational Safety and Health (NIOSH).[87] Norway is another region of the world known for its contributions to fishing OHS research.[88]The United Nations Food and Agriculture Organization (FAO) has also recently contributed to this literature with an analysis of international fisheries management and safety regimes.[89] Many of the earliest research projects undertaken in the CNA literature were direct responses to changes in fisheries management policies that altered how and where people fish and safety outcomes. This is certainly true of the pre-cod moratorium fisheries of the 1970's and

[86] Lawrence S. Finkelstein Reviewed Finkelstein, "What Is Global Governance?," *Global Governance* 1, no. 3 (1995): 367–72.

[87] Lincoln and Conway, "Preventing Commercial Fishing Deaths in Alaska"; Jennifer M. Lincoln and Devin L. Luca, "All Hands on Deck: Improving Deck Safety on Commercial Fishing Vessels," *Proceedings of the Marine Safety & Security Council* 64, no. 1 (2007); J. Lincoln and D. Lucas, "Occupational Fatalities in the United States Commercial Fishing Industry, 2000–2009," *Journal of Agromedicine* 15, no. 4 (2010): 343–50, https://doi.org/10/d4nmvm; Samantha Case et al., "Reported Traumatic Injuries among West Coast Dungeness Crab Fishermen, 2002–2014," *International Maritime Health* 66, no. 4 (2015): 207–10, https://doi.org/10/gdsgdt; Samantha L. Case, Jennifer M. Lincoln, and Devin L. Lucas, "Fatal Falls Overboard in Commercial Fishing — United States, 2000–2016," *Morbidity and Mortality Weekly Report* 67, no. 16 (April 27, 2018): 465–69, https://doi.org/10/gdrcdx.

[88] Storholmen et al., "Design for End-User Acceptance: Requirements for Work Clothing for Fishermen in Mediterranean and Northern Fishing Grounds"; Annbjørg S á Høvdanum et al., "A Review of Fatigue in Fishermen: A Complicated and Underprioritised Area of Research," *International Maritime Health* 65, no. 3 (2014): 166–172, https://doi.org/10/gdsm3k; Edgar McGuinness et al., "Fatalities in the Norwegian Fishing Fleet 1990–2011," *Safety Science* 57 (August 1, 2013): 335–51, https://doi.org/10/f4x5v7; Edgar McGuinness et al., "Injuries in the Commercial Fishing Fleet of Norway 2000-2011," *Safety Science* 57 (August 2013): 82–99, https://doi.org/10/f4x5fb; N. Bull, T. Riise, and B. E. Moen, "Occupational Injuries to Fisheries Workers in Norway Reported to Insurance Companies from 1991 to 1996," *Occupational Medicine* 51, no. 5 (August 2001): 299–304, https://doi.org/10/cjkrd3.

[89] Gunnar Knapp, "International Commercial Fishing Management Regime Safety Study: Synthesis of Case Reports" (FAO, 2016), https://search.proquest.com/docview/1786434710/citation/550E82CAB9874695PQ/1.

1980's as Canada exerted its maritime rights by expanding fisheries along the EEZ boundary (Fishery Research Group, 1986). Governance issues were also an important component of the post-cod moratorium fisheries research, due to the significant increase in fishing accidents as fleets restructured around new fisheries such as Northern Shrimp and Snow Crab.[90] As the future of the fishery starts to tip away from shellfish and back towards groundfish, there is a pressing need to anticipate and plan for the next chapter of commercial fishing. The future cod fishery will likely look different than the cod fishery of the past. How gear, fleets, and fishing grounds are structured and managed will have an impact on future fishing OHS concerns.

The role of OHS policies and frameworks has become much more central to the regional body of research over time. The SafeCatch report and related publications dealt heavily with issues of OHS policy in both research and recommendations. More recently, the work of Desai Shan is a direct effort to fill a critical gap in terms of the current context of OHS policy. Recent changes to federal policies, such as the Fishing Vessel Safety Regulations (FVSR), create new challenges and opportunities for research around industry consultation, implementation, and enforcement.

Studies of fatality, accident, injury, and incident rates have long been foundational to international fishing OHS research. Over half the papers identified in the international literature dealt with documenting these outcomes. Accident and incident rates have been closely studied in the risk analysis literature in the CNA. Because of the association with quantitative methods, this research often goes beyond counting occurrences to examining causal relationships. Causal relationships are a frequently understudied area of the international literature according to Lucas et al.'s (2014) assessment. There are numerous challenges associated with causal analysis of incidents, including matching datasets from different sources and at different scales, incomplete or inconsistent record of data, and having to rely on proxy metrics.[91] More research is needed on prescriptive studies that evaluate the effectiveness of policies in changing OHS outcomes. This is often difficult, but is necessary to shift research from the theoretical to the applied.

Weather and fishing safety is one area where the CNA appears to be leading the way in research.[92] There are many references to weather in the international literature, but few of them examine it in any depth as a source of risk. Recent and continuing research out of Newfoundland and Nova Scotia adds considerable depth to our understanding of how weather affects fishing safety. This includes weather's impact on traffic, incident rates, and incident severity as well as

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[90] A. Holly Dolan et al., "Restructuring and Health in Canadian Coastal Communities," *Ecohealth* 2, no. 3 (2005): 195–208, https://doi.org/10/fmpn4x; Stephen Bornstein and Michael Murray, "SafeCatch Final Report," Safecatch (SafetyNet, Memorial University of Newfoundland, 2006), https://www.mun.ca/safetynet/library/Fishery1/SafeCatch_Final_Report.pdf; Martha MacDonald, Barbara Neis, and Grant Murray, "State Policy, Livelihood Protection and Gender on Canada's East Coast," *International Journal of Canadian Studies/Revue Internationale d'études Canadiennes*, no. 38 (2008): 149–180.

[91] Binkley, Neis, and Bornstein, "Fishing Vessel Longitudinal Analysis: 1989 - 2001"; Windle et al., "Fishing Occupational Health and Safety: A Comparison of Regulatory Regimes and Safety Outcomes in Six Countries"; Wu, Pelot, and Hilliard, "The Influence of Weather Conditions on the Relative Incident Rate of Fishing Vessels"; Rezaee, "Risk Analysis of the Effects of Extreme Weather Conditions on Commercial Fishing Vessel Incidents."

[92] Shewmake and Finnis, "A Climatology of Marine Weather Hazards and Fishing Traffic"; Finnis and Neis, "Marine Forecast Production and Applications in Atlantic Canada"; James W Shewmake and Joel Finnis, "Working the Weather: Challenges to Forecasting and Fishing in Newfoundland and Labrador" (April 10, 2018); Reid and Finnis, "Summarizing Metocean Operating Conditions as a Climatology of Marine Hazards."

how harvesters make decisions based on forecasts and observed weather conditions. While weather forecasting has a history closely associated with the dangers of marine fishing, it is just now emerging as a topic in international literature and is an important avenue of future research.[93] Forecast communication is a significant area of future research and is central to issues of governance given that is an explicit component of Environment and Climate Change Canada's mandate.[94]

The final topic involves the vessel as a place of work where design, stability, work on moving platforms, noise and chemical and bioaerosol exposures are important areas of research. There were 10 sources identified in the international literature on vessel design, and 37 sources for stability (including studies of capsizing and vessel loss). Of the 10 vessel design studies, 6 were also part of the stability literature (3 of these also involved weather). The other four addressed issues of work process and ergonomics. Stability is an emerging theme in the CNA literature, focusing less on issues of static stability (what the boat is engineered to handle) and more on operational or dynamic stability (how stability relates to the way the boat is used). In regards to moving platform research, of the 11 sources identified in the international review, 6 were conducted in Newfoundland. Noise is poorly addressed in the international literature, at least based on the current list of sources. There was only one paper identified dealing with noise induced hearing loss in commercial fishing (Levin et al., 2016).[95] Currently there are several projects (outlined in the previous CNA review) that hope to address these shortcomings in future publications.

Fishing OHS is a complex system of interacting parts involving governance, individual decision-making, social and environmental concerns, changing contexts, and potentially harmful outcomes. OHS can be influenced by macro-level changes like changes in markets and the wider policy-making environment as well as micro-level changes on the shop floor. It encompasses not only injury, illness and fatality but also compensation and return to work. Navigating fishing safety risks is challenging at best, in both theoretical and practical terms, whether in work or research. This paper has attempted to take stock of the current state of fishing OHS research, particularly in the Canadian North Atlantic. Assessing existing research and placing it in an international context is a critical step in charting a course for future research priorities, methods and strategies. Understanding past and current strengths and weaknesses aides the planning process.

[93] Dry, "Safety Networks: Fishery Barometers and the Outsourcing of Judgement at the Early Meteorological Department."
[94] Environment and Climate Change Canada, "Mandate and Role: Who We Are and What We Do," aem, October 4, 2017, https://www.canada.ca/en/environment-climate-change/corporate/mandate.html.
[95] Levin et al., "Hearing Loss and Noise Exposure Among Commercial Fishermen in the Gulf Coast."

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Appendix A

Fishing Occupational Health and Safety Literature Citation Network