What happens with ships during an earthquake-tsunami event?

Lauryne Rodrigues, Floris Goerlandt, Ronald Pelot

Maritime Risk and Safety Research Group, Industrial Engineering, Dalhousie University, Halifax, NS, Canada

CONTEXT

Cascadia Earthquake M 9.2 – PGA, British Columbia

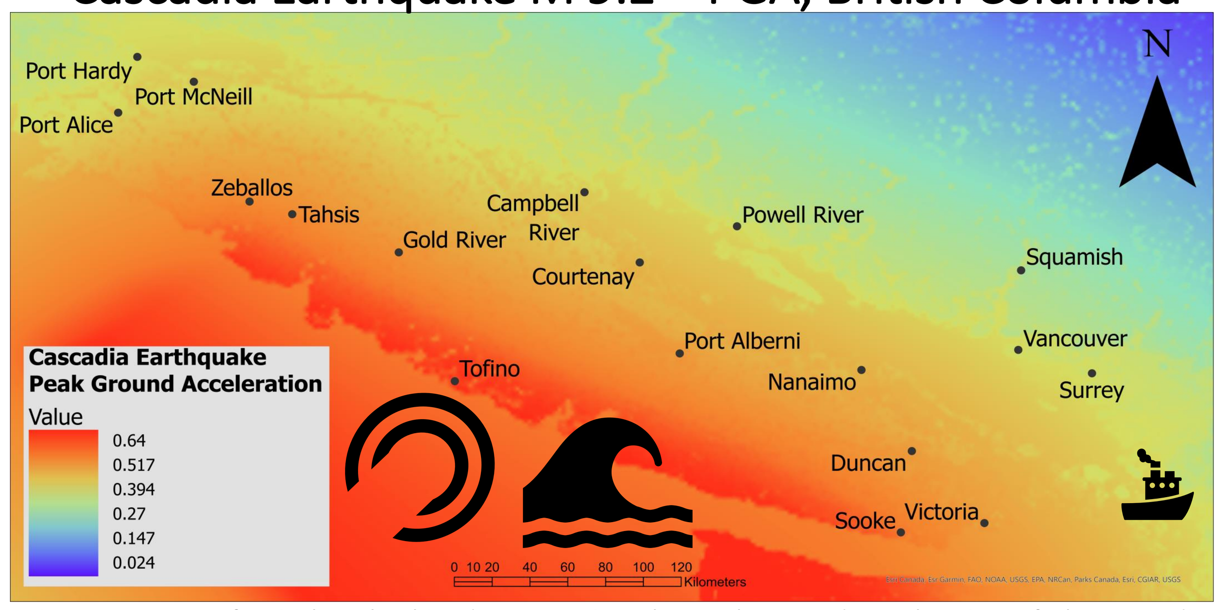

Figure 1. Map of British Columbia demonstrating the Peak Ground Acceleration of the Cascadia Earthquake, with some of the main coastal communities that will be affected [1]. Data source was the Geologic Survey of Canada

The West Coast of Canada is located near a seismic area composed of the Pacific, North America, and the Juan the Fuca plates [2]. This active seismic zone turns British Columbia into one of the high-risk areas for the occurrence of earthquakes and tsunamis. Impacts to major ports and damaged vessels can cause marine transportation disruption, severely affecting coastal communities.

PROBLEM DEFINITION

This study focuses on the possibility of using vessels to support emergency response logistics. Hence, any damage that incapacitates ships to promptly support deliveries in the immediate disaster response phase is of concern.

Examples of Ship Damage by Tsunami

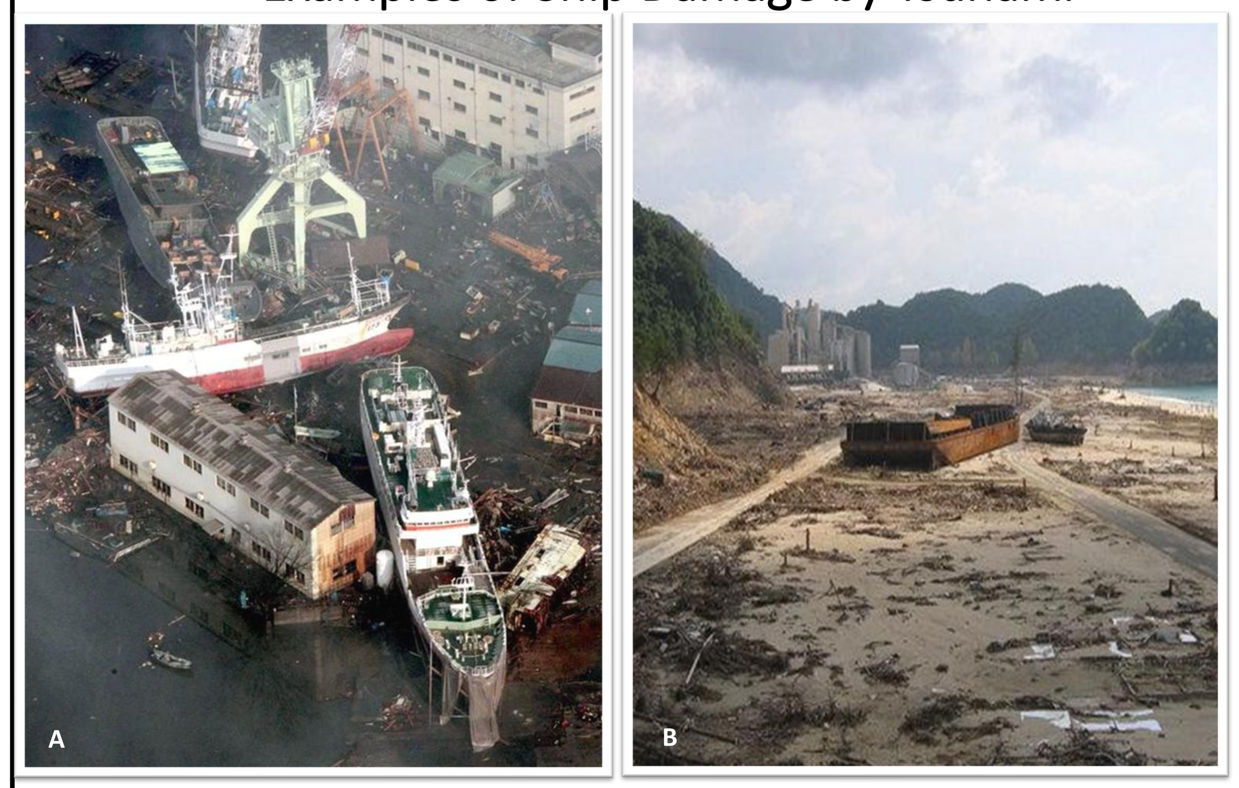

Figure 2. A- Ships drifted by tsunami, 2011 Japan. [3] B – Barge dragged by tsunami, 2004 Indian Ocean [4]

OBJECTIVES

Given the lack of research on ship availability in British Columbia (BC) following a major disaster, more specifically in the context of a Cascadia Earthquake event, this study aims to understand, investigate, and evaluate the impact of damaged marine vessels through developing a novel model using various BC datasets. This study is based on the day-to-day operation patterns in the study area, which are interpreted in the context of the described natural disaster event. This research proposes a new methodology to estimate the probability of a vessel being part of the humanitarian supply chain logistics operations. It uses spatial analysis tools with vessel movement data from the Automatic Information System (AIS). The model investigates the risk of damage to ferries and barge-tug combinations according to a specific path. The model considers various spatial and attribute components, such as the distance from collapsing structures, tsunami zone, safe depth areas, tsunami arrival time, and other nautical features.

RESEARCH QUESTIONS

RQ1: How many ships will be available to support humanitarian supply chain operations in the Vancouver Island coastal area?

RQ2: What is the relation between ship groups' sizes and damage probability considering Vancouver maritime logistic operations?

RQ3: What are hazardous sea areas or routes for a ship to navigate in case of a tsunami in a Cascadia earthquake-tsunami scenario?

METHODOS

Schematic Overview of the Study

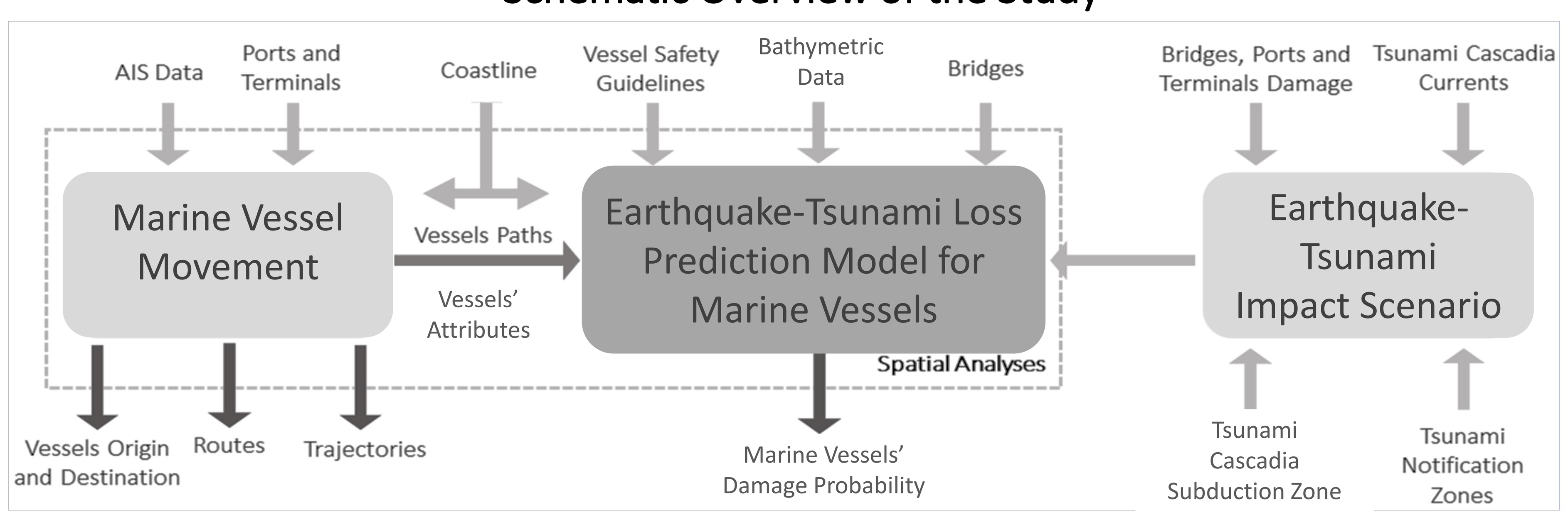

Figure 3. The study structure considers the two developed models and their input/output data. Marine vessel movement used AIS data to determine vessel trajectory, and the earthquake-tsunami model predicts vessels damage according to the Cascadia event.

Earthquake-Tsunami Loss Prediction Model for Marine Vessels

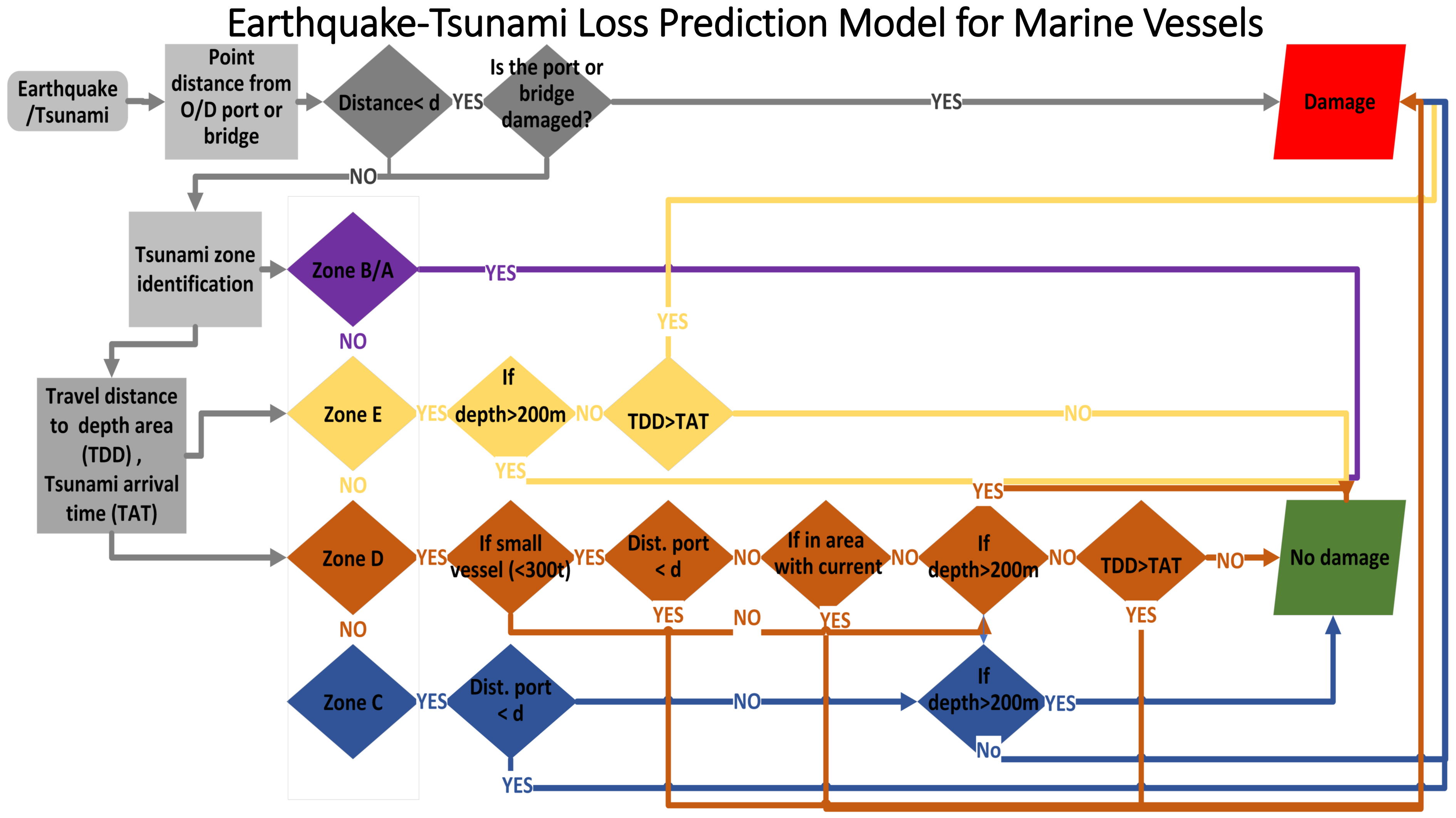

Figure 4. The model first considers the damage caused by the earthquake and then by the tsunami. Furthermore, according to point location and tsunami zones, the model calculates distances and travel times. It determines if there is a probability of damage considering all positions in the trajectory.

RESULTS

Probability of Damage by Ship Trajectory

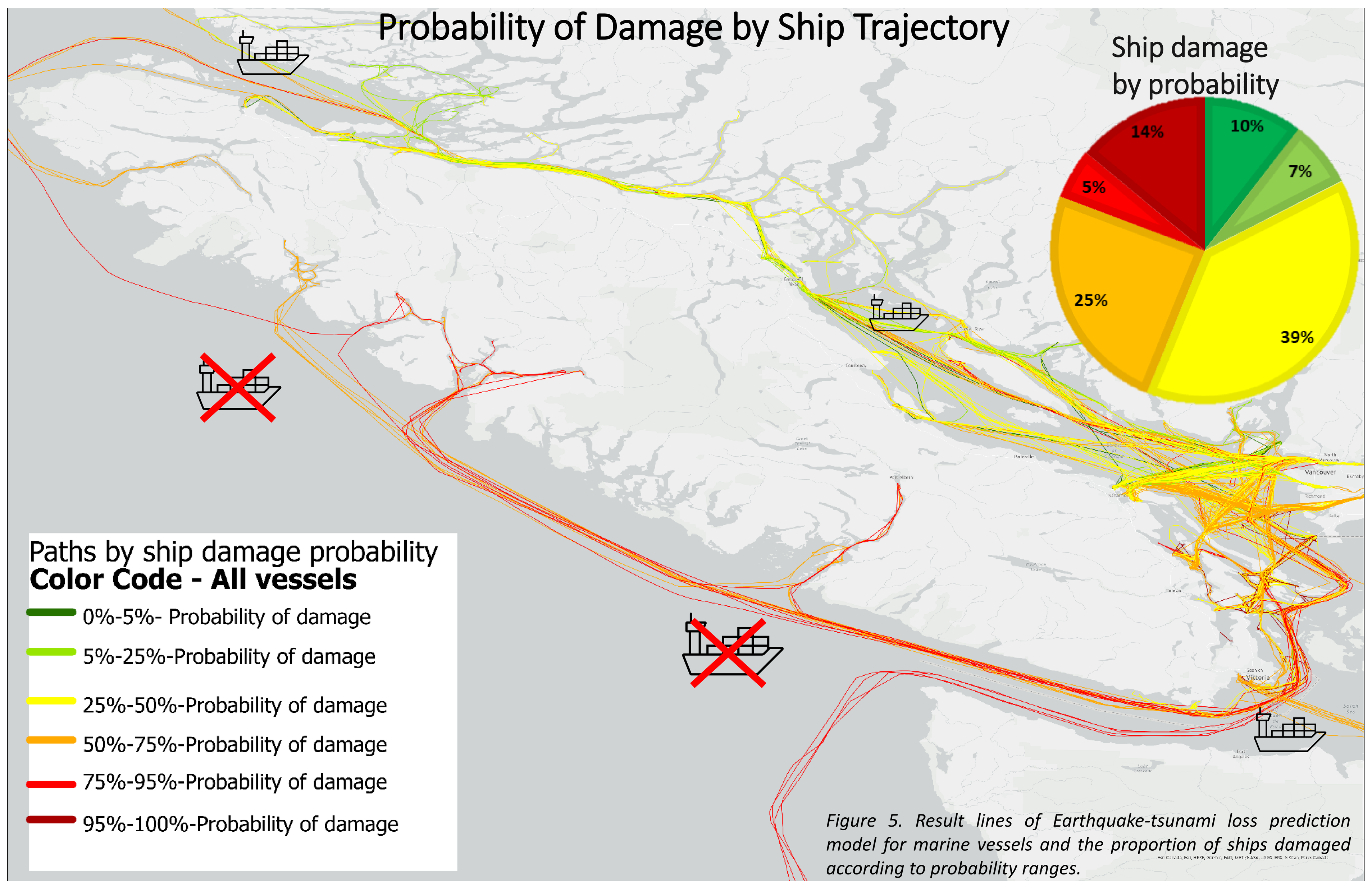

Figure 5. Result lines of Earthquake-tsunami loss prediction model for marine vessels and the proportion of ships damaged according to probability ranges.

Damage Types x Ship Group

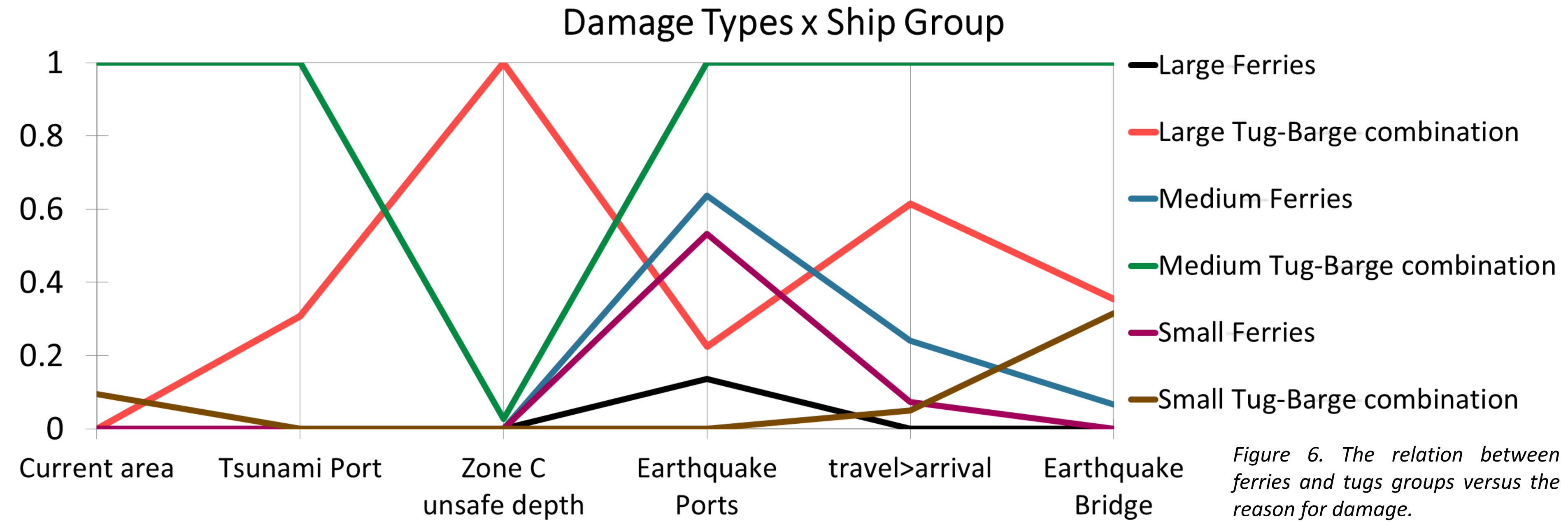

Figure 6. The relation between ferries and tugs groups versus the reason for damage.

CONCLUSION

The results indicate that many small ferries and some barge-tug combinations have a substantial probability of being unavailable to support emergency logistics, whereas larger ferries are less affected. The probability of certain parts of the fleet being unavailable, maps of dangerous navigational areas, and routes with reduced transportation capacity, can be used as a resource to support disaster preparedness and mitigation actions. Despite some uncertainties related to exact ship location, tsunami data, and some model simplifications, the findings can thus be used to inform emergency preparedness decision-making. Further research could link the findings of this work to network distribution models.

ACKNOWLEDGEMENTS

The study received funding through the Marine Observation, Prediction and Response (MEOPAR) Network of Centres of Excellence and by the Province of British Columbia in the context of the 'Shipping Resilience: Strategic Planning for Coastal Community Resilience to Marine Transportation Risk (SIREN) project. The AIS database was provided by exactEarth. The authors gratefully acknowledge the financial and data support of these institutions.

REFERENCES

[1] Chang S. et al. *"Planning for a Catastrophic Earthquake in British Columbia,"* 2020. Marine transportation disruption and coastal community resilience. SIREN Project Report, 112 p.
[2] D. W. Mason and A. Zegers, "*The Seismic and Tsunami Threat to Ships , Personnel , and Defence Infrastructure on Canada' s West Coast,*" no. October, 2013.
[3]*"Japan earthquake triggers tsunami.*"https://www.ndtv.com/photos/news/japan-earthquake-triggers-tsunami9342#photo-121586 (accessed Jan. 07, 2022).
[4]R. A. Feagin *et al.*, *"Shelter from the storm? Use and misuse of coastal vegetation bioshields for managing natural disasters," undefined*, vol. 3, no. 1, pp. 1–11, Feb. 2010, doi: 10.1111/J.1755-263X.2009.00087.X.