Weather and Climate Extremes 13 (2016) 73–85

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace

Will commercial fishing be a safe occupation in future? A framework to quantify future fishing risks due to climate change scenarios

Sara Rezaee [a,*], Christian Seiler [b], Ronald Pelot [a], Alireza Ghasemi [a]

[a] Dalhousie University, Industrial Engineering Department, Halifax, NS, Canada B3J2X4
[b] Pacific Climate Impacts Consortium, University of Victoria, Victoria, British Columbia, Canada V8N 6M2

ARTICLE INFO

Article history:
Received 28 September 2015
Received in revised form
27 July 2016
Accepted 17 August 2016
Available online 20 August 2016

Keywords:
Climate change
Extreme weather events
Fishing safety
Fishing incidents
Classification and Regression Trees

ABSTRACT

Weather factors are an intrinsic part of the fishing environment. Changes in weather patterns due to climate change may affect the fishing environment and fishing safety. This article proposes a general framework to quantify fishing incident risks in the future due to changes in weather conditions. This framework first builds relationships between fishing safety and weather conditions based on historical data and then predicts future risks according to these relationships with respect to potential changes in weather patterns. This paper applies the suggested framework using fishing incident data, fishing activity levels, and extreme weather conditions in Atlantic Canada to estimate the spatial distribution of fishing incident rates in the future. To do so, a classification tree is applied to historical storm tracks based on several climate models and then generated rules are applied to future storm tracks projected by selected climate change models towards the end of this century to predict fishing risk rates associated with changes in weather factors. We conclude that the environmental conditions that drive fishing incidents are projected to remain very similar by the end of this century.

1. Introduction

The fishing industry is one of the most hazardous occupations in the world. In addition to the high risk of life loss, fish harvesters are exposed to the risk of different non-fatal injuries during their work at sea (Murray et al., 1997). Fatigue, inadequate communication, decisions based on incomplete information, and the hazardous natural environment can contribute to incidents in the marine industry (Rothblum, 2000). Fish harvesters' appreciation of risk and safety are dynamic. This dynamism is caused by uncertain circumstances associated with changing regulations, technology development, industrial conditions and environmental circumstances (Power, 2008). Recently, fish harvesters' reliance on traditional weather patterns and familiar environmental conditions has become increasingly questionable due to climate change effects which can contribute to high risks associated with fishing industry. Although different fishing safety studies have shown that there is a correlation between fishing incidents and weather factors (Jin et al., 2001; Jin and Thunberg, 2005; Chatterton, 2008; Wu et al., 2008, 2009; Niclasen, 2010; Rezaee et al., 2016b; 2016c), there is nevertheless a gap in understanding about how changes in weather patterns in the future may affect fishing safety. Studies such as Berkes and Jolly (2002), and Furgal and Seguin (2006) have investigated the effects of climate change on fishing traditions of Canadian communities. Schulte and Chun (2009) have looked at different aspects of climate change on fish harvesters' occupational safety, and Rezaee et al. (2016a) have reviewed Canadian safety related polices with respect to climate change effects. However, research papers that apply mathematical models to estimate the risk to commercial fishing based on different climate change scenarios are scarce.

This research suggests a framework to estimate future risks to the fishing industry arising from changes in weather patterns. Fig. 1 visualizes this framework and presents some examples of its key elements. The inputs include fishing incident data, fishing activity levels (the amount of exposure), and extreme weather characteristics such as the frequency and intensity of storms. Based on the question at hand, some other key factors such as fishery type and vessel characteristics may be added to the list. Different mathematical models can be applied to the available data to reveal underlying relationships (i.e. fishing incidents as the dependent variable and weather conditions and/or other variables such as fishery type as predictors). After building historical relationships, mathematical models can be used to predict fishing incident probabilities for the period of interest based on weather factor predictions or new fishing locations. The results of this prediction can then be reported as vulnerability maps, statistical reports, or in some of other format stipulated by the user.

* Corresponding author.
E-mail address: Sara.Rezaee@dal.ca (S. Rezaee).

http://dx.doi.org/10.1016/j.wace.2016.08.002

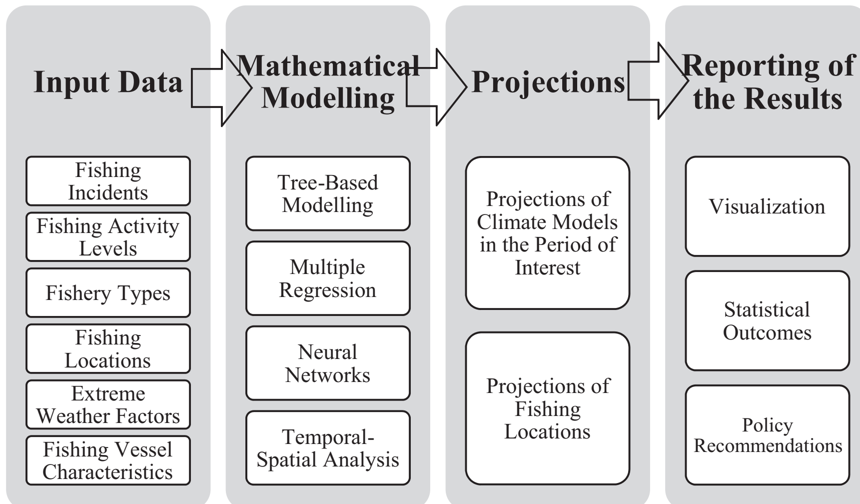

Fig. 1. Framework to estimate future risks in the fishing industry under climate change scenarios.

Fig. 2. Tracks of the 50 most intense extratropical cyclones that passed through Atlantic Canada (area limited to the red rectangle) during 2000–2005. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: STORMS Extratropical Cyclone Atlas (2011)

This paper explores the application of this framework to predict fishing incident rates (number of fishing incidents over the number of fishing trips) in the period 2081–2099 based on the historical relationships between fishing incidents, fishing trips, and the frequency and intensity of storms over the years 2000–2004 in Atlantic Canada. Fig. 2 illustrates the tracks of the 50 most intense extratropical cyclones (i.e. highest vorticity) in the area of interest during 2000–2005.

In this study it is assumed fishing locations, technology, and fishing methods would not change dramatically in the future. If any of this information becomes available, it should be added to the framework and considered in fishing incident rate estimations.

This article is organized as follows: Section 2 provides information on input datasets and the Classification Tree method; the Section 3 interprets the outcomes of the trees and Section 4 includes the concluding notes.

2. Materials and methods

The study area for this research encompasses Atlantic Canadian Waters from 40° to 60°N latitude, and 73° 20′ to 45° 50′W longitude (see Fig. 4). The historical fishing activity and incident data span the years 2000–2004, and the incident rate is forecasted for the period 2081–2099 (since the climate projections in the area are available for that period), and the incident rate predictions are compared to the patterns from the years 1980–1999 to identify changes.

2.1. Incident data

The Search and Rescue (SAR) Joint Rescue Coordination Centre (staffed by the Canadian Coast Guard and Department of National Defence) is responsible to provide help in the case of reported maritime incidents.

The SISAR database (Search and Rescue Programme Information Management System) records detailed information about these incidents and the actions that SAR resources have taken to provide help. This information includes time and location of the incident, type of vessel, type of incident, severity level of the incident, and characteristics of the assigned SAR resources. The total number of fishing incidents within our area of interest in the SISAR dataset over 2000–2004 is equal to 4782. Spatial distribution and some other characteristics of the incident data are shown in the data exploration section. As shown in Fig. 4, some of the grid cells of the study area comprise international waters, as well as U.S. areas of SAR responsibility, therefore incident numbers captured in the SISAR database might be under-reported in these areas.

Due to data quality, it was not possible to separate data based on the primary cause of incidents (e.g. harsh weather, engine failure, etc.) and all incidents regardless of their primary causes are considered for the analysis.

2.2. Fishing activity levels data

The fishing activity levels data comprises a post-processed version of a subset of the Department of Fisheries and Oceans (DFO) Zonal Interchange Fishery (ZIF) files for the years 2000–2004, within the specified study area of this research. The ZIF data include information on commercial fishing vessel trips such as date landed (of the catch), homeport, port landed, and Northwest Atlantic Fishery Organization (NAFO) subdivisions where the fishing effort(s) took place. A "Path Generation Algorithm" developed by Pelot et al. (2002) and Shields (2003) which includes an essential land-avoidance algorithm (Hilliard and Pelot, 2002) was applied to the ZIF files to generate feasible catch-effort positions within the NAFO unit areas reported by a fishing vessel for each day. The points are then connected in chronological order to simulate the travel history of the vessel for each trip. Fig. 3 shows