Environmental drivers of humpback whale (Megaptera novaeangliae) distribution in the North East of Iceland.

Introduction

Climate change in the Arctic

The Arctic Ocean is a fundamental component of the global transfer and redistribution of heat that connects the equator to the poles (Barnes & Tarling, 2017). However, global climate change has put the Arctic and North Atlantic environment under ever-increasing stress (Bopp et al., 2013). Due to a well-established phenomenon called Polar Amplification (PA) in fact, climatic changes brought on by anthropogenic emissions tend to emerge more quickly and more severely at higher latitudes, thus putting a further strain on these fundamental ecosystems (Brock & Xepapadeas, 2017; IPCC, 2013). The most prominent effect of this is the continuous reduction of sea-ice cover (Corbett et al., 2010). Over the past decades, the Arctic has experienced a significant reduction in its seasonal sea-ice sheet (Fig 1), hitting as low as 4.28 million km2 in 2007, compared to the almost 10 million km2 recorded during the 1970s (Corbett et al., 2010). Current climate change prediction models project this trend to continue well into the 21st century, possibly leading to a seasonally ice-free Arctic Ocean toward the end of the century (Melia et al., 2017).

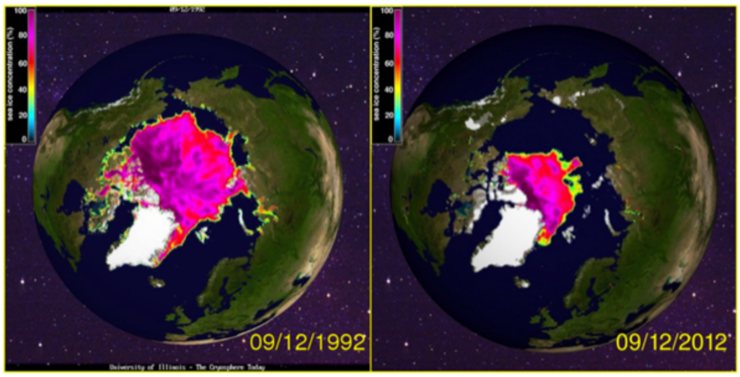

Figure 1: Changes in the Arctic Ice sheet cover between September 1992 and September 2012 (Walsh, 2014)

The significance of this for trans-arctic shipping

These future projections have reopened a discourse around the possibilities for trans-Arctic shipping in the era of climate change. While the decrease in sea-ice in the Arctic is a dramatic consequence of anthropogenic emissions, it has also been seen as a possible opportunity for the expansion of shipping routes in through the pole (Ng et al., 2018; Melia, 2016; Smith & Stephenson, 2013). The hypothetical availability of previously impervious routes straight through the North Pole would offer the possibility of a direct connection between the Pacific and Atlantic basins (Ng et al., 2018, Smith & Stephenson, 2013). This shorter journey, that would otherwise be undertaken by travelling via the Suez or Panama canals, could cut up to 40% of distance travelled (Ng et al., 2018; Melia et al., 2016). There are three main routes through the Arctic (Fig 2): Northern Sea Route, NRS, the Northwest Passage, NWP, and the hypothetical Central Arctic Route, across the Bering Strait to the Atlantic (Lindstad et al., 2016). Out of these, the NSR is the one that is most likely to become ice-free first, thus one of the most interesting one for future trans-Arctic shipping (Lindstad et al, 2016).

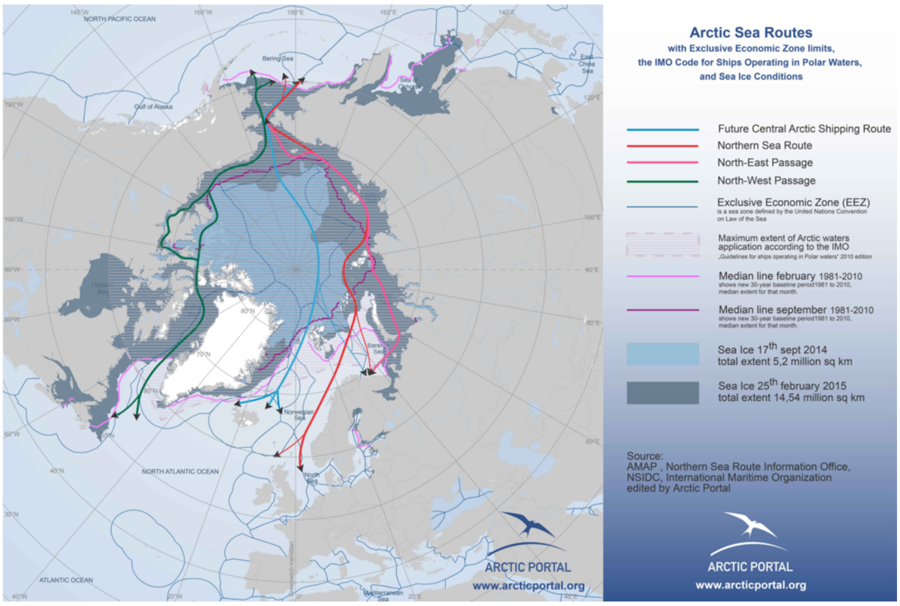

Figure 2: main Arctic Sea Routes, Sea Ice Conditions (summer and winter ice 2014/5; median line 1981-2010), Exclusive Economic Zones limits, and the area covered by the IMO Code for Ships Operating in Polar Waters, known as Polar Code (IMO Delimitations). Map from www.arcticportal.org

Introduction to the Finnafjord port project

To make the most out of these new opportunities, countries with an outlet to the Arctic Ocean are starting to plan and prepare for the possible expansion of their shipping routes. As one of the northernmost countries in the Atlantic, Iceland has been starting to plan for this eventuality. For this, the building of a new port and industrial hub is being developed on the North-Eastern shores of the country. This is the Finnafjord project, designed to be a major centre for current and future trans-Arctic shipping, especially for those travelling through the Northern Sea Route (NSR) and the hypothetical Central Arctic sea route (Bremenports, 2019). Furthermore, this port is also going to act as an industrial centre for a number of other activities such as energy generation, processing of raw mining materials, aquaculture and water desalinization (Bremenports, 2019).

The Local Environment

While this could represent a great opportunity for Iceland in the coming years, it is important to understand how the development of these new activities may affect the local environment. Most notably, the North East of Iceland represents a key area for cetacean species. In the last decades especially, Icelandic Humpback Whale (*Megaptera novaeangliae*) population has experienced unprecedented growth, going from around 1,800 individuals in 1987, to

14,600 in 2015, with most of this happening on the Western and Eastern shores (NAMMCO, 2017; Víkingsson et al., 2015). Humpbacks are a fundamental species for the local ecosystem and understanding their habitat preferences, in this area, could be very important for management strategies to ensure minimum conflict between human uses and wildlife (Dransfield et a., 2014). In fact, while most threats to Humpback Whales under climate change are expected to come in the form of habitat loss and changes in prey availability, the loss of sea-ice in the Arctic and the possible opening of new sea routes for shipping, oil and gas exploration and fishing, are likely to aggravate acoustic disturbances, prey depletion and ship strikes in these areas (Alter et al., 2010).

Objectives and Hypotheses

Aim of the study

As the project for the Finnafjord port is still in its planning stages, little to no environmental analyses and evaluations have been carried out as of now. Therefore, this project aims to be a starting point and to provide some early information to the condition of the ecosystem in the wider North Easter area of Iceland that may be affected by the construction of the Finnafjord. I will try to identify the main environmental drivers of Humpback distribution in the North East of Iceland, specifically focusing on the years between 2001 and 2015.

For this thesis, I hypothesise that the high number of Humpback Whales in my study area in the northeast can be explained by the presence of the 200m isobath (related to the shelf break), as Humpbacks have shown a preference for these lower depths (Zerbini et al., 2016; Víkingsson et al., 2015; Dransfield et al., 2014; Pike et al., 2005). Furthermore, these high population numbers could also be explained by higher productivity (Dalla Rosa et al., 2012) and cooler temperatures (Bassoi et al., 2020) in this area.

Methodology

Data collection

To carry this project out I will be using sighting data for Humpback Whales and several environmental variables. All of the data used in this dissertation has been collected by third parties and will be used following their User Policies.

Sighting Data

The data for Humpback whale presence has been already acquired from the North Atlantic Sightings Surveys (NASS), done periodically by the Regional Fisheries Management Organisation and the North Atlantic Marine Mammal Commission (NAMMCO). The terms of use for these datasets have already been agreed on via email with the people responsible for it. These datasets include sightings with the position of vessel and observer as well as sampling effort.

Environmental Variables

To carry out the habitat modelling, several environmental variables have to be selected to analyse their relationship to Humpback presence. The selection of environmental variables that I present here is based on a literature review of similar studies conducted all over the world (Table 1). While this is not a final list, this is a general indication of what are the main parameters that I am intending to use as of now.

Environmental Variable	Source	Notes	References
Bathymetry	EMODNET	- Mainly as Distance from land or 200m isobath (approximately the shelf break) - Possibly also as slope, shape, elevation and aspect of the sea floor	Bassoi et al., 2020; Chavez-Rosales et al., 2019: NAMMCO, 2017; Zerbini et al., 2016; Víkingsson et al., 2015; Dransfield et al., 2014; Dalla Rosa et al., 2012; Friedlaender et al., 2006; Pike et al., 2005.
Sea Surface Temperature (SST)	Copernicus/ NEODAAS	- Possibly running models for 1, 2 and 3 moths before the survey period	Bassoi et al., 2020; Chavez-Rosales et al., 2019; NAMMCO, 2017; Zerbini et al., 2016; Víkingsson et al., 2015; Dransfield et al., 2014; Dalla Rosa et al., 2012.
Mixed layer depth (MLD)	Copernicus	- As a proxy for the structure of the thermocline	Dransfield et al., 2014.
Chlorophyll	NEODAAS	- As a proxy for primary production	NAMMCO, 2017; Zerbini et al., 2016; Friedlaender et al., 2006.

Table 1: Summary table of proposed environmental parameters that will be taken into consideration for the project, including sources, brief notes and citations from where they have been previously used in the literature

Suggested Methodology for Data Analysis

The analysis of the relationship between the environmental variables is going to include several steps. Firstly, a GIS analysis (using either qGIS or ArcGIS) will be used to start analysing and breaking down some of the variables. Specifically, is at this point that the 200m contour line or distance from land layers will be created from the bathymetry data. Other components of bathymetry like slope, shape, elevation and aspect, would be able to be extracted at this stage as well using, in ArcGIS, the Spatial Analyst tool. This step is also going to be used for any further changes that need to be done to prepare all the data for analysis (eg: fixing resolution to make it consistent). The use of an initial GIS analysis will also allow me to get an overall idea of what the environment in my study area looks like, and to see if any patterns can be observed.

Before modelling, correlation analyses between the variables will be carried out to exclude collinearity between them. If I was to find any collinearity, those variables would then be removed for the final models.

To formalize the analysis, Generalized Additive Models (GAMs) or Generalized Linear Models (GLMs) will be used to explore the relationship between humpback distribution and environmental variables. In the literature, GAMs appear to be the preferred method for this sort of studies as they allow to model non-linear relationships better (Bassoi et al., 2020; Chavez-Rosales et al., 2019; Zerbini et al., 2016; Víkingsson et al., 2015; Dalla Rosa et al.,2012; Friedlaender et al., 2006). However, it is also important to take into consideration that GAMs can, sometimes, lead to overfitting (Chavez-Rosales et al, 2019; Friedlaender et al., 2006). All of the models and analyses will be carried out in R and RStudio. The package that can be used for GAMs in R is ***'mgcv'*** (Friedlaender et al., 2006).

If enough time is left at the end of this analysis and if any significant relationships between Humpbacks and other environmental variables are found, I would also attempt to create a Species Distribution Model (SDM) to try and predict future distribution.

Risk mitigation

This being a data analysis dissertation, my main concern is going to be my comfort while spending long hours at a computer. In order to make this experience less strenuous I will be working in appropriate light conditions, in a comfortable environment, making sure to take breaks when I need to.

Proposed timetable of activities

This table (Table 2) represents a general idea on when I would like to get started on specific tasks for my dissertation.

	Feb w1	Feb w2	Feb w3	Feb w4	March w1	March w2	March w3	March w4	April w1	April w2	April w3	April w4
DATA WRANGLING												
Collecting all environmental data												
Selecting geographic extent NASS data												
Initial GIS Analysis												
DATA ANALYSIS												
Pairwise comparison of variables for collinearity												
Final Selection of Variables												
Generalized Additive Models/Generalized Linear Models												
(?) Species Distribution Model												
DISSERTATION WRTING												
Intro												
Methods												
Results												
Discussion												
Conclusion												
Abstract												

Table 2: ideal timeline for dissertation work

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