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Modelling cetacean distribution and mapping overlap with fisheries in the northeast Atlantic

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ABSTRACT

Improving our knowledge of cetacean distribution and habitat use are key if we are to effectively ensure good conservation status for these species. Often however, sufficient data are lacking, inhibiting conservation efforts of many species. This study aims to combine historical datasets to generate habitat suitability models and thus maps, for eight species of cetacean regularly sighted in the Irish portion of the northeast Atlantic; fin whale, minke whale, pilot whale, sperm whale, white-sided dolphin, bottlenose dolphin, Risso's dolphin and white-beaked dolphin. Habitat suitability models were developed using MaxEnt modelling software for a range of environmental factors; sea-surface temperature, mixed layer depth, depth, slope, chlorophyll a concentration, sea surface salinity, distance to the 200 m contour. We predicted species exposure to fishing gears by integrating habitat suitability models with information on fishing vessel activities within the study area. The main predictors of habitat suitability for all species were topographic variables, particularly depth and slope, highlighted by two areas of high species richness around areas of topographic heterogeneity, along the continental shelf and on the west coast. Combining habitat models with fishing activity, indicated areas of high exposure off the north and south coasts and in an area known as the Porcupine Bank off the west coast. These results are valuable for conservation and management of cetaceans and fisheries in the study area. Methods can be easily adjusted to allow replication for other species and other anthropogenic activities. We recommend future effort focuses on winter months to fill in the gaps on year round cetacean distribution.

1. Introduction

There is a long history of humans having negative impacts on cetacean species through historic whaling, habitat degradation and an increase in anthropogenic activities in the marine environment (Rocha et al., 2015; Weir and Pierce, 2013). The International Union for Conservation of Nature (IUCN), Cetacean Specialist Group have evaluated 87 cetacean species and categorised 20 species as near threatened or higher (www.iucn-csg.org, Accessed 06.06.16). Critically however, forty-five species have been categorised as data deficient, whereby there is not enough data on their status to categorise risk. In order to ensure effective conservation of marine mammal species, we need to know more about their spatial and temporal distribution throughout the world.

Extensively surveying marine mammals is expensive and time consuming (Evans and Hammond, 2004), so high resolution surveys are rare. The best explanatory variable for mapping cetaceans is prey distribution, however this information is rarely available (Pirotta et al., 2011). To compensate for this, modellers use a range of environmental variables which act as proxies for prey distribution (Druon et al., 2012; Forney et al., 2012; Laran and Gannier, 2008; MacLeod et al., 2004a,b; Panigada et al., 2008). Using modelling techniques, we are able to understand and predict suitable habitats for a range of species and ultimately map areas of high density and/or diversity of cetaceans.

To date, in Europe there have been three large scale surveys for cetaceans using both aerial and boat based techniques. The Small Cetacean Abundance in the North Sea and adjacent waters (SCANS) I and II surveys were carried out in 1994 and 2005 (Hammond et al., 2002, 2013) and the Cetaceans Offshore Distribution and Abundance in the European Atlantic (CODA) was carried out in 2007 (Hammond et al., 2007). These surveys revealed abundance and density estimates using distance sampling methodology and environmental modelling for a range of cetacean species and

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although other smaller scale surveys have been conducted, these are currently our best source of information on the summer distribution of cetaceans in the northeast Atlantic. On a smaller spatial scale, such as in the Irish Economic Exclusion Zone (EEZ), there is a paucity of sightings data for some species which makes developing models challenging. In order to improve sightings, data records from several surveys could be pooled, however, this can be difficult where survey methods differ.

As well as difficulties with modelling distributions, it is even more difficult to analyse spatially the areas where human activities are affecting cetaceans the most. Studies such as Halpern et al. (2008) have attempted to map human impacts on the marine environment on a global scale and pressures and impacts on sea floor habitats have also been assessed (Goodsir et al., 2015). Combining habitat maps and maps of human activities to look at areas of impact have rarely been attempted in the northeast Atlantic. One of the most potentially damaging human activities is fishing, which causes mortality to cetaceans as a result of by-catch in commercial operations (Moore et al., 2009; Read et al., 2006). Accidental by-catch of cetaceans is a major cause of population decline, considering this, it is important that we mitigate and manage human activities to ensure minimal effects of our actions on these species (Praca et al., 2009). Understanding the spatial dimension of this threat is key if we are to develop suitable management plans within fisheries.

This analysis makes use of historical datasets, collected over 30 years, to build models for species which have a limited number of sightings. Twenty-four cetacean species have been recorded in the northeast Atlantic over the course of these surveys, including infrequent sightings of a blue whale, *Balaenoptera musculus* (Linnaeus, 1758) and sporadic sightings of beaked whale species. In this study, species that are considered data poor in terms of distribution and habitat use were chosen for modelling. To assess the effects of fishing on two balaenopterids and two delphinid species, we calculated an exposure to fishing measure spatially across the study area. The results will better inform management and conservation efforts in the Irish EEZ.

2. Materials and methods

2.1. Study area

The study area included a square box comprising the entire Irish EEZ in the northeast Atlantic waters from 56.9°N, 16.5°W to 48.1°N, 5.0°W and intersecting with the UK coastline (Fig. 1). The total survey area was 75,8667 km^2. The survey area is composed of a large continental shelf out to the 200 m depth contour which encompasses the Celtic Sea in the south and the Irish Sea in the east. The continental shelf continues outwards towards an area known as The Porcupine Bank where it drops steeply to over 2500 m. Beyond this region is the Rockall Trough and the abyssal plain running north to south respectively, an area of extremely deep water reaching depths over 3000 m. The area called Rockall (or Rockall Bank) is further offshore past the Rockall Trough where the depth shallows out again to around 300–500 m (Fig. 1).

2.2. Data

2.2.1. Sightings data

Only species where there were 15 or more sightings were included in the analysis, as this is the minimum number of sightings required to use the spatial jacknife method for modelling (Brown, 2014). Eight species were modelled including: fin whale, *Balaenoptera physalus* (Linnaeus, 1758), minke whale, *B. acutorostrata* (Lacepède, 1804), long-finned pilot whale, *Globicephala melas* (Traill, 1809), white-sided dolphin, *Lagenorhynchus acutus* (Gray, 1828), white-beaked dolphin, *L. albirostris* (Gray, 1846), bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821; 1855), Risso's dolphin, *Grampus griseus (*Cuvier, 1812) and sperm whale, *Physeter macrocephalus* (Linnaeus, 1758). Sightings data were gathered over 35 years (1980–2015) from three separate dedicated sightings surveys; SCANS I and II, CODA, and from sightings generated by The Policy and Recommendations from Cetacean Acoustics, Surveying and Tracking (PReCAST) project, and the European Seabirds at Sea surveys (ESAS) (Table 1). Due to variation in species distribution throughout the year only sightings for all years and all surveys which took place in the summer, i.e. July, August and September were used in analyses as this is the period with the greatest survey effort. Due to likely habitat differences between coastal and more "pelagic" and wider ranging populations of bottlenose dolphin (Louis et al., 2014; Mirimin et al., 2011) any sightings of this species within 12 nautical miles from the coast were removed from the dataset. Summer distribution models were developed for the eight species which had 15 or more sightings.

2.2.2. Environmental data

Environmental data were downloaded from a number of web sources, including the Marine Institute Data Portal and the NASA SeaWifs database. Environmental data used and sources can be seen in Table 1. Environmental datasets were either provided in, or modified so they were in, the projection WGS 1984, with a cell size of 0.0833decimal degrees and an extent consistent to the study area (Fig. 1).

2.2.3. Fisheries data

Information on fishing activity was obtained from vessel monitoring systems (VMS) and provided by the Marine Institute Ireland (Table 1) at the requested extent and cell size and in the requested projection showing the number of hours fished per grid cell. For static gears (gillnets and pots) interpreting VMS data is more difficult because the main indicators of effort are based on soak time i.e. the period of time the gear is left fishing before recovery and the size of the gear. Such data are rarely available, so in this analysis we have assumed that more VMS points recorded in a cell indicates more activity. This interpretation assumes that the ranges and mean size of the gear deployed are the same across the survey area. Similar assumptions are implicit in other studies using VMS to examine passive gear fishing effort (Fock, 2008; Palmer and Wigley, 2007). Although VMS data were only available from 2009 to 2015, this was not seen to be a major issue for this analysis since fishermen are thought to show high fidelity to fishing grounds between years (Lee et al., 2010) and because averaging all areas together reduced inter-annual variation between areas of high and low usage.

2.3. Modelling

Modelling of sightings against environmental variables were developed using the presence-background, Maxent modelling programme (version 3.3.3) (Phillips et al., 2004) and the Species Distribution Modelling (SDM) toolbox in ArcGIS 10.2 (Brown, 2014). Presence-background modelling uses point sightings as presence locations and then randomly generates absence points (pseudo-absences) from within the study area, these are known as background points. Presence-background modelling was used due to the difficulties involved with combining effort data collected using different methodologies and over a long time period. Maxent aims to achieve maximum entropy i.e. a model with uniform distribution which still accurately infers the observed data, throughout the study region and is considered to perform particularly well in