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Using kernel density estimation to explore habitat use by seabirds at a marine renewable wave energy test facility

Kirsty J. Lees [a,*,1], Andrew J. Guerin [b], Elizabeth A. Masden [a]

[a] Centre for Energy and the Environment, Environmental Research Institute, North Highland College, University of the Highlands and Islands, Ormlie Road, Thurso KW14 7EE, UK
[b] School of Marine Science and Technology, Newcastle University, Newcastle upon Tyne NE1 7RU, UK

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ABSTRACT

If Scottish Government targets are met, the equivalent of 100% of Scotland's electricity demand will be generated from renewable sources by 2020. There are several possible risks posed to seabirds from marine renewable energy installations (MREIs) and many knowledge gaps still exist around the extent to which seabird habitats can overlap with MREIs. In this study, underlying seasonal and interannual variation in seabird distributions was investigated using kernel density estimation (KDE) to identify areas of core habitat use. This allowed the potential interactions between seabirds and a wave energy converter (WEC) to be assessed. The distributions of four seabird species were compared between seasons, years, and in the presence and absence of WECs. Although substantial interannual variation existed in baseline years prior to WEC deployment, the KDEs for all four species analysed were closer to the mooring points in the presence of a WEC in at least one season. The KDEs for all four species also increased in area in at least one season in the presence of a WEC. The KDEs of the northern fulmar and great skua overlapped the mooring points during spring in the presence of a device. The density of observations close to the mooring points increased for great skua, northern gannet, and northern fulmar during summer in the presence of a device. These results suggest that none of the four species analysed have shown avoidance or an extreme change in distribution as a result of the presence of a WEC. The continued monitoring of seabirds during WEC deployments is necessary to provide further data on how distributions may change in response to the presence of WECs.

1. Introduction

The Scottish Government is committed to generating the equivalent of 100% of Scotland's electricity demand from renewable resources by 2020 [1] and offshore renewable energy has been given full consideration within Scotland's National Marine Plan [2]. Twelve sites in the Pentland Firth and Orkney waters have been leased for the development of commercial-scale wave or tidal renewable energy arrays. However, many knowledge gaps still exist concerning the possible ecological interactions of wave and tidal devices with marine organisms including seabirds [3–6].

Several possible risks to seabirds from marine renewable energy have been identified: collision [7] or entanglement mortality [8–10], barrier effects [11–13], displacement [14,15], and disturbance [16,17]. The relative infancy of the wave and tidal energy industry means that most marine renewable energy devices (MREDs) are still in the development phase, with limited opportunities to study environmental interactions in the field. Consequently, there are currently no empirical, quantitative accounts published in the peer-reviewed literature of how these risks are associated with wave energy converters (WECs) and tidal energy converters (TECs). In addition, there is considerable variety in the designs of WECs and TECs [18,19] and no standardised approach for the Environmental Impact Assessment (EIA) of MREDs, as the risks posed will most likely be location and species-specific [18,20,21]. The Pelamis Wave Power Ltd. ‘P2’ [22] is an example of a semi-submerged attenuator WEC, and the risk of collision mortality associated with WECs of this type is likely to be relatively low for the majority of species [18,21]. The main potential negative impact is loss of foraging habitats, either through exclusion due to the physical presence of the WEC or through underlying changes in the quality of the foraging habitat [4].

Much uncertainty also exists around how best to monitor and assess the biological effects of marine renewable energy arrays [23,24]. Further consideration still needs to be given to identifying

* Corresponding author.
E-mail addresses: k.lees1@newcastle.ac.uk (K.J. Lees), andrew.guerin@newcastle.ac.uk (A.J. Guerin), elizabeth.masden@uhi.ac.uk (E.A. Masden).
[1] Current address: School of Biology, Newcastle University, Newcastle upon Tyne NE1 7RU, UK.

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the drivers of habitat selection by foraging seabirds over multiple spatial and temporal scales. Establishing the degree of spatial overlap between seabird distributions and development sites will be important in addressing the uncertainty surrounding the potential risks [25].

A long-term dataset of land-based, spatially-explicit seabird observations were analysed using kernel density estimation (KDE) [26] to describe the distributions of the most commonly observed seabird species at a wave energy test facility where Pelamis P2 WECs were being tested. The aims were to assess the impact of the presence of a WEC on seabird distributions within the test site and to compare these changes with underlying seasonal or annual variation: are potential changes in seabird distributions in the presence of a P2 WEC identifiable using KDE and if so, how do these changes compare to intra- and interannual variation observed prior to WEC deployment?

2. Methods

2.1. Study site

The European Marine Energy Centre (EMEC), Billia Croo site (58.9775°N 03.3959°W) in Orkney, Scotland (Fig. 1) is the only accredited full scale wave test site in the world (area approximately 5.50 km^2), allowing for the simultaneous testing of multiple WECs in five grid-connected berths. All berths are capable of exporting electricity to the national grid [27] and testing of the P2 began in late 2010. The test site has a significant wave height of 2–3 m, and the highest recorded wave has been 17 m [28].

2.2. Data collection

Seabird distribution data were collected between March 2009 and February 2013 by two observers employed by EMEC as part of a Scottish Government funded wildlife monitoring programme [29]. The survey area extended approximately 5 km in all seaward directions from the observation point, forming a semi-circular arc that encompassed the full test site which was approximately 2 km from shore (Fig. 1) [29]. Surveys were undertaken 5 days out of every 7 between 04:00 h and 20:00 h, sampling evenly throughout the day and across the tidal cycle as conditions allowed. A survey period lasted 4 h and was conducted from a coastal observation point approximately 110 m above sea level (Fig. 1). Surveying was not undertaken in sea conditions above sea state 4 of the Beaufort scale, and was suspended in reduced visibility during thick fog or heavy rain. For each observation the date, time, species and number present, and the appropriate behaviour, were recorded. The angle of declination from the observation point to the point of interest, and the associated compass bearing, were also recorded and used to calculate the geographical location of each observation [29]. Only birds that were in contact with, or close to the sea surface were recorded. The data were stored in an Access database, and are freely available online [30].

Coordinates for each data point used in the analysis were transformed using ESRI ArcMap 10.0 to Universal Transverse Mercator (UTM) Zone 30, using WGS 1984 datum. Observations that overlapped land were removed and only data within 3 km of the elevated observation point were included; this was deemed a suitable distance range for describing habitat use within the test site and retained confidence in the detectability and identification of sightings. Pre-deployment baseline data were collected between 11th March 2009 and 28th February 2011, however during

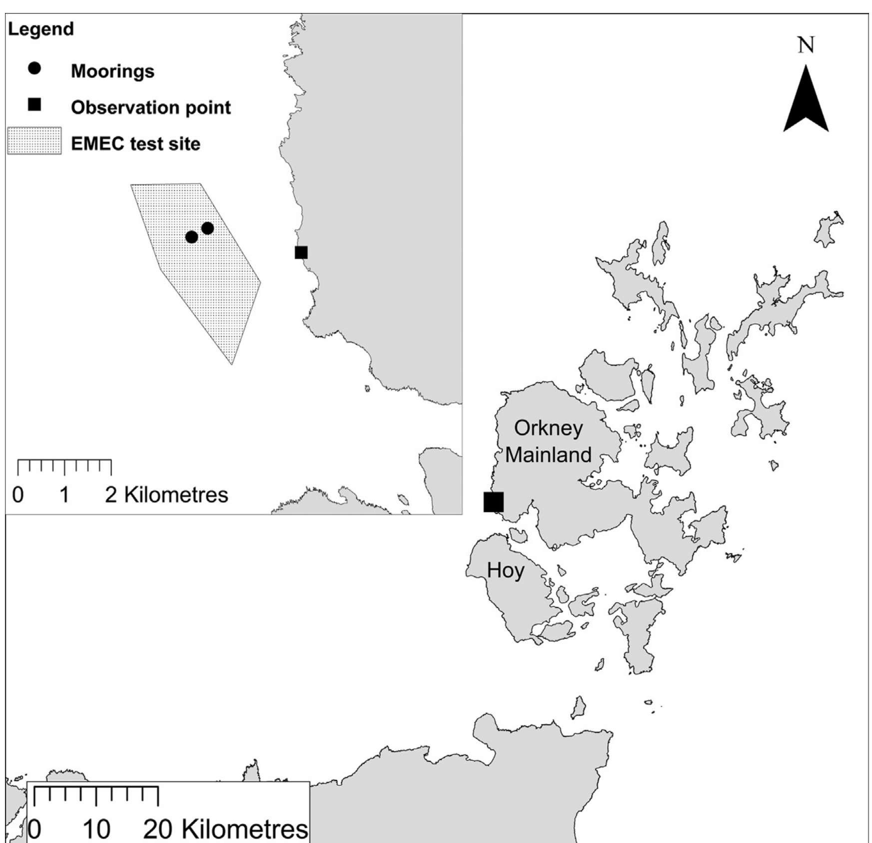

Fig. 1. Main image: map of the north east corner of mainland Scotland and Orkney Islands. Inset: map of the EMEC wave test site, detailing the location of the mooring points.