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Black guillemot ecology in relation to tidal stream energy generation: An evaluation of current knowledge and information gaps

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ABSTRACT

The black guillemot *Cepphus grylle* has been identified as a species likely to interact with marine renewable energy devices, specifically tidal turbines, with the potential to experience negative impacts. This likelihood is primarily based on the species being a diving seabird, and an inshore, benthic forager often associating with tidal streams. These behavioural properties may bring them into contact with turbine blades, or make them susceptible to alterations to tidal current speed, and/or changes in benthic habitat structure. We examine the knowledge currently available to assess the potential impacts of tidal stream turbines on black guillemot ecology, highlight knowledge gaps and make recommendations for future research. The key ecological aspects investigated include: foraging movements, diving behaviour, seasonal distribution, other sources of disturbance and colony recovery. Relating to foraging behaviour, between studies there is heterogeneity in black guillemot habitat use in relation to season, tide, diurnal cycles, and bathymetry. Currently, there is also little knowledge regarding the benthic habitats associated with foraging. With respect to diving behaviour, there is currently no available research regarding how black guillemots orientate and manoeuvre within the water column. Black guillemots are considered to be a non-migratory species, however little is known about their winter foraging range and habitat. The effect of human disturbance on breeding habitat and the metapopulation responses to potential mortalities are unknown. It is clear further understanding of black guillemot foraging habitat and behaviour is needed to provide renewable energy developers with the knowledge to sustainably locate tidal turbines and mitigate their impacts.

1. Introduction

Seabirds are affected by anthropogenic activities including fishing (Daunt et al., 2008; Furness, 2002), oil spills (Ewins, 1986; Golet et al., 2002), and climate change (Grémillet and Boulinier, 2009; MacDonald et al., 2015). The increase in anthropogenic activity arising from the growing marine renewable energy industry still has unknown effects on seabirds (Inger et al., 2009). In Scotland, this industry is driven by goals set by the Scottish Government to achieve 100% renewable energy by 2020 (Davies et al., 2014). Tidal stream energy devices, i.e. those based on tidally driven currents channelled through narrow areas between landmasses or around headlands, are currently being tested and installed in advance of potential large-scale implementation. In Scotland, 18 inshore areas have been leased for tidal development (The Crown Estate, 2016). In the Pentland Firth, arrays of up to 398 large tidal stream turbines are planned in areas with potential current speeds of > 2 m/s^{-1} (Rollings, 2011), with 3 trial turbines installed in winter 2016/17.

The potential impacts of tidal turbines on diving seabirds are largely unknown since only a few devices have been deployed to date (Savidge et al., 2014; SNH, 2016). In Scotland, the black guillemot *Cepphus grylle* has been highlighted as the seabird species most at risk from tidal turbines (Furness et al., 2012; Robbins, 2012), in part, due to their association with tidal streams (Nol and Gaskin, 1987; Waggitt et al., 2016b). It has been suggested that the impacts of tidal turbines on diving seabirds may include changes to foraging habitat, foraging efficiency, and diving behaviour (Benjamins et al., 2015; Scott et al., 2014) as well as direct mortality through collision (Furness et al., 2012; Wilson et al., 2006). The need for further research regarding impacts to and responses of seabirds to renewable energy installations has been highlighted (Inger et al., 2009; Langton et al., 2011; Scott et al., 2014), especially in relation to tidal turbines (Furness et al., 2012; Masden

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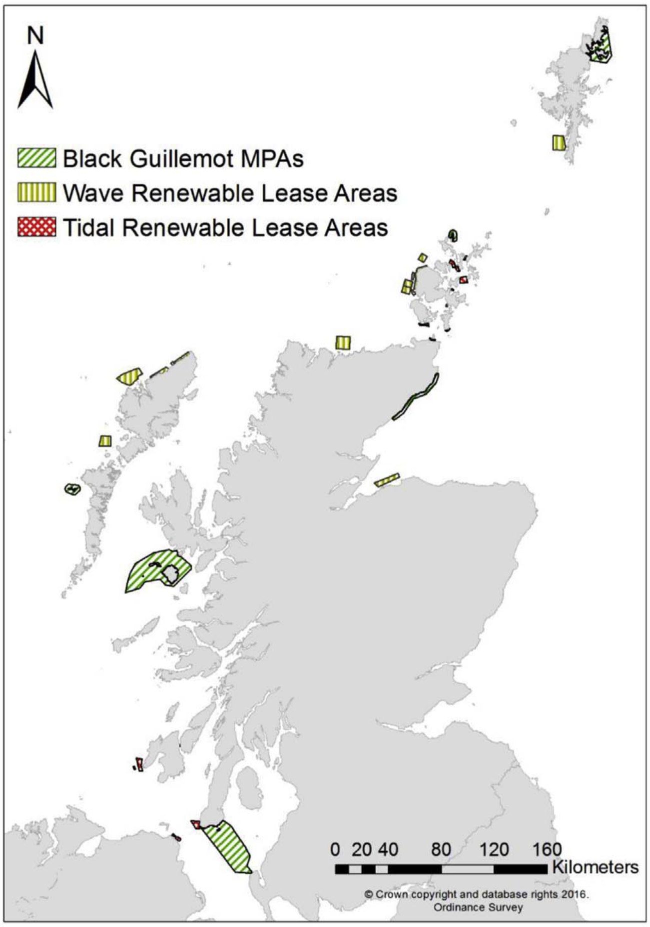

Fig. 1. Scottish wave and tidal renewable lease areas and black guillemot Marine Protected Areas.

et al., 2013) though it is acknoweldged that this poses challenges (Fox et al., 2018). The sensitivity of diving seabirds to the impacts of tidal turbines is likely to vary in relation to the extent of spatial and temporal overlap (Waggitt and Scott, 2014). In the absence of empirical data, sensitivity can be expected to relate to foraging locations, diving depth, variation in year-round distribution and behaviour, association with tidal currents, visual nature of foraging, and diurnal rhythms in foraging (Furness et al., 2012; Wilson et al., 2006). Further ecological knowledge of these factors is needed to inform decision makers on the potential impacts related to tidal turbine allocation and operation.

The siting of marine renewable lease sites around Scotland coincides with the designation of six Scottish Marine Protected Areas (MPAs) specifically with black guillemots as a major protected feature (SNH, 2014, Fig. 1). A further four MPAs have been established for benthic communities containing kelp which may in turn protect habitat associated with black guillemot prey (blennies and gadoids) (Ewins, 1990; SNH, 2014). This also emphasises the need for more information on black guillemot foraging ecology to ensure MPAs fulfil their desired conservation outcomes by encompassing foraging habitat.

The aim of this paper is to provide a synthesis of current knowledge regarding black guillemot ecology and its relevance to potential impacts from tidal stream turbines. Key aspects of black guillemot movement are reviewed, including: (1) foraging movements, (2) diving behaviour, and (3) seasonal distribution. Further factors, which may compound the impact of tidal stream turbines are also considered, including other sources of disturbance to nesting adults and the process of colony recovery. For each topic: (1) the knowledge required to assess the impacts of tidal stream turbines on black guillemots is outlined, (2) current knowledge is reviewed, (3) gaps in current research are highlighted, and recommendations for future research are provided.

2. Foraging movements

Tidal stream turbines may increase habitat heterogeneity through the addition of previously absent structures, which will potentially form reefs, act as Fish Aggregating Devices (FADs), and may alter seabed sedimentation patterns (Miller et al., 2013; Shields et al., 2009). How susceptible a seabird will be to these changes depends on their ecology (Wilson et al., 2006). Firstly, species which forage within the inshore environment rather than offshore will most likely encounter tidal devices (installed within 5 km of shore) (The Crown Estate, 2016). Secondly, temporally varying habitat use (related to season, time of day, or tidal phase) may influence the duration foraging birds experience disturbance from turbine construction, maintenance, or operation (Waggitt and Scott, 2014). Lastly, the dive depths exhibited by a foraging bird may indicate the extent of vertical overlap with turbine blades (Furness et al., 2012), dependent on the blade depth profile of the class of tidal device encountered, which include floating (3–19m) (Scotrenewables, 2017) and seafloor mounted (8–26m) (Masden et al., 2013; MeyGen, 2012). In terms of black guillemots, a small foraging range, frequent use of inshore areas, and deep/benthic diving behaviour could bring individuals into frequent contact with inshore tidal turbines (Furness et al., 2012). The assessment of the overlap between tidal turbines and foraging black guillemots requires ecological knowledge of both movement and habitat use at sea.

2.1. Foraging movements: current knowledge

Black guillemots are inshore, generalist, central place foragers with a small foraging radius. Initial work regarding black guillemot foraging ranges monitored the direction that adults flew from the nest by visually following individual birds (Cairns, 1992; Ewins, 1986; Nol and Gaskin, 1987; Petersen, 1981) (Table 1). More recently, electronic tracking studies of adult black guillemots have revealed more accurately the foraging locations and distances travelled by individuals (Owen, 2015; Sawyer, 1999) (Table 1).

These relatively small (Thaxter et al., 2012), inshore, foraging ranges are reflected in their diet, and lead to variability in prey species between colonies due to variations in the characteristics of the local habitat (Barrett and Anker-Nilssen, 1997; Ewins, 1990; Hario, 2001). In Scotland, butterfish *Pholis gunnellus* tend to dominate diet, followed by sandeels *Ammodytes marinus*, gadoids, blenny spp., sculpin spp., and flatfish spp. (Ewins, 1992, 1990; Harris and Riddiford, 1989; Sawyer,

Table 1
Summary of breeding season foraging distance studies for black guillemots.

Reference	Method	n	Seasons sampled	Mean (km)	Median (km)	Maximum (km)	Location
Petersen, 1981	Visual observation	65	3	2–4	–	7	Flatey Island, Iceland
Ewins, 1986	Visual observation	73	1	–	–	2	Shetland, Scotland
Sawyer, 1999	Visual observation	623	1	–	5.5 (300m offshore)	8.4 (840m offshore)	Holm of Papa, Orkney, Scotland
Sawyer, 1999	VHF tag	18	3	–	5.5 (275m offshore)	9 (700m offshore)	Holm of Papa, Orkney, Scotland
Shoji et al., 2015	GPS tag	1	1	–	–	1.8	Lighthouse Island, Copeland, Northern Ireland
Owen, 2015	GPS tag	19	1	–	–	7.45	Grass Holm, Shapinsay, Orkney, Scotland

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