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Comparative studies reveal variability in the use of tidal stream environments by seabirds

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ABSTRACT

The global increase in tidal stream turbine installations creates a need to identify and mitigate any impacts on seabird populations. Within Scotland, UK, the vulnerability of black guillemots *Cepphus grylle* and European shags *Phalacrocorax aristotelis* is dependent on their tendency to exploit microhabitats characterised by fast mean horizontal current speeds ($\geq 2\,ms^{-1}$), and tidal states with maximum current speeds, within tidal stream environments. Identifying consistencies in their relative use of different microhabitats (fast versus slow mean horizontal current speeds) and tidal states (increasing/decreasing versus maximum currents) across these habitats could assist risk assessment and mitigation measures at both a regional and development site level. Datasets from shore-based surveys collated across 6 tidal stream environments showed that the probability of detecting foraging black guillemots and European shags tended to be higher in fast and slow microhabitats, respectively. However, differences between microhabitats were reversed and/or marginal in 3 out of the 5 sites used for each species. Differences between tidal states were almost always marginal. These variabilities show that a species' vulnerability could differ greatly among development sites, and environmental impact assessments (EIA) must quantify habitat-use using dedicated and site-specific surveys to reduce uncertainty. However, a greater understanding of the mechanisms underlying variation in the use of tidal stream environments is needed when selecting a suite of potential development sites that reduce the possibility of population-level impacts. The current collection of physical and biological data across tidal stream environments could therefore prove invaluable for the protection of seabird populations.

1. Introduction

Increases in offshore anthropogenic activities (e.g. marine renewable energy extraction, oil/gas extraction, fisheries, shipping) place threats on seabird populations via mechanisms such as habitat modification, reduced prey abundance/quality, disturbance, and collisions with structures. There is a need to identify and mitigate threats if populations of species are to be protected [1]. One means of identifying potential impacts is to establish the range of threats posed by a particular anthropogenic activity, and then assess which species are vulnerable to this range of threats. These assessments often involve descriptions of the behaviour or ecology of a species, followed by an informed evaluation of whether this behaviour or ecology makes them vulnerable [2–7]. The quantification of behavioural or ecological tendencies, at least those aspects which are relevant to the threat of concern, can assess the extent of potential impacts on a population. For instance, quantifying the flight heights of a species can help to estimate the number of population members that may collide with moving components of wind turbines [8]. By enabling effort and resources to focus on particularly vulnerable species, these descriptions and quantifications can also aid environmental impact assessments (EIA) aiming to minimise the possibility of localised impacts from a specific activity [9].

Scotland, UK, has pledged to provide 100% of its energy from

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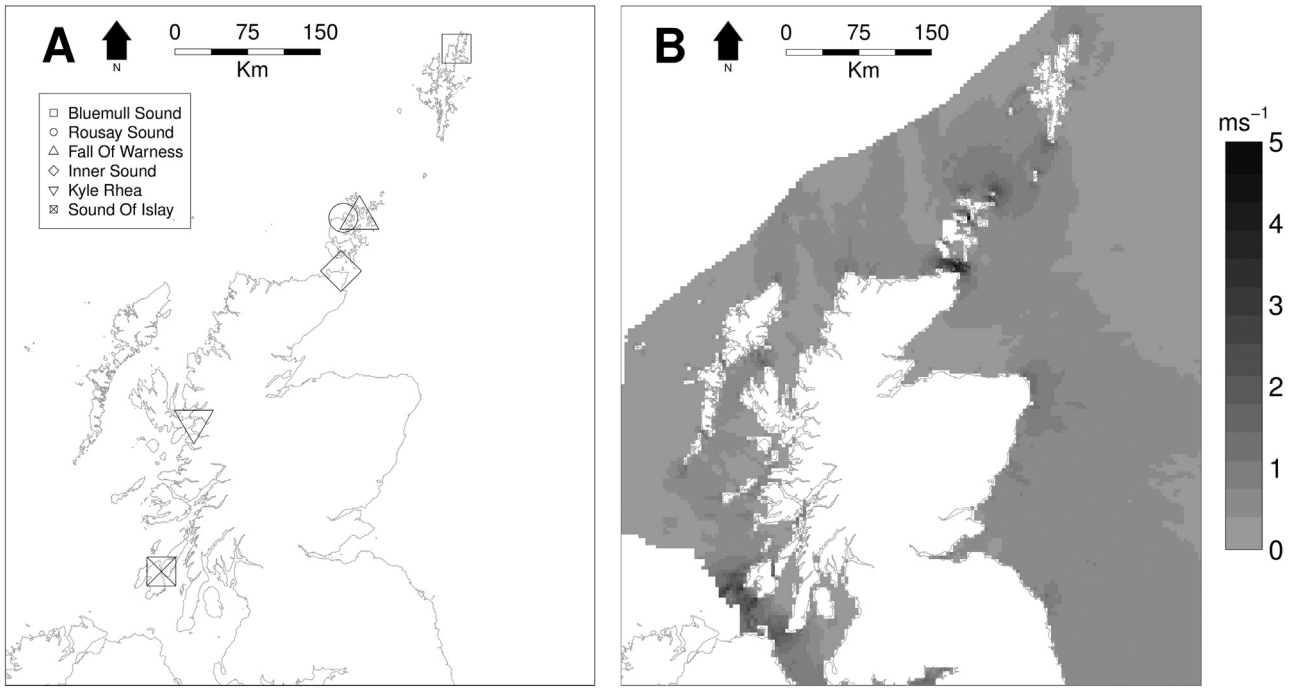

Fig. 1. The locations of the six study sites in Scotland, UK are shown in A. The distribution of tidal stream resources, shown in mean spring tide current speeds ($m\,s^{-1}$) are shown in B. Tidal stream resource information was obtained from the Atlas of UK marine renewable energy resources [10].

renewable sources by 2020 [10]. This has led to widespread interest in the development of marine renewable energy installations, in particular the extraction of tidal stream energy due to the prevalence of exploitable resource across this region [11]. However, Scotland is an important area for breeding seabirds [12], and this has raised concerns regarding the impacts of tidal stream energy extraction on these populations [13]. Mortality or serious injuries resulting from collisions between pursuit-diving seabirds and moving components remain the principal concern [14], as does the possibility of reduced foraging opportunities due to seabirds avoiding areas immediately around installations (displacement) [13,15]. Current assessments suggest that black guillemot *Cepphus grylle* and European shag *Phalacrocorax aristotelis* populations may be particularly vulnerable to collisions and displacement due to their tendency to exploit tidal stream environments, performance of deep dives whilst exploiting benthic fish, and year-round residency [2]. Scotland supports 86% and 57% of the UK black guillemot and European shag populations, respectively [12]. Therefore, identifying and mitigating impacts on these species is a research priority. However, studies focussing on black guillemot and European shag use of tidal stream environments remain scarce [16]. Consequently, there is much uncertainty surrounding these assessments [7]. Nevertheless, the increases in leased and proposed development sites within Scotland, alongside the requirement to assess potential impacts on seabird populations, have encouraged several studies into their behaviour and ecology within these habitats [17–21]. This provides an opportunity to investigate the possibility of consistencies in habitat-use, and contribute towards the identification and mitigation of impacts at a regional and development site level.

The assessment of a species' vulnerability to collisions and displacement can be broadly divided into two components: (1) the likelihood of a species interacting with an installation, (2) the likelihood of a species interacting with a rotating blade [22]. Such assessments require an understanding of the spatial and temporal use of tidal stream environments by a species. Firstly, interactions between strong horizontal currents and complex topography in tidal stream environments cause the former to accelerate on the seaward side(s) of headlands and islands, but decelerate in the wake of these features, creating adjacent areas of greatly contrasting speeds [16]. Therefore, these habitats are divisible into areas characterised by generally fast ($\geq 2\,m\,s^{-1}$) or slow ($< 2\,m\,s^{-1}$) mean horizontal current speeds (see [23]). Studies have found species foraging on benthic fish to associate with either fast or slow microhabitats [18,23,24]. As the majority of installations will be found in fast microhabitats, driven by the need to maximise energy returns [25], any species associating with these areas are considered more vulnerable [22]. Secondly, horizontal current speeds in tidal stream environments change greatly across ebb-flood tidal cycles, from almost stationary to $> 4\,m\,s^{-1}$ in some extreme cases [16]. Studies have also found species foraging on benthic fish to associate with either increasing/decreasing [17] or maximum currents [23]. Due to the faster rotation of blades during maximum currents, any species associating with this tidal state are also considered more vulnerable [14,26]. Combining information on the tendency of a species to exploit fast or slow microhabitats, and also increasing/decreasing or maximum currents, across Scotland would offer insights into possibility of collisions and displacement having impacts within this region [22].

This study compares the relative use of microhabitats, and the relative use of fast microhabitats over different current speeds, by black guillemots and European shags in tidal stream environments across Scotland during the breeding season. Datasets from methodologically similar shore-based surveys, recording spatial and temporal distributions, were collated across this region. Two questions relevant to the assessment of a species' vulnerability to collisions and displacement at a regional scale were then asked: (1) do species consistently associate with a particular microhabitat (fast versus slow) across all study sites, (2) do species consistently associate with fast microhabitats during a particular tidal state (maximum versus increasing/decreasing currents) across all study sites? The implications of the answers to the questions, with regard to the identification and mitigation of any negative impacts at a regional and development site level, were then discussed.

2. Methods

2.1. Study sites and survey periods

Shore-based surveys were performed in six sites across the Highlands and Islands region of Scotland: (1) Bluemull Sound, Yell,

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