



# Approaching population thresholds in presence of uncertainty: Assessing displacement of seabirds from offshore wind farms



Malte Busch <sup>\*</sup>, Stefan Garthe

Research and Technology Centre (FTZ), University of Kiel, Hafentörn 1, 25761 Büsum, Germany

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## ABSTRACT

Assessment of the displacement impacts of offshore wind farms on seabirds is impeded by a lack of evidence regarding species-specific reactions to developed sites and the potential ecological consequences faced by displaced individuals. In this study, we present a method that makes best use of the currently limited understanding of displacement impacts. The combination of a matrix table displaying the full range of potential displacement and mortality levels together with seasonal potential biological removal (PBR) assessments provides a tool that increases confidence in the conclusions of impact assessments. If unrealistic displacement levels and/or mortality rates are required to equal or approach seasonal PBRs, this gives an indication of the likelihood of adverse impacts on the assessed population. This approach is demonstrated by assessing the displacement impacts of an offshore wind farm cluster in the German North Sea on the local common guillemot (*Uria aalge*) population.

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## 1. Introduction

The marine environment is undergoing profound changes (Lange et al., 2010). In addition to a multitude of other anthropogenic uses, the expansion of offshore wind energy installations currently represents the most prominent development in the North Sea (Moksness et al., 2009). The direct impact of offshore wind farms (OWFs) on seabird mortality, e.g. due to collision with rotating blades, is regularly modelled and assessed within impact assessments in several European countries. However, indirect mortality and decreases in productivity as an ecological consequence of displacement from foraging habitats has been neglected until recently, due to the lack of evidence for impact pathways (Furness, 2013; Langton, 2013).

Seabirds show species-specific behavioural responses to operational OWFs. Several species groups show avoidance reactions to OWFs in response to specific stimuli, such as rotating turbines and/or related activities including movements of maintenance/service vessels (Fox and Petersen, 2006). Such behavioural avoidance equates to indirect habitat loss for some species (Furness et al., 2013). The ecological consequences of partial or complete exclusion of birds from the footprints of OWFs and any 'buffer zones' around them require careful consideration through environmental impact assessments (EIAs) (Busch et al., 2013; Langton, 2013; Masden et al., 2010a), where potential impacts of displacement have to be assessed based on 2 years of baseline data collected following the application for an OWF (BSH, 2013).

Two key impact pathways are important when considering displacement effects on mobile receptors: the relative strength of the displacement effect (e.g. the percentage of a population relocating as a consequence of a perturbation), and the ecological consequences (e.g. survival and fitness consequences) for the displaced individuals.

In this context, this study aimed to detail a methodology to approach and narrow down the potential effects of marine activities (particularly OWFs) on seabird species by triggering avoidance reactions, resulting in the displacement of individuals from the disturbed area.

We used available evidence on displacement rates and human-caused mortality rates populations can sustain to develop an appropriate method for assessing the biological consequences for seabirds of indirect habitat loss due to displacement from OWFs and their surrounding areas.

Our appreciation of the magnitude of species-specific displacement rates has improved as a result of the increased availability of post-construction monitoring results (e.g. Vanermen et al., 2012; Percival, 2012; Walls et al., 2012; Leopold et al., 2011; Petersen et al., 2006) and sensitivity indices informed by comprehensive literature reviews (Furness et al., 2013; Garthe and Hüppop, 2004). However, the results still need to be treated with caution because of uncertainties regarding their statistical validity (Furness, 2013) and significance (Maclean et al., 2013). Studies may only indicate whether or not displacement occurs, while species-specific displacement rates remain questionable. Accordingly, more data do not necessarily lead to more reliable results. Focused, post-construction monitoring programmes, involving power analysis to identify a suitable study design, as well as careful timing and appropriate numbers of surveys, are needed to collect data for

<sup>\*</sup> Corresponding author.

E-mail address: [der.malte.busch@gmail.com](mailto:der.malte.busch@gmail.com) (M. Busch).

single key species and thus help to improve our understanding of the problem. Moreover, population-modelling approaches increase our knowledge of population dynamics and the vulnerability of specific populations to human-caused mortality. The potential biological removal (PBR) approach (Wade, 1998) and other equivalent population models provide tools for assessing the number of additional casualties (above natural background mortality rates) that can be sustained each year by a certain population (Dillingham and Fletcher, 2008).

This study aimed to use the available information as summarised above to address the question of how to assess the biological consequences for displaced individuals, which represents a key parameter in determining the likelihood of a significant negative effect on a specific population. Combining realistic displacement rates with a 'sustainable harvest rate' allows the mortality of displaced individuals needed to meet a respective PBR threshold to be derived; if the mortality rate of displaced individuals would need to be unrealistically high, this would argue against a significant negative effect on the population under consideration. However, in light of the above-mentioned uncertainties, the approach developed in this study, rather than providing a definitive answer, aims to allow for more-informed discussion of the potential effects of displacement in the context of OWF approval processes by describing the full range of potential quantitative impacts.

The approach was demonstrated by investigating the potential displacement effects of an OWF cluster in the German North Sea on a common guillemot (*Uria aalge*) population on the island Helgoland.

## 2. Background

Displacement of seabirds by OWFs may have fitness consequences in terms of likelihood of survival and future reproductive output for both displaced individuals, and individuals that the displaced birds may interact with. Individual fitness may be affected by increased energy expenditure (due to relocating to other foraging grounds) and/or evasion of OWFs resulting in changes to daily energy and time budgets (Masden et al., 2010b), and consequent increases in the costs of average foraging bouts. Individual fitness may also be adversely impacted by reduced rates of energy acquisition if birds have to relocate to alternative and potentially less-profitable feeding grounds, indicating that the strength of any displacement effect will depend on the quality of the habitat that is lost.

Displacement can also have an impact via intensified intra-specific competition for resources within the remaining foraging habitat (e.g. Burton et al., 2006; Durell et al., 2001, 2000), thus potentially increasing the energetic costs of foraging or reducing the rate of energy gain, with possible consequences for individual body condition and reproductive success. OWFs may impact on individuals by any or all of these pathways to increase the mortality or reduce the productivity of bird populations.

The sensitivity of seabird species to displacement might also vary in accordance with specific stages of their annual life cycle, e.g. in relation to breeding, post-breeding or non-breeding seasons.

During the breeding/colony-attendance season, seabirds tend to become central-place foragers, bound to their colonies (Baird, 1991, Burke and Montevecchi, 2009), and are restricted to finding sufficient food within a foraging range, the extent of which is defined by its energetic costs. Accordingly, seabirds may be particularly vulnerable to displacement effects during the breeding season. Ecological theory predicts that breeding adults may buffer their own survival by not attempting to breed or by abandoning breeding efforts when conditions are/become unfavourable (Cairns, 1987; Furness, 2013). This was described by Ylönen et al. (1998) as a trade-off between investments in current breeding and self-maintenance. Long-lived species (Burke and Montevecchi, 2009) like seabirds are generally thought to safeguard their own survival to allow for subsequent breeding attempts in other years (Langton, 2013). Recent studies modelling the effects of displacement of foraging guillemots during the breeding season concluded that

displacement could result in changes to species time/energy budgets, with possible consequences for breeding performance and/or adult survival (Searle et al., 2014). The potential reduction in adult provisioning rates could in turn result in reduced chick growth and survival, and consequently decreased reproductive success (Langton, 2013). Moreover, longer foraging trips may be associated with temporary non-attendance of eggs or young, so increasing the likelihood of failure due to predation or conspecifics (Ashbrook et al., 2008; Ashbrook et al., 2010; Searle et al., 2014). This suggests that unfavourable nutrition during the breeding season may have a greater impact on breeding success than on adult survival (Cairns, 1987). Nevertheless, adult birds that abandon their breeding efforts to secure their own survival, or those reproducing at high individual costs, are likely to suffer from poor body condition by the end of the breeding season (Langton, 2013), and continuation of these fitness implications into the non-breeding season may have knock-on effects for over-winter survival (Erikstad et al., 2009; Harding et al., 2011; NSRAC, 2013). Masden et al. (2010b) suggested that displacement of foraging breeding adults could affect breeding success as well as survival rates. Moreover, the suggestion that colony size may be limited by intra-specific competition for food in the vicinity of colonies during the breeding season (Furness and Birkhead, 1984) highlights the potential ecological consequences of reducing the foraging habitat available to a respective colony.

Although central-place foraging constraints are removed during the non-breeding season, making birds more flexible in terms of habitat choice and thus potentially less vulnerable to displacement from a given area, these considerations may be offset by adverse weather conditions and reduced food availability. The effects of insufficient nutrition and poor body condition during the non-breeding season cannot be mitigated by behavioural changes (e.g. abandoning breeding effort to safeguard own survival), and displacement effects during the non-breeding season will accordingly impact on individual survival. The mortalities of both juvenile and adult auks seems to be highest during the winter (Furness, 2013), and prey abundance is thought to be the key driver of adult mortality (Mitchell et al., 2004), with contributions from other factors such as pollution and entanglement in fishing gear. However, seabirds will be less restricted in their habitat choice during the non-breeding compared with the breeding season, and may redistribute to alternative habitats at comparably low energetic costs in the absence of the need for regular commutes to a colony. As long as redistribution to an alternative habitat of similar quality is possible, the impacts of displacement may be tolerable, with little or no effect on body condition and survival. The average life span and very low adult mortality of seabirds such as guillemots in an environment characterised by strong fluctuations in prey stocks supports the idea that adult birds can survive periods of below-average prey abundance. However, in a population that is close to carrying capacity, habitat reduction due to displacement could mean that displaced individuals may struggle to find alternative habitats that are not already fully occupied. This situation also has the potential for carry-over effects, as adults unable to find sufficient food during the non-breeding season may not be in adequate body condition to attempt to breed the following spring (Furness, 2013).

A distinct, post-breeding season needs to be considered for several species and species groups, such as auks, seaducks, gannets, and Manx shearwaters. For example, guillemots and razorbills swim away from their colonies in late summer, guiding their flightless chicks into offshore areas and moulting to become flightless themselves during late summer and autumn. Thus although individuals are able to travel further afield than during the breeding season, they cannot cover large distances rapidly, so increasing their vulnerability to displacement if considerable portions of their foraging habitat becomes unavailable and the availability of suitable habitat within range is limited. According to Langton (2013), displacement is unlikely to have an impact if foraging sites can be switched with no effect on foraging efficiency. The ecology of these species indicates the need to consider the post-breeding

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