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Effects of tidal currents on seabird foraging behaviour and diet in the North Sea

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INTRODUCTION

In the marine environment, the relationship between the abundance of shoaling fish and their availability to seabird predators remains poorly understood. Hydrography is a key driver of the spatial and temporal distribution of primary production and associated higher trophic levels, and thus plays an important role in predator-prey dynamics in the marine ecosystem (Hunt et al. 1999). In coastal temperate regions, variations in physical ocean structure are caused by the interaction of bathymetry, seasonal and diurnal cycles of solar irradiation, seasonal wind patterns and monthly and daily cycles of the tide (Mann & Lazier 1996). Tidal currents are among the most significant physical forces operating in these regions, and a number of studies have shown that the interaction between tidal forces and bathymetry plays a key role in the distribution of fish in the water column, and thus their availability to top predators (e.g. Brown & Gaskin 1988; Hunt et al. 1998; Irons 1998, Zamon 2001; Mendes et al. 2002).

We investigated the effects of bimonthly and twice-daily cycles of tidal currents, collected at offshore moorings, with the foraging ecology of black-legged kittiwakes *Rissa tridactyla* and common guillemots *Uria aalge*, two seabird predators with highly contrasting foraging techniques. The black-legged kittiwake is a surface feeder, whereas the common guillemot obtains food by diving. Tidal effects on fish behaviour are likely to impact very differently on these two species.

Black-legged kittiwakes are predicted to rely on tidal conditions that drive fish prey to the surface. These conditions will only occur under certain tidal regimes, in conjunction with wind and bathymetric effects (Mann & Lazier 1996). Further, species and/or age claseses of fish are predicted to be affected by hydrographic conditions in different ways, due to their differing ability to swim against currents (Hunt et al. 1999). Therefore, we obtained food samples fomr black-legged kittiwakes throughout the breeding season and examined diet composition in relation to the biweekly tidal cycle.

Common guillemots are able to exploit prey through the water column, and are not therefore under the same spatial constraints as the black-legged kittiwake. Common guillemot foraging depth may reflect the impact of tidal currents on prey distribution in the water column. Therefore, we attached electronic depth loggers to breeding common guillemots to test whether foraging depth was related to the twice daily cycle of the tide.

Our study area was in the western North Sea in proximity to the seabird breeding colony on the Isle of May, south-east Scotland. We present data from two contrasting years, 2001 and 2002. We found effects of tidal phase on diet and foraging depth at different temporal and spatial scales, and discuss how tidals currents may influence the availability of fish prey to seabirds.

METHODS

Black-legged kittiwake diet composition

This species regularly regurgitates on capture (Harris & Wanless 1997), giving information on prey species composition. Adult birds were caught on nests using a nylon noose attached to the end of an 8m telescopic pole. 144 samples were obtained from 8th May to 6th August 2001 and 118 from 16th May to 18th July 2002. Each regurgitate was digested in biological washing powder (Biotex). The remaining otoliths and fish bones were identified using keys (Härkönen 1986; Leopold et al. 2001). Calculating the proportion of different species' otoliths in regurgitates provides an estimate of species proportions in the diet. Every year up to the present, the lesser sandeel *Ammodytes marinus* has been the most frequent prey recorded (Harris & Wanless 1997; Lewis et al.

2001). Each sandeel otolith was measured along the maximum otolith diameter (MOD). The age class (0 group, 1 group or older) of each otolith was determined from otolith macrostructure using counts of annuli (ICES 1995).

Common guillemot diving behaviour

Nine common guillemots were equipped with PreciTD temperature-depth loggers (IDE, Kiel, Germany) from 23rd June to 3rd Jul 2001. In 2002, eight common guillemots were equipped with PreciTDs between 18th and 26th June.

The loggers recorded temperature and depth at 2s intervals, but in this paper we will discuss the latter only. The raw data were converted into true depths using device-specific regression equations. Depth was corrected for the baseline value by subtracting the most common pressure value on the sea surface between dives during a foraging bout from all depths. Average dive depth per dive was analysed for all recorded dives for the 17 birds using Multitrace (Jensen Software Systems, Kiel, Germany).

Turbulence

Three long term moorings were placed from March to October in 2001 and 2002 in the study area. The moorings were each equipped with a current meter. Data from the current meter, together with wind, irradiation and bathymetry, were fed into a 1D vertical coupled physical-biological model (adapted from Sharples 1999). The model provides an hourly estimate for tidal turbulence throughout the study period.

Data analysis

Initial examination of the data revealed interesting patterns of the presence of 0 group sandeels in the diet in relation to turbulence. Therefore, each otolith from black-legged kittiwake diets was coded as '1' for 0 group sandeel and '0' if not. We investigated the impact of the twice-weekly tidal cycle on black-legged kittiwake diet by entering each otolith present in samples, into a generalized linear mixed model (GLMM) with a binomial error distribution and logit link function (Schall 1991), with turbulence as independent effect and individual as random effect. We examined the effect of the twice daily tidal cycle on common guillemot foraging depth by entering the mean foraging depth for each dive into residual maximum likelihood analysis (REML - Patterson & Thompson 1971), with turbulence as fixed effect and individual as random effect.

RESULTS AND DISCUSSION

We will be presenting effects of tidal turbulence on black-legged kittiwake diet and common guillemot foraging depth. The twice weekly tidal cycle between spring and neap tides had important impacts on black-legged kittiwake diet composition during certain periods of the breeding season. On a daily scale, the tidal cycle had a strong impact on common guillemot foraging depth. We discuss mechanisms by which the patterns of the tide are driving the distribution and behaviour of fish and their predators at different temporal and spatial scales.

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