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The effects of environmental factors on daytime sandeel distribution and abundance on the Dogger Bank

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ABSTRACT

Spring distribution and abundance of lesser sandeels during the day were linked to zooplankton densities, seabed substrate and various hydrographic factors using small scale empirical data collected in two areas on the Dogger Bank in 2004, 2005 and 2006. The results of a two-step generalized additive model (GAM) suggested that suitable seabed substrate and temperature best explain sandeel distribution (presence/absence) and that sandeel abundance (given presence) was best described by a model that included bottom temperature, difference between surface and bottom temperature and surface salinity. The current study suggests that suitable seabed substrate explains sandeel distribution in the water column. Bottom temperature and surface salinity also played an important role in explaining distribution and abundance, and we speculate that sandeels favour hydrographically dynamic areas. Contrary to our hypothesis sandeels were not strongly associated with areas of high zooplankton density. We speculate that in early spring on the western Dogger Bank plankton is still patchily distributed and that sandeels only emerge from the seabed when feeding conditions near their night-time burrowing habitat are optimal. The results also suggested that when abundance is over a threshold level, the number of sandeel schools increased rather than the schools becoming bigger. This relationship between patchiness and abundance has implications for mortality rates and hence fisheries management.

1. Introduction

The effects of shelf hydrography on the distribution and abundance of pelagic schooling fishes have been the subject of many studies. Some examples in recent literature are Pacific sardines in Mexico (Robinson et al., 2004, 2007), sprat and herring in the Gulf of Finland (Peltonen et al., 2007), European Anchovy off Spain (Drake et al., 2007), European anchovy and sardine in the Bay of Biscay (Petitgas et al., 2006) and herring in the northern North Sea (Maravelias, 1997) and there are many more. Solar heat, tide, wind and topography in shallow seas influence the development of spatially and temporally changeable areas of mixed and stratified waters and frontal zones (e.g. Bo Pedersen, 1994). These features can affect pelagic species distribution and abundance through a variety of mechanisms such as nutrient and plankton availability (see e.g. Cushing, 1989; Scott et al., 2006) as well as egg and larval dispersal (Proctor et al., 1998). The distribution of pelagic fish is however a complex phenomenon and in addition to oceanographic features, other factors such as seabed substratum can also play an important role (Maravelias et al., 2000).

Often considered a semi-pelagic species, lesser sandeels (*Ammodytus marinus*) spend most of the year buried in the seabed, only to emerge into the water column briefly in the winter and for an extended period in spring and summer. During a brief spell from November to January the sexually mature (mainly age 2+) sandeels enter the water column to spawn. The spring and summer months are the main feeding period and sandeels display a diurnal behavioural pattern where they emerge during the day to form large schools feeding on a variety of zooplankton prey, and bury themselves in the seabed at night. This strategy is probably adopted to conserve energy (Winslade, 1974a,b) and to avoid predators. The full extent of what triggers sandeel emergence from the seabed during the spring and summer, is not known but temperature, light intensity and food availability have been found to play an important role under laboratory conditions (Winslade, 1974a,b,c). During this pelagic stage growth rates increase rapidly (Bergstad et al., 2002).

When buried in the seabed, lesser sandeels require a very specific substratum (Macer, 1966; Reay 1970; Wright et al., 2000; Holland et al., 2005), favouring coarse sand with fine to medium gravel and low silt content. Bottom depth and bottom current flow also play an important role (Wright et al., 1998). These preferences have been attributed to the importance of both sediment permeability and bottom roughness for interstitial water movements to provide adequate oxygen supplies. The availability of this habitat was found to be strongly associated with the distribution of sandeels in the sediment

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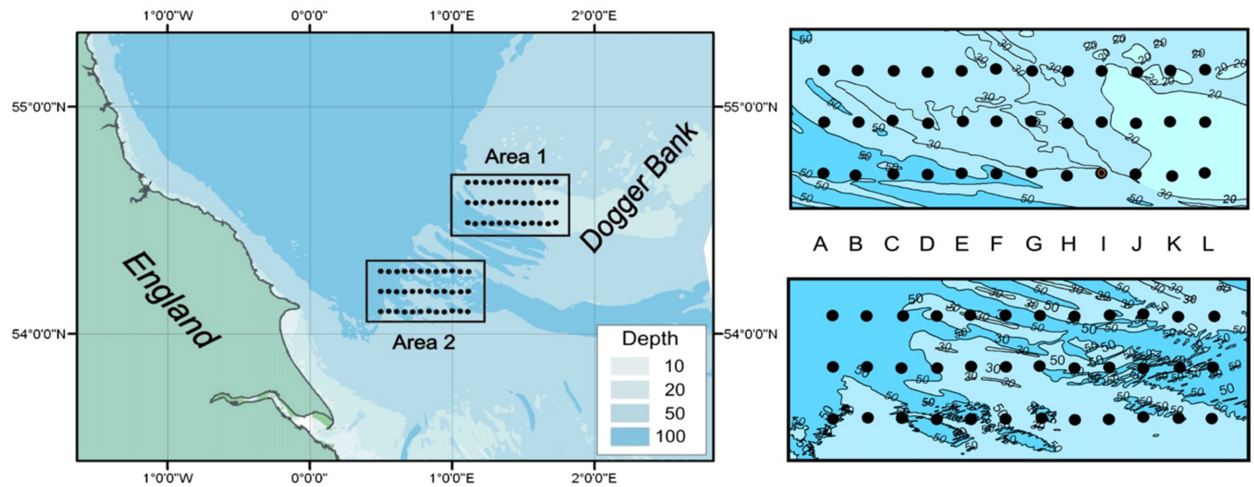

Fig. 1. Location of survey area showing the sample stations (●) and (right) detailed bathymetry maps of the two study areas. Each area consisted of a maximum of twelve approximately 18 km long transects A–L, 3.8 km spaced (see Table 1 for survey specific details).

in the northern North Sea and around Shetland (Wright et al., 2000; Holland et al., 2005).

Sandeels form an important trophic link between zooplankton and piscivorous predators and are also targeted by an industrial fishery. Although sandeels are preyed upon in the sediment (Hobson, 1986), it is more common when they are in transit to, or feeding in the water column. Here they are more readily available to a variety of mammalian, avian and piscean predators, and are under threat of pelagic trawls from the industrial fishery (Macer, 1966; Hobson, 1986; Engelhard et al., in press). In contrast to the well-documented characteristics of sandeel's seabed habitat, not much is known about the factors influencing sandeel distribution and abundance in the water column. This information is important for understanding and predicting the availability of sandeels to fisheries and predators (Frederiksen et al., 2007), by providing a better basis for spatially and temporally driven ecosystem-based management: Recent studies suggest that the North Sea lesser sandeels stock is divided into several reproductively isolated sub-stocks (Pedersen et al., 1999; Boulcott et al., 2007), which, in combination with spatially patchy fishing effort, makes them potentially vulnerable to local overexploitation.

Sampling sandeels in the water column using traditional methods such as trawls can be unreliable due to high variability in catches, particularly when abundance is low. Fisheries acoustics are often used in studies on pelagic fish species as they can provide a non-invasive, *in situ* insight into the species horizontal and vertical distribution in the water column. In this study we aimed to establish a qualitative relationship between acoustically derived data on sandeels in the water column and various environmental factors such as zooplankton, seabed substrate and hydrography using Generalized Additive Models. We hypothesise that sandeel distribution during the day is related to sandeel distribution in the seabed. As spring and summer are the main feeding seasons for sandeels we also expect sandeel distribution and abundance to be positively associated with areas of high zooplankton densities.

2. Materials and methods

2.1. Survey

The survey consisted of two areas in the southwestern Dogger Bank, central North Sea (Fig. 1). Area 1 covered an area known as the NW Riff, the western-most part of the Dogger Bank itself, and area 2, known as the Hills, was situated about 63 km southwest of area 1. Each area covered a maximum of approximately 800 km^2, with up to 36 sampling stations on regularly spaced North–South running transects. A total of three surveys were conducted in subsequent years each covering two weeks during spring and early summer (Table 1).

2.2. Sandeel data

Data on distribution and abundance of sandeel schools in the water column were collected using a calibrated dual frequency (38 and 120 kHz) splitbeam echosounder, stabilised for pitch and roll: a Simrad EK500 onboard the RV *Corystes* and an EK60 onboard the RV *CEFAS Endeavour*. Sandeels display strong diurnal behaviour patterns during spring (Freeman et al., 2004) so fisheries acoustic data were recorded during the morning from dawn until about 11:00 when the majority of sandeels were assumed to have entered the water column. Depending on the weather, the vessel steamed along transect with speeds of between 5 and 8 knots. To minimise temporal and spatial bias, each morning, two alternate transects were surveyed back to back (e.g. C and E), skipping one transect. After reaching the last transect, the remaining unsampled transects were surveyed in the opposite direction. Echograms from both frequencies were scrutinized and schools were selected using Sonardata Echoview's school detection module. Sandeel schools have a characteristic acoustic signature due to the absence of a swimbladder in this species. Their return echoes are less strong than those from clupeid schools (herring and sprat in this region) and produce a stronger signal on the high frequency (120 kHz) than on the low frequency (38 kHz) echograms. Sandeel backscatter was integrated (using 120 kHz data only at threshold of −65 dB) over 1 n.mi equidistant sampling units (EDSU) and biomass calculated using standard methods detailed in MacLennan and Simmonds (1992). Target strength (TS) values for sandeels were obtained from existing literature (see Mackinson et al., 2005) and validated with *in situ* TS measurements.

2.3. Zooplankton data

Each acoustic transect contained 3 sample stations, one at each end and one in the middle (Fig. 1). At each station a ringnet with 0.5 m radius (mesh 200 μm) and a mounted CTD profiler, measuring conductivity

Table 1
Surveys details

Year	Dates	Vessel	Transects	
			Area 1	Area 2
2004	19 April–5 May	*RV Corystes*	A–L	A–L
2005	6–18 May	RV *CEFAS Endeavour*	C–L	C–K
2006	10–19 May	RV *CEFAS Endeavour*	C–L	C–J+L