Journal of Sea Research 73 (2012) 1–6

Contents lists available at SciVerse ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Abundance analyses of mega-epibenthic species on the Dogger Bank (North Sea): Diurnal rhythms and short-term effects caused by repeated trawling, observed at a permanent station

Moritz Sonnewald *, Michael Türkay [1]

Biodiversity and Climate Research Centre (BiK-F), Senckenberganlage 25, 60325 Frankfurt am Main, Germany
Senckenberg Research Institute and Natural Histroy Museum, Marine Zoology, Crustacean Section, Senckenberganlage 25, 60325 Frankfurt am Main, Germany

ARTICLE INFO

Article history:
Received 20 October 2011
Received in revised form 16 May 2012
Accepted 26 May 2012
Available online 7 June 2012

Keywords:
Dogger Bank
North Sea
Megafauna
Diurnal rhythms
Trawling impact

ABSTRACT

Within our long term monitoring programme at the Dogger Bank (North Sea), a permanent station at the north-eastern tail end of the Dogger Bank was sampled yearly with a 2 m beam trawl since the year 1994. The sampling procedure was repeated every 3 h within a timeframe of 48 h. All species above a size of 1 cm were recorded quantitatively. The analysis of the dataset, consisting of thirteen sampling years, revealed rhythmic abundance fluctuations of one crustacean and two fish species, depending on the time of day. In order to check the accuracy of the results obtained, we further analysed the dataset for short-term effects of continuous trawling at the same track on the abundance of individual species. No direct effect on the abundance of particular species was detected, but the analysis revealed a periodic fluctuation of the mean number of individuals and the mean catch volume.

1. Introduction

The Dogger Bank is a sandbank in the central North Sea, covering an area of approximately 30.000 km². Except the detailed time series on the Dogger Bank infauna (Kröncke, 1988, 1990, 1992, 2011; Kröncke and Knust, 1995; Wieking and Kröncke, 2001, 2003, 2005), prior to our study there were no comparable long term data sets for demersal and epibenthic species. Since 1991, we are performing yearly summer research cruises on a grid of 37 (initially 40) fixed locations, covering an area of around 17,000 km² on the top of the bank within the 30 m depth contour (Fig. 1). Our main sampling gear, a 2 m beam trawl, is used at all stations to sample the (mainly epi-) benthic animals (Sonnewald and Türkay, 2012, in press; Türkay and Kröncke, 2004). The primary goal of the Dogger Bank long-term monitoring project was—and still is—to investigate long-term changes in the distribution and abundance of the Dogger Bank demersal species community and to look for connections with the general water temperature trend in this relatively uniform marine area.

During the first years of our programme, we also performed sporadic night sampling at some locations, observing faint differences in species composition and abundance compared to samples gained by day. As a first measure, we confined sampling to daylight to achieve a better comparability of our samples. Furthermore, we began to investigate in literature for studies concerning the influence of the time of day on the abundance of demersal and (epi)benthic species.

It is well known that the life rhythms of a broad variety of marine species underlie the periodicity of sun and moon, represented by light and tides (Tessmar-Raible et al., 2011).

On this understanding, Ferlin-Lubini and Ribi (1978) observed daytime-related activity patterns of burrowing Asteroids in the Mediterranean by means of scuba diving. Quinn and Kojis (1987) compared day and night fish and prawn samplings (3 m beam trawl) in an estuary of Papua New Guinea. Engås and Soldal (1992) compared differences in the catch rates of North Sea cod and haddock between day and night. A more comprehensive work was done by Petrakis et al. (2001), who investigated day–night differences in a broad variety of trawl samples from the North Sea concerning four different fish species.

In order to resolve possible diurnal rhythms of (epi)benthic and demersal Dogger Bank species, we decided to establish a permanent station (station 40), running since the year 1994 at the eastern tail end of the Dogger Bank, within the 30 m depth contour. Here, we sampled every 3 h during a timeframe of 48 h on each cruise. After thirteen years of successive sampling at station 40, we detected distinct daytime-related abundance patterns in one crab and two fish species, included herein.

Since we kept the respective sampling track as constant as possible within each cruise, we were also in need to analyse and exclude the direct effects of continuous beam trawl sampling at the same

* Corresponding author. Tel.: +49 69 7542 1559; fax: +49 69 746238.
E-mail addresses: Moritz.Sonnewald@Senckenberg.de (M. Sonnewald), Michael.Tuerkay@Senckenberg.de (M. Türkay).
[1] Tel.: +49 69 7542 1240; fax: +49 69 746238.

1385-1101/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.seares.2012.05.015

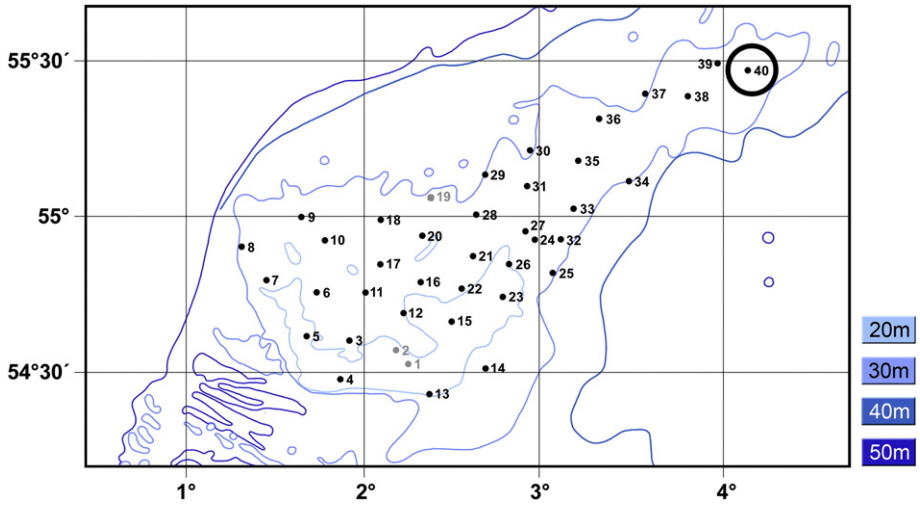

Fig. 1. The Dogger Bank with the associated sampling stations. The 48-h station 40 (55°28,3′N 4°10,6′E) is marked with a black circle. In winter 2010 (DOGR), station 7 was also chosen as 48 h-station. Stations 1, 2 and 19 were skipped after the first cruise in 1991 for reasons of improper seafloor. These are not involved in this study.

track (like e.g. overfishing) on the epibenthic animals during this rather short period of time, as these effects were supposed to interfere with the analysis of diurnal abundance variations.

The fact that trawling causes long term disturbance effects on epibenthic (and endobenthic) communities is widely known and observed (Bergman and Hup, 1992; Callaway et al., 2002; Collie et al., 1997; Freese et al., 1999; Hinz et al., 2009; Jennings et al., 1999, 2001; Jones, 1992; Kaiser et al., 1998; Thrush and Dayton, 2002; Tillin et al., 2006). Interestingly, the direct short-term effects by repeated trawling seemed to be much less studied. Our analyses showed no observable short-term impact on the abundance of individual species, but they revealed some interesting insight into the effects of repeated sampling on the mean number of individuals and catch volume, included in the present work.

2. Materials and methods

2.1. Sampling procedure

At station 40 (trawl starting point at 55°28′ N, 4°11′ E, depth range: 26.9–31.3 m, depth average from all 48 h samplings: 29.3 m) of our sampling grid at the Dogger Bank (Fig. 1), the following, standardised procedure was repeated every 3 h, during 48 h, since 1994. Our standard sampling gear, a 2 m beam trawl (BT) with a mesh size of 1 cm² in the cod end, was deployed and towed for one nautical mile at two knots of speed over a pre-defined transect. The transect location and direction differed slightly between years, depending on the weather conditions, but were kept the same within each 48 h sampling cycle. After each pass, the catch was photo-documented, its wet volume was quantified and it was sieved to separate the megafauna (>1 cm) from the fine fractions, which were preserved in a 4% formaldehyde-sea water solution for later analysis. The megafauna was sorted, identified to species level and counted on board ship. Undetermined or scientifically interesting megafaunal species were also preserved in a 4% formaldehyde-sea water solution for final lab determination and census. Finally, the combination of field and lab data led to a quantitative species dataset.

2.2. Data processing

Only the 48 h-data of 13 successful summer cruises (July/August 1994–1997, 1999, 2001–2004, 2006, 2008–2010) were used for the present analyses. We did not take into account incomplete data sets due to bad weather conditions, which occurred in 1993, 2005 and 2011. To ensure seasonal comparability, we also omitted the 48 h data from our winter sampling cruises. The species abundance data from our 48 h samplings were first analysed for recurring periodic patterns of abundance changes within a day. In order to gain adequate species numbers to support further analyses, we omitted all species that were missing on more than six 48-h sampling periods (>50%) and were represented with less than 20 individuals per cruise at station 40. This treatment resulted in seven species being available for statistical analyses: *Liocarcinus holsatus* (Fabricius, 1798); *Pagurus bernhardus* (Linnaeus, 1758); *Asterias rubens* Olivi, 1792; *Astropecten irregularis* (Pennant, 1777); *Ophiura albida* Forbes, 1839; *Buglossidium luteum* (Risso, 1810) and *Limanda limanda* (Linnaeus, 1758). For all samplings, the mean time of sampling was determined, using the temporal means of the beginning (end of BT descent) and end (beginning of BT ascent) of sampling. Respectively, the mean sampling time was linked with the abundance of each of the seven species being considered. In a one-way analyses of variance (ANOVA) and a Bartlett's test for equal variances (Snedecor and Cochran, 1989), we statistically determined if the overall abundance variation of the seven species suggested further analyses. As the results showed highly significant variation inbetween the groups (species), we used a Fourier analysis (more precisely a linear combination of sin(2 pi t/24), cos(2pi t/24), sin(2pi 2 t/12) and cos(2pi 2 t/12)) to fit a trigonometric polynomial of degree two to the hourly abundance data of each cruise, with the null hypothesis (that the coefficients of

Table 1
p-Values for the goodness of fit of the model curves in Figs. 3, 5 and 7, sorted by species and year. Bold emphasis: significant values.

Species/year	1994	1995	1996	1997	1999	2001	2002	2003	2004	2006	2009	2010	Mean
Liocarcinus holsatus	0.068	**<0.001**	**<0.001**	**0.004**	**<0.001**	**0.002**	**0.027**	**<0.001**	**<0.001**	**0.009**	**<0.001**	**<0.001**	**0.009**
Buglossidium luteum	**0.013**	**0.018**	**0.03**	**0.016**	**<0.001**	**<0.001**	**0.019**	0.83	**0.02**	0.064	**0.002**	**0.004**	0.084
Limanda limanda	**0.027**	0.18	0.11	0.87	**0.025**	**0.001**	**0.026**	0.093	**0.051**	0.72	0.1	0.52	0.23
Astropecten irregularis	0.18	**0.01**	0.25	0.21	0.16	0.12	0.14	0.16	0.051	**0.005**	0.13	**0.006**	0.12
Ophiura albida	0.09	**0.015**	0.68	n/a	0.7	0.44	n/a	0.1	n/a	0.44	n/a	n/a	0.35