Journal of Sea Research 85 (2014) 18–28

Contents lists available at ScienceDirect

Journal of Sea Research

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

Trophic look at soft-bottom communities — Short-term effects of trawling cessation on benthos

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ARTICLE INFO

Article history:
Received 14 February 2013
Received in revised form 23 September 2013
Accepted 27 September 2013
Available online 9 October 2013

Keywords:
Trawling Impact
Trophic Functioning
Stable Isotopes
Energy Flow
Macrozoobenthos
North Sea

ABSTRACT

The trophic structure of the German Bight soft-bottom benthic community was evaluated for potential changes after cessation of bottom trawling. Species were collected with van-Veen grabs and beam trawls. Trophic position (i.e. nitrogen stable isotope ratios, $\delta^{15}N$) and energy flow (i.e. species metabolism approximated by body mass scaled abundance) of dominant species were compared in trawled areas and an area protected from fisheries for 14 months in order to detect trawling cessation effects by trophic characteristics. At the community level, energy flow was lower in the protected area, but we were unable to detect significant changes in trophic position. At the species level energy flow in the protected area was lower for predating/scavenging species but higher for interface feeders. Species trophic positions of small predators/scavengers were lower and of deposit feeders higher in the protected area. Major reasons for trophic changes after trawling cessation may be the absence of artificial and additional food sources from trawling likely to attract predators and scavengers, and the absence of physical sediment disturbance impacting settlement/survival of less mobile species and causing a gradual shift in food availability and quality. Our results provide evidence that species or community energy flow is a good indicator to detect trawling induced energy-flow alterations in the benthic system, and that in particular species trophic properties are suitable to capture subtle and short-term changes in the benthos following trawling cessation.

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1. Introduction

Fishing, in particular bottom trawling, is one of the most severe anthropogenic impacts on marine environments (Dayton et al., 1995; Jennings and Kaiser, 1998; Thrush et al., 2001). Besides the removal of fish and bycatch, bottom trawling has two major impacts on benthic communities: (i) a direct physical effect that causes sediment disturbance and resuspension (Jennings et al., 2001b; Watling et al., 2001) as well as dislocation, damage and mortality of benthic organisms (e.g. Bergman and van Santbrink, 2000; Ramsay et al., 2000); and (ii) an indirect trophic impact through fishery bycatch and discards which become a significant additional food source for scavengers and predators (Arntz and Weber, 1970; Groenewold and Fonds, 2000; Rumohr and Kujawski, 2000). Long-term bottom trawling pushes benthic communities towards smaller, short-lived and fast growing species. After at least five decades of intense trawling in the North Sea (Lindeboom and de Groot, 1998; Rijnsdorp et al., 1998) changes add up to a shift from high to low diversity and from a high biomass–low turnover to a low biomass–high turnover system (Callaway et al., 2007; Hiddink et al., 2006a; Kaiser et al., 2002).

Particularly in coastal zones with a long fishing history it is difficult but not impossible to identify distinct and persistent effects of bottom trawling (De Juan et al., 2007; Gray et al., 2006; Thrush and Dayton, 2002), as long-term frequent trawling might have created a highly artificial benthic system with a trophic structure which is resistant against environmental stressors (Jennings et al., 2001a; Menge and Sutherland, 1987; Yachi and Loreau, 1999). Moreover, shallow coastal marine systems can be extremely dynamic in terms of hydrographic conditions. Abundance, biomass and species inventory are shaped by seasonal and year-to-year variability, governed by and adapted to abiotic and biotic forcing factors (Clark and Frid, 2001; Kröncke et al., 2001). Last not least, bottom trawling itself creates variability by an uneven distribution of trawling impact in space and time (e.g. Rijnsdorp et al., 1998). Hence, artificial robustness of the benthic system and statistical "noise" are principal problems of studies on trawling effects in shallow water systems, particularly in sandy habitats, but see e.g. Cranfield et al. (1999), Wolff (2005) and Reise (2005) as examples for distinct trawling effect on mussel beds in dynamic environments.

Biological traits of the constituting species (e.g. Collie et al., 2005; Tillin et al., 2006), species trophic properties and species-dependent trophic properties (e.g. energy flow patterns) are of particular significance to detect trawling effects. Several studies of the last decade, therefore, focused on changes in habitat complexity (e.g. levelling habitat structure along with species loss, see Thrush et al., 2001; Thrush and

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http://dx.doi.org/10.1016/j.seares.2013.09.005

Dayton, 2002), on community size spectra, trophic positions and derived energy flow patterns (Hiddink et al., 2006a; Jennings et al., 2001b, 2002a), as well as on benthic community functioning as indicated by biological trait composition (e.g. Blanchard et al., 2004; Tillin et al., 2006). Previous studies of trawling effects on trophic structure suffered from methodological problems: they either compared subsystems only, such as fish communities (e.g. Badalamenti et al., 2002) and/or lacked appropriate untrawled reference sites (e.g. Jennings et al., 2001a, 2002b). However, working at coarser systematic resolution (e.g. feeding guilds) might not be sufficient to capture subtle and/or short-term changes (e.g. within a few years; see Queirós et al., 2006; Tillin et al., 2006).

Hence, trophic properties at the species level might be more sensitive to detect effects of trawling. On the one hand, many ecological studies provided evidence that trawling does not only cause direct mortality, but also alters the physical and biogeochemical composition of the sediment and causes trophic distortion by food input (discards and gear-induced mortality) which, finally, affects the benthic ecosystem to a certain extent as a whole (Jennings and Kaiser, 1998; Malakoff, 2002). On the other hand trophic interactions between organisms are an important basis of ecological functioning (Cohen, 1978; May, 1974; Pimm, 1982), and these interaction patterns entail communities' ability to cope with perturbations (e.g. Dunne et al., 2002).

The construction of the research platform FINO 1 in the German Bight (North Sea) and the concurrent closure of the site for fishery in the year 2003 provided for the first time the opportunity to compare the development of benthic communities at one protected site and further trawled sites in the German Bight. In this study, we investigate whether changes in the trophic structure of a shallow sand-bottom community after cessation of trawling can be measured based on species trophic properties (e.g. trophic position: species vertical trophic position within the trophic hierarchy) and species-dependent trophic properties (e.g. energy-flow pattern). We evaluate whether these trophic properties are suitable to detect trophic alterations (e.g. trophic distortion and sediment biogeochemistry changes) after short-term closure (only 14 months) of fishery.

2. Material and methods

2.1. Study site

In July 2003, the research platform FINO 1 was built as a pilot project for future offshore wind farms. The platform is located at 28 m water depth in the German Bight, 45 km off the Island Borkum (Fig. 1). The surroundings of the platform (500 m radius) are closed for all shipping activities (except scientific activities) and are thus protected from fisheries (for further details see Dannheim, 2007).

Beam trawling is the predominant type of fishery in this part of the German Bight, targeting sole (*Solea solea*) and plaice (*Pleuronectes platessa*). Seasonal patterns in trawling intensity are attributed to seasonal migration of target fish stocks (see Pastoors et al., 2000; Piet and Rijnsdorp, 1998). To estimate the impact of trawling in the study area, trawling intensity was calculated by means of the satellite-based "Vessel Monitoring System" for the main operating fleets (VMS-data for Dutch and German fleet; unpublished data provided by S. Ehrich, Federal Research Centre for Fisheries and by G. Piet and F. Quirins, Netherlands Institute for Fisheries Research). Trawling intensity was calculated as times trawled month^{-1} (i.e. $\times$ spot^{-1}) following Rijnsdorp et al. (1998). There were no spatial trends or differences in trawling intensity detectable between the study sites prior to closure, i.e. seasonality is the major determinant of trawling intensity (Fig. 2, see Schröder and Dannheim, 2006).

Sampling areas (Fig. 1) were defined as follows: The "protected area" (hereafter referred to as PA) comprised the zone between an inner circle of 150 m radius and an outer circle of 400 m radius around the platform, i.e. an area of about 0.43 km^2. These distances from the

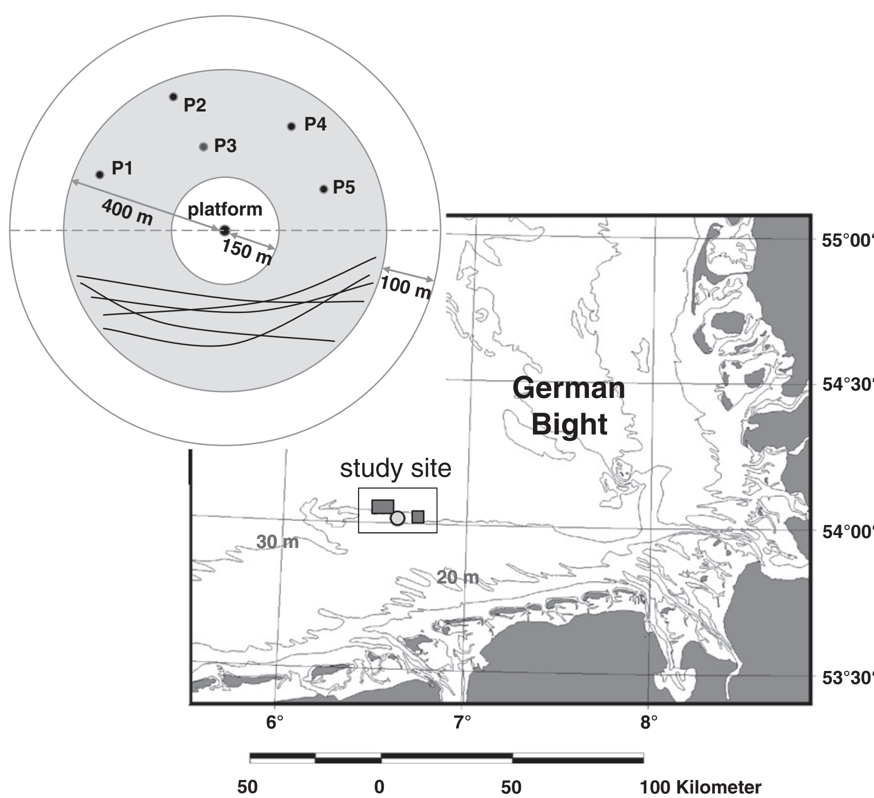

Fig. 1. Study site in the German Bight with the two trawled areas (dark grey squares) and the protected area (light grey circle). The upper left circle shows the sampling scheme in the protected area, the zone between an inner circle of 150 m radius and an outer circle of 400 m radius around the platform. P: grab sampling stations north of the platform, grey lines: exemplary beam-trawl tracks south of the platform.

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