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Short-term effects of fishery exclusion in offshore wind farms on macrofaunal communities in the Belgian part of the North Sea

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ABSTRACT

With the wide scale construction of offshore wind farms (OWFs) throughout the entire North Sea, large areas are permanently being closed to beam trawl fisheries. Beam trawling has affected macrobenthic assemblages for centuries, especially the fragile and long-lived species. Due to the prohibition of bean trawling in many OWFs, opportunities are being provided to investigate the potential recovery of vulnerable species and the creation of de-facto Marine Protected Areas (MPAs). The soft-substrate macrobenthic community was investigated from 2008 to 2012, before and after the construction of an OWF in the Belgian part of the North Sea, situated on the Bligh Bank. The fishery enclosed area (±21 km^2) within the OWF (No Fishery area) was compared with a surrounding control area (±30 km^2) where regular fishing activities were registered through vessel monitoring system (VMS) data throughout the period 2010–2011. Three years after the exclusion of beam trawl fisheries, subtle changes within the macrobenthic community were observed in the No Fishery area. The benthic mysid shrimp *Gastrosaccus spinifer* (30 ± 15 ind m^{-2}), tube-building polychaetes Terebellidae sp. (196 ± 151 ind m^{-2}) and the echinoderm *Echinocyamus pusillus* (73 ± 71 ind m^{-2}), sensitive to trawling activities, showed increased abundances within the No Fishery area. With an expansion of the wind farm concession area to 238 km^2 in the future, the likely increase of dense Terebellidae patches (e.g., *Lanice conchilega* reefs) within the No Fishery area could create an ecological important large-scale refugium for higher trophic levels. This study creates a baseline for the evaluation of long-term changes due to the fishing impacts and effects related to the presence of OWFs and highlights the importance of executing long-term monitoring programs in combination with targeted research.

1. Introduction

The development of offshore wind farms (OWFs) across the North Sea is increasing rapidly to create renewable energy sources as alternative for fossil fuels (Pineda et al., 2015). The seascape of the Southern North Sea is being altered in a large area, causing unknown and cumulative effects to the marine environment at different scales (Lindeboom et al., 2015). Environmental impacts of OWFs to the soft-substrate macrofauna can be divided into relatively short-term effects (several months) during the (pre)-construction phase (Coates et al., 2015) and effects related to the much longer (>20 years) operational phase. The construction phase mainly impacts the macrobenthic communities due to the physical disturbance of the seabed during preparation works e.g., dredging activities. Coates et al. (2015) illustrated a rapid (1–2 years) recovery potential of macrobenthic communities on a subtidal sandbank in the Belgian part of the North Sea (BPNS) after construction of six offshore wind turbines. The operational phase of an OWF could impact the soft substrate macrofaunal community due to the prohibition of beam trawl fisheries in many OWFs. The North Sea has been heavily trawled for centuries with an increasing trend in the 1960s and 1970s (de Groot, 1984; Jones, 1992; Kaiser et al., 2002). Beam trawling has a direct physical impact by scraping and ploughing the seabed at least up to a depth of 3–6 cm, re-suspending sediments and removing or damaging non-targeted benthos (Bergman and Hup, 1992; Dayton et al., 1995; Jones, 1992; Rabaut et al., 2008). Over the past decades, macrofaunal assemblages in heavily trawled areas have shifted towards an alternative stable state with a dominance of opportunistic, short-lived and fast-growing species with high reproduction rates (Collie et al., 2000;

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Frid et al., 2000; Jennings et al., 2001; Kaiser et al., 2002; Kaiser and Spencer, 1996). Furthermore, additional food supplies due to bycatch discards (Enever et al., 2007) attract and increase abundances of scavenging and predatory species (e.g., *Asterias rubens* and *Pagurus* sp.) to these fishing areas (Dannheim et al., 2014; Rumohr and Kujawski, 2000).

Long-term changes and potential recovery of the macrofauna are not only dependent on the frequency and scale of trawling but also on the nature of the sediments and the existing resilience to natural disturbances (Collie et al., 2000; Kaiser et al., 2002). Macrofaunal assemblages in sandy substrates are adapted to the high natural stress of the area due to strong tidal currents and frequent storms (Rijnsdorp et al., 1998), leading to a faster recovery after the physical disturbance of anthropogenic activities (Bonne, 2010; Coates et al., 2015). However, these substrates are mostly located in areas which have been subjected to frequent trawling for centuries (Kaiser et al., 2002; Rijnsdorp et al., 1998). Slow-growing or fragile macrofaunal species living in the upper layer of sandy sediments such as certain bivalves (e.g., *Spisula* sp.), echinoderms (e.g., *Echinocardium cordatum*) and tube forming polychaetes (Terebellidae sp.) are known to be highly vulnerable to frequent trawling activities and have declined in abundance throughout the past century (Bergman and Hup, 1992; de Groot, 1984; Jennings et al., 2001; Kaiser and Spencer, 1996; Kröncke, 2011; Tuck et al., 1998). A long-term study on the Dogger Bank, a fine sandy bank in the Southern North Sea, owed the disappearance of dense *Spisula* and *Mactra* patches throughout the 20th century to the increased fishing pressure (Kröncke, 2011). Kröncke (2011) observed the random occurrence of new patches which would disappear after weeks or months most likely due to fishing pressure. These results suggest the viable ability of such bivalves to re-establish dense patches if trawling would be prohibited over longer periods. In the Irish Sea, Kaiser and Spencer (1996) observed a higher abundance of tube building polychaetes such as *Lagis koreni* and Terebellidae sp. in unfished areas in comparison to fished areas. Likewise, video analysis in a closed sandy Bay off the coast of Scotland revealed a higher number of *Lanice conchilega* (Terebellidae sp.) beds in comparison to a Bay open to frequent trawling (Defew et al., 2012). The higher occurrence of these habitat-structuring beds would lead to the development of a more diverse community as closely associated species of the *L. conchilega* beds (e.g., *Eumida sanguinea*) are known to be highly sensitive to fishery impacts (Rabaut et al., 2008). The long-term prohibition of beam trawling within OWFs could provide fragile and long-lived species with the space and time to re-establish and recover. With the predicted expansion of the size and amount of constructed OWFs in the Southern North Sea (Pineda et al., 2015), OWFs could develop into important conservation areas for macrobenthic communities (Hammar et al., 2016) increasing the overall habitat complexity and biodiversity of the area (Defew et al., 2012).

At present, three OWFs have been constructed in the Belgian part of the North Sea (BPNS). The OWF constructed on the Bligh Bank was the first to cover a large area with 55 monopile foundations. Within the Belgian OWFs all vessels, including beam trawl fisheries, are prohibited. Data from the satellite based Vessel Monitoring System (VMS) are used to estimate fishing effort over time (Foden et al., 2010). VMS data provides information on the position of fishing vessels larger than 15 m (Mills et al., 2007). Vandendriessche et al. (2013b) investigated the presence of Belgian, Dutch and British fishing vessels around the Belgian OWFs based on VMS data and visual observations of smaller vessels (<15 m). In the BPNS, a maximum of 401–800 VMS registrations have been detected per grid cell (3 km^2) per year, with a decreasing trend (51–200 VMS registrations) in more offshore areas. Inside the Bligh Bank OWF, 1–50 VMS registrations per grid cell were observed in 2010 and 2011. In 2011, a slight increase in fishing pressure was observed around the wind farm with 51–100 registrations per grid cell.

Until now, the macrofauna has not been investigated within a large area closed to fishery activity in the BPNS before. The OWF creates an ideal situation to record and closely follow-up any macrobenthic recovery processes related to the prohibition of beam trawl fisheries during a long period and potentially act as a defacto Marine Protected Area (MPA) in the future (Hammar et al., 2016). The macrofaunal species inhabiting the sandy substrates of the Bligh Bank form a typical community for the BPNS which has adapted to the natural stress of the area and anthropogenic impacts (e.g., beam trawl fisheries) (Reubens et al., 2009). The recovery potential of macrofaunal communities in sandy sediments have only been derived from short-term experimental trawling studies. Collie et al. (2000) suggested a recovery potential of 100 days after one trawling event for a macrobenthic community dominated by short-lived species. With a clear history of frequent trawling in the southern North Sea and an average rate of 2–3 disturbances per year (Collie et al., 2000), a much longer recovery time is expected (Rijnsdorp et al., 1998). Recovery rates of 12 months to 4 years after sediment extraction in terms of abundance and diversity (Newell et al., 1998) could suggest a possible timeframe for the increased recruitment of long-lived and fragile organisms inside fishery excluded areas (Hiddink et al., 2006).

The soft sandy sediments and accompanying macrofauna were sampled around (control area) and inside (No Fishery area) the Bligh Bank OWF before construction (2008), during (2009) and 2–3 years after construction and implementation of fishery exclusion (2011–2012). After three years of fishery exclusion, we hypothesize that the macrofaunal community inhabiting the sandy substrates of the Bligh Bank will demonstrate first signs of recovery, with an increase in abundance of known fragile and long-lived macrobenthic species to the area.

2. Material and methods

2.1. Study area

The Belgian OWF concession zone is situated at the eastern side of the BPNS (Fig. 1). The Bligh Bank belongs to the most eastern part of the Hinder Banks, approximately 40–50 km offshore. The construction of the first phase of the Bligh Bank OWF commenced in 2009 and was completed early in 2010. The OWF consists of 55 monopile foundations with a total capacity of 165 MW. The foundations are located 500–650 m apart from each other at a water depth ranging between 15–40 m. All vessels including beam trawl fisheries have been excluded from this area since 2009 with a 500 m safety radius around the OWF (Fig. 1 Blue area), creating a large area of approximately 21 km^2 closed to fisheries.

2.2. Sampling design and treatment

A Before, After Control Impact (BACI) design was applied with the baseline study (before) carried out in 2008. Since then, samples were collected in autumn (September–October) in 2009 (construction year), 2011 and 2012 (Table 1). Samples could not be obtained in 2010 due to the prohibition of the research vessel into the wind farm. The collected samples on the Bligh Bank were divided into two areas: the No Fishery area inside the 500 m exclusion zone (±21 km^2) and a control area outside the exclusion zone (±30 km^2). All stations were positioned to cover the entire area, including the gullies and tops of the sandbanks. Samples were collected inside the No Fishery area from a small survey vessel (Geosurveyor IV) in 2011 and the R.V. Simon Stevin in 2012. All other samples were obtained from the R.V. Belgica.