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Short communication

Aggregation and feeding behaviour of pouting (*Trisopterus luscus*) at wind turbines in the Belgian part of the North Sea

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ABSTRACT

A substantial expansion of offshore wind farms in the North Sea has been planned, inducing a growing interest in the effects of these artificial habitats on the marine environment. Numerous researches have been done to consider the possible effects of wind farms. However, to date little research investigated actual effects on the ichthyofauna.

This study provides the first insights into the use of the artificial hard substrates by *Trisopterus luscus* (pouting) at the Thorntonbank wind farm in the Belgian part of the North Sea.

Scuba diving operated visual surveys around one wind turbine revealed a distinctly higher pouting population size and biomass (i.e. 22 000 individuals yielding a total biomass of 2700 kg) as compared to the population size present at the soft sediments surrounding the wind turbines. Stomach content analyses further demonstrated the dietary preference for prey species that lived on the turbines (i.e. *Jassa herdmani* and *Pisidia longicornis*). Yet, the present study clearly demonstrates that wind turbines built at sea may attract fish populations considerably, possibly related to the enhanced provision of resident food items on the turbines.

1. Introduction

An enhanced demand for green energy resources has stimulated the implementation of wind turbines at sea. These wind turbines may provide a suitable habitat for hard substrate dwelling fish (Bohnsack, 1989; Bull and Kendall Jr, 1994; Fabi et al., 2006; Leitao et al., 2007) since hard substrates, e.g. shipwrecks and other artificial reefs, have been reported to attract and concentrate fishes and/or to enhance local fish stocks (Bohnsack, 1989; Leitao et al., 2008, 2009; Pickering and Whitmarsh, 1997). Several mechanisms may stimulate this behaviour, including (1) shelter against currents and predators (Bohnsack, 1989; Jessee et al., 1985), (2) additional food provision (Fabi et al., 2006; Leitao et al., 2007; Pike and Lindquist, 1994), (3) increased feeding efficiency and (4) provision of nursery and recruitment sites (Bull and Kendall Jr, 1994).

The construction of the first wind farm in the Belgian part of the North Sea (BPNS) was initiated in 2008 at the Thorntonbank, a natural sandbank 27 km offshore. At present, six gravity-based foundations have been built. In the near future a total of 54 wind turbines will be constructed on this sandbank, creating an area of 0.0864 km^2 of artificial hard substrate and by 2020 more than 200 wind turbines will be present in the BPNS (Degraer and Brabant, 2009). The frequent observations of several fish species such as *Trisopterus luscus* (Linnaeus, 1758) (pouting), *Gadus morhua* (Linnaeus, 1758) (cod), *Dicentrarchus labrax* (Linnaeus, 1758) (sea bass), *Scomber scombrus* (Linnaeus, 1758) (mackerel), *Trachurus trachurus* (Linnaeus, 1758) (horse mackerel) and *Pollachius pollachius* (Linnaeus, 1758) (pollack) in close proximity of ship wrecks in the BPNS (Mallefet et al., 2007; Zintzen et al., 2006) illustrates that artificial hard substrates may influence fish population distribution in the BPNS. However, (1) quantitative information on the fish community structure around the windmill artificial reef (further referred to as WAR) and (2) knowledge on the trophic relationships between fish species and resident organisms on the WAR do currently not exist for the BPNS. This is the first study that investigates the density and diet of a commercially important demersal fish, i.e. pouting, in the vicinity of a WAR in the BPNS.

2. Materials and methods

2.1. Study site and data collection

The density and diet of pouting occurring around the foundation of one wind turbine (coordinates WGS 84: 51°32.88′N–2°55.77′E) at the Thorntonbank was monitored in July–October 2009. The foundation has a diameter of 6 m at the sea surface expanding to 14 m at the seabed, about 25 m deep at high tide. The foundation is

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Table 1
Overview of the nine visual surveys performed at one wind turbine to estimate pouting density. Each column represents a survey. Each number (individuals/m^2) in the same column is assessed by one observer. Within a survey all observations were made at the same position.

	Period								
	July	July	July	August	September	September	September	October	October
Individuals/m^2	9	9	2	7	9	44	11	11	16
	11	7	20		32	22	6		
		4							
Visibility range (m)	3	3	5.1	3.7	2	1.2	3.4	3	2

surrounded by a scour protection layer that consists of two coats: a filter layer, made up by pebble (2.5 mm up to 75 mm) which is overtopped by the armour layer that consists of a protective stone mattress with rocks (250 mm up to 750 mm). The armour layer has a diameter of 44 m (1600 m^2). The surrounding soft sediment is composed of medium sand (mean median grain size 374 μm, SE 27 μm) (Reubens et al., 2009).

Nine underwater visual censuses were carried out on the scour protection by applying a variation of the stationary sampling method (Bannerot and Bohnsack, 1986) to count pouting. Observers rotated around themselves for 180°. Fish behind the divers were not counted. Each survey lasted up to 20 min or until no new activity was recorded for 2 min and took place 4 h after high tide or 2 h before high tide. Before each survey the average visibility was estimated by tape measure and used as the radius of the area observed. Observations were limited to the first meter above the seabed and within a survey all observations were made at the same position. If large schools of fish were present, abundance groups were used to count the number of individuals since this technique considerably facilitates the enumeration process and lessens the chance of error (Bortone and Kimmel, 1991). In addition, fish lengths were assessed by comparing the fishes to a ruler attached to a writing board. The surveys were unevenly distributed over the monitored period as diving was weather dependant (Table 1). As only one wind turbine was surveyed, extrapolation of the results should be considered with care.

To quantify the contribution of preys on and around the wind turbine foundation to the diet of pouting line fishing was conducted. Angling (hooks: Arca, size 4; bait: *Arenicola marina*) was performed 1–10 m away from a turbine (i.e. within the erosion protection layer radius) just above the bottom of the seabed, assuring catching individuals hovering at the WAR. After the fish were measured (total length) and weighed (wet weight), stomachs were removed and preserved in an 8% formaldehyde–seawater solution. All food components in the stomachs were identified to the lowest possible taxonomic level. Dry weight (60 °C for 48 h) and ash free dry weight (500 °C for 2 h) were measured for all separate food contents in each stomach.

2.2. Data analysis

To assess the pouting population dimension on the scour protection the number of fish per square meter in the area observed was multiplied by the surface of the armour layer, which covers an area of 1600 m^2, since it was assumed that the fish were evenly distributed across the scour protection.

Dietary composition was assessed by the occurrence (%FO) and abundance (%*A*) indices (Hyslop, 1980). The abundance index can be either numeric (%*N*) or gravimetric (%*G*). For the gravimetric analysis ash-free dry weight (AFDW) was used.

$$\%FO_i = \frac{N_i}{N} \times 100$$

$$\%A_i = \frac{\sum S_i}{\sum S_a} \times 100$$

N_i is the number of predators with prey type i in their stomach, N the total number of non-empty stomachs, S_i is the stomach content composed by prey i and S_a the total stomach content of all stomachs together (Amundsen et al., 1996). In addition, the feeding coefficient ($Q = \%N \times \%G$) (Hureau, 1970) and the index of relative importance ($IRI = (\%N + \%G) \times \%FO$) (Pinkas et al., 1971) were used to evaluate the dietary importance of each prey category.

To investigate the feeding strategy of pouting and the importance of prey items in their diet, the multivariate Principal Component Analysis (PCA) was used. Prior to analysis the numeric and gravimetric community abundance data were standardised (De Crespin de Billy et al., 2000) and a similarity matrix was constructed using the Bray–Curtis index of similarity. To investigate seasonality in feeding behaviour, similarities between and within species assemblages were assessed for each sampling period by the analysis of similarity (ANOSIM) (Clarke and Gorley, 2006). Statistical analyses were performed using the Plymouth routines in multivariate ecological research (PRIMER) package, version 6.1.6 (Clarke and Gorley, 2006). A significance level of $p < 0.05$ was used in all tests.

3. Results

3.1. Pouting density assessment

Pouting was present at all surveys near the wind turbine foundation. Densities varied between 2 and 44 specimens/m^2 (Table 1) with an average density of 14 ± 11 individuals/m^2 on the scour protection yielding an average local population of 22 000 individuals near one wind turbine foundation. A large variation in densities, however, was detected both between observers and over time (Table 1). Both juveniles (<22 cm total length) and adults were present at the WAR, since the estimated size ranged between 15 and 35 cm (with an average of 20 cm). Based on a Length–Wet weight relationship (Merayo and Villegas, 1994), the population had a biomass of 2700 kg.

3.2. Contribution of WAR to diet of pouting

Caught fish weighed 70 g up to 345 g and lengths varied between 17.1 cm and 29.2 cm, which indicates they belonged to year class 1–3 (Heessen and Daan, 1996; Merayo and Villegas, 1994). Of the 72 stomachs analysed, five were empty (6.9%). The diet of pouting contained a wide variety of prey items: 41 prey types were identified, although 17 occurred only once in the stomachs analysed (Table 2). *Jassa herdmani* and *Pisidia longicornis*, both hard substrate associated prey items, occurred most in the stomachs (%FO > 35%), while Brachyura sp., fish scales, *Mytilus edulis*, *Liocarcinus holsatus* and *Phtisica marina* were also frequently preyed upon (%FO > 10%). *Q* and IRI indicated that *J. herdmani* and *P. longicornis* were the most important prey species contributing to the diet of pouting (Table 2). Numerically, *J. herdmani* (84.6%) was most important, followed by *P. longicornis* (10.3%). All other prey species represented less than one percent of the total prey density. Gravimetrically *P. longicornis* (46.8%) contributed