Short communication

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

J.T. Reubens, S. Degraer, M. Vincx

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 2,700 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. Jasus 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.

Keywords: Artificial hard substrates, Ecology, Pouting, Trisopterus luscus

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; Jessen 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 km² 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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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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 m²). The surrounding soft sediment is covered with a pebble layer (2.5 mm up to 75 mm) which is 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 selecting process was assessed by the occurrence (%FO) and abundance (%Ai) 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.

\[
%\text{FO}_{i} = \frac{N_i}{N} \times 100
\]

\[
%\text{Ai} = \frac{\sum S_i}{\sum S_{ij}} \times 100
\]

\(N_i\) 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 \(S_{ij}\) 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/m² (Table 1) with an average density of \(14 \pm 11\) individuals/m² 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 analysed (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

### 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/m²) in the same column is assessed by one observer. Within a survey all observations were made at the same position.

<table>
<thead>
<tr>
<th>Period</th>
<th>July</th>
<th>July</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>September</th>
<th>September</th>
<th>September</th>
<th>October</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuals/m²</td>
<td>9</td>
<td>11</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>44</td>
<td>11</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Visibility range (m)</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3.7</td>
<td>2</td>
<td>1.2</td>
<td>3.4</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>%FO</th>
<th>%Ai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mytilus edulis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liocarcinus holsatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. longicornis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>edulis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. herdmani</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisidia longicornis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

J. herdmani (10.3%). All other prey species represented less than one percent of the total prey density. Gravimetrically P. longicornis (46.8%) contributed...
Table 2
List of prey items. Frequency of occurrence (%FO), densities (%N), ash-free dry weight (%G), feeding coefficient (Q) and index of relative importance (IRI) of prey items present in the stomachs of pouting (Trisopterus luscus). N/A indicates that no quantification could be made or the information is missing. *Taxa living on hard substrates. +Taxa living on soft substrates. **Taxa found on both substrates. ***Not applicable.

<table>
<thead>
<tr>
<th>Species</th>
<th>%FO</th>
<th>%N</th>
<th>%G</th>
<th>Q</th>
<th>IRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrozoa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>4.48</td>
<td>0.03</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.21</td>
</tr>
<tr>
<td>Nematoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>10.45</td>
<td>0.38</td>
<td>0.02</td>
<td>0.01</td>
<td>4.16</td>
</tr>
<tr>
<td>Polychaeta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>10.45</td>
<td>0.17</td>
<td>1.36</td>
<td>0.23</td>
<td>16.02</td>
</tr>
<tr>
<td>Nematoda</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>4.48</td>
<td>0.03</td>
<td>0.04</td>
<td>&lt;0.01</td>
<td>0.33</td>
</tr>
<tr>
<td>N/A</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Polychaeta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>10.45</td>
<td>0.24</td>
<td>0.03</td>
<td>0.01</td>
<td>2.78</td>
</tr>
<tr>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myxine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified sp.</td>
<td>2.99</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**Most to the diet of pouting, followed by J. herdmani (28.63%) (Table 2).**

PCA sufficiently illustrated the main structure in the diet composition (with the first two axes explaining respectively 43 and 18% of the total variation in gravimetric diet composition; and 66 and 15% of the total variation in numeric diet composition) (Figs. 1 and 2). In both analyses many stomachs were positioned at the edge of one of the explanatory variables, demonstrating high selectivity for a particular prey, i.e. *J. herdmani* and *P. longicornis*, which both clearly dominated the gut contents of pouting. Only few samples were positioned near the amid of the explanatory variables which indicates that these species rather foraged on a broader range of prey species and thus expressed less selectivity for a particular prey.

Furthermore, despite the observed moderate overlap in gut contents for the different samples, pouting diets significantly differed over time (*Anosim* \( p = 0.001, R = 0.254 \) and \( p = 0.001, R = 0.304 \) for gravimetric and numeric data respectively). *J. herdmani* dominated the gut contents at all times, but *P. longicornis* was rarely preyed upon in July while this species became a dominant prey item in September.

4. Discussion

In the BPNS pouting is frequently observed near artificial hard structures (Mallefet et al., 2007; Zintzen et al., 2006) which is consistent with the results obtained from the current research.
Underwater observations indicated that a large local population of pouting (22,000 individuals, 2700 kg) was present in the vicinity of the wind turbine investigated. It can be guaranteed that the same fishes were not counted several times. During all surveys the school of pouting remained at the same position. Sometimes individuals swam against the current at the same but opposite velocity, staying in position. In other occasions they swam against the current, turned and drifted on the current, turned again and started swimming against the current once more.

Linear extrapolation reveals that once the wind farm reaches its full capacity (i.e. 54 wind turbines) a biomass of $1.46 \times 10^3$ kg of pouting could be present. In comparison, according to FAO Fisheries and Aquaculture Information and Statistics service (2008) roughly $400–500 \times 10^3$ kg of pouting were landed in the Belgian harbours annually between 2000 and 2006. As only one wind turbine was surveyed, extrapolation of the results should be considered with care. Our results however do have an important signalling function as it comes to the effect of offshore wind farms on the distribution of pouting.

Interesting to note is that the population size near the WAR should be considered a minimum estimate because (1) visual census methods are known to underestimate abundant fish species (Banneroth and Bohnsack, 1986; Brock, 1982; Sale and Douglas, 1981); (2) although high densities of pouting were observed near the foundation, the estimation was restricted to the erosion protection layer, as abundances near the former are more difficult to estimate; (3) using a stationary observation method in low visibility waters induces an extra source of underestimation since individuals located at the outer edges of the visibility range are more difficult to detect and often overlooked.

In comparison with pouting densities present on soft-sediments surrounding the wind turbine as retrieved from beam trawling in autumn (i.e. <0.001 specimens m$^{-2}$) (Vandendriessche et al., 2009), pouting densities are highly enhanced near the WAR (i.e. 2–44 specimens m$^{-2}$, based on visual observations). Though no information is available on beam trawl efficiency for catching Gadidae and the former comparison may be temporally biased and by the fact that pouting may respond differently to beam trawl gear versus divers, our results clearly indicate an aggregation effect of the turbines on pouting populations. Moreover, stomach content analyses clearly revealed the preference for hard substrate preys over divers, our results clearly indicate an aggregation effect of the turbines on pouting populations. Moreover, stomach content analyses clearly revealed the preference for hard substrate preys in the diet of pouting: J. herdmani and P. longicornis were the most abundant prey types. Both preferred prey species are recorded in high densities (i.e. 100 to >1000 individuals sample$^{-1}$) at the investigated wind turbine (Kerckhof et al., 2009) and also are dominant members of the epifaunal community on the foundation of other wind farms and shipwrecks in the North Sea (Mallefet et al., 2007; Schröder et al., 2006).

Furthermore, the diet composition varied temporally which resembled the natural succession of epifauna on the WAR: P. longicornis only appeared in the diet from September onwards, which is the period that the species became very abundant in the epifaunal community (Kerckhof et al., 2010). No tidal influence is to be expected on fish diet, as epifaunal preys are resident and pouting is a demersal species.

This study provided for the first time insights on the dimension of the pouting population near a WAR in the BPNS and the importance of epifaunal food resources as one of the factors that governs the structure and spatial and temporal dynamics of the fish community. As a substantial development of offshore wind farms in the BPNS has been planned for the next coming years, the increasing number of wind turbines and subsequent biofouled scour protection could influence pouting populations. Whether these WAR increase the local pouting productivity or merely attract and concentrate the fishes is questioned and longer term investigation is needed to be done.

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**References**


