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Energy profiling of demersal fish: A case-study in wind farm artificial reefs

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ABSTRACT

The construction of wind farms introduces artificial hard substrates in sandy sediments. As Atlantic cod (*Gadus morhua*) and pouting (*Trisopterus luscus*) tend to aggregate in order to feed around these reefs, energy profiling and trophic markers were applied to study their feeding ecology in a wind farm in the Belgian part of the North Sea. The proximate composition (carbohydrates, proteins and lipids) differed significantly between liver and muscle tissue but not between fish species or between their potential prey species. Atlantic cod showed to consume more energy than pouting. The latter had a higher overall energy reserve and can theoretically survive twice as long on the available energy than cod. In autumn, both fish species could survive longer on their energy than in spring. Polyunsaturated fatty acids were found in high concentrations in fish liver. The prey species *Jassa* and *Pisidia* were both rich in EPA while *Jassa* had a higher DHA content than *Pisidia*.

Energy profiling supported the statement that wind farm artificial reefs are suitable feeding ground for both fish species. Sufficient energy levels were recorded and there is no indication of competition.

1. Introduction

Global concern on climate change together with decreasing non-renewable fossil fuel supplies has led to an increasing interest in generating electricity from renewable energy sources (Gill, 2005; Pelc and Fujita, 2002). Therefore, a massive expansion of offshore wind power is under preparation in North-western Europe, with some 10.000 offshore turbines planned to be constructed in the near future (Wilhelmsson et al., 2006). Constructing offshore wind turbines introduces artificial hard substrates in a region that is mainly characterised by sandy sediments. With the construction of wind farms in the sandy sediments of the Belgian part of the North Sea (BPNS) (currently 91 wind turbines, more than 200 to be constructed) a unique situation is created to investigate the effects of these artificial hard substrates. This change of habitat type (from sandy to hard substrate) is called the reef-effect and is considered as one of the most important changes of the marine environment (Kerckhof et al., 2010). The construction of wind farms can also affect the marine environment through noise, electromagnetic fields and changes in hydrological conditions (Wilhelmsson et al., 2006).

In contrast to these expected negative effects, natural or man-made solid structures on the seabed are known to be effective in attracting and concentrating fishes (Bohnsack and Sutherland, 1985; Pickering and Whitmarsh, 1997; Reubens et al., 2011, 2013a; Wilhelmsson et al., 2006). Artificial reefs (AR), such as oil platforms, breakwaters, pontoons, shipwrecks and windmill foundations serve also as habitats for fishes and invertebrate assemblages (Wilhelmsson et al., 2006). Local fish aggregations in the BPNS, e.g. Atlantic cod (*Gadus morhua* L.) and pouting (*Trisopterus luscus* L.), were observed in the vicinity of the Belgian wind turbines (Reubens et al., 2010, 2011, 2013b). This supports the function of wind farms as AR as the same fish species are also attracted to shipwrecks studied in the BPNS (Zintzen et al., 2006).

Moreover, the irregular rough reef surfaces promote the settlement of sessile organisms allowing fouling communities to establish (Hixon and Brostoff, 1985; Kerckhof et al., 2010). These communities are an important source of food for fishes and other organisms. Adding hard bottom habitat can thus turn a low productive environment into a dynamic, highly productive system providing direct shelter and food for many organisms (Stone et al., 1979).

In spite of the growing evidence of higher fish densities and biomasses at ARs compared to the surrounding areas (Wilhelmsson et al., 2006), it remains subject of debate whether the reefs actually

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generate new fish biomass or solely attract fish (Bohnsack, 1989; Bohnsack and Sutherland, 1985; Pickering and Whitmarsh, 1997). The attraction hypothesis is mainly based on behavioural preferences, whereas the production hypothesis assumes an actual increase of the carrying capacity of the system which will eventually lead to an increase in the abundance and biomass of reef fishes (Bohnsack, 1989). Mechanisms that can contribute to the latter are additional food availability, higher feeding efficiency, shelter from predation and currents, and provision of recruitment habitat for settling organisms (Bohnsack, 1989; Randall, 1963; Reubens et al., 2013c; Stone et al., 1979). The relative importance of the attraction versus production hypotheses is likely to depend on the physical characteristics and the location of the reef (Bohnsack and Sutherland, 1985).

In order to evaluate the attraction versus the production hypothesis, it is necessary to analyse the feeding ecology of the fish in the AR. More specifically, not only trophic interactions should be studied but also whether the new habitat can support the necessary energy to maintain the increased population. Only in the latter case, the production hypothesis can be validated. Better knowledge on the potential of AR as feeding, breeding and nursery grounds for fish may generate insights for possible co-use of these specific areas by e.g. sustainable energy industry and fisheries (see e.g. Verhaeghe et al., 2011).

Recent studies on the stomach content analysis of Atlantic cod and pouting caught near the wind farms in the BPNS revealed that the tube building amphipod *Jassa herdmani* and the long-clawed porcelain crab *Pisidia longicornis* are the most important prey species (Reubens et al., 2010, 2011). These epifaunal species were also the dominant hard substrate species present on the windmill foundations (Kerckhof et al., 2010) suggesting that the fish come to feed on the epifaunal species on the pillars and profit of the larger erosion protection. However, stomach analyses can underestimate the importance of soft and highly digestible food items and overestimate that of recently consumed items (Graeve et al., 2001; Latyshev et al., 2004).

Far beyond the 'snapshot' level of resolution provided by stomach analysis, the use of trophic biomarkers and energy profiling allows to study the feeding ecology of consumers and to estimate the energy transfer from prey to consumer on the long-term (Iverson et al., 2004). In the present study, the proximate composition (proteins, lipids and carbohydrates) and the energy content (based on respiratory electron transport system) were estimated for two abundant and commercially relevant fish species (i.e. Atlantic cod and pouting) and some of their potential prey, sampled at an offshore wind farm in the BPNS. This functional approach will contribute to a better explanation of the occurrence and attraction of the target fish species to this specific site. Moreover, the obtained data on the energy levels, both in prey and consumer, will allow to draw conclusions on the contribution of AR in the energy flow between primary and secondary consumers. If this energy flow shows to be substantial, this would imply an important contribution to the production hypothesis for AR. So far, any information on the nutritional value of particular prey in the overall diet of Atlantic cod and pouting at the wind farm is lacking. Moreover, the obtained net energy budgets will allow to estimate how long the consumers can survive on the energy gained in the AR.

In addition to the overall energy profiling, fatty acid (FA) profiling of prey and consumers was included as FA are known as important biomarkers (so-called trophic markers). By means of FA profiling, we aim to trace any directional assimilation of a particular FA in order to estimate in every detail what a particular prey contributes to the FA pool of the consumer. Here, we opted to analyse total FA, including structural FA used for growth and FA stored as reserve. Special attention was given to the presence of polyunsaturated FA (PUFA) as important label for dietary quality (Dalsgaard et al., 2003), also for human consumption.

The specific objectives of this study are (1) to quantify proximate composition and energy content of Atlantic cod and pouting and their main prey species and (2) to identify the contribution of dominant prey species (*J. herdmani* and *P. longicornis*) to the diet and energy requirements of both fish species. Ultimately, in combination with data on density and productivity of the prey species, it should be possible in the future to estimate whether the fish species obtain sufficient energy from the food sources available at the AR in wind farms to sustain their basal metabolism or growth.

2. Material & methods

2.1. Field sampling

Samples were collected in the BPNS at the C-Power wind farm (51°33'N – 2°56'E) on the Thorntonbank, a natural sandbank situated 27 km off the Belgian coast. The windmill foundations surveyed in this study are surrounded by a scour protection layer to prevent the erosion of the backfill sediment around the foundations. This protection layer consists of two layers: a filter layer of about 48 m diameter for which crushed gravel with a diameter of 10–88 mm was used; and an armour layer with a diameter of about 44 m consisting of quarried rock (Brabant and Jacques, 2010; Reubens et al., 2011). The scour protection layer together with the foundation forms the AR.

In the period of October–November 2011 (autumn), several sampling campaigns were organised at the wind farm with the research vessel 'Zeeleeuw'. Atlantic cod and pouting were collected by line fishing (hook type: Arca, size n° 4) with the lugworm *Arenicola marina*, fresh or frozen, as bait. Angling was performed close to the turbine (1–10 m distance) just above the armour layer to make sure that the fish caught were associated at that moment with the AR. Muscle and liver tissue was collected from 10 individuals and frozen at −80 °C until further analysis. Fish length ranged between 39–46 cm and 20–22 cm respectively for Atlantic cod and pouting. The obtained data were compared with a similar yet smaller dataset collected in spring (February–March 2011) consisting of 5 and 6 individuals of Atlantic cod and pouting, respectively. Fish lengths were 21–45 cm (Atlantic cod) and 19–22 cm (pouting). In both seasons all fish analysed in the present study were immature and therefore no well-developed gonads were available for analysis.

To collect the prey species, small rocks were taken by divers from the armour layer of the windmill pillars. The prey species present on the rocks were identified and sorted on board, and frozen at −80 °C until further biochemical analysis in the laboratory. Triplicate samples of the prey species *J. herdmani* and *P. longicornis* were prepared. Each replicate consisted of a homogenised mix of several individuals (typically 4–5) in order to meet the minimum weight requirements for reliable measurements. The prey species are further referred to by the genus names. *Jassa* is a tube-dwelling amphipod, constructing tubes that can form organic mats (Kerckhof et al., 2010). These mats were analysed separately from *Jassa* after picking out the amphipods.

2.2. Biochemical analyses

2.2.1. Energy availability (E_a)

The proximate composition (proteins, carbohydrates and lipids) was determined to quantify the total available energy. Samples of liver and muscle tissue of the fish species and whole organisms of the prey species were subjected to a cellular energy allocation (CEA) protocol. The original CEA protocol was developed by De