# CHAPTER 4

# DEFINING REFERENCE CONDITION ($T_0$) FOR THE SOFT SEDIMENT EPIBENTHOS AND DEMERSAL-BENTHOPELAGIC FISH

## IN THE NORTHER AND RENTEL CONCESSION ZONES

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## Abstract

In the near future, two new offshore wind farms (OWFs) will be constructed in Belgian waters, Norther and Rentel. In this chapter, we explored whether the epibenthos and demersal-benthopelagic fish assemblage in these future OWFs differed from the (reference) assemblages that are currently monitored within the WinMon program *i.e.*, for the OWFs C-Power and Belwind. Secondly, the $T_0$ reference conditions for both new concession zones are described. All samples were taken in autumn 2016, as such excluding both interannual variability and seasonality.

A clear north-south gradient was observed within the wider OWF area for both soft sediment epibenthos and demersal-benthopelagic fish assemblages. Norther, the concession area closest to shore (ca. 23 km), exhibited much higher density and biomass (for epibenthos), and also community structure differed from the other concession areas. Norther is inhabited by an assemblage most related to a typical coastal community, while Rentel comprises a typical offshore assemblage, comparable with Belwind and C-Power. Because of the different epibenthos and fish assemblages, a follow-up of Norther seems justified as the extrapolation of previous monitoring results from the other OWFs cannot be guaranteed. Monitoring of Rentel, on the other hand, seems redundant within the current WinMon monitoring program, as there is a high similarity with the C-power epibenthos and fish assemblages. Although, integration of Norther in the monitoring framework is recommended, it is important to consider that natural variability within this zone is very high, especially for epibenthos, which may obscure both short and long-term potential effects related to the presence of the Norther OWF, and the fisheries exclusion in this concession zone.

## 1. Introduction

In order to meet the targets set by the European Directive 2009/28/EC on renewable energy, the Belgian government reserved an offshore area of 238 km² for the production of electricity. Since 2017, 232 offshore wind turbines are operational in the Belgian part of the North Sea (BPNS) with an installed capacity of 877 MW. A further 309 MW is under construction in the Rentel concession area, and in 2018 construction of the Norther offshore wind farm (OWF) will start, good for another 370 MW.

Construction of OWFs introduces artificial hard substrates into the typical soft bottom sandy environment in the BPNS. These hard substrates generate a new 'rocky' habitat, attracting hard substrate species (Lindeboom *et al.* 2011; Kerkhof *et al.* 2012; De Mesel *et al.* 2015) and creating a reef effect for epibenthic fauna and demersal-benthopelagic fish (Reubens *et al.* 2011, 2013; Stenberg *et al.* 2015). This reef effect, in combination with fisheries exclusion in the wider OWF area, may affect the original soft bottom epibenthos and fish assemblages between the wind turbines.

Since 2005, ILVO performs beam trawl monitoring surveys to evaluate the potential effects of OWFs on soft sediment epibenthos and demersal-benthopelagic fish. The study effort has been concentrated on the C-Power and Belwind OWFs, the first OWFs in Belgian waters. Both OWFs are located on a sand bank, respectively on Thornton Bank and Bligh Bank, approximately 30 and 50 km offshore. Their epibenthos and fish assemblages are characterized as a typical offshore assemblage (Derweduwen *et al.* 2010). The future Rentel OWF is situated in a gully in between both OWFs, while Norther is situated closest to shore (23 km from Zeebrugge). This hints at potentially different epibenthos and demersal-benthopelagic fish assemblages. If so, results of the current impact monitoring in C-Power and Belwind may not directly be extrapolated to the future OWFs.

We sampled both future concession areas in autumn 2016:

1) to evaluate whether the soft sediment epibenthos and fish assemblages of the future OWFs (Rentel and Norther) differ from the reference zones currently monitored for the OWFs (C-Power and Belwind);

2) to determine the reference conditions ($T_0$) for both future OWFs (Rentel and Norther), and to evaluate the suitability of the reference locations for future impact assessments.

## 2. Material and methods

### 2.1. Sampling

Sampling for the reference condition ($T_0$) was performed on board RV Simon Stevin in autumn 2016. Trawl samples were taken inside the future concession areas of Rentel and Norther, and at potential reference locations outside the concession areas (fig. 1). At the location of ftNor2, a fishing vessel had been fishing right before our sampling, with a lot of dead fish and epibenthos in the sample as a consequence. This dead material was not taken into account in the analyses. Additionally, in this same monitoring survey, we also performed the impact monitoring in the Belwind and C-Power OWFs and their respective reference zones (see De Backer & Hostens 2017). On all track locations, epibenthos and fish fauna were sampled with an 8-meter shrimp beam trawl (22 mm mesh in the cod end) equipped with a bolder chain. The net was towed during 15 minutes at an average speed of 4 knots over approximately 1 nautical mile. Data on time, start and stop coordinates, trajectory and sampling depth were noted to enable a correct conversion towards sampled surface units. The fish tracks are more or less positioned following the depth contours parallel to the coastline, thereby minimizing the depth variation within a single track, except for ftNor1 and ftNor2 within the Norther concession which are perpendicular to the coastline due to the future positioning of the infield electricity cables. On board, epibenthos and fish were identified, counted, measured (fish, crabs and shrimps) and wet weighted (only epibenthos). The samples that could not be fully processed on board were frozen and further processed in the lab.

### 2.2. Data used and statistical analyses

Pelagic species (based on www.fishbase.org) such as *Sprattus sprattus*, *Trachurus trachurus*, *Scomber scombrus*, next to jellyfish and polychaetes were excluded from the analyses, as these are not quantitatively sampled with a beam trawl.

### 2.2.1. Community analysis of the wider Belgian offshore wind farm area

The reference locations of the Belwind and C-Power impact monitoring of 2016 were included to test for differences in the soft sediment epibenthos and fish assemblage between the future concession areas Norther and Rentel and the reference zones of the operational OWFs Belwind and C-Power (fig. 1; De Backer & Hostens 2017). This allowed for a community analysis in the wider OWF area. For this analysis, we tested the area effect for two ecosystem components (epibenthos and demersal-benthopelagic fish) in a one-way PERMANOVA design with factor 'concession area' for univariate variables (species number, density, biomass) and for community structure. Multivariate data were fourth root transformed and similarity among samples was quantified using Bray-Curtis similarity index. PERMANOVA analyses on univariate data (species richness, density and biomass) were performed on Euclidean distance resemblance matrices with unrestricted permutations of raw data. PERMDISP test was used to test for homogeneity of dispersion within groups for a correct interpretation of the PERMANOVA results. Whenever a significant 'concession' effect was found, pairwise tests were performed to determine where the differences were situated. P values for pairwise test were, due to the restricted number of possible permutations, drawn from Monte Carlo (MC) permutations (Anderson & Robinson 2003). SIMPER analyses were done to appoint the species most responsible for the observed differences.

All analyses were executed using Primer v6 with PERMANOVA add-on software (Clarke & Gorley 2006; Anderson *et al.* 2008).

### 2.2.2. Reference condition ($T_0$) for Norther and Rentel

To determine the $T_0$ in both future OWFs, a descriptive analysis was executed at the sample level in order to be able to observe the degree of variability between samples in one area. The number of samples (2 impact and 2 reference) was too low for a statistically sound evaluation of the suitability of the reference locations for Norther and Rentel. Therefore, univariate measures, species number, density and biomass (for epibenthos only), were calculated for each fish track, together with relative abundance of the dominant species. Univariate measures were then visualized in ArcGIS, allowing for an expert judgement on the suitability of the reference locations for future impact assessments of Norther and Rentel.

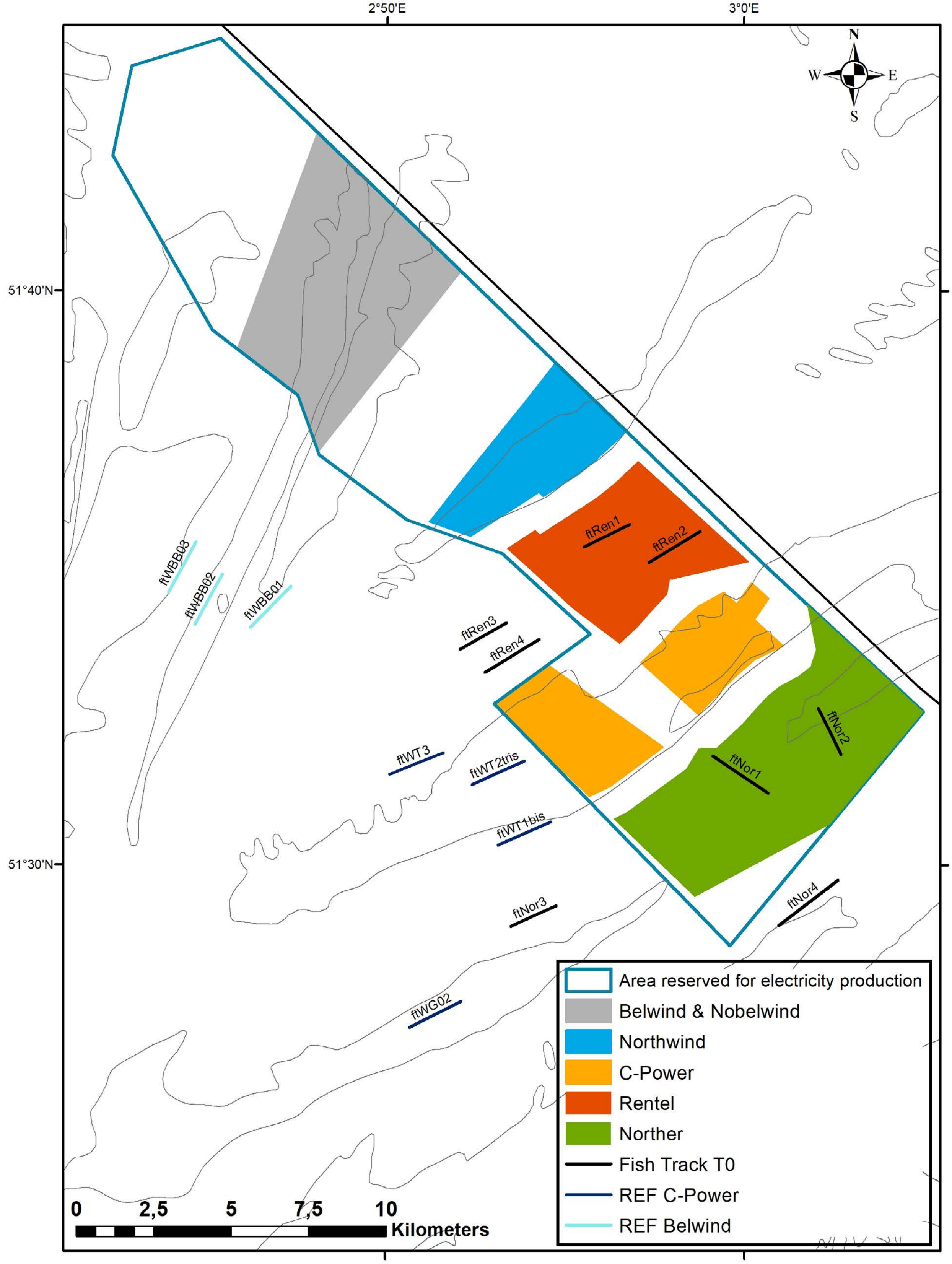


**Figure 1.** Overview map showing the T0 trawl locations in the Norther and Rentel concession areas and their respective reference locations (black). Dark blue are reference locations for C-Power and light blue reference locations for Belwind, which were included for the wider offshore wind farm area community analysis.

## 3. Results

### 3.1. Community analysis of the wider offshore wind farm area

#### *3.1.1. Epibenthos*

Number of species (S) per sample did not differ significantly between the four zones. Average S ranged between 15 species in Belwind and 18 species in Norther and Rentel. Density and biomass showed an overall significant effect (resp. p = 0.02 and 0.04) with a very high average density and biomass in the Norther concession zone, resp. 1212 ind. 1000 $m^{-2}$ and 3921 g · 1000 $m^{-2}$ (fig. 2). However, pairwise differences did not prove to be significant due to the high variation observed within the Norther samples.

Epibenthic community structure was significantly different between the different zones (p = 0.0002), and dispersion differed significantly as well (Permdisp p = 0.01). Pairwise tests showed that Norther differed significantly from all other concession zones, both in community structure and dispersion level, indicating a high degree of heterogeneity in the Norther zone (fig. 3). Rentel and Belwind showed as well a significantly different community structure.

Norther differed significantly from the other zones (average dissimilarity with C-Power 55%, Rentel 53% and Belwind 65%) due to the high relative abundance of the sea-urchin *Psammechinus miliaris*, the star fish *Asterias rubens* and the brown shrimp *Crangon crangon*, and the lower relative abundance of the hermit crab *Pagurus bernhardus* (fig. 4). Rentel differed significantly from Belwind (avg. dissim. 41%) due to high relative abundance of the dog whelk *Tritia reticulata* and the serpent star *Ophiura ophiura*, and a lower relative abundance of Cephalopoda species (fig. 4).

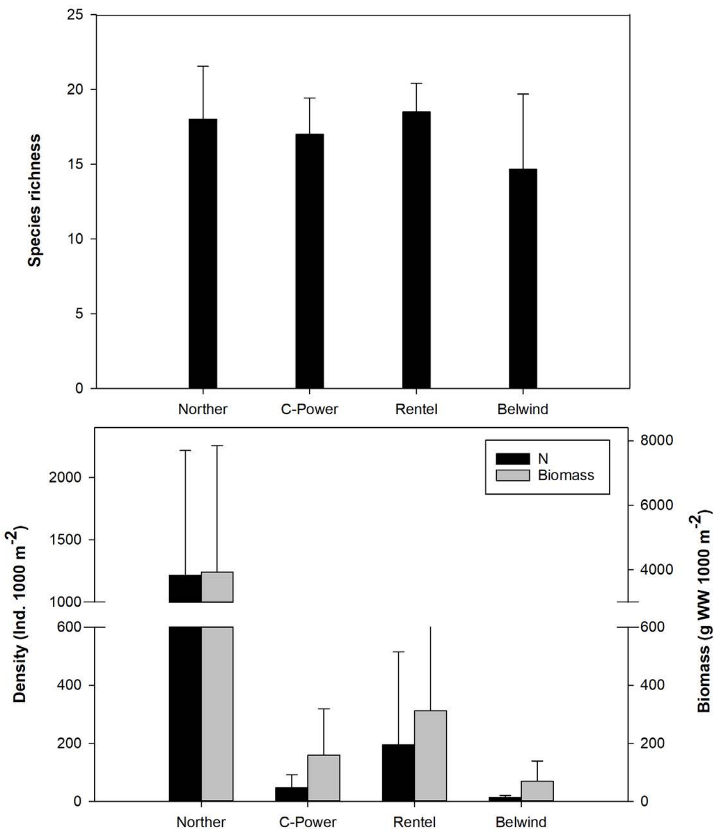


**Figure 2.** Bar plots showing average species richness, density and biomass (± SD) for epibenthos in the different concession/reference zones.

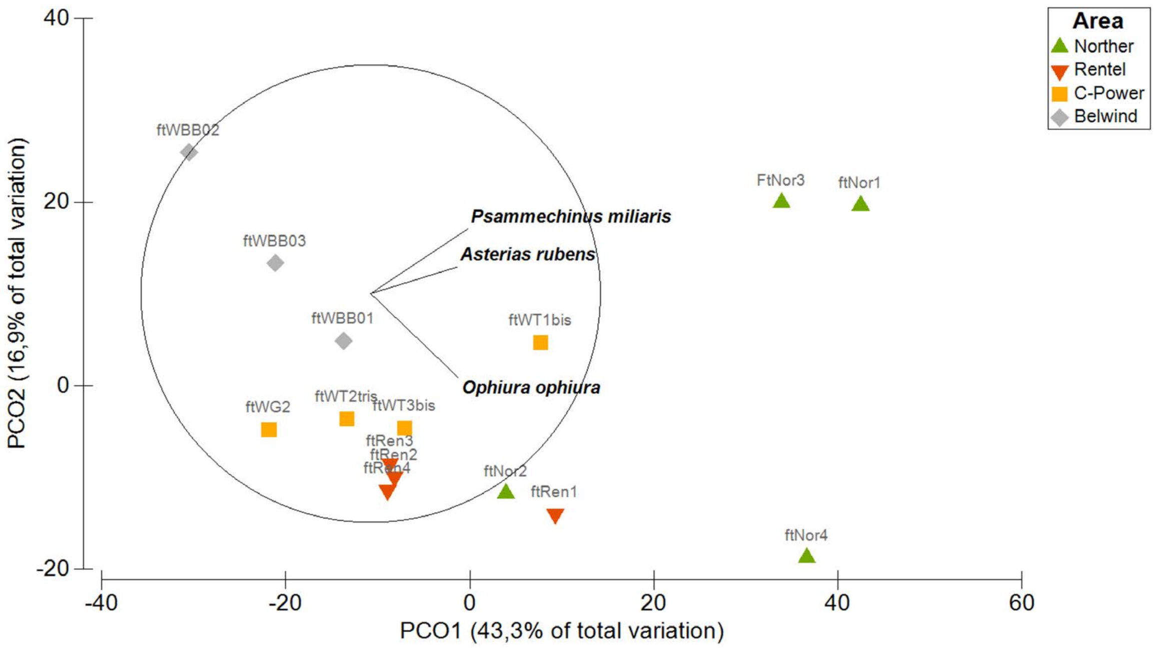


**Figure 3.** PCO plot of the epibenthos community in the wider offshore wind farm area with indication of the different concession/reference zones. Vector overlay shows the species that are best correlated (multiple correlation r > 0.35) with the observed multivariate pattern.

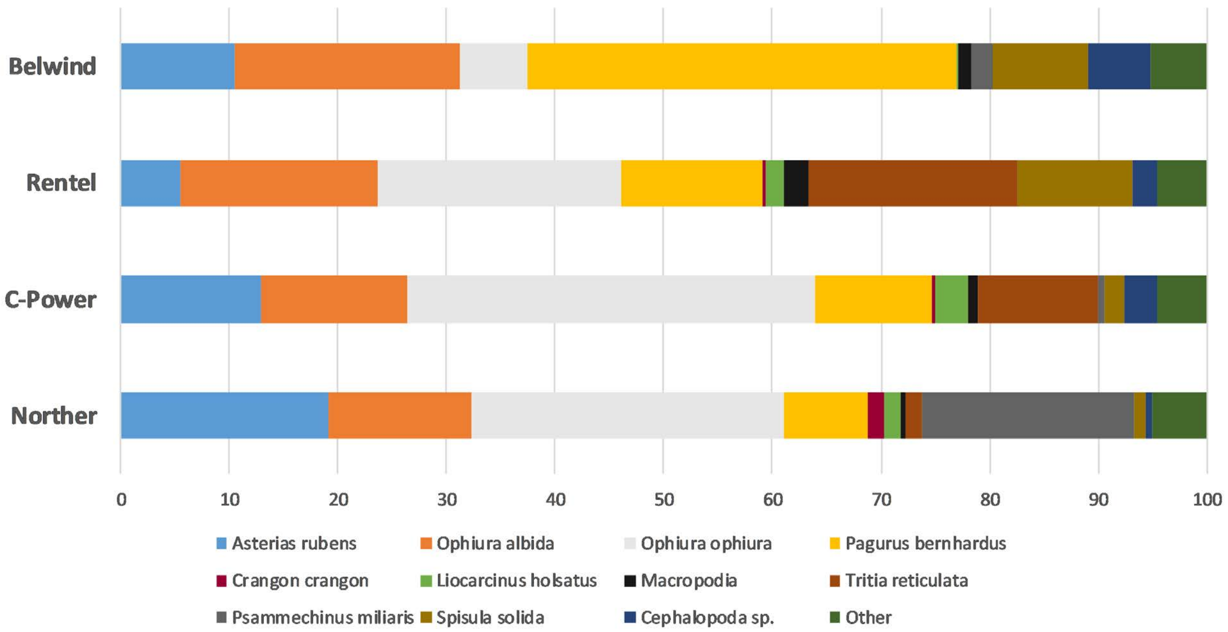


**Figure 4.** Relative abundance of the most common epibenthos species in the different concession/reference zones.

### *3.1.2. Demersal and bentho-pelagic fish*

No significant differences in number of species (S) or density (N) were observed between the four zones. Average S ranged between 12 species in Norther and 17 species in Rentel. Average density was lowest in C-Power with 20 ind. 1000 $m^{-2}$ and highest in Norther with 126 ind. 1000 $m^{-2}$ (fig. 5).

Fish community structure differed significantly between the different zones ($p = 0.0001$), as did dispersion (Permdisp $p = 0.004$). Norther differed most from Belwind (average dissimilarity = 64%), but it also differed significantly from C-Power (avg. diss. = 44%) and Rentel (avg. diss. = 42%) (pairwise test $p < 0.02$) (fig. 6). Rentel only differed significantly in community structure from Belwind (avg. diss. = 39%).

Norther had high relative abundances of dragonet *Callionymus lyra*, whiting *Merlangius merlangus,* pouting *Trisopterus luscus* and hook nose *Agonus cataphractus* compared to the other zones. Relative abundance of lesser weever *Echiichthys vipera* was much lower (fig. 6; fig. 7). The Belwind reference zone is mainly dominated by lesser weever, while solenette *Buglossidium luteum* is characteristic for C-Power and Rentel (figs 6 & 7).

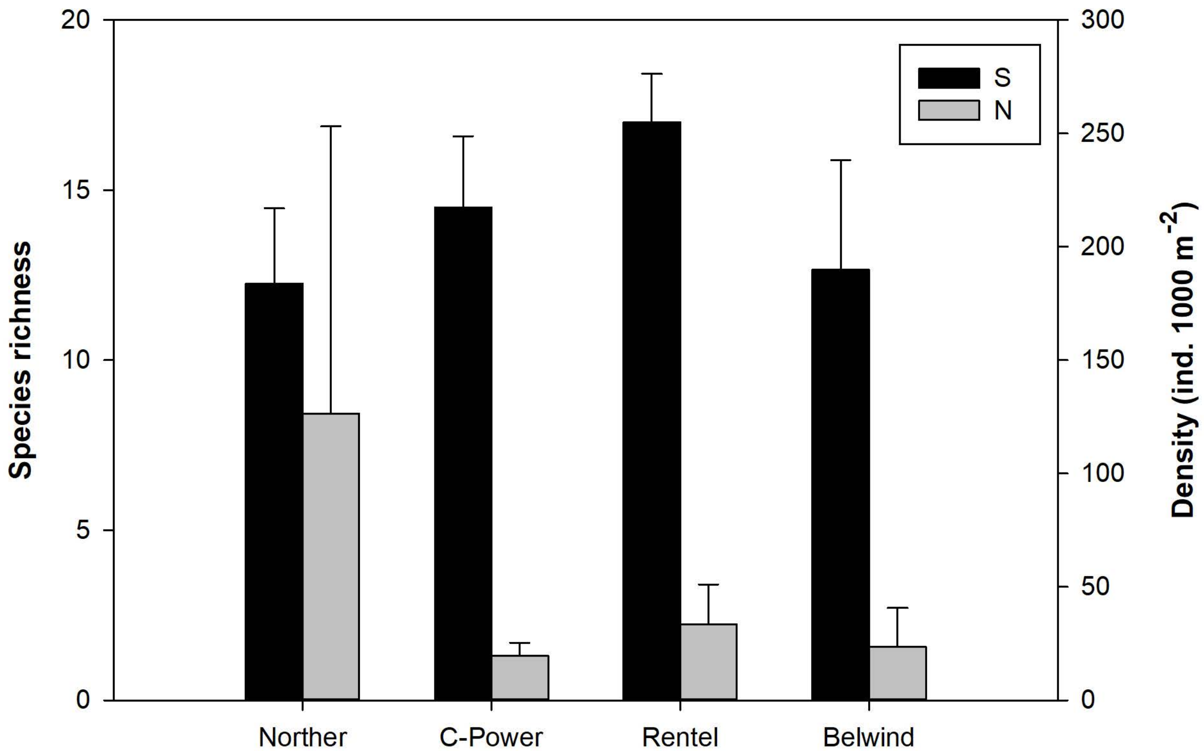


**Figure 5.** Bar plots showing average species richness and density for demersal-benthopelagic fish in the different concession/reference zones.

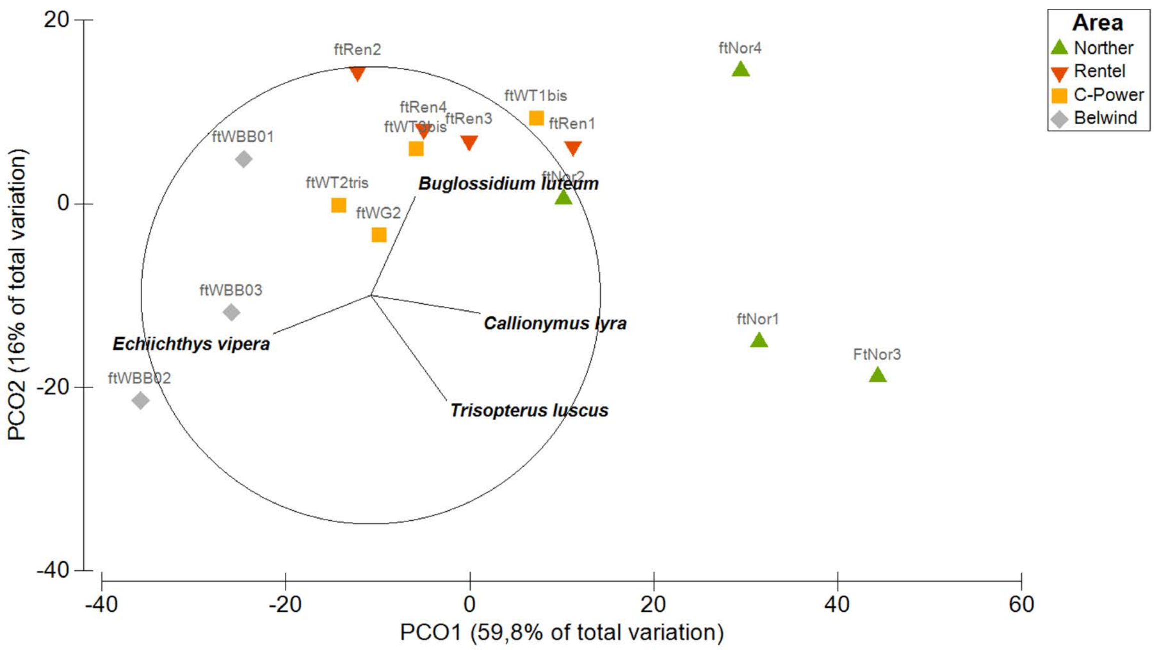


**Figure 6.** PCO plot of the fish community in the wider offshore wind farm area with indication of the different concession/reference zones. Vector overlay shows the species that are best correlated (multiple correlation r > 0.4) with the observed multivariate pattern.

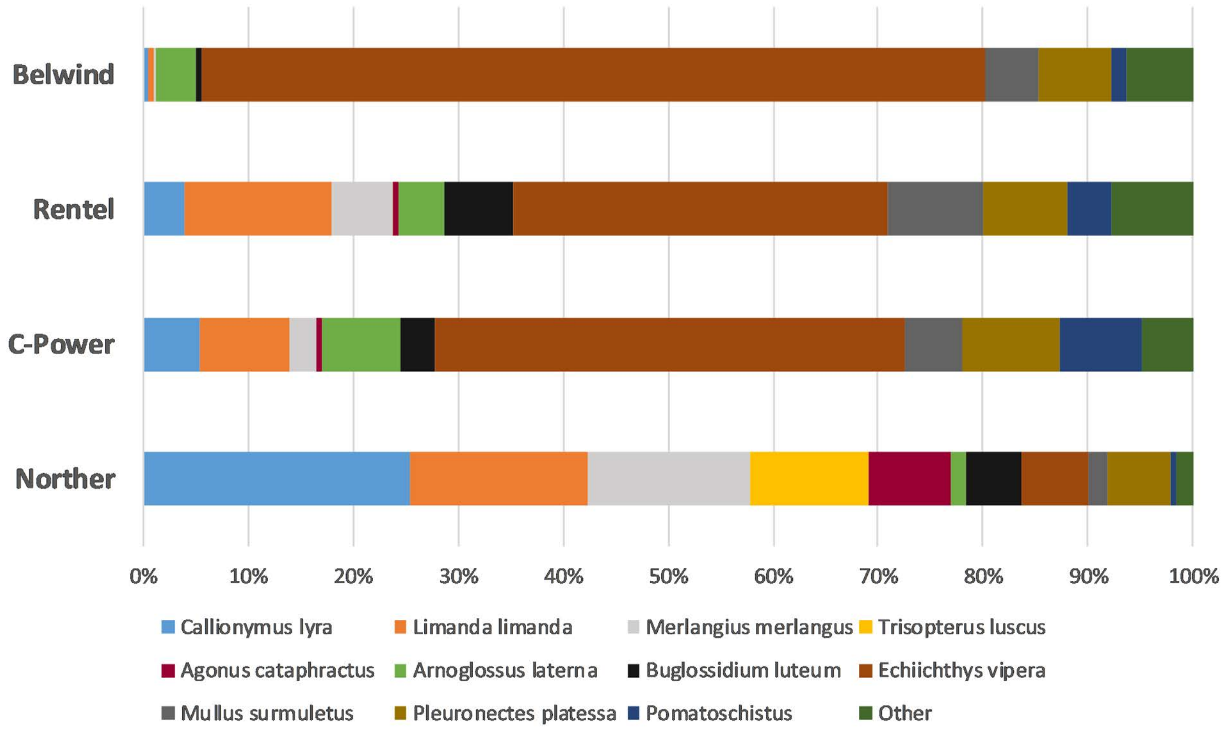


**Figure 7.** Relative abundance of the most common demersal-benthopelagic fish species in the different concession/reference zones.

## 3.2. $T_0$ situation in Norther and Rentel

To determine the $T_0$ situation for Norther and Rentel, we zoom in on the fish tracks sampled in both concession areas and their respective reference tracks.

### 3.2.1. Epibenthos

For Norther, a high variability in species richness, density and biomass was noted between fish tracks for epibenthos. Number of species ranged between 15 and 22, density between 58 and 2270 ind. 1000 $m^{-2}$, and biomass between 238 and 10571 g WW . 1000 $m^{-2}$. Density and biomass were especially low in ftNor2, where fishing activity was taking place during sampling (table 1; fig. 8).

Also relative abundance of species was highly variable within Norther: similar species were present, but dominant species differed between fish tracks (fig. 9). The sea urchin *P. miliaris* formed the bulk density of ftNor1 (68%), the serpent star *O. ophiura* (34%) and the hermit crab *P. bernhardus* (23%) dominated in ftNor2, while in the reference fish tracks the star fish *A. rubens* (55%) together with *O. albida* (27%) dominated ftNor3, and *O. ophiura* (78%) dominated ftNor4 (fig. 9).

For Rentel, variability in epibenthos measures between fish tracks was relative low, only ftRen1 showed much higher density and biomass. The other fish tracks all showed highly similar values around 35 ind. 1000 $m^{-2}$ for density and around 180 g WW · 1000 $m^{-2}$ for biomass (table 1; fig. 8). Number of species ranged between 17 and 21.

Relative abundance of species was also very similar for the different fish tracks, except for ftRen1 which was dominated by *Tritia reticulata* (62%) (fig. 10). In the other fish tracks, species composition was more evenly distributed with most important species being *A. rubens, O. albida, O. ophiura, P. bernhardus* and *Spisula solida* (fig. 10).

**Table 1.** Epibenthos species richness (S), density (N) and biomass for each fish track in the Norther and Rentel concession and respective reference zones, with indication whether the track is located inside (C) or outside (R) the concession zone

| Zone | Station | Conc/Ref | S | N (Ind. 1000 $m^{-2}$) | Biomass (g WW 1000 $m^{-2}$) |
|---|---|---|---|---|---|
| Norther | ftNor1 | C | 15 | 2270 | 10571 |
| | ftNor2* | C | 22 | 58 | 238 |
| | ftNor3 | R | 20 | 723 | 1992 |
| | ftNor4 | R | 15 | 1797 | 2883 |
| Rentel | ftRen1 | C | 17 | 675 | 697 |
| | ftRen2 | C | 17 | 31 | 181 |
| | ftRen3 | R | 19 | 36 | 181 |
| | ftRen4 | R | 21 | 36 | 189 |

* commercial fishing activity right before sampling

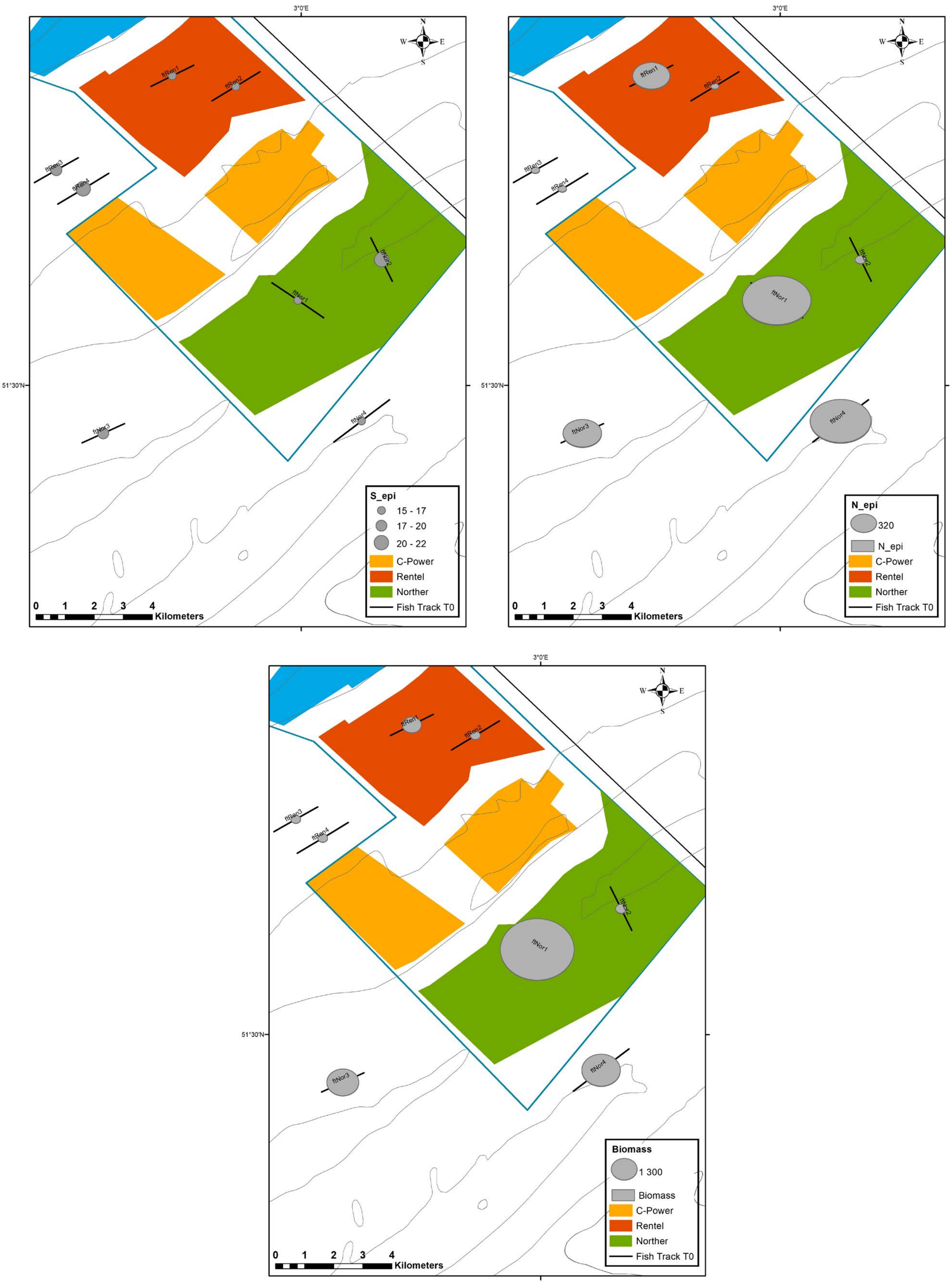


**Figure 8.** Map visualising number of species (left), density (middle) and biomass (right) for epibenthos of each fish track in the Norther and Rentel concession area. Size of pie charts varies with the values of each parameter.

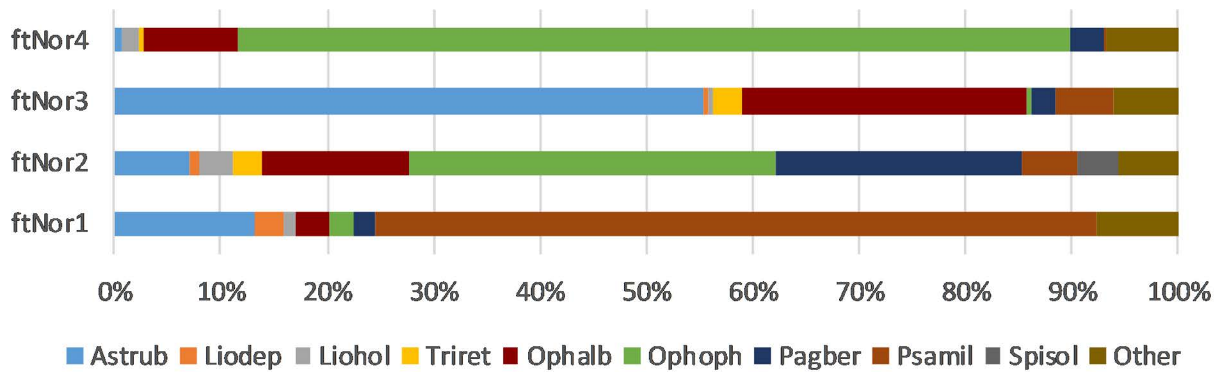


**Figure 9.** Relative abundance of epibenthic species in the different fish tracks of the Norther concession and reference zone. List for full species names in annex 1.

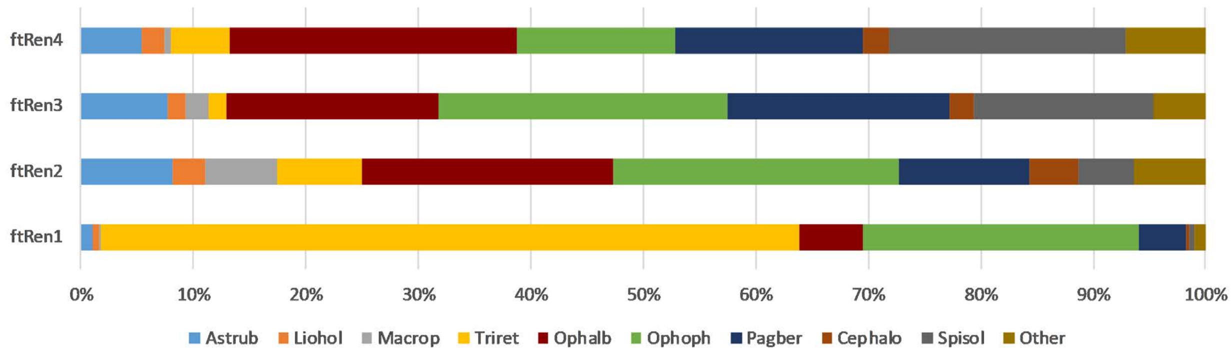


**Figure 10.** Relative abundance of epibenthic species in the different fish tracks of the Rentel concession and reference zone. List for full species names in annex 1.

*3.2.2. Demersal-benthopelagic fish*

Within the Norther concession, a relatively high variability was noted between fish tracks for demersal-benthopelagic fish measures. Species richness ranged between 10 and 15 species. Fish tracks with the highest number of fish species had the lowest number of epibenthos species and the other way around (table 2; fig. 11). Density was highly variable with very low density in ftNor2, where there had been fishing activity just before sampling, and as for epibenthos, density was highest in ftNor1 with almost 300 ind. 1000 m$^{-2}$.

Species composition was less variable: three species were responsible for 40 to 75% of the cumulative relative abundance in all four fish tracks namely dab *Limanda limanda*, whiting *Merlangius merlangus* and common dragonet *Callionymus lyra* (fig. 12). Other species showed a higher variability in relative abundance between fish tracks: lesser weever *Echiichthys vipera* (25%) and plaice *Pleuronectes platessa* (18%) were only relatively dominant in ftNor2, pouting *Trisopterus luscus* (38%) was dominant in ftNor3, while in ftNor4 solenette *Buglossidium luteum* (18%) and hook nose *Agonus cataphractus* (15%) were relatively abundant (fig. 12).

Within the Rentel concession and reference zone, variability in fish measures was again lower between the different tracks compared to Norther. Species richness (S) ranged between 15 and 18 fish species. Density ranged between 19 and 58 ind. 1000 m$^{-2}$ (table 2; fig. 11).

For relative species composition, ftRen2 to 4 were almost identical with lesser weever as dominant species (40 to 45% relative abundance) (fig. 13). As for epibenthos, ftRen1 showed a different pattern compared to the other samples: there was not one single dominant species and species composition was more evenly distributed over dab, whiting, common dragonet, solenette, plaice and lesser weever (fig. 13).

**Table 2**. Demersal-benthopelagic fish species richness (S) and density (N) for each fish track in the Norther and Rentel concession and respective reference zones with indication whether the track is located inside (C) or outside (R) the concession area

| Zone | Station | Conc/Ref | S | N (ind. 1000 m$^{-2}$) |
|---|---|---|---|---|
| Norther | ftNor1 | C | 13 | 297 |
| | ftNor2* | C | 11 | 11 |
| | ftNor3 | R | 10 | 144 |
| | ftNor4 | R | 15 | 53 |
| Rentel | ftRen1 | C | 17 | 58 |
| | ftRen2 | C | 15 | 19 |
| | ftRen3 | R | 18 | 34 |

* = commercial fishing activity right before sampling

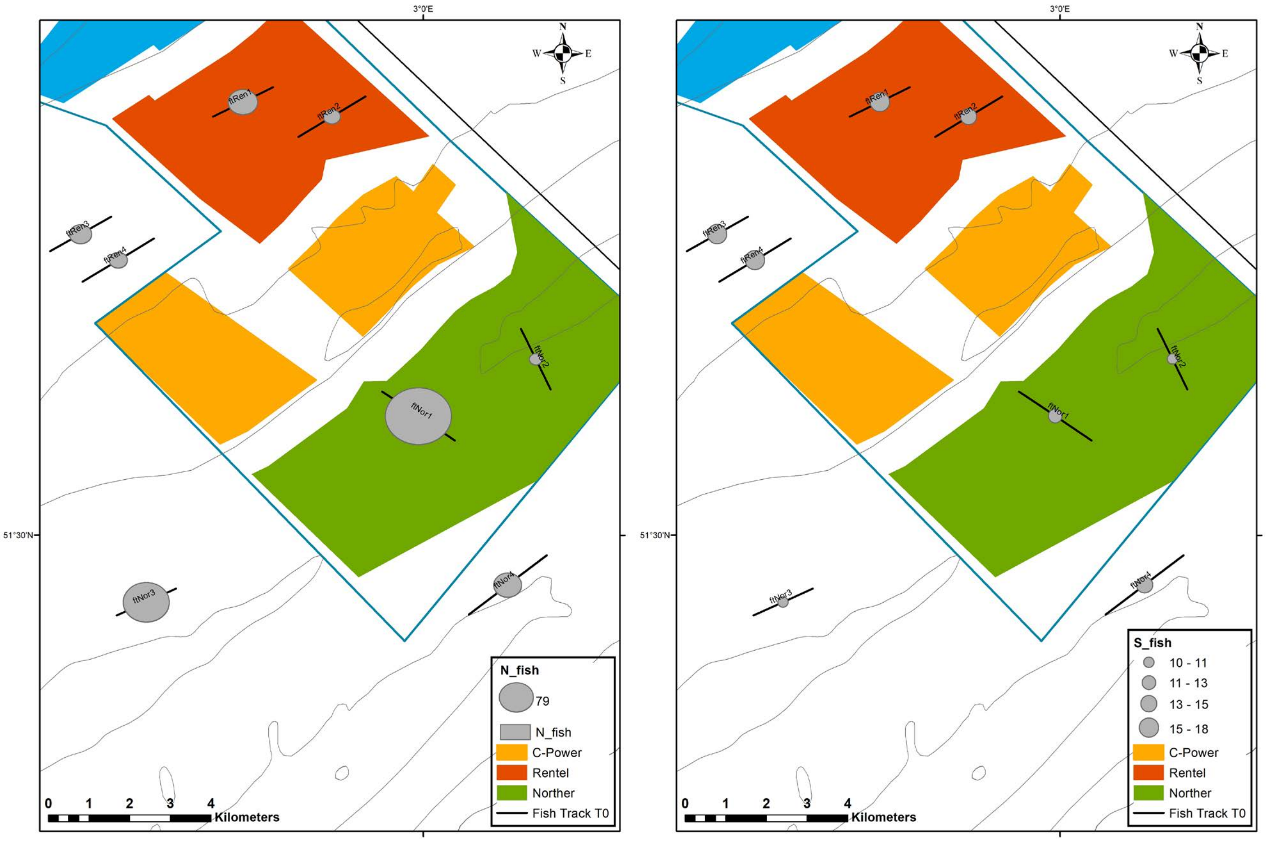


**Figure 11.** Map visualising number of species (left) and density (right) for demersal-benthopelagic fish of each fish track in the Norther and Rentel concession and reference zones. Size of pie charts varies with the values of each parameter.

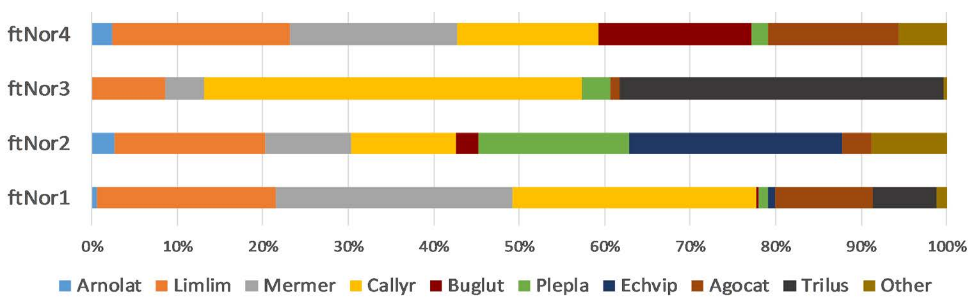


**Figure 12.** Relative abundance of demersal-benthopelagic fish species in the different fish tracks of the Norther concession and reference zone. List for full species names in annex 1.

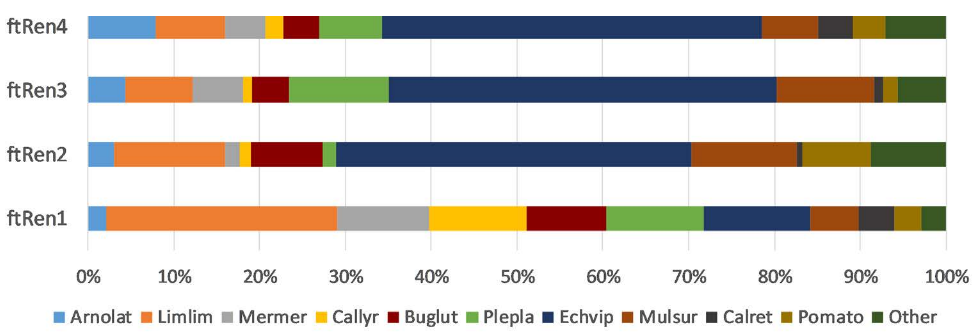


**Figure 13**. Relative abundance of demersal-benthopelagic fish species in the different fish tracks of the Rentel concession and reference zone. List for full species names in annex 1.

## 4. Discussion and conclusions

The aim of this chapter was twofold. First, it explored whether the epibenthos and demersal-benthopelagic fish assemblage in the future OWFs Norther and Rentel differed from the assemblages that are currently monitored in the reference zones of the C-Power and Belwind OWFs. If soft sediment epibenthos and fish assemblages are different, the existing results of previous monitoring surveys in C-Power and Belwind cannot directly be extrapolated to the future OWFs. Secondly, the reference condition for both concession areas was described, together with a suitability evaluation of potential new reference locations for both OWFs. As all samples were collected in autumn 2016, we excluded the influence of interannual variability and seasonality.

The main conclusions are:

- A clear onshore-offshore gradient was observed within the wider OWF area for both soft sediment epibenthos and demersal-benthopelagic fish assemblages. Norther, the concession zone closest to shore (23 km), exhibited much higher density and biomass (for epibenthos) compared to the other zones, while the Belwind reference zone, 50 km offshore, showed the lowest density and biomass. A similar gradient was observed for community structure with Norther differing from all other concession zones. For epibenthos, this was due to high densities of *Ophiura ophiura*, *Asterias rubens* and *Psammechinus miliaris* and the occurrence of brown shrimp *C. crangon*. When going further offshore towards Belwind, the hermit crab *P. bernhardus*, the bivalve *Spisula solida* and squid species Cephalopoda sp. gained relative importance. For fish, the Norther concession/reference zone was characterized by high densities of dragonet *C. lyra*, dab *L. limanda* and whiting *M. merlangus*, and the typical occurrence of pouting *T. luscus* and hook nose *A. cataphractus*. When going further offshore, lesser weever *E. vipera* was the only dominant species. The Rentel concession/reference zone comprises a typical offshore assemblage, as described for Belwind and C-Power and their reference zones in Derweduwen *et al.* (2010). Rentel and C-Power are very similar, and differ from Belwind in epibenthos due to the occurrence of the netted dog whelk *T. reticulata* and high densities of *O. ophiura*. For fish, dominance of lesser weever is lower in Rentel and C-Power and solenette *B. luteum*, dab, whiting and dragonet occur in relative higher abundances compared to Belwind. The epibenthos and fish assemblage observed at the Norther concession/reference zone best related to the coastal 1 assemblage described by Vandendriessche *et al.* (2009), which was characterized by high density and diversity, although the current data rather characterize the Norther assemblage as a transition between the coastal 1 and the typical offshore assemblages as observed in the other concession/reference zones.
- Since Norther exhibits a quite different epibenthos and fish assemblage compared to the other zones, a follow-up of this future OWF seems justified, as an extrapolation of the results of the ongoing monitoring in the existing OWFs (C-Power and Belwind) cannot be considered reliable. Rentel, on the other hand, has a soft sediment epibenthos and fish assemblage which is very similar to C-Power, indicating that results of C-Power can be extrapolated to this area, assuming that effects of jacket and monopile foundations are comparable at further distances from the turbines. Preliminary results on macrobenthos and sediment characteristics near different foundation types showed no differences between foundation types (Colson *et al.* 2017). Monitoring of Rentel seems

redundant within the current WinMon monitoring program. Nevertheless, if it were to be included in the program, the sampling design is adequate: variability between the different fish tracks is low and reference locations are suitable for the concession area. Only ftRen1 inside the concession area differed due to a more even distribution of densities over the different species.

- Integration of Norther in the WinMon monitoring framework is recommended. However, the high degree of variability observed between the different fish track locations in the Norther concession and reference zone could be a bottleneck for the effect monitoring. Species occurrence is quite similar between locations both inside and outside the concession zone, but densities and relative abundance of common species differ largely from one fish track to the other, especially for epibenthos. This can hamper a sound impact assessment, since it will be difficult to measure effects of the future OWF when natural variability is so high, both inside and outside the concession zone. Furthermore, for ftNor2 located within the Norther concession zone, we measured the impact of a fishing vessel that just passed by, leaving very low densities and lots of dead fish and epibenthos, making this not the most ideal sample for a $T_0$ reference condition. In that respect, it would be best to exclude this outlier sample for future impact assessments. Nevertheless, including this sample in the current chapter gives an indication on what effect fisheries activity can have on the epibenthos and fish assemblage, and thus also on what might be expected when fisheries are excluded once the OWF comes in place *i.e.*, a richer and more diverse assemblage.
- The decision on whether or not to include Norther in the overall WinMon monitoring program should be made by taking into account as well the results for the other ecosystem components sampled by UGent, being hyperbenthos and macrobenthos. For epibenthos and demersal-benthopelagic fish, we showed that results of previous monitoring in C-Power and Belwind cannot be directly extrapolated to Norther, since it is a different assemblage inhabiting the concession zone. However, the natural variability in the Norther concession and reference zone is high. Consequently, effects will only be picked up when the impact is huge or after a certain amount of time when time series in the area are long enough to be able to detect a potential fisheries exclusion effect. On the other hand, the fisheries exclusion effect in this more diverse and richer epibenthos and demersal-benthopelagic fish assemblage might be even stronger than for the offshore assemblages in the other OWFs.

## Acknowledgements

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## Annex 1

Species names with according abbreviations used in the figures in this chapter.

| | Species name | Abbreviation |
|---|---|---|
| Epibenthos | *Asterias rubens* | Astrub |
| | *Cephalopoda* sp. | Cephalo |
| | *Liocarcinus depurator* | Liodep |
| | *Liocarcinus holsatus* | Liohol |
| | *Macropodia* sp. | Macrop |
| | *Ophiura albida* | Ophalb |
| | *Ophiura ophiura* | Ophoph |
| | *Pagurus bernhardus* | Pagber |
| | *Psammechinus miliaris* | Psamil |
| | *Spisula solida* | Spisol |
| | *Tritia reticulata* | Triret |
| Fish | *Agonus cataphractus* | Agocat |
| | *Arnoglossus laterna* | Arnolat |
| | *Buglossidium luteum* | Buglut |
| | *Callionymus lyra* | Callyr |
| | *Callionymus reticulatus* | Calret |
| | *Echiichthys vipera* | Echvip |
| | *Limanda limanda* | Limlim |
| | *Merlangius merlangus* | Mermer |
| | *Mullus surmuletus* | Mulsur |
| | *Pleuronectes platessa* | Plepla |
| | *Pomatoschistus* sp. | Pomato |
| | *Trisopterus luscus* | Trilus |