CHAPTER 8

EFFECTS OF BELGIAN WIND FARMS ON THE EPIBENTHOS AND FISH OF THE SOFT SEDIMENT

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ABSTRACT

This chapter focuses on the changes in epibenthos and demersal fish of the soft substrates in and around the C-Power and Belwind wind farm. The time series graphs from Vandendriessche *et al.* (2015) were extended and scanned for non-parallelisms between reference and wind farm trend lines. Also size distribution graphs were drawn and analysed. The analyses showed differences between wind farm and reference areas for the period 2013-2014.

The positive short-term effects from Vandendriessche *et al.* (2015) seemed to be a reaction of opportunistic species (i.e. common starfish (*Asterias rubens*), green sea urchin (*Psammechinus miliaris*), brittle star (*Ophiura ophiura*)) since the observed effects disappeared shortly after. The positive short-term effects on plaice (*Pleuronectes platessa*) and sole (*Solea solea*) could be explained by natural variations in the ecosystem. The earlier reported signals of a ‘refugium effect’

are no longer observed. The decreasing trend for dab (*Limanda limanda*) continued, resulting in a net emigration from the wind farm. Sandeel (*Ammodytes tobianus*) displayed episodic increases and short-term positive effects on juveniles. No long-term sandeel trends were visible.

Long living species were not yet encountered but may get a chance to establish and recover with the expansion of the wind farm area to a large continuous no-trawling area.

8.1. INTRODUCTION

The construction of wind farms implies the introduction of artificial hard structures into the soft sediment. Many studies already demonstrated the reef effects on epibenthos and fish in the immediate vicinity of wind turbines (May, 2005; Peterson & Malm, 2006; Wilhelmsson *et al.*, 2006a; Wilson *et al.*, 2007; Wilhelmsson *et al.*, 2009; Andersson *et al.*, 2009; Andersson & Öhman, 2010; Reubens *et al.*, 2011; Simon *et al.*, 2011; Krone, 2012; Langhamer, 2012; Bergström *et al.*, 2013; Krone *et al.*, 2013; Reubens *et al.*, 2013, Bergström *et al.*, 2014). The surrounding natural soft sediment and its associated macrofauna also seems to be affected by the artificial hard structures and by the absence of fisheries (Barros *et al.*, 2001; Duineveld *et al.*, 2007; Simon *et al*, 2011; Coates *et al.*, 2014; Dannheim *et al.*, 2014; Gutow *et al.*, 2014; Bergman *et al.*, 2015; Coates *et al.*, 2015; Coates *et al.*, 2016), e.g. shifts in macrobenthic assemblages, higher densities of species sensitive to trawling activities, changes in species or community energy flow.

A Dutch study (van Hal *et al.*, 2012) found no significant wind farm effects or effects of fisheries exclusion on the abundance and community structure of demersal fish, including whiting. Similarly, Bergström *et al.* (2013) revealed no large-scale wind farm effects on benthic fish diversity and abundance. A German study (Gutow *et al.*, 2014) described notable changes in epibenthic biomass and abundances, resulting in differences between reference areas and the wind farm area, A Danish study of Stenberg *et al.* (2015) again noted an overall positive wind farm effect on fish abundance, mainly on a small spatial scale (close to the turbines). At the level of key fish species, e.g. whiting (*Merlangius merlangus*) however, wind farm effects seemed limited: there were similar length distributions and catch levels in the wind farm and the reference area. Similarly, populations of the sand-dwelling species dab (*Limanda limanda*) and sandeel (*Ammodytidae* spp.) were not altered by the wind farm.

In Belgium, Vandendriessche *et al.* (2015) indicated several wind farm effects, including an increase in epibenthos biomass and densities. The higher sole densities in the wind farm and changes in length-frequency distributions for dab (*L. limanda*) and plaice (*Pleuronectes platessa*) may signal a ‘refugium effect’. Positive short-term effects on sandeel densities were both described by van Deurs *et al.* (2012) and Vandendriessche *et al.* (2015).

Edge effects due to changes in fisheries intensity or ‘spillover’ from the wind farm could not be demonstrated in Belgian wind farms (Vandendriessche *et al.,* 2015). However, such effects will probably emerge as soon as the wind farm area is becoming a single entity and the effects of fisheries exclusion will further develop. For this reason, edge effects are not within the scope of this study and will be further investigated once the construction of this large wind farm is completed.

The present study focuses on wind farm effects (combined effect of the wind farm presence and fisheries exclusion) on those epibenthic and demersal fish species that showed remarkable changes in density, biomass and/or size distribution in Vandendriessche *et al.*, 2015.

The research question for this study is:

"Are the previously observed wind farm effects still present and expanding?", including the subquestions

- Are there significantly different densities of epibenthic and fish species in the wind farm compared to the reference area for the years 2013-2014?
- Are there shifts in size distribution of certain species in the wind farm compared to the reference area?

8.2. MATERIAL AND METHODS

In 2013 and 2014, beam trawl samples were taken within the wind farms, i.e. between the turbine rows, just outside the concessions and at reference stations away from the concessions, both in spring and autumn. A number of stations could not be sampled due to bad weather conditions and logistic problems (Figure 1, Table 1 and Figure 2). Up till now, no samples could be taken on the Lodewijckbank (Northwind) due to the fact that no straight line of 1 Nm can be fished because of the orientation of the infield cables. Epibenthos and demersal fish are organisms living on or in the vicinity of the sea bottom and which can efficiently be sampled with this shrimp trawl. They were sampled with an 8-meter shrimp trawl (22 mm mesh in the cod end) equipped with a bolder-chain in the ground rope. The net was towed over 1 nautical Mile, approximately covering 15 minutes at an average speed of 3.5 to 4 knots in the direction of the current. 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 depth contours that run parallel to the coastline, thereby minimizing the depth variation within a single track, except for track 2 and track 3 in the C-power concession area due to the positioning of the electricity cables.

All samples gathered in 2013 and 2014 have been processed (on board and in the lab). All data are entered in the ILVO database (developed and maintained in close cooperation with VLIZ), and were delivered to the Belgian Marine Data Centre for archiving.

Due to serious logistic problems with the R.V. Belgica, no samples could be taken in 2015.

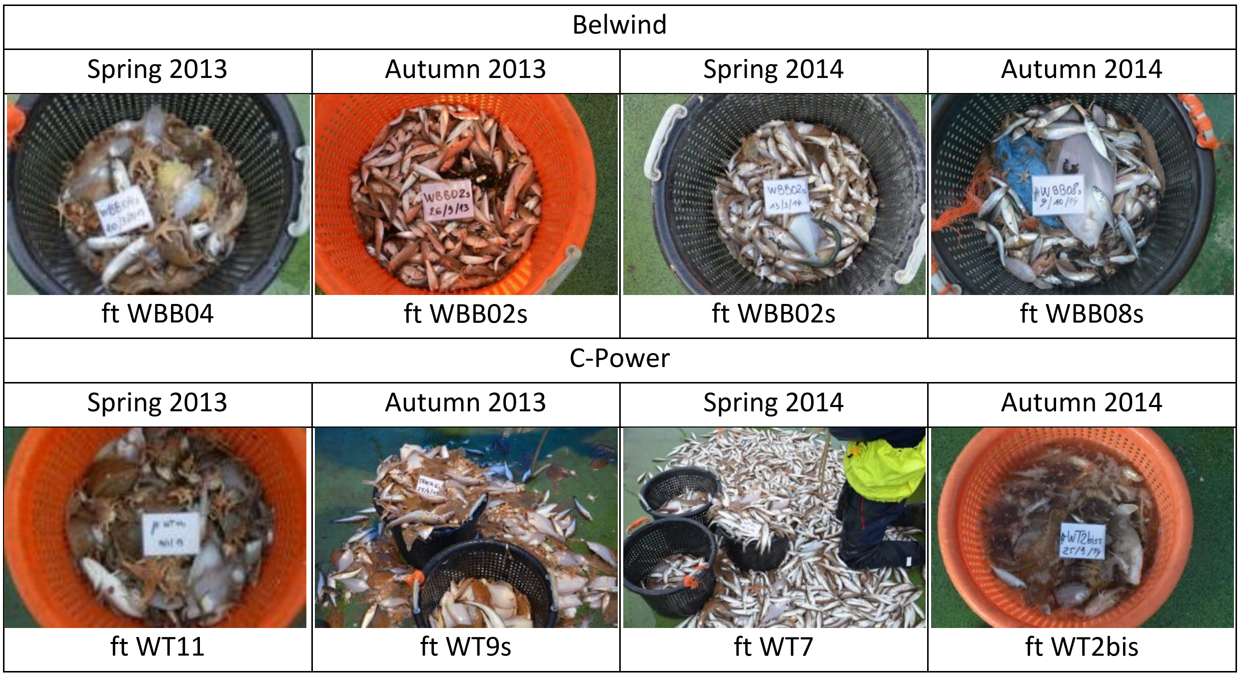

Figure 1. Some impressions of the beam trawl catches in and around the C-power and Belwind wind farms.

Table 1. Stations per sandbank system, with indication of sampling activities in spring and autumn.

sandbank system	station	imp/ref/fri	top/gully	spring 2014	autumn 2014
Gootebank	WG2	ref	top	X	X
	330	ref	gully	X	X
Thorntonbank (C-Power)	WT1(bis)	ref	gully	X	X
	WT2(bis)	ref	top	X	X
	WT3	ref	gully	X	X
	WT7	fringe	gully	X	X
	WT9	fringe	gully	X	X
	WT10	fringe	gully	X	X
	WT11	fringe	gully	X	X
	track 2	impact	top	X	
	track 3	impact	top	X	
	track 5	impact	top	X	X
	track 6	impact	top	X	X
Lodewijckbank	BZN01	impact	top		
Bligh Bank (Belwind)	WBB01	ref	gully	X	X
	WBB02	ref	top	X	
	WBB03	ref	gully	X	X
	WBB04	fringe	gully	X	X
	WBB05	impact	gully	X	X
	WBB06a	impact	top	X	
	WBB06b	impact	top	X	
	WBB07	impact	gully	X	X
	WBB08	fringe	gully	X	X
Oosthinder	WOH01	ref	gully	X	
	WOH02	ref	top	X	
	WOH03	ref	gully	X	

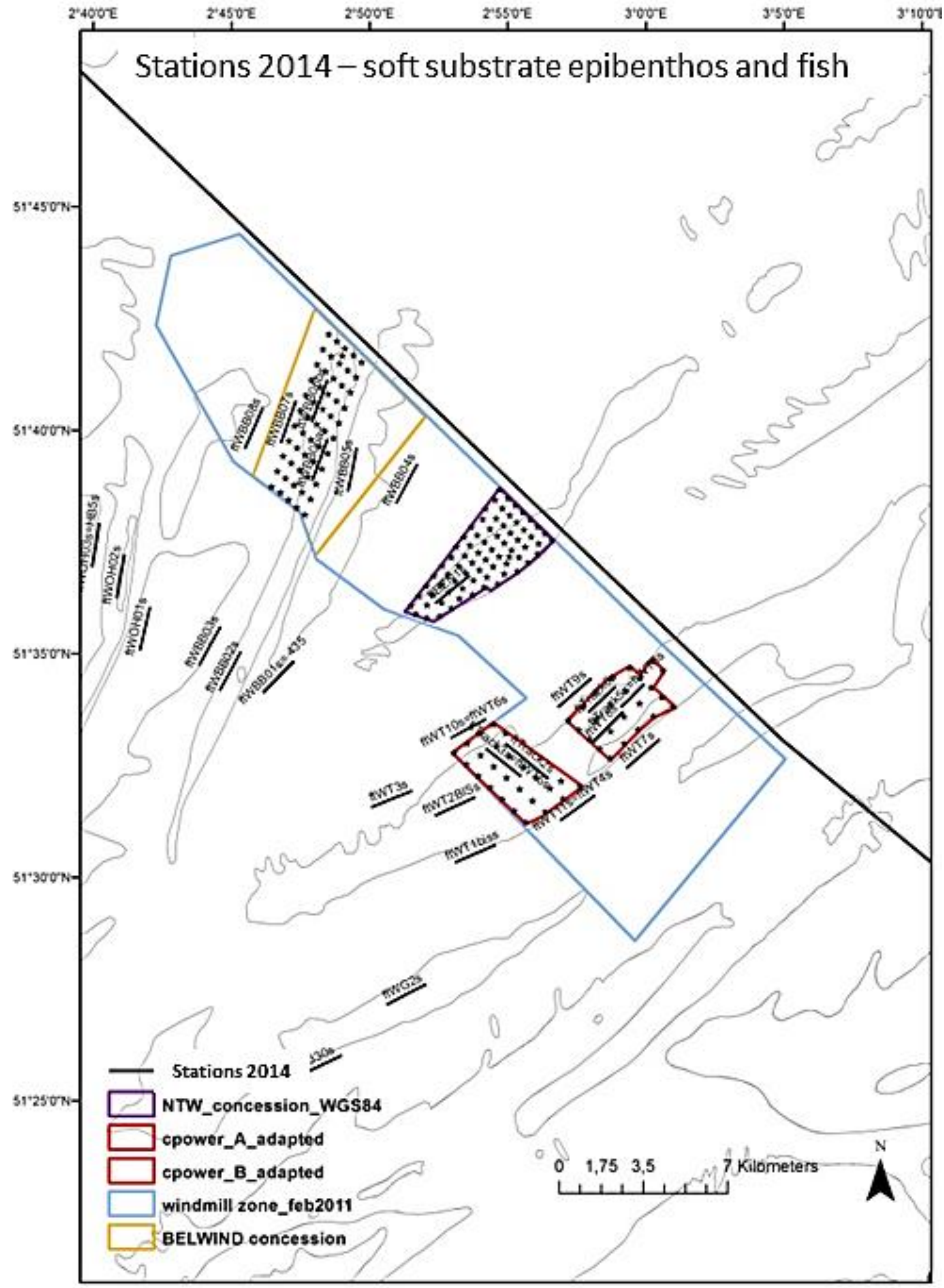

Figure 2. Map showing the 2014 sampling stations at the wind farm concession areas of C-power, Belwind (and Northwind).

The time series graphs from Vandendriessche *et al.* (2015) were expanded in this study.

If clear non-parallelisms occurred in the density time series graphs for the period 2013-2014, statistical analyses were performed with “area” (Control/Impact) as factor. If significant results were found, statistical analyses were executed for 2013 and 2014 separately. The Plymouth routines in multivariate ecological research (PRIMER)e-package + PERMANOVA add-on, version 6.1.6 (Anderson *et al.*, 2007) were used.

8.3. RESULTS

GENERAL

An exploratory overview of the average densities of the five most abundant species in the wind farm (impact) and the surrounding reference (ref) area for 2013 and 2014, is given in Figure 3.

Lesser weever (*Echiichthys vipera*) was a dominant species in the Belwind area (Bligh Bank) (both in autumn and spring) (Figure 3 left) and a subdominant species in the C-Power area (Thorntonbank) in autumn (Figure 3. right up). Density differences between impact and reference area emerged but the pattern was not unambiguous. The hermit crab *Pagurus bernhardus* was also important in the Belwind area (Bligh Bank) and in both seasons but in lower densities and with hardly no differences between impact and reference area.

The soft-bottom community of the C-Power area (Thorntonbank) was dominated by the common starfish (*Asterias rubens*) in autumn (Figure 3. right up) and by the brown shrimp (*Crangon crangon*) and the common starfish in spring (Figure 3. right below). The common starfish densities showed higher values in the wind farm, but also high standard errors. Detailed graphs and analysis on this species are described in paragraph 3.2.

Figure 4 (left) indicates wind farm effects on the epibenthos biomass at the sand bank tops in the Belwind area (Bligh Bank) with increased values at the wind farm top stations, both in autumn (up) and spring (below). From 2011 onwards however, these biomass values decreased and evolved towards (spring) or even below (autumn) the reference top values.

A similar trend is visible in the C-Power area (Thorntonbank) in autumn (Figure 4. right up), the epibenthos biomass was higher at the wind farm top stations (purple line) and declined from 2012 onwards to similar values as the reference top stations (light blue line).

Epibenthos density graphs showed similar patterns (figures not shown).

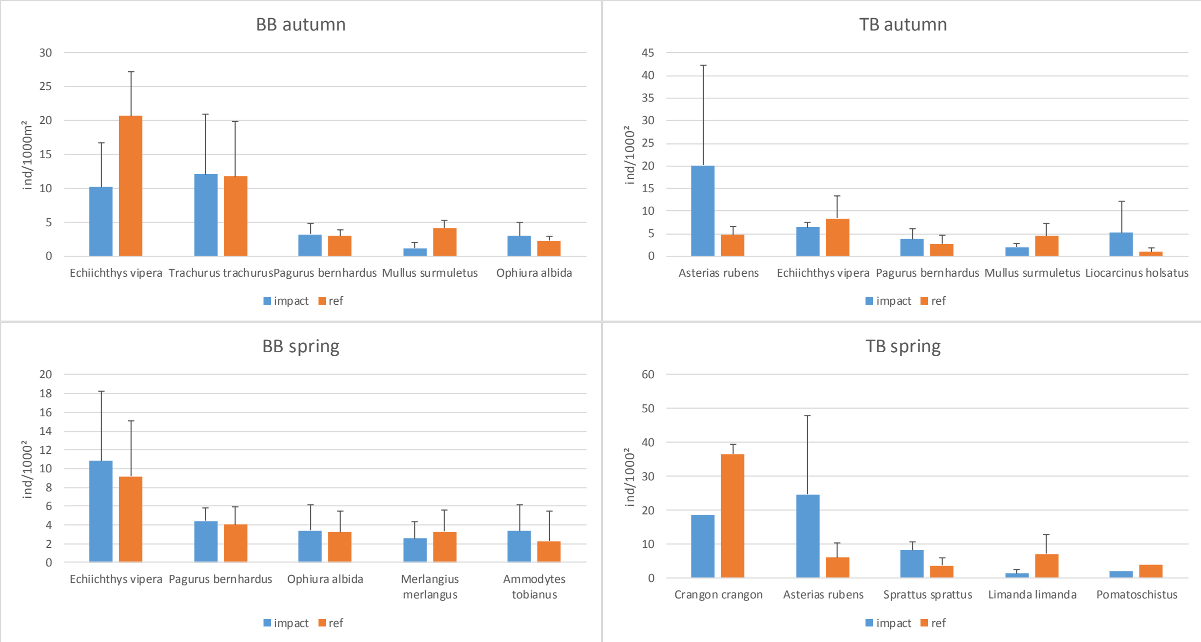

Figure 3. Average densities (ind/1000m²±SE) of the five most abundant species for 2013 and 2014 together, for the Belwind (Bligh Bank) (left) and C-Power area (Thorntonbank) (right) and in autumn (up) and spring (below).

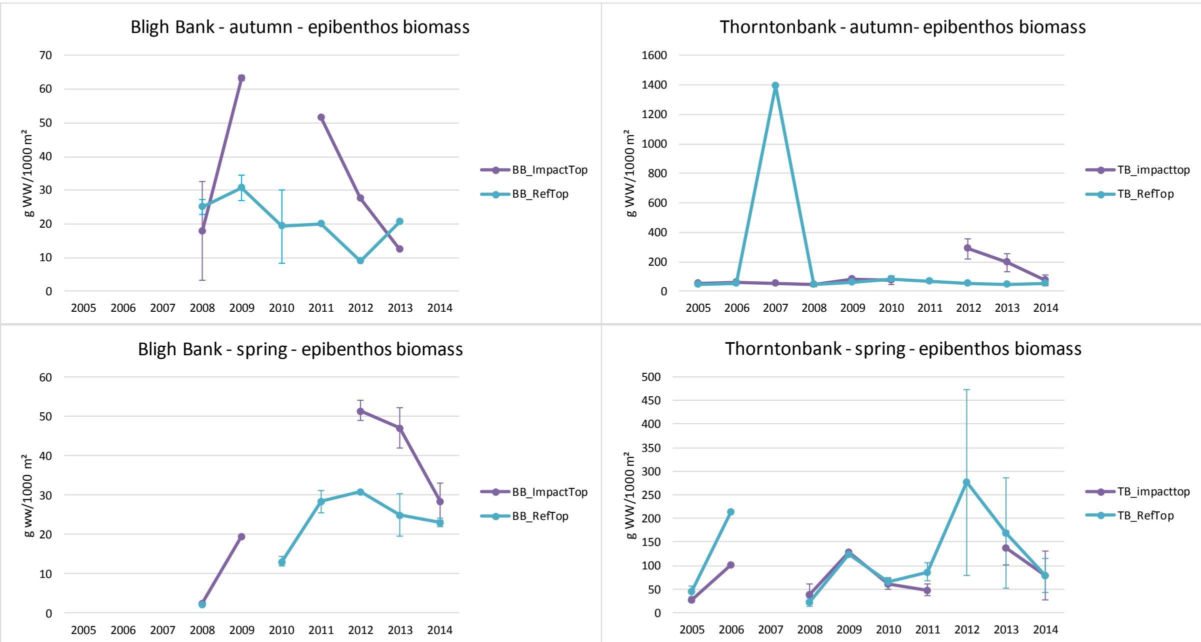

Figure 4. Epibenthos biomass (average gWW/1000 m^2±SE) for the Belwind (Bligh Bank) (left) and C-Power area (Thorntonbank) (right), in autumn (up) and spring (below) between 2005 and 2014.

DENSITY AT SPECIES LEVEL

Common starfish (*Asterias rubens*) & green sea urchin (*Psammechinus miliaris*)

The high densities of **common starfish** (*A. rubens*) in the Belwind area (Bligh Bank) in 2011 suggested a significant wind farm effect (in spring) and significant effects within years (in autumn) (Vandendriessche *et al.*, 2015). From 2011 onwards however, an overall decrease in common starfish densities occurred (Figure 5), in both wind farms (C-Power not shown), seasons and sandbank systems. Both reference and impact densities were very low in 2014, with no significant differences between reference and impact values. This might indicate that the previously observed wind farm effect was a temporary phenomenon.

A similar pattern appears for **green sea urchin** (*P. miliaris*) in the Belwind area (Bligh Bank) (Figure 6): high densities in the wind farm area and a declining trend from 2011 onwards.

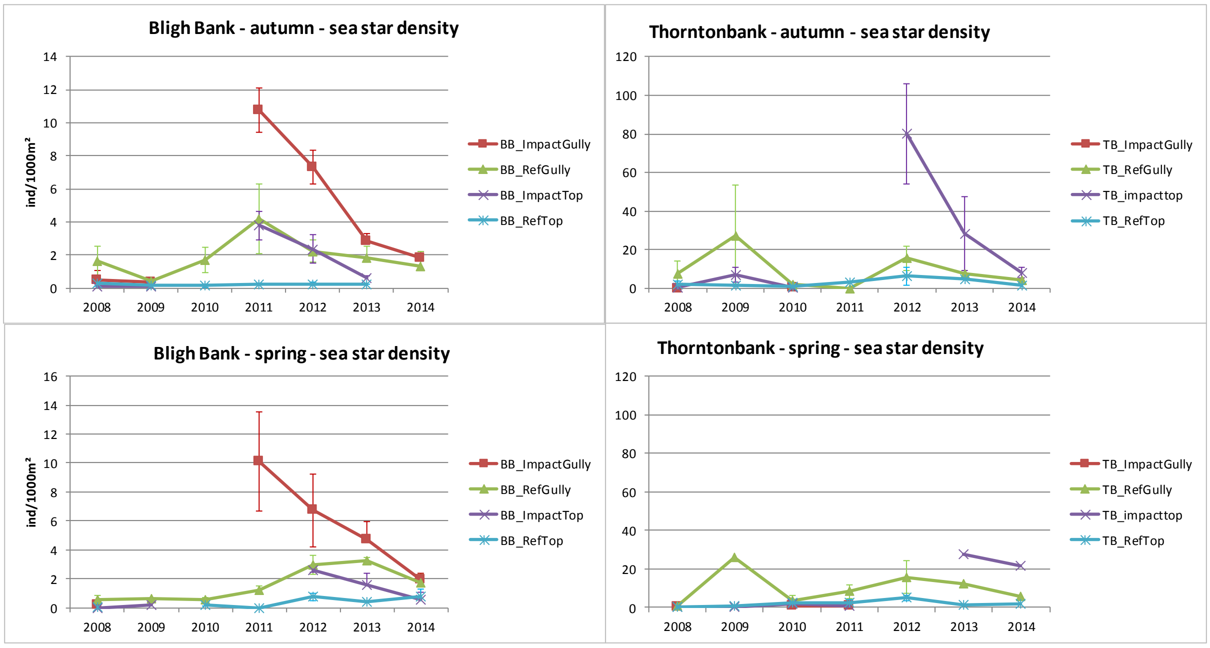

Figure 5. Average common starfish (*A. rubens*) density (ind/1000 m^2±SE) for the Belwind (Bligh Bank) (left) and C-Power area (Thorntonbank) (right), in autumn (up) and spring (below) between 2008 and 2014.

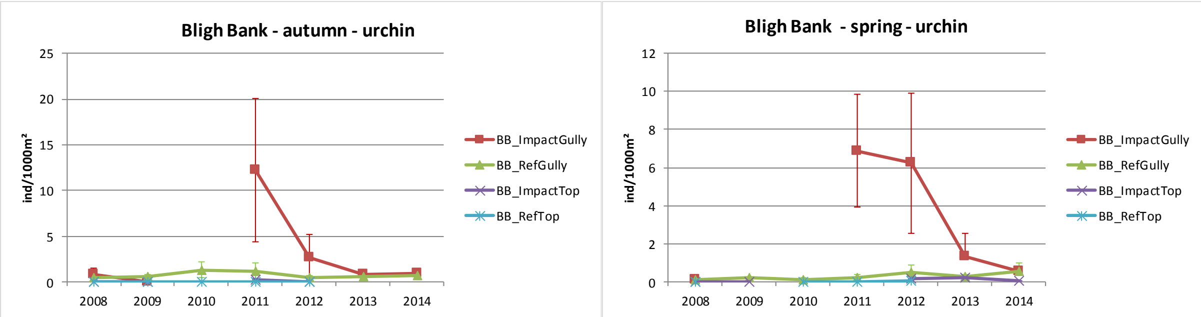

Figure 6. Average green sea urchin (*P. miliaris*) density (ind/1000 m^2±SE) for the Belwind area (Bligh Bank) in autumn (left) and spring (right) between 2008 and 2014.

Brittle star (*Ophiura ophiura*)

A wind farm effect on **brittle star** densities of the gullies was observed in 2009 (Vandendriessche *et al.*, 2015): densities in the Belwind wind farm (Bligh Bank) dropped dramatically. After the wind farm construction, the population recovered and followed the same trend as the reference population.

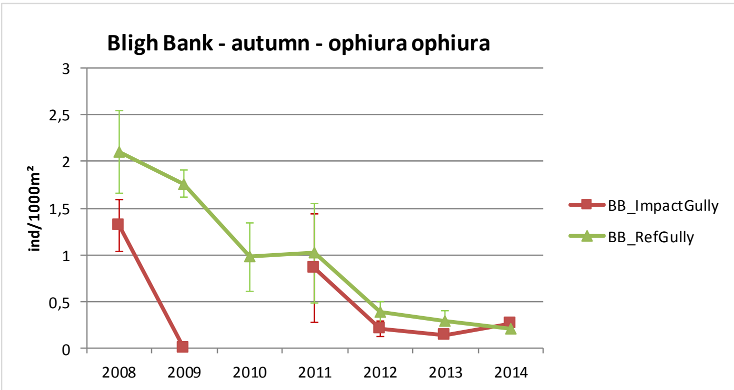

Figure 7. Average brittle star (*O. ophiura*) density (ind/1000 m^2±SE) for the Belwind area (Bligh Bank) in autumn between 2008 and 2014.

Dab (*Limanda limanda*)

For autumn **dab** densities in the Belwind area (Bligh Bank) (Figure 8. left), there is a downward trend from 2008 onwards. Non-parallelisms between the autumn wind farm and reference densities occurred, both at the tops (between 2011-2013) and in the gullies (between 2013-2014). This may indicate a wind farm effect on the density of dab. For the period 2013-2014, the autumn density differences between wind farm and reference gully stations turned out to be significant (p=0,03) and more specifically, the density difference in 2014 (p=0,01). In spring 2012 (Figure 8. right), the high density of dab in the wind farm in 2012 and the subsequently steep decline between 2012 and 2013 is striking. No differences between impact and reference densities occurred in spring for the period 2013-2014.

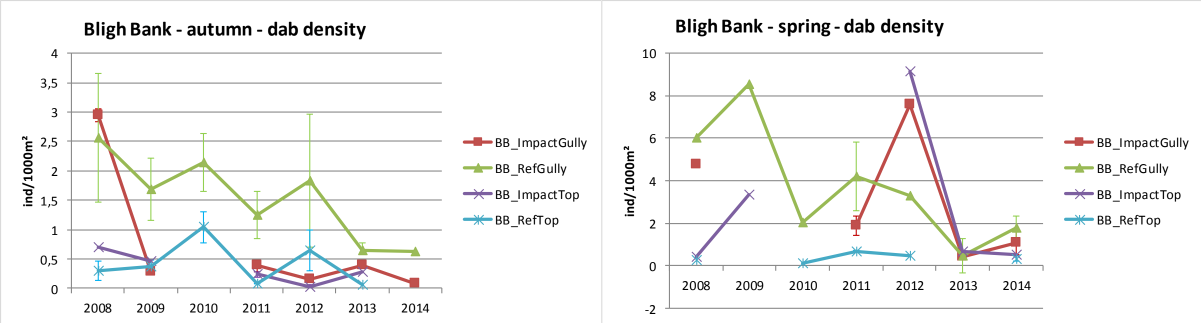

Figure 8. Average dab (*L. limanda*) density (ind/1000 m^2±SE) for the Belwind area (Bligh Bank) in autumn (left) and spring (right) between 2008 and 2014.

Plaice (*Pleuronectes platessa*)

A general increase in **plaice** density was established over the years. From 2011-2012 onwards however, densities generally decreased again towards similar or even lower values than those before the construction of the wind farm (Figure 9). In 2013-2014, spring plaice densities were higher, but not significantly, at the wind farm tops compared to the reference tops.

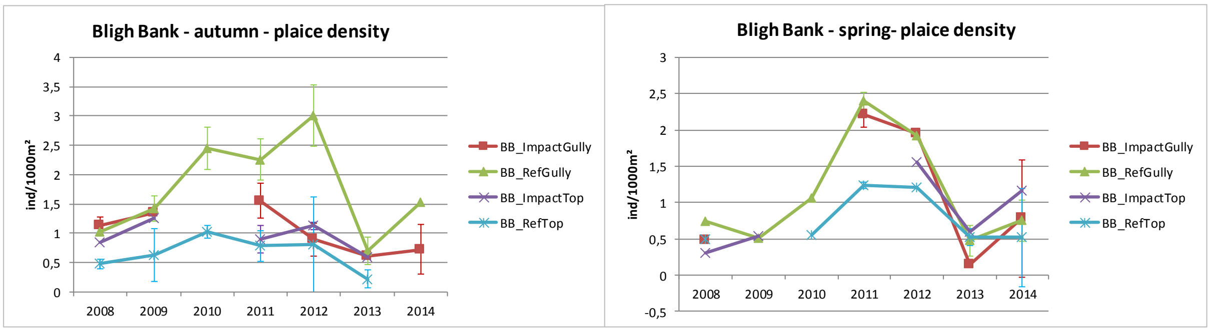

Figure 9. Average plaice (*P. platessa*) density (ind/1000 m^2±SE) for the Belwind area (Bligh Bank) in autumn (left) and spring (right) between 2008 and 2014.

Sole (*Solea solea*)

Higher sole densities were observed in the Belwind area (Bligh Bank) wind farm area in spring 2011 and 2012, both in the gullies and at the sandbank tops (Figure 10). From 2013 onwards however, this difference between impact and reference stations disappeared and sole densities reached approximately the same values. The previously observed wind farm effect on the density of sole (cfr. Vandendriessche *et al.*, 2015) seems to have been a temporary phenomenon.

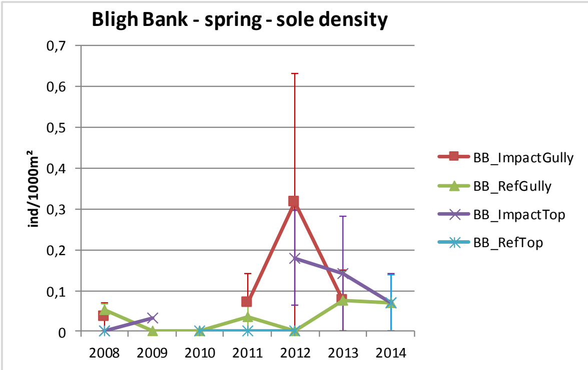

Figure 10. Average sole (*S. solea*) density (ind/1000 m^2±SE) for the Belwind area (Bligh Bank) in spring between 2008 and 2014.

Sandeel (*Ammodytes tobianus*)

Over the years, sandeel densities showed episodic increases at both wind farms, in both seasons, at both impact and reference stations (Figure 11). Non-parallelisms in the time series included higher autumn densities at the reference stations than at the impact top stations in the C-Power area (Thorntonbank) in 2014 (Figure 11. right up). The opposite pattern was observed for the differences in spring densities in the C-Power area (Figure 11. right below). Also in the Belwind area (Bligh Bank), a non-parallelism occurred (Figure 11. left below): lower reference densities in 2012, higher reference values in 2013 and again lower reference densities in 2014, compared to the gradually decreasing impact densities. These non-parallelisms may signal a wind farm effect on the sandeel densities, but statistical analyses showed no significant differences between reference and impact sandeel densities for 2013 and 2014.

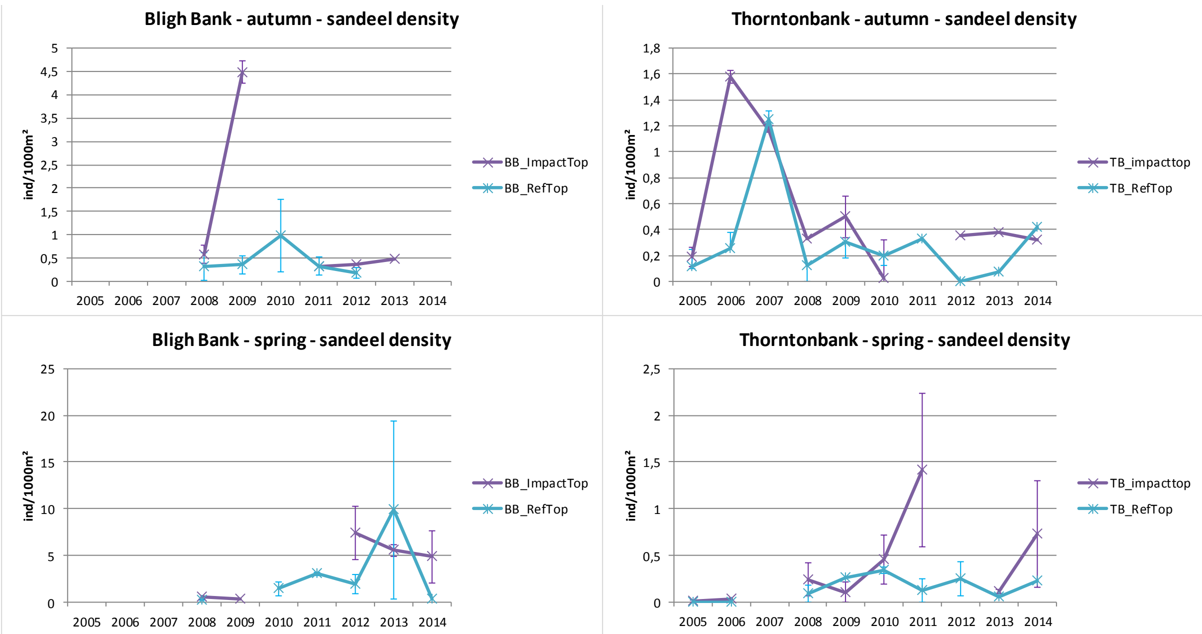

Figure 11. Average sandeel (*A.tobianus*) density (ind/1000 m^2±SE) for the Belwind (Bligh Bank) (left) and C-Power area (Thorntonbank) (right), in autumn (up) and spring (below) between 2005 and 2014.

Time series graphs were also made for whiting (*Merlangius merlangus*), swimming crab (*Liocarcinus holsatus*) and brown shrimp (*Crangon crangon*). However, no significant changes could be denoted.

SIZE DISTRIBUTION

Dab (*Limanda limanda*)

Figure 12 shows the size distribution of dab between 2008 and 2014. From 2008 to 2013, two size classes could be distinguished, both in reference and impact areas. However, densities decreased dramatically over the years, first in the impact area but also in the reference area. The smallest size class completely disappeared in 2014 which automatically leads to a higher average length of 22 cm, in both areas.

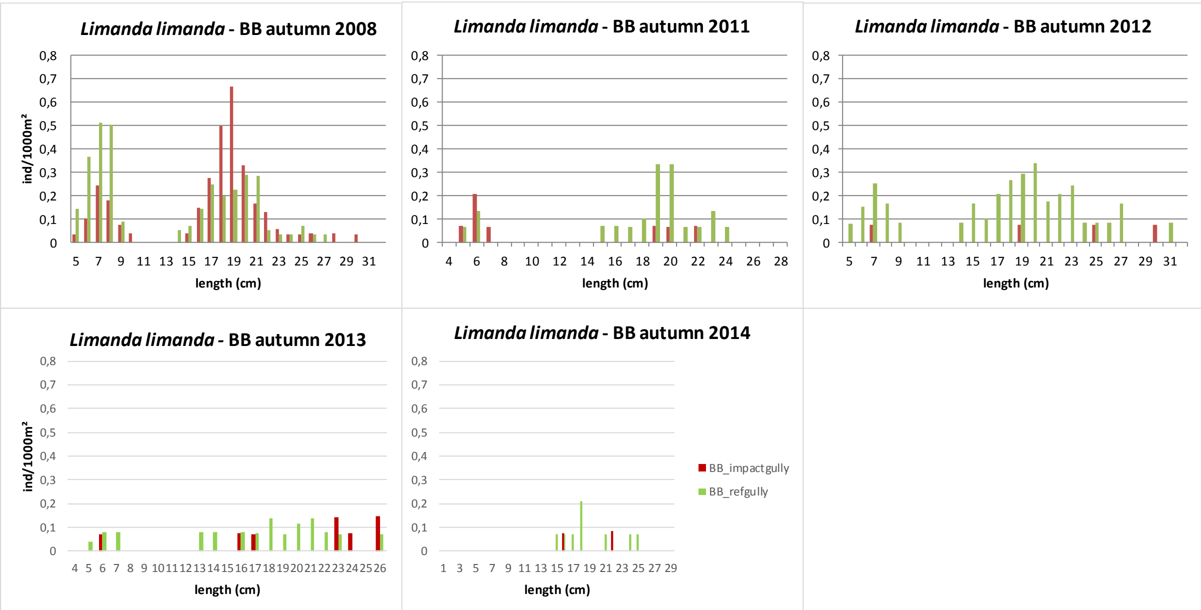

Figure 12. Length-frequency distributions of dab (*L. limanda*) at the Belwind (Bligh Bank) gully stations in autumn 2008, 2011, 2012, 2013 and 2014.

Sandeel (*Ammodytes tobianus*)

Time series graphs of the size distribution of **sandeel** from Vandendriessche *et al*. (2015) could not be complemented for the impact and reference stations of autumn 2013 and 2014 in the Belwind area (Bligh Bank) due to missing data.

Spring data on size distributions are represented in Figure 13. In the Belwind wind farm area (Bligh Bank) (Figure 13. up), no changes in sandeel size distribution occurred. In the C-Power area (Thorntonbank) (Figure 13. below) however, there was a shift towards smaller individuals in the wind farm area.

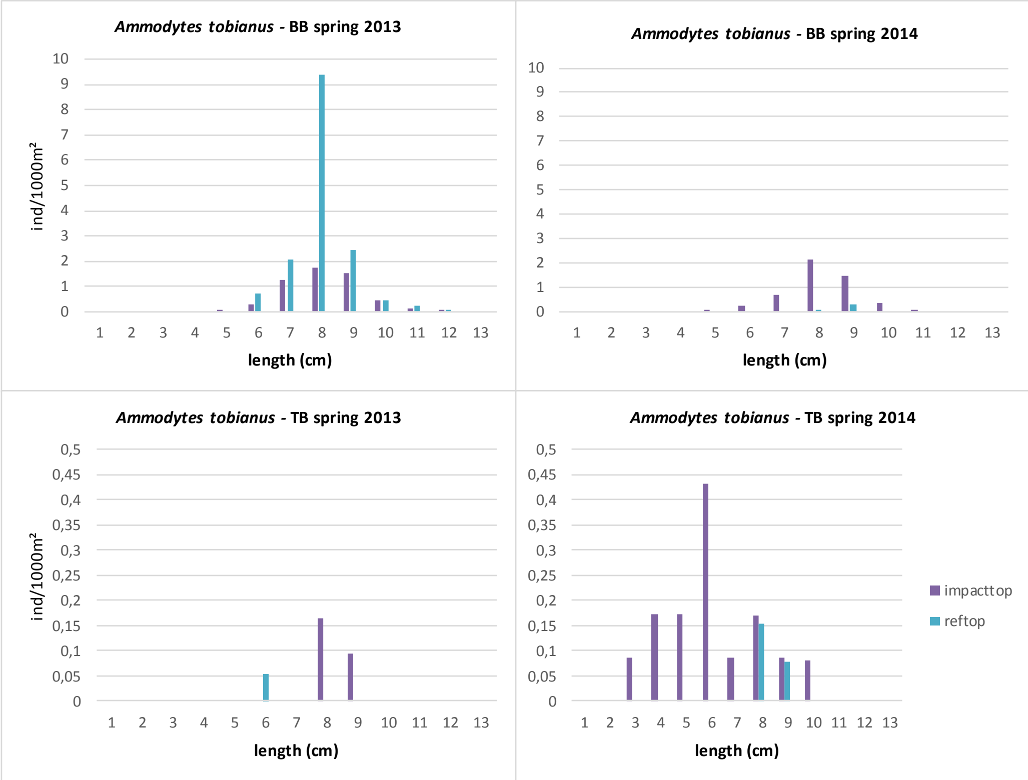

Figure 13. Length-frequency distributions of sandeel (*A. tobianus*) for the Belwind (Bligh Bank) (up) and C-Power area (Thorntonbank) (below) in spring 2013 and 2014.

8.4. DISCUSSION

GENERAL

The observed wind farm effects on soft bottom epibenthos, demersal and benthopelagic fish described in Vandendriessche et al. (2015) were further investigated in this study. This was done by extending existing time series graphs and size distribution graphs and by scanning for non-parallelisms between reference and wind farm trend lines. These analyses showed differences between wind farm and reference areas for the period 2013-2014.

EPIBENTHOS BIOMASS

The epibenthos biomass values showed remarkable post-construction increases in Vandendriessche et al (2015) (data 2008-2012). However, the extended time series show that these increases in both the C-Power (Thorntonbank) and Belwind (Bligh Bank) wind farms only lasted for a couple of years. In 2013-2014, biomass values at the wind farms decreased to comparable or lower values compared to the reference areas. This might indicate that the observed wind farm effect was a temporary phenomenon. Similarly, Gutow et al., (2014) found a significant wind farm effect on the epifauna biomass, which disappeared again the year after. In Gutow's study however, the reference and wind farm values further diverged. It is not yet clear whether this was a transient development.

COMMON STARFISH (*Asterias rubens)*

The previously observed wind farm effect on the common starfish (A. rubens) densities (i.e. higher densities in the wind farm) was mainly due to a recruitment of small individuals (Coates et al., 2014; Vandendriessche et al, 2015). From 2012 onwards, the wind farm starfish densities strongly decreased to values similar to the ones recorded at the reference stations. This may be due to a lower recruitment following unfavourable environmental conditions (Coates et al., 2014) or the decreased food availability.

The positive wind farm effect on common starfish seems to have been a temporary phenomenon.

This phenomenon of large numbers of juvenile starfish alternated by a low number of large individuals is observed on the foundations as well (Kerckhof et al., 2012).

GREEN SEA URCHIN (*Psammechinus miliaris*)

Similar to the common starfish, the high wind farm densities of green sea urchin (P. miliaris) in the Belwind wind farm (Bligh Bank) drastically declined to similar values as in the reference area. This may be due to a:

- Infringements: the species is sensitive to physical damage by trawling (Lokkeborg, 2005). However, the data from RBINS-OD Nature do not show an increased number of violations to the trawling prohibition for the period 2013-2014 and most infringements seems limited to the safety zone.
- Dislodgment: De Mesel et al. (2015) observed large feeding fronts of the sea urchin on the turbines, which may be an indication of urchin concentrations on the turbines.

BRITTLE STAR *(Ophiura ophiura)*

A sudden decline in brittle star (O. ophiura) densities was caused by the construction of the Belwind (Bligh Bank) wind farm. From 2011 onwards, wind farm densities recovered and both reference and wind farm densities displayed comparable densities with a naturally varying pattern. In this case, the wind farm effect seemed to be a temporary construction effect.

DAB (*Limanda limanda)*

A general decreasing trend in autumn dab (L. limanda) densities occurred from 2008 onwards, both in the Belwind wind farm (Bligh Bank) and the reference area. Dab seemed to move away from the wind farm and its reference area until only a few adult individuals remained. However, the significantly lower autumn densities in the impact area and the non-parallelism between impact and reference densities may suggest a wind farm effect, i.e. a higher net emigration from the wind farm. In spring 2012, there was a temporarily higher attraction/production of dab in the wind farm. Similarly, Leonhard et al. (2011) also observed short-term changes in dab densities after deployment of the Danish wind farm Horns Rev 1. These changes mostly reflected the general trend of this fish population in the North Sea (Leonhard et al., 2011). Long-term wind farm effects on dab were not encountered, both in this study and in Stenberg et al., 2015.

OTHER FLATFISH

For sole (Solea solea) and plaice (Pleuronectes platessa), there seemed to be a temporarily higher attraction/production in the Belgian wind farm area. Lindeboom et al. (2011) denoted a significant increase of sole inside the Dutch OWEZ wind farm. However, telemetry experiments indicated that the majority of sole movements took place at spatial scales larger than the wind farm area and that no large scale avoidance nor attraction occurred (Winter et al., 2010).

In general, a short residence time of adult flatfish in the wind farm was already hypothesized by Winter et al. (2010), Lindeboom et al. (2011) and Vandendriessche et al, (2015). Altered flatfish densities and size distributions (e.g. no large individuals of plaice or turbot (Psetta maxima), in contrast to Vandendriessche et al., 2015) indicate that the previously reported 'refugium effect' was rather limited. In 2013-2014, the Belgian wind farms were still rather small and discontinuous. From 2015 onwards, the wind farm area is becoming a larger and continuous area. With the expansion of the wind farm area to a continuous area in the future, the area may act as a no-trawling zone. Short-term positive effects are expected to occur with the construction of every new wind farm. We may also expect long-term positive effects since the wind farms constitute a sanctuary area for trawling-sensitive organisms. For example, the likely increase of dense Lanice conchilega reefs in the wind farm area could create an ecological important large-scale 'refugium' for higher trophic levels (Coates et al., 2016). Juvenile fish will have a higher chance to survive and even older, bigger fish will improve survival rates (Langhamer, 2012).

However, environmental parameters should also be considered here. Temperature may cause inter-annual variability in catchability: high temperatures may reduce the gear efficiency because of higher escape rates induced by increased activity in dab and plaice (Bolle et al, 2001). So, the fact that the temperature at the Belwind wind farm (Bligh Bank) was approximately one degree higher in 2013 and 2014 (17,0-17,3 C°) than in 2012 (16,0-16,1 °C) may partly explain the decreased densities of dab and plaice for 2013 and 2014.

SANDEEL (*Ammodytes tobianus)*

In this study and in Vandendriessche et al. (2015), episodic increases of sandeel (A. tobianus) occurred with slightly positive effects on juvenile sandeels. Leonhard et al. (2011) and Van Deurs et al. (2012) also observed a positive short-term wind farm effect on the densities of sandeel which were mainly related to changes in sediment composition and predator abundance.

The fining of the sediment in the immediate vicinity of the turbines (Coates et al., 2014) and the sandeel's preference for sand habitats (Van Deurs et al., 2012), suggest that sandeels are moving away from the turbines. However, this hypothesis should be further investigated to be confirmed. The patchy sandeel distribution, shifts in predator abundance, changes in pelagic activity and changes in recruitment due to changes in zooplankton availability during the larval stage may also offer an explanation for the observed changes (Arnott & Ruxton, 2002; Frederikson et al., 2006; Van Deurs et al., 2012). The significant attraction of herring gull (Larus argentatus), a piscivorous bird species, to the Belwind wind farm (Bligh Bank) (Vanermen et al., 2015) may be linked to the decreasing sandeel densities from spring 2012 to 2014.

Still, no significant long-term effects on this species could be detected, in this study nor in the studies of Van Deurs et al. (2012) and Stenberg et al. (2015).

Since sandeel plays an inevitable key role in the North Sea ecosystem (Leonhard et al., 2011) and has been nominated as a candidate indicator species of the health of the North Sea Ecosystem (Rogers et al., 2010), it is important to further monitor this species with a more suitable sampling strategy for quantitative estimations of sandeel densities.

LONG LIVING SPECIES

Due to the prohibition of beam trawling in the wind farms, vulnerable species (e.g. Lanice conchilega and Echinocyamus pusillus) are getting the opportunity to recover in the Belwind wind energy concession zone (Coates et al., 2016). Long living species vulnerable to trawling (e.g. Ostrea edulis and Sertularia cupressina at Horns Rev (Anonymous, 2006) have not yet been encountered in the Belgian wind farms. This may be attributed to the occurrence of infringements in the past (Vandendriessche et al. 2011) and -to a lesser extent- in the recent years, combined with the fact that long living species grow extremely slowly and thus have a highly limited and prolonged recovery capacity (Clark et al., 2016). Once these long living species re-establish and recover, overall habitat complexity and biodiversity will increase and far-reaching positive effects may be expected.

FUTURE MONITORING

The patterns observed so far should be considered as short-term effects. They most probably reflect the initial stages of the ecological change and succession. Some impacts may not have been detected yet because they are still not developed to the extent needed to become detectable. Long-term monitoring remains an important tool to detect changes in the epibenthos and fish community. To know whether these changes are caused by the presence of the turbines or by fisheries exclusion, specific experiments and targeted monitoring (such as diet study Derweduwen et al., 2016) are needed to gain important knowledge on cause-effect relationships (Callaway et al., 2007;

Lindeboom et al., 2011; Lindeboom et al., 2015).

8.5. CONCLUSION

The positive wind farm effects on the epibenthos biomass, common starfish, green sea urchin and the negative wind farm effects on the brittle star reported in Vandendriessche et al. (2015) seemed to be short-term reactions of opportunistic species. The disturbance effects have faded in 2013-2014 and the ecosystem is again subordinate to natural fluctuations.

Similarly, the earlier reported signals of a 'refugium effect' are no longer observed for sole and plaice. The overall decreasing trend in densities is a result of natural variations (e.g. higher temperature in 2013-2014).

The negative trend in dab densities further declined with a significant higher net emigration from the Belwind wind farm in autumn.

Episodic increases in sandeel densities were encountered with short-term positive effects on juvenile sandeels. However, no significant long-term effects could be detected. Therefore, a more suitable sampling strategy for quantitative estimations of sandeel densities is necessary.

Long living species (e.g. Ostrea edulis and Sertularia cupressina) were not yet encountered in the Belgian wind farms. The expansion of the wind farm area to a large continuous, no-trawling area in the future and more time to recover may favour those species. Once these long living species re-establish and recover, overall habitat complexity and biodiversity will increase and far-reaching positive effects may be expected.

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