Chapter 7. Monitoring the effects of offshore windmill parks on the epifauna and demersal fish fauna of soft-bottom sediments: baseline monitoring

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Beam trawl catches

Photo ILVO- fisheries

Abstract

This chapter reports on the condition of demersal fish, benthopelagic fish and epibenthos in the concession zones and reference zones of the Thorntonbank windmill park in the third year after the installation of the first six turbines, and on the effects of increased fishing effort just outside the Thorntonbank concessions. Due to practical issues following access restrictions in the Belwind concession area, no samples could be taken in 2010 of the Bligh Bank impact area. Hence, the data of 2010 on the Bligh Bank and Oosthinder reference zones were stored for future analyses concerning natural temporal variation in the vicinity of the Belwind windmill park.

In 2009, some alterations within the epibenthos and fish assemblages were observed in the impact area on the Thorntonbank. These included (1) higher densities of horse mackerel (*Trachurus trachurus*) in autumn 2009 and (2) lower densities of sole (*Solea solea*) in spring 2009, compared to the reference areas around the Thorntonbank. These observations, however, were not confirmed by the 2010 data. Newly observed differences between the impact area and the reference areas in 2010 included (1) generally larger individuals of the swimming crab *Liocarcinus holsatus* and the brown shrimp *Crangon crangon* at the impact station, which may reflect either increased growth due to a high food availability or increased predation pressure eliminating smaller individuals; (2) higher autumn densities of small whiting *Merlangius merlangus* at the impact station.

The observed increase in fisheries intensity of the Belgian fleet and recreational fisheries in the area north of the concession had little effect on the level of density, biomass and diversity. However, the length-frequency distributions of sole showed an absence of the smallest size classes in both seasons of 2010, which could be the result of increased indirect fishing mortality (such as discards) or of changes in the local benthic community. Similarly, there was a striking reduction in the individuals in the size classes ranging between 21 and 26 cm for whiting *M. merlangus* in spring 2010 at the fringe stations. There were some differences between fringe stations and reference stations for small demersal fish and for epibenthos. Generally, these differences were highest in 2009 and more or less normalized by 2010.

These differences between the impact station, fringe stations and reference stations may indicate changes in predation pressure, food supply and recruitment. Further monitoring and targeted research actions are needed to confirm causal relationships between these observations and the investigated pressures.

Samenvatting

Dit hoofdstuk geeft de resultaten weer van de analyses betreffende de toestand van het epibenthos, de demersale vissen en de benthopelagische vissen in de concessiezones van de Thorntonbank tijdens jaar 3, en betreffende de effecten van verhoogde visserijdruk aan de rand van deze concessies. Als gevolg van toegangsbeperkingen in het Belwind windmolenpark konden in de loop van 2010 geen stations worden bemonsterd in de Bligh Bank impact zone. De verzamelde gegevens over de referentiezones werden opgeslagen voor toekomstige analyses betreffende de natuurlijke temporele variatie in het gebied.

Tijdens de analyse van de gegevens van 2009 werden reeds verschillen aangetroffen tussen het impactgebied van de Thorntonbank en de referentiegebieden, nl. hogere densiteiten van de horsmakreel in het najaar en lagere densiteiten van tong in het voorjaar. Deze observaties herhaalden zich echter niet in 2010. ‘Nieuwe’ verschillen tussen de impact zone en de referentiezones omvatten (1) een verschuiving naar grotere individuen bij de zwemkrab en de grijze garnaal in het impactgebied, wat zou kunnen wijzen op een verhoogd voedselaanbod of een verhoogde predatiedruk bij kleinere individuen, en (2) een hogere najaarsdensiteit van jonge wijting ter hoogte van de turbines.

De geobserveerde veranderingen in visserijactiviteiten van de Belgische vloot en van de sportvisserij gingen niet gepaard met grote veranderingen in densiteit, biomassa en diversiteit van de verschillende ecosysteemcomponenten. Er werden echter wel belangrijke verschillen waargenomen betreffende de lengte-frequentiedistributies van tong (ontbreken van de kleinste lengteklasses tijdens voorjaar en najaar 2010) en wijting (lagere densiteiten van individuen in de lengteklasse 21-26cm in

het voorjaar). Deze verschillen zouden kunnen wijzen op een verhoging van indirecte sterfte (bijvoorbeeld door teruggooi) of veranderingen ter hoogte van de bodemgemeenschappen. Er waren tevens wat verschillen tussen het randgebied en de referentiegebieden bij epibenthos en kleine demersale vissoorten, vooral in 2009, maar deze waren grotendeels verdwenen in 2010.

De geobserveerde verschillen tussen het impactgebied, de randgebieden en de referentiegebieden zouden veranderingen kunnen weerspiegelen in predatiedruk, voedselaanbod en rekrutering. Om enige causale verbanden tussen deze observaties en de onderzochte menselijke activiteiten te bevestigen, zijn er echter verdere monitoring en gerichte onderzoeksacties nodig.

7.1. Introduction

The already constructed wind turbines at the Thorntonbank and the Bligh Bank constitute patches of hard substrate on a seafloor dominated by soft sediments. Next to reef effects on and in the near vicinity of the artificial hard substrates (e.g. Andersson *et al.*, 2009; Wilhelmsson *et al.*, 2009), effects are also expected on the fauna inhabiting the surrounding soft substrate. These effects include (adapted from Wilhelmsson *et al.*, 2009):

- Depletion of phytoplankton by high densities of filtrating organisms (i.e. mussels) on and around the turbine could adversely affect growth of filter feeders on the seabed
- Input of organic material from organisms associated with the turbines, as well as entrapment of material by the turbines, could enrich the seabed and enhance abundances of deposit-feeding organisms, and in turn benefit predators on these.
- Predation by fish and crabs associated with the turbines could negatively affect abundances of prey species.
- An artificial reef (here turbine and scour protection) can enhance abundances of pelagic fish species, and attract flatfishes to the reef.

Additionally, the exclusion of fisheries activities from windmill parks and their safety buffers may have positive effects within the closed areas (e.g. Jaworski *et al.*, 2006), but also negative effects outside the windmill park borders due to a local reallocation of fishing effort (Berkenhagen *et al.*, 2010). The effects of such reallocations on fauna inhabiting soft substrates were termed “fringe effects” in the current analysis. The changes in fisheries activities as observed by Vessel Monitoring System data (VMS) were described in Chapter 8.

This chapter specifically reports on the condition of demersal fish, benthopelagic fish and epibenthos in the concession zones and reference zones of the Thorntonbank windmill park in the third year after the construction of the first six turbines, and on the effects of increased fishing effort in the immediate vicinity of the closed areas concerning these ecosystem components. These results form the basis of the impact assessment concerning the construction and exploitation of the windmill parks under investigation.

7.2. Material and Methods

For the baseline monitoring in 2010, 17 stations were sampled in spring and 20 stations in autumn (Table 1). In 2010, the station WT1 was moved southward (WT1bis) due to increased sand extraction activities at the original position since 2007. Station 330 was included in the analyses since it proved to be a good reference for Thorntonbank gullies (Derweduwen *et al.*, 2010).

All fish tracks were ‘short’ tracks of 1/2 Nm instead of 1Nm as in the previous monitoring years (see Derweduwen *et al.*, 2010). On these track locations, demersal fish fauna and macro-epibenthos were sampled onboard the research vessel Belgica with an 8-meter shrimp trawl (stretched mesh width 22 mm in the cod end) and a bolder-chain but no tickler chains (to minimize the environmental damage). The net was dragged during 15 minutes at an average speed of 4 knots over the bottom. 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 were positioned following depth contours that run parallel to the coastline, thereby minimizing the depth variation within a single track. After each fish track, a photograph was taken of the net content prior to the processing of the catch. All fish, except gobies, were identified, measured and/or counted or wet weighed on board. In the case of small catches , the epibenthos (including gobies) was processed on board as well; in the case of a large catch, a subsample of 6 litres was frozen for further laboratory analyses. Rare or peculiar species/individuals were stored for further reference or investigation. The net contents were divided into ‘bentho-pelagic fish’,‘demersal fish’ and ‘epifauna’. For these ecosystem components density, biomass (epibenthos only), diversity and length frequency distribution were analysed. The number of individuals per sample and per species was converted to number of individuals per 1000m² (abundance). Biomass was expressed as grams of wet weight (WW) per 1000m² and diversity was evaluated based on Hill’s diversity indices N0 and N1 and on the variable Expected Number of Species (ES(n)).

The evolution of these parameters since 2005 was investigated on an ecosystem component level (benthopelagic fish, demersal fish, epibenthos). Density was analysed in further detail for a selection of species. This selection was based on the species’ importance as discriminating components in the community composition analyses concerning the windmill park concession area and the adjoining reference areas, as conducted in Derweduwen *et al.* (2010).

For these analyses, stations were pooled based on their classification as windmill reference station, windmill impact station, impact fringe station or reference fringe station. The initial description of the BACI design (see table 3.1) was adapted according to the actual situation in 2010:

- Stations WT7-8 in zone B were considered as references for zone A, since there were still no turbines in this zone during the study year 2010.
- Stations WT6 and WT9 were considered as fringe stations, since VMS analyses indicated an increase in fisheries activities in the area north of the six existing turbines at the Thorntonbank (see chapter 8, this volume)

Table 1.
Overview of stations in the windmill park area sampled during the spring and autumn campaigns of 2005 and 2008-2010.

sandbank system	station	description	spring 2005	autumn 2005	spring 2008	autumn 2008	spring 2009	autumn 2009	spring 2010	autumn 2010
Goote Bank	**WG1**	reference C-Power gully	x	x	x	x				
	WG2	reference C-Power top	x	x	x	x			x	x
	WG3	reference C-Power gully	x	x	x	x				
Thorntonbank	**WT1(bis)**	reference C-Power gully	x	x	x	x			x	x
	WT2	reference C-Power top	x	x	x	x	x	x	x	x
	WT3	reference C-Power gully	x	x	x	x		x	x	x
	WT4(bis)	fringe C-Power top	x	x	x	x			x	x
	WT5(bis)	impact C-Power top	x	x	x	x	x	x	x	x
	WT6	fringe C-Power gully	x	x	x	x			x	x
	WT7	fringe C-Power gully	x	x	x	x	x	x	x	x
	WT8	impact C-Power top	x	x	x	x	x	x	x	x
	WT9	fringe C-Power gully	x	x	x	x	x	x	x	x
Bank Zonder Naam	**BZN01**	impact Eldepasco top					x	x	x	x
Bligh Bank	**WBB01**	reference Belwind gully			x	x		x	x	x
	WBB02	reference Belwind top			x	x		x	x	x
	WBB03	reference Belwind gully			x	x		x	x	x
	WBB04	fringe Belwind gully			x	x	x	x		x
	WBB05	impact Belwind top			x	x				
	WBB06	impact Belwind top			x	x	x	x		
	WBB07	impact Belwind gully			x	x		x		
	WBB08	fringe Belwind gully			x	x	x	x		x
Oosthinder	**WOH01**	reference Belwind gully			x	x				x
	WOH02	reference Belwind top			x	x		x	x	x
	WOH03	reference Belwind gully			x	x		x	x	x
other	**330**	reference C-Power gully	x	x	x	x	x	x	x	x
	340	reference C-Power gully	x	x	x	x	x	x		
	545	reference Belwind gully	x	x	x	x	x			
	840	reference Belwind gully	x	x	x	x	x	x		

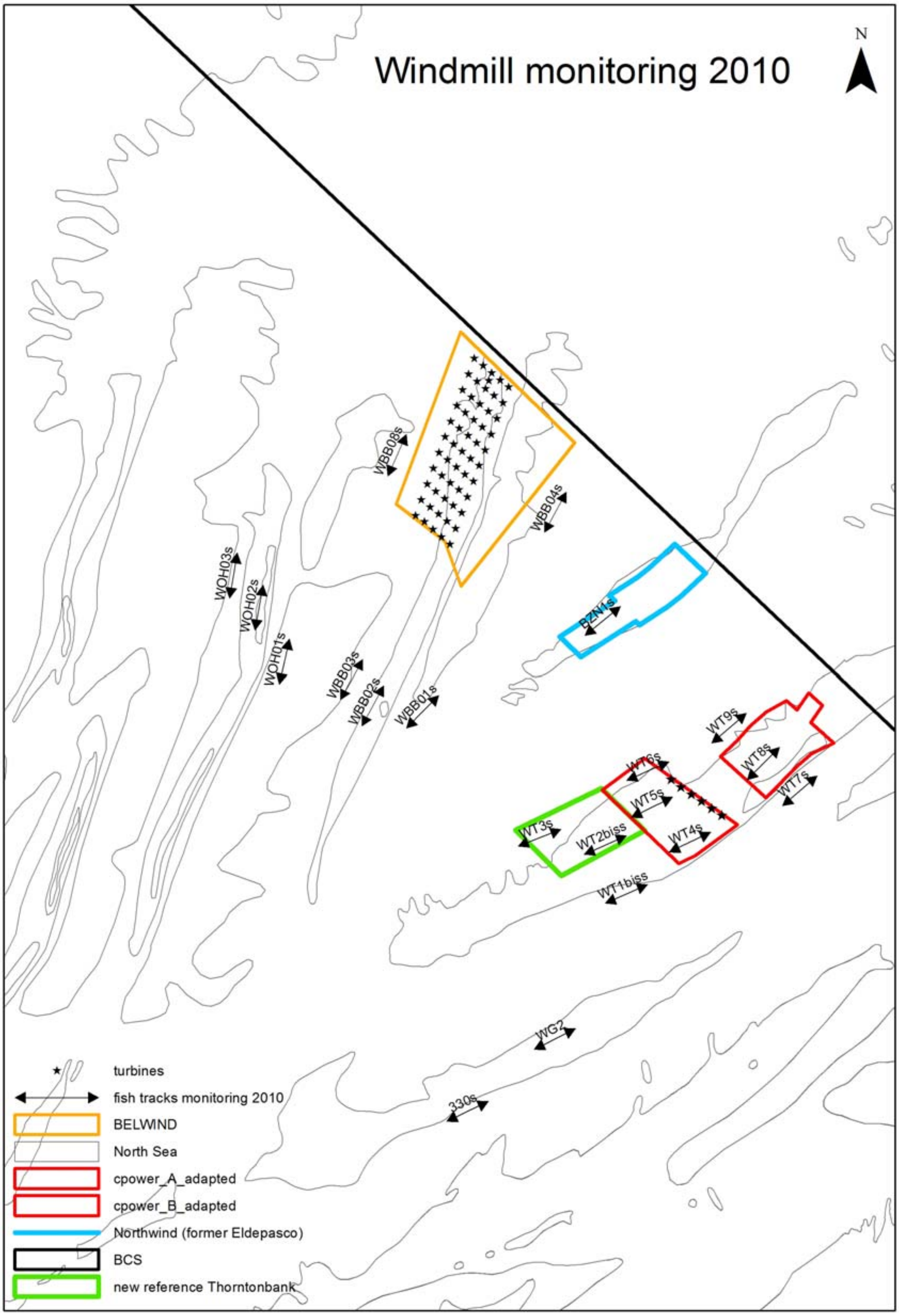


Figure 1. Sampling stations visited in 2010 in the framework of the windmill park monitoring activities.

Due to practical issues following access restrictions in the Belwind concession area, no samples could be taken of the Bligh Bank impact area in 2010. Consequently, the analyses were limited to the evolution of the soft sediment epibenthos and demersal fish at the Thorntonbank impact zone and in the adjoining reference areas. The data of 2010 on the Bligh Bank and Oosthinder reference zones were stored for future analyses concerning natural temporal variation in the vicinity of the Belwind windmill park.

7.3. Results

The analyses were split up according to the possible source of environmental change:

- Impact of the presence of turbines: the C-Power turbines are located on top of the Thorntonbank. One station (WT5biss) was considered as an impact station, other sandbank top stations were considered reference stations.
- Impact of changing fisheries activities in the vicinity of the windmill park concessions: these impacts were expected in the gullies outside the C-power concessions, and were confirmed by VMS analyses (see Chapter 8, this volume). Two stations were considered fringe stations, other gully stations were treated as references.

7.3.1. Impact of the presence of turbines

On an ecosystem component level (benthopelagic fish, demersal fish, epifauna), no impact on the total density could be observed in either of the seasons (Figure 2A). The fluctuations were considerable, but could all be attributed to natural interannual and seasonal variation. This was also the case for the epifaunal biomass (Figure 2B). The species richness fluctuated between 1 and 5 spp. for benthopelagic fish, between 4 and 8 spp. for demersal fish and between 6 and 20 spp. for epibenthos (Figure 2C). Persistent divergences between the impact station and the reference stations after 2008 were not observed. The same conclusion could be drawn from diversity estimates based on the Expected Number of Species method (figures not shown).

For the benthopelagic fish species horse mackerel (*Trachurus trachurus*) and sprat (*Sprattus sprattus*), the differences between the impact station and the reference stations were minimal. For whiting (*Merlangius merlangus*), a higher density was observed at the impact station (19 ind/1000m²) than at the references (av. 10 ind/1000m²) in autumn 2010 (Figure 2D). In spring, however, no individuals were found at the impact station, while low densities were observed at the references (av. 1 ind/1000m²). Insufficient data were available for herring (*Clupea harengus*) to evaluate the density evolution since 2005. Pouting (*Trisopterus minutus*) was not encountered in any sandbank top sample at the Thorntonbank since 2005.

For the flatfish species sole (*Solea solea*) and dab (*Limanda limanda*), the evolution of density over the seasons and years was almost identical for the impact station and the reference stations. For plaice (*Pleuronectes platessa*), the 2009 spring density at the impact station was a lot lower (0.2 ind/1000m²) than in the adjoining reference station (1 ind/1000m²). In 2010, the values were again very similar. In autumn, the values were similar in 2009, but the density at the impact station in 2010 was again a lot lower (0.1 ind/1000m²) than in the reference stations (av. 2 ind/1000m²).

For the dragonets *Callionymus lyra* and *C. reticulatus*, autumn densities were very similar for impact and reference stations. In spring 2009, the density of the common dragonet was higher (1.2 ind/1000m²) in the impact station than in the reference station (0.6 ind/1000m²), but the species was not seen in the impact station in 2010, while there were still low densities (av. 0.1 ind/1000m²) at the reference stations. The reticulated dragonet on the other hand was only seen at a very low density at the impact station in spring 2010, while the species was not seen at the reference stations.

The lesser weever (*Echiichthys vipera*) was abundantly present on top of the Thorntonbank, but in persistently lower densities at the impact station compared to the reference stations. That was already the case in 2005, so this feature is probably not the result of the presence of windmill turbines. The densities of solenette (*Buglossidium luteum*) were quite similar at the impact and the reference stations in spring. In autumn, however, densities were persistently higher at the impact station. Again, this was already the case prior to the construction activities. Hooknose (*Agonus cataphractus*) densities were very low at all sandbank top stations. In autumn, the species was no longer observed in any of the stations after 2007. In spring, low densities were only observed in 2005 and 2009 at the impact station. More individuals were retrieved from the reference samples.

For epibenthos, the differences between the impact station and the reference stations were generally smaller than for demersal and benthopelagic fish species. For the species *Ophiura albida*, *Ophiura ophiura*, *Allotheutis subulata*, *Pagurus bernhardus and Liocarcinus holsatus*, the observed density evolution was virtually identical for both station types. For the shrimp *Crangon crangon*, the density evolution was similar until 2009. In 2010, spring and autumn densities were both lower at the impact station (sp: 12ind/1000m²; aut: 9 ind/1000m²) than at the reference stations (sp: av. 21 ind/1000m²; aut: av. 35 ind/1000m²). The urchin *Psammechinus miliaris* and the shrimp *C. allmanni* were not found often enough to evaluate differences between impact and reference stations.

Concerning the length-frequency distributions determined for 8 species, there were some differences between the impact station and the reference stations, especially in autumn 2010:

- *Crangon crangon*: lower numbers and slightly larger individuals at the impact station (dominant size class: 50mm at impact station, 45mm at reference stations).
- *Liocarcinus holsatus*: lower numbers and slightly larger individuals at the impact station (dominant size class: 42mm at impact station, 30mm at reference stations).
- *Limanda limanda*: lower numbers of year class 0 at the impact station
- *Merlangius merlangus*: higher densities of individuals ranging between 10 and 17 cm in length, but lower densities of larger individuals compared to the reference stations.

A. Density: benthopelagic fish, demersal fish and epibenthos

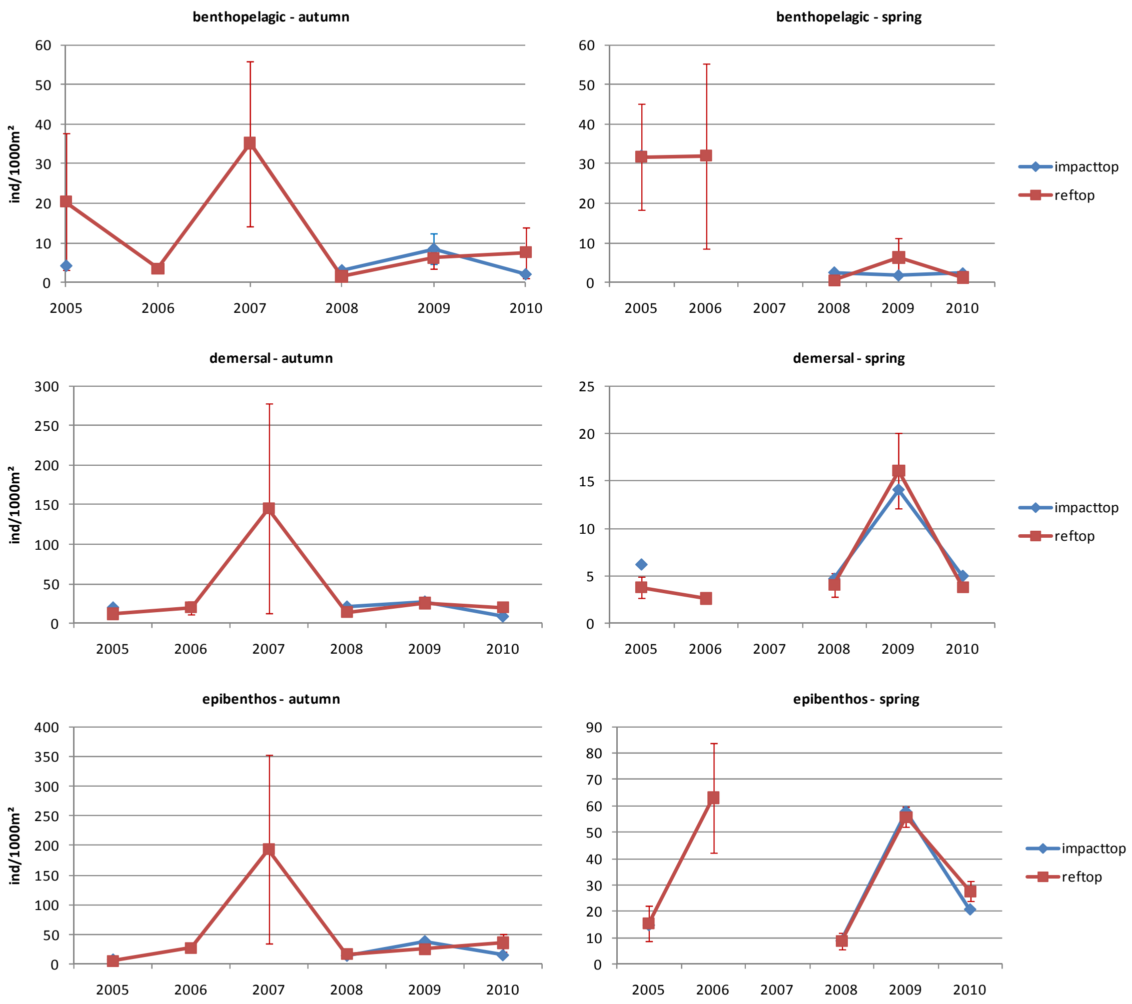


Figure 2. Charts representing differences between the impact station and reference stations concerning density, biomass and diversity for the species groups benthopelagic fish, demersal fish and epibenthos; differences in density for a selection of species; differences in length frequency distribution for a selection of species.

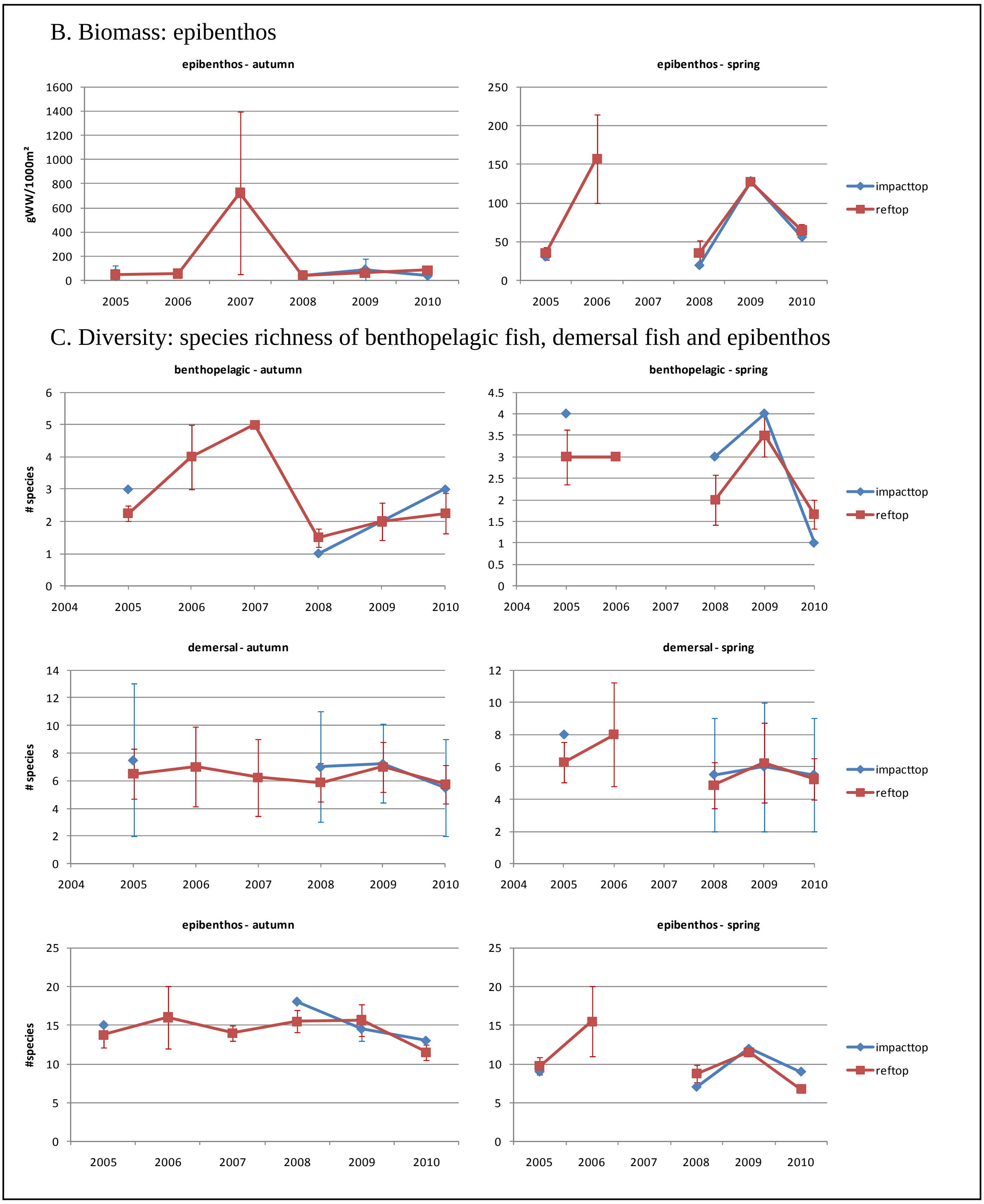


Figure 2. Continued.

D. Species selection: density evolution (only species featuring important differences between impact station and reference stations are shown)

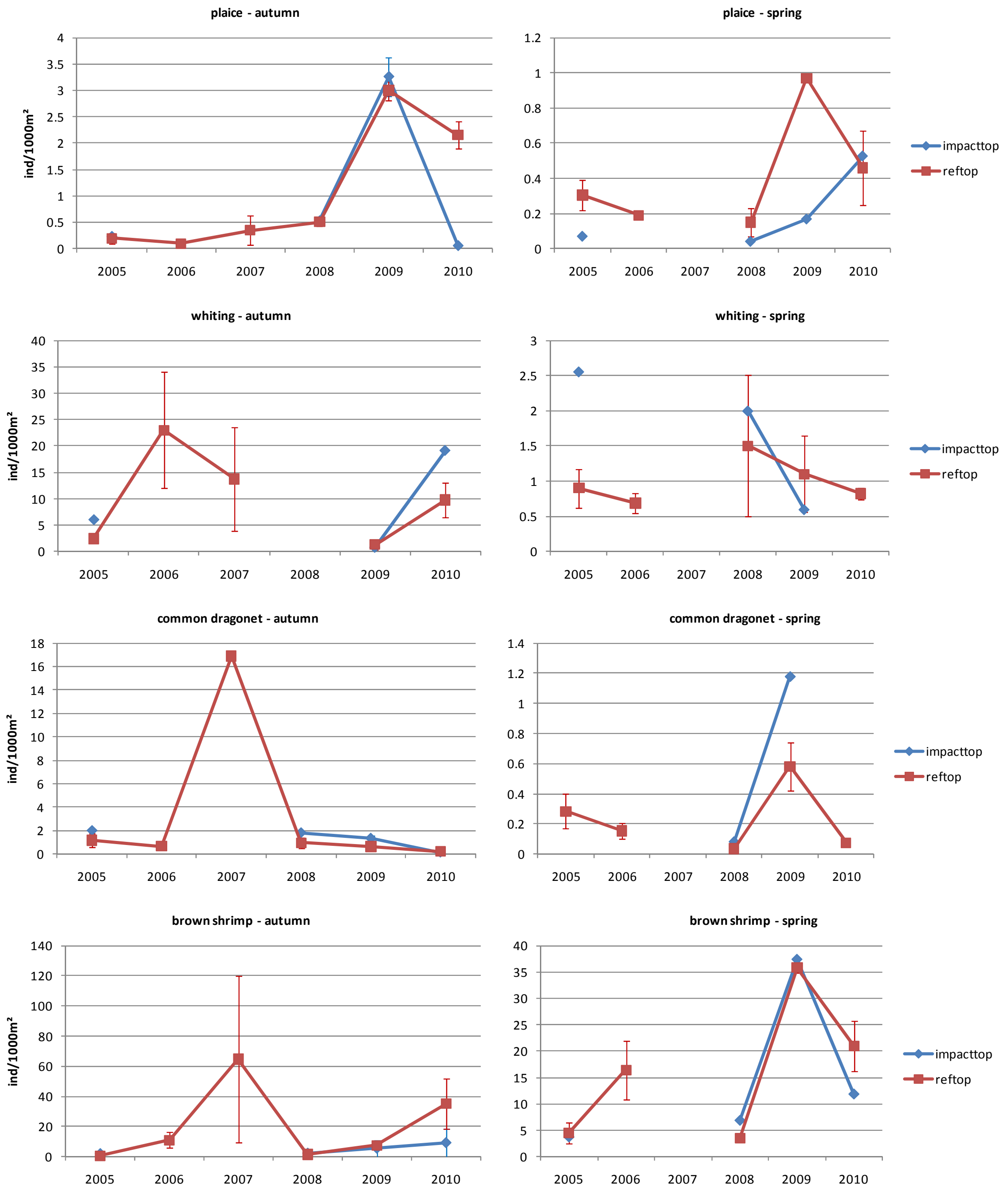


Figure 2. Continued.

E. Length-frequency distributions, data 2010 (only species featuring important differences between impact station and reference stations are shown)

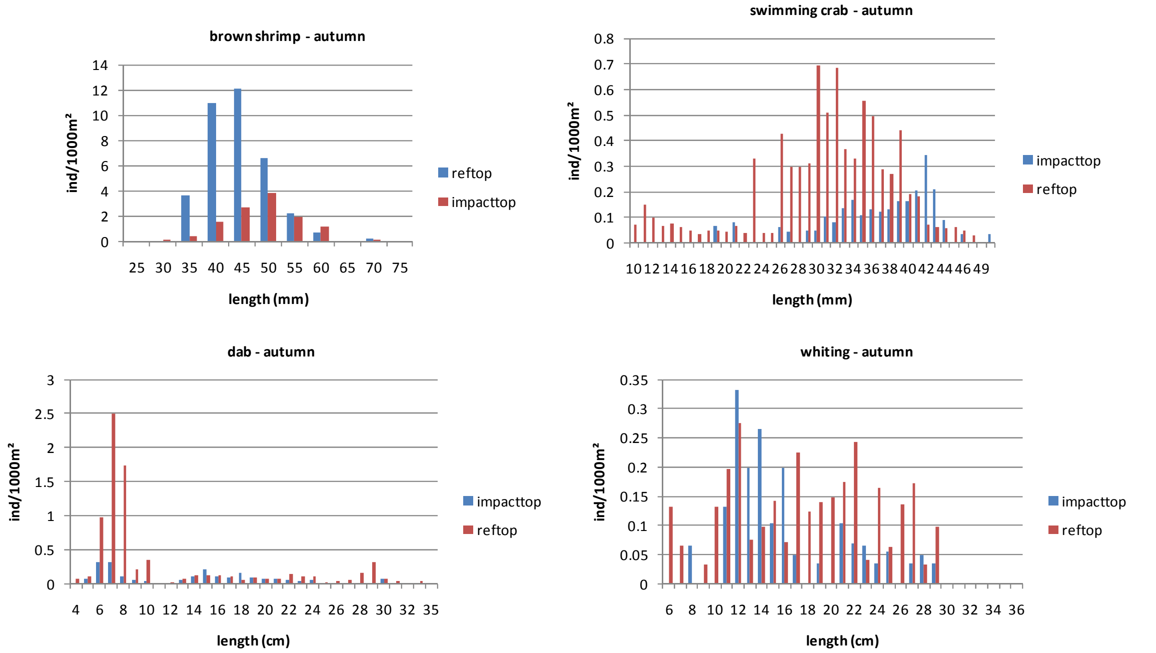


Figure 2. Continued.

7.3.2. Impact of changes in fisheries intensity

On an ecosystem component level (benthopelagic fish, demersal fish, epifauna), no persistent differences in total density could be observed between the fringe stations and the impact stations in either of the seasons (Figure 3A). The fluctuations were considerable, but could all be attributed to natural interannual and seasonal variation. The epifaunal biomass was generally lower in 2009 in the fringe stations compared to the reference stations, but this difference disappeared by 2010 (Figure 3B). The species richness fluctuated between 2 and 8 spp. for benthopelagic fish, between 5 and 13 spp. for demersal fish and between 8 and 20 spp. for epibenthos (Figure 3C). Persistent divergences between the fringe stations and the reference stations after 2008 were not observed. The same conclusion could be drawn from diversity estimates based on the Expected Number of Species method.

The autumn densities of the benthopelagic fish species horse mackerel (*T. trachurus*) were similar until 2009. In autumn 2010, the densities at the fringe stations were a lot lower (av. 10 ind/1000m²) than at the reference stations (av. 623 ind/1000m², but with considerable standard error of 553 ind/1000m²). Autumn sprat (*S. sprattus*) densities of 2009 and 2010 were a little higher in the fringe stations compared to the references. For whiting (*M. merlangus*), the density evolution was very similar in autumn for all stations. In spring 2008 to 2010, less individuals were found at the fringe stations (max av. 5 ind/1000m²) compared to the references (av. up to 38 ind/1000m²). Insufficient data were available for herring (*C. harengus*) to evaluate the density evolution since 2005. Pouting (*T. minutus*) was only encountered in the reference stations at the Thorntonbank since 2005.

For the flatfish species sole (*S. solea*), plaice (*P. platessa*) and dab (*L. limanda*), the evolution of density over the seasons and years was very similar for the fringe stations and the reference stations. For the common dragonet *Callionymus lyra*, autumn and spring densities increased drastically between 2008 and 2009 in the fringe stations but not in the reference stations, and again decreased in 2010 (no common dragonets were found in spring 2010). The density evolution of the reticulated dragonet *C. reticulatus* did not show such a pattern: the density evolution was similar for all stations.

The density patterns of the lesser weever (*E. vipera*) was very similar for all stations. The densities of solenette (*Buglossidium luteum*), however, were very variable at the fringe stations, especially in spring: densities dramatically increased between 2008 and 2009 (from av. 0.3 to 10 ind/1000m²) and then decreased again to 0.3 ind/1000m² by 2010. In autumn, densities were quite high in the fringe stations in 2008, but decreased to a level similar to the reference stations by 2010. Hooknose (*A. cataphractus*) densities were similar at all stations in autumn, but were very different between fringe and reference stations in spring. Especially in 2008, the density difference was very high, with an average of 0.1 ind/1000m² at the fringe stations and 0.6 ind/1000m² at the reference stations.

For the species *C. crangon* in both seasons *and for O. albida* in spring, the observed density evolution was virtually identical for both station types. For other species, there were quite some differences, especially in 2009:

- *O. albida* & *O. ophiura* – autumn: fringe densities higher than reference densities, but again similar values in 2010
- *O. ophiura* – spring: fringe densities lower than reference densities, but again similar values in 2010
- *L. holsatus* – spring: fringe densities higher than reference densities

Densities of *L. holsatus* were persistently higher in the fringe stations, but that was already the case in 2005, so this feature is probably not the result of changes in fisheries intensity.

Concerning the length-frequency distributions determined for 8 species, there were some differences between the fringe stations and the reference stations for the 2010 data (fig 3E):

- *Solea solea*: virtual absence of individuals smaller than 18 cm in autumn, while these were abundantly present in the reference stations. Also in spring, the absence of the smallest size classes is striking.
- *Liocarcinus holsatus*: higher densities of individuals of all size classes in autumn at the fringe stations
- *Merlangius merlangus*: striking reduction in the numbers of individuals in the size classes ranging between 21 and 26 cm at the fringe stations in spring

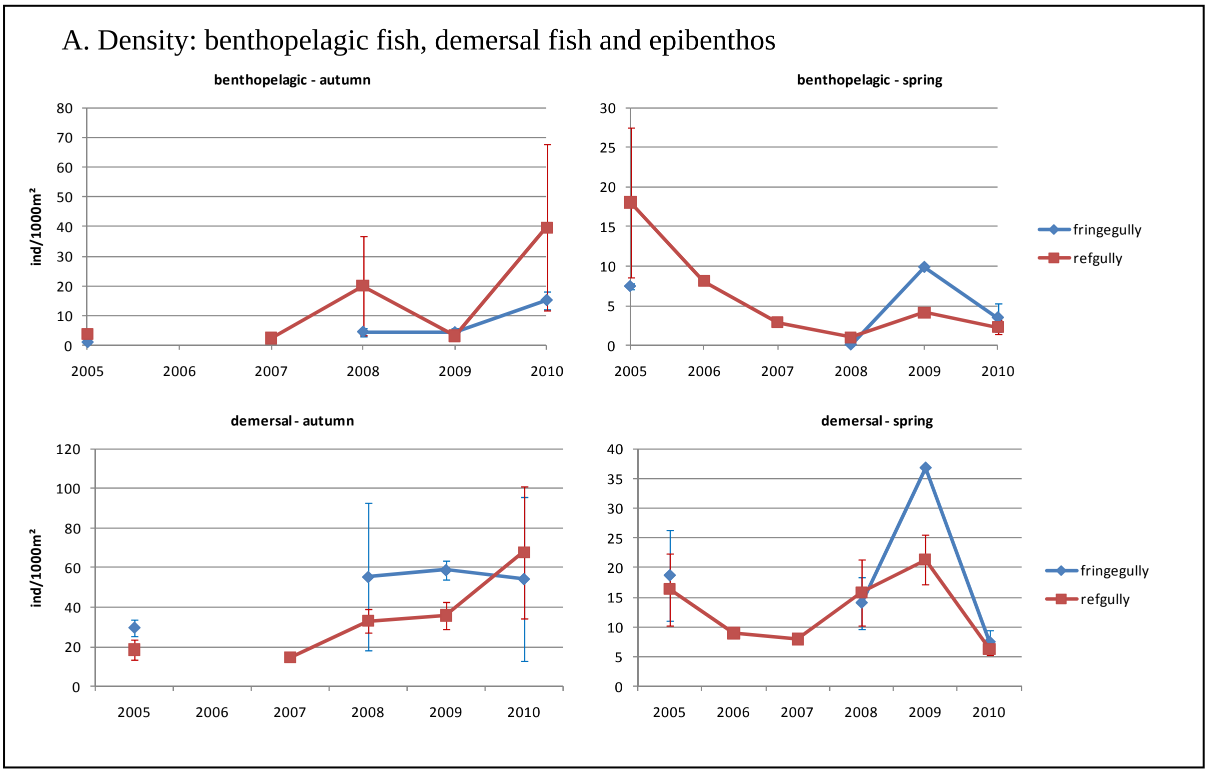
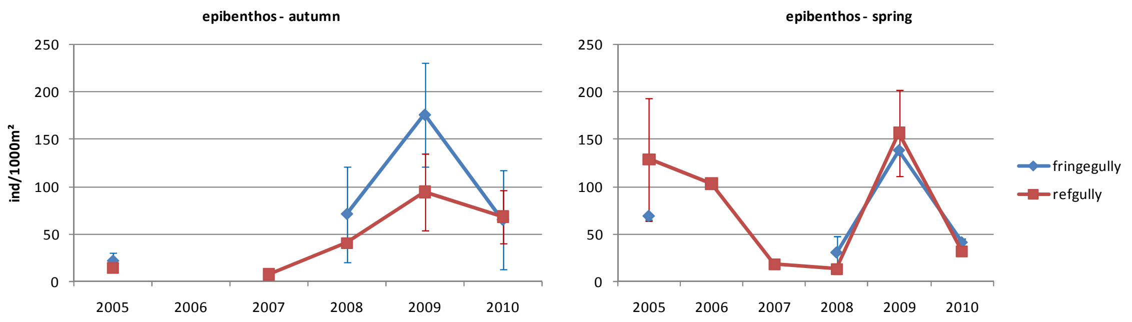
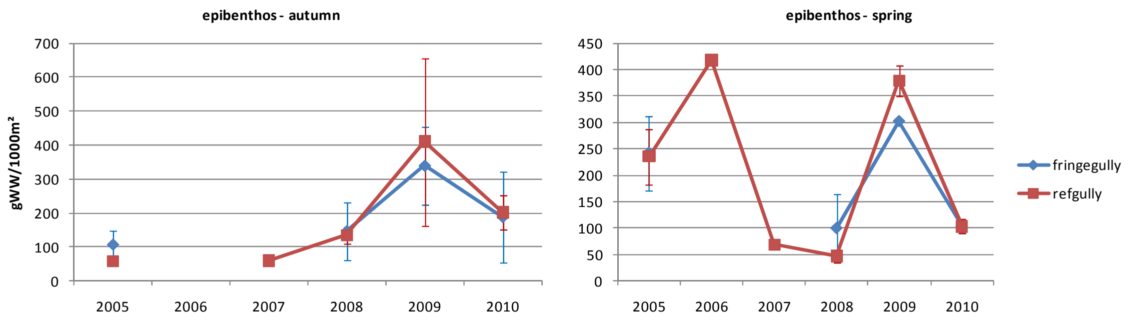


Figure 3. Charts representing differences between the fringe stations and reference stations concerning density, biomass and diversity for the species groups benthopelagic fish, demersal fish and epibenthos; differences in density for a selection of species; differences in length frequency distribution for a selection of species.



B. Biomass: epibenthos



C. Diversity: species richness of benthopelagic fish, demersal fish and epibenthos

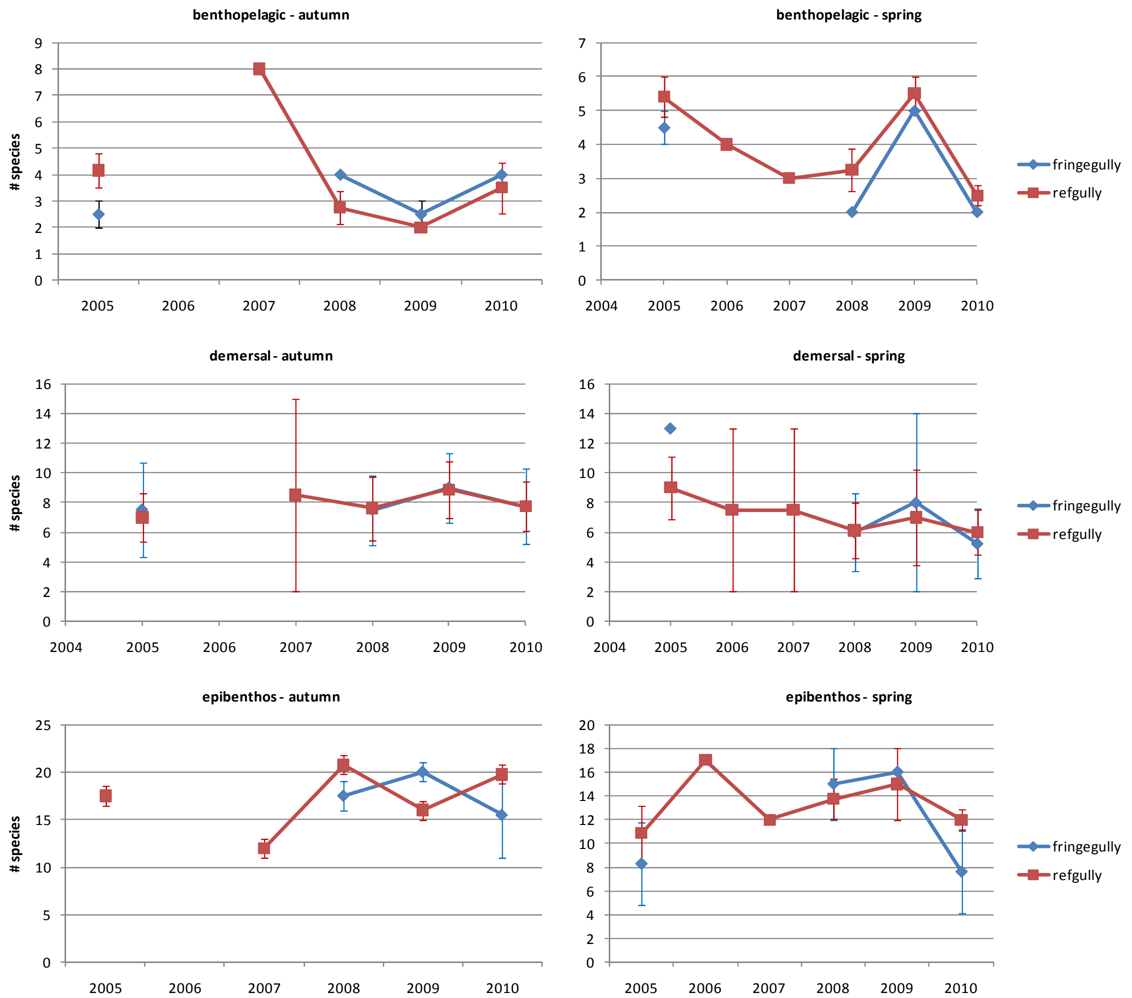


Figure 3. Continued.

D. Species selection: density evolution (only species featuring important differences between fringe stations and reference stations are shown)

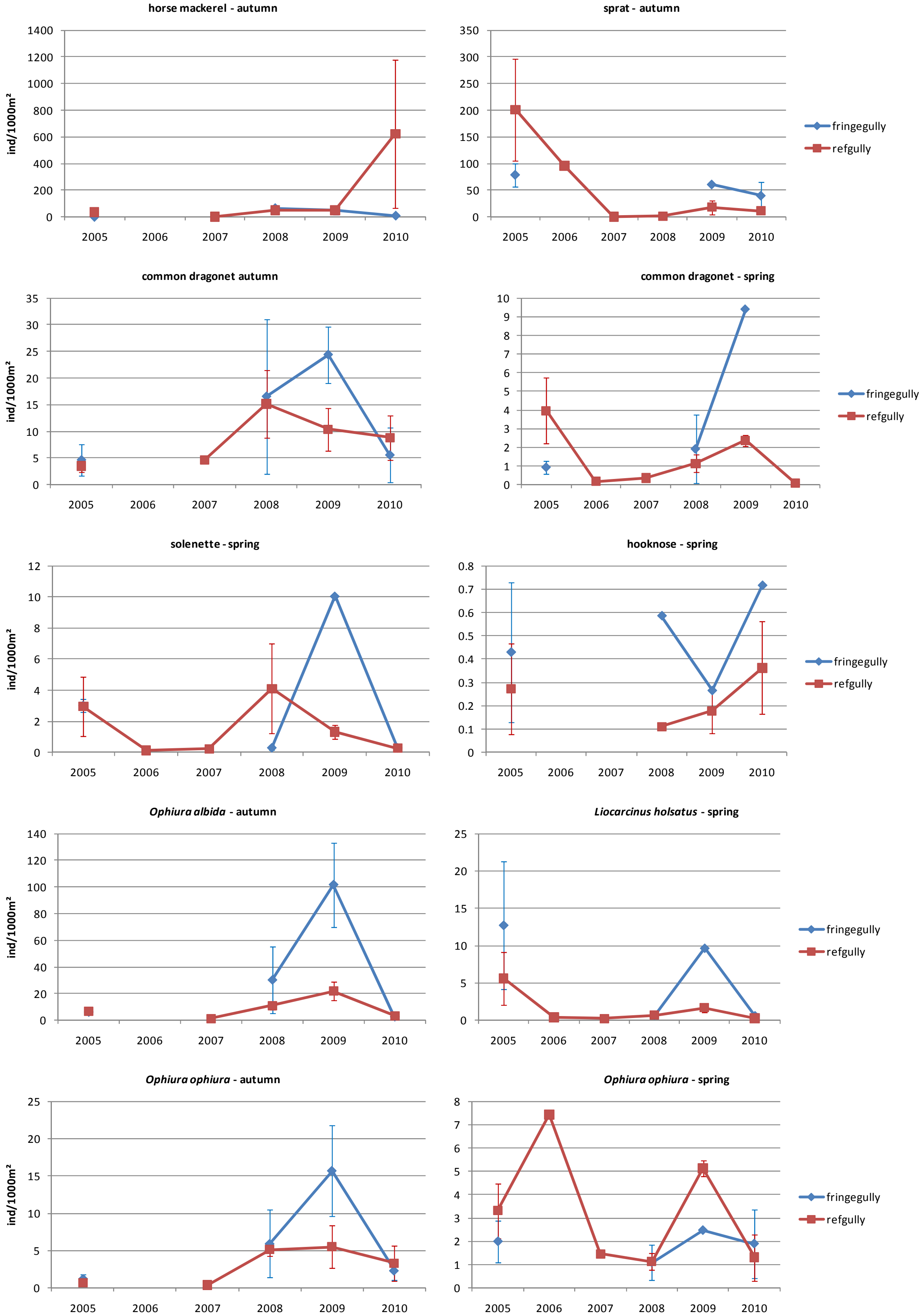


Figure 3. Continued.

E. Length-frequency distributions, data 2010 (only species featuring important differences between fringe stations and reference stations are shown)

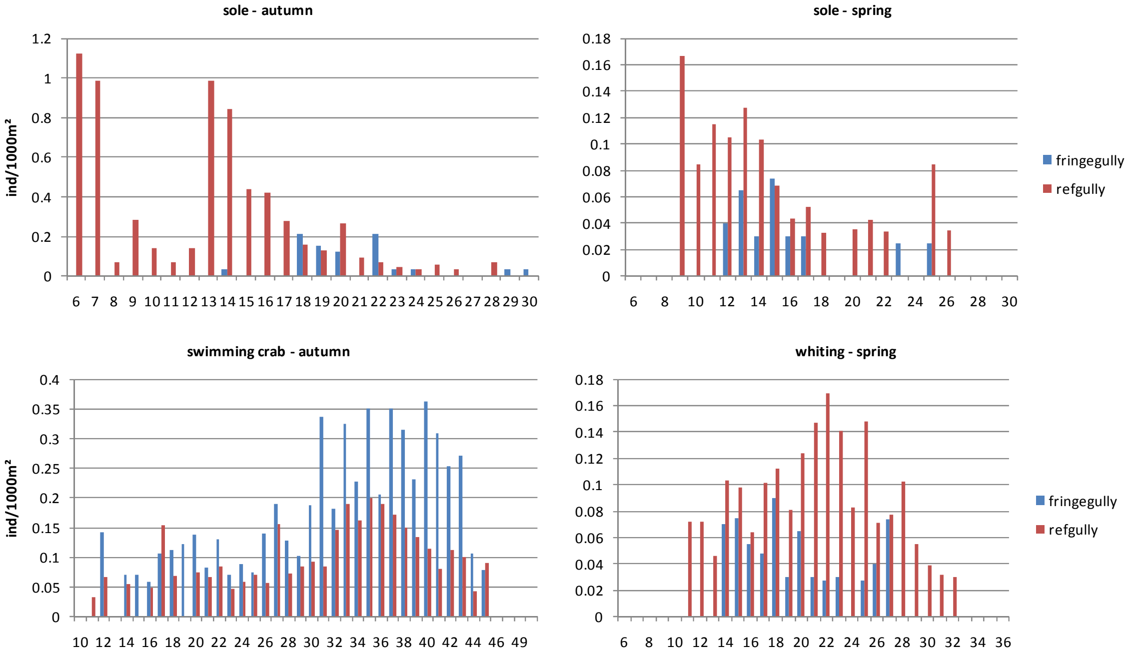


Figure 3. Continued.

7.4. Discussion

7.4.1. Impact of the presence of turbines

Since the fish track trajectories were positioned at a respectable distance (> 500 m) from the turbines due to safety precautions, only two of the effects described by Wilhelmsson *et al.* (2009) were expected to be observed by the adopted sampling design (Figure 1):

- Predation by fish and crabs associated with the turbines could negatively affect abundances of prey species.
- An artificial reef (here turbine and scour protection) can enhance abundances of pelagic fish species, and attract flatfishes to the reef.

Other effects are usually limited to a radius of 20m around the turbines, while attraction of fish may occur in a radius of 400m (Wilhelmsson *et al.*, 2009). In studies concerning other windmill farms, especially crab densities seemed to be favored by the presence of turbines, more specifically the shore crab *Carcinus maenas* (Maar *et al.*, 2009), the edible crab *Cancer pagurus* (Wilhelmsson *et al.*, 2009) and the thumbnail crab *Thia scutellata* (May, 2005). Such increased densities were not observed in the trawl samples, but the individuals of the swimming crab *Liocarcinus holsatus* were generally larger at the impact station in 2010 compared to the reference stations. The same was observed for the brown shrimp *Crangon crangon*. This may reflect either increased growth due to a high food availability or increased predation pressure eliminating smaller individuals. An increased food supply may also have caused the higher autumn densities of small whiting *Merlangius merlangus* observed in autumn 2010. Dense shoals of juvenile whiting have also been observed at the North Hoyle windmill Park (UK), where they intensively fed on the amphipod *Jassa falcata* (May, 2005). Since the Thorntonbank turbines support a substantial biomass consisting of *Jassa herdmani* (Kerckhof *et al.*, 2010) and since Reubens *et al.* (2011) described intense feeding on *J. herdmani* by pouting *Trisopterus luscus* at the Thorntonbank turbines, it is likely that a similar relationship exists between these amphipods and whiting.

The alterations within the epibenthos and fish assemblages observed in the impact area on the Thorntonbank in 2009 included (1) higher densities of horse mackerel (*Trachurus trachurus*) in autumn 2009 and (2) lower densities of sole (*Solea solea*) in spring 2009, compared to the reference areas around the Thorntonbank. These observations, however, were not confirmed by the 2010 data.

The observed differences between the impact and the reference area in 2009 and 2010 may indicate that changes within the ecosystem do occur due to the presence of the turbines. However, the lack of replication within the windmill farm (only one impact sample) and between windmill parks (no impact samples from the Bligh Bank), make it difficult to draw sound conclusions on the evolution of the epibenthos, demersal fish and benthopelagic fish in the windmill park area. This will be mediated by the planned increase of turbines on the Thorntonbank in 2011 and the planned sampling of the Bligh Bank impact area from 2011 onwards.

7.4.2. Impact of changes in fisheries intensity

An important effect of the closure of areas for fisheries is the reallocation of fishing effort to the remaining available fishing grounds, often just outside the closed area's border (Rijnsdorp *et al.*, 2001; Hiddink *et al.*, 2006). Hence, any data interpreted as showing an improved quality of benthic communities within the closure need to be nuanced because of changed post-closure fishing intensity in the "control" area outside the closure (Grizzle *et al.*, 2009). An analysis of Belgian VMS data showed increased trawling activity in the area north of the Thorntonbank. Additionally, recreational line fisheries seemed to have intensified in the same area (see Chapter 8). Consequently, the stations within this area were labeled as "fringe stations" and were no longer used as references for assessing the impact of turbine construction and operation. To evaluate possible changes due to increased fisheries intensity, the data of the fringe stations were compared with reference gully stations. Generally, we expected a general decline in diversity, a shift towards species that are more tolerant to disturbance, and higher densities of scavengers, omnivores and small-bodied organisms (Jones, 1992; Kaiser *et al.*, 2002; Finger, 2005). The results showed no effects on densities of the commercially important flatfish species sole *S. solea*, plaice *P. platessa* and dab *L. limanda*. However, the length-frequency distributions of sole showed an absence of the smallest size classes in both seasons of 2010, which could be the result of increased indirect fishing mortality (such as discards) or of changes in the local benthic community. Similarly, there was a striking reduction in the individuals in the size classes ranging between 21 and 26 cm for whiting *M. merlangus* in spring 2010 at the fringe stations. There were some differences between fringe stations and reference stations for small demersal fish (e.g. common dragonet *C. lyra*, solenette *B. luteum*, hooknose *A. cataphractus*) and for epibenthos (ophiuroids *O. ophiura* and *O. albida*, and swimming crab *L. holsatus*). Generally, these differences were highest in 2009 and more or less normalized by 2010. Whether this corresponds with a local reduction of fisheries activities in the fringe area after 2009 is unknown, since the 2010 VMS data have yet to be analyzed. For 2008-2009, the period with a confirmed increase of fishing activity by the Belgian fleet, the impact of increased fisheries activity was not drastic for fish and epibenthos, which could be expected since the fringe area already had a history of rather intensive trawling. Nevertheless, the reduction in densities of young fish might signal an increased pressure on their populations. Reiss *et al.* (2009) already stated that even in areas with high chronic fishing disturbance, further increases in fishing activity may still cause additional damage to benthic invertebrate communities, and hence to other ecosystem components.

7.5. Conclusion

The current analyses about the impact of the presence of windmill turbines did not reveal consistent patterns of changed density, biomass or diversity between the impact station and reference stations for epibenthos, demersal fish and benthopelagic fish. However, there were some new observations in 2010 concerning differences in length-frequency distributions for swimming crab, brown shrimp and whiting. Similarly, the local increase of fisheries intensity by the Belgian fleet in the area north of the Thorntonbank was accompanied by differences in the length-frequencies of sole and whiting. These differences between the impact station, fringe stations and reference stations may indicate changes in predation pressure, food supply and recruitment. Further monitoring (with increased replication) and targeted research actions are needed to confirm causal relationships between these observations and the investigated pressures.

7.6. References

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