CHAPTER 4

FISHING ACTIVITIES IN AND AROUND BELGIAN OFFSHORE WIND FARMS:

TRENDS IN EFFORT AND LANDINGS OVER THE PERIOD 2006-2017

DE BACKER Annelies, POLET Hans, SYS Klaas, VANELSLANDER Bart & HOSTENS Kris

Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Aquatic Environment and Quality, Ankerstraat 1, 8400 Oostende, Belgium

Corresponding author: annelies.debacker@ilvo.vlaanderen.be

Abstract

Fishing is prohibited within most offshore wind farms (OWFs) within Europe. With a European target set to reach 20% renewable energy by 2020, the number of OWFs in the North Sea is increasing fast, and thus fishing grounds are decreasing. This could cause changes in fishing activity in the vicinity of OWFs. Using the 238 km² area dedicated for offshore energy production in the Belgian part of the North Sea as a case, this study aimed to investigate whether beam trawl fishing activity (effort, landings and catch rate of target species sole and plaice) changed over the period 2006-2017 in relation to the presence of OWFs. To our knowledge, this is the first study investigating the effect of operational wind farms, closed for shipping, on fishing activity.

To this end, trends in fishing activity within and around the Belgian OWF area were compared to the wider area surrounding the OWF. The active Belgian OWF area (now ca. 140 km² operational, not yet contiguous) only subtly changed the fishing activity of the Belgian and Dutch beam trawl fleet. Mostly, a "business as usual" scenario, comparable to the wider area, was noted in the vicinity of the OWF concessions in both fishing effort and landings of the top 10 species. Of course, since fishing is forbidden within operational OWFs, a remarkable decrease in fishing effort was observed. However, with the current design and size of the operational OWF area, the fishermen seem to have adapted to the new situation, and are not avoiding the areas around the OWFs, they even seem to be attracted to the edges (especially of the more offshore concessions). Catch rates of target species sole in the vicinity of the operational OWFs remain comparable to catch rates in the wider area, but for plaice, catch rates and landings seem to be even higher around some operational wind farms.

1. Introduction

Within European Directive 2009/28/EC, Europe has set a target to reach 20% renewable energy by 2020. Installation of offshore wind farms (OWFs) is a major component to reach this target. Currently, 4543 wind turbines produce 18,499 MW of renewable energy in Europe, of which 70% in the North

Sea (Wind Europe 2019). In 2018, Belgium had the fourth highest offshore wind capacity (6.4%), after the UK, Germany and Denmark (44; 34 and 7% respectively) (Wind Europe 2019). In 2004, the Belgian government delineated an offshore area of 238 km² for the production of electricity. At the moment, 5 OWFs are operational in the Belgian part of the North Sea (BPNS), good for an installed capacity of 1186 MW. Another one, which will produce another 370 MW, is under construction, and 3 others are in the pre-construction phase.

For safety reasons, shipping is prohibited within most OWFs in Europe. Consequently, commercial (and artisanal) fishing activities are excluded as well. The North Sea is one of the most heavily fished regions in the world, so with the further expansion of OWFs in the North Sea region, fishermen see their fishing grounds disappear, which makes them feel afraid to lose valuable areas and to see their catches and profit decline (Gray *et al.* 2016; Bolongaro 2017). On the other hand, OWFs, as fisheries exclusion zones, might provide shelter, spawning or nursing grounds, and higher food biomass (*e.g.* Leitao *et al.* 2007; Reubens *et al.* 2013 a & b; Stenberg *et al.* 2015), at least for certain fish species, which may then benefit the fisheries for these specific fish stocks. Closure of OWF areas for commercial fisheries will most probably result in changes in fishing intensity in the vicinity of the OWFs and/or in displacement of the fishing activity.

The Belgian OWF area is predominantly situated outside the 12 Nmile area in the southern North Sea. The fishery in this area is mainly dominated by Dutch and Belgian beam trawlers (incl. pulse trawlers since 2011), targeting sole and plaice (Gillis *et al.* 2008; Eigaard *et al.* 2017). The first Belgian turbines were operational in 2009, and since then increasingly more are built, enlarging the fisheries exclusion zone over the past decade. As such, the Belgian OWF area forms an interesting case to study whether the presence of OWFs has an effect on the fishing activity of Dutch and Belgian beam trawlers.

Our first objective was to study whether or not the effort, the landings and the landings per unit effort (LPUE) changed over the period 2006-2017 in relation to the presence of OWFs. The second objective was to investigate whether spatial changes in fishing activity took place due to OWFs by comparing the period 2006-2007 (pre-turbines) with 2016-2017 (232 operational turbines).

2. Material and methods

2.1. Study area

To investigate changes in fisheries activities, it is important to include a wider area to deduct general trends over time. The Belgian OWF area is covered by ICES rectangles 31F2, 31F3, 32F2 and 32F3, which were selected to represent the general trends within the wider area (fig. 1). VMS and landing data for these four rectangles were collected for the Belgian and Dutch beam trawl fleet (including both small and large beam trawls, with vessels respectively $\leq$ 221 kW and > 221 kW, including also the Dutch pulse trawlers operational since 2011). The ICES rectangles were gridded with a resolution of 0.05 x 0.025 decimal degrees (further referred to as "grid cells"), a trade-off between having a fine enough resolution for analyses in the Belgian OWF area, and still being adequate for VMS registrations that are recorded at a 2 hour ping rate (fig. 1).

The spatial coverage, construction and operation dates and number of turbines for each OWF concession area are summarised in table 1. Three wind farms (Seastar, Northwester2 and Mermaid) still have to be built (dashed lines in fig. 1). The other ones have been constructed between 2009 and 2019 (with the exception of 6 gravity-based turbines that were already constructed in 2007-2008 in the C-Power A concession zone).

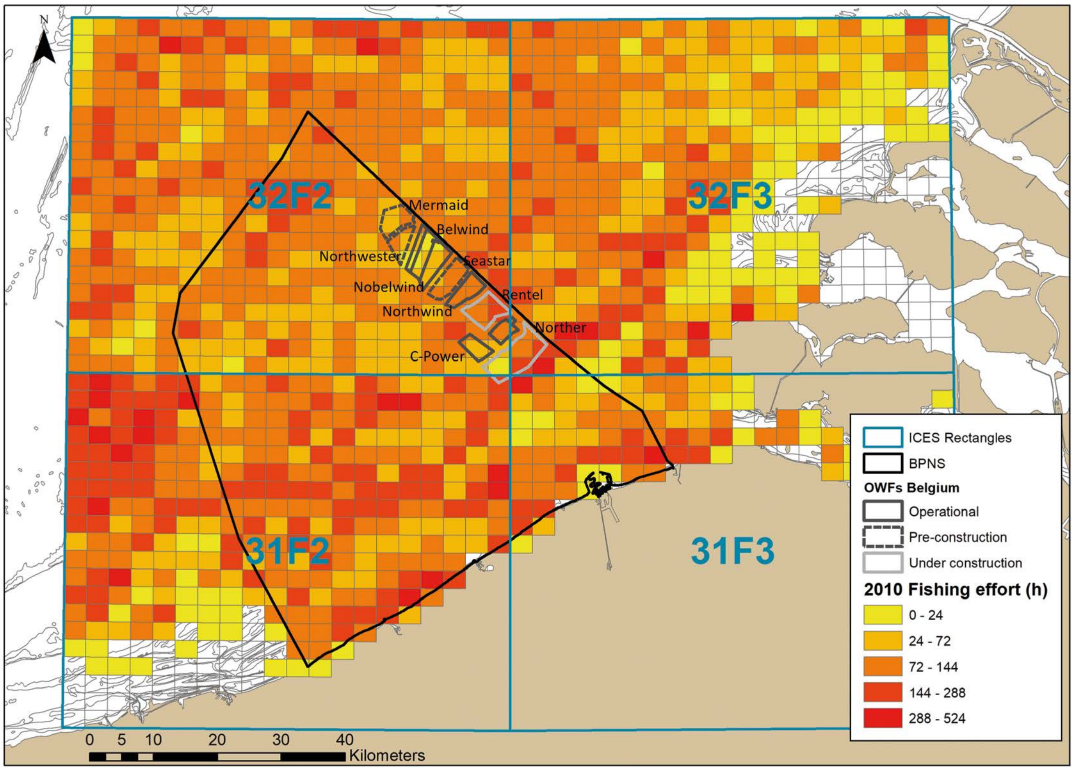


Figure 1. Overview of the study area with indication of ICES rectangles, used grid, Belgian territorial area, Belgian OWF concessions, and 2010 fishing effort of Belgian and Dutch beam trawlers (both = < 221 kW and > 221 kW).

Table 1. Summary of the Belgian OWF concession areas (ordered in relation to distance from the coast, *i.e.* from east to west, see fig. 1) with indication of surface area, number of turbines, start of construction and moment when first power is generated

Windfarm	Area (km²)	Turbines	Start construction	First power generated
Norther	44	44	2017	Foreseen in 2019
C-Power A	10.68	6 + 24	May 2007 & November 2010	January 2009 & September 2013
C-Power B	9.16	24	November 2010	September 2013
Rentel	23	42	July 2017	January 2019
Northwind	13.8	72	April 2013	May 2014
Seastar	18.4	30	Planned summer 2019	
Belwind	17	56	September 2009	January 2011
Nobelwind (S & N)	19.8	50	April 2016	December 2017
Northwester 2	15.2	23	Planned summer 2019	
Mermaid	16.3	28	Planned summer 2019	

2.2. VMS and logbook data

Fishing intensities, based on VMS (Vessel Monitoring by Satellite) data, and landed catches, based on logbook data, of Dutch and Belgian fishing vessels were calculated and combined for ICES statistical rectangles 31F2, 31F3, 32F2 and 32F3 per gear class. We distinguished fishing activity of vessels with different engine classes (engine power = < 221 kW and > 221 kW). Fishing intensities and landings were calculated on a yearly basis from 2006 until 2017.

VMS is a satellite-based monitoring system which, at regular intervals (mainly every 2 hours), provides data to the fisheries authorities on the location, date

Table 2. Overview of the top 10 species landed by the Dutch and Belgian beam trawl fleets

Common name	Scientific name	FAO code
Sole	*Solea solea*	SOL
Plaice	*Pleuronectes platessa*	PLE
Turbot	*Psetta maxima*	TUR
Brill	*Scophthalmus rhombus*	BLL
Dab	*Limanda limanda*	DAB
Flounder	*Platichthys flesus*	FLE
Cod	*Gadus morhua*	COD
Whiting	*Merlangius merlangus*	WHG
Tub gurnard	*Chelidonichthys lucerna*	GUU
Bib/Pouting	*Trisopterus luscus*	BIB

time, course and speed of vessels. Logbook data is compulsory for almost all commercial fishing vessels and contains information on daily catch composition, fishing gear usage, engine power and departure, and arrival harbours. Belgian VMS and logbook data are collected by dienst Zeevisserij (Departement Landbouw en Visserij; Afdeling landbouw- en visserijbeleid) and analysed by ILVO. The processed Dutch data were provided by Wageningen Marine Research.

All data processing of VMS and logbook data was made in R using the vmstools package (Hintzen *et al.* 2012). Before we analysed the Belgian fishing activities, an extensive quality control of the data was performed. We checked for duplicated data, locations inside the harbours, impossible time, dates, headings and locations. Only VMS records with speeds that correspond with fishing activity were selected. VMS and logbook data were linked based on vessel identity and date time. Using this link, we combined data on fishing location, date and time, fishing speed, fishing gear and landed catch. To derive the number of times fishing vessels have actively fished inside a grid cell, and to calculate their corresponding catches, we performed a spatial overlay analysis using routines in the R package sp (Bivand *et al.* 2013).

Given the low frequency of VMS pings (every two hours) and the determination of fishing activity based on speed, these results are only an estimation of the actual fishing activity in these areas.

2.3. Temporal trends in effort, landings and LPUE

In order to be able to link trends in fishing activities in and around the OWF concession area to real wind farm effects, the ICES rectangles covering the Belgian OWF area (31F2, 31F3, 32F2 and 32F3) were selected for a general trend analysis. Therefore, total yearly fishing effort (in hours fished) and landings (kg) of the top 10 species of the Dutch and Belgian beam trawl fleets are presented for the period 2006 to 2017 for the selected ICES rectangles. Similarly, landings per unit effort (LPUE) of the target species sole and plaice were calculated as total landings (kg) divided by fishing effort for the selected ICES rectangles.

To calculate fishing effort (hours fished) and landings of the top 10 species within each OWF concession area, the Geofish platform (developed by ILVO for the Geofish project (https://geofish.be/ – still in test environment) was used, which allows to sum fishing effort or landings within each OWF concession polygon on a yearly basis. For grid cells that are partly inside a specific polygon, a percentage of the value in that grid cell is taken relative to the surface area of the grid cell in the polygon. Afterwards LPUE of sole and plaice per OWF concession were calculated by dividing total landings within the concession by total hours fished (fishing effort) within the same concession.

This implies that the values that are presented for the operational wind farms, actually include edge effects, since fishing activities occurring just outside the OWF polygon are allocated to the OWF. This can be seen as a drawback, but it especially provides insight in the "whether or not" overall avoidance of or attraction to the areas surrounding the active concession areas. As such, fishing activity within operational concessions should not be interpreted as ongoing fishing within the wind farm, but it is mainly representing edge effects.

To get an idea on the real intrusions of fishing vessels in the closed area, and thus the actual fishing inside the OWFs, information on intrusions of commercial fishing vessels was requested to and provided by Parkwind (representing the OWFs Belwind, Nobelwind and Northwind) and C-Power. These figures are proxies, since especially in the earlier years, when no AIS detection tools were available, intrusions might have happened unnoticed (pers. comm. Kristof Verlinden).

All data processing and analyses were made in R version 3.5.1 (R Core Team 2018) using R Studio (R Studio Team 2016) using the packages reshape2, dplyr and ggplot2.

2.4. Spatial changes in effort and LPUE distribution

We compared changes in effort and LPUE distribution for the period 2006-2007 (pre-OWF period) to the period 2016-2017 (3 operational OWFs and 3 OWFs under construction) for the combined Dutch and Belgian fishing effort data of the large beam trawl segment (> 221 kW). We excluded the small beam trawl segment (= < 221 kW) from this analysis, since these were only fishing within the 12 Nmile zone before 2009 due to high fuel prices, and thus not inside the OWF area. Including the effort data of the small beam trawl segment in this type of analysis would therefore distort the outcome in and around the OWF area, since it was zero in the pre-OWF period.

The change in effort and LPUE distribution was calculated as a deviation of proportional effort or LPUE in the period 2016-2017 compared to the reference period 2006-2007. Since effort and LPUE can vary over years, effort and LPUE are expressed as a proportion of the average effort and LPUE (within the study area *i.e.* four statistical ICES rectangles) in each grid cell for the defined period. In this way, the general temporal trend was excluded.

Thus, for each grid cell, proportional effort and LPUE (relative to the average effort and LPUE for the wider ICES area) were calculated for both periods. Afterwards, the deviation was calculated as the difference in proportional effort or LPUE between period 2016-2017 and period 2006-2007. A negative deviation means that there is relatively less effort or lower LPUE in the grid cell in 2016-2017 compared to 2006-2007, while a positive deviation reveals a relative increased fishing effort or a higher LPUE.

Analyses were done in R version 3.5.1 (R Core Team 2018) using R Studio (R Studio Team 2016) using the package reshape2. Visualisation of calculated deviations was done using ArcMap 10.4.

3. Results

3.1. Temporal trends in fishing activity within the wider ICES area and the OWF concessions

3.1.1. Fishing effort

Over the period 2006-2017, Dutch and Belgian beam trawls spent on average around 108,000 (± SD 13,680) hours at sea in the selected ICES rectangles. Total fishing effort within the wider ICES area surrounding the OWF area showed a general decreasing trend over the years (fig. 2).

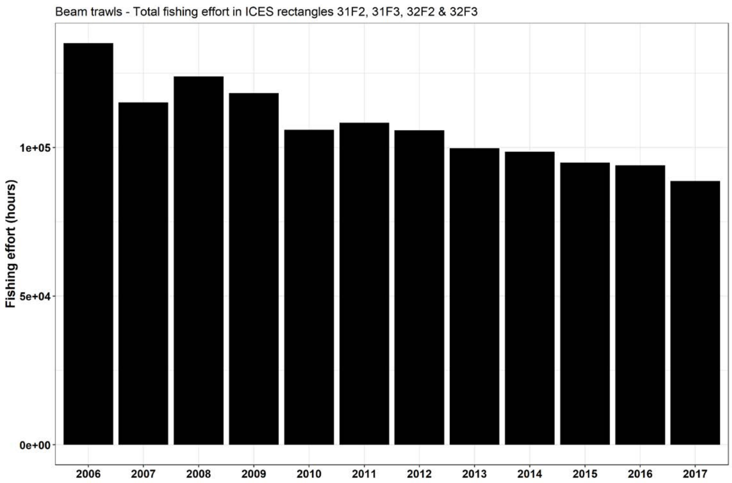


Figure 2. Time series of total fishing effort in hours of Dutch and Belgian beam trawlers in ICES rectangles 31F2, 31F3, 32F2, 32F3.

For the OWF area, a clear drop (up to 50%) in fishing effort is observed during the construction phase for all concessions where turbines have been built (fig. 3). Once in the operational phase, the reduced fishing effort continues to exist in C-Power A&B and Northwind. While in Belwind, fishing effort gives the impression to increase again in the operational phase, this is due to the resolution of the grid cells, since grid cells are only partially inside the Belwind concession, which means that fishing along the edges is (proportionally) seen as fishing inside the wind farm, but this actually is mainly an edge effect. In 2016, with the construction of Nobelwind (OWF surrounding Belwind),

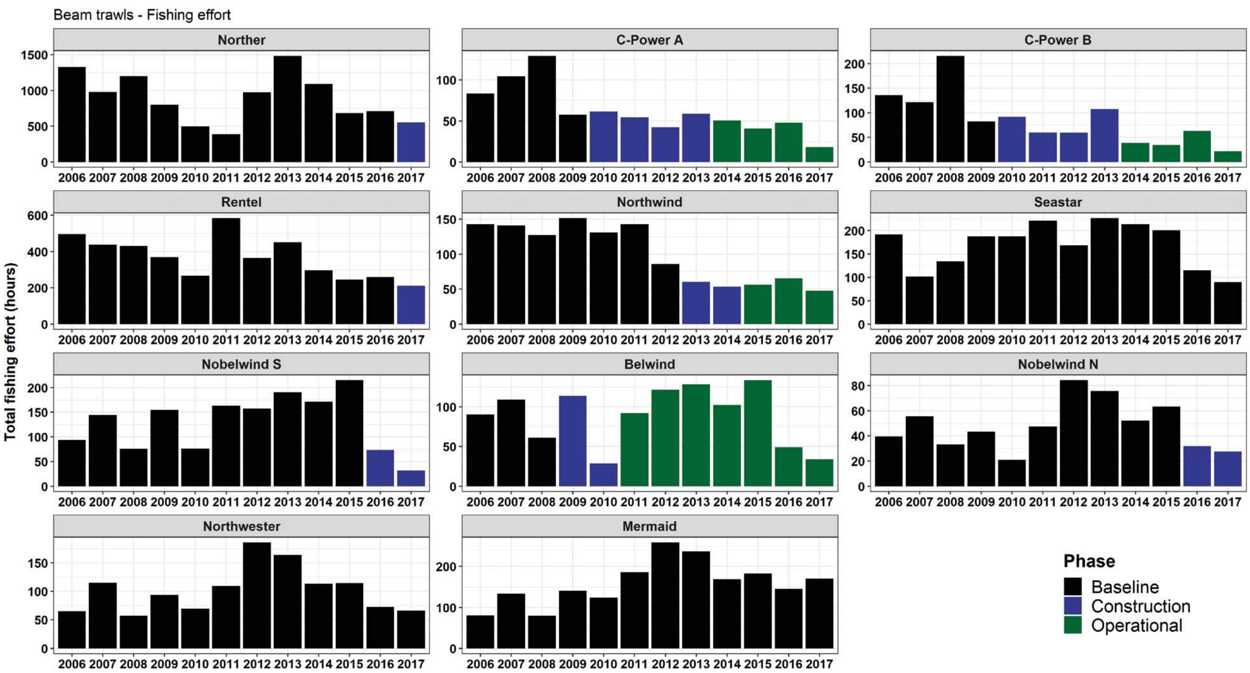


Figure 3. Time series of fishing effort of Dutch and Belgian beam trawlers for the different OWF concession areas in the BPNS with indication of the baseline, construction and operational phase. ! Nuanced interpretation of trends is needed: ongoing fishing effort during construction and operational phase (where fishing is forbidden) is mainly due to grid cells overlapping the edges of concessions, as such fishing activity along the edge of the concession is allocated to the concession.

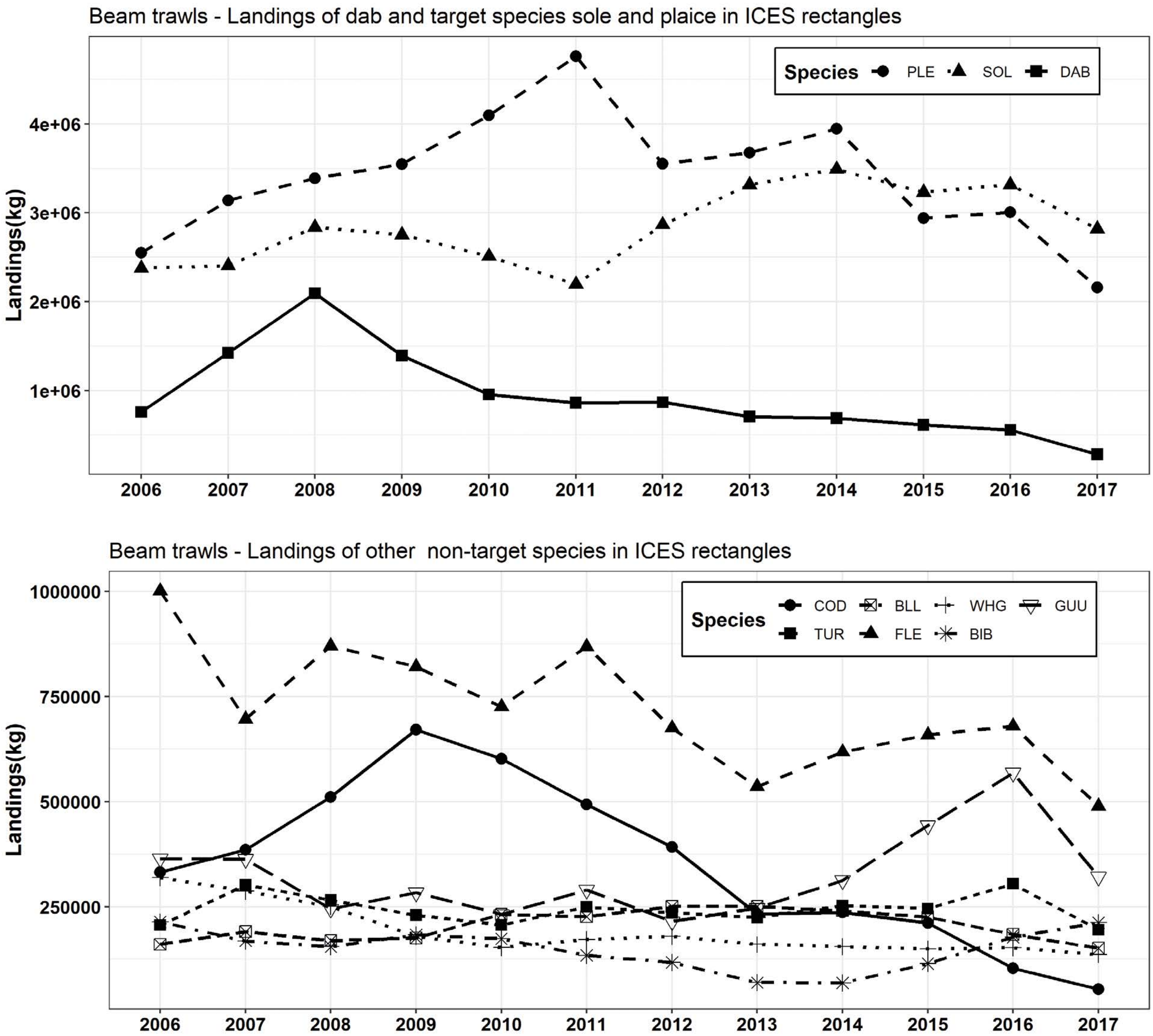


Figure 4. Time series of landings in kg of top 10 species for Dutch and Belgian beam trawlers in ICES rectangles 31F2, 31F3, 32F2, 32F3. Top: landings of dab and target species, plaice and sole; bottom: non-target species.

and thus expansion of the none-fishing area, fishing effort drops again, since grid cells are now predominantly situated entirely inside either Belwind or Nobelwind, where fishing is prohibited. In the OWFs without turbines yet (Seastar, Northwester and Mermaid), temporal variation in fishing effort is observed mainly in the earlier years, while in the later years (from 2012-2013), a decreasing trend is found, similar to the general trend in the selected ICES rectangles. For Northwester and Seastar, OWFs bordering Nobelwind, a drop in fishing effort in 2016 and 2017 was observed when construction started at Nobelwind.

3.1.2. Landings of top 10 species

Within the wider ICES area, Dutch and Belgian beam trawlers landed on average 2.8 MM (± SD 0.4 MM) kg of sole and 3.4 MM (± SD 0.7 MM) kg of plaice, their target species. Landings are in general well related to fishing effort. Landings of plaice, dab, cod and flounder increased in the earlier years, but decreased later on (fig. 4). Sole is the only species with a clear increase (26%) in landings after 2012. Although, gurnard landings were higher as well in 2015 and 2016. Landings of the other species (turbot, brill, whiting and bib) remained more or less stable (fig. 4).

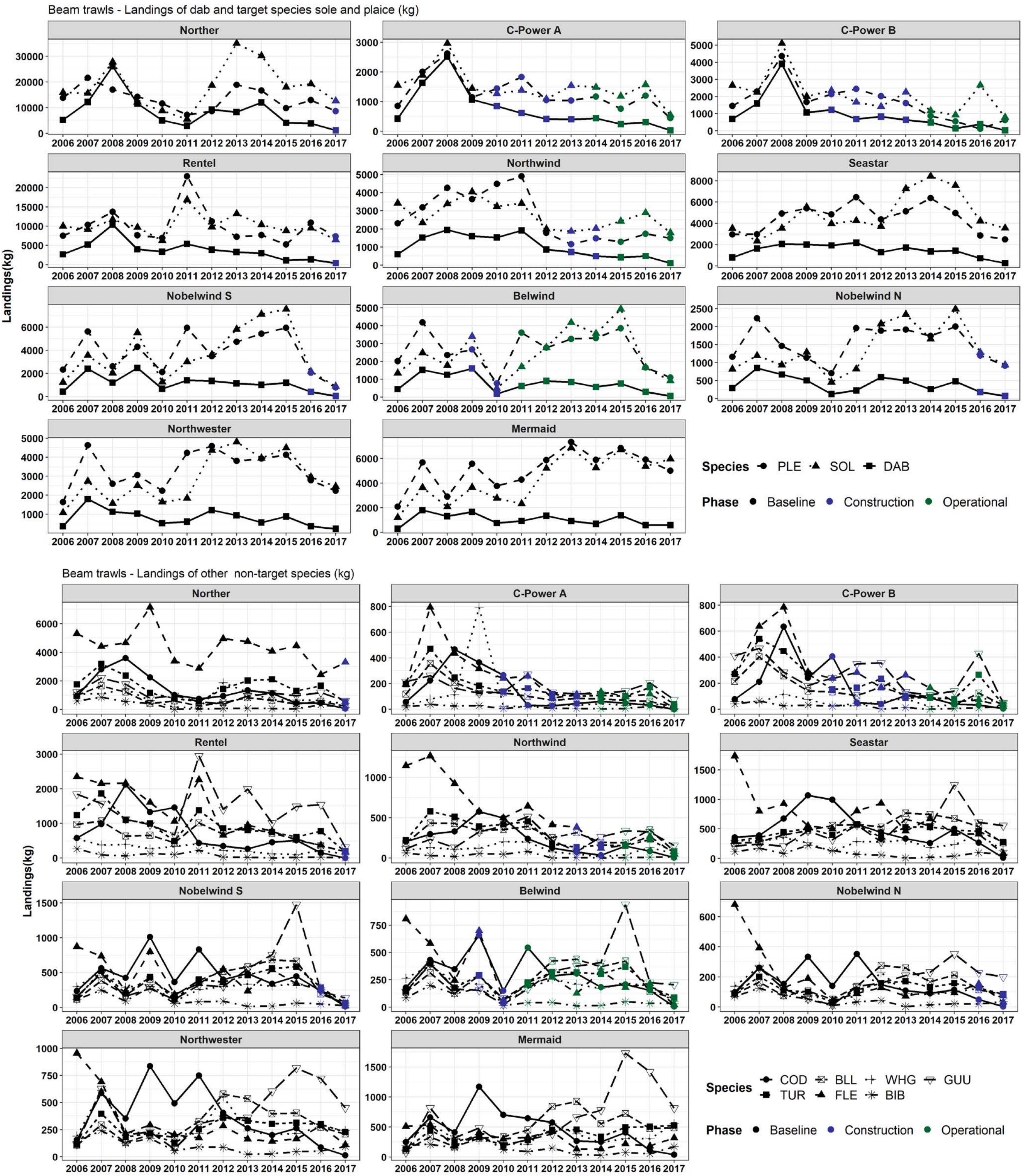


Figure 5. Time series of landings of top 10 species of the Dutch and Belgian beam trawlers for the different OWF concession areas in the BPNS. Top: landings of dab and target species, plaice and sole; bottom: non-target species.

! Nuanced interpretation of trends is needed: landings during construction and operational phase (where fishing is forbidden), is due to grid cells overlapping the edges of concessions, as such the landings of fishing activities along the edge of the concession are allocated to the concession.

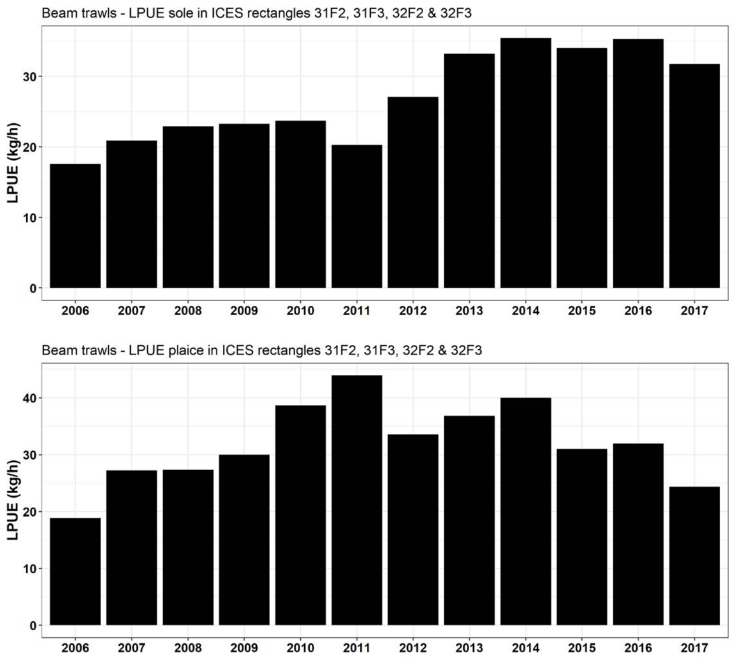


Figure 6. Time series of LPUE for sole (top) and plaice (bottom) of Dutch and Belgian beam trawlers in ICES rectangles 31F2, 31F3, 32F2, 32F3.

For the OWF area, trends in total landings for the top 10 species are highly correlated with fishing effort ($r > 0.8$ for all concessions, except for Mermaid $r = 0.72$), so similarly as for fishing effort a drop in the landings is observed for all species during construction and remains lower once operational (except for Belwind) (fig. 5). The target species sole and plaice are caught in the highest volumes in all concession areas. Especially in the earlier years and the areas closer to shore (Norther, Rentel and C-Power), dab is caught in higher volumes, but shows a decreasing trend, just as in the wider ICES area (fig. 5). Also the other species show very similar trends in the OWF concession areas (especially in OWFs without turbines) compared to the general ICES area trend: increased landings of sole after 2012 and of gurnards in later years, decreased landings for flounder and stable for brill, turbot, bib and whiting (fig. 5). Only for plaice, trends in landings in most OWF concessions seem to deviate a bit from the wider general trend, not really showing a decrease in landings after 2011, as seen in the general trend (fig. 5).

3.1.3. Landings per unit effort for sole and plaice

Landings per unit effort (LPUE) of the target species sole and plaice over the years are shown in fig. 6. A remarkable increase (almost 50%) for sole LPUE is visible from 2012 onwards going from 20-25 kg/h to 30-35 kg/h indicating increased catch rates. LPUE for plaice shows more yearly variation and is on average 32 (± SD 7) kg/h (fig. 6). LPUE of plaice follows more or less the landing trend, increasing towards 2011 and decreasing again in the later years (fig. 6).

For LPUE of sole within the concession areas, we found an increase in LPUE from 2012 onwards similar to the selected ICES rectangles surrounding the OWFs. Construction of wind turbines or presence of an operational wind farm do not affect the catch rate of sole in the vicinity (fig. 7). For LPUE of plaice, catch rates are highest in the wind farms furthest offshore compared to the more coastal ones (avg. LPUE of plaice in Mermaid is 33 [± SD 7] kg/h while in Norther it is 16 [± SD 4] kg/h). The time trend in LPUE of plaice shows some

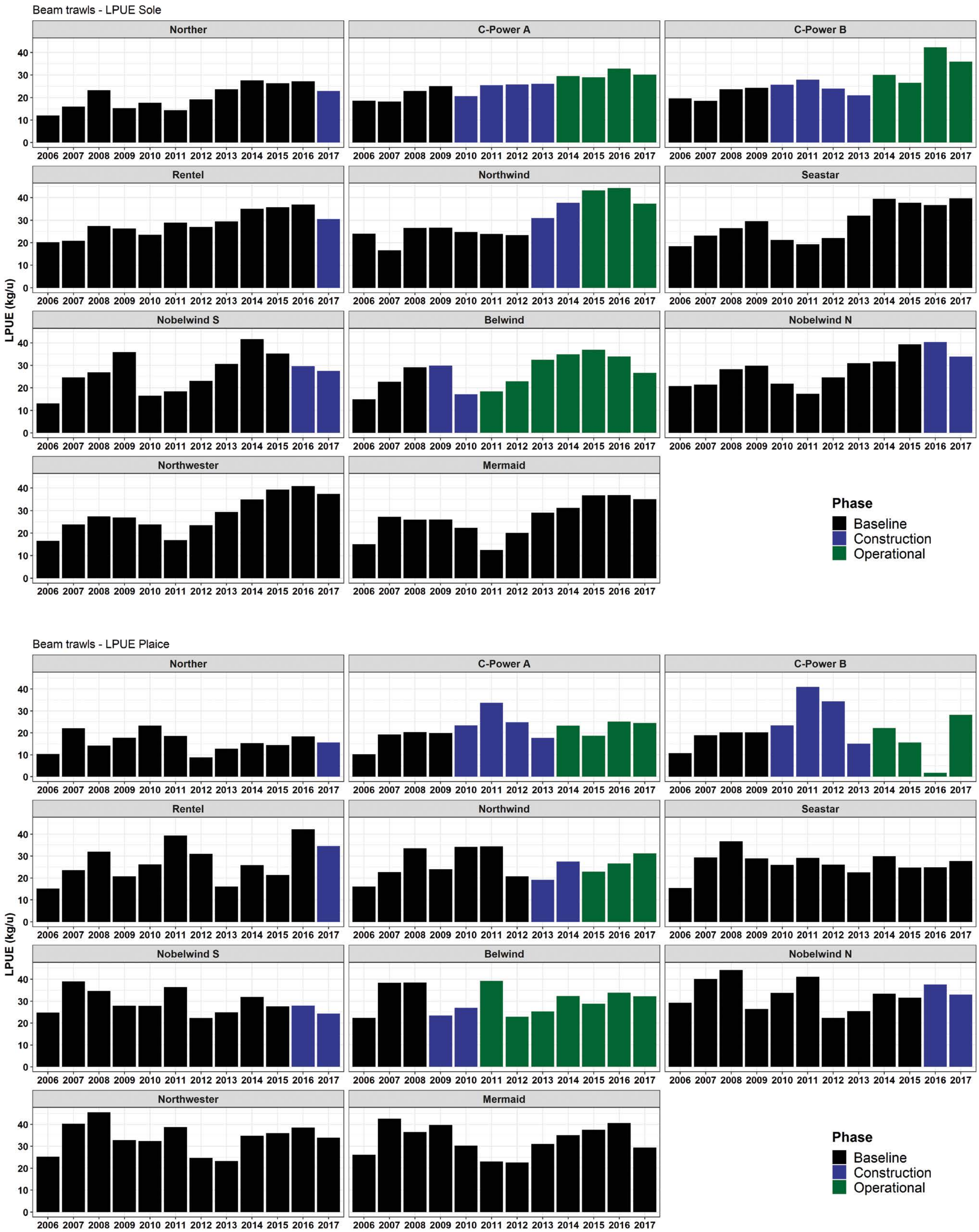


Figure 7. Time series of LPUE for sole (top) and plaice (bottom) of Dutch and Belgian beam trawlers for the different OWF concession areas in the BPNS with indication of baseline, construction and operational phase. ! Nuanced interpretation of trends is needed: LPUE during construction and operational phase (where fishing is forbidden), is due to grid cells overlapping the edges of concessions, as such values of LPUE just outside the concession are allocated to the concession.

Table 3. Overview of registered intrusions by commercial fishing vessels for C-Power, Northwind, Belwind and Nobelwind concessions

Wind farm	2012	2013	2014	2015	2016	2017
C-Power	12 intrusion by fishing vessels registered over entire period					
Northwind			0	0	7	6
Belwind & Nobelwind	3	6	0	3	14	17

year-to-year variation within most concession areas, and it seems to deviate a bit from the general trend, not really showing a decrease in the later years (fig. 7).

3.2. Registered intrusions of fishing vessels inside OWFs

Based on the intrusion reports received from Parkwind and the information provided by C-Power, we have an idea of the violations of fishing vessels within or inside the safety perimeter of the 4 operational concession areas with the longest history in Belgian waters (C-Power, Northwind, Belwind and Nobelwind). Table 3 presents the intrusions by commercial fishing vessels inside the "no-shipping" area of 3 operational concession areas. Some fishing vessels ignored the no-shipping area, and intruded concessions or their safety perimeter. The data suggests intrusions have increased in the later years.

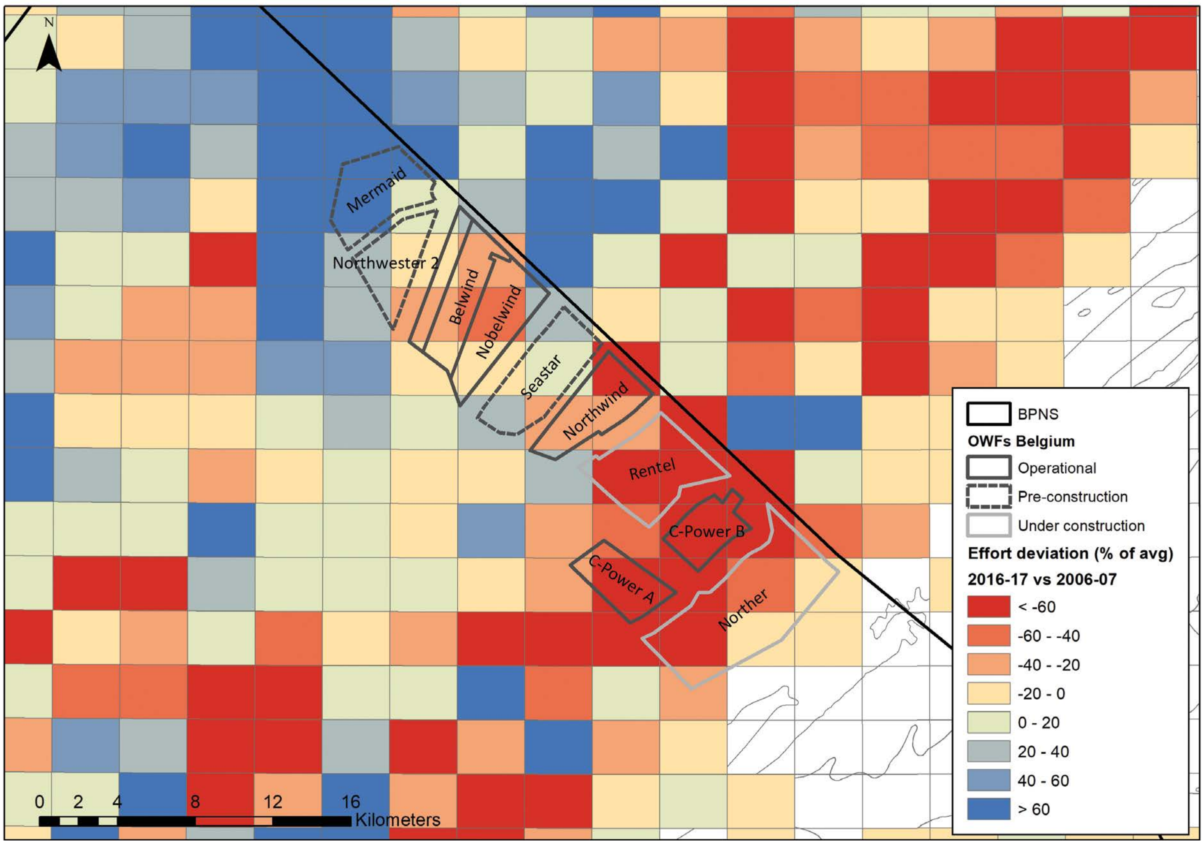
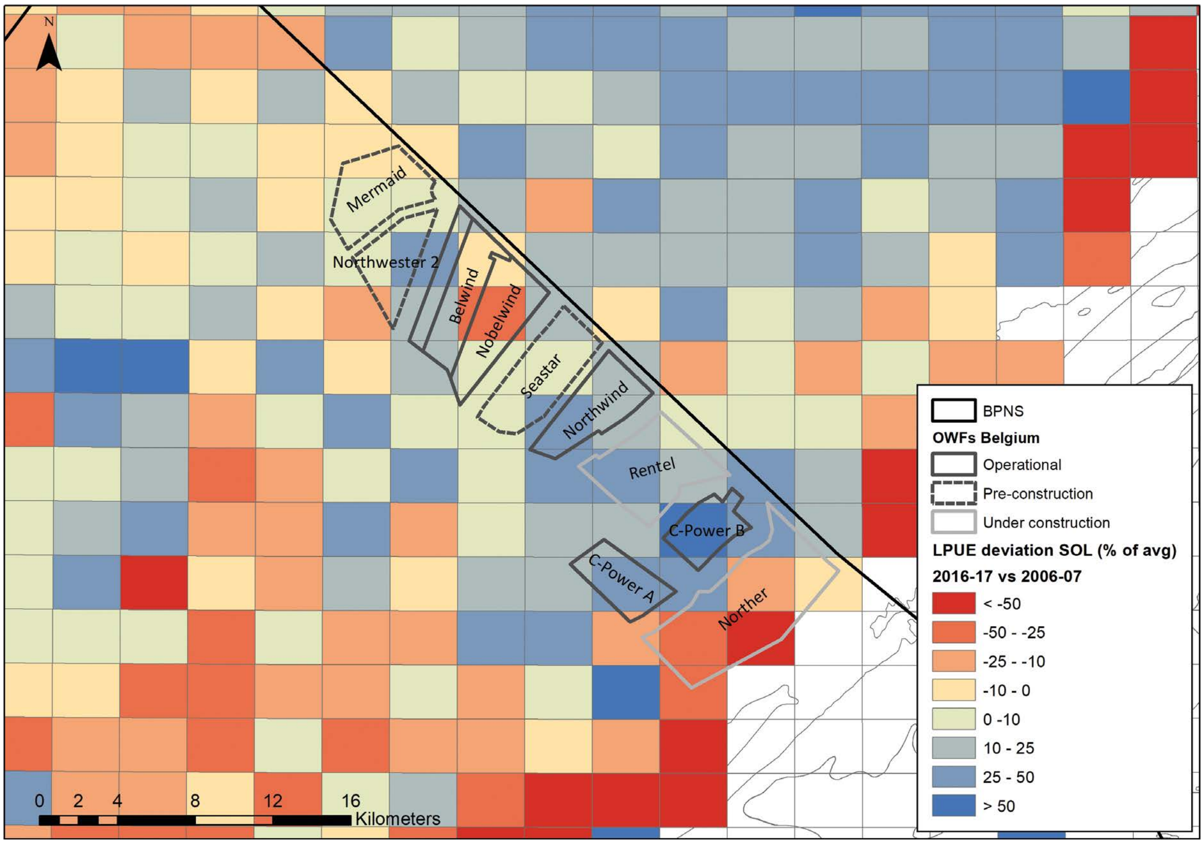


Figure 8. Spatial changes in fishing effort based on the deviation in proportional effort for Dutch and Belgian large beam trawls in 2016-2017 compared to 2006-2007.



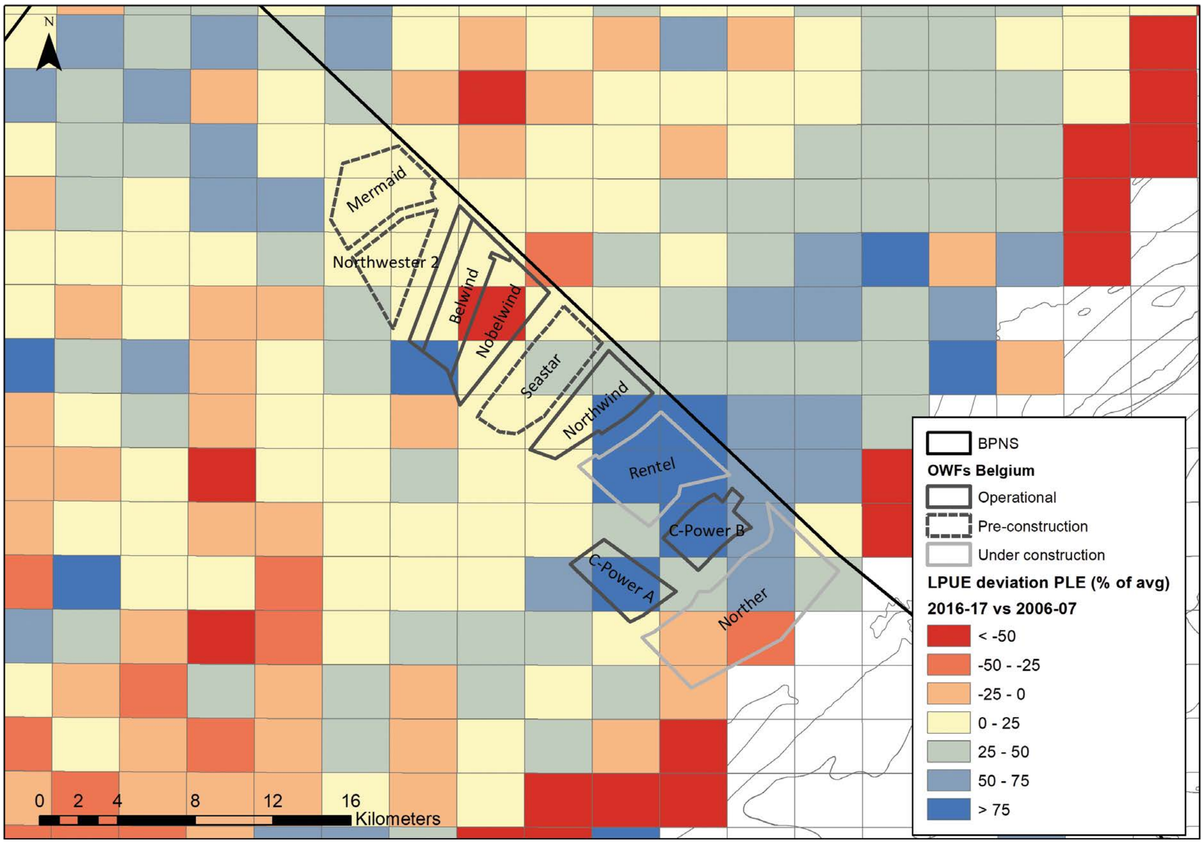


Figure 9. Spatial changes in LPUE of sole (top) and plaice (bottom) based on the deviation in proportional LPUE for Dutch and Belgian large beam trawls in 2016-2017 compared to 2006-2007.

This, however, may be considered an artefact because most likely intrusions might have been missed in the earlier years in absence of proper AIS tools (pers. comm. Kristof Verlinden).

3.3. Spatial changes in fishing effort and LPUE of sole and plaice

Within the grid cells covering the operational wind farms C-Power, Northwind, Nobelwind and Belwind, a large reduction in proportional fishing effort (up to more than 60%) was observed when comparing the period 2006-2007 with 2016-2017. However, a similar trend was also observed in the wind farms Norther and Rentel, where construction only started in 2017 (fig. 8). In fact, a general shift towards more offshore fishing activity away from the 12 Nmile line within the selected ICES rectangles can be observed (fig. 8). Around the operational OWFs situated further offshore (Belwind, Nobelwind and also Northwind), proportional fishing effort increased slightly, especially towards the NE for Belwind and Nobelwind, and SW for Northwind, which suggests that fishermen might be attracted to the edges of these more offshore wind farms. On the other hand, fishing effort in general increased in these more offshore areas as well by over 60%, as seen in the wider area north of Belwind (fig. 8). The proportional effort distribution around the wind farm area thus more or less mirrored the fishing effort in the wider area.

Spatial changes in proportional LPUE of sole do not indicate a clear wind farm effect. Proportional increases in catch rate of sole are observed around the wind farms, especially around C-Power, Rentel and Northwind when comparing the period 2006-2007 with 2016-2017. However, similar increases in proportional sole LPUE are seen in the wider area to the NE (fig. 9). For plaice however, a remarkable increase of more than 75% in proportional LPUE was observed in C-Power and Rentel and SW of Belwind, indicating an increased catch rate and a deviation of the general proportional trend around these wind farms, where lower increases are observed (fig. 9).

4. Discussion and conclusions

This chapter provides an overview of the spatio-temporal fishing patterns of the Belgian and Dutch beam trawl fleets (both small = < 221 kW and large > 221 kW engine power) in and around the Belgian OWF area over the period 2006-2017. To our knowledge, this is the first study investigating the effect of OWF concessions closed for shipping, on fishing activity.

An important thing to note is that the data seem to imply that fishing is still ongoing in operational OWFs and OWFs under construction, although this is actually forbidden. Some violations have indeed been registered during the studied period. However, the observed fishing activity inside active OWFs is mainly a consequence of the necessary aggregation of VMS and landings data on grid cell level (both due to the low frequency of VMS pings and due to confidentiality reasons). Grid cells are not belonging entirely to a concession area, which makes that fishing activity along the edge of an OWF may be counted for (on a percentage basis) as being located inside the concession zone. This forms a potential drawback on the results and edge effects might be missed in this way, but it does provide clear insights in the “whether or not” overall avoidance of or attraction to the immediate vicinity of the active concession areas. In fact, the observed fishing activity within the operational concessions partly represents the edge effects. Despite the aggregation at grid cell level, the VMS and landing data do give a good idea on the trends in the OWFs and the surrounding area, indicating that beam trawlers are still fishing very close to the edges of the OWFs.

Apart from the expected and observed decreases in fishing effort in the Belgian OWF concession areas once construction of the turbines has started, we noted mostly a "business as usual" in both fishing effort and landings for the Belgian and Dutch beam trawl fleets in the four selected ICES rectangles in the southern North Sea. No clear avoidance nor attraction towards the onshore operational wind farm edges could be noticed. Though this could be an artefact of working with aggregated grid cell making it harder to reveal edge effects. Nevertheless, for the more offshore situated wind farms, the deviation maps (comparing the pre-turbine with the post-turbine period) seem to suggest that fishermen are slightly attracted to the edges. Furthermore, we found an indication that during construction of a certain OWF also the immediate surroundings are avoided by fishermen; for example, a decreased fishing effort was observed in the Seastar concession (bordering Nobelwind) during the construction of Nobelwind.

Catch rate of the target species sole (expressed as LPUE) showed the same time trends as in the wider ICES area, indicating that the presence of the Belgian wind farms did not affect "efficiency" of the beam trawl fleet in catching soles. On the other hand, we found an indication of increased catch rates for plaice in the presence of OWFs, C-Power and Rentel and also to the SW of Belwind. This is supported by the monitoring results investigating potential effects of OWFs on demersal fish, where increased densities of plaice have been found inside OWFs compared to the reference areas (De Backer & Hostens 2017). More in depth research, on potential attraction of plaice towards wind farms is needed to confirm these results.

During the studied time period (2006-2017), some notable changes in beam trawl fishing in general took place, which may obscure potential real wind farm effects. Between 2011 and 2017, 80 pulse trawl vessels were introduced in the Dutch beam trawl fleet (largely replacing the original beam trawlers). This caused a displacement towards the English Channel, but also further offshore the Dutch and Belgian coasts (Turenhout *et al.* 2016). Furthermore, pulse trawlers focus more on sole, and are clearly more efficient in catching this species (Turenhout *et al.* 2016). This effect was picked up as an increase in LPUE for sole since 2012, both in the OWF area and the wider ICES area, indicating that OWFs as such do not (yet) affect sole catches. Distribution of fishing activity is also dependent on catch composition, available quotas, fish prices and oil prices. High oil prices make that fishermen stay closer to port (Bastardie *et al.* 2010; Poos *et al.* 2013). During our study period, oil prices raised rapidly from 2006 to a peak in 2008 but decreased fast again afterwards. We noted a tendency in the distribution data that fishermen were fishing further offshore in the later years. Especially for the small beam trawl segment, this pattern was very prominent: in the years 2006 to 2009, they all stayed within the 12 Nmile zone, with a shift more offshore in the later years. Based on the overall distribution and deviation maps, a similar but smaller offshore shift may be observed in the later years for the larger beam trawlers as well.

When filtering out the general trends in fishing effort and landings in the deviation maps, our results indicate that the active Belgian OWF area (now ca. 140 km^2 operational not yet contiguous) only subtly changed the fishing activity of Belgian and Dutch beam trawlers (including the pulse trawlers). With the current design and size of the operational OWF area, fishermen seem to have adapted to the new situation, and are certainly not avoiding the areas around the OWFs, they even seem to be attracted to the edges. They keep fishing in the surroundings of the OWFs, still with comparable LPUE, at least for the two main target species sole and plaice. For plaice, LPUE seems even higher around some operational wind farms. As such, the relatively small loss of potential fishing grounds did not yet result in a real decrease of catches in the region or thus of the potential profit of the fishermen. However, this conclusion can change when more OWFs will be operational in the North Sea and larger "connected" areas will be excluded for fisheries. Also, the possible effect of increased nursery or feeding grounds for the targeted commercial fish species, especially plaice, potentially offered by the OWFs still needs to be further investigated.

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