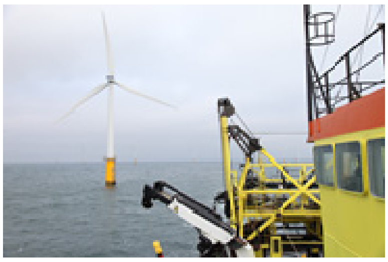
Roundfish monitoring
Princess Amalia Wind Farm

Ralf van Hal

Report number C117/13-A

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Summary

This report describes the results of field work in the Princess Amalia Wind Farm (in Dutch: Prinses Amaliawindpark, or PAWP). It is to realize the requirements of the Monitoring and Evaluation Program, which is part of the Wbr-permit of the wind farm. The objective is to determine if the wind farm functions as a refugium for roundfish. PAWP is expected to act as a refugium because fisheries are excluded in the farm area since 16 October 2007. It is expected that larger and older individuals as well as species vulnerable for fisheries would have a better chance to survive which would result in an increase in numbers and larger individuals.

The methods and design of the field work were decided upon by the client and the government and follow closely the protocols of the International Bottom Trawl Survey (IBTS). Following these protocols as close as possible, eight tows in the farm were performed by the Dutch vessel Tridens with the ground gear used in the IBTS. The catches in these eight tows were compared to the catches of the IBTS in the surrounding area in the last 10 years (2004-2013), 43 tows. Unfortunately in 2012 and 2013, only two IBTS tows a year (a French and a Dutch) were made in the vicinity of the wind farm that could be used for the comparison. This provides limited data to perform proper analysis on to conclude on the potential effect of the farm.

The catches in the wind farm do not significantly differ from those in the surrounding IBTS, not when all the 43 IBTS tows were combined neither when the comparison was done by year. The analysis were performed on the number of species caught, the total catch per unit of effort (CPUE), and the CPUE of a number of species (herring, sprat, whiting, cod, plaice, dab, greater sand-eel).

In total 17 fish species were caught in the eight tows, all of these were also caught in the 43 IBTS tows. The sprat and herring caught in PAWP were larger than those in the 2013 IBTS tows, however the collected data was too limited to explain this larger size. It is more likely that this is caused by catching a school of larger herring and sprat by chance than an effect of the wind farm.
Only a single juvenile cod was caught in the farm, while other wind farm studies show a positive effect for cod, mainly due to the attraction to the monopiles. The sampling was, due to safety reasons, not done close to the monopiles but on the sandy bottom in the middle of the farm. The low number of cod is thus as expected comparing it with the catches of the IBTS and not in contrast to the positive findings of the other wind farm studies.
There is a suggestion of a positive effect of PAWP on the presence of greater sand-eel. This is a species that is buried in the sediment for a large part of its life and also its eggs stick to the sediments. It might be a species that, if the sediments in the farm are suitable, profits from the refugium function of the farm. However, the data collected are too limited to conclude this.

The expectation that larger and older individuals as well as species vulnerable for fisheries would have a better chance to survive and so increase in size and numbers, is not supported nor reject by the data collected. The field work conducted as part of this study is too limited to draw statistically significant conclusions regarding the refugium function of the wind farm for roundfish.

1 Introduction

In March 2005, Eneco and Q7 Holding signed a declaration of intent for the construction and operation of a wind farm situated some 23 kilometres offshore from IJmuiden, in block Q7 of the Dutch continental shelf. The construction of this wind farm named Princess Amalia Wind Farm (in Dutch: Prinses Amaliawindpark, or PAWP) started in October 2006 by laying the first foundation. Foundations measuring 54 metres, a diameter of 4 metres and 320 tons in weight were sunk into the sea-floor. The transition pieces weighing 115 tons were placed on the foundations using the Jumping Jack. To support the turbine foundations, a 15 m diameter scour-protection consisting of mixed size rocks was deposited on the soft sediment around the base of each monopile. Cables and wind turbines were installed from May 2007 to April 2008. Fisheries are excluded from the farm area since 16 October 2007 and the wind farm is operational since June 2008.

A Monitoring and Evaluation Program (MEP) to monitor potential effects of constructing and operating a wind farm on its surrounding is needed according to the Wbr-permit of the wind farm. The MEP for PAWP consists of a number of research topics. Monitoring roundfish species (all none flatfish species) is one of those. The objective is to determine if PAWP acts as a refuge area (refugium) for these roundfish species. This report focusses on this objective by analysing the data from field work executed in February 2013, five years after the construction of the farm. The results are placed in the context of data of the last ten years (2004-2013) of a yearly survey using the same methods.

2 Assignment

The MEP described in detail field work that had to be performed as well as the data to be collected during the field work. Updated detailed descriptions were approved by Rijkswaterstaat[1] (RWS) Noordzee, on January 2013, as described in the program "Operationeel plan voor het bepalen of het Prinses Amaliawindpark als refugium fungeert voor rondvis" ((van Steen and Dam, 2013 in-house document in Dutch only), with adjustments in the fishing locations (Dam and van Steen, 2013). IMARES was requested to execute the field work. The data, analyses and conclusions are presented in this report.

The objective of the Operational plan is to determine if the wind farm functions as a refugium for roundfish. PAWP is expected to act as a refugium because fisheries are excluded from the farm. The expectation as phrased in the Operational plan (van Steen and Dam, 2013) was that larger and older individuals as well as species vulnerable for fisheries would have a better chance to survive and so increase in numbers, or return to the area.

The assignment was to measure once in the fifth year after the construction of the farm, e.g. in the T5. The proposal was to follow as close as possible the approach used in the international bottom trawl survey (IBTS; Heessen *et al.*, 1997), which is coordinated under the auspices of the International Council for Exploration of the Seas (ICES). The minimum requirements were successful completion of two tows (primary transects) in the wind farm following the guidelines of the IBTS.

The species to focus on according to the Operational plan were:

- *Clupea harengus* (herring)
- *Sprattus sprattus* (sprat)

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[1] The executive arm of the Dutch Ministry of Infrastructure and the Environment

- *Scomber scombrus* (mackerel)
- *Gadus morhua* (cod)
- *Melanogrammus aeglefinus* (haddock)
- *Merlangius merlangus* (whiting)
- *Trisopterus esmarkii* (Norway pout)
- *Pollachius virens* (saithe)

These species are the target species of the IBTS covering the North Sea, Skagerrak and Channel. The IBTS provides data for the stock assessments of these target species.

3 Materials and Methods

3.1 Field work

The protocols of the international IBTS were followed during the field work (The International Bottom Trawl Survey Working Group, 2012), which were adjusted to the Dutch situation in the Dutch survey manual by (van Damme *et al.*, 2013).

The field work occurred shortly after the IBTS Q1 2013 enabling comparisons between the catches to place those in the wind farm in the perspective of (historic) catches in a similar environment. The Dutch IBTS Q1 2013 ended after five weeks of survey on February 21. The field work in the farm was done on Thursday February 28, a week later. The exact day was chosen based on the weather conditions because only with reasonable to good weather the work could be executed inside the wind farm.

3.2 Vessel and gear

The work was done on the same vessel as the Dutch IBTS, the R.V. Tridens II a vessel from the Rijksrederij (Figure 3-1). This vessel has performed the Dutch contribution to the IBTS since 1991.

Figure 3-1: The Rijksrederij vessel R.V. Tridens II.

The IBTS gear is the so-called 'Grande Ouverture Verticale' (GOV). This is a ground gear that has a flexible net geometry depending on depth and current. A schematic picture of a similar gear is shown in Figure 3-2. On each side of the net there is a door, the width between the doors (Doorspread) varies depending on depth and current and can be between 50 and 120 m. The Doorspread is measured continuously during a fishing tow using Marport net sensors. The doors are followed by the sweeps, which in the Dutch situation have a length of 60 m. The horizontal net opening (wingspread) is variable around 20 m, while the vertical opening is about 5 m. The mesh size varies from 100 mm in the net opening and 10 mm (20mm stretched mesh) in the codend (where the fish are retained). The gear is rigged with three tickler chains (not shown in the figure) to disturb the bottom more than the groundrope alone does. The construction of the gear is shown in Appendix A.

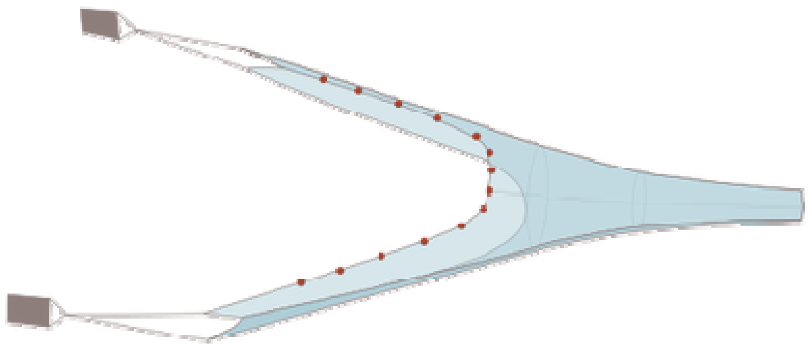

Figure 3-2: Schematic picture of a benthic otter trawl, resembling the overall construction of the GOV gear

3.3 Fishing

A standard IBTS tow should be fished for 30 minutes. Start time is defined as the moment when the vertical net opening and doorspread are stable. End time is defined as the start of the winches hauling the net back in. It may be acceptable to fish for less than this i.e. haul early for safety reasons or in the case of very large catches, however in the standard IBTS any tow under 15 minutes should be either invalid or tagged as non-standard. The standard fishing speeds is 4 knots as measured trawl speed over the ground.

The stratification of the survey grid has been based on ICES statistical rectangles of roughly 30 x 30 nautical miles (one degree longitude x 0.5 degree latitude). Each rectangle is usually fished by ships of two different countries, so that typically, at least two tows are taken per rectangle. The rectangles close to PAWP are in the normal situation fished by the Dutch (i.e. Imares) and the French (i.e. Ifremer).

The standard IBTS practice was followed as close as possible. A deviation is that the towing positions were prescribed in the Operational plan, such that a straight line was fished without crossing ground cables of the farm (Figure 3-3). Fishing started in the middle of the farm where the gear was set followed by steaming with 4 knots out of the farm. Safe trawling distances in the wind farm were too short to fish for a full 30 minutes per transect. It was decided to fish up to the boundary of the safety zone of the farm, the boundary of the exclusion zone for fisheries activities, leading to shorter towing durations varying between 15 and 23 minutes.

The minimum requirements for the MEP were successful completion of two primary transects inside the wind farm. Good weather conditions and availability of time allowed completing more tows. All four transects were fished, three of these were fished a second time and a single transect just outside of the safety zone was fished. In total 8 tows were successfully completed in the wind farm area.

3.4 Handling the catch

The IBTS protocol was also followed in handling the catch. This means that the whole catch was sorted and all fish and invertebrate species were identified to species level where possible. Individual fish (by species), or in case of large catches a known subsample of the catch, were measured to the nearest cm below or in case of sprat and herring to the nearest 0.5 cm below. All invertebrate species were counted.

Biological samples were collected of the eight target species. A length stratified sample of 5 individuals per cm-class was taken from each tow. Information collected of these individual fish was length (mm), weight (g), gender and maturity stage (juvenile, maturing, spawning, spent).

All data were processed on-board by entering them in the IMARES program Billie Turf. Back in the lab, these data were checked following standard IMARES procedures and imported in the IMARES database Frisbe, from which they could be extracted for further use.

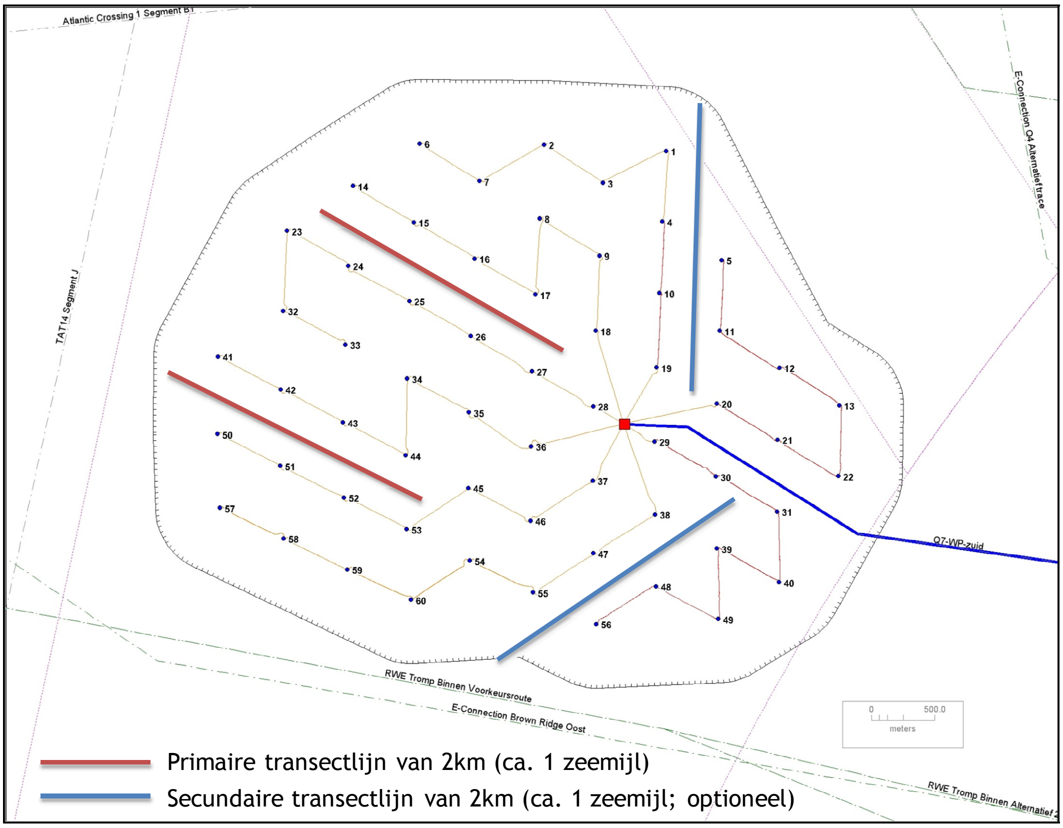

Figure 3-3: The planned locations in the PAWP from the Operational plan (van Steen and Dam, 2013, Dam and van Steen, 2013), actual fished transects are presented in figure 4.2. The smaller blue dots are the locations of the turbine and the thin lines the locations of cables. The difference between the red and blue lines is the priority to fish given to them in the Operational plan.

3.5 CTD measurements

A seabird CTD was used to collect data on Conductivity (salinity), Temperature and Depth. This CTD is deployed for a downcast, measuring from surface to bottom, giving a vertical impression of the water column. In this way three stations were sampled at set intervals during the day.

3.6 Comparison with the international IBTS Q1 data

The international IBTS data is stored in the ICES DATRAS database available online in various formats. The format Catch Per Unit of Effort (CPUE, number per hour) at length per tow was selected here. For the comparison the data of the PAWP tows were also raised to number per hour.

Comparison data were downloaded for the last ten years (2004-2013) from roundfish area 6 (The International Bottom Trawl Survey Working Group, 2012), this is the south-eastern North Sea including the area of PAWP. This set was further reduced to those tows within the depth range of 15-25 m which corresponds to the depths in the wind farm. Data points in the far eastern German Bight were still in this set, therefore the spatial coverage was limited to 51.5-53.5 N and everything east of 3 E. This left 60 tows in which 52 different fish species (or families in case of gobies, sand-eel and pipefish which are not determined to species level) were caught. However, the catches differed spatially, mainly in species composition. To match the wind farm habitat as close as possible the spatial coverage was further restricted to 52-53 N and everything east of 3.5 E. This reduced the dataset to 43 tows including 39 fish species or families (Table 3-1).

Age-length keys (ALK) for herring and sprat were downloaded from the ICES DATRAS database as well. The ALK's downloaded were from the years 2012 and 2013 restricted to roundfish area 6. The averages of these two years were used to convert the total catch length measurements to age. This gives an impression of the age structure of these two species in PAWP.

Table 3-1: The number of international IBTS Q1 tows by year and country in the dataset used to compare to PAWP.

Year	Dutch	French	total
2004	1	4	5
2005	1	4	5
2006	4	3	7
2007	4	1	5
2008	4	2	6
2009	3	1	4
2010	3	1	4
2011	2	1	3
2012	1	1	2
2013	1	1	2

3.7 Statistics

The data consists of numbers of species per tow, abundance (n/hour) and length measurements. In the statistical test the 8 PAWP tows are one group, which is compared to all the IBTS tows as a group by using a student's t-test, or all the years as separate groups using an analysis of variance (aov). In case the aov indicates a significant effect between the groups a Tukey's HSD test to find the means of the groups that differ from each other. The statistical tests are performed in R 2.13.1.

4 Results

4.1 Field work

4.1.1 Field day

The field work was done on Thursday 28 February 2013, a week after finishing the annual Dutch IBTS Q1 survey. The weather was reasonable the whole week, but the weather forecast for this particular day was most favourable. In the morning it was foggy and grey (Figure 4-1 and Figure 4-6), but this improved later in the day. The wind direction was North-North-Eastern with a strength of 2 Bft resulting in a swell height of ±0.5 m.

The first tow started around 10 o'clock (Table 4-1) on the northern secondary transect (Figure 3-3). This transect was selected based on the direction and strength of the dominant current. As the currents change during a day the other transects (primary and secondary) could be fished later. Following the IBTS protocols, fishing continued within the limits of day light. Tow 8 was planned outside the safety zone of the farm as reference (Figure 4-2), however due to time constrains (nearly sunset) the tow was performed just outside, partially crossing the safety zone. The catches were very similar to those in the farm and therefore the tow is treated as one from the farm area.

Table 4-1: Information for each tow in PAWP (lacking information for tow 8 is due to a failure in starting the continues recording system); number of species are only the fish species.

tow	date	time	latitude start	longitude start	latitude haul	longitude haul	Duration (min)	Trawl dist (m)	depth (m)	Doorspread (m)	salinity bottom (PSU)	temperature bottom (˚C)	number of species
1	28-3-2013	9:52	52.587	4.2425	52.6078	4.2445	19	2323	18.5	76	33.982	4.48	6
2	28-3-2013	10:48	52.579	4.24333	52.569	4.22	15	1919	19.4	74			11
3	28-3-2013	12:39	52.58183	4.20917	52.5907	4.1805	18	2164	21	71			8
4	28-3-2013	13:50	52.5905	4.22917	52.604	4.195	23	2753	19.1	71	34.276	4.69	10
5	28-3-2013	14:56	52.58933	4.24317	52.608	4.24483	16	2060	18.5	75			10
6	28-3-2013	15:49	52.58	4.24317	52.5688	4.2205	16	1984	20.5	73			7
7	28-3-2013	16:35	52.5915	4.22867	52.6027	4.19667	17	2485	20.5	73			7
8	28-3-2013	17:10	52.60317	4.19667	52.583	4.17667	20		20.5		33.929	4.53	8

4.1.2 CTD measurements

CTD data were collected at three stations spread over the day. The first CTD downcast was conducted prior to the first tow in the farm. For safety reasons CTD's were taken just outside the wind farm where the water conditions are expected to be the same as inside the wind farm. The bottom temperature at that time was around 4.5 °C and the salinity was 33.982 PSU. The second downcast was done prior to tow 4 and the third was done after the last tow of the day (Table 4-1). The temperature and salinity were very similar at the three stations.

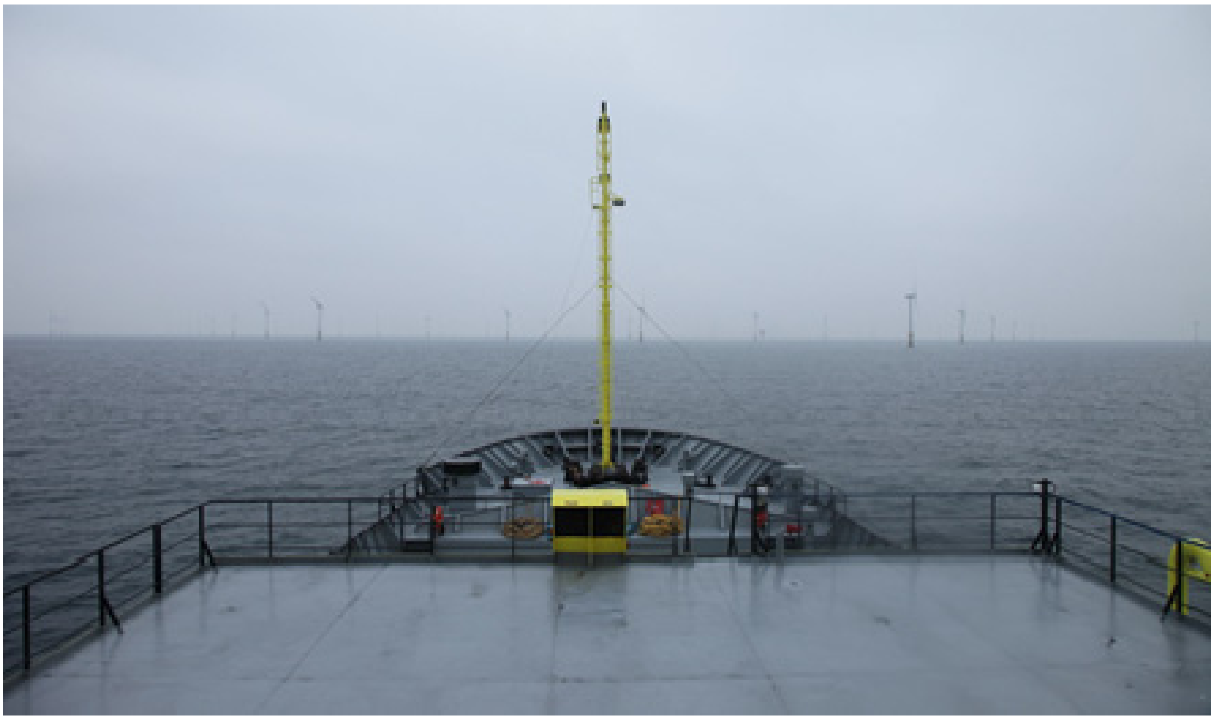

Figure 4-1: Arrival at PAWP.

4.1.3 Catch data

17,686 organisms were caught in the eight tows. These were divided over 17 fish species and 14 invertebrate species. Five fish species: herring, sprat, whiting, plaice and dab were caught in all eight tows. Common starfish was the only invertebrate species caught in all tows. The most dominant species were sprat and herring (Table 4-2). The first tow was the largest containing around 43% of the total number of fish. The tow was dominated by herring and sprat. 78% of all the herring and 37% of all the sprat was brought on board in this single tow. This first tow thus dominates the length-frequency plot for these species. Besides these two species only four other fish species were caught in this first tow.

Tow 6 was the second largest containing 21% of the total number of fish. Tow 7 and 8 were the smallest with only slightly more than 1% of the total number of fish. Tow 2 with 11 different fish species had the highest species richness. Followed by tow 4 and 5 each having 10 different fish species. The first tow had the lowest species richness with only 6 different fish species.

Sprat was the most dominant species (Table 4-2). The largest part of the sprat was caught in the first tow (37%). Tow 6 (25%) and tow 2 (16%) also contained a reasonable part of the sprat catch. The catches of herring were divided less equal, with 78% in the first tow followed by tow 4 with only 7% of the total number of herring.

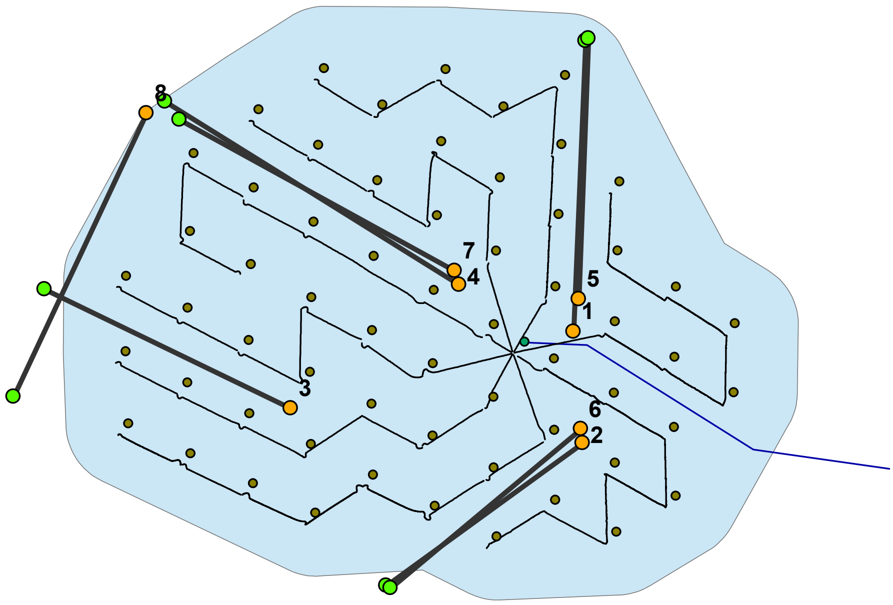

Figure 4-2: Trawl locations, orange dots start position, black line trawl track and green dots the end position. The numbers are the tow numbers corresponding to Table 4-1. The smaller green dots are the locations of the turbine and the thin lines the locations of cables.

Herring and sprat were measured to the 0.5 cm below, all other fish species were measured to the 1.0 cm below. To combine this, the length measurements of herring and sprat were converted to match the other measurements. The combined length measurements are presented on a log-scale as the length frequency distribution of the total catch (Figure 4-3). This length-frequency, due to the dominance of sprat, has its peak around 10 to 12 cm. The maximum length was 34 cm, the largest fish (>30 cm) were all plaice and flounder.

Table 4-2: Species list of the eight tows in PAWP, the number of individuals per species by tow and the total number of individuals caught.

Scientific name	Tow 1	Tow 2	Tow 3	Tow 4	Tow 5	Tow 6	Tow 7	Tow 8	total number
Clupea harengus	2308	133	107	270	40	62	8	16	2944
Sprattus sprattus	5628	1888	952	1680	268	3264	232	156	14068
Merlangius merlangus	4	2	6	9	5	7	6	3	42
Limanda limanda	5	15	10	19	14	10	5	50	128
Pleuronectes platessa	1	8	15	5	7	2	5	14	57
Hyperoplus lanceolatus		1	9	72	18				100
Platichthys flesus		3	1		1			1	6
Myoxocephalus scorpius				3			1	4	8
Pomatoschistus sp.		1		1	1				3
Aphia minuta		1			3	3			7
Syngnathus rostellatus		1				1			2
Echiichthys vipera			1					2	3
Ammodytes sp.				1	1				2
Gadus morhua							1		1
Gasterosteus aculeatus	1								1
Agonus cataphractus		1							1
Buglossidium luteum				1					1
Asterias rubens	3	5	11	6	19	11	9	10	74
Cyanea lamarckii		12	7	10	40	30	13	20	132
Ophiura ophiura		13	14	8	7	32	7	4	85
Pagurus bernhardus		1	1			1	2	2	7
Hydractinia echinata		1	1			1		1	4
Crangon crangon					1	1			2
Hydrozoa			1						1
Metridium senile				1					1
Pleurobrachia pileus					1				1
Ensis sp.			1						1
Cancer pagurus						1			1
Liocarcinus holsatus				1					1
Ophiura albida								1	1
Brissopsis lyrifera	1								1

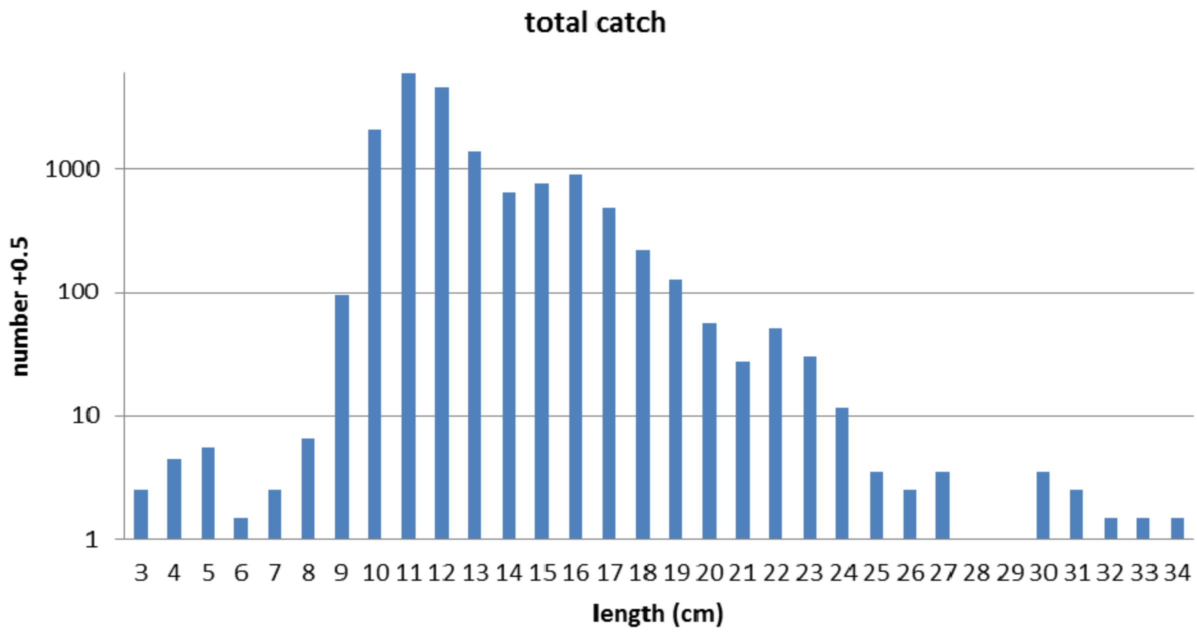

Figure 4-3: Length frequency all fish species caught in all eight tows. Data is on a log10-scale. The absolute numbers are summed with 0.5 to make the lowest number per length class (1) visible.

4.1.4 Target species

Four of the eight target species were caught: herring, sprat, whiting and cod. Cod was caught only once, this was a single female juvenile with a length of 18.1 cm.

Herring was caught in all eight tows, in total 2,944 were caught of which the largest part in the first tow. From each tow a length stratified sample was taken, resulting in 152 herring that were measured at the mm, weighed and gender and maturity determined. This were 84 females of which nine adults and 68 males of which three adults. The 2012 and 2013 Age-Length Keys (ALK) from roundfish area 6 indicated that all the herring of 9 – 15 cm were 1 year-old. For 16 cm this was 95%, 17 cm it was 70% and 18 cm only 22-25%. The herring of 19 cm were all age 2, while from 20 to 23 cm they were age 2 or 3. A combination of the length-frequency and age distribution is presented indicating that most of the herring had a length around 15-17 cm and these were mainly 1 year-old (Figure 4-4). The length distribution is dominated by the large amount of herring in the first tow. But also in the other tows the smallest herring was 12 cm and the peak was around 16 cm.

Sprat was also caught in all tows, in total 14,068. A stratified sample was taken from the first six tows, resulting in 108 sprat. All of these were adults spread over 66 females and 42 males. The maximum length of sprat is much smaller than that of herring. Fish of the same length might be attributed to multiple ages. Based on the ALK, the sprat up to 6 cm were 100% age 1, however sprat this small was not caught in the farm. Sprat in the length of 6 to 8.5 cm were age 1 or age 2, while from a length of 8.5 cm they can also be age 3 and from a length of 10.5 they can be age 4 or 5. Most of the sprat caught were around a length of 10-12 cm, most likely dominated by the ages 2 and 3 (Figure 4-4). Based on the ALK, only a very small number of sprat of the lengths caught is age 1, due to this age 1 is not visible in figure 4-4.

Like herring and sprat, whiting was caught in all eight tows. The total number of whiting was much smaller, only 42 whiting were caught. These were 13 females of which 10 adults and 29 males of which 28 adults. Because all the whiting instead of a stratified sample were measured the sex ratio (f:m) can be determined easily which is around 4:9.

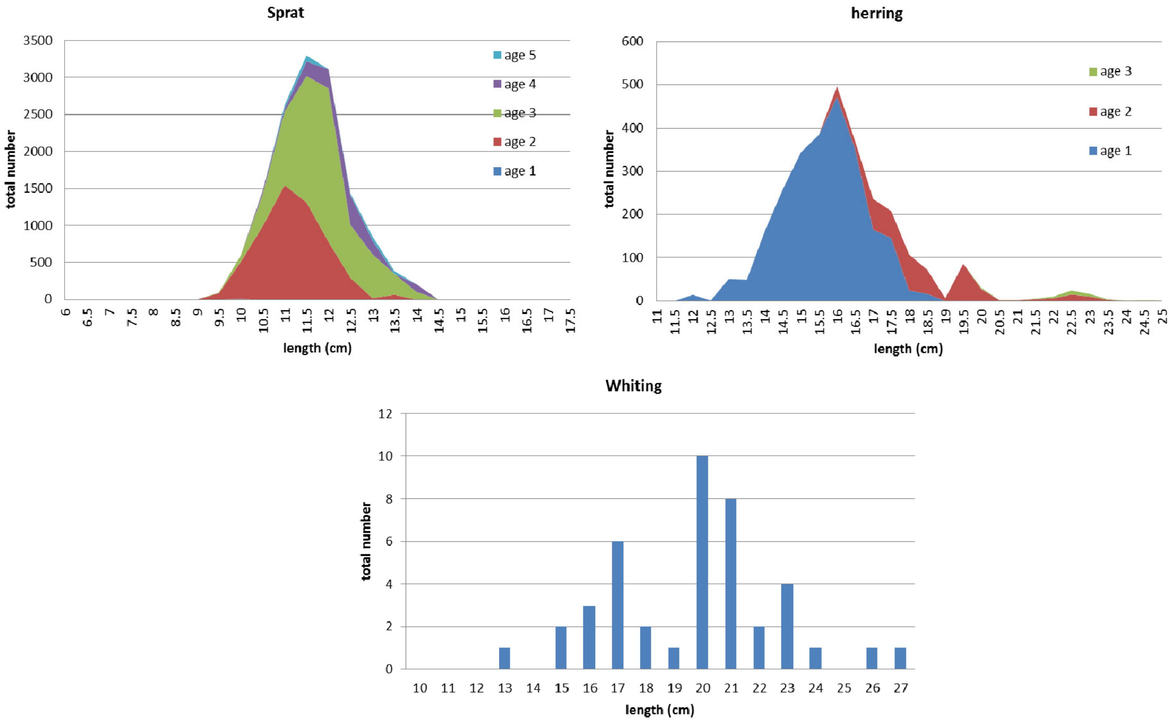

Figure 4-4: Length frequency distribution of sprat (0.5 cm), herring (0.5 cm) and whiting (1.0 cm). For sprat and herring the figure includes the distribution over age.

4.1.5 Non-target species

The length-frequencies of two flatfish species dab and plaice and the greater sand-eel, which were caught in reasonable numbers, are presented as well (Figure 4-5). Dab and plaice were caught in all eight tows, while greater sand-eel was caught in only four of the tows. A single greater sand-eel was caught in tow 2, 9 were caught in the tow 3, 73 in tow 4 and 18 in tow 5. Thus sand-eel was caught on all transects in PAWP. Three transects were duplicated, however sand-eel was only caught in a single tow at each transect. The highest number was caught in tow 4, which was duplicated 2.5 hours later by tow 7 in which no sand-eel were caught.

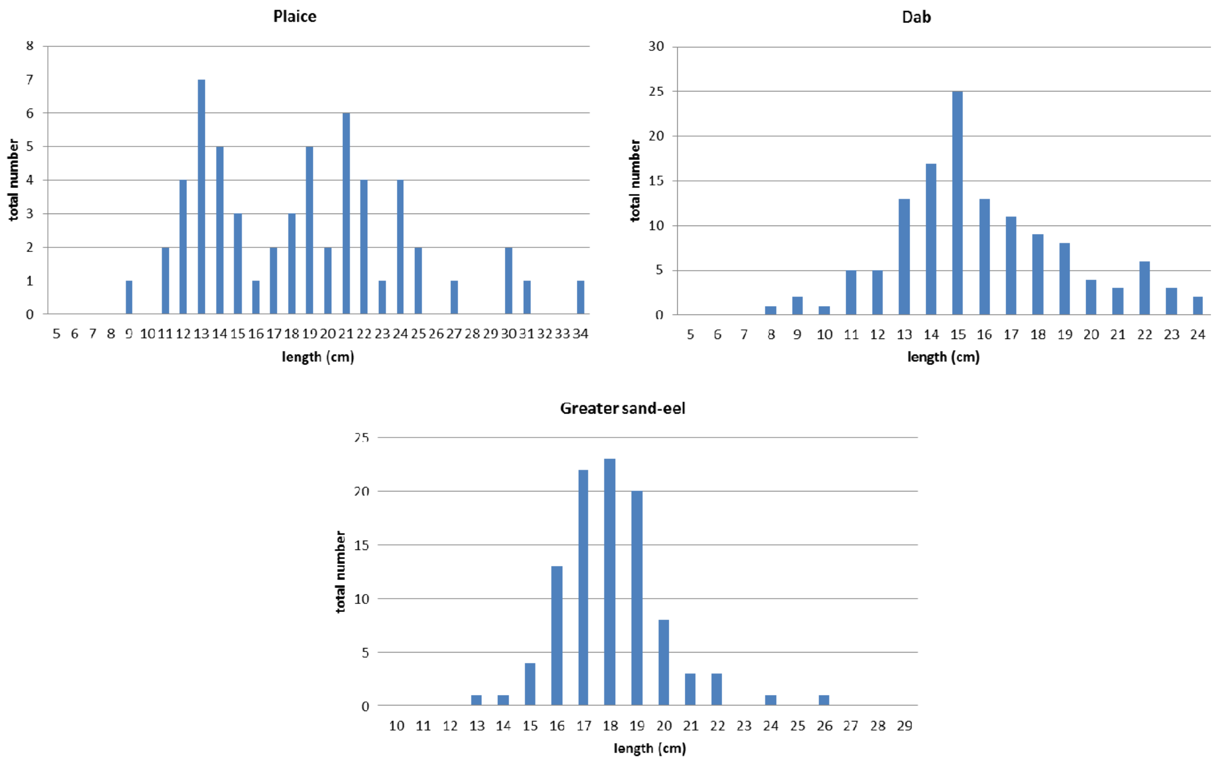

Figure 4-5: Length frequency distribution of plaice (1.0 cm), dab (1.0 cm) and greater sand-eel (1.0 cm).

4.2 Comparison with the international IBTS Q1 data

4.2.1 Species richness

The reduced IBTS Q1 dataset contained 43 tows in the surrounding of PAWP. In these tows 39 fish species were caught. This included all the 17 species caught in the wind farm. The spatial distribution of the number of species per tow of the 43 IBTS and 8 PAWP tows are shown (Figure 4-7). The tows in PAWP overlap as the starting positions were the same, making the separate points difficult to see. This is similar for some tows done by the French research vessel Thallassa south of PAWP. The number of species caught per tow of PAWP varies between 6 and 11 (Table 4-1), while for the IBTS tows these were between 4 and 17. The Tridens tow directly east of PAWP is the 2013 reference tow containing 6 species. The 2013 reference tow by the Thallassa is located in the cloud of larger overlapping circles south-southwest of PAWP, as the Thallassa has been sampling a fix position within this ICES-rectangle in the last years.

These data are limited for statistically analysing the species richness as in the last two years (2012-2013) only a single tow per vessel was made in the surrounding area. The Thallassa caught 14 species in 2013 and 11 in 2012, while the Tridens caught 6 in 2013 and 8 in 2012. The two tows by the Thallassa were nearly on the same location in the cloud of points south-southwest of PAWP, while the 2012 tow by the Tridens is the most eastern tow in Figure 4-7. Thallassa seems to catch a larger number of species per tow on their towing position in latest years compared to the number of species per tow caught in the PAWP area, also compared to earlier years (2004, 2005 and 2006 prior to the construction of the wind farm). A student's t-test indicates that the number of species per tow in the southern cloud (all Thallassa hauls) is significant higher than the number of species per tow in a group of tows in the wind farm area (Thallassa 2004, 2005, 2006, Tridens 2013, and the 8 PAWP tows) ($t = -4.0795$, $df = 12.602$, $p\text{-value} < 0.005$, mean number of species in South= 12.625, mean number of species PAWP area= 8.333).

Visualizing the species richness by tow, indicates that the median number of species per tow in PAWP is around eight which is the same as the number of species caught in the 2012 Tridens tow (Figure 4-8).

4.2.2 Target species

In the 43 IBTS tows, five of the eight target species were caught. These were the same four target species as were caught by the tows in PAWP plus mackerel. Mackerel was only caught in one tow out of the 43, which was a tow in 2005. Larger numbers of cod were caught, however not a single cod was caught in the last three years (2011-2013). The other three species were caught in larger numbers and for these species the length ranges were compared to those in PAWP.

Figure 4-6: The fishing deck of the Tridens with the turbine of PAWP in the background.

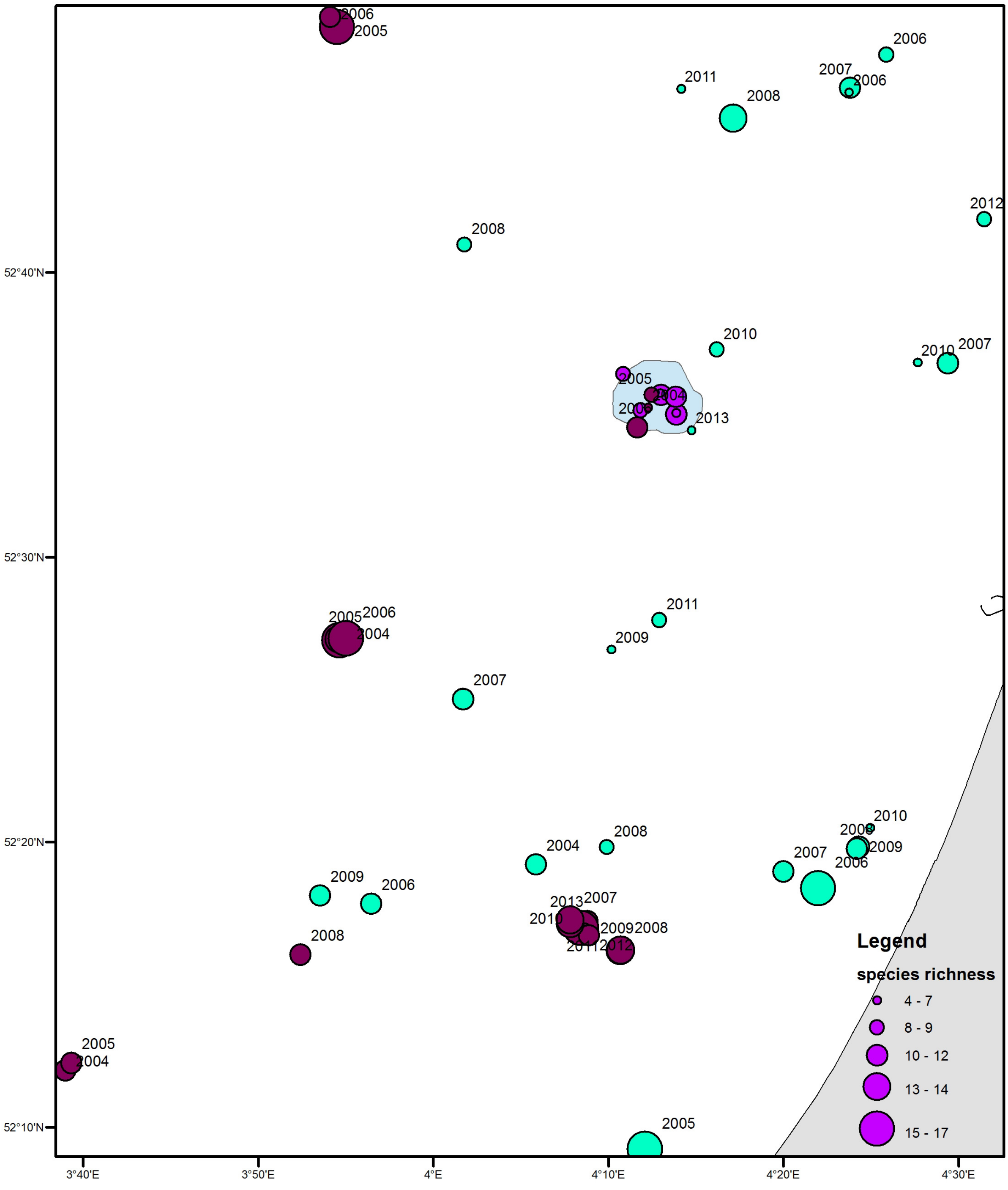

Figure 4-7: Spatial distribution of the starting positions of the tows. Green is IBTS Tridens (2004-2013), red IBTS Thallassa (2004-2013) and Purple PAWP (2013). The size of the points is an indication of the number of fish species caught ranging from 4 to 17 species per tow.

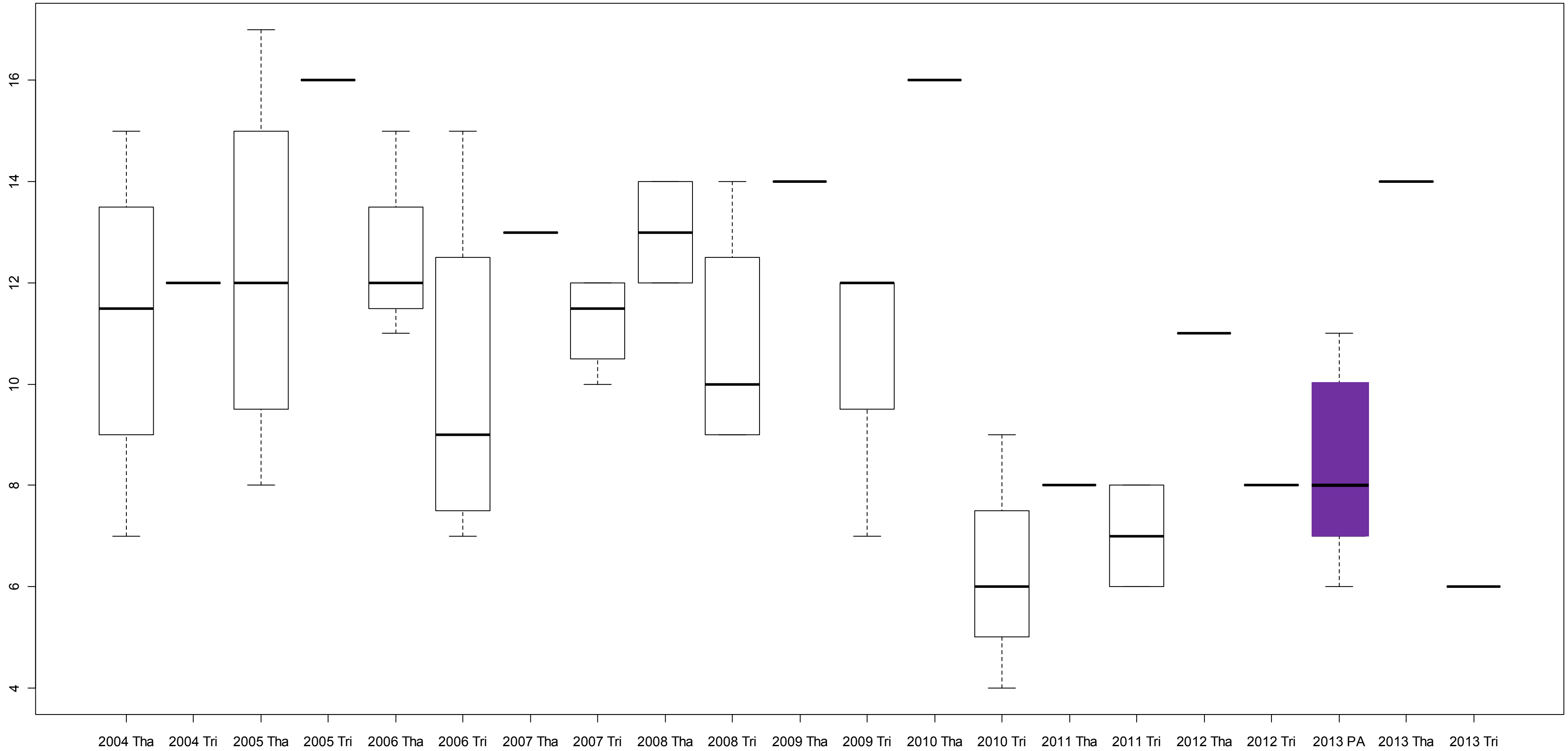

Figure 4-8: Boxplots of the median number of species per tow by year and ship, in purple the data collected for PAWP. Years range from 2004-2013; the ships are Tha=Thallassa (French) and Tri=Tridens (Dutch).

4.2.3 Catch data

The length range in the IBTS is between 3 and 90 cm. The peak in number per hour lies around 9-12 cm (Figure 4-9) over all 43 tows as well as for only the two tows in 2013. This is comparable to the dominant length in PAWP. A difference between the PAWP and IBTS data is at the smaller lengths. The smaller lengths were caught less in PAWP compared to the difference between the larger lengths.

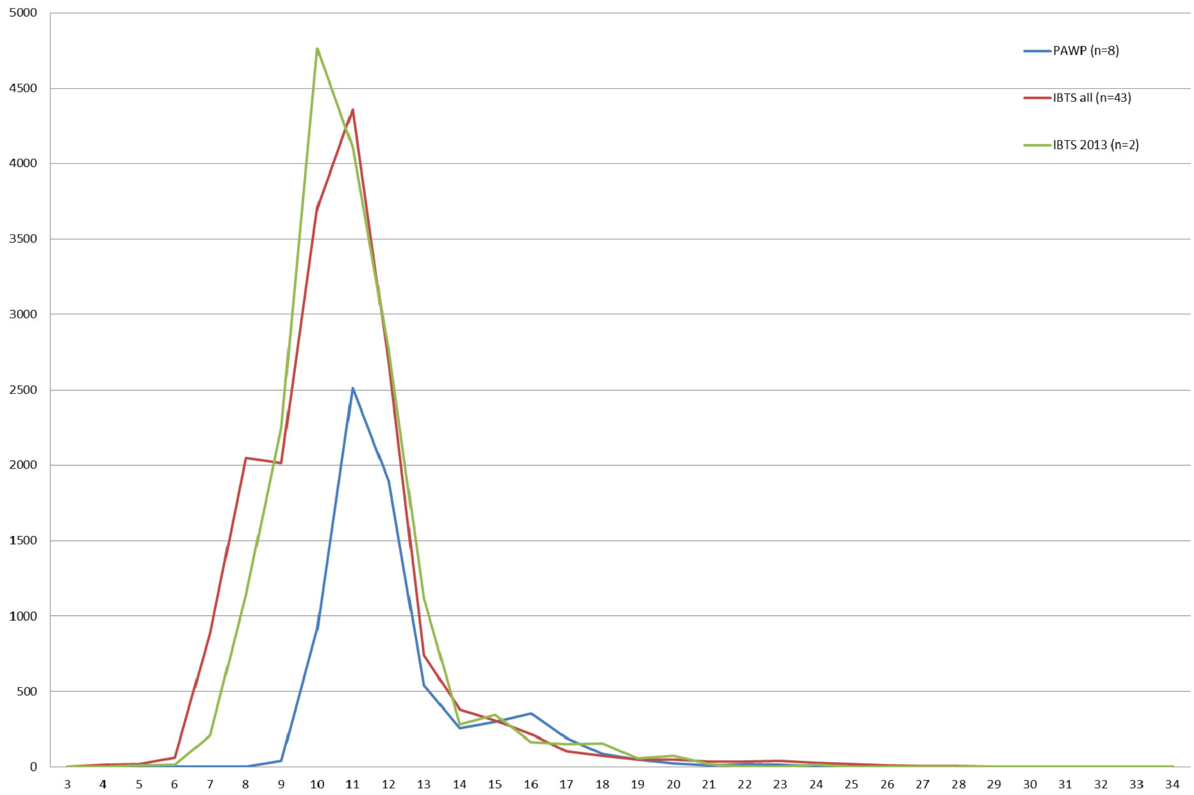

Figure 4-9: Length frequency distribution (cut off at 34cm, maximum length caught in PAWP) in average numbers caught per hour. Blue PAWP: number of tows =8; Red all the IBTS tows in the vicinity: number of tows=43; Green only the 2013 IBTS: number of tows=2.

Analysing the CPUE (number/hour) indicates that the numbers caught in PAWP are within the range of the other surrounding IBTS tows (Figure 4-10). Analysis of variance (aov) shows no significant difference between the PAWP tows and any of the years separately. Neither when all the IBTS tows (43) were combined and compared to the eight tows in PAWP.

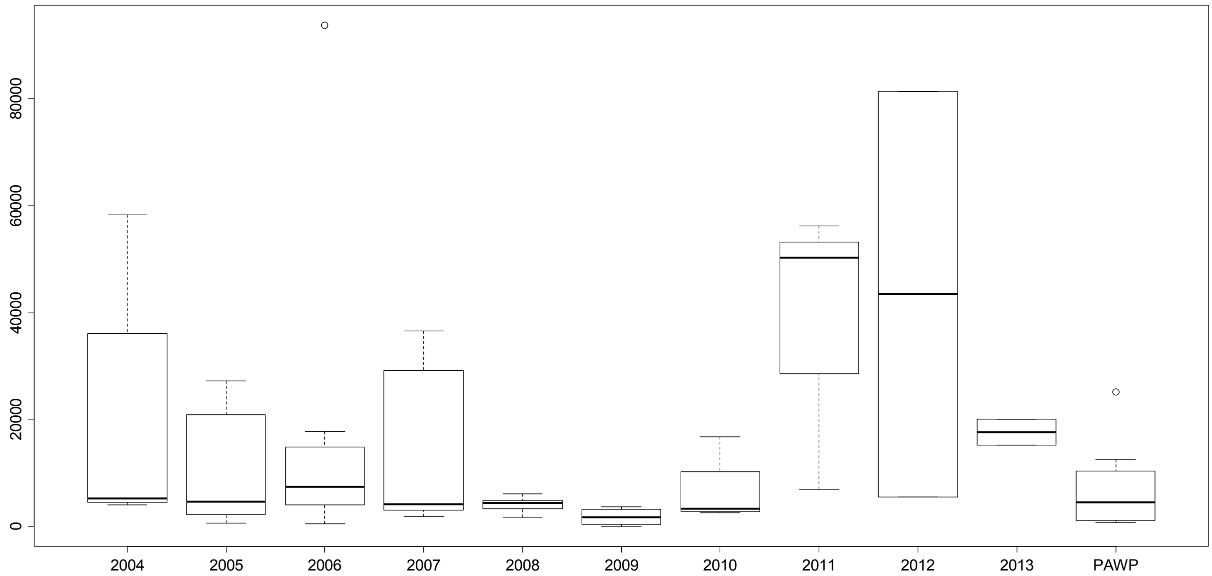

Figure 4-10: Total number of fish per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 7 values + 1 outlier (the open circle: tow 1).

4.2.4 Herring

The lengths of the herring caught in PAWP were relatively large compared to the overall catches in 43 IBTS tows, and also compared to the two tows of the 2013 IBTS (Figure 4-11). In the IBTS the catches of small herring up to 14 cm were large, while this length was not caught in the PAWP tows. In more detail, the 2013 data (Figure 4-12) show that the large peak at the smallest length is based on the catches of the French vessel. The numbers of herring in the Dutch IBTS tow were lower and these fish were of a slightly larger size, and those in PAWP were even lower and these fish were the largest. The French tow was done on 30 January, the Dutch IBTS tow was on 18 February and the PAWP tows on 28 February another 10 days later. Thus 29 days between the French tow and the PAWP tows and the length difference between the peaks is 7 cm, which would mean a growth rate around 2.4 mm a day. This is too large to let growth explain the difference.

Till a length of 15.5 cm all the herring were age 1 according to the ALK. The majority of herring in the IBTS were below this length and thus most likely age 1. The peak of herring in PAWP is around 16 cm, which means that a part is likely to be age 2. The ALK was however created using the IBTS catches and not on the herring caught in PAWP because no otoliths for age determination were collected in PAWP. Thus there is no certainty to conclude this.

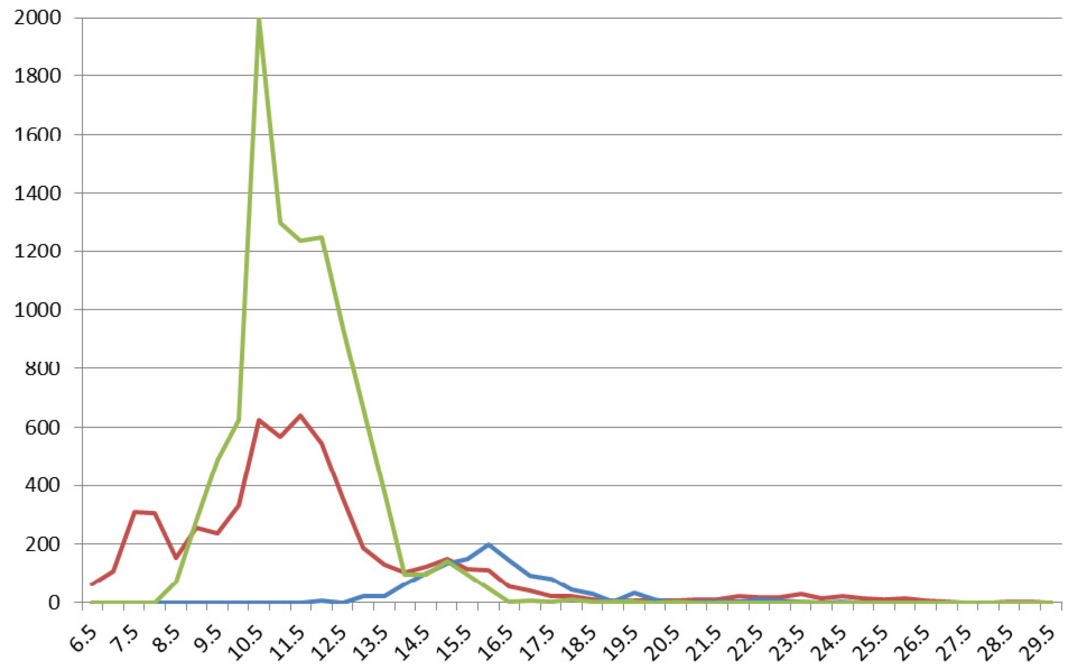

Figure 4-11: Herring Length frequency distribution in average numbers caught per hour. Blue PAWP: number of tows =8; Red all the IBTS tows in the vicinity: number of tows=43; Green only the 2013 IBTS: number of tows=2.

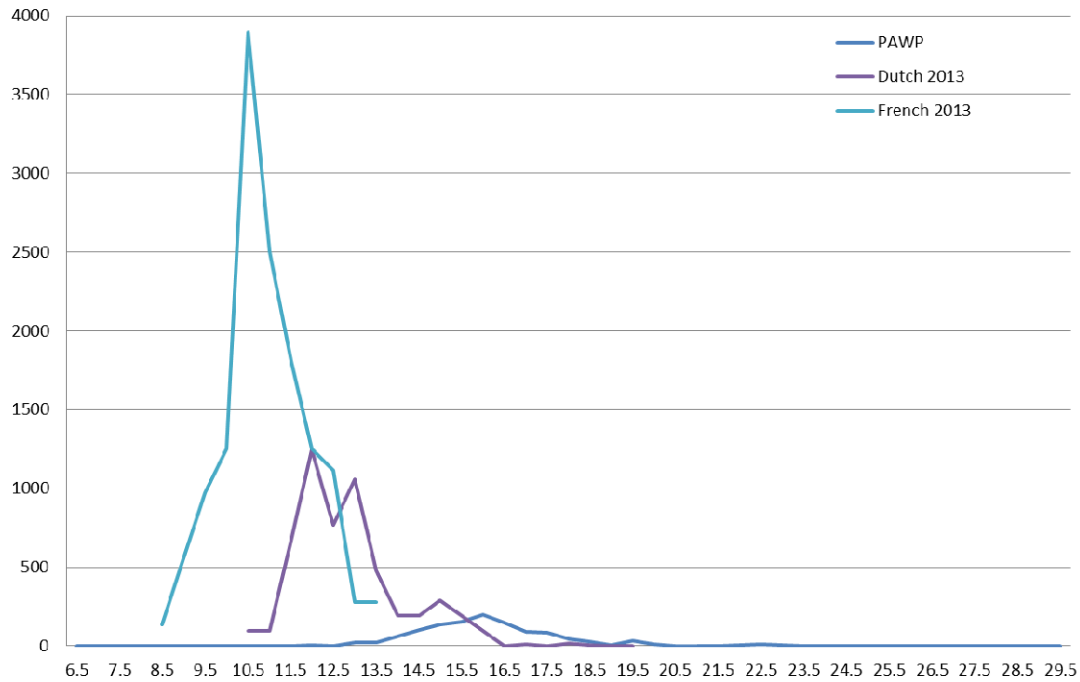

Figure 4-12: Herring Length frequency distribution in average numbers caught per hour. Blue PAWP: number of tows =8; Purple the catch of the single 2013 Dutch IBTS tow in the vicinity and aqua the single 2013 French tow.

The CPUE of herring is presented as boxplots per year in Figure 4-13. Analysis of variance (aov) followed by a TukeyHSD test shows that there is a significant difference between the boxes. The CPUE of herring in 2011 was significantly higher than the CPUE in PAWP, but the CPUE in 2011 was also significantly higher than 2006 and 2008. Testing the log transformed CPUE, only 2006 and 2011 differ significantly. Thus rather than being an effect of the wind farm 2011 was a good year for herring catches.

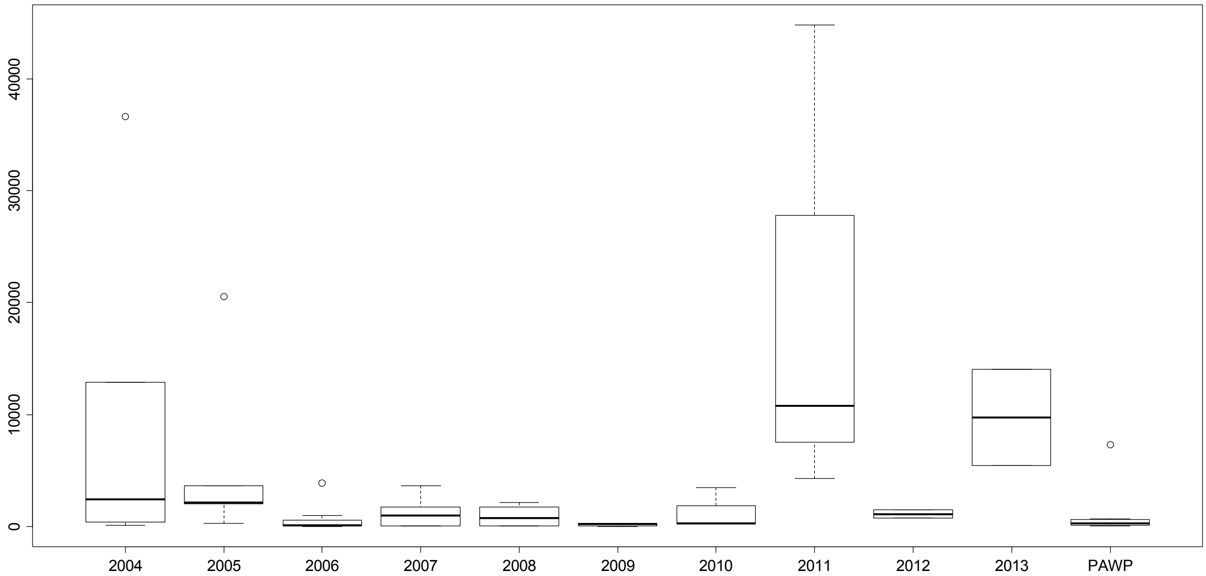

Figure 4-13: Total number of herring per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 7 values + 1 outlier (the open circle: tow 1).

4.2.5 Sprat

The sprat catches in PAWP were mainly the larger individuals compared to the overall IBTS and the 2013 IBTS tows (Figure 4-14). The CPUE per tow did not show a significant difference between the catches in PAWP and all the IBTS or the IBTS catches by year. The boxplot of the tows in PAWP shows no outlier like in the herring data. As said before an indication that the catches of sprat were distributed more equal in the farm.

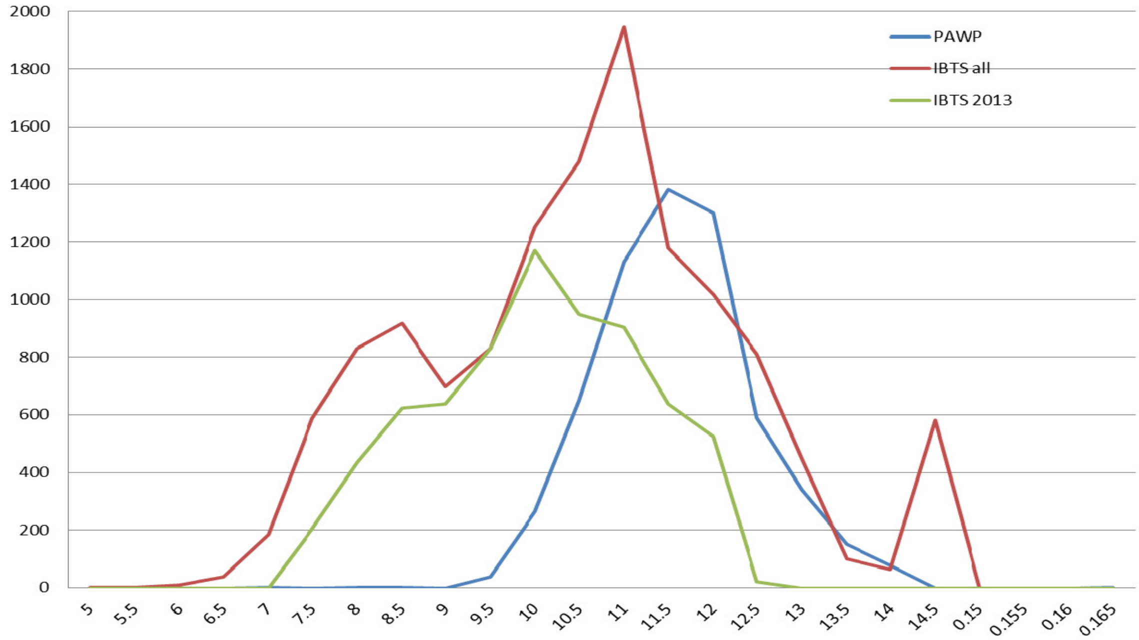

Figure 4-14: Sprat Length frequency distribution in average numbers caught per hour. Blue PAWP: number of tows =8; Red all the IBTS tows in the vicinity: number of tows=43; Green only the 2013 IBTS: number of tows=2.

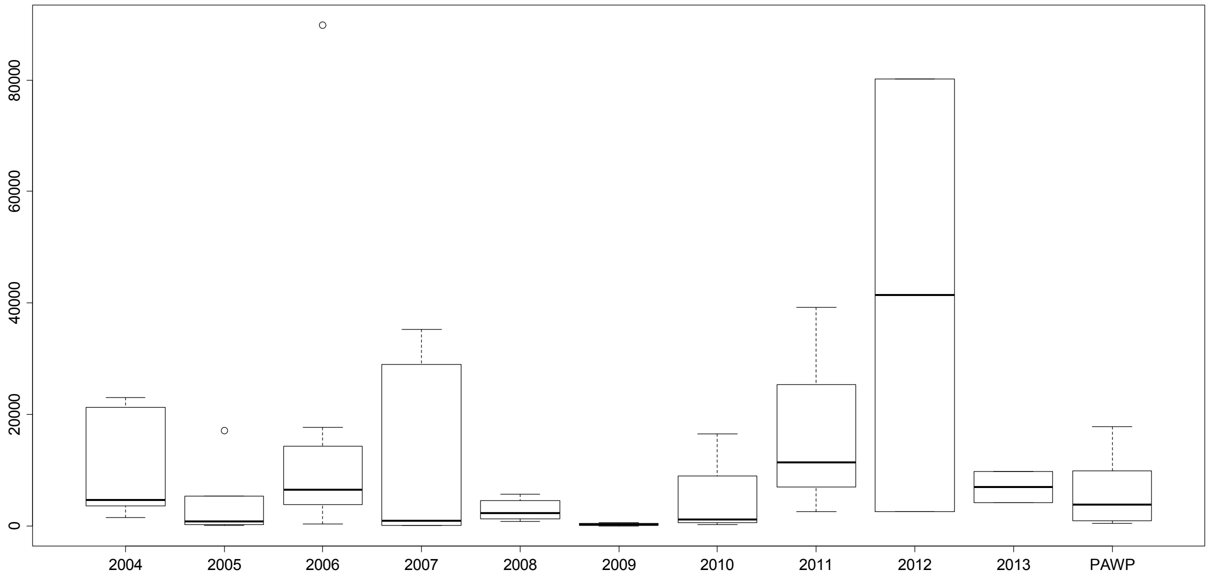

Figure 4-15: Total number of sprat per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 8 values.

4.2.6 Whiting

The length range of whiting caught in PAWP is similar to the overall IBTS and corresponds with the length of the seven whiting caught in the two IBTS 2013 tows (Figure 4-16). The whiting catches were much smaller than herring and sprat in PAWP, but this is similar for the surrounding IBTS tows. The numbers per hour in the PAWP catch were within the range of the surrounding IBTS (Figure 4-17).

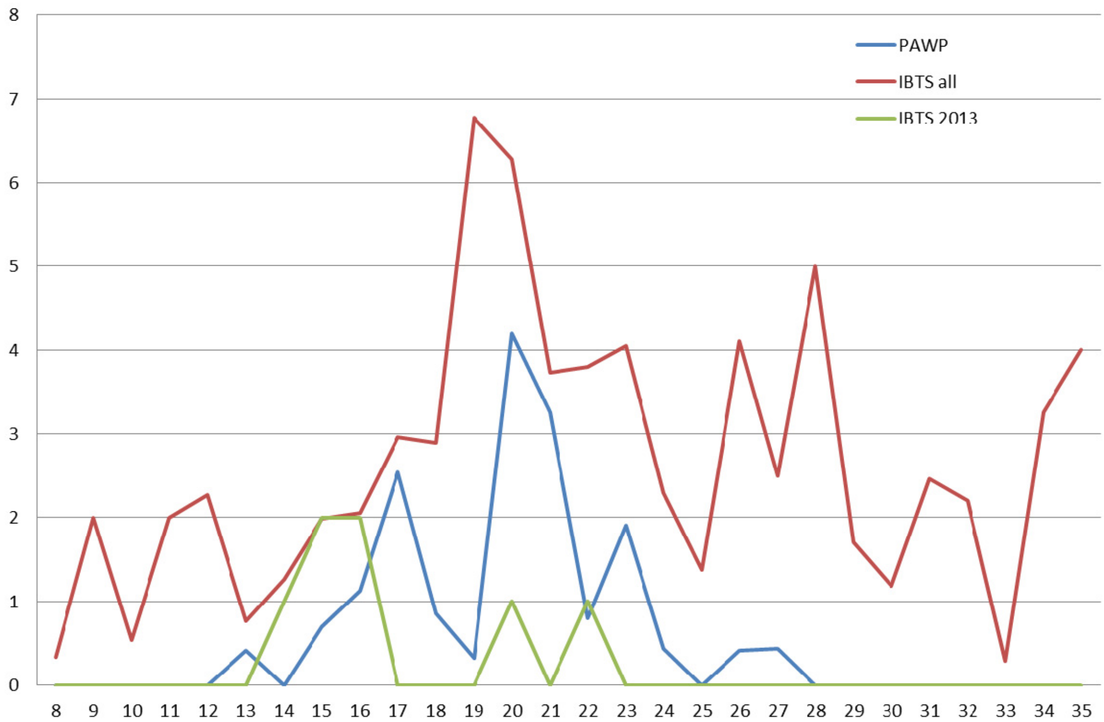

Figure 4-16: Whiting Length frequency distribution in average numbers caught per hour. Blue PAWP: number of tows =8; Red all the IBTS tows in the vicinity: number of tows=43; Green only the 2013 IBTS: number of tows=2.

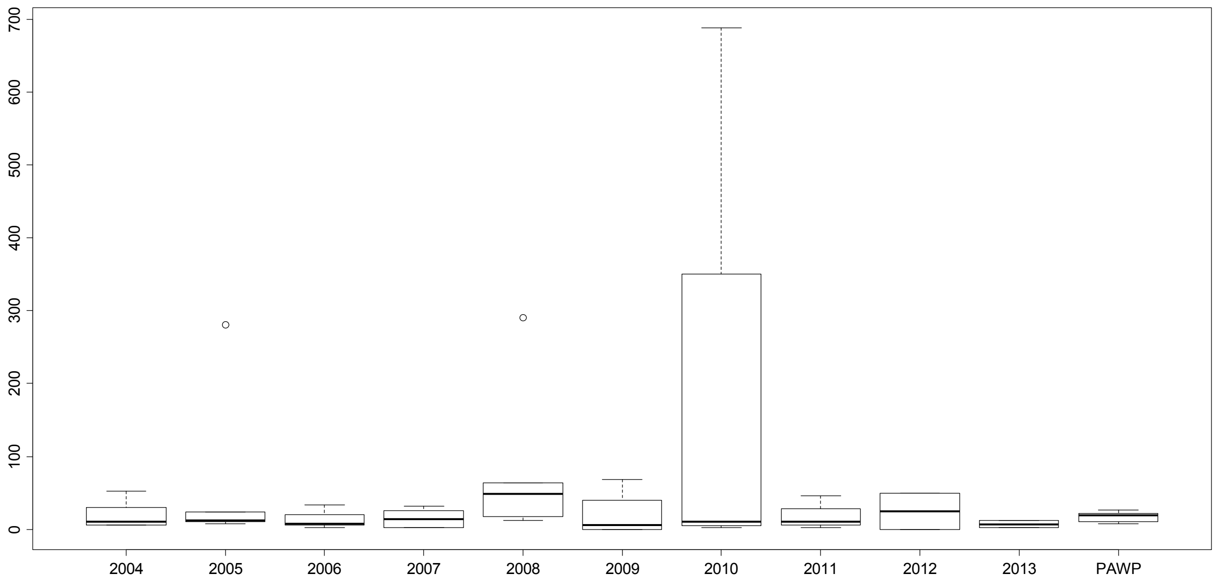

Figure 4-17: Total number of whiting per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 8 values.

4.2.7 Non-target species

Besides the target species, the numbers per hour per tow of the two flatfish species plaice and dab were analysed (Figure 4-18; Figure 4-19). For both the numbers caught in PAWP are well within the range found in the surrounding IBTS.

Also the numbers per hour of greater sand-eel were analysed. These show no significant difference with the surrounding IBTS due to zero catches (half of the tows in PAWP, while only a third of the tows in the surrounding IBTS had greater sand-eel). However, it is clear that the catches in PAWP were large for this species (Figure 4-20). Especially the outlier which is much larger than all the other 43 catches done in the surrounding IBTS.

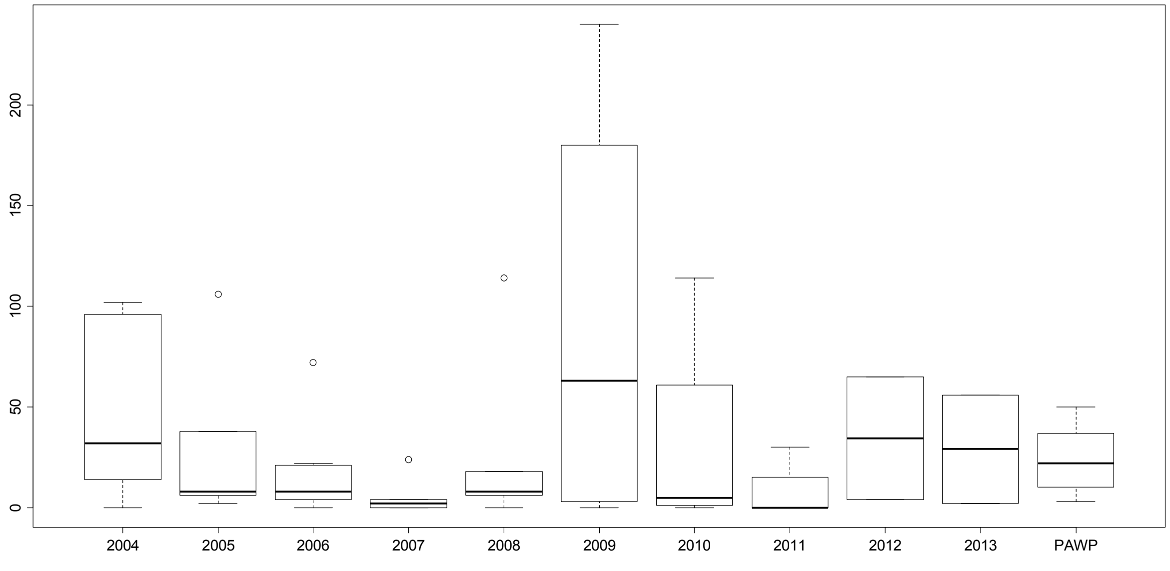

Figure 4-18: Total number of plaice per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 8 values.

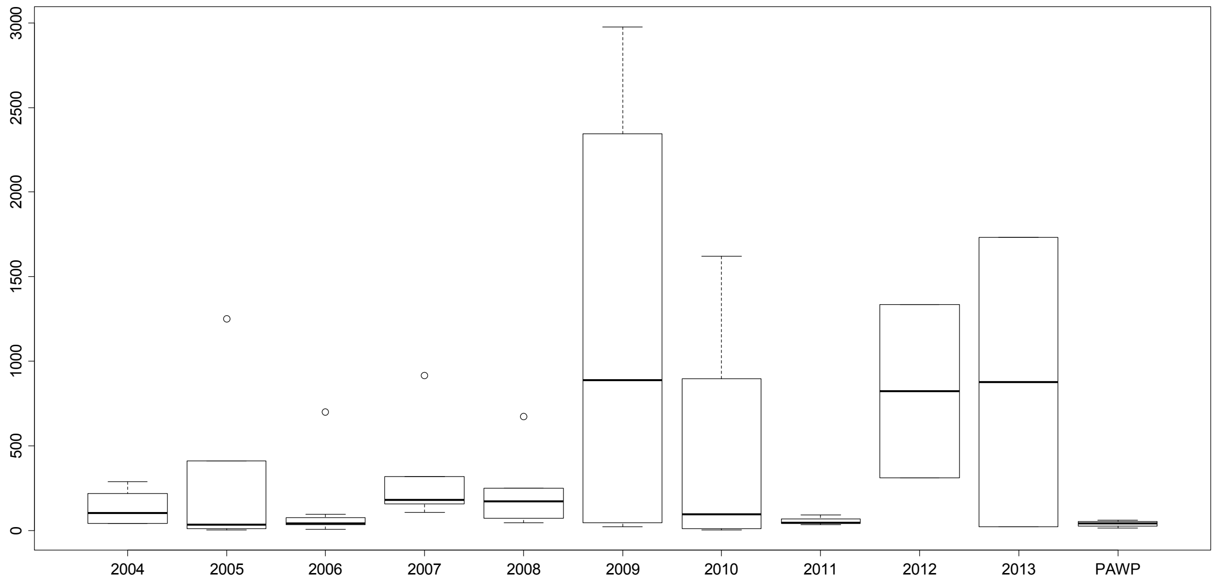

Figure 4-19: Total number of dab per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 8 values.

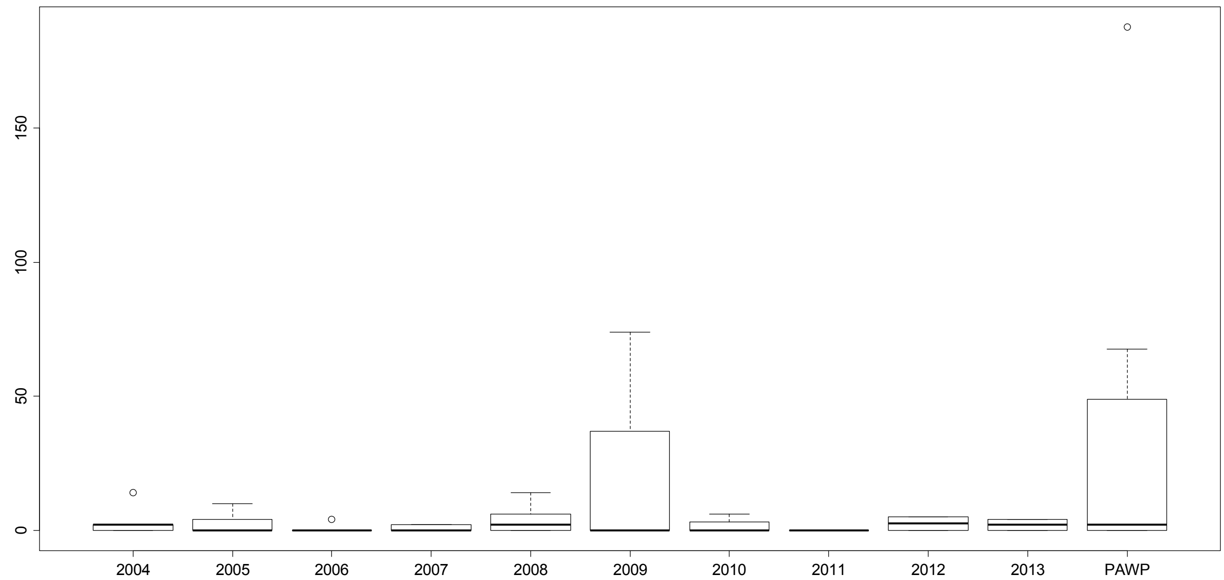

Figure 4-20: Total number of greater sand-eel per hour. Boxplot based on a single value for each tow. The 2012 and 2013 boxes are thus based on only two values. The PAWP box is based on 7 values+1 outlier.

5 Discussion

There were four safe locations to perform tows in the farm. To increase the amount of information tows were duplicated. For proper analyses these should not have been treated as independent samples, thus not straightforward increasing the sample size. However, this would have complicated the analysis, without affecting the current results. The same analyses were done using only the first four tows (each transect separately). The results were very similar to those presented in this report. For example: the largest tows in numbers of fish were tow 1 and tow 6. Tow 6 was the duplicate of tow 2; the other two duplicates were smaller compared to the first tow at that position. Herring was in all cases caught in lower numbers in the duplicates, while sprat was caught in higher numbers in duplicate tow 6 than in tow 2. For whiting the catches were similar for the first and duplicate tows.

The last tow (tow 8) was started just outside the wind farm area and was intended to be an additional reference tow. However, due to time constrains it was not possible to perform the two further away from the farm. Now this tow crossed the safety zone of the wind farm and the largest part of the tow was done within the safety zone. Therefore, it was decided to include it as a tow from the farm area. The total numbers of fish in this tow were the lowest of all tows; however the difference with tow 7 is very small. Leaving this tow out of the analyses would only result in a slight increase in the mean values and would not have significantly changed the outcomes of the comparisons with the IBTS-survey data.

The low number of tows, without proper reference locations, could only show very large changes in the catches. This is because there is high variability in catches in this area. This is clearly presented in the baseline study performed for the Offshore Windfarm Egmond aan Zee (OWEZ) (Tien *et al.*, 2004) and in the final results of the monitoring program of OWEZ (van Hal *et al.*, 2012). Compared to the beam trawl catches, the catches of the GOV targeting schooling fish as herring and sprat are even more variable reducing the power of the analysis. A power analysis based on the variance shown in demersal catches of the baseline study indicated that with eight tows a decrease less than 35% or an increase of more than 155% in fish biomass could be shown statistically. The expectations were that potential effects of the wind farm would not be outside this range. The results presented: none of the species showed a significant increase or decrease compared to the IBTS data, are thus in line with these expectations.

The comparison with the IBTS data is complicated. The IBTS is performed to give North Sea wide indices for a number of species. It is not designed to look at a smaller spatial scale or to focus on tow to tow comparisons, even though it is used as such for various purposes. There is large variability between tows in the same year, which is averaged out in the calculations for North Sea wide indices, but is of major influence in the analysis needed here. For example, the difference between the two tows in 2012 in total numbers of fish (Figure 4-10) is very large. Indicating that catches in the area can be small or large and everything within this range. This implies that a large number of tows is needed to be able to answer questions on differences in catches in the wind farm. In 2013 only two tows, one Dutch and one French tow were done within a reasonable distance from the wind farm. More tows were done, but these differed in depth or showed a completely different species composition related to other environmental conditions, which invalidates them for the comparison. Due to the limited number of tows in 2013, also historic data were used to give some impression of potential ranges in numbers, species and length. These are not valid reference tows, because of year to year variation in the fish community (van Hal *et al.*, 2012, Casini *et al.*, 2005).

The Operational plan defined eight target species. Four were caught in the farm area, while only five were caught in the 43 IBTS tows in the surrounding area. This is according to the expectations, the eight target species are based on the North Sea wide IBTS. The haddock, Norway pout and especially saithe are caught further north (see ICES Fishmap). Mackerel was caught in 2005 in the area as an exceptional catch, but is regularly caught in the wind farm area in the summer period (van Hal *et al.*, 2012). North Sea mackerel overwinter in deep water, to the east and north of Shetland and on the edge of the Norwegian Deep. In the springtime, they migrate south into the central part of the North Sea to spawn in a period from May until July (Simmonds, 2001).
Catching only four, herring, sprat, whiting and cod, of the target species in PAWP in winter is according to the expectations and the IBTS data used as comparison.

17 fish species were caught in the eight tows, which is less than the number of species found in the surrounding IBTS (39). Some of the 39 species in the IBTS were caught only once in all the 43 tows, for example *Salmo trutta trutta* (the 2013 Tridens tow next to the wind farm), *Callionymus maculatus* and *Crystallogobius linearis*. The species richness in PAWP is also less than reported in (Bos *et al.*, 2011),

that showed between 23 to 34 fish species in the area. This was based on a larger number of trawls from multiple years and also longer trawl duration per tow. A longer trawl duration or more tows increases the chance of catching a "new" species (Daan, 2006). The number of species by tow indicates that PAWP is similar to the surrounding area. The 2013 Dutch IBTS tow caught six species which is as low as the lowest number of species caught in PAWP. The French 2013 tow had however a higher number of species than caught in any of the tows in PAWP, but was performed further away from the farm area. In species richness the tows in the wind farm give no indication of a difference compared to the IBTS. All the species caught in the farm were expected. No unexpected or rare species were caught in contrary to the static gear catches in OWEZ (van Hal *et al.*, 2012), where goldsinny wrasse and grey trigger fish were caught.

The numbers per hour of all the target species and the non-target species were not significantly different from the catches of the IBTS in 2013 and the previous years. The total number of 100 greater sand-eel in the PAWP tows was however somewhat surprising. In all the 60 IBTS Tridens tows in 2013 only 32 and in the 58 tows in 2012 only 29 greater sand-eel were caught. Looking at the tows of the IBTS in the PAWP area, the four Thallassa tows prior to the construction and the 2013 Tridens tow next to PAWP, not a single greater sand-eel was caught in these five hauls. The statistical tests, however, do not show a significant difference for this species, but it is worth looking at it more thoroughly because it gives a suggestion of an effect.

The 100 greater sand-eel were caught in 4 of the eight tows, with high numbers in one of these tows. Sand-eels are associated to sandbank areas, where they, due to their seasonal and diurnal feeding cycle, remain buried in the seabed during winter and night. Sand-eels are adapted to specific seabed conditions and display restricted tolerance to sediment textures. Sand-eels live in well-oxygenated medium coarse sand with grain sizes between 0.25-1.2 mm and avoid both coarser and finer sediments (Stenberg *et al.*, 2011). In Horns Rev 1 wind farm a positive effect on sand-eel by the wind farm on the short term was shown (using different methods than we used) (van Deurs *et al.*, 2012). In the longer term there was no effect detectable (Stenberg *et al.*, 2011, van Deurs *et al.*, 2012). Their expectation was that the exclusion of fisheries inside the wind farm area might be beneficial to the recruitment of greater sand-eel due to rehabilitation of trawled sea beds. We share this expectation. However, no effect of fisheries was detected in the Horns rev study due to the location of the control site which was not intensively trawled either before or after the establishment of the wind farm or in a study on a larger spatial scale (van Deurs *et al.*, 2009). The potential positive effect shown in the current study might thus be in contrast with their results but in line with their and our expectations that greater sand-eel could profit from the protection of fisheries and thus the refugium function of the farm.

However, the larger catches of greater sand-eel might just as well be related to the seasonal and diurnal feeding cycle of the species. The number of this type of sand-eel caught fluctuated during the day, with no catches in the morning tow and evening tows, which would be in line with their diurnal feeding cycle. The PAWP tows were done slightly later in the year, with a higher chance that the sand-eel become active already. However, in Horns Rev 1 first activity was seen in March and in OWEZ the sand-eel became active in large numbers in April (Lindeboom *et al.*, 2011) when temperature increased. In the cold winter of 2013, with a water temperature of 4.5 °C during the survey in PAWP, it is not likely that the sand-eel would become active already.

In case the sand-eel benefit from the refugium function of the farm, it is likely that a greater sand-eel population will stay in de farm the whole year. The sand-eel are buried most of the year in the same location, they spawn in the same location and the eggs stick there to the substrate, often partly buried in the upper few centimetres. The larvae are pelagic and drift freely, but after one to three months they metamorphose and burry themselves again in the sediment.

Sand-eel (*Ammodytes*), which are a very similar fish in shape and behaviour as the greater sand-eel, were only caught twice in PAWP. This is similar to the surrounding IBTS and thus do not indicate a positive effect of the exclusion of fisheries. There are no other species in the surrounding area with this same kind of behaviour for which due to this behaviour a positive effect of the exclusion of fisheries might be expected.

A positive effect was expected for cod as the species is attracted by structures. This was shown around oil rigs (Lokkeborg *et al.*, 2002), and also around monopiles of wind farms (van Hal *et al.*, 2012, Winter *et al.*, 2010, Reubens *et al.*, 2011, Reubens *et al.*, 2013). The tows in the farm were however done in the middle between the monopiles and thus not close to the structures. The OWEZ demersal fish trawls were also done in the middle between the monopiles and the catches of cod were limited in those tows as well (van Hal *et al.*, 2012). The tows are done in the middle between the monopiles, because the safety measures prohibit trawled fisheries closer to the monopiles than 200m.

The length data indicate that the single cod and the whiting caught were of a similar length as those caught in the IBTS tows in the surrounding area. The lengths of sprat and herring in PAWP were at the upper part of the length range caught in the surrounding IBTS. An increased growth in the wind park area was the first idea, however the growth rate should have been very large to explain the shift in length from the French to the Dutch IBTS tow and then to the PAPW tow. It would surely not explain the difference in sprat as these are already older fish with a low growth rate. The lack of small herring and sprat might be related to a shorter trawl duration as this might affect the catchability of the gear during the tow. More likely is however that a school of larger sprat and herring was present in the wind farm during that day. Monitoring using acoustic techniques used in OWEZ is a better method to show the occurrence of schools in a larger area (van Hal *et al.*, 2012). It is expected that the school(s) of larger sprat and herring occurred by chance rather than being an effect of the wind farm. However, this cannot be concluded based on the available data. It is however further supported because the expectation is that the residence time of these pelagic species is only short. The schools which are freely moving in the coastal zone are not expected to stay on one location for a long period of time. A link with the exclusion of fisheries from the farm is also not very likely. The herring in the coastal zone in this period are mainly juveniles on which no fishery occurs, the fishery on sprat is limited in this area.

The monitoring done in this project is very limited and owing to that the results of this study are limited as was expected. An extended monitoring with more frequent observations also in reference areas resembling the wind farm area are needed to be able to use this fishing technique to answer the questions. Even then, the results are expected to be limited as other techniques, for example acoustics for schooling fish, are needed as well. The techniques should target the species of interest in the locations were they occur. For example the cod is expected near the monopiles, thus a technique (for example static gear as used in OWEZ) is need that will catch them there. To understand the effects and from that the consequences of the construction of wind farms at sea, process studies (for example the telemetry studies in OWEZ (Winter *et al.*, 2010) and the Belgium wind farm (Reubens *et al.*, 2011)) are preferred over the BACI type of studies.

6 Conclusions

The field work is performed according to the program “Operationeel plan voor het bepalen of het Prinses Amaliawindpark als refugium fungeert voor rondvis” and followed the IBTS protocols. The deviations were a larger number of completed transects (8 instead of 2) and a shorter tow duration for safety reasons. Even with this larger number of tows and along with that the lack of proper reference tows the potential of the analysis was limited. This issue was already mentioned in the tendering phase and is according to the expectation.

1) The expectation as phrased in the Operational plan was that larger and older individuals as well as species vulnerable for fisheries would have a better chance to survive and so increase in numbers, or return to the wind farm area. The data collected neither supports nor reject this expectation.

2) The field work conducted as part of this study is too limited to draw statistically significant conclusions regarding the refugium function of the wind farm for roundfish. There is large variability in the species that are caught and in the amount of fish that is caught. To be able to capture the extend of the variability requires a large number of tows. In the farm area however only a small number of tows could be executed. Besides that the used IBTS tows were not proper reference tows, but did result in valuable information about PAWP roundfish community in the wider historical context.
3) If all the limitations of the data are neglected, there is no clear indication of a positive or a negative effect of the wind farm on the overall catches or on the target species of the IBTS that were found in the farm area: herring, sprat, whiting and cod.
4) The 17 fish species caught in PAWP were all collected in the IBTS tows in the vicinity.
5) Sprat and herring in PAWP were larger in length than those in the IBTS tows, however the collected data was too limited to explain this larger size.
6) Only a single juvenile cod was caught in PAWP, but the tows are done in the middle between the monopiles, while other sources showed that cod aggregate close to the structures.
7) There is a suggestion of a positive effect of PAWP on the presence of greater sand-eel.

7 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

8 References

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Justification

Report number: C117/13-A
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The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved: Dr. Pauline Kamermans
Researcher

Signature: B/a Drs. J.H.M. Schobben

Date: 11th November 2013

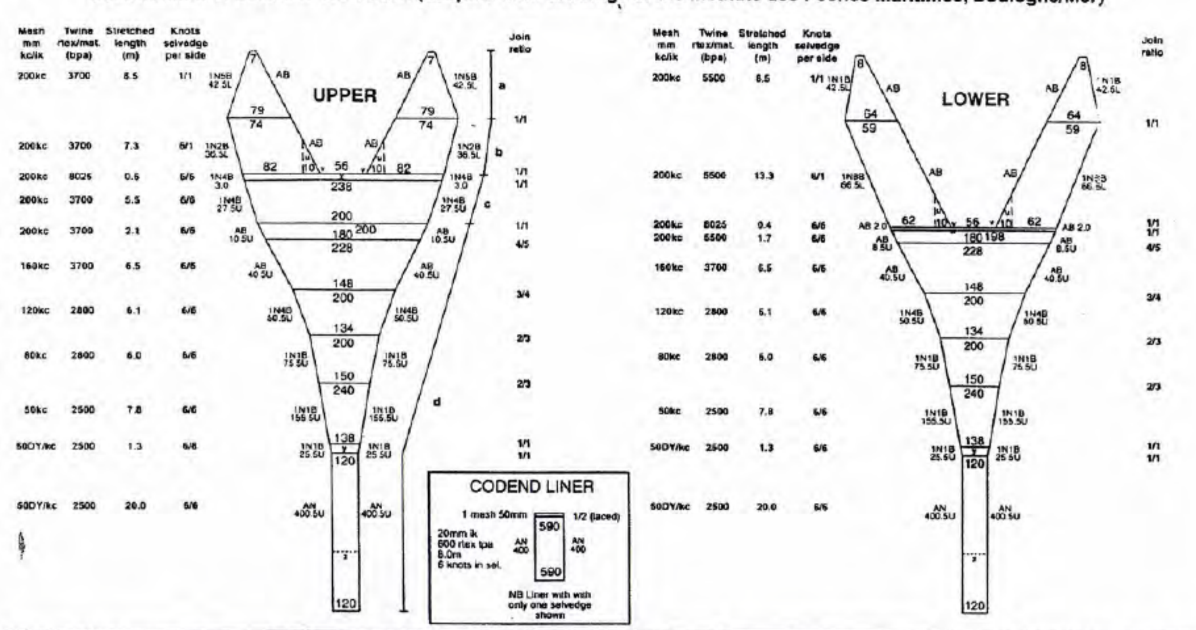
Approved: Drs. J.H.M. Schobben
Head of department Fish

Signature:

Date: 11th November 2013

Appendix A. Construction of the GOV gear

Construction of the 36/47 GOV trawl (adapted from drawings of the Institute des Peches Maritimes, Boulogne/Mer)



Headline : 36m (15.50 + 5.00 + 15.50) x 14mm ϕ wire (f/c) served (6/19 - 12/6/1 65.8kg/100m).
Fishingline : 47.20m (21.10 + 5.00 + 21.10) x 22mm ϕ combination wire 6 strand/steel core 54.6kg/100m).
Winglines : Upper 8.2m, Lower 8.2m x 20mm ϕ combination wire (6 strand/steel core 54.6kg /100m)

a - 7.1m x 14mm ϕ wire (6/19 - 12/6/1 - 65.8kg/100m)
b - 5.7m x 20mm ϕ combination wire (6 strand/steel core - 54.4kg/100m)
c - 5.55m x 20mm ϕ combination wire (6 strand/steel core - 54 4kg/100m)
d - length for length x 22mm ϕ nylon (3 strand - 26kg/100m)

u - Gussets 8025rtex
v - 4 meshes gathered at quarters

w - 200 198
x - 240 238
y - 138 120

z - Joining position for Liner

kc = knot centre to knot centre
ik = inside knot measurement
tpa = polyamide twine/twisted
bpa = polyamide twine/braided
dy = double yarn

Method of join used, sewing.
Type of knot, weavers knot.

NOTE TO NETMAKERS
The numbers of meshes shown for netting panel widths do NOT include selvedge meshes. Five meshes (six knots) per selvedge must be added where indicated. Conversely to obtain panel depths one row (1/2 mesh) must be subtracted from each panel as the joining row is included in the number of meshes deep. The total numbers of meshes (width and depth) for each individual panel are set out in GOV 36/47 Groundfish Survey Trawl Checklist (Page 2 of 5)