Refugium Effects of the MEP-NSW Windpark on Fish:
Progress Report 2007

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Interim report demersal fish

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Summary

The Dutch government has decided to allow the construction of the Off Shore Wind Farm Egmond aan Zee (OWEZ) demonstration project by NoordZee Wind, a consortium of Shell and NUON. The wind farm was completed August 2006. As the environmental impact of off-shore wind turbines is not well known, NoordZee Wind is funding an extensive monitoring programme to evaluate the possible impact of the wind farm. Within this programme, IMARES is (among others) undertaking projects designed to study the effects of windfarm operation on fish, and noise.

This progress report summarizes the research undertaken during 2007 for demersal fish. In particular, it contains a preliminary study focussing on the differences between the data collected for demersal fish during the periods T0 and T1.

The Off Shore wind Farm Egmond aan Zee has a subsidy of the Ministry of Economic Affairs under the CO2 Reduction Scheme of the Netherlands

Section 1: Project aim and research design

1.1. Introduction

This section presents a detailed strategy of approach for describing the situation for demersal[1] fish in the Dutch coastal zone, after the construction of the Off Shore Wind Farm Egmond aan Zee (OWEZ) (T1 and T2), and is taken from Hofstede & HilleRisLambers (2006). The studies on demersal fish during T1 and T2 (2007 and 2011) will compare the occurrence, density, population structure and migration patterns of demersal fish with the baseline (reference) study (T0 2003 / 2004: Tien *et al.*, 2004). All studies are designed to quantify the possible impacts of the wind farm on the occurrence, density, population structure and migration patterns of the demersal fish fauna. The design of the monitoring programme is justified to meet these goals. The specific terms of reference for this study are as used in the baseline study (Grift & Tien, 2003):

- Data obtained from the surveys during T1 and T2 must be comparable to the baseline study and to relevant data of ongoing IMARES surveys (Grift 2001). In case of conflict the comparability to the baseline study will prevail.
- Monitoring must at least result in data on number, density, weight, and length-frequency distribution per species;
- Frequency of monitoring must be sufficient to describe the spatial variation through time (T0, T1, T2);
- The number of hauls that need to be collected must depend on the homogeneity of the seabed morphology in the area (grain size, depth), it is important that enough samples are collected to be able to describe the spatial variation and population structure of the area in the reference situation;
- The sample tracks must be registered;
- The sampling programme must be designed in such a way that possible impacts can be shown;
- To be able to select reference areas for the impact study, an area around the wind farm area must be included in the programme. The surface of the area and the number of samples must be large enough to be able to select at least 2 reference areas of the same size as the wind farm area. These reference areas must be similar to the wind farm area on the following points: seabed morphology, water depth, water currents and species community.

The sampling programme for the T1 and T2 studies is based on the baseline study (Grift & Tien, 2003; Tien *et al.*, 2004) and designed such that it can be copied to the impact study for the wind farm (MEP-OWEZ). Comparable results are guaranteed because IMARES is both involved in this study and in the impact study. Similar sampling programmes before and after the creation of the OWEZ provide a unique opportunity to assess the impact of a wind farm on the demersal fish community.

In this document a detailed description of the sampling programme (locations, period and methods and analysis is given in Chapter 1, Chapter 2 gives a short overview of work completed in 2007, while chapter 3 gives preliminary results on the effects of a windfarm on demersal fish community.

[1] Demersal fish are bottom dwelling fish, i.e. fish that live in or close to the bottom such as plaice, sole, cod and whiting.

1.2. Sampling programme

The sampling programme for T1 and T2 is identical to the baseline (T0) programme but differs from the earlier proposed program in three aspects:

1. We did not collect age data from fish as we can easily estimate ages from the measured length-frequency by Age-Length-keys.

2. Stomach content data was be collected as it is important to describe the relationship between benthic fauna and fish well.

3. The cables that connect the turbines in the OWEZ are orientated perpendicular to the coastline. During the baseline, all sampling transects were taken parallel to the coastline. In order to avoid damage to the cables in the OWEZ and to be consistent in reference areas, during T1 and T2 all transects will be carried out parallel to the cables and thereby perpendicular to the coast.

Below, we will describe the program in further details.

1.2.1. Sampling period and sampling locations

Following the set-up of the baseline study (T0), demersal fish sampling within phase T1 took place in June 2007 (weeks 26 and 27) and January 2008 (weeks 4 and 5). Within phase T2 sampling will take place in June 2011 (weeks 26 and 27). Sampling areas comprise the OWEZ area and three reference areas that are similar to the wind farm area with regards to distance offshore, water depth and seabed morphology (Figures 2.1 and 2.2). The two reference areas directly north and south of the wind farm site (Ref N and Ref Z) are similar to reference areas for pelagic fish the most southern reference area (Ref S) and the northern area (Ref N) overlap with reference areas for benthic fauna which is sampled by Royal NIOZ within this programme. As a relationship between density of certain demersal fish species and distance to the shore exists (Grift et al. 2002), all three reference areas were selected at a similar distance from the coast as the wind farm area. Water depth varies slightly within the wind farm area and reference areas with similar bathymetry have been selected (Figure 1.1). Due to physical similarity of the areas and their vicinity, we assume that water currents are qualitatively similar in all areas.

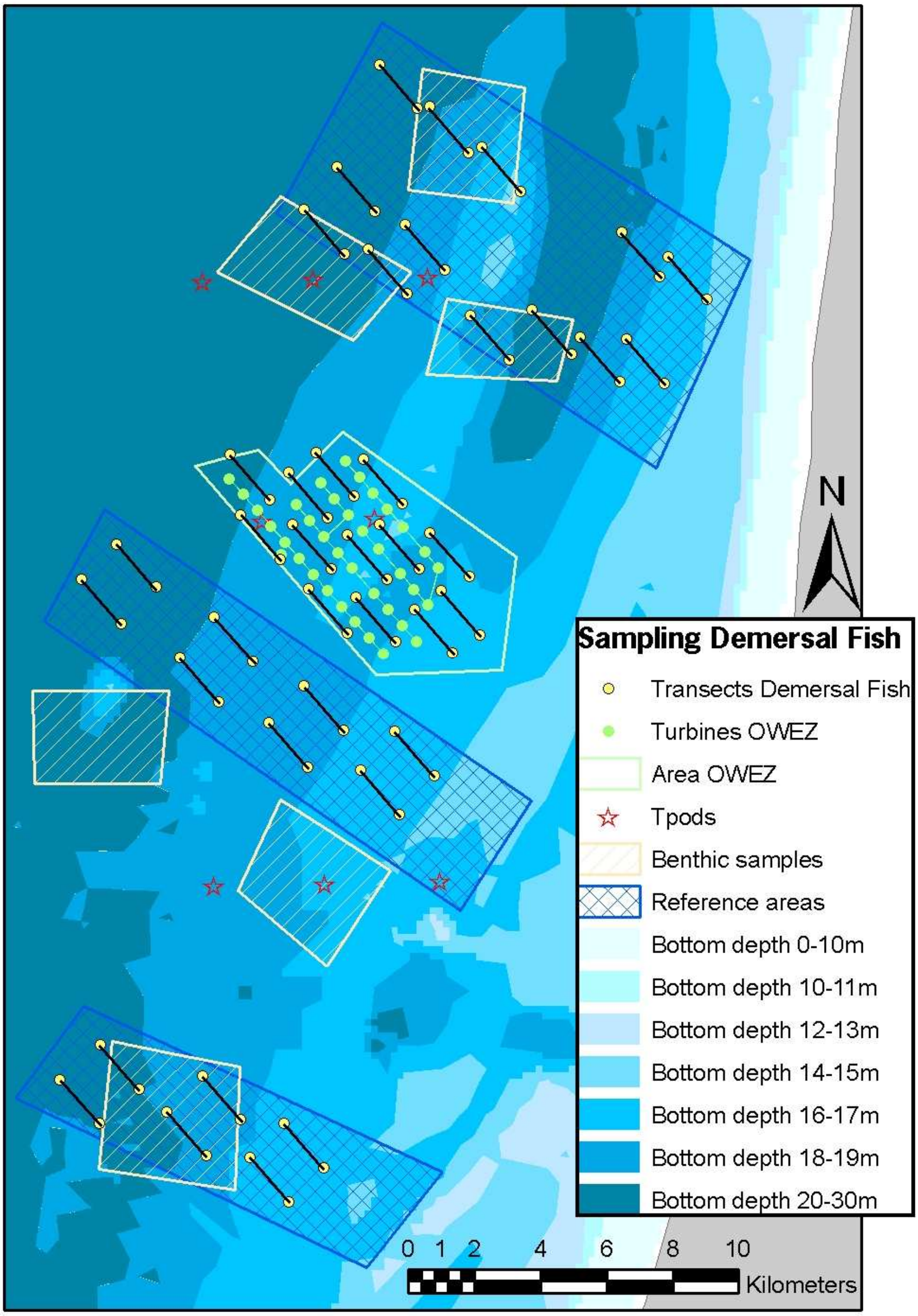


Figure 1.1 . ***Bathymetric map of the Dutch coastal zone with the planned sampling transects (black lines with yellow dots) in three reference areas (Ref N, Ref Z and Ref S) and the wind farm area (OWEZ). Depth in m. below sea level.***

The sampling scheme has been designed to sample the variation in depth, grain size and distance offshore within the wind farm representatively and to replicate this scheme in the three reference areas. The sampling scheme comprises 40 transects, divided among three reference areas and the wind farm area. One third of the samples are taken in the wind farm area, one third north of the wind farm area and one third south of the wind farm area (Figure 1.1). Within the wind farm area, transects are located at a very high spatial resolution. As possible effects of the wind farm on the occurrence of fish are predicted to be on a fine scale, a high resolution sampling scheme is needed to detect these effects.

1.2.2. Fold back scenario for unworkable weather conditions

At sampling transects, hauls were made parallel to the cables in the wind farm (more or less perpendicular to the coast) in order to minimize within-haul variation in depth. The transects cover depths of ca. 15 to 22 m. In case of unworkable weather conditions, priorities for areas were set (Table 1.1). Obviously, the wind farm area (OWEZ) has highest priority because that is the area of interest. Other areas were prioritised according to overlap with other sampling programmes. During T1 all areas were sampled according to plan and their was no need to fall back upon the prioritisation.

Table 1.1. Priorities for sampling areas.

Area	**Description**	**Hauls**	**Priority**	**Reason priority**
OWEZ	Off Shore Wind Farm Egmond aan Zee	13	1	Area OWEZ
REF N	Reference site North of OWEZ	13	2	Overlap with benthic and pelagic sampling
REF Z	Reference site directly South of OWEZ	8	3	Overlap with pelagic sampling, near OWEZ
REF S	Reference site more south of OWEZ	6	4	Overlap with benthic sampling, further from OWEZ

1.2.3. Methods and equipment

As in the baseline study, two 6 m beam trawls were used for our study with the vessel GO58 "Jakoriwi". On one side of the ship, we used a beam trawl with a 40 mm net also used in an annual coastal survey (SNS; since 1969). Because this gear catches a low number of smaller fish, a fine meshed net (with 20 mm in the bag) was used on the other side of the ship. This net is used in another annual survey (DFS; since 1970) but has to be attached to a heavy beam to keep the ship in balance. Therefore, the catches with the larger mesh-sized net are fully comparable to the SNS, whereas catches with the fine meshed net are not fully comparable to the DFS. Length frequency distributions from both nets show that they are complementary, and thus provide a good description of the demersal fish population (Grift & Tien, 2003). The same procedure as in the SNS was followed to make catches from the baseline study comparable to the SNS data, meaning the towing speed was 6.5 km hr-1 (3.5 knots) over the ground, and each haul lasted 15 minutes.

Environmental conditions at sampling locations were measured using a CTD measuring device. This device, attached to the net, continuously records water temperature, depth, conductivity and turbidity. Positions of all tracks sampled with the CTD were recorded with a GPS device. The use of the CTD data contributes to the explanation of the spatial distribution of different species. Hence, variation in species distribution and composition in the impact study can be explained better and the possible influences of a wind farm on fish can be better detected

1.2.3. Processing of the trawl catches

On board, the whole catch was sorted out per net and all fish species will be identified. Fish that could not be identified unambiguously were taken to the laboratory.

For <u>all</u> fish species caught in the trawl, length distributions were assessed and for a selection of species, biological data was collected (see table 1.2). Selection criteria to collect biological data were determined during the baseline study and based on species abundance and the existence of biological data of a species from other sampling programmes (IMARES surveys, market sampling programme).

In addition to the baseline study, for several species the stomach contents were collected in order to be analysed in the laboratory after the surveys (see table 1.2). In order to limit the number of stomachs to be analysed, for each species 3 stomachs were be collected per size class (cm), per survey per area. The stomach analysis was carried out according to recent work studies of IMARES on the diet of demersal fish species in the coastal parts of the Dutch Delta (Binnendijk, 2006).

Table 1.2. Fish species of which biological data (length, weight, sex, maturity, and stomach contents) will be collected during T1 and T2.

	Species	Scientific name	Dutch name	Length, weight, sex, maturity	Stomach contents
1.	Plaice	*Pleuronectes platessa*	Schol	yes	Yes
2.	Dab	*Limanda limanda*	Schar	yes	Yes
3.	Solenette	*Buglossidium luteum*	Dwergtong	yes	Yes
4.	Lesser weever	*Echiichthys vipera*	Kleine pieterman	yes	Yes
5.	Dragonet	*Callionymus lyra*	Pitvis	yes	Yes
6.	Sole	*Solea vulgaris*	Tong	yes	Yes
7.	Scaldfish	*Arnoglossus laterna*	Schurftvis	yes	Yes
8.	Hooknose	*Agonus cataphractus*	Harnasmannetje	yes	No
9.	Brill	*Scophthalmus rhombus*	Griet	yes	No
10.	Turbot	*Psetta maxima*	Tarbot	yes	No
11.	Cod	*Gadus morhua*	Kabeljauw	yes	Yes
12	Whiting	*Merlangius merlangus*	Wijting	yes	Yes

1.3. Data analysis, report writing and database delivery

1.3.1. Data analysis

As in the baseline study, all catch and biological data recorded on board were processed with the IMARES application tool 'Billy'. All data was stored in the IMARES database. Retraction from the databases and analysis of the data was be carried out using the SAS software package.

Observed densities of species were be compared with densities observed in the baseline study. In addition, data collected in this project will be analysed together with data collected in the three routine surveys BTS (Beam Trawl Survey), DFS (Demersal Fish Survey), and SNS (Sole Net Survey), carried out during the month September (van Damme *et al.*, 2004).

1.3.2. Report writing: Final Report

After the second survey in 2011, an extensive final report on the study, will be written containing:

- a description of the information needed to answer the objective(s);
- a description of the methods used in research, monitoring and analyses;
- a description of the sources used;
- a description of the base line, T1 and T2 situation in sufficient detail;
- relevant graphics, tables, figures, maps and explanations;
- a description of the knowledge gaps;
- a bibliography;
- a recommendation on an approach for later (quantitative) evaluation of the learning objectives, including how to use gathered knowledge;
- a summary.

1.3.3 Database delivery

The final report will focus on an integration of all results and on a discussion of the possible effects of a wind farm on the demersal fish community.

The project will result in four types of datasets that will be delivered electronically in the form of DONAR files (.dif files):

1) stomach content data
2) catch data from the trawls
3) aggregated data: densities of fish species, sexes and age classes per location.
4) Environmental data (turbidity, temperature and conductivity).

Section 2: Description of work in 2007

2.1 Monitoring program demersal fish

This section describes the progress gained in monitoring the local effects on the demersal fish stock community due to the construction of the Offshore Windfarm Egmond aan Zee (OWEZ).

The monitoring program comprehends a baseline study (T0) before the construction of the windfarm, one study period a year after its construction (T1) and a monitoring study 5 years afterwards (T2). The baseline study was carried out in July 2003 (T0-summer) and January 2004 (T0-winter). The T1-study was carried out in July 2007 (T1-summer) and January 2008 (T1-winter), while the T2 study will be executed in July 2011.

The monitoring program throughout the three different study periods is designed to quantify the possible effects of the wind farm on the occurrence, density, population structure and migration patterns of the demersal fish community. The sampling scheme has been designed to sample the variation in depth, grain size and distance offshore within the wind farm representatively and to replicate this scheme in the three reference areas. The sampling scheme comprises a minimum of 40 transects to be divided among three reference areas and the wind farm area. One third of the samples will be taken in the wind farm area, one third north of the wind farm area and one third south of the wind farm area (Figure 1.1).

2.2 Progress

The baseline study was completed in 2004 and its results are presented in the RIKZ-report "Baseline studies wind farm for demersal fish" (Tien *et al.*, 2004). This report compared the demersal fish community in the wind farm area and the reference areas based on two conducted baseline surveys. It also provided a description of the Dutch coastal community for the period 2001-2004 using data from two monitoring surveys (SNS, Sole Net SNS, 6m beam trawl; and BTS, Beam Trawl Survey, 8m beam trawl), which are both carried out annually during the 3rd quarter.

The baseline study showed large variations in catches, and in general the same applied for the annual monitoring surveys: snapshots of the fish community from one moment are collected (Tien et al, 2004). The large mobility of most fish makes single-moment sampling less informative when they are used as the only method in an effect study, and the function of an area for the different fish species cannot be understood based on this information alone. It is needed to assess the importance of the area for the dynamics of the species. What is the function of a specific area (feeding, spawning or is the species merely passing through?), how long does the species stay in the area, etc. In order to assess the effect of a large infrastructural development, more knowledge is needed of the mechanisms that determine the distribution of fish. From the baseline study it was therefore concluded that research into the underlying processes would make an impact assessment more efficient.

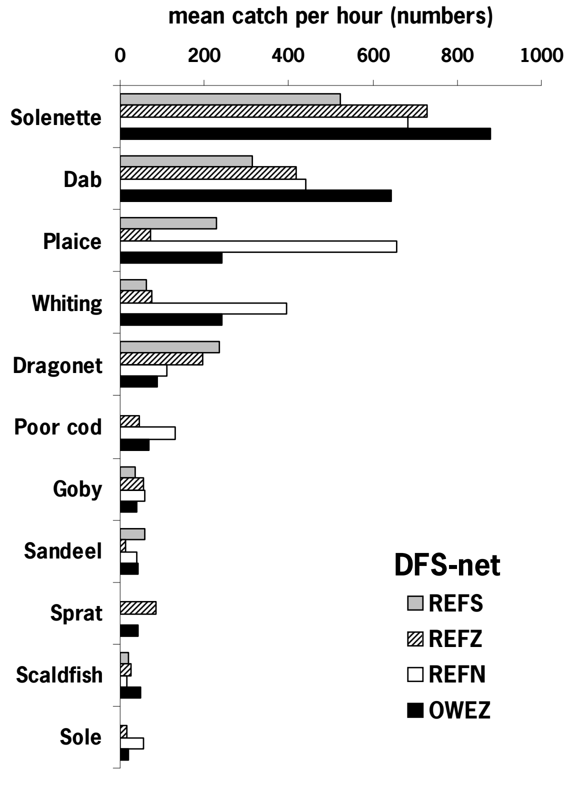
Consequently, to fulfill the need of gathering information for the process-oriented studies within the demersal fish community, the T1 and T2 studies are designed according to the baseline, but with the extension to collect data on fish diets by sampling stomach contents of the most important fish species. This will allow us to study the interaction between the demersal fish and benthic fauna communities. Sampling within the reference areas that overlap with the reference area for the benthic fauna (Ref S and Ref N), studied by NIOZ, is particularly important, because we expect that the closure of the wind farm area will have an impact on the bottom fauna, and thus on food for demersal fish. Sampling fish and benthic fauna in the same areas provides the unique opportunity for comparison between demersal fish and benthic fauna communities. Therefore, during the monitoring periods T1 and T2, data on fish diets will be collected by sampling stomach contents of the most abundant fish species in the area, i.e. flounder, cod, dragonet, dab, plaice, sole and whiting.

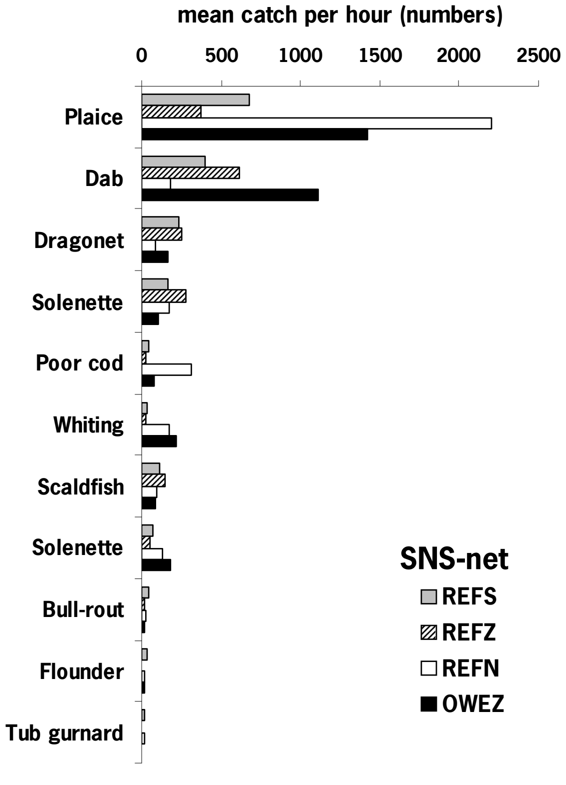
The T1 study has been completed, with surveys both in summer 2007, and early January 2008.

Table 2.1. Numbers of fish from which stomach samples were collected, including information on length, weight, sex, and maturity, during the T1-summer survey in 2007.			
Species (EN)	*Species (NL)*		Number of stomachs
Flounder	*Bot*	*Platichthys flesus*	99
Cod	*Kabeljauw*	*Gadus morhua*	29
Dragonet	*Pitvis*	*Callionymus lyra*	112
Dab	*Schar*	*Limanda limanda*	132
Plaice	*Schol*	*Pleuronectes platessa*	170
Sole	*Tong*	*Solea vulgaris*	94
Whiting	*Wijting*	*Merlangius merlangius*	124

As during the baseline summer survey, plaice, dab and solenette are again the most common species (see figure 2.2, and section 3 of this report). Furthermore, stomach samples have been collected for the species flounder, cod, dragonet, dab, plaice, sole and whiting, which will be analyzed for diet composition in spring 2008 (see table 2.1)

Figure 2.2: Mean catch per hour (numbers) for the 10 most dominant species by surveyed area (OWEZ, REFN, REFZ, REFS) for the two different trawl nets (DFS vs SNS).





2.3 Future Work

The collected data during was analysed in 2008, after the execution of the final T1 survey in January. The catch data was compared with the baseline study, and a sample of collected stomachs of important demersal fish species were analyzed for diet composition. The T1 period will be finalized with an extensive report in 2011, containing a description of the methods used in research, monitoring and analyses, and a description of the base line and T1 situation in sufficient detail to describe possible changes in the local demersal fish community before and after the construction of the Offshore Windfarm Egmond aan Zee. A separate section will be devoted to a description of the diet composition of the main demersal fish species, with possible relations due changes in the abundance of prey items due to the Windfarm.

Section 3: Effects of a windfarm on the demersal fish community: preliminary results

3.1 Introduction

The current document presents a first comparative study of the data on the fish communities collected during the baseline (T0) before the construction of the wind farm, and during the period after the construction phase (T1). The study focuses on differences in the fish communities between areas (wind farm versus reference areas) throughout time (T0 versus T1), and includes comparisons of species richness and the abundance of the catch in total, by ecotype (habitat usage and trophic guild), and by species. A more detailed analysis of the collected data will be carried out after phase T2 in 2011, when the monitoring programme is fully completed.

Figure 3.1: One of the 6 m beam trawls used for sampling the demersal fish community. Attached is the 20 mm net. In the middle of the net the CTD device is visible. (photo: R. ter Hofstede).

3.2 Materials and Methods

A description of survey methods, location and other aspects is given in section 1. In this section we limit ourselves to a description of methods specifically geared to the analysis.

Table 3.1: Number of valid stations that are used in the data analysis for each survey.

Area	T0 summer	T0 winter	T1 summer	T1 winter	*total*
OWEZ	13	14	12	12	*51*
REFN	7	12	12	13	*44*
REFZ	8	8	8	8	*32*
REFS	5	6	6	6	*23*
total	*33*	*40*	*38*	*39*	*151*

Table 3.2: List in alphabetical order of fish species caught during the baseline and T1 surveys, including their habitat type and trophic guild (from Ellis et al., 2008), the parameters for their length weight relationships ($weight_{(in\ gram)} = a * length_{(in\ cm)}^{b}$) (from IMARES database), their overall mean CPUE (in number and gram) and their maximum length caught (Lmax in cm) .

Species	Name	habitat	trophic guild	a	b	CPUE (number)	CPUE (gram)	Lmax (cm)
AGONUS CATAPHRACTUS	HOOKNOSE	DEMERSAL	BENTHIVORE	0.0196	2.1639	18.2	41.1	20
ALOSA SP.	SHAD	PELAGIC	PLANKTIVORE	0.0096	2.9810	0.4	48.2	38
AMMODYTES SP.	SAND-EEL	BENTHOPELAGIC	PLANKTIVORE	0.0013	3.3200	20.0	253.4	25
APHIA MINUTA	TRANSPARENT GOBY	PELAGIC	PLANKTIVORE	0.0098	2.9400	0.1	0.1	5
ARNOGLOSSUS LATERNA	SCALDFISH	DEMERSAL	BENTHIVORE	0.0030	3.4023	87.8	1146.9	17
ATHERINA BOYERI	BIG-SCALE SAND-SMELT	PELAGIC	BENTHIVORE	0.0015	3.1934	0.1	0.2	11
BELONE BELONE	GARFISH	EPIPELAGIC	PISCIVORE	0.0002	3.4420	0.6	41.8	55
BUGLOSSIDIUM LUTEUM	SOLENETTE	DEMERSAL	BENTHIVORE	0.0055	3.2670	378.6	3151.4	17
CALLIONYMUS LYRA	DRAGONET	DEMERSAL	BENTHIVORE	0.0162	2.5781	212.8	3282.8	27
CALLIONYMUS MACULATUS	SPOTTED DRAGONET	DEMERSAL	BENTHIVORE	0.0162	2.5781	0.1	0.3	9
CALLIONYMUS RETICULATUS	RETICULATED DRAGONET	DEMERSAL	BENTHIVORE	0.0162	2.5781	5.7	34.2	12
CILIATA MUSTELA	FIVE-BEARDED ROCKLING	DEMERSAL	BENTHIVORE	0.0108	2.9590	2.0	101.1	23
CLUPEA HARENGUS	HERRING	BENTHOPELAGIC	PLANKTIVORE	0.0060	3.0904	83.6	686.9	25
CYCLOPTERUS LUMPUS	LUMPSUCKER	BENTHOPELAGIC	BENTHO-PISCIVORE	0.0587	2.9390	0.0	0.1	4
DICENTRARCHUS LABRAX	SEA BASS	BENTHOPELAGIC	PISCIVORE	0.0074	3.0963	0.1	14.7	23
ECHIICHTHYS VIPERA	LESSER WEEVER	DEMERSAL	BENTHO-PISCIVORE	0.0018	3.4099	31.6	284.4	18
ENCHELYOPUS CIMBRIUS	FOUR-BEARDED ROCKLING	DEMERSAL	BENTHIVORE	0.0035	3.1062	0.1	0.4	12
ENTELURUS AEQUORAEUS	SNAKE PIPEFISH	PELAGIC	PLANKTIVORE	0.0001	3.5270	0.2	2.9	39
EUTRIGLA GURNARDUS	GREY GURNARD	DEMERSAL	BENTHIVORE	0.0062	3.1003	0.3	11.2	21
GADUS MORHUA	COD	DEMERSAL	PISCIVORE	0.0049	3.1966	52.4	4517.8	67
HYPEROPLUS LANCEOLATUS	GREATER SAND-EEL	BENTHOPELAGIC	PISCIVORE	0.0013	3.3200	2.6	103.3	32
LIMANDA LIMANDA	DAB	DEMERSAL	BENTHIVORE	0.0074	3.1128	942.8	20592.1	31
LIPARIS LIPARIS	SEA-SNAIL	DEMERSAL	BENTHIVORE	0.0587	2.9390	4.8	75.5	16
MERLANGIUS MERLANGUS	WHITING	DEMERSAL	PISCIVORE	0.0042	3.0565	927.5	31713.1	35
MICROSTOMUS KITT	LEMON SOLE	DEMERSAL	BENTHIVORE	0.0255	2.7643	2.4	137.0	20
MULLUS SURMULETUS	STRIPED RED MULLET	DEMERSAL	BENTHIVORE	0.0047	3.3088	1.9	90.2	24
MUSTELUS ASTERIAS	STARRY SMOOTHHOUND	DEMERSAL	CARCINOPHAGE	0.0049	2.9269	0.0	3.0	31
MYOXOCEPHALUS SCORPIUS	BULL-ROUT	DEMERSAL	BENTHO-PISCIVORE	0.0126	3.1235	15.1	1318.8	28
OSMERUS EPERLANUS	SMELT	PELAGIC	BENTHIVORE	0.0053	3.0319	0.1	0.2	9
PLATICHTHYS FLESUS	FLOUNDER	DEMERSAL	BENTHIVORE	0.0087	3.0978	10.2	3078.1	43
PLEURONECTES PLATESSA	PLAICE	DEMERSAL	BENTHIVORE	0.0082	3.0260	707.6	17080.5	45
POMATOSCHISTUS SP.	GOBY	DEMERSAL	BENTHIVORE	0.0098	2.9400	362.0	555.7	9
PSETTA MAXIMA	TURBOT	DEMERSAL	PISCIVORE	0.0044	3.3862	0.8	181.8	44
RAJA CLAVATA	THORNBACK RAY	DEMERSAL	BENTHO-PISCIVORE	0.0187	3.0062	0.0	1.4	14
SCOMBER SCOMBRUS	MACKEREL	PELAGIC	PISCIVORE	0.0030	3.2900	0.1	18.0	29
SCOPHTHALMUS RHOMBUS	BRILL	DEMERSAL	PISCIVORE	0.0055	3.3047	1.2	242.8	42
SOLEA VULGARIS	SOLE	DEMERSAL	BENTHIVORE	0.0036	3.3133	63.7	6053.0	41
SPRATTUS SPRATTUS	SPRAT	PELAGIC	PLANKTIVORE	0.0021	3.4746	142.1	539.2	14
SYNGNATHUS SP.	PIPEFISH	DEMERSAL	PLANKTIVORE	0.0001	3.5270	3.0	7.3	38
TAURULUS BUBALIS	SEA SCORPION	DEMERSAL	BENTHIVORE	0.0154	3.0000	0.2	4.2	14
TRACHURUS TRACHURUS	HORSE MACKEREL	PELAGIC	PISCIVORE	0.0034	3.2943	1.4	144.6	30
TRIGLA LUCERNA	TUB GURNARD	DEMERSAL	BENTHIVORE	0.0080	3.0610	7.3	637.8	35
TRISOPTERUS LUSCUS	BIB	DEMERSAL	BENTHIVORE	0.0038	3.3665	2.9	194.3	23
TRISOPTERUS MINUTUS	POOR COD	DEMERSAL	BENTHIVORE	0.0092	3.0265	48.5	515.2	16

3.2.1 Data processing

3.2.1.1 Data selection

Only stations for which both hauls (with 20 mm and 40 mm net) were valid are used in the analysis. Information on the number of stations used per survey is given in Table 3.1. The purpose of the study is to analyse changes in the demersal fish community before and after the construction of the wind farm, and it is not the intention to compare differences in catchability of the two gear types. Therefore, before analysis of the data the catches of the two gears have been combined and each station is considered as a single sample. In addition, combining the two gear types into one sample has the advantage over treating them separately, that each sample covers a broader range of species types and length distributions.

During the T1 winter survey, at one station in the wind farm area an exceptionally large catch of over 300 times the average in the same survey and area was taken, which was composed of mainly juvenile whiting and cod. It is clearly stated that this large catch has been recorded, but to avoid distortion of the results due to this one outlier, the station was not used in the further analysis of the data.

3.2.1.2 Data analyses

The data were explored to compare differences in catches between the wind farm area and reference areas, and to find changes in catches before and after the construction of the wind farm. Comparisons between the summer en winter surveys are were performed separately, since it is known that the fish community along the Dutch coast varies between seasons. Unless stated otherwise, the catch was expressed as Catch Per Unit Effort (CPUE), defined as the number of individuals per hour fished. In case the catch was given in biomass, the weight was estimated by using the length-weight relationships in table 3.2 hand defined as the weight per hour fished.

Species richness

The total number of species caught during both periods (T0 and T1) in each of the four areas was compared, for both seasons separately (summer/winter). Also, the number of species per haul was calculated after which the average number of species and the standard error of the mean per period for each area were calculated.

Catch Per Unit Effort (CPUE)

The mean CPUE and standard error were calculated per area and period, for all species combined as well as per species, by first calculating the catch (in numbers per hour) per haul, then by averaging it per survey.

Relative abundance by ecological group

In order to achieve a general idea of the effect of the wind farm on the composition of the local fish community, species were grouped into two types of ecological groups: habitat type and trophic guild, following Ellis *et al.* (2007). Table 3.2 shows the ecological groups for all fish species caught.

In terms of *usage of habitat*, four categories were defined: 'pelagic' (living in the open water column), 'epipelagic' (living in the open water column near the surface), 'benthopelagic' (living in the open water column near the bottom), and 'demersal' (dwelling at or near the bottom).

Using the feeding behaviour and foraging strategy as grouping factor, the fish species were categorised into five types of *trophic guilds*: 'piscivores' (i.e. those species for which the adults predate primarily on fish (and cephalopods), 'plankto-piscivores' (species which predate on a variety of larger zooplankton and fish), 'planktivores' (predating primarily on zooplanktonic organisms), 'bentho-piscivores' (species predating on a variety of larger epifaunal invertebrates and fishes) or 'benthivores' (species predating primarily on benthic and epibenthic invertebrates).

The relative abundance for each ecological group within the catch was determined by comparing the mean CPUE for each group per area and period.

3.2.1.3 Statistical analyses

The variation between areas and period was investigated by using analysis of variance (ANOVA). This analysis investigates factors that cause variation in the CPUE. The analyses were performed for both seasons separately.

Log-transformed data were used in order to obtain or as good as approach normally distributed values, which is a basic assumption in this type of analysis. The normality of the distribution was tested using a Shapiro-Wilk test.

To test the effect of area (OWEZ, reference areas) and period (T0, T1) on the CPUE, a linear model was used:

$$Log(DataType) \sim Area_i + Period_j,$$

where *DataType* is 'mean Species Richness (number of species caught per haul)', 'mean CPUE (total number of fish caught per haul)', 'mean CPUE per species', 'mean CPUE by habitat type', or 'mean CPUE by trophic guild type', *Area* is one of the four areas (i=4) and *Period* is the survey period (T0 and T1, j=2). In fact, the model estimates average CPUE and the variation for each combination of Area and Period. The averages from the combinations are compared, and it is tested if they differ statistically with a LSmeans procedure (in which catch estimates are compared pair wise), using a Tukey correction to adjust for multiple comparisons.

3.2.2 Comparison with routine survey

In order to be able to judge whether the observations during the T0 and T1 surveys are in accordance with the fish community in the broader Dutch coastal area, the results were compared with data from the Demersal Fish Survey (DFS). The DFS is a routinely beam trawl survey that is annually executed in the 3rd quarter (summer) since 1970. The design of the DFS survey is comparable to the wind farm survey, since it served as the basis of the design of the wind farm survey. The DFS data that are used for the comparison were collected in the coastal area of North- and South-Holland during the summer in corresponding years (2003 and 2007). More information on these surveys can be found in van Damme *et al.* (2005).

3.3 Results

3.3.1 Species richness

Figure 3.3 shows an increase of the total number of species caught when comparing catches before and after the construction of the wind farm, both during the summer and winter.

When comparing the average of the catches at a haul level (see Figure 3.4), during the summer season the mean number of species has increased significantly ($p<0.0001$) but no differences were found among the four study areas ($p=0.7792$). On the contrary no significant change was found ($p=0.6188$) in the winter season between the two sampling periods, but catches in areas OWEZ and REFN were significantly ($p=0.0487$) different from those in REFZ.

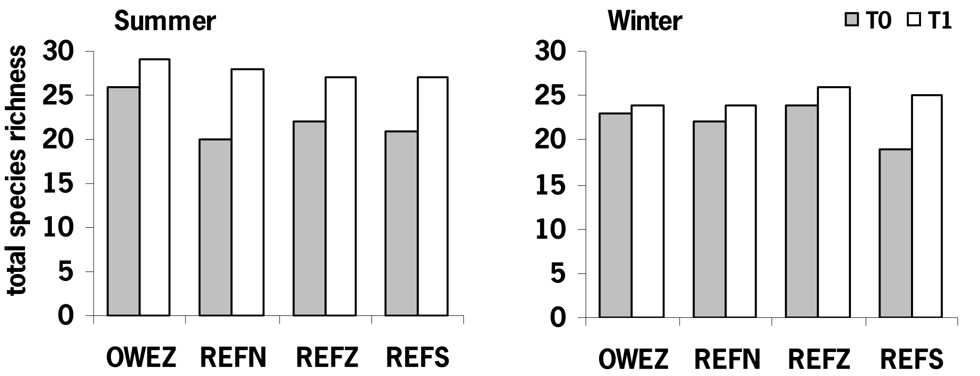


Figure 3.3: Total number of species caught during T0 (grey) and T1 (white) in each of the four areas, during summer (left) and winter (right).

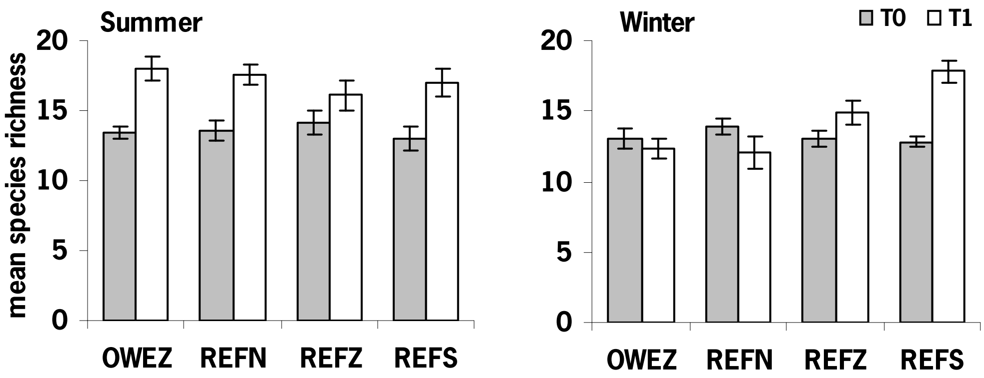


Figure 3.4: Mean +/- s.e. number of species caught per haul during T0 (grey) and T1 (white) in each of the four areas, during summer (left) and winter (right).

3.3.2 Catch Per Unit Effort (CPUE)

3.3.2.1 CPUE of total catch

The mean Catch Per Unit Effort (CPUE) of all fish caught during a haul (in numbers) has significantly increased (p=0.0002) after the construction of the wind farm during the summer (see Figure 3.), but no change was detected during the winter (p=0.1048). However, no difference between the wind farm and the reference areas was found during the summer (p=0.1905). During the winter surveys, catches within the wind farm were significantly different from the reference areas (p=0.0462), which can be attributed mainly to the high catches in reference areas REFN and REFZ during the T1 survey.

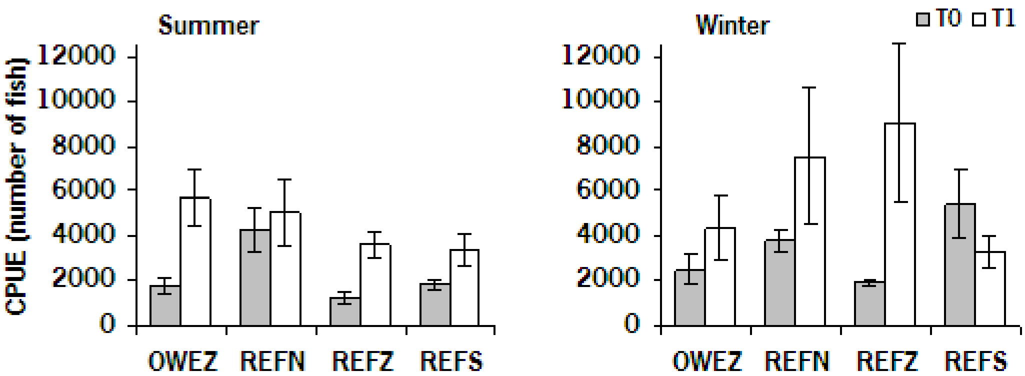


Figure 3.5: Mean +/- s.e. Catch Per Unit Effort (CPUE) (total number per hour of fish caught per haul) during T0 (grey) and T1 (white) in each of the four areas, during summer (left) and winter (right).

3.3.2.2 Relative abundance by ecotype

The catches clearly consisted mainly of demersal fish species both during the summer surveys (p<0.0001) and winter surveys (p<0.0001) (see Figure 3.6). During the summer the composition of species by habitat type was equal amongst the different areas (p=0.5122), but during the winter the catch composition in all three reference areas (especially REFZ) differed significantly (p=0.0003) from the wind farm area (OWEZ), due to a higher relative abundance of the (bentho)pelagic species herring and sprat.

Although this relative higher abundance of these planktivorous herring and sprat in the reference areas during the winter can also be seen in the data when comparing the catches by trophic guild (see Figure 3.), the difference in catches by trophic guild between the areas is not significant (p=0.5097). From the same figure, one can conclude that during the wintertime much more piscivorous fish (mainly cod and whiting) are caught than during the summertime, when catches are dominated by benthivorous fish such as dragonets, gobies, dab, plaice and solenette. For both seasons applies that the catch composition has changed significantly (summer: p<0.0001; winter: p=0.0006), but the change did not vary amongst areas (summer: p=0.1361; winter: p=0.5097).

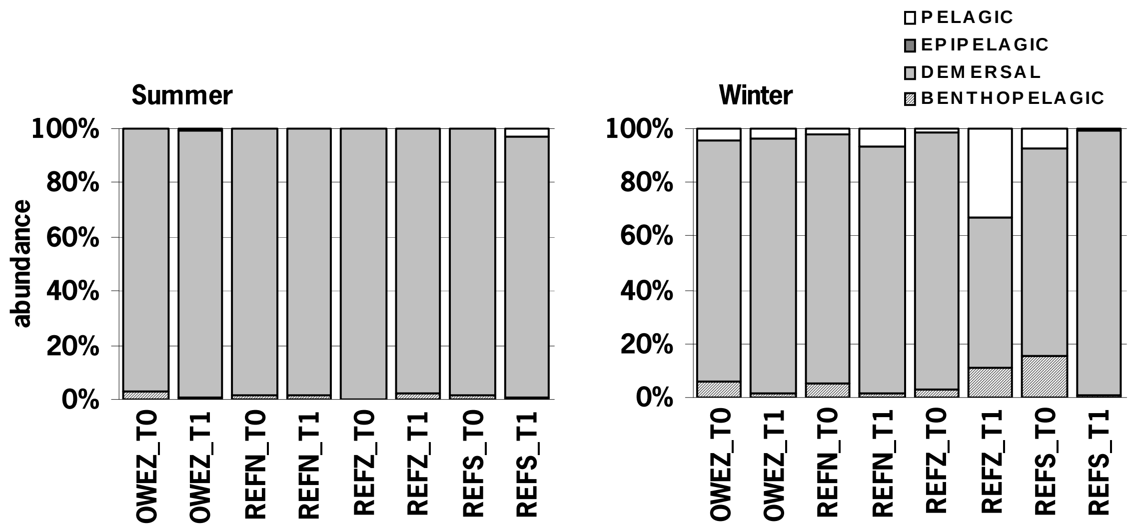


Figure 3.6: Relative abundance of the mean Catch Per Unit Effort (CPUE) (number of fish) of catches divided into habitat type during T0 (grey) and T1 (white) in each of the four areas, during summer (left) and winter (right).

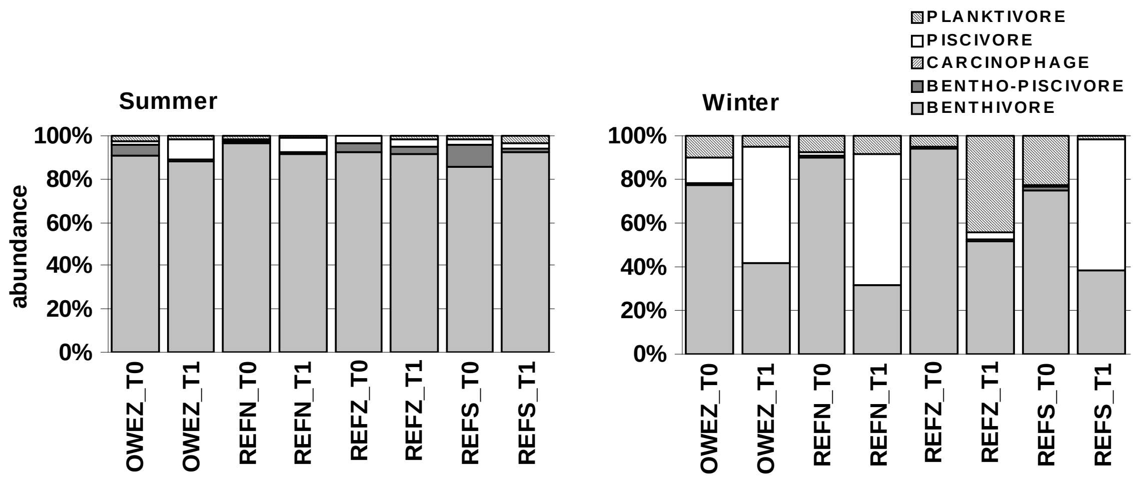


Figure 3.7: Relative abundance of the mean Catch Per Unit Effort (CPUE) (number of fish) of catches divided into trophic guild type during T0 (grey) and T1 (white) in each of the four areas, during summer (left) and winter (right).

3.3.2.3 Change in CPUE by species in the wind farm area

When looking at the difference in the CPUE by species between T0 and T1 within the wind farm area, in general an increase in CPUE can be found for the greater part of the species (see Figure 3.7). Such would be expected, since the overall CPUE was higher in the wind farm area during T1 as well, as shown in section3.3.2.1 and Figure 3..

During the summer, a significant increase was found for bull-rout (p=0.0030), dab (p=0.0435), plaice (p=0.0056), solenette (p=0.0309), sole (p=0.0034), whiting (p<0.0001), and striped red mullet (p=0.0427). However, the CPUE of the first four species was also significantly higher in one or more of the reference areas during T1. The catch of the latter three species sole, whiting and striped red mullet only increased significantly in the wind farm area, and not in the reference areas. A decrease in CPUE during the summer was found for lesser weever (p=0.0373), which was significant in the wind farm area and not significant in the reference areas.
During the winter, a significant increase in CPUE in the wind farm area during T1 was found for cod (p=0.0130), whiting (p=0.0098), solenette (p=0.0060), sole (p=0.0004), and scaldfish (p<0.0001), but the increase was also significant in one ore more of the reference areas. The catch of plaice (p=0.0055), goby (p<0.0001), and lesser weever (p=0.0195) significantly decreased in the wind farm area, but for plaice and sole this also occurred significantly in (most of) the reference areas.

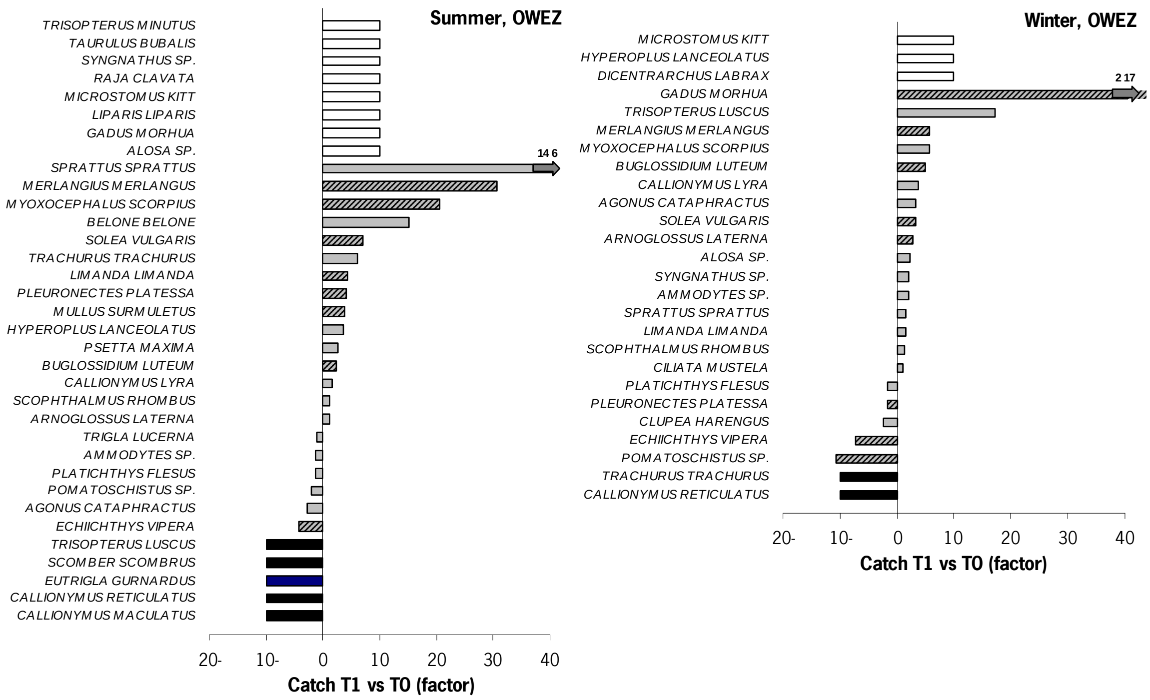


Figure 3.8: Change in mean Catch Per Unit Effort (CPUE) (number of fish per hour) per species between T0 and T1 in the Offshore Wind farm Egmond aan Zee area (OWEZ) during summer (left) and winter (right). In grey the factor of change (factor = $CPUE_{T1}$ / $CPUE_{T0}$; positive is increase, negative is decrease), striped bars show a significant change (p<0.05). White bars indicate species that are 'new' (caught in T1, absent in T0), black bars indicate species that are 'gone' (absent in T1, caught in T0).

3.4 Discussion and conclusions

In this study, effects of the construction of a wind farm on the local fish community were studied. The baseline study (T0) showed large variations in catches (Tien *et al.*, 2004), and the same accounts for the surveys after the construction of the wind farm. This is illustrated most clearly by the exceptional large catch of over 300 times the average during the T1 winter survey, which was consequently excluded from the analysis of the data in order to avoid distortion of the results.

The remaining data were tested on differences in catches between the wind farm area and reference areas, and explored for changes in catch before and after the construction of the wind farm.

Looking at species richness, the *total* number of species caught was significantly higher during the T1 survey than during the baseline, both in summer and winter. During the summer also the *mean* species richness increased significantly. However, since this rise in both total and mean richness was consistent in all areas, it is unlikely to be caused by the construction of the wind farm. For verification, data from a routine survey (DFS) in the Dutch coastal area during the same season (summer) and years (2003, 2007) were studied, and these data do not show an increase in species richness (neither total, nor mean).

During the winter period on the contrary, the mean species richness did vary significantly between the wind farm area and the reference areas, but no significant differences were found before and after the construction of the wind farm.

The mean Catch Per Unit Effort (CPUE) of all fish combined was significantly higher after the construction of the wind farm in all areas during the summer, but since no difference between the wind farm and the reference areas was found, increase in catch could not be attributed to the construction of the wind farm. During the winter survey, catches within the wind farm were significantly different from those in the reference areas. However, the mean total catch was not significantly different when comparing T0 with T1, so the construction of the wind farm did not have an apparent effect on the total catch of fish.

When studying the catches in the light of habitat preference of fish, it becomes clear that during both seasons the catches were dominated by demersal species. This is in full accordance with the expectations, since the surveys were carried out in a shallow coastal area where one may expect a fish community to be dominated by bottom-dwelling species, and just as important since sampling was carried out with a gear that is designed to target demersal fish. Same as with the total catches of all fish combined, no clear relation between the catch categorised by habitat type and the construction of the wind farm was found.

When splitting up the catch into CPUE by trophic guild, it was found that during the summer the catches were dominated by benthivores, species that primarily predate on (epi)benthic invertebrates. In the winter, the catches during T0 consisted also mainly of benthivorous fish, but the catch composition changed significantly into much more piscivorous fish during T1. This change however occurred rather consistent over all areas and therefore the cause could not directly be attributed to the construction of the wind farm.

Overall, when comparing the CPUEs between the different areas before and after the construction of the wind farm at the level of total catch or categorised by ecotype (habitat usage or trophic guild), no relationships have been found between the construction of the wind farm and the local fish community.

Only when studying the fish community in more detail at a species level, effects of the wind farm area were found. The CPUE of certain species had significantly increased or decreased in the wind farm area after the construction, while it had not in the reference areas. Such a significant increase in mean CPUE in the wind farm area exclusively was found for sole, whiting and striped red mullet during the summer, whereas a significant decrease was found for lesser weever, both during the summer and the winter.

A clear explanation why these species have increased or decreased in the wind farm area can so far not be given. The three species that have increased have in common that they are demersal fish feeding partly on polychaetes, molluscs, and crustaceans, and have a preference for muddy and sandy bottoms. But on the other hand, the same applies for the decreasing species lesser weever. This latter species rests on the bottom, often even buried with only its eyes exposed so it is not unlikely that disturbance due to construction work of a wind farm chases the species away from the area. But than again, the species sole displays similar behaviour and would have the same discomfort, but has significantly increased in abundance.

Still, these findings indicate an effect of the wind farm on the fish community at a species level. Whether the effect can be attributed to the construction work itself or to the physical presence of the wind farm, needs further investigations and may be clarified after the T2 survey in 2011, when the full monitoring programme has finalised. In the final report, comparison of T0 with T1 and T2 data will reveal whether fish community abundance and diversity has changed significantly within the windfarm when compared to the control areas. Results from other studies on fish residence time (tagging) and fish behaviour (telemetry) (report in early 2010) will give an indication of fish residence times and mortality in the windfarm, allowing for an estimate of the population effects of the OWEZ windfarm. However, it will still be unclear as to how an accumulation of windfarms in the north sea will affect fish. For this an integrative approach incorporating data and models of the dynamics of fish and benthos as well as fishers is to be recommended, but is currently beyond the scope of this project.

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