BOWind

BARROW OFFSHORE WIND FARM

Pre and Post-Construction Fisheries Surveys

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1 Executive Summary

To address certain conditions contained within the BOW FEPA licence 31744/08/1, a number of fish surveys were carried out within and outside the windfarm area, both before and after construction of the turbines, and installation of the cables.

The scope of the work was agreed with CEFAS, advisers to the MFA, and included both otter trawling and beam trawling during three seasons both pre and post-construction. Ten otter trawl and 7 beam trawl locations were identified, with fishing planned for October, December and March. The schedule was designed to catch flatfish and shellfish in the autumn, roundfish in winter, and spawning species in spring.

The first pre-construction survey took place in October 2004; although the otter trawling was not completed due to inappropriate fishing gear being provided by the fishing vessel, beam trawling was completed successfully. All aspects were completed successfully in December 2004 and March 2005. Post construction work commenced in December 2006, and was completed in March and October 2007. All post-construction sampling was carried out successfully, however, one beam trawl sampling location needed to be moved as hard ground in the original location was damaging the net and affecting the catch.

The pre and post construction otter trawl results from the windfarm area show similar patterns of abundance, with the most frequently caught fish in both periods being dab, plaice, whiting and dogfish. Results from the reference locations show a similar pattern, and there are no statistically significant differences between the catches of the two most abundant species (dab and plaice) made before and after installation of the windfarm, or between the numbers caught in reference locations and within the windfarm area after the windfarm was constructed.

Significant differences were noted between the numbers of dab recorded between seasons, however this is not an effect of the windfarm, and is related to the lifecycle of this species (there were high numbers of dab at all otter trawl locations in December 2006).

Different species spawn at different times of the year, though mostly eggs are laid between December and April. It appears from the results that there have been no changes to the general time of gonad maturation, or the sizes at which the fish are becoming mature, between the pre and post construction periods. In addition to this no impact is seen on the time of spawning.

Results show that for most of the surveys, and most of the major species no changes in the ratio of male to female is observed. However, there are some differences in the proportions of male and female whiting between the windfarm and reference sites in March 2007, though this was not apparent in the October survey. Dogfish showed strong seasonal sexual segregation both spatially and temporally, which is widely reported for this species. There did not appear to be any clear effects with regard to pre- and post-construction, although the October 2007 survey coincided with dominance of males within the windfarm and dominance of females at a single reference site (with no clear pattern at other reference sites).

Each of the individuals caught in the otter trawls were measured, and a comparison of their lengths against the legal minimum landing size (MLS) was made. For dab, plaice and whiting there are no significant differences in the proportions of fish above and below their respective MLS between the windfarm and reference locations, nor between the pre and post construction periods.

A total of 7,582 individual organisms and 51 taxa were recorded in the beam trawls. Around half of these taxa were infrequently occurring, with ten or less individuals being recorded. Overall taxonomic composition of the samples was dominated by crustaceans (19 species) and fish (18 species). With the exception of brown shrimp *Crangon* sp., the beam trawl did not record any commercial fishery species in abundance, and no rare, protected or unusual species were recorded.

In terms of abundance invertebrates dominated, with just 12% of all individuals being fish. Although a relatively low number (five) of echinoderm species were recorded, these were the most abundant group; just two species (the brittlestar *Ophiura ophiura* and the seastar *Asterias rubens*) comprised over half of all individuals recorded. Echinoderm abundance showed strong temporal and spatial variation; for example in individual surveys *O. ophiura* varied between comprising 1.2% and nearly 75% of all individuals. Crangonid (brown) shrimps, which comprised just 12% of total abundance, were nonetheless dominant in the first survey (October 2004) and significant components of other surveys.

In contrast to otter trawling, beam trawling did not produce clear seasonal patterns in terms of abundance. No clearly visible effects attributable to windfarm construction or operation were observed on the fauna sampled by beam trawl.

In summary, there were no statistically significant examples of abundance being affected by the construction or presence of the Wind farm. This is also the case with regard to diversity and abundance of the fish and invertebrates sampled, and the size and maturity of commercial fish species. There are a few species where some differences in sex ratio have been noted for catches within and outside the windfarm since it was constructed. This is particularly the case for dogfish, though this species has been recorded previously living in almost single sex groups. Statistical analyses do not indicate that the presence of the windfarm is responsible for these ratios.

2 Introduction

Licence conditions issued by the Marine Consents and Environment Unit (MCEU), now the Maritime and Fisheries Agency (MFA), for the construction and operation of the Barrow Offshore Windfarm in 2003 included the requirement for a range of environmental monitoring surveys.

One of the conditions required of the Operator (Barrow Offshore Wind Ltd (BOW)) was that it undertook a series of surveys of the commercial fish species within the windfarm area and at selected reference sites. BOW completed pre-construction fisheries surveys in October and December 2004, and March 2005, a report on which was issued to the Centre for Environment, Fisheries and Aquaculture (CEFAS). This report presents the results of the post-construction surveys performed in December 2006, March and October 2007 and a comparison of that data with historical results from the Barrow Offshore Windfarm.

2.1 Licence Conditions

The BOW FEPA licence states:

> *Supplementary condition – 9.6*
>
> *Since very little is known about the potential effect of windfarms in terms of enhancing or aggregating fish populations, the Licence Holder must produce proposals for adequate pre-construction baseline and post-construction surveys of fish populations in the area of the windfarm. The Licence Holder shall, in drawing up such proposals, canvas the views of local fishermen. The proposals must be submitted to the Licensing Authority at least one month prior to the proposed commencement of the monitoring work.*

A fisheries monitoring plan was produced and agreed with CEFAS in 2004; a program of three pre-construction and three post-construction surveys was agreed. Each set of surveys were to be undertaken in March, October and December, with the intention of collecting data on spring spawning species, the summer flatfish and shellfish fishery and the winter roundfish fishery respectively.

2.2 Survey Schedule

The pre-construction surveys were completed in October and December 2004, and March 2005. The construction of the wind farm commenced in May 2005 and was completed in July 2006. The post-construction surveys were completed in December 2006, and March and October 2007.

3 Surveys

3.1 Design

The methods outlined below for the fish surveys are the result of discussions with CEFAS' Lowestoft Laboratory, DEFRA, National Federation of Fishermen's Organisations (NFFO), Fleetwood Fish Producers Organisation, and local Fleetwood and Barrow skippers.

The methods were designed to sample both small and immature fish as well as adult commercial species. With regard to commercial species the methodology, as far as was practically feasible, reflected local commercial fishing practices. The surveys therefore involved the use of a standard single net otter trawl typical of that used in the general area; a 2-metre small mesh scientific beam trawl was also used to sample juvenile fish and invertebrates.

Discussions with local fishermen suggested that the area did not contain any clearly defined, or species specific, fishing grounds of high commercial value. Information provided by local fishermen and merchants indicated that the main commercial species caught in the general area of the windfarm site were: Dover sole, plaice, cod, whiting, dabs, bass, and thornback ray. There is also some potting for lobsters, crabs and whelks.

Vessel

A local trawler rigged to tow both the beam trawl and the otter trawl was contracted to undertake the sampling work.

Trawls

1 x 2m width beam trawl rigged with 20mm mesh outer net with 5mm square mesh inner net.

1 x standard commercial single net demersal otter trawl, 80mm stretched mesh. The headline height of the net was 2.5 metres with a headline length of 15 metres.

3.1.1 Beam Trawling

The tow tracks are as shown in Figure 3.1.

The survey consisted of seven stations, each to be trawled for 15 minutes duration. Three of the stations were the same as those used in the baseline survey (March 2002). These three trawls covered the local seabed types of 1) smooth sand with rare concretion patches 2) smooth sand with abundant concretion patches and 3) tillite (clay with surficial sands). The fourth trawl location was also positioned in an area of smooth sand with rare concretion patches. The locations for the beam trawling were selected to conform with the specification provided in the FEPA licence, and to continue to provide data from locations which had already been sampled, such that a longer term dataset would be provided.

The fifth trawl location was added close to the cable route, and was intended to provide information on the demersal fish species which may be affected by the cable. This location was changed during the December 2004 survey when rough ground was continually encountered in the area, which resulted in some damage to the beam trawl. Figure 3.1 presents the post December 2004 position of this beam trawling location.

The sixth and seventh trawl locations are reference stations, and are situated outside of the windfarm site. The benefit of having reference sites is that data from them may assist in the interpretation of any changes to the diversity and abundance of species caught at other locations. In the absence of reference sites, natural variations may be interpreted as significant changes as a result of the development. The positions of these trawls were also changed in December 2004, as hard ground was continually encountered.

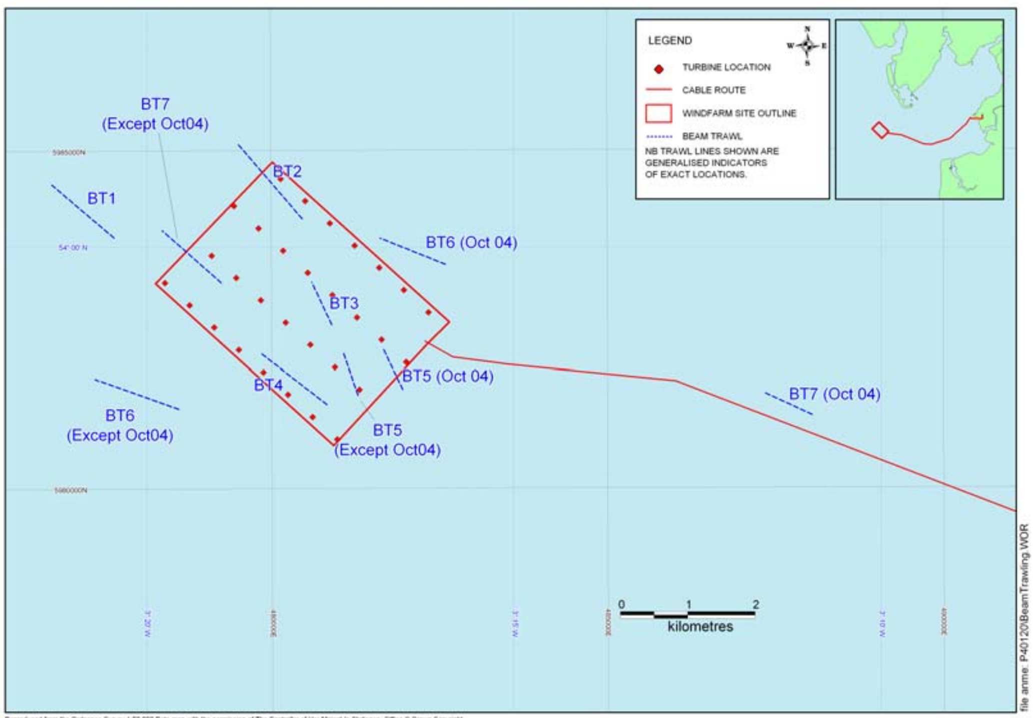

Figure 3.1: Beam trawl sampling locations

Otter Trawling

Six parallel otter trawl tows were taken along approximately NW-SE headings between the lines of turbines, as shown in Figure 3.2. The average towing speed was between 2.0-2.5 knots over the ground with tow durations (i.e. time that the net is actually on the bottom and fishing), not including shooting and hauling of around 30 minutes.

Four reference tows were undertaken in adjacent areas close to the wind farm site with, as near as possible, similar depth and seabed type profiles as at the wind farm site.

3.2 Schedule

Three **pre-construction** sampling trips were undertaken in the following periods:

October 2004 (to gain information on the flatfish and shellfish fishery)

December 2004 (winter roundfish fishery)

March 2005 (Spring spawning season)

Three **post-construction** sampling trips were undertaken in the following periods:

December 2006 (winter roundfish fishery)

March 2007 (Spring spawning season).

October 2007 (flatfish and shellfish fishery)

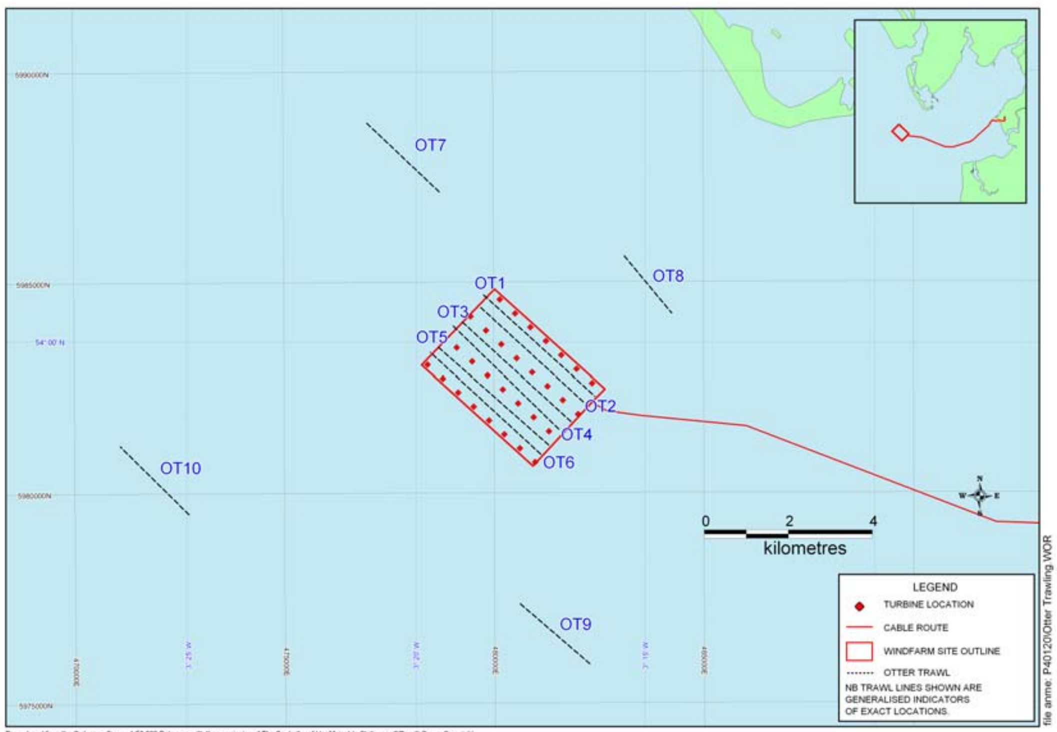

Figure 3.2: Otter trawl sampling locations

3.3 Data Recorded

The trawl tow tracks were recorded using a GPS receiver interfaced with a laptop using GIS software interfaced with ARCS Hydrographic charts.

The following information was recorded for each trawl tow:

- Enumeration of all species
- Sex of commercial species
- Spawning condition of commercial species
- Length distribution by species

Measurements used were as follows:

Finfish:	Total lengths to cm below
Crabs:	carapace width
Lobsters:	carapace length
Whelks:	shell height
Scallops:	shell width

Any other relevant observations were also recorded.

4 Results

4.1 Survey summaries

Otter trawling during the first survey in October 2004 was aborted due to inappropriate trawl gear having been provided by the vessel skipper. It was determined by the survey crew, in discussion with the skipper that rock-hopper trawls were the only appropriate gear for trawling on the site. Otter trawling was subsequently completed in December 2004 and all other surveys.

All beam trawls were completed successfully on all surveys.

Table 4.1 presents a summary of the surveys and the numbers of otter and beam trawls which were completed on each occasion.

Table 4.1: Summary of survey schedule

Stage	Date	Number of otter trawls		Number of beam trawls	
		WF	Ref	WF	Ref
Pre-construction	Oct 2004	0	0	4	3*
	Dec 2004	6	4	5	2
	March 2005	6	4	5	2
Construction (completed summer 2006)					
Post-construction	Dec 2006	6	4	5	2
	Oct 2007	6	4	5	2
	Mar 2007	6	4	5	2

WF: windfarm; Ref: Reference
* - some beam trawl locations changed after the October 2004 survey, resulting in one more trawl location in the windfarm area, and one fewer reference station (Figure 3.1)

4.2 Otter trawl

4.2.1 Diversity and taxonomic composition

A complete species list and totalled abundance for all surveys (excluding data from the aborted Oct 2004 survey) is presented in Table 4.2.

A total of 32 taxa comprising 27 fish and 5 invertebrate species were recorded in the otter trawl survey program. The overall taxonomic composition of the fish was dominated by flatfish (Pleuronectiformes: 8 species), sharks & rays (Elasmobranchii: 5 species), cods (Gadidae: 4 species) and gurnards (Triglidae: 3 species), all of which are primarily demersal and therefore most effectively sampled by otter trawling. All invertebrates were either decapod crustaceans or squid.

Table 4.2: Species list and abundance of organisms recorded during all otter trawls.

	Common name	Scientific name	Type	Total number	%	Cumul-ative %
1	Dab	*Limanda limanda*		4049	45.55	45.55
2	Plaice	*Pleuronectes platessa*		1884	21.19	66.74
3	Whiting	*Merlangius merlangus*		1189	13.37	80.11
4	Lesser spotted dogfish	*Scyliorhinus canicula*		632	7.11	87.22
5	Poor cod	*Trisopterus minutus*		450	5.06	92.28
6	Cod	*Gadus morhua*		115	1.29	93.58
7	Bib/pouting	*Trisopterus luscus*		73	0.82	94.40
8	Thornback ray/roker	*Raja clavata*		70	0.79	95.19
9	Short-spined sea scorpion	*Myoxocephalus scorpius*		68	0.76	95.95
10	Sprat	*Sprattus sprattus*		48	0.54	96.49
11	Red gurnard	*Aspitrigla cuculus*		48	0.54	97.03
12	Grey gurnard	*Eutrigla gurnardus*		45	0.51	97.54
13	Dragonet	*Callionymus lyra*		38	0.43	97.96
14	Lemon sole	*Microstomus kitt*		31	0.35	98.31
15	Flounder	*Platichthys flesus*		31	0.35	98.66
16	Tub gurnard	*Chelidonichthys lucernus*		25	0.28	98.94
17	Dover sole	*Solea solea*		16	0.18	99.12
18	Pogge	*Agonus cataphractus*		13	0.15	99.27
19	Herring	*Clupea harengus*		10	0.11	99.38
20	Starry smooth hound	*Mustelus asterias*		10	0.11	99.49
21	Lobster	*Homarus gammarus*		9	0.10	99.60
22	Scaldfish	*Arnoglossus laterna*		7	0.08	99.67
23	Squid	*Alloteuthis* sp.		6	0.07	99.74
24	Edible (brown) crab	*Cancer pagurus*		6	0.07	99.81
25	Tope	*Galeorhinus galeus*		4	0.04	99.85
26	Brill	*Scopthalmus rhombus*		3	0.03	99.89
27	Mackerel	*Scomber scombrus*		3	0.03	99.92
28	Topknot	*Zeugopterus punctatus*		2	0.02	99.94
29	Velvet swimming crab	*Macropipus puber*		2	0.02	99.97
30	Bull huss/nursehound	*Scyliorhinus stellaris*		1	0.01	99.98
31	Bass	*Dicentrarchus labrax*		1	0.01	99.99
32	Squid	*Loligo sp.*		1	0.01	**100.00**
				8890	**100**	

Key: High/low value* flatfish; High/low value* elasmobranch; commercial shellfish; commercial roundfish; low value/trash fish; commercial pelagic fish
* - classification based on relative commercial values

The surveys included a number of "core" species that occurred in all otter trawls in any given survey (Table 4.3), these were also four most abundant species. Of these, only plaice was recorded in every trawl in all surveys.

Table 4.3: "Core" species from otter trawls. A tick represents presence in all trawls in that survey.

Species		Dec 04	Mar 05	Dec 06	Mar 07	Oct 07
Lesser spotted dogfish	*Scyliorhinus canicula*	✓		✓	✓	✓
Whiting	*Merlangius merlangus*	✓		✓		✓
Plaice	*Pleuronectes platessa*	✓	✓	✓	✓	✓
Dab	*Limanda limanda*	✓		✓	✓	✓

Over a third of the species found during the surveys were represented by a total of less than 10 individuals throughout the entire survey program.

To review the seasonality of total numbers of species recorded, the average number of species was calculated for the two December and two March surveys. There was no clear difference in the average number of species recorded for December (18) and March (17.5) surveys, although the higher number recorded in the single October survey (25) is likely to reflect the recording of migratory summer species (e.g. tope, mackerel) in addition to more resident species.

All species encountered were those to be expected within the eastern Irish Sea (Parker-Humphreys, 2004) and none were particularly rare or unusual. None of the species recorded are protected by conservation designation, although a number of the commercial species have applicable minimum landing sizes and/or are part of the "Grouped Commercial Fish" Biodiversity Action Plan".

4.2.2 Abundance

A total of 8,890 individuals were caught by the five surveys, nearly all of which were fish: invertebrates amounted to less than 1%.

Abundance was dominated by a few key species, with over 90% of all individuals sampled comprising just five species. Of these, the most significant was dab, which comprised over 45% of all individuals, and totalled more than double the 2nd most abundant species (plaice), whiting was 3rd in overall abundance (Table 4.4).

While dab is a low-value flatfish usually discarded or only landed for pot bait, the next two most abundant species are of some commercial importance. Plaice, the second most abundant species, is a relatively high value target species. Whiting is also landed when at marketable size, although of lesser commercial importance than plaice. With the exception of plaice and whiting, species of any commercial value were not abundant over the survey area.

Table 4.4: Abundance of the five most abundant species caught during the survey program.

Species		Dec 04	Mar 05	Dec 06	Mar 07	Oct 07	Total
Dab	*Limanda limanda*	749	114	1868	254	1064	**4049**
Plaice	*Pleuronectes platessa*	450	411	158	365	500	**1884**
Whiting	*Merlangius merlangus*	588	62	143	28	368	**1189**
Lesser spotted dogfish	*Scyliorhinus canicula*	97	29	257	61	188	**632**
Poor cod	*Trisopterus minutus*	401	2	35	7	5	**450**

4.2.2.1 Commercial flatfish

Only dab and plaice were caught in large numbers. Some lemon sole, Dover sole and a few brill were caught, but not in sufficient numbers to make any inferences from.

4.2.2.2 Lobster & crab

As expected, using trawling as a survey method is likely to have undersampled these commercial shellfish with only 9 lobster and 6 crab caught in the entire survey program. As such it is difficult to make any inferences, although the presence in the Windfarm block (since construction) of two small lobsters (March 2007) and 2 edible crabs (December 06 and October 07) indicates that the area is being used by them.

4.2.2.3 Commercial pelagics

Commercial pelagic fish (herring, sprat, mackerel) were collectively insignificant within the survey area, although catchability of these species would have been limited by both the demersal gear being used and the timing of all surveys.

4.2.2.4 Elasmobranchs

Elasmobranch fish (sharks and rays) are of particular interest to the offshore wind farm industry given their ability to detect very low levels of electromagnetic field, and COWRIE have funded research to address this.

A total of five elasmobranch species were recorded over the entire survey duration (Table 4.5). By far the most abundant of these was the lesser-spotted dogfish, a common inshore species of low commercial value. The next most abundant species was the thornback ray (roker), an economically important species.

Table 4.5: Elasmobranch species abundance caught during the survey program.

Species		**Dec 04**	**Mar 05**	**Dec 06**	**Mar 07**	**Oct 07**	**Total**
Lesser spotted dogfish	*Scyliorhinus canicula*	97	29	257	61	188	**632**
Bull huss	*S. stellaris*				1		**1**
Tope	*Galeorhinus galeus*					4	**4**
Starry smoothhound	*Mustelus asterias*			1		9	**10**
Thornback ray	*Raja clavata*	2	2	20	40	6	**70**
	Total	**99**	**31**	**278**	**102**	**207**	**717**

4.2.3 Temporal variation in abundance

4.2.3.1 Overall-all species

Overall abundance of trawled individuals over the survey area showed strong seasonal variation aswell as notably consistent totals for pre- and post-construction surveys in each season. Both Spring (March) surveys showed a lower total (ca 7-800) compared to those surveys conducted in Autumn/Winter (October/December), which all recorded a similar total of ca. 2,200-2,600 (Figure 4.1).

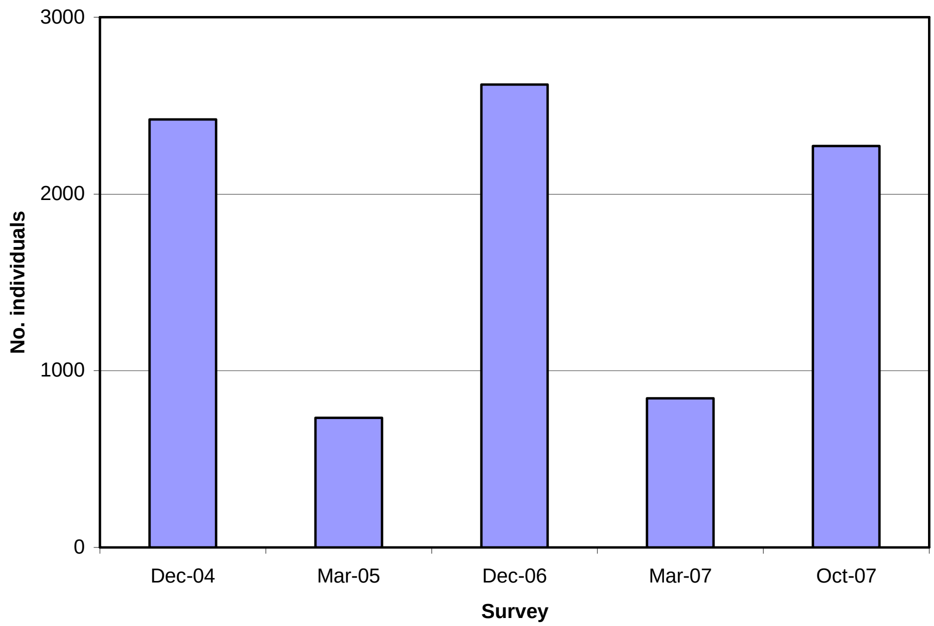

Figure 4.1: Seasonal variation in total abundance of individuals recorded in otter trawl surveys (all species).

4.2.3.2 *Individual species*

Plaice was the most abundant species in Spring surveys, and always in the top 3 during other surveys. Conversely, dab was the most abundant species in all October/December surveys, but always in the top 2 during Spring surveys. Whiting was overall the third most abundant species, and in the five individual survey periods was 2nd, 3rd, 4th, 6th and 3rd most abundant respectively.

Some other species showed noticeable seasonal changes in abundance: for example, the small benthic short-spined sea scorpion (*Myoxocephalus scorpius*) was found in relatively high abundance in Spring, but absent or rare in autumn/winter surveys. This is likely to reflect an inshore movement for spawning; in the Norwegian North Sea this species is thought to undergo breeding-related migrations, with spawning in Spring (January to March) (Luksenburg *et al.*, 2004).

4.2.4 Key species: pre- and post-construction

Abundance of the three most frequently occurring teleost species (i.e. dab, plaice and whiting) and the most frequently occurring elasmobranch (lesser spotted dogfish) in relation to the two comparable sets of pre- and post-construction surveys (i.e. December 2004 and 2006; March 2005 and 2007) is discussed in more detail below. Together these species contributed more than 87% of all individuals caught during the survey program.

4.2.4.1 December surveys

For windfarm sites for dab, all sites (except OT3, which remained constant between surveys) showed an increase from pre- to post-construction, with abundance, on average, doubling per station from 81 to 169 fish.

For reference sites for dab, this followed the same pattern as the windfarm sites (i.e. increase over time), but with an overall greater effect-on average per station, an increase by a factor of 5 from ca. 40 to over 200. This increase in reference areas is likely to indicate that any changes in abundance are due to natural variation.

For windfarm sites for plaice, effects were less clear compared to dab, with some sites showing reductions (OT1-4) or staying much the same (OT5-6). Plaice catches at reference sites did not show any clear pattern either: one site increased (OT10), and the remainder (OT7-9) decreased, with OT8 showing a large reduction.

Numbers at four of the windfarm sites decreased for whiting between the two December surveys, with small increases at the other two sites (OT1 and OT2). For reference stations, OT7 and OT9 showed an increase, while decreases were seen at the other two sites (though the decrease at OT10 was relatively small).

Compared to pre-construction, dogfish showed an increase in abundance at all WF stations (and reference station OT9) post-construction; the three remaining reference stations remained at similar levels.

4.2.4.2 March surveys

For windfarm sites, for both dab and plaice numbers in all but one instance (OT2 dab) increased between the pre- and post construction surveys (Table 4.6), with numbers per station on average increasing by a factor of 4 for dab and about 3.5 for plaice. For whiting, numbers recorded in both March surveys were too few to see notable changes in abundance.

Table 4.6: Abundance of key species pre- (Dec 04 and Mar 05) and post-construction (Dec 06 and Mar 07). Green: increase from pre- to post-construction; white: no apparent change; red: decrease over time

	Windfarm						Reference			
	OT1	OT2	OT3	OT4	OT5	OT6	OT7	OT8	OT9	OT10
Dab										
Dec 04	47	50	183	68	89	50	56	23	59	27
Dec 06	102	185	185	168	204	170	146	60	258	390
Mar 05	5	16	10	14	2	3	0	2	47	15
Mar 07	22	15	17	36	52	58	20	6	8	20
Plaice										
Dec 04	59	111	65	31	9	7	32	71	46	7
Dec 06	16	18	15	6	6	7	25	3	16	46
Mar 05	12	10	9	16	2	15	10	8	285	44
Mar 07	33	44	40	39	29	35	23	28	48	46
Whiting										
Dec 04	3	1	195	17	89	39	5	36	30	50
Dec 06	8	5	7	1	13	5	17	3	46	38
Mar 05	4	1	4	5	1	3	1	0	25	18
Mar 07	4	3	1	4	0	1	0	2	7	6
Lesser spotted dogfish										
Dec 04	8	6	9	12	10	6	12	1	4	11
Dec 06	40	40	39	25	26	20	11	2	40	14
Mar 05	1	2	2	1	1	1	1	0	20	0
Mar 07	9	10	5	3	5	4	7	3	7	8

For reference stations, there was no clear overall pattern. However, dab and plaice showed a similar pattern per site: for the two northern stations (OT7&8) numbers increased (if only slightly) from pre- to post-construction; for the SE station (OT9) the opposite was true, and for the SW station (OT10) numbers stayed approximately the same. Numbers of whiting recorded at OT7 and OT8 were minimal in both surveys, while decreases were seen at the other two reference sites.

Dogfish were rare or absent at all stations (excepting reference station OT9) pre-construction; numbers increased slightly post-construction at all stations, excepting station OT9.

4.3 Sex ratio & spawning condition

4.3.1 Sex ratio

Table 4.7 presents a summary of the ratios of male to females for dab, plaice, whiting and lesser spotted dogfish in each survey, split into windfarm and control sites. The colouration of the number indicates which sex was most abundant, while the number is the percentage of the catch which was that sex.

Table 4.7: Percentage male and female individuals in windfarm and reference sites for the four most abundant species. Pink/blue=female/male majority, respectively.

	Dec 04		Mar 05		Dec 06		Mar 07		Oct 07	
	WF	**Ref**	**WF**	**Ref**	**WF**	**Ref**	**WF**	**Ref**	**WF**	**Ref**
Dab	92	95	98	98	92	78	93	93	77	70
Plaice	61	54	94	89	63	54	80	90	53	51
Whiting	57	59	95	59	72	64	92	57	54	54
LSD	99	86	100	81	89	96	52	68	90	87

For dab, females were strongly dominant (>90%) over the entire survey (both WF and Ref sites) right through to March 07, with the exception of slightly more males in Dec 06 at the reference areas. In the last survey (Oct 07) however, male abundance was higher at both windfarm and references sites; this is likely to be an artefact of being the only October survey, and related to seasonal movements of this species. There were no apparent differences in pre- or post construction surveys.

The sex ratio of plaice was more seasonally variable than dab over the survey area. In all autumn/winter (Oct/Dec) surveys there was an approximately equal sex ratio, but in spring (March) females were dominant (80%); this pattern was the same both pre- and post construction.

Female whiting dominated throughout the majority the surveys, with males only outnumbering them within the windfarm in December 2004, and at the reference sites in March 2007. In both March surveys the percentage of females from the windfarm trawls was similar. In October 2007 relatively high numbers of mature whiting were recorded both at windfarm sites and at control sites, with the same percentage of each sex being present at both groups. It is notable that this percentage showed almost an equal division between male and female whiting.

Figure 4.2 presents the sex ratios for whiting caught in December 2004 and March 2007, showing the differences in proportions of male and females caught inside and outside the windfarm area. While the data from March 2007 appear to indicate that the presence of the windfarm may somehow influence the sex ratios, data from October 2007 (Table 4.7) show no continuing influence.

Data recorded in 2004 were not detailed enough to provide a breakdown of sex ratios per trawl. Numbers of whiting caught in March 2007 were low, and presentation of those data on a per trawl basis would not be appropriate.

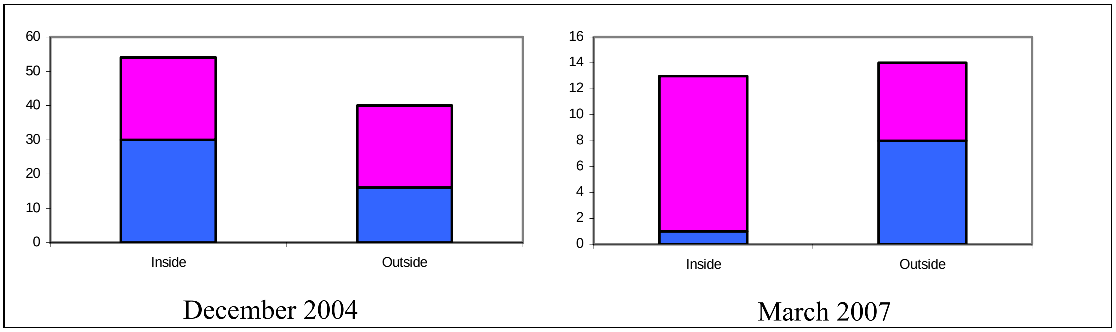

Figure 4.2: Sex ratios for whiting caught inside and outside the windfarm area in December 2004 and March 2007

Lesser-spotted dogfish sex ratio showed noticeable variation both temporally and spatially; numbers of males and females caught at each station in each survey are presented in Table 4.8

Table 4.8: Sex ratio of lesser spotted dogfish at stations over the survey period.

	Dec04		Mar-05		Dec-06		Mar-07		Oct07	
	#♀	#♂	#♀	#♂	#♀	#♂	#♀	#♂	#♀	#♂
OT1	**8**	**0**	**1**	**0**	**36**	**4**	**5**	**4**	**0**	**10**
OT2	**6**	**0**	**2**	**0**	**39**	**1**	**6**	**4**	**0**	**12**
OT3	**9**	**0**	**2**	**0**	**33**	**6**	**3**	**2**	**0**	**2**
OT4	**12**	**0**	**1**	**0**	**24**	**1**	**1**	**2**	**0**	**13**
OT5	**10**	**0**	**1**	**0**	**21**	**5**	**1**	**4**	**2**	**15**
OT6	**23**	**1**	**1**	**0**	**16**	**4**	**1**	**3**	**6**	**20**
OT7/7A/B	**8**	**4**	**1**	**0**	**10**	**1**	**5**	**2**	**3**	**0**
OT8	**1**	**0**	**0**	**0**	**2**	**0**	**2**	**1**	**1**	**2**
OT9	**4**	**0**	**17**	**4**	**39**	**1**	**5**	**2**	**0**	**8**
OT10	**11**	**0**	**0**	**0**	**13**	**1**	**5**	**3**	**89**	**4**

NB Only one trawl was completed in October 2004, on the western margin of the WF block (both inside and outside): 17 males and 1 female were recorded.

The variation can be summarised as follows:

- Total *S. canicula* abundance was lowest in both March surveys. However, total abundances of all fish were also lowest in March, suggesting that this period has naturally lower abundance for many fish species, which may be associated with e.g. food availability; it may also represent a seasonal migration of *S. canicula* away from the area to more suitable egg-laying substrate;
- Strong sexual segregation is the norm both for sharks in general and for *S. canicula*; mature females are known to “refuge” from mature males. Strong sexual segregation was observed in most surveys, although this was least apparent in March surveys, which may be a function of the lower total numbers;
- Females dominated strongly in both December surveys (both within and outside the windfarm area). Males were dominant in October for most sites (based on the post-construction survey and a single trawl from the aborted pre-construction survey);

- Males were essentially absent across the entire survey area pre-construction (for December and March), but present in October (based on a single trawl sample);
- In post-construction surveys for both December and March, numbers of males within the WF increased; this effect was in general reflected in control sites in March, but less clearly so in December.
- In the October post-construction survey males were overwhelmingly dominant within the WF, however, there was no such clear pattern at control sites. This may indicate that the WF area is naturally "male-rich" in October, which was indicated by data from the incomplete pre-construction survey.
- In a single control site in the post-construction October survey, an anomalously high number of females were recorded, in comparison to the almost complete dominance by males at all other sites during that survey. This may simply be natural sexual segregation, with the females at this site refuging from the males in the WF, although this is difficult to confirm in the absence of pre-construction data;
- Although it is known that *S. canicula* shows strong domination by one sex in one area at certain times, little work has been done on the spatial extent of these areas and whether or not they change over time, although some work has shown sexual segregation in one year over consecutive years. It is also known that the species may show sex-based prey preferences; therefore naturally high (or WF-induced) abundance of a certain prey type in one location may have an aggregative effect on either males or females. Without full pre-construction data it is not possible to assess with any certainty the observed changes; however, the survey data appear to indicate that males aggregate in the WF.

These observations are made in the context of several studies on the species. Sexual segregation is considered a general characteristic of shark populations and is found in a range of species (Sims, 2005). Sexual segregation in *S. canicula* has been widely reported previously, in waters of the UK (e.g. Ford, 1921; Harris, 1952; Lyle, 1983; Ellis and Shackley 1997), Ireland (Ivory *et al*., 2004) and the Atlantic coast of Spain (e.g. Rodriguez-Cabello *et al*., 2007). Many of these papers report seasonal shifts in relative abundance of sexes; Table 4.9 presents examples from UK waters from the literature.

Table 4.9: Examples of seasonal sexual segregation in UK populations of lesser spotted dogfish.

Location	Sample size	Males dominant	Females dominant	Reference
SE of Isle of Man, Irish Sea	2255	All except winter	Winter*	Lyle (1983)
Swansea & Oxwich Bays, Bristol Channel	972	April	January, June	Ellis and Shackley (1997)
Ilfracombe, Bristol Channel	1898	May, June	Winter, Spring	Harris (1952)
Plymouth, English Channel	4638	Winter	May-Oct	Ford (1921)

*January to March

The study by Lyle (1983), in an area relatively close to BOW, found that overall sex ratios were biased in favour of males in all except winter (Jan-March), where they marginally favoured females. This was partially reflected in the current study (the post-construction March survey showed a relatively equal ratio); conversely however, females were dominant in three of the current surveys. Lyle split samples into those above and below an arbitrary maturity length of 60cm and found that smaller ("immature", <60cm) fish were almost equally spread throughout the year, while larger mature fish >60cm were heavily dominated by males in all surveys except a winter (Jan-March) survey. This reiterates the natural strong sexual segregation of mature *S. canicula* in the area, and, in combination with data from the current surveys, suggests that March is naturally a period of less marked segregation. Although only a limited study, Sims *et al*., (2001) provided evidence (from mark-recapture work) to suggest geographic sexual segregation in *S. canicula* in consecutive years, although in general, little is known about the permanence and/or extent of single-sex dominated areas.

S. canicula is known to be a generalist and opportunistic predator, feeding on a wide variety of invertebrate and fish prey (e.g. Lyle, 1983; Ellis *et al*., 1996); there is also some evidence for sex-based dietary preferences (possibly as a function of body side and/or energy requirements); Rodriguez-Cabello *et al*. (2007), for example, found euphausiid crustaceans to be preyed upon significantly more by adult females. It is possible that effects of WF construction/operation (e.g. temporary restrictions on trawling effort, addition of new substrata and habitats etc.) may have changed the distribution and/or abundance of *S. canicula* prey species.

The almost complete absence of females in the October surveys (except at control Station OT10) may be explained by egg-laying requirements: erect sessile epifauna (such as sponges, bryozoans and hydroids) are known to be important as these provide a substrate to attach egg-case tendrils to (Ellis and Shackley, 1997). However, these habitats are not present over the survey area, with the substrate largely consisting of soft sediments such as muds and sands; little in the way of cobbles, boulders or associated epifaunal growth were reported by a pre-construction dive survey. The entire survey area may not therefore provide suitable habitat for egg-laying females; the lower abundances of females (and *S. canicula* in general) observed in March surveys may therefore indicate a seasonal migration to more suitable egg-laying substrate.

In the Bristol Channel, peak egg-laying has been reported in June and July (also high in March), with no egg-bearing females apparently present in August and September (Ellis and Shackley, 1997). Harris (1952), also reporting on Bristol Channel populations, found no egg-bearing females in September and October; these findings reflected those of an even earlier study by Ford (1921) who found samples from the English Channel from these two months to have the lowest percentage of egg-bearing females. The literature therefore indicates that autumn is a significant point in the annual reproductive cycle of the species; it is not therefore unreasonable to expect that this time may show distinct patterns in distribution and abundance of females.

4.3.2 Spawning condition

It is considered very unlikely that the presence of the windfarm influences the spawning condition of the species inhabiting the area. Data were collected to determine maturity of the most abundant species caught in each survey period, they were pooled to present an overall picture of maturity across the area, and are summarised below for the four most abundant species overall.

4.3.2.1 Dab

During both December 2004 and 2006, male and female dab were recorded in various states of maturity, including some females that had already spawned. There was a wide range of sizes of both males and females at which maturity was evident.

In March 2005 only two male dabs were caught, both were immature, at a maximum length of 18cm. In March 2007, some male dab of only 14cm were mature, while all were mature over a length of 18cm. Several males were either running, or spent during the 2007 survey.

In March 2005, some female dabs were mature at 15cm, while all were mature above a length of 20cm. Much greater numbers of females than males were recorded. In March 2007, females were maturing between lengths of 13 and 22cm, with all being mature over 22cm. Around 25% of the females were immature, with 34% either running or spent at the time of the survey.

4.3.2.2 Plaice

During the December 2004 survey, some male plaice of 18cm had begun maturing (no males of less than 18cm were caught), and all male plaice of 24cm and greater length were mature. In December 2006 some mature plaice were recorded at 13cm, while all were mature by the time they had reached 18cm in length. A single spent male of 24cm length was recorded in December 2006.

In 2004, both mature and immature females were identified between the ranges of 21 and 26cm. All females of 27cm and above were identified as mature. In 2006 both mature and immature females were recorded in the size range 19-27cm, all females of 27cm and above were mature.

Few male plaice were caught in March 2005, those that were mature ranged from 18cm to 21cm in length, including some fish which were running.

In March 2007, males were maturing in a range of 18 – 22cm, while all were mature at greater length than 22cm. Of the 59 males caught, 23 were running or spent.

In March 2005, females of greater length than 16cm were mature, with 39% of female plaice being recorded as spent. In March 2007, females were maturing between 12 and 19cm, while all were mature beyond 23cm in length. Of the 316 females caught, 218 were either running or spent.

4.3.2.3 Whiting

In December 2004, all male whiting of 20 cm and below were found to be immature. Both mature and immature males were identified between the ranges of 21 and 23cm. All males of 23cm and above were identified as mature. In 2006, all male whiting below 15cm were immature, maturing males were recorded between 18 and 24cm, will all males above 24cm being mature.

In December 2004, all female whiting of 23 cm and below were found to be immature. Both mature and immature females were identified between the ranges of 24 and 25cm. All females of 25cm and above were identified as mature.

In March 2005, male whiting were maturing between 15cm and 25cm. In March 2007, all males recorded were immature below a length of 21cm, with only 2 individuals being mature or maturing above this length.

In March 2005, some females were maturing above a length of 19cm, while one of 23cm length was identified as spent. In March 2007, all females below 20cm were immature, with all individuals greater than this length being mature, and one of them running.

4.4 Distribution/proportion of market-sized fish

Table 4.10 presents data on the percentage of fish in each survey found to be above or below the minimum landing size (MLS), for dab (15cm), plaice (27cm) and whiting (27cm).

Table 4.10: % of fish above/below minimum landing size of species in Windfarm (WF) and reference (Ref) sites. Red/blue=Below/above MLS, respectively.

	Dec 04		Mar 05		Dec 06		Mar 07		Oct 07	
	WF	**Ref**	**WF**	**Ref**	**WF**	**Ref**	**WF**	**Ref**	**WF**	**Ref**
Dab	99	100	98	100	99	90	92	100	98	97
Plaice	79	83	77	78	87	80	71	74	82	83
Whiting	69	72	78	96	59	86	92	100	96	98

For dab, there was no apparent difference either over time or between windfarm and reference sites, with the vast majority of fish caught over the MLS.

The majority of plaice caught were below MLS, indicating the area has some importance as a nursery ground. Plaice showed no apparent difference in the percentage above/below MLS between windfarm and reference stations over the entire survey period. There did appear to be a slightly greater percentage of larger marketable fish in March as opposed to October/December surveys.

Whiting also showed a predominance of fish below MLS. In the two most recent surveys nearly all individuals were below MLS, while in earlier surveys a greater percentage of marketable fish was recorded. Levels in- and outside the Windfarm were similar in all but the Mar 05 and Dec 06 surveys, where reference stations showed a higher percentage of marketable fish.

4.5 Statistical & community analysis

RSK commissioned CMACS Ltd to examine any relationships in the otter trawl dataset for the two most abundant species (dab and plaice) for trends over seasons, in- and outside the Windfarm, and pre- and post-construction.

Due to the low number of replicates (data from all 6 WF sites was pooled) and uneven sample size, non-parametric tests were selected (Kruskal-Wallis and Dunn's discriminatory test). Parametric tests (2 way ANOVA, with natural log transformation) were also performed; although this is not strictly appropriate due to the small and uneven samples these did provide some support to the weaker Kruskal-Wallis tests.

In addition, some initial Primer (Plymouth Routines In Multivariate Ecological Research) analysis was carried out on the overall community data.

Some statistically significant differences were found in dab and plaice data, although this related only to seasonal differences (with more fish being caught in December). There was no statistically significant evidence to suggest that construction or operation of the Windfarm site had affected abundance.

Primer results supported the conclusions of the species-specific tests, with differences related principally to season and not to the presence of the Windfarm. However, some minor differences were detected, such as the high abundance of dab at all stations in December 2006 (post construction).

4.6 Beam trawls

4.6.1 Diversity and taxonomic composition

A complete species list and total abundance from all beam trawls is presented in Table 4.11.

Much of the diversity was comprised of infrequently occurring species: of the 51 taxa recorded, half were found in 10 or fewer trawls (13 species occurred on only 1 occasion). The majority of taxa recorded comprised crustaceans (19 species) and fish (18 species). Molluscs contributed 6 species (4 of which were bivalves), with echinoderms only numbering 5 species, even though this was the most numerically abundant group. Anemones (2 species) and a single polychaete species (the sea mouse *Aphrodita aculeata*) were also recorded, although the beam trawl is not designed to effectively sample these two groups.

Table 4.11: Species list & abundance of organisms recorded during beam trawls.

	Name		Species	No.	%	Cum %
1	Brittlestar		*Ophiura ophiura*	2852	37.62	37.62
2	Starfish		*Asterias rubens*	1930	25.46	63.07
3	Brown shrimp	**C**	*Crangon allmanni*	509	6.71	69.78
4	Brown shrimp	**C**	*Crangon crangon*	429	5.66	75.44
5	Starfish		*Astropecten irregularis*	305	4.02	79.46
6	Dragonet		*Callionymus lyra*	261	3.44	82.91
7	Swimming crab		*Liocarcinus holsatus*	217	2.86	85.77
8	Dab		*Limanda limanda*	195	2.57	88.34
9	Hermit crab		*Pagurus bernhardus*	180	2.37	90.71
10	Whiting	**C**	*Merlangius merlangus*	93	1.23	91.94
11	Goby		*Pomatoschistus minutus*	88	1.16	93.10
12	Solenette		*Buglossidum luteum*	78	1.03	94.13
13	Plaice	**C**	*Pleuronectes platessa*	66	0.87	95.00
14	Scaldfish		*Arnoglossus laterna*	52	0.69	95.69
15	Pogge		*Agonus cataphractus*	43	0.57	96.25
16	Prawn		*Palaemon serratus*	31	0.41	96.66
17	Goby		*Gobiidae indet.*	29	0.38	97.05
18	Spider crab		*Macropodia rostrata*	24	0.32	97.36
19	Crab		*Pisidia longicornis*	22	0.29	97.65
20	Krill		*Meganictiphanes norvegica*	21	0.28	97.93
21	Black goby		*Gobius niger*	20	0.26	98.19
22	Pink shrimp	**C**	*Pandalus montaguii*	16	0.21	98.40
23	Plumose anenome		*Metridium senile*	15	0.20	98.60
24	Sea mouse		*Aphrodita aculeata*	14	0.18	98.79
25	Sprat	**C**	*Sprattus sprattus*	14	0.18	98.97
26	Poor cod		*Trisopterus minutus*	11	0.15	99.12
27	Prickly cockle		*Acanthocardia echinata*	10	0.13	99.25
28	Dover sole	**C**	*Solea solea*	10	0.13	99.38
29	Edible crab	**C**	*Cancer pagurus*	7	0.09	99.47
30	Velvet swimmer		*Necora puber*	7	0.09	99.56
31	Prawn		*Pandalina brevirostris*	4	0.05	99.62
32	Cod	**C**	*Gadus morhua*	3	0.04	99.66
33	Little cuttle		*Sepiola atlantica*	3	0.04	99.70
34	Whelk	**C**	*Buccinum undatum*	2	0.03	99.72
35	Five-bearded rockling		*Ciliata mustela*	2	0.03	99.75
36	Prawn		*Hippolyte varians*	2	0.03	99.78
37	Prawn		*Palaemon longirostris*	2	0.03	99.80
38	Long-spined sea scorpion		*Taurulus bubalis*	2	0.03	99.83
39	Queen scallop	**C**	*Aequipecten opercularis*	1	0.01	99.84
40	Clam		*Arctica islandica*	1	0.01	99.85
41	Clam		*Chamelea gallina*	1	0.01	99.87
42	Herring	**C**	*Clupea harengus*	1	0.01	99.88
43	Crab		*Goneplax rhomboides*	1	0.01	99.89
44	Lobster	**C**	*Homarus gammarus*	1	0.01	99.91
45	Spider crab		*Hyas araneus*	1	0.01	99.92
46	Swimming crab		*Liocarcinus depurator*	1	0.01	99.93
47	Brittlestar		*Ophiothrix fragilis*	1	0.01	99.95
48	Crab		*Pilumnus hirtellus*	1	0.01	99.96
49	Sea urchin		*Psammechinus miliaris*	1	0.01	99.97
50	Bib/pout		*Trisopterus luscus*	1	0.01	99.99
51	Dahlia anenome		*Urticina felina*	1	0.01	100.00
				7582	100.00	

C=commercially important species. Echinoderms; Crustaceans; Fish; Molluscs; Anthozoa.

"Core" species recorded at every station in each survey are presented in Table 4.12. No species was present in all surveys at every station.

Table 4.12: "Core" species from beam trawls. A tick represents presence at all sites in that survey.

Species		Oct 04	Dec 04	Mar 05	Dec 06	Mar 07	Oct 07
Brown shrimp	*Crangon allmanni*		✓		✓		
Swimming crab	*Liocarcinus holsatus*		✓				
Seastar	*Astropecten irregularis*					✓	
Common seastar	*Asterias rubens*		✓	✓		✓	✓
Hermit crab	*Pagurus bernhardus*					✓	✓
Dab	*Limanda limanda*		✓			✓	
Dragonet	*Callionymis lyra*		✓	✓			
Pogge	*Agonus cataphractus*		✓				

Number of species recorded varied most inter-annually in October and December surveys, which had an average of 26 and 26.5 species respectively. The two March surveys showed less variation, with a slightly lower average of 21.5 species (Figure 4.3).

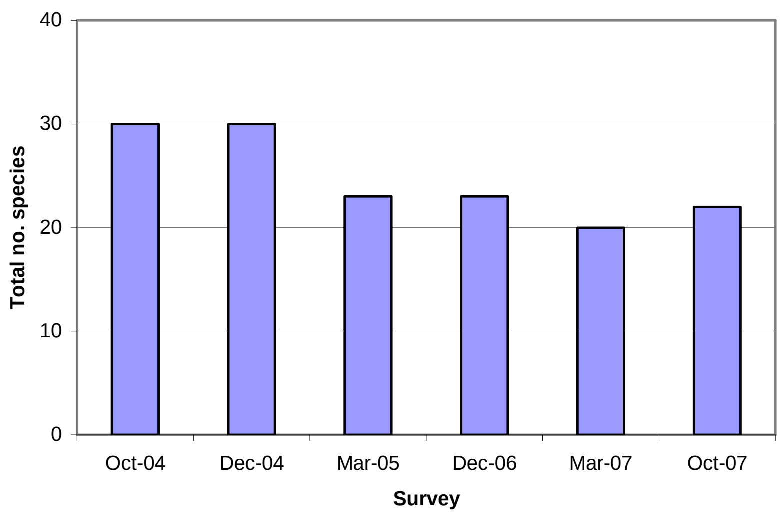

Figure 4.3: Seasonal variation in total number of species recorded in beam trawl surveys.

While the majority of fish species sampled by beam trawl were those also recorded from otter trawling, a number of additional smaller species were recorded: gobies (black, sand and unidentified juveniles), solenette, five-bearded rockling, and long-spined sea scorpion, bringing the total fish fauna for the survey area to 33. None of these additional species are of commercial value, rare or protected.

With the exception of the brown shrimp (*Crangon* sp.), the beam trawl did not record any commercial species in abundance.

4.6.2 Abundance

A total of 7,582 individuals were recorded by the six beam trawl surveys; invertebrates comprised the majority of this total, with fish contributing around 12%.

In terms of abundance, echinoderms formed by far the most important group (ca. 67% of all individuals). The ophiuroid (brittlestar) *Ophiura ophiura* was the most important of these, comprising over a third of all individuals recorded and up to 72% of all individuals recorded in individual surveys. The next most abundant species (also an echinoderm) was the common seastar *Asterias rubens* (25% of all individuals).

While only comprising around 12% of total individuals recorded, Crangonid (brown) shrimps, the next most important group in terms of abundance, were important: they comprised nearly half of all organisms in the first (Oct 04) survey, and were significant components in other surveys (Dec 04, Mar 05 and Dec 06).

4.6.2.1 Total abundance

Overall abundance for beam trawls did not produce clear patterns of seasonal changes, as observed for otter trawl data; total individuals recorded per survey are presented in Figure 4.4. While both October surveys show a similar total, December and March surveys appear to be much more variable. The exceptionally high abundance recorded in December 2004 was due to high numbers of two species that comprised nearly 75% of all organisms in that survey: the brittlestar *Ophiura ophiura* and the starfish *Asterias rubens*. While numbers of the latter were relatively evenly spread over all trawl sites, the vast majority of *O. ophiura* (1,264 organisms, greater than the total of all organisms in most other surveys) in December 2004 were recorded at just two sites, BT1 and BT6.

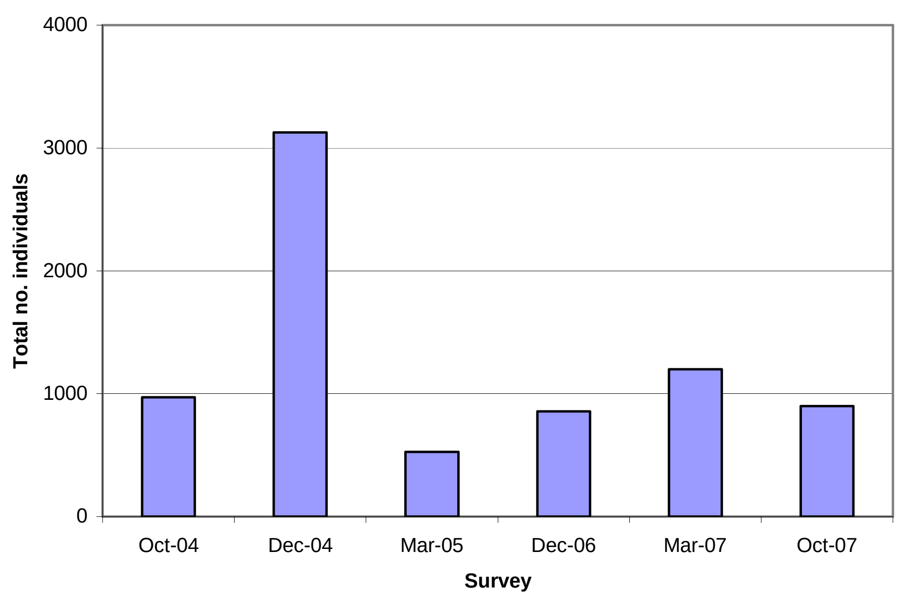

Figure 4.4: Seasonal variation in total abundance of individuals recorded in beam trawl surveys

4.6.2.2 Species abundance

Although echinoderms dominated total abundance, they showed strong variation both temporally and spatially. The overall most important species (*Ophiura ophiura*), for example, was unimportant in the Oct 04 and Mar 05 surveys (1.2% and 2.7% of total abundance respectively), but comprised nearly 75% of all individuals in the March 07 survey. This species showed very strong site affinity, with the vast majority of its recorded abundance coming from control stations B1 and B6. However, it was recorded in large numbers at these stations in both pre- (December 2004) and post-construction (March and October 2007) surveys, indicating that construction and/or presence of the windfarm did not have an effect. In other surveys (both pre- and post-construction) this species was much less abundant, suggesting either occasional peaks of abundance or a highly localised brittlestar bed habitat which may have not been sampled on all occasions.

In 1998 Ellis *et al.* (2000) sampled demersal communities in the eastern Irish Sea with a 4 m beam trawl, including a station (no. 198) in the general vicinity of BOW. From this survey, four main community types were defined, and station 198 was characterised as belonging to the "*Alcyonium*" assemblage. Significant components of this community type comprised dead-mans fingers *Alcyonium digitatum*, the common seastar *Asterias rubens*, dab *Limanda limanda*, plumose anemone *Metridium senile*, velvet swimming crab *Necora puber* and the sea urchin *Psammechinus miliaris*.

While the stations sampled in the monitoring program reported here showed some similarities to the above "*Alcyonium*" assemblage, it is perhaps more similar to the "*Pleuronectes platessa-Limanda limanda*" assemblage defined by Ellis *et al.* (2000), which was the most commonly occurring type in inshore areas of the eastern Irish Sea. This discrepancy may be explained by slight differences in location of stations (and therefore substrate type) and differing methodology.

5 Conclusions

As expected, the surveys recorded a wide variety of species from a range of taxonomic and ecological groups. Dab, a flatfish of little commercial value, was by far the most abundant fish over the area. Plaice and whiting, the next two most abundant species, were the only species of commercial value occurring in any significant numbers. Numbers of these two species were dominated by fish below the minimum landing size, indicating the importance of the area as a nursery ground. Along with the lesser-spotted dogfish (the most commonly recorded elasmobranch), these four species comprised the "core" of fish species. The fifth most overall abundant species, poor cod (of no commercial value), was only present in significant numbers in a single survey (December pre-construction).

No rare, unusual or protected fish species were recorded.

Notable (and in some cases significant) differences in fish diversity and abundance were apparent in relation the season of sampling, which is likely to reflect the normal migrations of fish associated with feeding, breeding and spawning.

There were no statistically significant examples of abundance being affected by the construction or presence of the Windfarm.

Sex ratio appeared to be associated with the season of sampling. Female dab dominated the area throughout, and female plaice dominated in spring; plaice showed a roughly equal sex ratio in autumn/winter. Neither of these two species appeared to show any effects related to the construction or presence of the Windfarm. However, lesser-spotted dogfish showed strong sexual segregation both spatially and temporally, which has been widely reported for this species. December and October surveys were generally dominated by females and males respectively, with low numbers of both sexes being present in March surveys. This was generally the case for both windfarm and reference stations, both pre and post construction; however the October 2007 results showed dominance of males within the windfarm, while one of the reference stations contained large numbers of females (while there was no clear pattern of segregation at the other reference stations).

Beam trawling recorded a faunal assemblage expected and previously recorded for the area, with no rare, protected or unusual species present. Echinoderms, specifically starfish and brittlestars, dominated the fauna although other groups (e.g. crangonid shrimps) were also important. Abundance of species appeared to be highly seasonally variable, with no clearly visible effects on fauna pre- or post-construction.

In summary, there were no statistically significant examples of abundance being affected by the construction or presence of the wind farm. This is also the case with regard to diversity and abundance of the fish and invertebrates sampled, and the size and maturity of commercial fish species. There are a few species where some differences in sex ratio have been noted for catches within and outside the windfarm since it was constructed. This is particularly the case for dogfish, though this species has been recorded previously living in almost single sex groups. Statistical analyses do not indicate that the presence of the windfarm is responsible for these ratios.

6 References

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