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Report to ELSAM
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Final report

Sandeels in the wind farm area at Horns Reef

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Content:

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1. Summary and conclusions

This report summarises preliminary results from a survey carried out in the Horns Reef area in March 2004 and contrast these results to those from a previous survey carried out in February/March 2002. The surveys were designed to analyse the effect, if any, of the construction of a wind farm on sandeels in the area. The 2002 survey was done prior to construction of the wind turbines and the 2004 survey was done after the construction of the wind turbines.

There are no indications that the construction of the wind farm has had any effect on the sediment composition in the impact area (the wind farm area). Especially there was no indication that the content of the finest particles, the Wentworth sediment classes silt/clay and very fine sand, has increased in the impact area from 2002 to 2004. In this respect the construction of the wind farm is not likely to have had any effect on sandeels in the area of the wind farm.

The effect of the wind farm on sandeels was evaluated on the basis of changes in distribution and densities of all species of sandeels combined, as there is no information available to suggest that the possible effects, if any, on sandeels of the construction of a wind farm is dependent on the species.

At all locations fished during both of the years a markedly increase in density of sandeels (all species combined) was observed in the impact area from 2002 to 2004. This increase coincides with a small decrease in densities in the control area (away from the wind farm/impact area). Average densities of sandeels in the impact area increased about 300% from 2002 to 2004, whereas densities decreased about 20% in the control area. It is therefore concluded that the construction of the wind farm has had no negative impact on sandeels in this area.

A large change was found in the species composition and densities of sandeels from 2002 to 2004. The density of *A. tobianus* and *H. lanceolatus* increased markedly from 2002 to 2004 whereas the density of *A. marinus* decreased markedly. The largest increase in densities of sandeels from 2002 to 2004 is due to a large increase in densities in the impact area in 2004 of sandeels smaller than 8 cm (all 1-group sandeels, although there was some uncertainty in the age determination of *A. tobianus* <6 cm). Of these most of the sandeels smaller than 6 cm were *A. tobianus* and most of those from 6-8 cm were *H. lanceolatus*.

The variation in sandeel abundance, which is observed from 2002 to 2004 in the Horns Reef area, is likely to be due to environmental factors influencing recruitment in sandeels. The decrease in *A. marinus*, observed in the Horns Reef area from 2002 to 2004, may be an example of this as the abundance of *A. marinus* seems to have followed a similar decrease in most of the North Sea in the same time period.

The possible effect of the wind turbines on sandeel predation mortality was not evaluated in this report, due to a lack of information about changes in diet, distribution, and densities of sandeel predators. Although the influence of environmental factors on recruitment is a likely explanation to the increase in sandeel abundance, observed in the wind farm area from 2002 to 2004, changes in predation mortality may also have contributed to the observed changes in densities.

The sampling design used was found to be appropriate for mapping areas where the distribution of seabirds and sandeels overlap.

Overall, there is no indication that the construction of the wind farm area has had a negative effect on sandeels in this area. There was no indication of an increase in the content of silt/clay and very fine sand in the impact area from 2002 to 2004. Further, there was no indication of a decrease in densities of sandeels (all species combined) in the same area from 2002 to 2004.

2. Purpose of the report

To determine the impact of the construction of a wind farm on sandeels in the Horns Reef area, a field programme has been suggested by DIFRES (see Jensen et *al*. 2003).

Two surveys have now been carried out. The first survey was carried out in February/March 2002, prior to the construction of the wind turbines. The results of this survey are presented in Jensen et *al*. (2003). The second survey was carried out in March 2004, after the construction of the wind turbines (see Table 1).

The purpose of this report is to evaluate the results of the post-construction survey, and compare these to the results from the pre-construction survey, to analyse if the construction of the wind farm have had any impact on sandeels in this area.

As described by Jensen et *al*. (2003) the most likely effects of the construction of wind turbines on sandeels are indirect effects, i.e. changes of the sediment composition and changes in densities of sandeel predators. An increase in the content of the finest particles silt/clay and very fine sand (particles with a grain size diameter less than 0.09mm) may occur during the construction phase of the wind farm area, and afterwards in case the wind turbines will have an effect on the hydrography. Such a change in sediment composition will lead to decrease in sandeel densities if the weight fraction of these fine sediments increases above a certain threshold (see section 4.1). The wind turbines may potentially lead both to an increase and to a decrease in predation mortality of sandeels. If densities of sandeel predators in the wind farm area increase, for example because the so called artificially reef effect, predation mortality will be expected to increase. However, in case of a decrease in predation, for example if seabirds avoid the windfarm area, predation mortality will be expected to decrease. Predation mortality has a significant effect on sandeel population dynamics and abundance.

3. Methods

The distribution and relative abundance of sandeels in the wind farm area at Horns Reef was mapped in conjunction with seabed sampling during a survey in March 2004, using the methods described in Jensen et *al*. (2003). All samples at each location were collected on the same day, both during the 2002 and the 2004 surveys. Day-to-day changes in the distribution pattern of sandeels within the areas surveyed were thus not analysed. Furthermore, as all samples were collected in the daytime, differences in densities of sandeels in the sediment between day and night were not investigated. However, as the same sampling procedure was used in both surveys the sampling design is suitable for analysing differences in sandeel densities between years and areas.

The International Advisory Panel of Experts, in an evaluation of the sandeel report from 2003 (Jensen et *al*. 2003) suggested that the sampling design used for mapping sandeel distribution should be modified to “allow for more powerful tests of the impact hypothesis” (see Anon. 2003). A statistical analysis of the data collected in 2002 showed that the ability to detect changes in sandeel densities or differences in densities between the impact and the control area would increase if:

- the number of measurements/stations at each location was reduced from 5 to 4 and
- the number of sample locations in the impact area was reduced and
- the number of sample locations in the control area was increased.

Therefore:

- 3 of the 9 locations sampled in the impact area in 2002 were randomly chosen and removed from the sampling programme for 2004 (locations 15, 29 and 56 were removed)
- 4 new/additional locations in the control area were randomly chosen and added to the sampling programme for 2004 (locations 64, 67, 69 and 71)

Due to an error in the database that holds information on the sample locations, location 45, which was not sampled in 2002, was sampled in 2004. In addition, one haul was carried out with the modified dredge at location 29. The consequences of changing the sampling design to test the hypotheses, of an impact of the wind farm area on sandeels, will be presented in the final report.

Anon. (2003) also stated that "more detailed information on the spatial distribution of sandeel in the Horns Reef area could be used in the attempt to explain the distribution of e.g. common scoter (*Oidemia nigra*) in the area". Consequently collaboration was established between DIFRES and The National Environmental Research Institute, Denmark (Ib Krag Petersen), to define areas of potential importance to both seabirds and sandeels. In total 22 additional locations on 4 transects outside both the impact and the control areas were defined for this purpose (location 73-76 and 78-95). These locations were situated close to and in areas where common scoter had been observed prior to the 2004 survey. Furthermore, the 4 transects were placed crossing gradients in depth and seabed types (and therefore likely sandeel habitats) to maximise the ability to detect patches of sandeel habitat.

Due to very windy weather in 4 of the 5 days of the survey a considerable amount of time was used for manoeuvring the vessel between the wind turbines. The weather generally made both sandeel and sediment sampling difficult and time-consuming, and there were times when sampling was impossible. Consequently, sandeel sampling was not carried out at locations 67 and 71, and only 3 sediment samples were collected at locations 68 and 70 in the control area. Furthermore, of the 22 additional locations in the sandeel/seabird areas, only sandeel sampling was carried out and only at locations 78-80.

The number of samples collected at each of the sampling locations appears in Table 2. Figure 1 and 2 display maps of the sample locations.

The samples of sandeels and sediment was worked up using the methods described in Jensen et *al*. (2003).

4. Results

4.1. The sediment composition

The weight fraction of silt/clay and very fine sand (see Table 3 in Jensen et *al*. 2003 for the definition of the Wentworth grade classes) in the sediment samples in both 2002 and 2004 are shown in Figure 3 for the control area and in Figure 4 for the impact area. In the following the combination of the two Wentworth grade classes silt/clay and very fine sand is denoted "silt/clay and very fine sand" and the sum of the weight fractions of silt/clay and very fine sand is denoted "the weight fraction of silt/clay and very fine sand".

In Figure 5 the average weight fractions of silt/clay and very fine sand in the sediment at the 2004 sample locations are plotted against the equivalent values from 2002, for the locations for which comparable samples exist. The average weight fractions of silt/clay and very fine sand at each sample location and for each year/survey are shown in Figure 6.

At all locations the average weight fraction of silt/clay and very fine sand recorded was below 2%. This lies below the 6% threshold above which sandeels would avoid the sediment (see Jensen et *al*. 2003). The highest content of silt/clay and very fine sand was measured in 2004 at locations 68 and 70 in the control area (Figure 3) and in 2002 at locations 15 and 29 in the impact area (Figure 4). The content of silt/clay and very fine sand in the control area was generally higher in 2004 than in 2002, while in the impact area the content was lower in 2004 than in 2002. Furthermore, in 2004 the content of silt/clay and very fine sand was generally higher in the control than in the impact area (Figure 5 and 6). However, the above described differences in the content of silt/clay and very fine sand, between areas (impact and control) and years (2002 and 2004), are below the threshold where this would be expected to have a significant impact on the distribution pattern of sandeels.

Although only small differences in sediment composition was found a statistical analysis was carried out to test if the content of silt/clay and very fine sand differed between areas (control and impact) and time of sampling (2002 and 2004). The weight fraction of silt/clay and very fine sand was assumed to be normal distributed. First an analysis of variance (ANOVA) was carried out to test the null hypothesis (H_0) that the weight fraction of silt/clay and very fine sand did not differ between sampling locations within an area and year (model 1 in Table 3). Bartlett's test was used to test the assumption about variance homogeneity between sampling location for each year and area. The GLM procedure in the statistical software package SAS^{TM} was used to carry out the analyses. A remarkable high content of silt/clay and very fine sand was measured at location 68 in one of the sediment samples in the Control area in 2004 (see the text above). This is assumed to be a sampling error, as the weight fraction of silt/clay and very fine sand is about 100% higher than for the rest of the samples collected during the cruises in both areas. The sample probably only represents the upper most layer of the sediment and should therefore have been discarded. This sample was omitted from the statistical analyses. Further, the variance of the weight fraction of silt/clay and very fine sand was higher for the samples collected at location 70 in the control area in 2004 and for the samples collected at location 15 and 29 in the Impact area in 2002 than for the samples collected at the other locations. Excluding these samples from the statistical analyses ensured variance homogeneity between locations (Table 4). The results of this first statistical analysis (model 1, see Table 3) are listed in Table 4. There was no difference in the content of silt/clay and very fine sand between the sampling locations for each of the areas and years, except for the impact area in 2002 in which the there was a smaller content of silt/clay and very fine sand at location 56 than at the other locations in this area in this year.

As there were only minor differences in the weight fraction of silt/clay and very fine sand between the sample locations within each of the two areas (impact and control) in both 2002 and 2004, the effect of sampling location was omitted when testing differences in sediment composition between years and areas. However, the data material was too small (there was too few observations) to test the effect of year, area, and the combined effect of year and area in the same statistical model. Therefore this analysis was carried out as two separate analyses, one analysis testing the effect of year for each of the two areas (model 2 in Table 3) and one analysis testing the combined effect of year and area (model 3 in Table 3). The results of these analyses are given in Table 5 to 7. The content of silt/clay and very fine sand was higher in 2004 than in 2002 in the control area but did not differ between 2002 and 2004 in the impact area. Further, the content of silt/clay and very fine sand was higher in the control area than in the impact area.

The final conclusion is that there are no indications that the construction of the wind farm has had any effect on the sediment composition in the impact area. Especially there was no indication that the content of the finest particles silt/clay and very fine sand increased in the impact area from 2002 to 2004. In this respect the construction of the wind farm is not likely to have had any effect on sandeels in the area of the wind farm.

4.2. Sandeels

The total number of sandeels caught during the surveys in 2002 and 2004 are given in Table 8. The number of dredge stations was 60 in 2002 and 61 in 2004. Table 8 thus indicates higher overall densities of sandeels in 2004 compared to 2002. The species composition in the catches changed from 2002 to 2004. The number of *A. tobianus* and *H. lanceolatus* increased markedly from 2002 to 2004 whereas the number of *A. marinus* decreased markedly. Mean densities of sandeels by species, location, area and year are given in Table 9. The table confirms the overall change in densities and species composition from 2002 to 2004.

Of the three species of sandeels recorded during the surveys in 2002 and 2004 sediment preference have only been analysed in more detail for *A. marinus* (Jensen 2001, Wright et al. 2000). However, similar studies of other species of sandeels (Pearson et *al.*, 1984 Pinto et *al.* 1984) indicate that there are only small, if any, differences in sediment preference between different species of sandeels. A range of studies have also shown that, although there are general differences in the distribution pattern of these species, there are areas where these species coexist (Macer 1966, Jensen et *al*. 2003, and this report). Changes in sediment composition are therefore likely to have the same impact on the 3 species of sandeels caught during the two surveys. Further, there is no information available to substantiate that changes in predator distribution and abundance would effect the three species of sandeels differently (e.g. because of species dependent differences in burying behaviour), as there is no information available that indicate that the three species of sandeels are not equally preferred by their predators. There is thus no information available that suggest that the effect, if any, on sandeels of the construction of a wind farm (i.e. the effect of changes in sediment composition and on predator distribution and abundance) is species specific. An exception from this could be if the construction of a wind farm had a positive influence on sandeels, by for example decreasing predator abundance and thereby predation mortality on sandeels. This could lead to high densities of sandeels and competition for food and suitable sediment, a situation where even small differences in habitat requirement and foraging behaviour could favour one species over another. However, the relative small densities of sandeels measured in both the reference and the impact area during both surveys, compared to much higher densities measured during other surveys in other areas of the North Sea (see e.g. Jensen et *al*. 2001), indicate that competition between the three species of sandeels for food or sediment is not an important factor determining neither distribution nor abundance in the reference or impact area. For example, the decrease in density of *A. marinus* in both the impact and the control areas from 2002 to 2004 follows a general decrease that has been observed for the whole North Sea (ICES 2004, STECF 2004a and b), and is thus not likely to be due to competition between the three species of sandeels. To evaluate the effect of the wind farm on sandeels only the densities of all species of sandeels combined is therefore considered.

The main result from Table 9 is the increase in total density of sandeels from 2002 to 2004 in the impact area. At all locations fished during both of the years a markedly increase in density of sandeels (all species combined) are observed from 2002 to 2004. This increase coincides with a small decrease in densities in the control area. Average densities of sandeels in the impact area increased about 300% from 2002 to 2004, whereas it decreased about 20% in the control area (Table 9 and Figure 7). No statistical analysis can therefore substantiate that the densities of sandeels in the impact area have decreased from 2002 to 2004. It is therefore concluded that the construction of the wind farm have had no negative impact on sandeels in this area.

The spatial distribution pattern of sandeels is shown in Figure 7 (all species combined) and in Figure 8 to 11 (by species). The Length compositions of sandeels are shown in Figure 12 (all species combined) and Figure 13 (by species). The largest increase in densities of sandeels from 2002 to 2004 is due to a large increase in densities in the impact area of sandeels smaller than 8 cm (Figure 12). Of these most of the sandeels smaller than 6 cm were *A. tobianus* and most of those from 6-8 cm were *H. lanceolatus*. These small sandeels were all 1-group sandeels, although the age determination of the smallest sandeels (<6 cm) was associated with some uncertainty. Contrary to in 2002, where *A. tobianus* smaller than 6 cm were classified as 0-group sandeels, those in 2004 were, with some uncertainty, classified as 1-group sandeels. These results indicate the timing could have an influence on the densities of *A. tobianus* and *H. Lanceolatus* measured, because previous studies in other areas of the North Sea have shown large variations in both timing of hatching and settlement of sandeels between years (Jensen 2001, Wright and Bailey 1996). An analysis of differences in timing of hatching and/or settlement between 2002 and 2004 was however outside the scope of this report. There are however indications that the increase in densities of sandeels from 2002 to 2004 is not driven by timing of sampling. First of all there was only little difference in the timing of the surveys between the two years (Table 1), and the small length classes of both *A. tobianus* and *H. lanceolatus* was caught during the surveys in both years (Figure 12 and 13). Further, the time of sampling and the time of spawning of the three species (see e.g. Macer 1965 and 1966) makes it unlikely that large densities of 0-group sandeels of the size classes caught during the cruises would occur during this time of the year.

Because sandeels are short lived fish species their population dynamics is strongly influenced by recruitment, i.e. number of 0-group sandeels that recruit to the adult population. Variation in recruitment in sandeels is highly variable and seems to be strongly influenced by environmental factors (Arnott and Ruxton 2002, Jensen 2001, Wright and Bailey1996). The variation in sandeel abundance that is observed from 2002 to 2004 may therefore be due to environmental factors affecting recruitment. The decrease in *A. marinus* from 2002 to 2004 may be an example of this (see the text above) as a similar decrease in abundance, as that observed in the Horns Reef area, seems to have taken place in most of the North Sea.

The possible effect of the wind turbines on sandeel predation was not evaluated in this report, due to a lack of information about changes in diet, distribution, and densities of sandeel predators. Although the influence of environmental factors on recruitment is a likely explanation to the increase in sandeel abundance, observed in the wind farm area from 2002 to 2004, changes in predation mortality may also have contributed to the observed changes in densities.

The effect of the fishery on sandeels in the wind farm area is not considered in this report. However, as sandeel fishery does not seem to have occurred in the wind farm area before the construction of the wind turbines (see Jensen et al. 2003), any effect of the fishery on sandeels in this area will be indirect, through exploitation of sandeels in areas nearby the windfarm where higher densities of sandeels seem to occur (see Jensen et al. 2003). In 2003 and 2004 the sandeel fishery at grounds close to the Danish east coast seem to have been larger than in previous years (DIFRES unpublished information). The information available are however not sufficient to allow for an analysis of the effect of this change in the fishing pattern on sandeels densities in the wind farm area.

Only 3 of the 22 new locations in important seabird areas were sampled during the survey in 2004 (Table 2, Figure 1). However, the sampling design used seems appropriate for mapping areas where the distribution of seabirds and sandeels overlap. No sandeels were found in the seabed at location 78 (located at relative larger depths, see Figure 1) whereas increasing densities were found at locations 79 and 80, as the water depth decreased (Figure 7). These preliminary results indicate that the sampling programme is suitable for identifying areas where the distribution of sandeels and seabirds overlap (for further explanation of the relationship between sediment, depth and sandeel distribution see e.g. Jensen et *al.* 2003).

Overall, there is no indication that the construction of the wind farm area has had a negative effect on sandeels in this area. There was no indication of an increase in the content of silt/clay and very fine sand in the impact area from 2002 to 2004. Further, there was no indication of a decrease in densities of sandeels (all species combined) in the same area from 2002 to 2004.

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Table 1.

Overview of surveys and survey operations carried out during cruises.

Year	Date	Vessel	Sediment sampling	Sandeel sampling
2002	21/2	Havfisken	X	X
2002	28/2-1/3	Havfisken		X
2002	24/3-25/3	Cardium	X	
2004	10/3-14/3	m/s Christoffer	X	X

Table 2.

Number of measurements carried out by year, location and gear type.

		2002		2004	
		Dredge	Van Veen	Dredge	Van Veen
Area	Location				
Control	64			4	4
	66	5	5	4	4
	67				4
	68	5	5	4	3
	69			4	4
	70	5	5	4	3
	71				4
Impact	4	5	5	4	4
	14	5	5	4	4
	15	5	5		
	19	5	5	4	4
	29	5	8	1	
	33	5	5	4	4
	38	5	8	4	4
	45			4	4
	56	5	8		
	57	5		4	4
New transect	78			4	
	79			4	
	80			4	
Sum		60	64	61	54

Table 3.

Statistical models tested, using the GLM procedure in the statistical package SAS^{TM}.

Model no.	Effects	Model
1	location	$S=c+b_l$
2	year	$S=c+d_y$
3	year*area	$S=c+e_{ya}$

Where S is the weight fraction of silt/clay+very fine sand in the sediment samples, *l*=location, *y*=year, *a*=area (Impact or Control), and *c* is a constants.

Table 4.

Results of statistical analyses of variance homogeneity and by the effect of location (model 1 in Table 3) on the content of silt/clay and very fine sand in the sediment samples.

Year	Area	Bartlett's test P>ChiSq	ANOVA				
			N	Type III SS	F	P<	R-square
2002	Control	0.084	15	0.12	1.69	0.226	0.22
2002	Impact	0.426	36	0.43	2.70	0.040	0.31
2004	Control	0.620	23	0.37	2.48	0.073	0.42
2004	Impact	0.188	28	0.30	0.90	0.510	0.21

Table 5.

Results of statistical analyses of the effect of year (model 2 in Table 3) on the content of silt/clay and very fine sand in the sediment samples.

Area	ANOVA				
	N	Type III SS	F	P<	R-square
Control	38	0.92	23.46	0.001	0.39
Impact	64	0.01	0.25	0.617	0.00

Table 6.

Results of statistical analyses of the effect of year*area (model 3 in Table 3) on the content of silt/clay and very fine sand in the sediment samples.

ANOVA				
N	Type III SS	F	P<	R-square
102	3.64	28.05	0.001	0.46

Table 7.

Mean weight fraction of silt/clay and very fine sand in sediment samples in by year and area.

Year	Area	Mean	Std dev
2002	Control	1.029	0.198
2004	Control	1.348	0.199
2002	Impact	0.897	0.199
2004	Impact	0.870	0.231

Table 8.

Number of sandeels caught during the surveys, by species and year.

Year	*A. marinus*	*A. tobianus*	*H. lanceolatus*	*G. semisquamatus*	Unidentified sandeels	Total
2002	149	69	306	0	16	540
2004	24	363	589	0	1	977
Total	173	432	895	0	17	1517

Table 9.

Mean densities of sandeels (sandeels$\cdot m^{-2}\cdot$1000) by species, year, area and sample location.

2002

	Area														
	Control				Impact										
	Location				Location										
	66	68	70	Mean	4	14	15	19	29	33	38	56	57	Mean	Mean
Species															
A. marinus	2.5	3.5	3.9	3.3	1.2	1.9	5.1	1.0	4.2	1.6	3.6	2.4	1.1	2.5	0.5
A. tobianus	0.8	3.0	0.9	1.6	0.8	1.5	1.0	1.2	0.5	1.9	0.0	1.8	1.4	1.1	0.3
G. semisquamatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H. lanceolatus	2.7	7.4	5.3	5.1	5.8	2.1	11.3	2.1	5.0	5.6	8.5	6.7	3.6	5.6	0.9
Sandeel ssp.	0.0	0.5	0.0	0.2	0.0	0.2	0.2	0.7	1.1	0.0	0.2	0.0	0.9	0.4	0.3
Sum	6.1	14.4	10.2	10.2	7.8	5.7	17.6	5.0	10.8	9.1	12.4	10.8	6.9	9.6	9.7

2004

	Area																			
	Control						Impact										New				
	Location						Location										Location				
	64	66	68	69	70	Mean	4	14	19	29	33	38	45	57	Mean	78	79	80	Mean	Mean
Species																				
A. marinus	0.7	1.0	0.0	0.0	0.0	0.3	0.7	0.7	0.3	0.0	0.0	0.7	1.6	1.0	0.6	0.0	0.3	1.0	0.4	0.5
A. tobianus	1.0	0.3	1.2	0.3	1.3	0.9	7.8	4.0	3.4	10.8	7.2	6.1	11.4	37.9	11.1	0.0	3.0	32.4	11.8	8.0
G. semisquamatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H. lanceolatus	10.5	10.8	7.3	2.7	4.0	7.1	32.4	9.8	13.9	18.9	10.5	13.8	22.7	26.4	18.6	1.3	3.7	17.5	7.5	12.9
Sandeel ssp.	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	12.1	12.1	8.8	3.0	5.4	8.3	40.8	14.5	17.6	29.7	17.7	20.6	35.7	65.2	30.2	1.3	7.1	51.0	19.8	21.4

Figure 1.
Map of wind turbines and locations included in the 2004 survey plan (see Table 2). Location numbers are shown for the new locations (see the text) and the 3 new locations sampled (location 78-80) are indicated (square symbols). The distribution of substrate sediment was supplied by GEUS (see Kuijpers 1993). The blue contours are water depths.

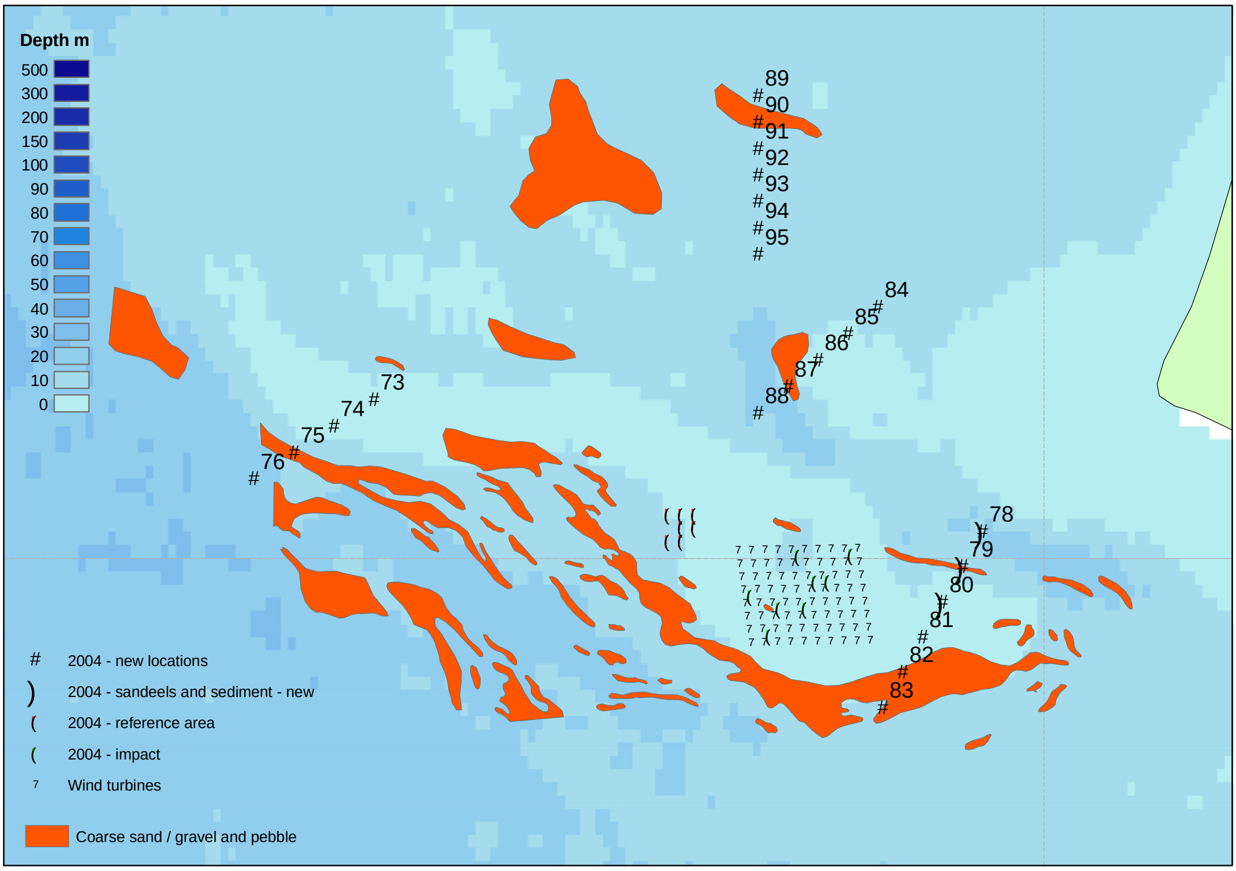
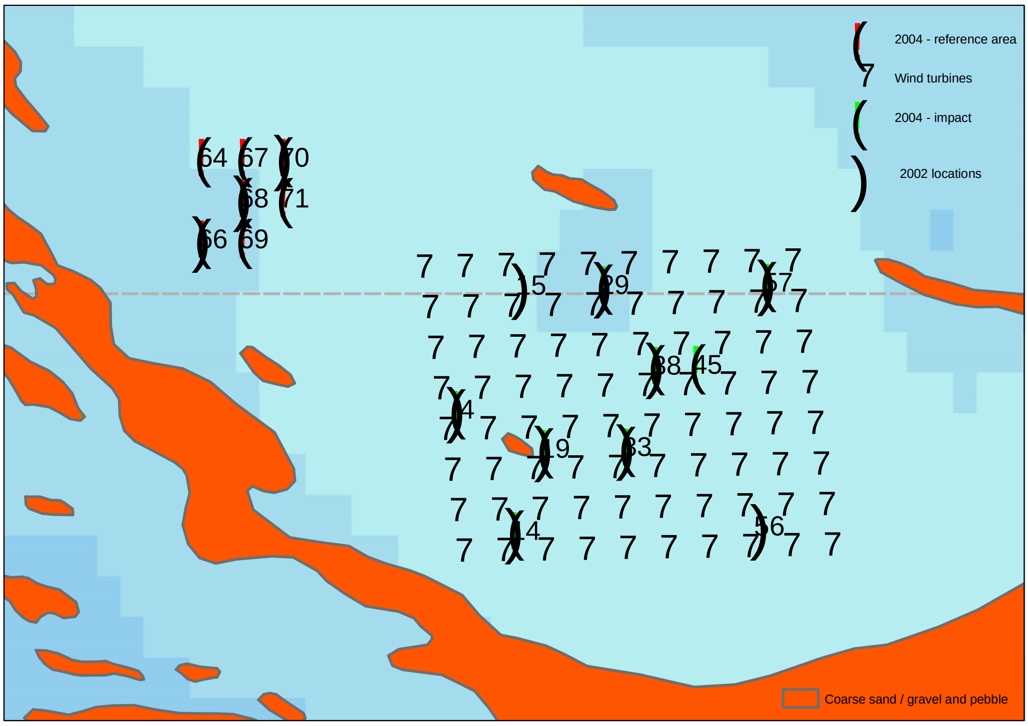


Figure 2.

a) Map of wind turbines and locations planned to be sampled in the 2004 survey (see Table 2). Location numbers are indicated. The locations sampled in the 2002 surveys are also displayed.



b) Map of locations sampled in the 2004 survey. Location numbers are indicated. The locations sampled in the 2002 surveys are also displayed.

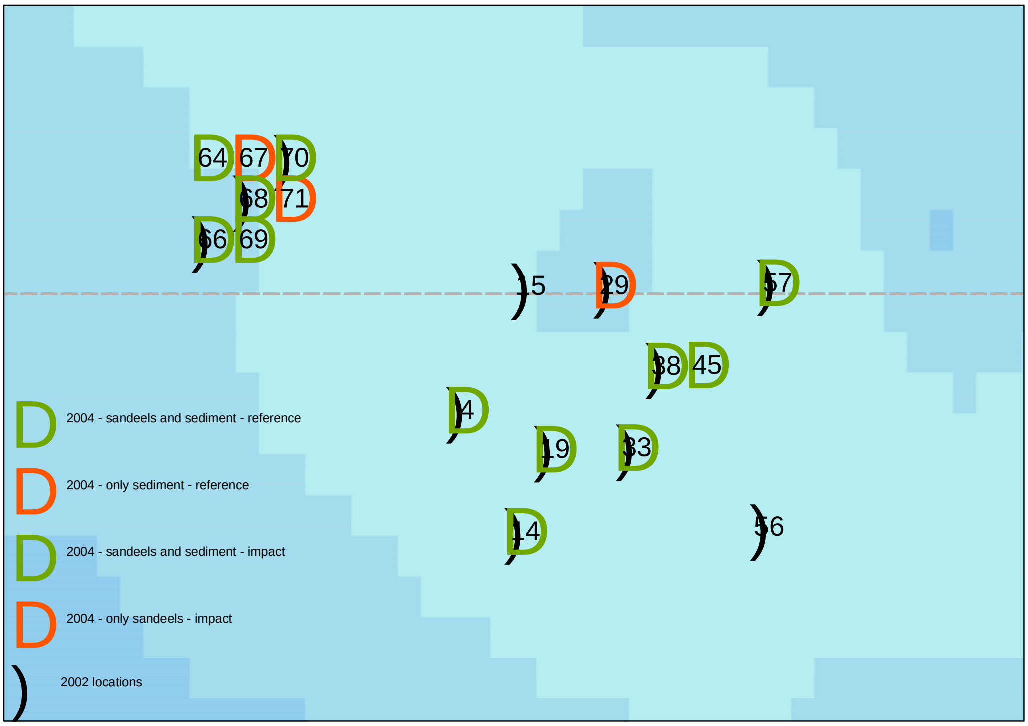


Figure 3.
Proportion of the Wentworth grade classes silt/clay and very fine sand in sediment samples collected in the control area, by station, location and year/cruise, based on sieve analyses.

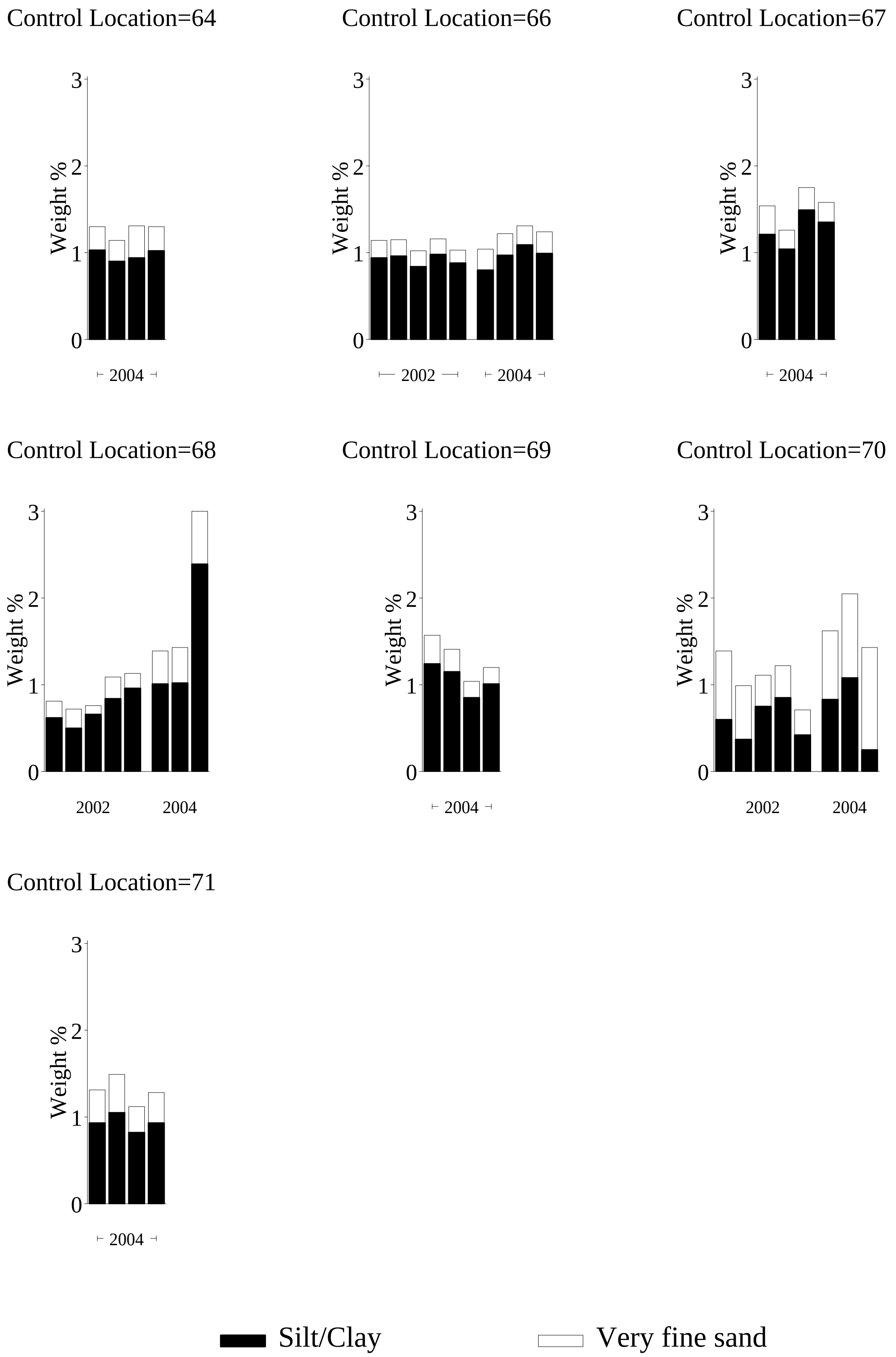


Figure 4.
Proportion of the Wentworth grade classes silt/clay and very fine sand in sediment samples collected in the impact area, by station, location and year/cruise, based on sieve analyses.

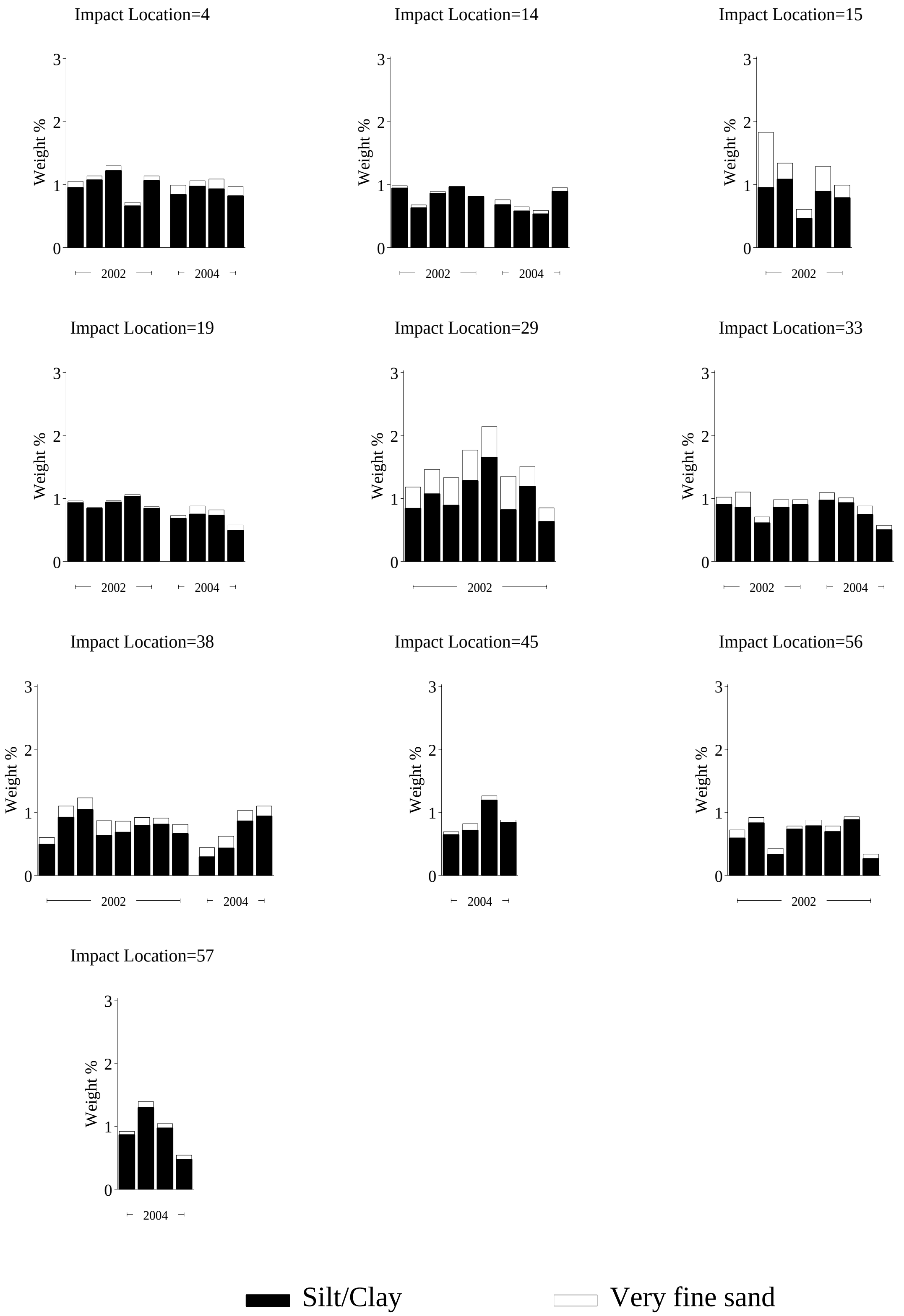


Figure 5.
Mean proportion of the Wentworth grade classes silt/clay and very fine sand in sediment samples collected in 2002 plotted against samples collected in 2004 by location, based on sieve analyses.

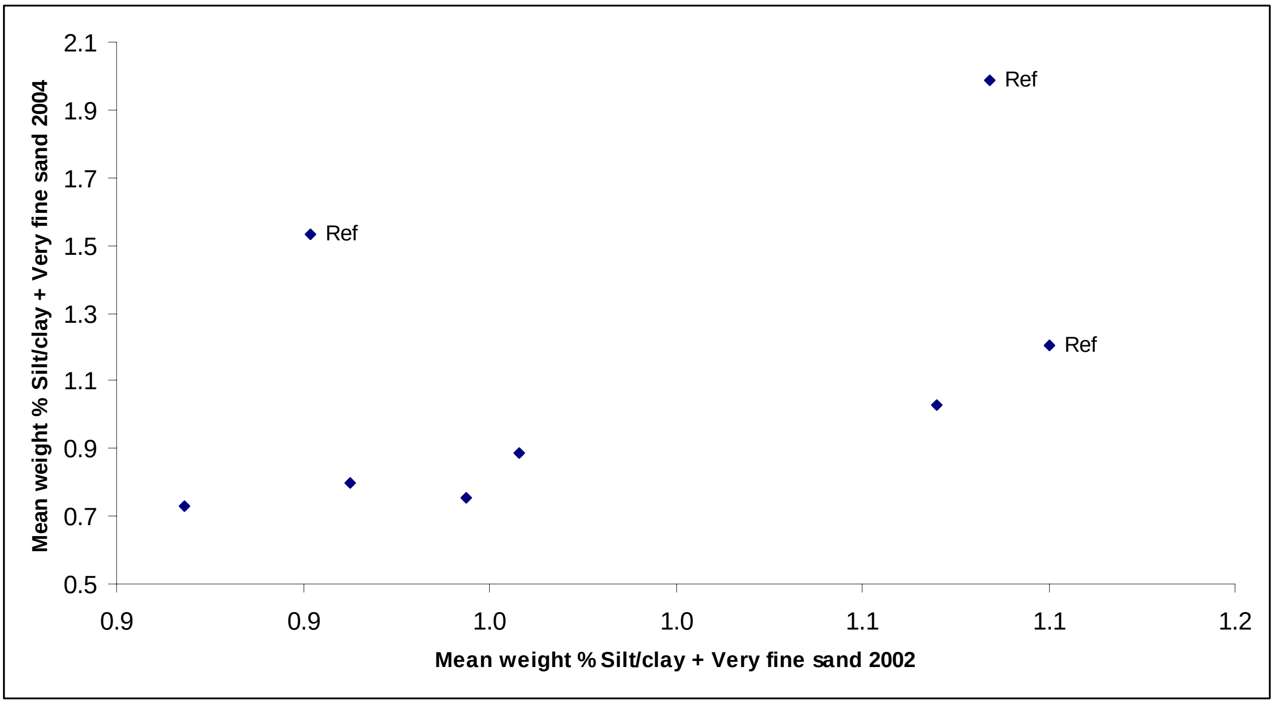


Figure 6.
The weight fraction in the sediment samples of silt/clay and very fine sand at each of the sample locations are shown as circles. Black circles are 2002 and red circles are 2004. Surface sediments in the windmill farm area are also indicated.

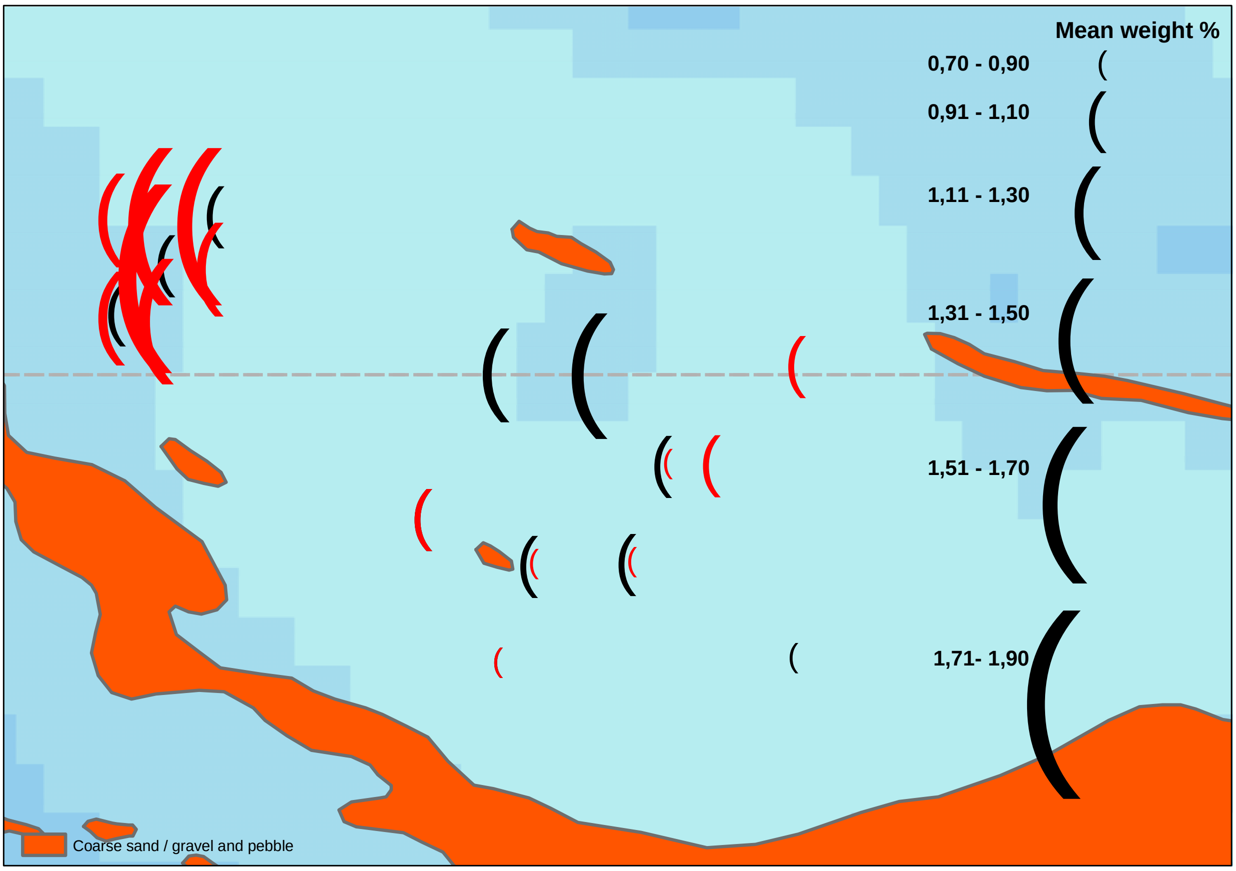
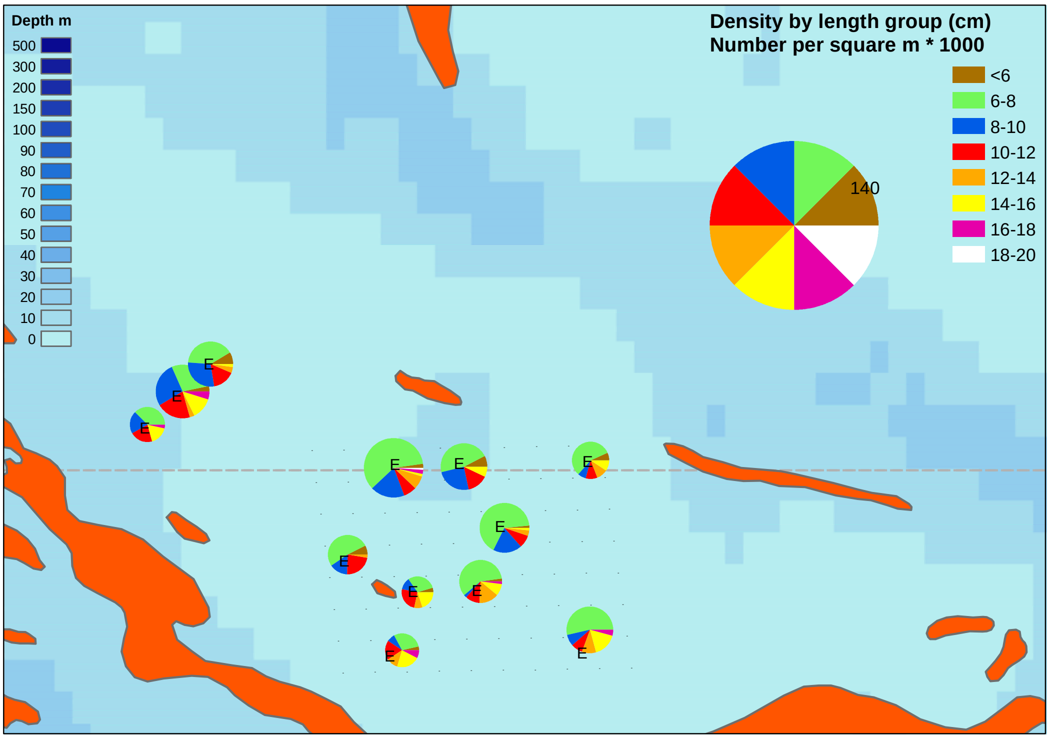


Figure 7.
Average number Sandeel ssp (all species combined) $m^{-2}\cdot 1000$ in dredge hauls by year and survey location. Crosses indicate midpoint of sample locations. Small open circles indicate locations of wind turbines. Orange shading are areas with coarse sand/gravel. The map of surface sediments was made available by GEUS (see Kuijpers 1993).

2002



2004

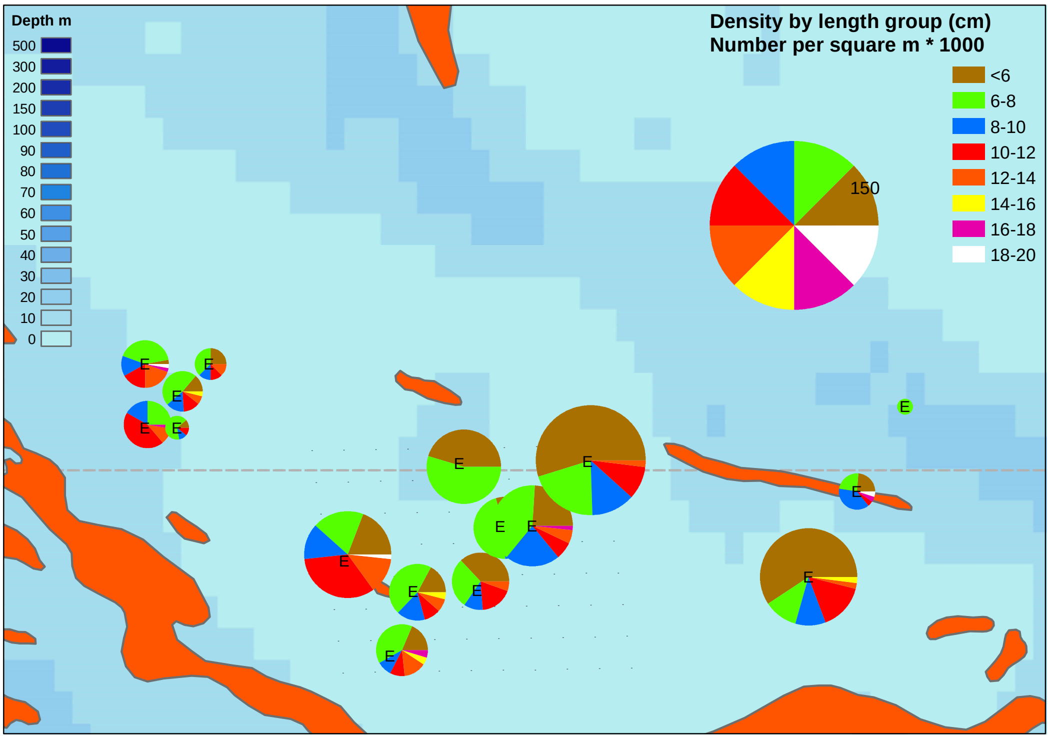
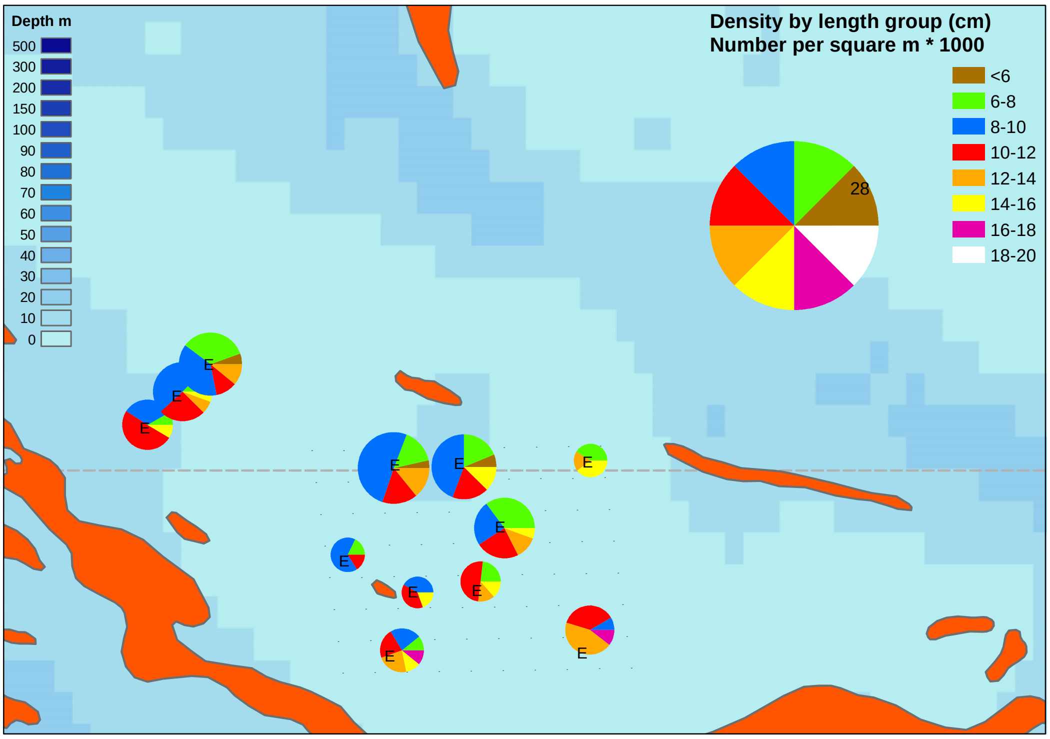


Figure 8.
Average number *of A. marinus* $m^{-2} \cdot 1000$ in dredge hauls by year and survey location. Crosses indicate midpoint of sample locations. Small open circles indicate locations of wind turbines. Orange shading are areas with coarse sand/gravel.

2002



2004

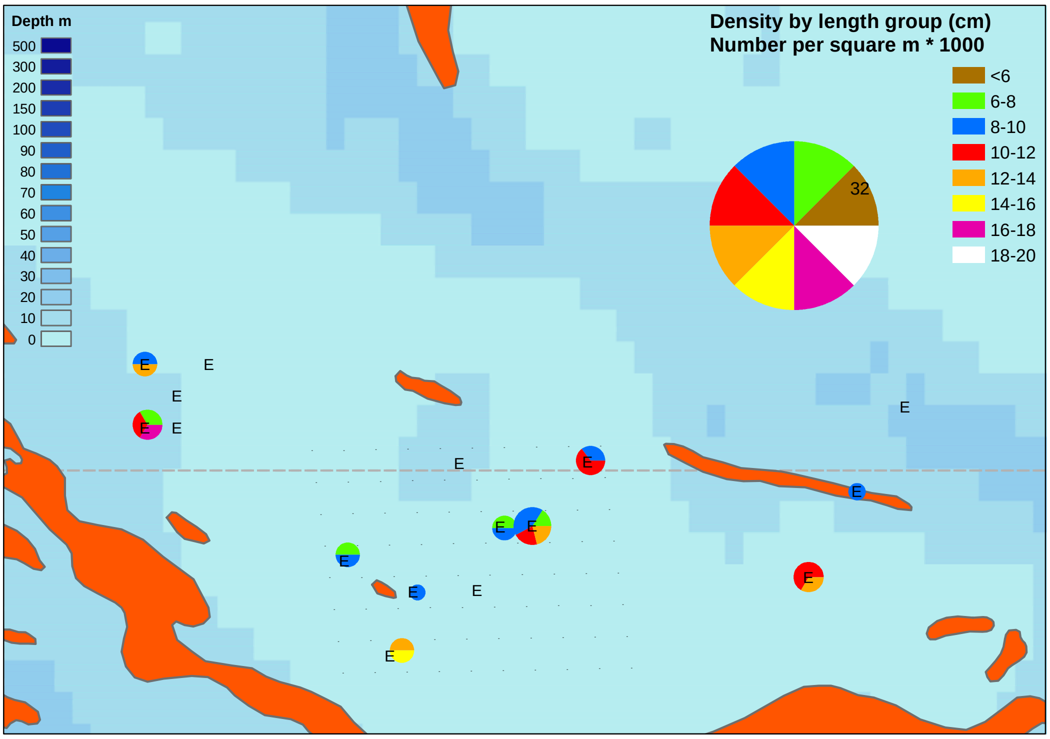
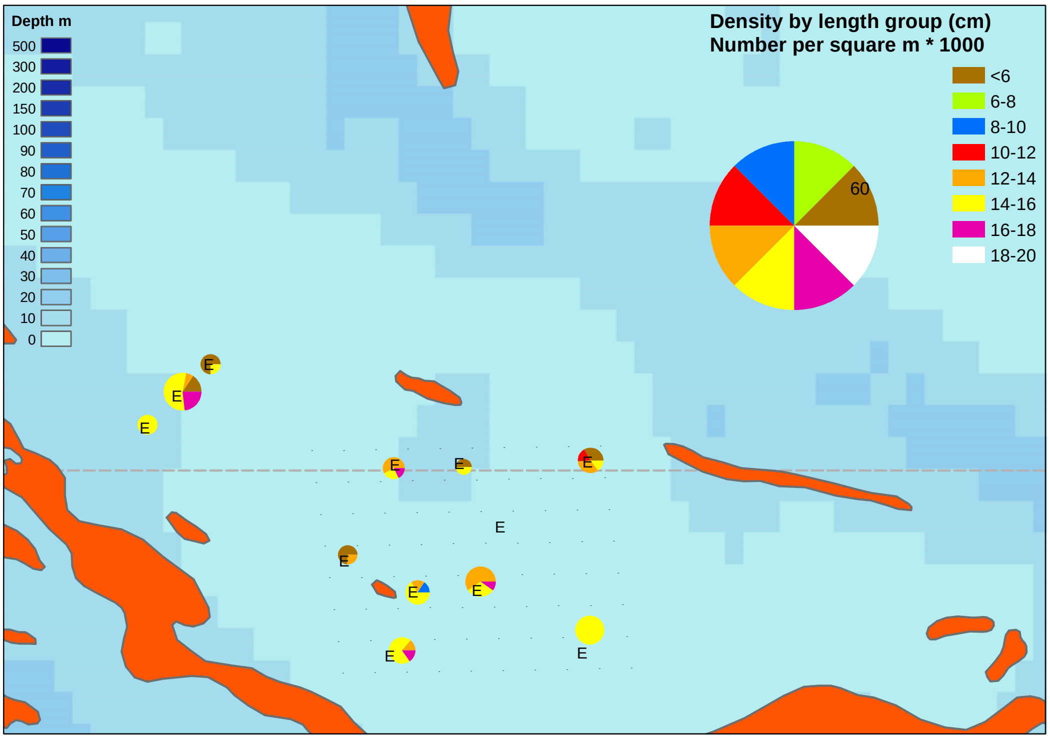


Figure 9.
Average number *of A. tobianus* m^{-2}·1000 in dredge hauls by year and survey location. Crosses indicate midpoint of sample location. Small open circles indicate locations of wind turbines. Orange shading are areas with coarse sand/gravel.

2002



2004

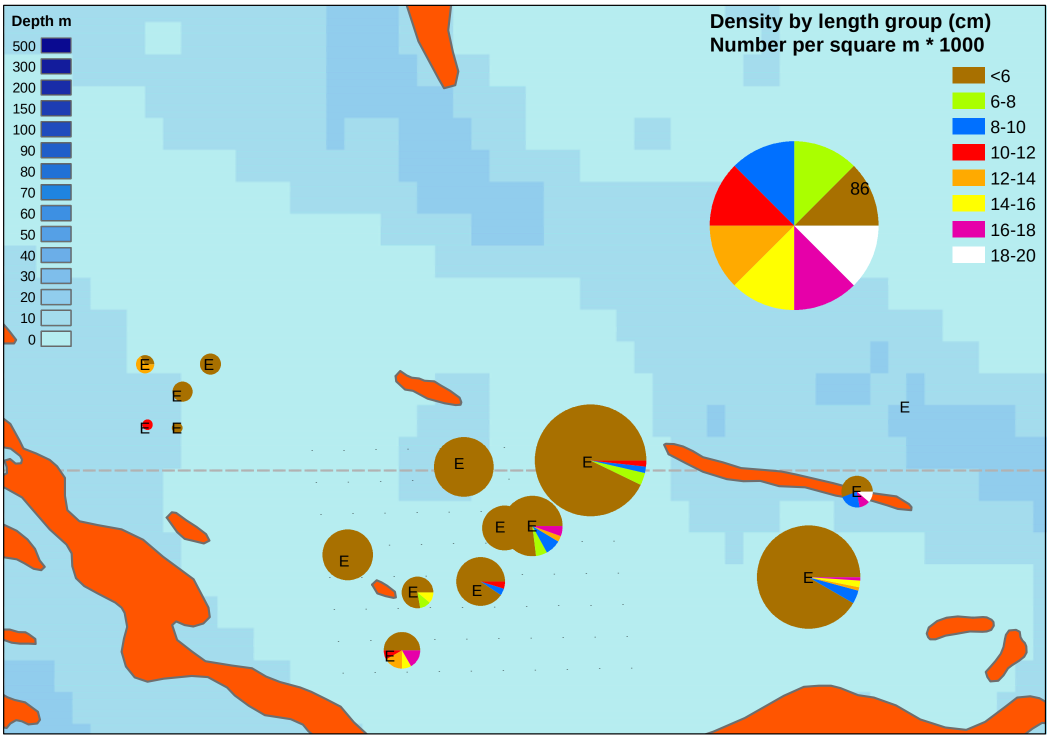
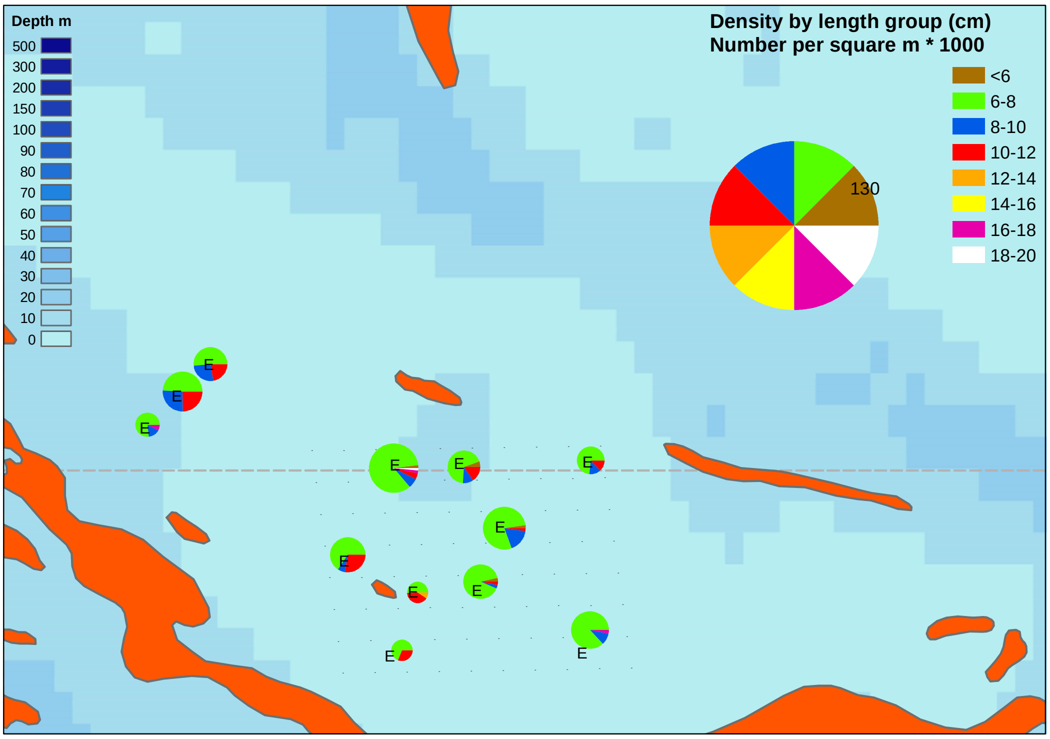


Figure 10.
Average number *of H. lanceolatus* m^{-2}·1000 in dredge hauls by year and survey location. Crosses indicate midpoint of sample location. Small open circles indicate locations of wind turbines. Orange shading are areas with coarse sand/gravel.

2002



2004

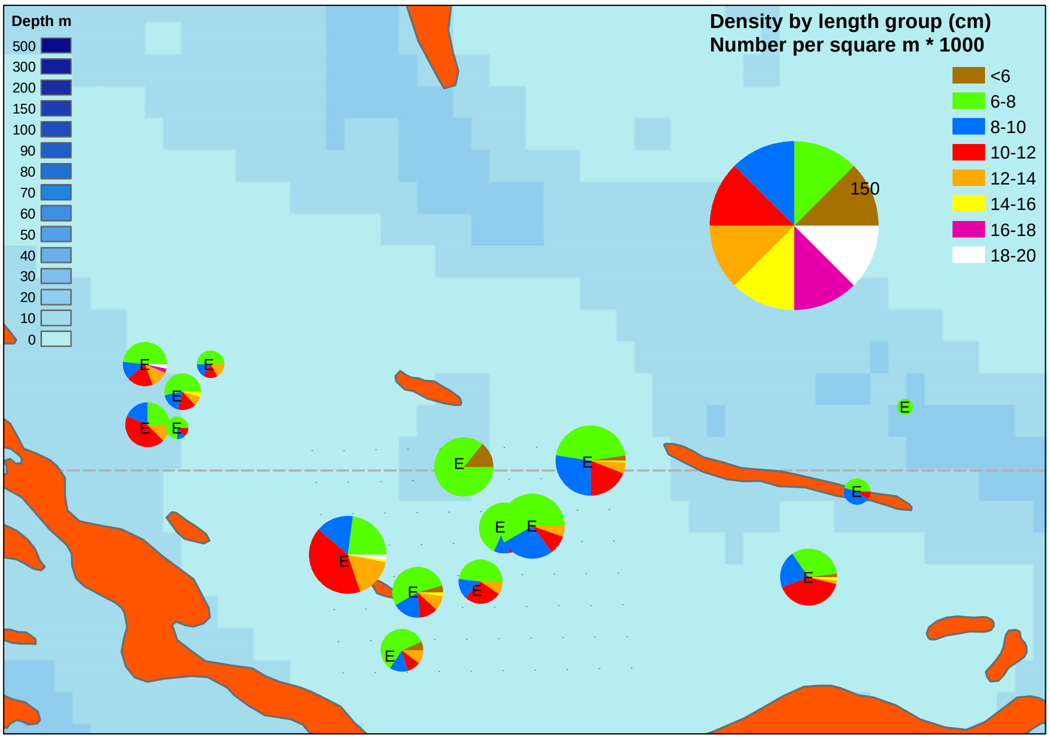
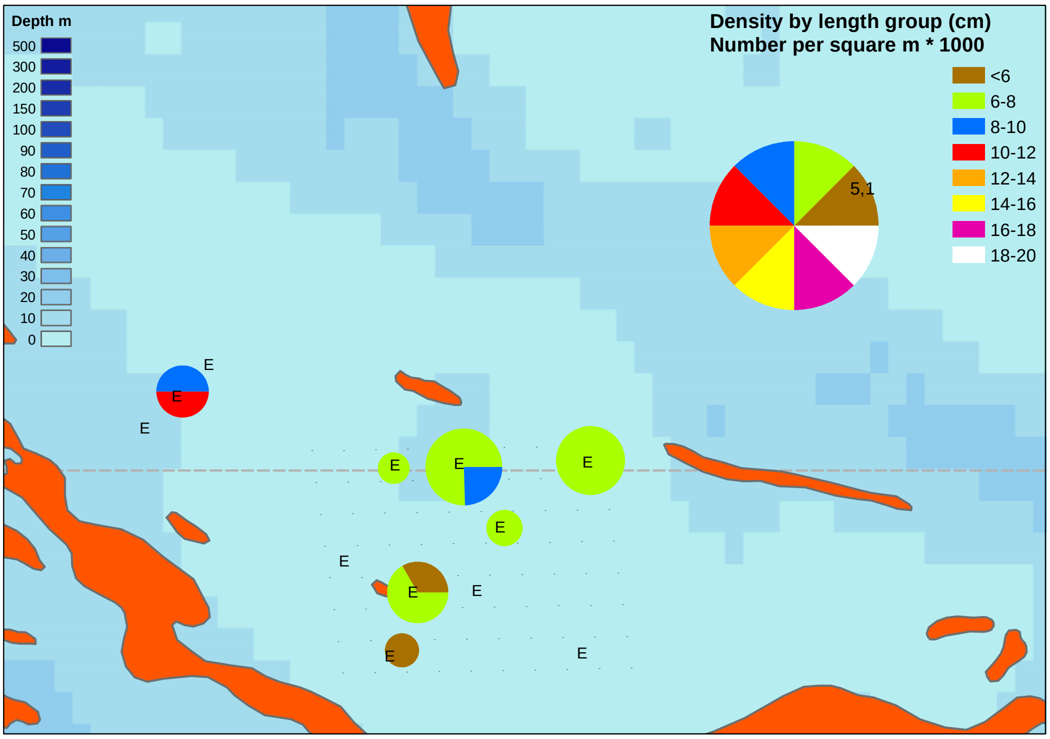


Figure 11.
Average number of unidentified sandeels m^{-2}·1000 in dredge hauls by year and survey location. Crosses indicate midpoint of sample location. Small open circles indicate locations of wind turbines. Orange shading are areas with coarse sand/gravel.

2002



2004

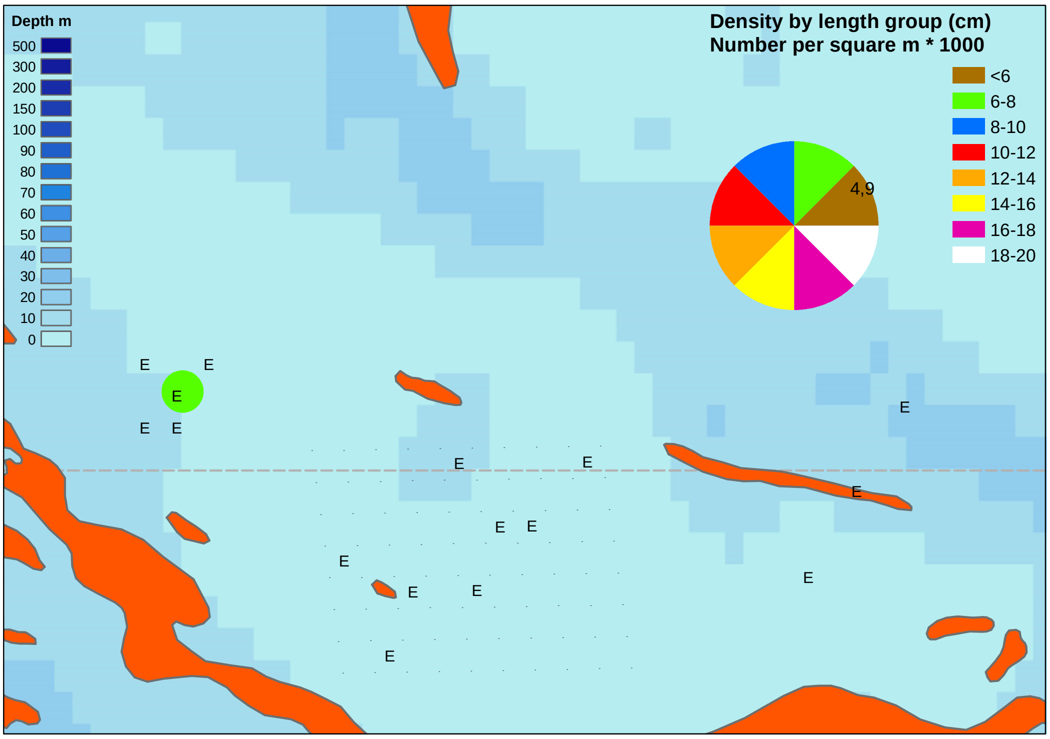


Figure 12.
Mean densities (sandeels·10^3·m^{-2}) of sandeels (all species combined) by length, year and area (control and impact respectively). Error bars are confidence limits: 95%.

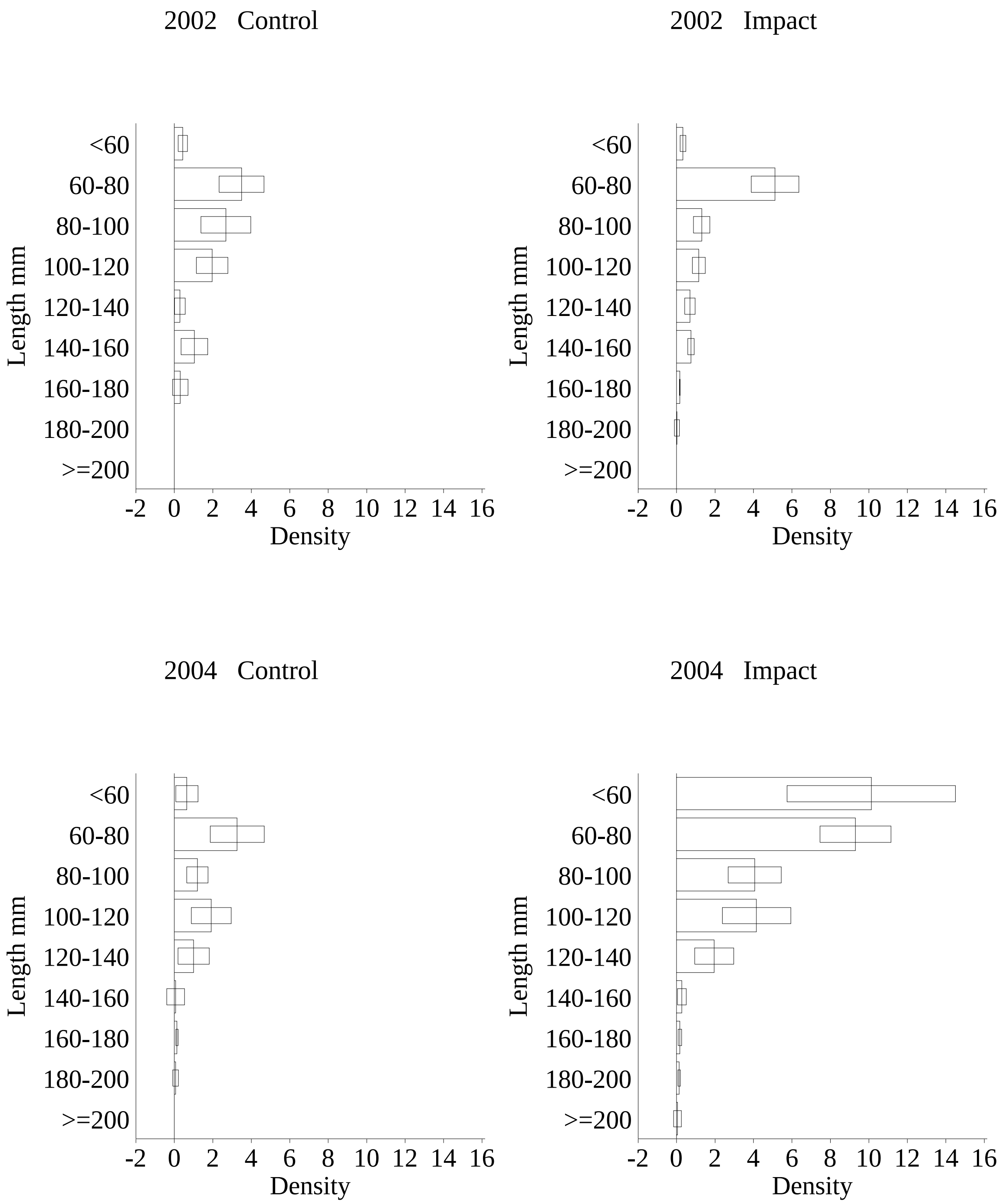


Figure 13.
Mean densities (sandeels·10^3·m^{-2}) of sandeels by species, length, year and area (control and impact respectively). Error bars are confidence limits: 95%.