Baseline studies wind farm for demersal fish

RIKZ

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Final Report
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SUMMARY

The Near Shore Wind Farm (NSW) off the Dutch coast is commissioned as a demonstration project, in which knowledge and experience on the construction and maintenance of offshore wind farms should be gained. The Dutch government has set the condition that a monitoring programme on - among other subjects - the impact on the demersal fish community is carried out. The Dutch government is responsible for providing a thorough description of the present demersal fish community. With this information, the effect of the wind farm on the demersal fish community will be assessed (outside of this programme). The area was sampled in June/July 2003 and in January 2004. Sampling stations cover the planned location of the Near Shore Wind Farm and three reference areas. A 6 metre beam trawl with tickler chains was used with two type of nets; a fine mesh size (20 mm) to sample smaller fish and a 40 mm mesh size to sample larger fish.

This final report describes the present situation (2003/2004) of the demersal fish community in the area of the wind farm. The description is supplemented with data from other surveys (from 2001-2004) which allows a more general description of the Baseline situation of the demersal fish community.

In the beam trawl surveys, a total of 41 species were observed along the Dutch coast and most species were found in every season investigated. Their abundance varied greatly among seasons. Flatfish are the dominant ecological group in the demersal community in the Dutch coastal zone. In spring and winter, Dab is the most abundant flatfish, followed by Plaice in most length classes. In summer, Sole is the most abundant flatfish in the smaller length classes, while Plaice dominates the larger flatfish. The commercially unimportant Solenette and Scaldfish are also abundant, especially in summer. Next to flatfish, the group of Gobiids were important in the Dutch coast in all seasons but due to their small size they are not important in terms of biomass. For all species, the annual variation in abundance in the Dutch coastal zone is large. The age structure varied among species: large age ranges within one length class were observed for Lesser weever (individuals of 4-13 years old found within one cm group) and Solenette whereas of Dab only two age classes in total were observed. Spatial variation was generally large but seemed often not random, it was significantly correlated with temperature, depth, pH and salinity. In terms of biomass, there were differences in the species composition between NSW and the other areas but the differences were small.

For demersal fish we expect that the largest effect of the wind farm is the closure of the area to fishing. In two ways, this could have an effect on the demersal fish community; 1) indirectly, via a change in sediment structure and availability of benthic organisms and 2) directly, the wind farm could act as a refuge area because in the middle of an intensively fished area, fishing mortality is locally zero. We think, however, that effects are mainly local and do not extend to the level of North Sea fish populations.

A power analysis showed that the detection of an effect of the wind farm on fish biomass through a monitoring programme is not completely unfeasible. The sampling intensity in the current baseline study (13 hauls in the wind farm area) allows the detection of a 30% downward or 40% upward trend. To strengthen the results of monitoring, and to prove

effects, research into the underlying processes is essential. This will also make an impact assessment more efficient.

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1 INTRODUCTION

The Dutch Government has decided to allow the construction of the Near Shore Wind Farm (NSW) demonstration project. The future wind farm will be located at least 8 km off the coast near Egmond aan Zee and will contain 36 turbines in a 20—25 km^2 area. One objective of the demonstration park is to assess the ecological impacts of the construction and operation of a wind farm offshore. The Dutch government is responsible for providing a description of the present ecological situation. In October 2002, the National Institute for Coastal and Marine Management (RIKZ), part of the Directorate-General of Public Works and Water Management, procured a Baseline study on the North Sea situation. This Baseline study must provide data on the current occurrence of benthic fauna, demersal fish, pelagic fish, sea mammals, marine birds and non-marine migratory birds. These results will be used as a reference for the evaluation of ecological effects during and after the construction of the wind farm, which will be assessed in the Monitoring and Evaluation Programme Near Shore Wind Farm (MEP-NSW).

Demersal (bottom-dwelling) fish have an important role in the ecosystem and are of high environmental value. The abundant Gobiids, for example, are important prey items for birds and form a link between secondary production and birds. Many species are protected under the various national and international conservation laws. Demersal fish also have a high commercial value. Especially flatfish are commercially important to the Dutch North Sea fishery (Photo 1), and constituted 46% of the total Dutch landings in 1998. Of the most important flatfish species, such as Plaice, Sole and Turbot, Dutch fishermen landed 43-89% of the total European landings from the North Sea. In 2000, landings of Plaice by Dutch vessels amounted to roughly 50 000 tons, representing an economic value of about a hundred million euro (Grift *et al.* 2001)

In the Baseline study for demersal fish the occurrence, density, population structure and migration patterns of demersal fish in the present situation should be described. The set-up of the programme was to deliver a well-investigated before-situation of the area. To achieve this, the situation in the wind farm area and three reference areas was investigated. After the creation of the wind farm, the changes in the wind farm area can thus be compared to those in the reference areas. A high spatial resolution of sampling is used which should allow detection of the (potentially) small-scaled effects of the relatively small-scaled wind farm. Standard surveys use larger-scaled sampling grids and do not cover the Baseline area adequately nor provide well-chosen reference areas. Also seasonal variation cannot be assessed using only standard surveys, since these are executed only once a year (in late summer/autumn). Sampling different seasons is necessary in order to arrive at a more complete picture of the community.

A Strategy of Approach (Grift and Tien 2003) was delivered early 2003, after which surveys were conducted in summer (2003) and winter (2004). For both surveys, reports were delivered containing the sampling scheme, a cruise report and preliminary results (Tien *et al.* 2003, and 2004). Also, a report on the biological data collected during these two surveys has been delivered (Tien & Grift 2004). Detailed descriptions of the surveys and biological data (e.g. length-maturity keys) are published in these reports and will not be presented here. This final report focuses on comparing the results from the wind farm area to those of the reference areas, in order to describe the current situation in all areas and investigate the use of the chosen reference areas during the effect studies.

Photo 1. Demersal fish are important to the Dutch fishery, especially for the beam trawl fleet.

Surveys on the coastal demersal fish community have been conducted by the Netherlands Institute for Fisheries Research (RIVO) since 1969, focusing on the abundance of the commercially important Plaice, Sole and Dab. Additional research has been conducted within other RIVO projects on the ecology, for example on the nursery function of the coast, the effect of water currents on the distribution of fish and the food preferences of some species (e.g. Grift *et al.* 2001). However, taking into account the high costs of marine field work and the focus on commercial species, knowledge on the coastal demersal fish community and its intrinsic processes is still sparse. The spatial and temporal variation of most species is supposed to be large but detailed information on this variation and the processes determining it are lacking. Considering this gap of knowledge it was decided to supplement data from the baseline study with a more general description of the coastal demersal community (of the Dutch provinces Zuid and Noord Holland). Also, fish that occur in the wind farm area are part of the fish assemblage in the entire coastal zone. It is not likely that they will stay in the wind farm area for their entire life and understanding the processes behind the community is of essential value to understanding the effect of the wind farm on the community. Although a complete description of the demersal community is outside the scope of this project and requires many more years of research, a first investigation into the dynamics of the system is carried out here.

In conclusion, this final report (1) compares the demersal community in the wind farm area and the reference areas, but also (2) provides a description of the Dutch coastal community and the variation found on various levels of investigation. For part (1), data from the two conducted baseline surveys are used (2003-2004). For part (2) the Baseline data is complemented with data from other surveys to achieve a description of the Dutch coast for the period 2001-2004

The Baseline surveys are described in detail in Chapter 2, together with a short description of the other surveys. Also, the method of data processing and storage is discussed in this Chapter, and the method of analysis is described per subject. The results are discussed in Chapter 3, beginning with a more detailed description of the demersal fish community in the wind farm and reference areas, followed by a general description of the demersal fish community in the Dutch coastal zone. The chapter also contains the result of a power analysis, in which the number of samples needed to statistically find a change in the community is calculated. The discussion, in which possible effects of a wind farm are discussed, is presented in Chapter 4. To reduce the number of figures and tables in the main text, for most analyses only one example is presented in the main text, while the remaining figures are presented in the Annexes. All Annexes are numbered as “Chapter. Annex “. So Annex 2.4 is the fourth Annex of the second Chapter.

2 MATERIALS AND METHODS

2.1 Description of the study area

The future wind farm is an area bordered by an imaginary line eight kilometres from the shore and the 20-metre lowest low-tide level depth contour (Figure 2.1). The area lies off the coastline between Castricum and Egmond aan Zee in which the boundaries are determined by the existing cables and pipelines. The wind farm area and a 500-metre safety zone surrounding the farm will be closed off for all forms of shipping, except for maintenance vessels and government ships. This means that the area will be closed to fishing which is very intensive in the Dutch coastal zone. Fisheries in the wind farm area are dominated by beam trawlers with less than 300 Hp and otter trawlers. About 60% of the fishing activities in this zone is executed with beam trawls targeting Sole and Plaice (see Annex 2.1 for the species list with scientific and Dutch names). Every spot in this zone is estimated to be fished more than once every 1.5 years (Verver *et al.* 2003).

The wind farm area is located within the Southern Bight of the North Sea, with seawater coming mainly from the English Channel. Fresh water flows in from the Rivers Rhine and Meuse, which discharge about 90 kilometres to the south. This forms a low salinity plume ('coastal river'), which moves northeast along the Dutch coast into the German Bight. Some salinity stratification can occur in the area during high river discharge events, but is not expected to affect the wind farm area. The tidal currents in the Dutch coast are among the strongest in the North Sea (up to 1.4 m sec^{-1}) (Jarvis *et al.* 2004). The high current speed affects the bottom characteristics by winnowing out fine-grained sedimentary and organic particles. Sediments therefore consist of fine to medium sands with low organic carbon content. Benthic species richness and abundance of infaunal and epifaunal animal communities are usually low here in comparison to other North Sea areas (Jarvis *et al.* 2004). For a more complete description of the physical properties of the area and the benthic community, we refer to the Baseline report on benthic fauna by Jarvis *et al.* (2004).

2.2 Sampling strategy of the Baseline survey

2.2.1 Selection of sampling areas

Sampling areas for the Baseline survey comprised the wind farm location (NSW) and three reference areas that are similar to the wind farm location regarding distance offshore, water depth and seabed morphology. The two reference areas directly north and south of the wind farm site (Ref N and Ref Z) are similar to reference areas of the Baseline study on pelagic fish, the most southern reference area (Ref S) and Ref N overlap with reference areas for the Baseline study on benthic fauna. The spatial variation of the bathymetry and the sampling position of the hauls of the Baseline survey are presented in Figure 2.1. Also presented in this figure are the trawl positions of the various other surveys of which data were used in this report (Beam trawl survey (BTS), Sole net survey (SNS) and the Mare survey), which are discussed in section 2.3.

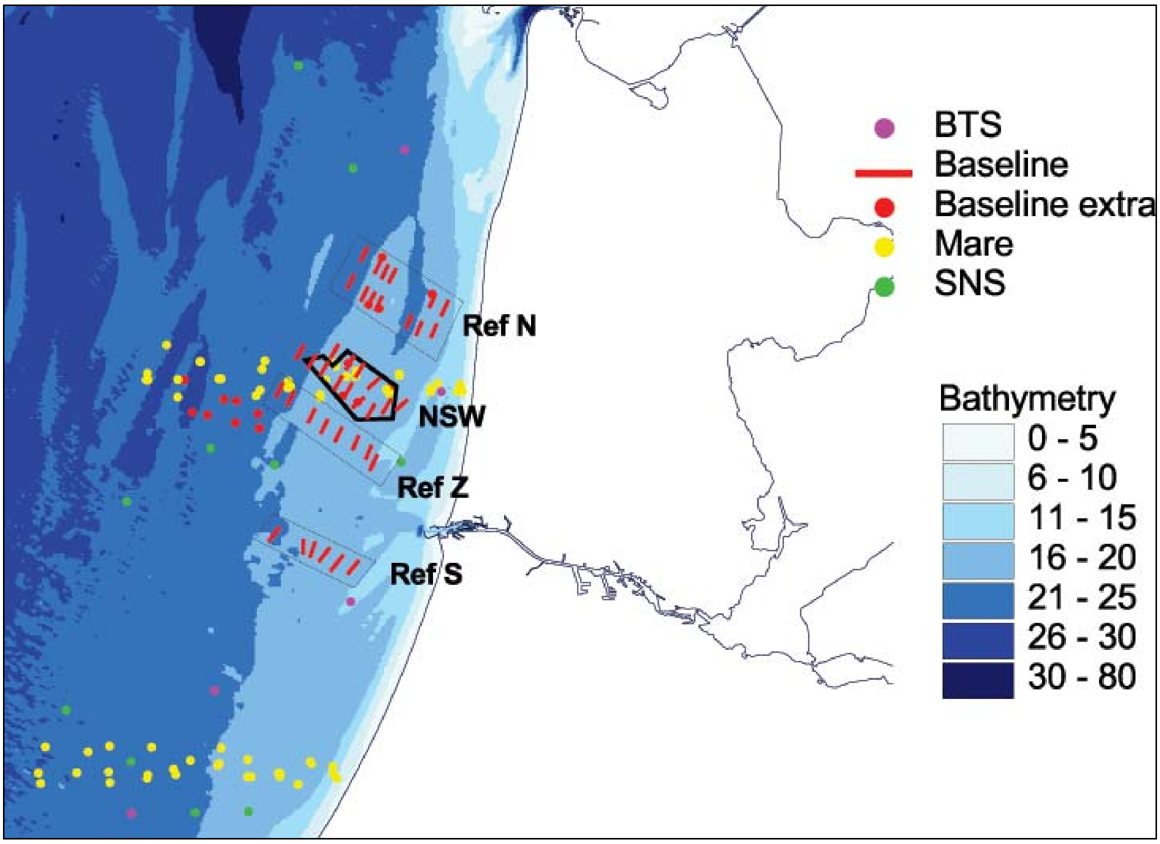

Figure 2.1. Map of the Dutch coastal zone indicating bathymetry, positions of wind farm NSW, the three reference areas and the sampling stations of RIVO beam trawl surveys Baseline, Mare, SNS and BTS. The SNS, BTS and Mare hauls are from 2001. The red lines represent the standard Baseline hauls, whereas the extra Baseline points (red points named NSW extra) represent the additional hauls conducted during the Baseline survey in winter 2004 and during the BTS survey in 2003 (see section 2.2.2 and 2.3.2).

The Baseline sampling scheme consisted of 40 stations, divided over the three reference areas and the planned wind farm area. One-third (13) of the samples were taken in the wind farm area, one-third north of the wind farm area and one-third of the samples is divided over the two reference areas south of the wind farm area. Within the wind farm area, stations are located closely together to allow detection of possible small-scaled spatial effects during the impact study MEP-NSW.

2.2.2 Beam trawling

The best available method for sampling demersal fish species living near or in the sea bottom is using beam trawls, in which a triangular purse-shaped net is extended by a horizontal beam and the under portion is towed over the seabed (Photo 2).

Two 6-metre long beams were used with the research vessel ‘Isis’. On one side of the ship, a 40 mm (stretched mesh in the cod-end) net was attached, a mesh size also used in two international surveys (SNS and BTS) conducted by RIVO. Because this gear catches a relatively small number of smaller fish, a finer meshed net (20 mm) was used on the other side of the ship. This mesh size is used in another RIVO survey (Demersal fish survey (DFS)) and has to be attached to the same (heavy) beam to keep the ship in balance. In general, the catch per haul is lower in the 20 mm than in the 40 mm net because the flow velocity of water through the small-meshed net is lower. Consequently, larger fish can more easily out swim the net before they are engulfed.

Photo 2. One of the 6m beam trawls used on board the research vessel 'Isis' during the Baseline surveys. Attached to this beam is the 20 mm net. In the middle of the net, the CTD device is visible.

The haul duration was 15 minutes with an average speed of 3.5 knots (~6.5 km h^{-1}). Temperature, salinity (conductivity), pH, oxygen level (% saturation), time and depth were recorded by a Hydrolab data logger (CTD device), which was attached to the 20 mm net. Maps with the temperature, salinity and pH values per haul are presented in Annex 2.2.

The first survey was carried out in weeks 26 and 27 of 2003 (23rd of June until 4th of July). Due to adverse weather conditions, six transects in Ref N could not be sampled. In addition, one transect had to be aborted due to adverse seabed conditions. In total 33 transects were successfully sampled in five days at sea. The second survey took place in week 4 and 5 of 2004 (19th until 30th of January). In spite of adverse weather conditions during three days of the sampling period, all 40 transects were successfully sampled. Because some time was left over, we decided to sample extra transects in the area west of the wind farm and RefZ (see Figure 2.1).

2.2.3 Processing of the catch and collection of biological data

On board the catch was sorted per net and all fish, except Gobiids, were identified to the species level (Photo 3). The Gobiids (or a sub sample of them) were taken to the laboratory to be identified to the species level. Fish were measured to the centimetre below (length was rounded off downwards to the nearest centimetre). For all fish species caught in the haul, length-frequency distributions were assessed.

Photo 3. Sorting of the catch on board the research vessel 'Isis'.

In the first field survey benthos was also identified to the species level and the length distribution of shrimp was assessed. However, because this sampling programme proved to be too demanding, the programme for the second survey was adapted and shrimps and other benthos were not processed. Shrimps were also sampled in another part of the Baseline project (the benthic program, see Jarvis *et al.* 2004) and sorting shrimps from fish is very time consuming. A description of the abundance of shrimp during the first survey can be found in Tien *et al.* (2003). With less time spent on processing per transect, all transects could be fished in the second survey. A full report on the catch data can be found in Tien *et al.* (2003, 2004).

For a selection of species, biological data were collected for five individuals per length group (5 cm). This consisted of measuring length, weight, sex and maturity. Length was measured to the nearest millimetre and weight to the nearest gram. Sex and maturity stage were determined by a visual observation of the gonads. Also, two otoliths were collected (Photo 4) and brought back to the lab where age was determined by counting the growth zones. The ages were read following standard procedures (Bolle *et al.*, 2003). Otoliths from Dragonet and Hooknose could be read with a microscope without any preparation. Otoliths from Lesser weever, Turbot, Brill, Scaldfish and Solenette had to be processed before they could be read. For these otoliths, the thin transversal section method was applied (Bolle *et al.*, 2003). In this method, the otoliths are moulded in wax, and after the wax has hardened, thin slices from the otoliths are cut with a diamond saw (with a blade of 0.53 mm). The slices are glued to a glass plate and are coloured to clarify the pattern of annual growth zones.

We consider all fish to increase one year in age at the 1st of January. So, when in summer 2003 a fish of 1 year was observed, it was born in 2002. This same fish reaches an age of two at the 1st of January 2004.

Photo 4. Collection of the otholiths of a Lesser weever on board the research vessel 'Isis' during the second field survey.

In total, biological data were collected for 493 fish. The number of individuals processed per species is presented in Table 2.1. In the second survey, extra biological data was collected for Lesser weever and Solenette because in the first survey samples of these small fish proved to comprise many age groups. To obtain an accurate age length key, at least 15 fish per cm class were sampled instead of 5 for these species.

We did not collect data for the economically important demersal fish species (Dab, Sole and Plaice), but used data collected from routine programmes of the institute. These programmes comprise market surveys, in which landings are sampled in the auction, and discard surveys in which fish are sampled on board commercial vessels. Biological data from a section of the North Sea (51.00°-53.00°N, 3°-5°E) covering the research area and from the same months (June, July and January) as the Baseline survey were selected.

Table 2.1. Numbers of fish from which biological data were collected (length, weight, sex, maturity and otoliths) in the first (June/ July 2003) and second (January 2004) survey. Fish for which data were collected in other programmes are presented in the lower rows. Data from 2004 for these species are not yet available

Programme	Species	1st survey	2nd survey
Baseline study	Brill	17	13
	Dragonet	50	79
	Hooknose	22	20
	Lesser weever	38	78
	Scaldfish	48	35
	Solenette	28	58
	Turbot	6	1
	Total number of fish	209	284
Routine programmes	Dab	55	-
	Plaice	267	-
	Sole	653	-
	Total number of fish	975	-

2.3 Other RIVO surveys

Data were only used from surveys that used comparable gear types to make comparison to the Baseline data possible. Only surveys in which a six or eight metre beam trawl with tickler chains and mesh sizes of 20 or 40 mm were used. In total, catch data from three other RIVO surveys were used to complement the Baseline data. Two of these surveys (SNS and BTS) are long-term surveys, executed annually to obtain data on commercial fish species. The Mare survey lasted two years, but in one year (2002) a different net type was used and the data of that year were omitted. A description of the surveys including towing speed, mesh size and beam length is given below. A description of the sampling stations per survey is given in Figure 2.1

2.3.1 Mare project

The Mare project (1999-2003) was executed to predict the impact of an airport island (Flyland) on the coastal and sea systems. One part of the research focussed on calculating the effect on the demersal fish community. As part of this programme, the Flyland area and two reference areas (all in the neighbourhood of the NSW area) were sampled five times within 2001. Perpendicular to the coast, in every area 10 transects were sampled with two 8 metre beam trawls and 40 mm nets. Fishing speed was ca. 3.5 knots with a haul duration of 15 minutes. Sampling took place end of February, March and May and beginning of June and July.

2.3.2 Beam Trawl Survey

The annual Beam Trawl Survey (BTS) started in 1985 in order to obtain abundance indices of adult Sole and Plaice. RIVO is responsible for the North Sea indices. The survey is conducted in August and September. Eight-metre beam trawls with 40 mm nets are towed for a period of 30 minutes at about 4 knots.

Within the BTS survey, 8 extra hauls were conducted in the wind farm area in summer 2003 for the Baseline study. These extra hauls are here defined as belonging to the Baseline study, resulting in 8 Baseline hauls conducted with an eight- metre beam (in stead of the usual 6 metre beam used in the Baseline study). In total the Baseline study thus obtained 15 extra hauls; 8 made during the BTS survey in 2003 and 7 during the second Baseline survey in the 2004 winter.

2.3.3 Sole Net Survey

The annual Sole Net Survey (SNS) started in 1969 to obtain abundance indices of 1- and 2-year old Sole and Plaice. A 6 metre beam trawl with 40 mm net is used to sample transects perpendicular on or parallel to the coast with a towing speed of 2-3 knots and a haul duration of 15 minutes. Sampling period is in September and October

2.4 Data processing and storage

Catch and biological data were recorded on board. Catch data were digitalised using the RIVO-program 'Billy', biological data using the RIVO programme 'Snij 2.0'. Afterwards, both catch and biological data were stored in RIVO databases. Retraction from the databases and analysis of the data was carried out using the SAS software package.

2.5 Data analysis (all data)

The baseline situation of the demersal fish community in the Dutch coastal zone is described in two steps; (1) a comparison of the wind farm area to the reference areas, in which only data from the Baseline surveys are used to present a description of the similarities and differences between the investigated areas. An extra analysis was done, in order to estimate the amount of samples needed to statistically show a difference between before-and-after the wind farm construction. This analysis is called a power-analysis. Also, (2) a general description of the demersal fish community in the Dutch coast is given This description is investigated using the Baseline data, supplemented with data from the surveys BTS, SNS and Mare for the years 2001-2004.

Catch per unit effort (CpUE) was defined as number of individuals per hectare fished. The hectares fished were estimated by multiplying the distance towed with the width of the beam. Seasons were defined according to the regular definition (e.g. spring is March 21^{st} to June 20^{th} etc.).

The number of hauls per survey is shown in table 2.2. Also, the width of the beam, average fishing speed and the number of hauls per survey, per mesh size and per season are given. For the 20 mm net, only Baseline data are available, in summer 2003 (n=33) and winter 2004 (n=48). For the 40 mm net trawl data from different surveys are available, for spring (n=66), summer (n=129) and winter (n=170).

Table 2.2 Characteristics of and number of hauls per survey. Mesh size, beam length and average towing speed (meters per hour) are presented, plus the number of hauls per season and year

Mesh size (mm)	Beam width (m)	Speed (m/hr)	Survey	Spring 2001	Spring 2002	Spring 2003	Summer 2001	Summer 2002	Summer 2003	Winter 2001	Winter 2002	Winter 2003	Winter 2004	Total
40	6	6300	Baseline						33				48	81
			SNS			16	10	11						37

	8	7200	Baseline						8					8
			BTS				5	8	11					24
			Mare	50			12			74				136
20	6	6300	Baseline						33				48	81
			Total	50	0	16	27	19	85	74	0	0	96	367

Because the demersal fish community represent more than 40 species, not all species were investigated in detail. Therefore, data were aggregated at higher levels (in total or per ecological group) for most analyses. Also, during various analyses, a sub selection was made of single species, which were investigated in more detail. Three commercial species were chosen (Plaice, Sole, Dab), two common long-living and sedentary species (Lesser weever and Solenette), and the common Scaldfish and the group of gobiids. When the analysis describes single species, this list of species (Plaice, Sole, Dab, Lesser weever, Solenette, Scaldfish and gobiids) is meant.

The analyses of the comparison of the baseline and reference areas are described separately (section 2.5.1) from those of the general description of the Dutch coast (section 2.5.2). In all results, we treated data from the 20 and 40 mm net separately because efficiencies of both nets are different.

2.5.1 Comparison of the wind farm to the reference areas

The wind farm is compared to the three reference areas in abundance and biomass characteristics of the fish community. Investigation of the similarity of the areas is necessary for the future comparison of changes in the various areas. The data is also used to try to explain the abundance patterns using environmental variables as temperature and salinity.

Biomass of the community, ecological groups and single species
The biomass (g) per species, per length group (5 cm) and haul was estimated, using the length-weight relationships in Annex 2.4. In this project data on length and weight of demersal fish was also collected but the number of observations was too low to predict biomass from these relationships accurately (Tien *et al*. 2004). Therefore we used the standard RIVO length-weight relationships that gave precise estimates.
The relative abundance per species, area, survey and mesh size is calculated. Also, the total biomass per ecological group, area, survey and mesh size is presented. Total biomass was calculated by summing the biomass of the individual species per haul and averaging it over all hauls per mesh size.
The total biomass of all species per area and mesh size was calculated and statistical differences in biomass per area were tested with analysis of variance (Annex 2.3), to find differences in biomass between the wind farm area and the reference areas.

Spatial distribution of the biomass; single species
The CpUE (kg/ha) per haul was plotted per mesh size and survey for the subset of species (see section 2.5) on maps to describe the spatial distribution. This variation between areas was investigated visually.

Spatial distribution in relation to environmental variables
Environmental data were used to explain the spatial distribution of species. Additional interest was put in whether some species aggregate or not. This could contribute to assessing shifts in aggregations in a future wind farm. In contrast with traditional

regression methods, in which usually the effect of (several) explanatory variable(s) on only one response variable is investigated, multivariate methods can deal with more than one response variable. Instead of the abundance of one species at a time, the effect of several abiotic variables on a species community can be analysed simultaneously. The analyses of the relationship between abiotic factors (pH, oxygen, temperature, salinity, turbidity) and the catch composition were limited to the hauls from the Baseline studies in July and January. Only for these surveys complete sets of CTD measurements were available for the majority of the hauls (Table 2.3). Samples taken with 20 and 40 mm mesh size are analysed separately.

Table 2.3. CTD data from the Baseline study: Range of values of environmental variables measured using a CTD. The last column presents the variation in each variable expressed as percentage of the maximum. Measurements of oxygen concentration failed in January 2004.

year	variable	min	max	%
July 2003	temperature (ºC)	16.1	17.8	9
	pH	8.4	8.7	3
	water depth (m)	13.0	23.0	43
	salinity (ppm)	30.9	33.4	8
	oxygen (% sat)	106.6	131.8	19
January 2004	temperature (ºC)	5.4	6.3	14
	pH	9.4	9.6	3
	water depth (m)	15.0	24.0	38
	salinity (ppm)	27.0	33.5	20
	oxygen (%sat)	no measurements		

Ordination was carried out using Canoco 4.5 (Ter Braak and Šmilauer 2002). To explore the relationship between species and environmental variables a direct gradient analysis was used, Redundancy Analysis (RDA, Jongman *et al.* 1995) on the fish abundance (n/ha) and environmental data. In this method environmental variables are used to explain the variation in species composition. Data for each period (June 2003 and January 2004) were analysed separately.

RDA assumes that a linear response model best describes the abundance of every species (for example a linear relationship between fish abundance and depth). If the length of the axis only covers a small fraction of the response curve, or if the response curve is not unimodal, multivariate analyses assuming a linear response curve can be used. The choice between methods based on unimodal or linear response curves can be based on the length of gradients. As these were smaller than four times the standard deviation, we used RDA (Jongman *et al*. 1995). Fish abundance data were log-transformed. Analyses were limited to demersal species only. Rare species (occurring in less than 10% of hauls) were excluded from the analysis.

Power analysis
With data collected in the baseline study the power of the sampling programme can be investigated. This power analysis addresses the question: to what extent are the results statistically significant, and consequently, will this monitoring programme be able to detect possible ecological effects of future works? The details and the results of the power analysis are described in Annex 2.3.

2.5.2 General description of the Dutch coast.

Only recent data (January 2001 until January 2004) were selected to achieve an as recent as possible dataset of the area. Next to the Baseline data, also data from the surveys BTS, SNS and Mare were used. Of these three surveys, only data were used from hauls, which were executed at depths between 5-30 metres, between 52°-53° latitude and 3°-4.74° longitude. Different mesh sizes (20 mm and 40 mm) were treated separately, because different mesh sizes result in different catch compositions. Differences in towing speed and beam length are assumed to have a negligible influence on the catch composition.
For the analysis of annual variation, a different dataset was used: the long-term SNS data from 1969 onwards is used, with sampling in the vicinity of the wind farm area in four locations per year for every year.
Not all fish were identified to the species level in each survey. Gobiids, dragonets, grey mullets, pipefish, rays, sandeels and wrasses had in some cases only been identified to the genus level and were therefore grouped at this level.

Various characteristics of the demersal community were investigated, to achieve an as complete as possible description of the community.

Average number of species per haul.
The number of species per haul was calculated after which the average number of species and the standard error of the mean per season and mesh size were calculated.

Presence of species per season
The presence or absence of every species was determined per season and per mesh size. Also, the number of hauls per season and per mesh size is given, because the number of species caught depends on the effort.

Relative abundance of most common species
The average CpUE over all years was calculated per mesh size and species. Only species that contributed at least 1% to the total catch were selected. The list of these species was almost similar in both mesh sizes (see Annex 3.1 and 3.2). The pelagic species (see Annex 2.1 for the list of pelagic species found) were not further investigated in this sub analysis, since they are analysed in another Baseline study (Grift *et al.* 2004) and because catchability in beam trawls of pelagic species is supposed to be very low. The relative abundance of these species was calculated per season and mesh size. The relative abundance of the various Gobiid species was determined by only using the Baseline data, since they have only been identified to the species-level in this survey.

Length frequency distribution: groups
Species were grouped into four groups: flatfish, roundfish, pelagic fish and ‘other’ (see Annex 2.1 for the used grouping). The CpUE per group was calculated per haul and length class (1 cm). The average of all hauls was taken per ecological group, per season and per mesh size. For a sub selection of groups, length classes, mesh sizes and seasons, the average CpUE per haul was calculated per species using the same data.

Length frequency distribution: single species

LF distributions were calculated using the same method as above, only per species instead of group. Data from all surveys but only from the 40 mm net were used, because the two nets show similar trends in the LF distribution.

Length biomass distribution; ecological groups
The biomass (g) per species, per length group (5 cm) and haul was estimated, using the length-weight relationships in Annex 2.4. In this project data on length and weight of demersal fish was also collected but the number of observations was too low to predict biomass from these relationships accurately (Tien *et al*. 2004). Therefore we used the standard RIVO length-weight relationships, that were available for all species, that gave precise estimates. After grouping species into groups (see above), the total biomass per group per haul was estimated and averaged over all hauls per season and mesh size.

Annual variation; single species
To describe temporal variation, data from the SNS survey (1969-2003) were used. The CpUE per species per haul was calculated and averaged over every year for the four (constant) sampling points in the direct vicinity of the wind farm area (SNS area 603). Also the standard error was caclulated. The average CpUE per species was also calculated for the 40 mm net (also used in the SNS survey) of the Baseline survey and plotted per year (2003 and 2004) into the long-term variation plot of the SNS data.

3 RESULTS

3.1 Comparison of the wind farm and reference areas

The (standardized) number of fish caught per area, mesh size and season is shown per species in Annex 3.1 and 3.2. Some species like Solenette, Dragonet and Plaice are found in every area and season investigated. Other species are mostly found in one season (e.g Tub gurnard in summer and sprat in winter). Various aspects of the community are investigated in detail in this chapter.

3.1.1 Biomass of the community, ecological groups and single species

The biomass distribution over the length classes is dominated by flatfish in all areas (Figure 3.1). Roundfish were a large part of the larger length classes of the wind farm area, while they were less abundant in the other areas. The other ecological groups were not very abundant in terms of biomass in any area.

There were differences in the species composition between NSW and the other areas but the differences were small (Figure 3.2). In all areas, all important species were represented similarly. Only in the NSW area, Whiting was clearly more abundant in January but this was mainly due to one single haul in which 22 kg of Whiting was caught.

Overall (not regarding sampling period), there is no significant (P>0.05) difference in total biomass among areas in the 20 mm net (Annex 2.3). In the 40 mm net, the total biomass differed significantly among areas; it was lower in the NSW area than in the northern (RefN) and most southern reference area (RefS).

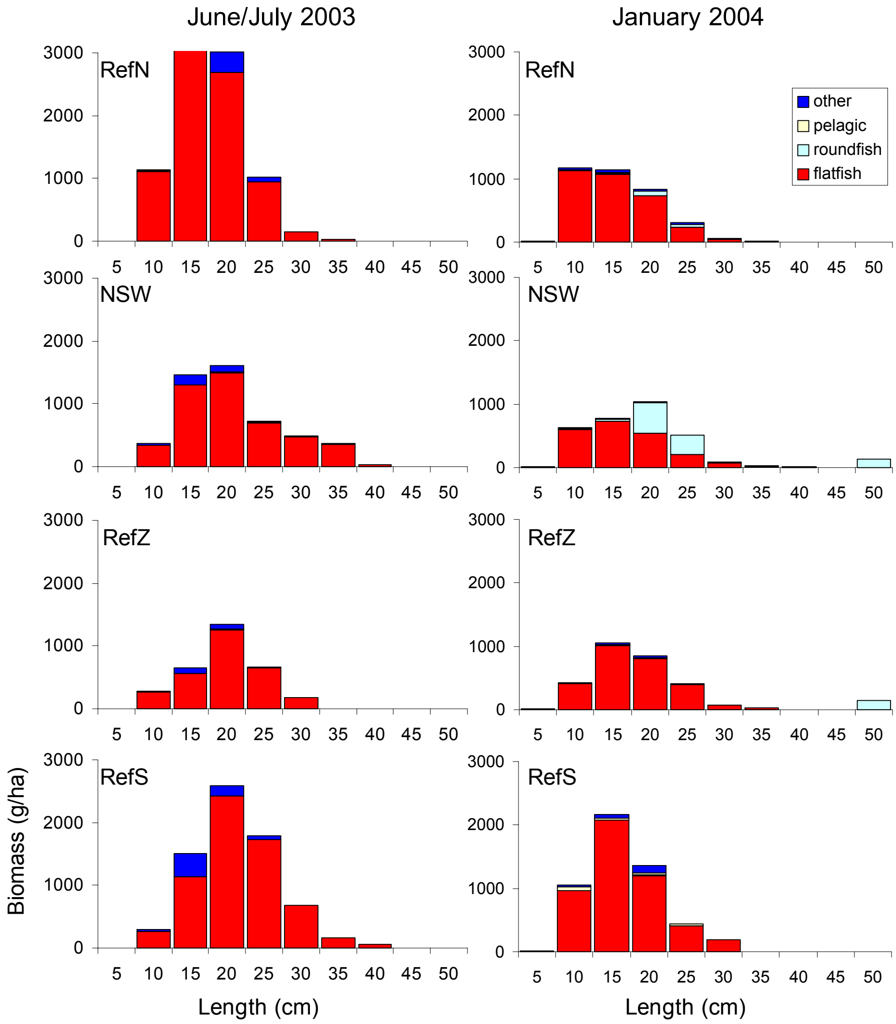

Figure 3.1 Biomass size distributions from both Baseline surveys for each of the four areas (results of the 40 mm net). The biomass for flatfish of 15 cm in June/July 2003 extended the scale of the y-axis but was 3481 g/ha (biomass of 'other' was 426 g/ha).

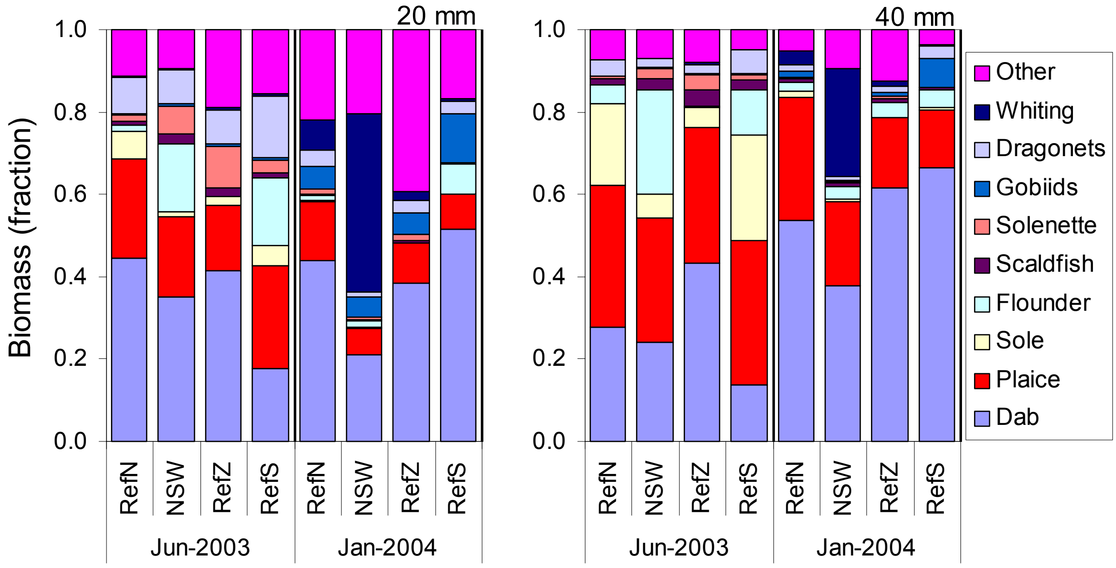

Figure 3.2. Species composition in terms of biomass for the NSW and reference areas. Biomass of each species as the fraction of the total biomass in the trawl catches. Data are averages over trawl hauls for the 20 mm net (left panel) and the 40 mm net (right panel) for both periods the Baseline survey was executed.

3.1.2 Spatial distribution of biomass; single species

The spatial variation of the Baseline data is shown for both mesh sizes and both surveys separately (Annex 3.3). As an example, the spatial distribution of Sole is presented here (Figure 3.3). As shown, the numbers caught vary within and between areas and with the net type used and the season sampled. Sole is found in lower densities in winter than summer, but seems evenly distributed over the areas. Plaice and Dab seem quite evenly distributed over the investigated areas and seasons, although Dab seems to be closer to the coast than Plaice. Lesser weever and Solenette however are most abundant around the NSW area, and mostly in the deeper areas. Scaldfish seems evenly distributed over the various areas, but more abundant in summer than winter. Gobiids are found mostly in the winter and somewhat more in the most northern and southern parts than in the NSW area. The distribution of the two most abundant Gobiid species (Lozano's goby and Sand Goby) shows similar patterns to the overall Gobiid spatial distribution.

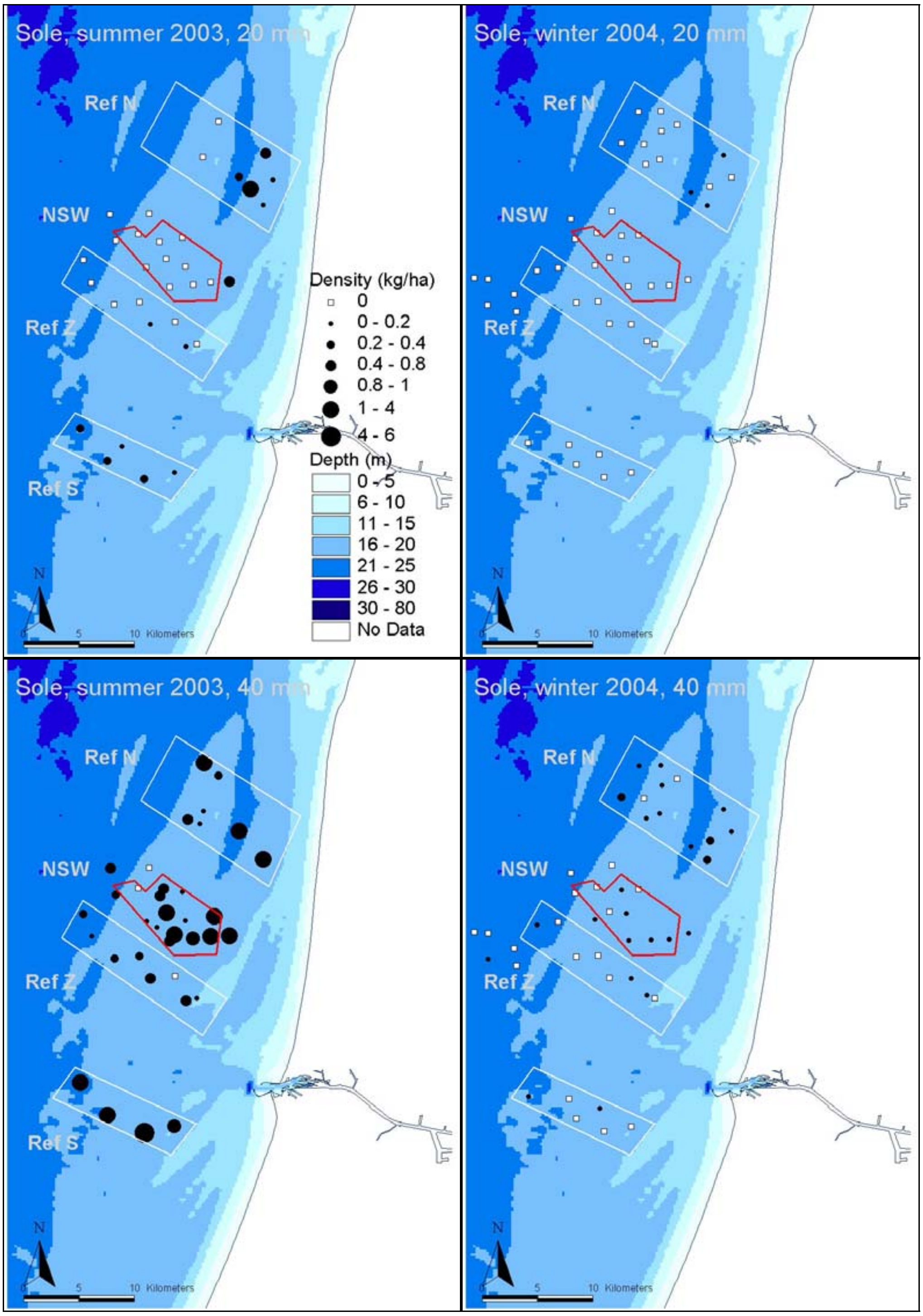

Figure 3.3. Spatial distribution of Sole in the Baseline study summer 2003 (left panels) and winter 2004 (right panels) in the 20 mm (upper panels) and 40 mm (lower panels) net. The dots represent the abundance of Sole (kg per hectare) in each haul. The NSW area is indicated with the red line, the reference areas in white lines.

3.1.3 Distribution in relation to environmental variables

Most environmental variables show little variation in both sampling periods (Table 2.3; Annex 2.2). Water depth, salinity, temperature and oxygen (the latter only available for July 2003) showed variation of more than 10% between the minimum and maximum value.

July 2003

Ordinations for the 20 and 40 mm nets generally show the same pattern (Figure 3.4). The environmental variables together explained about 44% of the variation. Environmental variables explaining a significant proportion of the variation included temperature, water depth and pH (Annex 3.4). Most flatfish species (Dab, Sole, Plaice and Brill) were grouped together with other species such as Bull Rout and Gobiids. Sandeel species were the only species that did not co-occur with other species. Solenette, Lesser Weever and Scaldfish responded strongest to variation in temperature, with highest densities occurring at lowest temperatures. Solenette, Scaldfish and Red mullet were the only species showing a depth effect.

Winter 2004

The patterns are slightly different for the data from winter 2004. Environmental variables explained about 33% of the variation. Significant variables were salinity, water depth, temperature and pH. The significance of pH is surprising regarding the low variation (Annex 3.4). The grouping of the species was similar to summer 2003 but less distinct, with Lesser Weever, Solenette and Scaldfish separated from the other species. These were also the species that showed the strongest response to temperature, pH and water depth. Solenette, Scaldfish and Dragonet occurred in higher densities at deeper sites. Flatfish showed the largest difference between the two mesh sizes. In the 20 mm mesh size, most flatfish species were grouped together, but not in the 40 mm mesh size.

3.1.4 Power analysis

The power analysis showed that the detection of an effect of the wind farm on fish biomass through a monitoring programme is not completely unfeasible (Annex 2.3). The sampling intensity in the current baseline study (13 hauls in the wind farm area) allows the detection of a 30% downward or 40% upward trend.

3.1.5

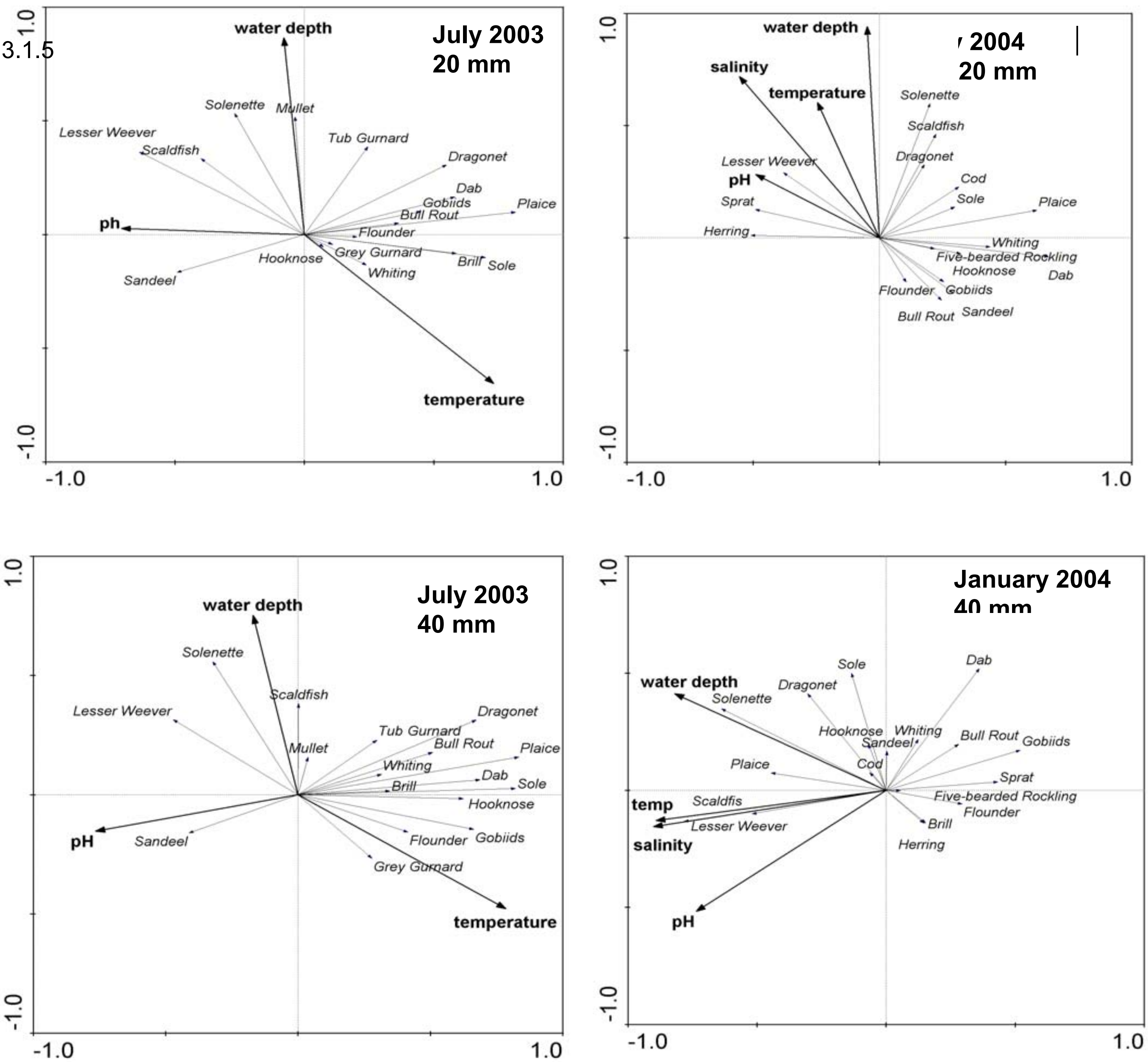

Figure 3.4 Redundancy analysis ordination bi-plots of species and variables per surveys and per mesh size. Only variables that were correlated with one of the two axes are shown. Every arrow (extended in both directions) represents a factor and determines a direction in the diagram. The projections of the species on the arrows show their correlations with environmental variables. The closer the projection of a species to the arrow of the vector, the stronger the relationship.

3.2 General description of the North Sea coast

3.2.1 Species distribution over the seasons

A total of 41 species were observed along the Dutch coast in recent years (2001-2004, see Photo 5) in the surveys Baseline, Mare, BTS and SNS. Most species were found in every season investigated (Annex 3.5), but the average abundance varied greatly between seasons (Annex 3.6).

Photo 5. A typical catch from a beam trawl in the Dutch coastal zone.

3.2.2 Relative abundance of the most abundant species

The numerically most abundant species in the Dutch coast are (in descending order) Dab, Gobiids, Plaice, Solenette, Dragonets, Lesser weever, Whiting, Sole, sandeels and Scaldfish. The relative abundance of these species (Figure 3.5) varies greatly over the seasons and per mesh size used. Using a wider mesh size (40 mm), flatfish such as Dab and Plaice are most abundant. In winter and spring, Dab makes up almost half of the catch of these species, while in summer Plaice is the most abundant species. With a finer mesh size (20 mm), a different composition is found. Dab is still very common, but Gobiids are the most abundant group in winter. In summer Solenette and Dragonets also make up a significant part of the catch.

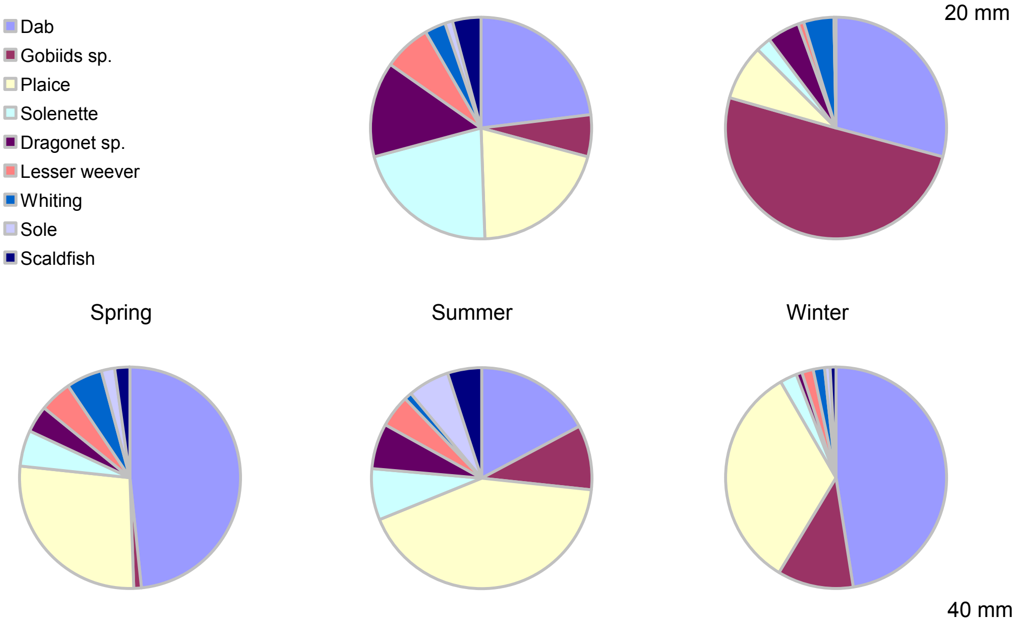

Figure 3.5 Relative abundance (in numbers) of the 9 most abundant demersal species caught in the Dutch coast. Data from the Baseline, SNS, BTS and Mare survey from 2001-2004, separated per mesh size used. These 9 species together contribute at least 96% to the total catch per season (excluding pelagic species)

Because Gobiids are so abundant, the species composition of this group was further investigated using the Baseline data, in which Gobiids were identified to the species level (Figure 3.6). In both Baseline surveys, Sand Goby and Lozano's goby make up the largest part of the Gobiids, while Painted Goby is much less common and Transparent goby is rare. In summer Lozano's goby is the most abundant species in the catches, while in winter (when Gobiids are dominant) Sand Goby is the most abundant Gobiid.

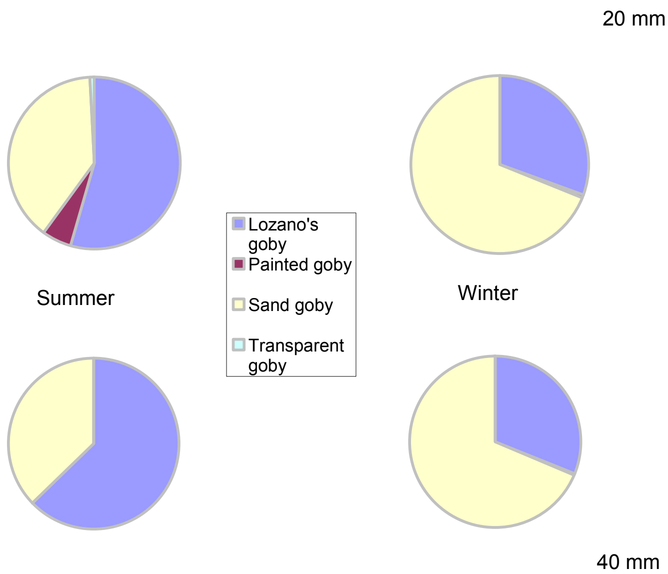

Figure 3.6 Relative abundance (in numbers) of the four Gobiid species in the Dutch coast found in the Baseline survey, in summer 2003 and winter 2004, separated per mesh size used

3.2.3 Length frequency distributions

Most demersal fish caught are between 3 and 25 cm long (Figure 3.7). Flatfish are the most abundant group in most length classes and seasons, particularly in the 5-20 cm length class. Focussing on this group (Annex 3.7), Sole and Plaice are the dominant species in summer. In winter and spring, Dab and Plaice are the most abundant species. With the fine-meshed net, in winter, a large number of small fish are found, with the smaller ones being mostly fish from the group 'other' (mostly Gobiids) and flatfish, and the somewhat larger ones being pelagic (herring and sprat).

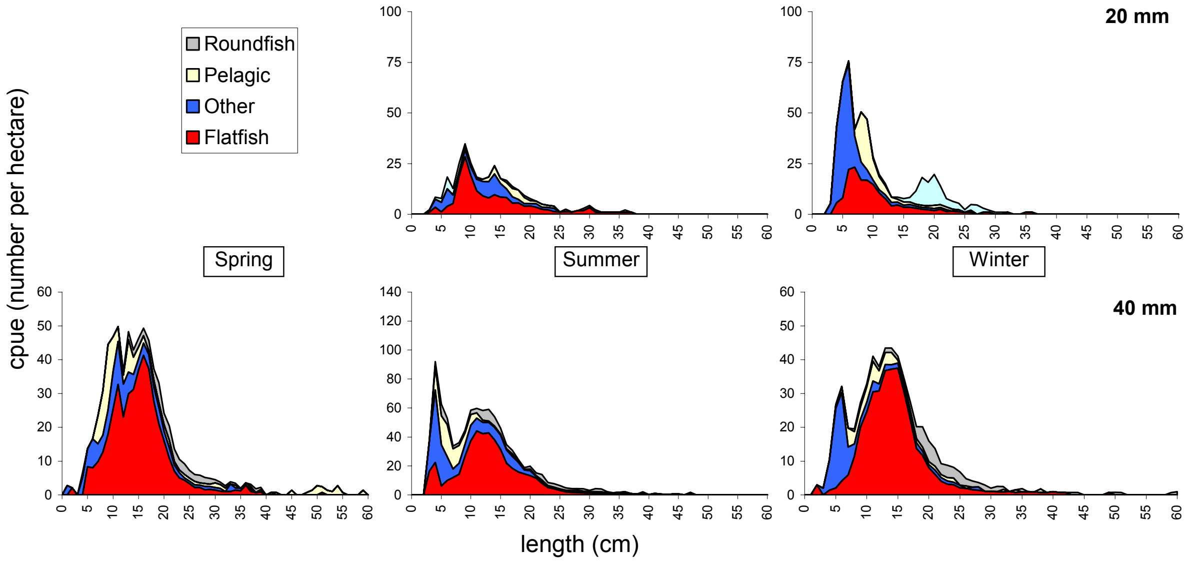

Figure 3.7 Length frequency distributions per season and mesh size used. The fish are aggregated into groups. Based on data from the Baseline, SNS, BTS and Mare surveys from 2001-2004

3.2.4 Length frequency distribution; single species

The LF distribution of some species (such as Sole) varies greatly among years due to variation in recruitment. The length- frequency distribution per species is presented for all survey data for 2001-2004 in Annex 3.8. The average summer length in 2001 is, for example, half the length found in both other years. Also among seasons the variation can be large, as seen in Sole, while in other species the LF distribution is almost identical in all seasons and years (e.g. Solenette).

Age ranges differ greatly among seasons (see the Baseline biological report for all age data; Tien *et al.* 2004). Individuals of Sole (1-18 years), Lesser weever (2-13 years) and Solenette (2-8 years) were the oldest fish found in these surveys, while in contrast, individuals of Dab were aged 2 and 3 years.

3.2.5 Length biomass distribution; groups

Almost the whole biomass in all length classes is accounted for by the flatfish (Figure 3.8). Data from the finer meshed net in winter show that, a large part of the biomass of the larger fish (15-25 cm) is made up by roundfish (mostly Whiting), while the smaller fish (5-10) are also often pelagic species. This is surprising because the small-meshed net generally catches lower numbers of roundfish of this size. The high biomass of roundfish in this net is caused by one haul in which 22 kg of Whiting was caught. In summer, fish from the 'other' group make up a significant part of the total biomass of the 5-15 cm length class. This group mainly comprises Hooknose and Dragonets.

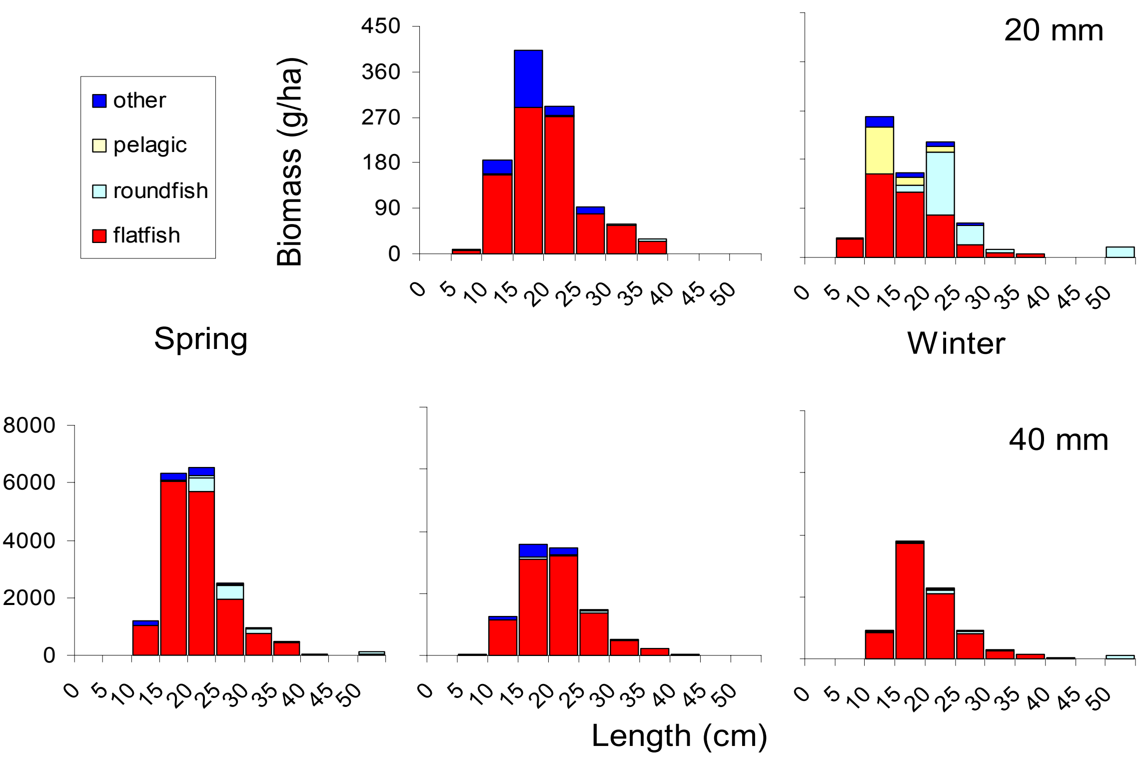

Figure 3.8 Biomass size distributions per season and mesh size used. The fish are aggregated into ecological groups. Based on data from the Baseline, SNS, BTS and Mare surveys from 2001-2004

3.2.6 Annual variation; single species

For all species, the annual variation in abundance in the Dutch coastal zone is large. The temporal variation is shown using the SNS dataset from 1969 onwards for the area, which overlaps with the Baseline area (Annex 3.9). The mean CpUE found in the 40 mm net in the two years of Baseline surveying are also plotted in this picture, showing the variation between surveys. As an example, the temporal variation of Plaice is presented here (Figure 3.9). The average number of Plaice per hectare per year fluctuates strongly throughout the years and also the variation within one year (reflected by the standard error) is large. The CpUE found in the SNS and Baseline survey do not seem statistically different. The yearly variation varies greatly among most species. Dab shows similar annual variation to Plaice, while Sole seems to exhibit more constant annual dynamics with some extreme outliers through the years. Interestingly, the population dynamics of Lesser weever, Solenette, Scaldfish and the Gobiids seems to have changed since about 1990.

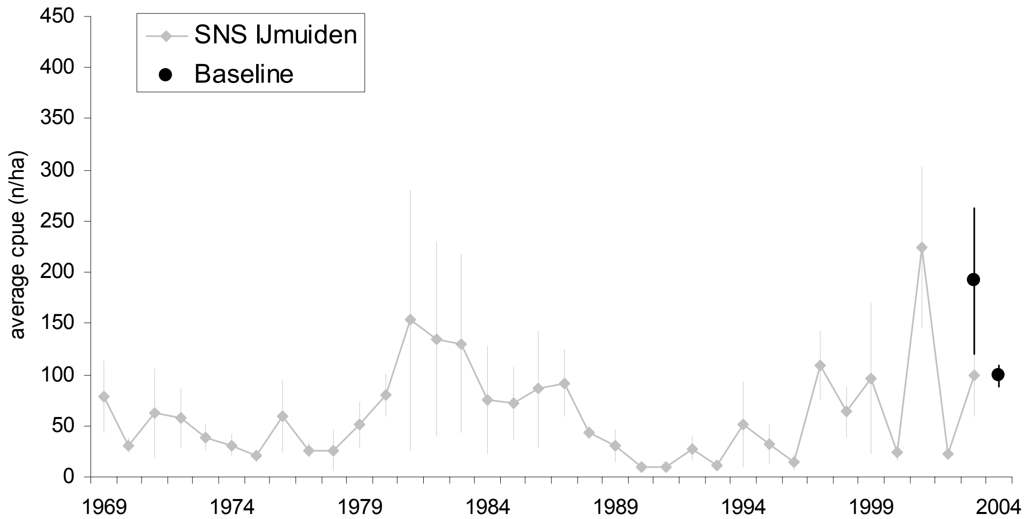

Figure 3.9. The annual variation in mean CpUE (number per hectare) of Plaice, caught in the SNS hauls conducted in the wind farm area (the four hauls from the IJmuiden transect). Vertical bars are the standard error of the mean. In black, the mean CpUE of the (40 mm net of the) two Baseline surveys are shown. Baseline is sampled in summer (2003) and winter (2004), SNS in summer (except for 2003; in spring)

4 DISCUSSION

4.1 The Baseline survey

The Baseline project was set up in order to provide information on the occurrence, density, population structure and migration patterns of the demersal fish community before the erection of the NSW wind farm. With this information the effect of the construction and operation of the NSW wind farm in sea on the demersal fish community will be assessed outside this project. The baseline situation in the wind farm is compared to that in three reference areas, which are similar to the wind farm area in position offshore, bathymetry and sea bed morphology. This way, the influence of variables other than the wind farm itself (such as annual variation) can be excluded when judging the effect of the wind farm.

Two surveys were conducted, in the summer of 2003 and in winter in 2004. Both surveys were successfully executed, reports on both surveys have been delivered (Tien *et al.* 2003 and 2004) and the data has been stored in an accessible database. In this final report, the wind farm is compared to the three reference areas, in order to assess the suitability of the chosen reference areas.

In this chapter, we will synthesize the results and describe the baseline situation of the demersal fish community in the wind farm and reference areas. Based on this description, we will discuss the effects of the wind farm on the demersal fish community that we expect.

4.2 The coastal demersal community

Using beam trawls to sample the demersal fish assemblage during the years 2001-2004, the following picture emerges: Flatfish are the dominant ecological group in the demersal community in the Dutch coastal zone, both in terms of numbers and biomass. In spring and winter, Dab is the most abundant flatfish, followed by Plaice in most length classes. In summer, Sole is the most abundant flatfish in the smaller length classes, while Plaice dominates the larger flatfish. The commercially unimportant Solenette and Scaldfish are also abundant, especially in summer. Next to flatfish, the group of Gobiids were important in the Dutch coast in all seasons but due to their small size they are not important in terms of biomass. Especially in winter, Gobiids are one of the dominant groups (next to Dab). Studies on the distribution and abundance of Gobiids are sparse. Identification to the species level was carried out for the first time within the Baseline study and this yielded new information on the relative occurrence of Gobiid species: Lozano's goby and Sand Goby were the only two important Gobiid species, with Sand Goby being the dominant Gobiid in winter and Lozano's goby in summer. Transparent goby and Painted Goby were only found occasionally.

The density of the various species varied greatly between summer and winter. Many species (Plaice, Sole, Lesser Weever, Solenette, Scaldfish) were more abundant in summer than in winter, while some (Sand Goby and Lozano's Goby) were more abundant in winter.

The age structure of the demersal fish community varied among species: large age ranges within one length class were observed for Lesser weever (individuals of 4 up to 13 years old found within one centimetre group) and Solenette, whereas of Dab only two age classes were observed. Thus the age range within a length range varies greatly between species, which implies different interpretations are needed for the catch data of the various species.

Both Lesser Weever and Solenette are two rather sedentary species that were both found in the deeper part of the wind farm area. Also interesting for both species and Scaldfish is the change in annual population dynamics that has been observed since 1990, with a strong increase in variation in numbers within and between years. This is assumed to be a result of the general increase in water temperature (Heessen, 1996). Lesser Weever, Scaldfish and Solenette were also consistently grouped in the multivariate analysis (see below). They thus seem to have similar lifestyles; small, long living (ages up to respectively 13, 8 and 5 years) species with a preference for deeper coastal water, and all found in high densities in the Dutch coastal waters.

The abundance of most species fluctuates strongly among years, with high densities in one year, which can be followed by low densities in the next. To a large extent, the annual variation in the coastal zone is determined by the age structure of the ambient population. Species that only use the coastal zone as a nursery area, and of which only juveniles occur, probably show a higher annual variation than species that complete their entire life cycle in this area. Temporal variation of species that use the coastal zone as a nursery is caused by annual differences in recruitment. According to Van der Veer *et al.* (2000), variability in recruitment of flatfish stocks, for example, is generated during the pelagic egg and larval stage, probably by variations in the hydrodynamic circulation and in the mortality rates of eggs and larvae.

There is no single type of sampling gear available that samples the entire demersal fish community evenly and some notes on the selectivity of the gear used here should be made. The type of gear employed here (6 metre beam with tickler chains and 20/40 mm nets) is an effective method but does have certain constraints; large individuals are caught less well, since the finer mesh sizes and tickler chains limit the towing speed and larger fish are able to escape the approaching gear by swimming away; some species (e.g. Cod) are badly sampled using this fishing method since they aggregate in places where the beam trawl cannot be used (e.g. ship wrecks, rocky bottom). More general problems are that sampling can differ between seasons, with temperature influencing the swimming speed (and thus catchability) of some species; and as described above, the negative influence of the large variation in time and space on the power of future effect analyses. However, employing two mesh sizes simultaneously provided better information on the demersal fish community.

Supplementing the Baseline dataset with data from other RIVO surveys proved to be very informative. It allows the description of the complete coastal area and puts the Baseline survey data in a wider perspective. The content of this report could thus be broadened from only a detailed comparison of the wind farm area and reference areas to the inclusion of a general description of the area, in several years and seasons.

4.3 Factors influencing the distribution and community structure

Spatial variation was generally large but seemed often not random, with some species (e.g. Lesser weever) occurring in deeper waters, while other species (e.g. Solenette) being more abundant in the wind farm area than in the reference areas. Multivariate statistics were employed to explain this spatial variation, in which the distribution of the species was significantly correlated with temperature, depth, pH and salinity. Grouping of species and responses to variables yielded a consistent pattern between mesh sizes and seasons. Solenette, Lesser weever and Scaldfish seem to congregate and occurred in highest densities in the deeper areas. In summer, Lesser weever, Grey gurnard and Flounder showed a strong response to temperature. Lesser weever occurred mostly in areas with high temperatures, while the other species showed highest densities in colder conditions. The absence of a significant effect of salinity in July is explained by the fact that temperature and salinity work in opposite directions (contrary to the situation in winter), which means that most variation is already explained by temperature. This is obvious because salinity increased with the distance offshore. Temperature also decreases in the same direction in summer, but in winter there is a gradient in opposite direction.

Variables that are missing form the analysis but that potentially have a significant effect are sediment structure (grain size, silt content) and flow velocity. Sediment structure is an important characteristic for many demersal species. For flatfish species, sediment structure determines possibilities to bury in the sand (to avoid predation). Also, the composition of benthic fauna, which forms the prey for most demersal species, is largely determined by the sediment structure. For Plaice the structure of the sediment is an important characteristic that determines the suitability of an area for larvae settlement (Pihl and Van der Veer, 1992). Juvenile Sole prefer muddy substrate (Rogers, 1992). Different age groups differ in habitat preferences. Also for Flounder the sediment characteristic is the most influential factor determining the distribution (Jager *et al.*, 1993). Solenette was found to concentrate near riverine outflows in shallow muddy and muddy-sand bottoms moderately influenced by estuarine waters (Amara et al. 2004). Lesser Weever only occurs on clean sandy sediments at depths < 40 m. For most other species habitat preferences are poorly understood. Data from Lot 1 (benthic fauna) from the baseline study showed that there was only small variation in grain size in the study area (Figure 4.1). Despite the small variation, there could be an effect of grain size on fish abundance but because sampling stations for fish and sediment only partly overlap, a direct coupling of the sediment data to fish data is difficult.

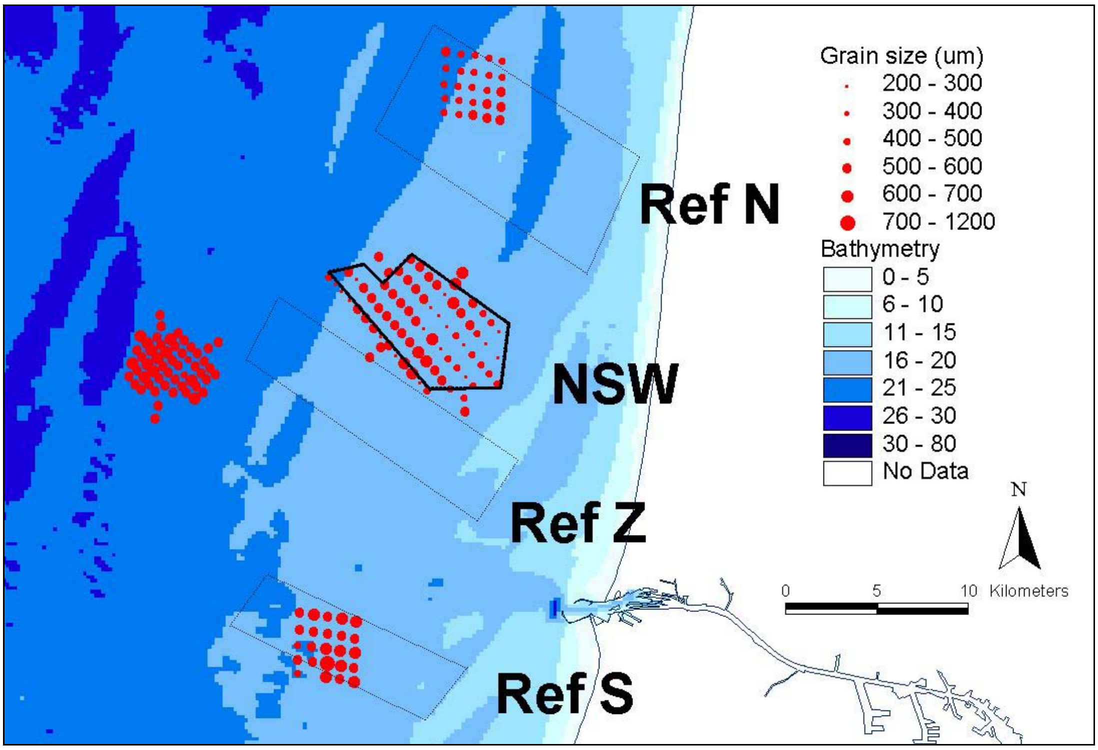

Figure 4.1 Map of the study area with the grain sizes measured by IECS. The dots represent grain size (μm).

Confounded with environmental factors such as depth and sediment structure, food availability is also an important factor structuring species distribution. For demersal fish and for flatfish in particular, benthic fauna is the most important food type. Young flatfish such as Plaice, Sole, Dab and Flounder mainly feed on polychaetes, shrimps, young fish, siphons of bivalves, copepods and amphipods (Beyst *et al.*, 1999; Rijnsdorp and Vingerhoed, 2001). For adult Flounder, molluscs, Corophium and polychaetes are important prey (Kühl & Kuipers 1978). Although Turbot and Brill are demersal species, they often leave the bottom to feed higher in the water. For young specimens fish is the most important prey (Beyst *et al.*, 1999). Solenette feeds on a wide range of bottom-living organisms similar to those found for other flatfish species (Amara et al 2004). The diet of adult Whiting consists of crustaceans and fish as Norway Pout and and Smelt (Hislop 1997), while smaller specimens feeding on crabs and shrimps. The diet of Lesser Weever largely consists of small benthic organisms such as crustaceans, amphipods, isopods and shrimps, small fish such as Gobiids, juvenile Smelt and flatfish (Wheeler, 1969). In the North Sea fish (predominantly Gobiids) is the most important prey type. In the impact assessment (MEP-NSW), data on benthic fauna could be used to explain the variation in fish abundance and to explain possible effects of the wind farm.

4.4 Expected effects of a wind farm

We expect that the largest effect of the wind farm area is the closure of the area to fishing. In two ways this could have an effect on the demersal fish community; 1) indirectly, via a change in sediment structure and availability of benthic organisms and 2) directly, the wind farm could act as a refuge area because locally, in an intensively fished area, fishing mortality is zero. We think, however, that effects will be mainly local and will not extend to the level of North Sea fish populations. Since the processes underlying the demersal fish community and individual species are so poorly understood, reliable predictions on individual species are difficult to make at this moment, but attempted in this section as far as possible.

It is well proven that bottom trawling affects benthic communities, but it is yet not possible to predict whether this effect is positive or negative for demersal fish. The effect of trawling on the composition of the benthic community has been subject of some studies, both in descriptive field studies and experimental studies (Kaiser & de Groot 2000, Schratzberger & Jennings 2002). In general, intensively fished areas are characterised by smaller short-lived benthic species, whereas undisturbed areas are characterised by larger long-lived sessile species. Several studies show that in areas subject to intensive trawling benthic species diversity, biomass and production of benthic macrofauna is reduced (Collie *et al*. 2000, Kaiser *et al.* 2000a,b, Jennings *et al.* 2001, Schratzberger & Jennings 2002). Jennings *et al.* (2002) showed that trawling did not have a significant effect on total productivity. We do, however, not know how trawling affects biomass and productivity of small infauna or polychaetes, the main food source for the dominant flatfish. Therefore we do not know if the wind farm has a positive or a negative effect on food availability of the demersal fish community. The increase in benthic biodiversity may however attract a wider range of demersal fish species. Changes in the benthic community will be investigated in another part of the effect study (see Jarvis *et al.* 2004); the results from that study are essential for the effect study of the demersal fish community. However, additional studies on the diet of demersal fish are needed to link changes in the benthic community to changes in the demersal fish community.

Because fishing mortality and disturbance from fishing will decrease in the wind farm, the area may function as a refuge for local demersal fish which are caught in significant numbers in the local fisheries. This effect will depend on the importance of the area for the various life stages of the species (e.g. spawning, nursing, feeding). For species that migrate over large distances, and use the coastal zone for only short time periods, the refuge function will be limited. The dominant flatfish species Dab, Sole and Plaice for example, migrate over large distances (Daan *et al.*, 1990) and will therefore probably be less influenced than species that spend much time and many life stages in the coastal area. For species that complete their entire life cycle in a small area, the refuge function may be large. Of Lesser weever and Solenette for example, a wide range of age classes was observed within the wind farm area. Every maturity stage (juvenile, ripening, ripe and spent adults) was found in the Baseline survey for these species. In addition, in contrast to Sole and Plaice, both species complete their life cycle in a small area. For such species, the wind farm area may act as an important refuge area. Although the wind farm may have an effect on the local abundance of these species, it is not likely that the wind farm will have a detectable effect on the North Sea populations. The surface area of the future wind farm is relatively small compared to the total potential living area of demersal fish species in the Dutch coastal zone. If, however, the numbers of offshore wind farms increase, which is to be expected, positive effects may accumulate. For many species, like the various abundant Gobiid species, Dragonet species and Whiting, the precise distribution and migration patterns are unknown. More research would be needed to predict the effect on these species.

It is possible that the only species where changes in numbers are statistically detectable, are rare species which thrive in the conditions set by the wind farm. An important example is the artificial structures of the turbines under water, where refuge seeking species such as Cod, Grey mullet *Mugil cephalus* and Sea Bass *Dicentrarchus labrax* could accumulate. Special attention should be given to such species in the effect study. These refuge-seeking species cannot be sampled adequately using a beam trawl. Other species which may be positively affected are more sedentary species (for example rays) who are very sensitive to beam trawling. However, densities of these species are so low such that the probability of detecting them in beam trawl surveys is very low.

Next to effects on species levels, the wind farm can potentially also have an effect on the community level. Locally, the total biomass or number of fish could increase due to the absence of fishing mortality. Again, an effect on North Sea level is not expected due to the same reasons as stated above.

Obviously, any expected positive effect of a wind farm may be reduced by negative effects such as potentially noise and electric or magnetic fields. At present, detailed knowledge of such effects on fish is absent. It is advised to include research onto these effects in future impact assessments.

4.5 Power of the sampling programme

With the Baseline data, a power analysis was conducted in order to assess the number of samples needed to statistically prove a change in the community after the construction and operation of the wind farm (Annex 2.3). The power analysis showed that the detection of an effect of the wind farm on fish biomass through a monitoring programme is not completely unfeasible. Only three hauls are required to prove a 50% reduction in fish biomass, whereas the detection of a 10% reduction requires more than 100 hauls to be statistically significant. The sampling intensity in the current baseline study (13 hauls in the wind farm area) allows the detection of a 30% downward or 40% upward trend. However, noting that the observed spatial and temporal variation is large, a mere increase in sampling intensity would probably fall short: intricate alterations in the spatial or temporal patterns of fish abundance might easily result in erroneous conclusions. Consequently, further analysis of the spatial and temporal patterns and of the experimental factors affecting the results, as well as the derivation of required precision levels (and consequentially required sampling intensities) is recommended.

Changes in the spatial distribution in and around the future wind farm may be detected with the use of the reference areas. The fish assemblage in the NSW area resembled those of the reference areas; there were differences in biomass but differences were small (Annex 2.3). Because the demersal fish community in the NSW area resembled that of the three reference areas for most species, these areas seem to be chosen well. These reference areas could have an important function in assessing the impact of the wind farm: a difference in the spatial patterns in the wind farm area from those in reference areas may indicate effects of the wind farm. To make such indications clearer and to prove effects, research into the underlying processes is however essential.

4.6 Conclusions

Research into the underlying processes will make an impact assessment more efficient. The large variation found in the demersal fish community and the lack of knowledge on the life history of most fish species calls for behavioural and process-oriented studies. In surveys, snapshots of the fish community from one moment are collected. However, the large mobility of most fish makes single-moment sampling less informative when they are used as the only method in an effect study. Also, the function of an area for the different fish species cannot be understood based on this information alone and is needed to assess the importance of the area for the dynamics of the species. What is the function of a specific area (feeding, spawning or is the species merely passing through?), how long does the species stay in the area, etc. In order to assess the effect of a large infrastructural development, more knowledge is needed of the mechanisms that determine the distribution of fish. For example, behavioural studies on Cod and other refuge-seeking species can determine the use of the windmill structures under water as favoured living environment for these species. The residence time of individual species in the wind farm area could be monitored using mark-recapture or telemetric studies, thereby estimating the temporal importance of the area.

In conclusion, the Baseline survey of the demersal fish community has been conducted successfully, a good foundation has been laid down for investigation of future effects and much information is gained on the complexity of the community and the research needed for an adequate effect study.

References

- Amara, R., K. Mahé, O. LePape & N. Desroy. 2004. Growth, feeding and distribution of the solenette Buglossdium luteum with particular reference to its habitat preference. Journal of Sea Research 51: 211-217.
- Beyst, B., Catrijsse, A. and Mees, J. 1999. Feeding ecology of juvenile flatfishes of the surf zone of a sandy beach. Journal of Fish Biology, 55: 1171-1186.
- Bolle, L., Eltink, G., Schaap, L., Vries, M. d., Bakker, K., Groot, P., Rink, G., Beintema, J., Groeneveld, K., Bol, R., Stoker, M., Jongejans, Y. and Rijs, S. 2003. Handboek Leeftijdsbepalingen. Netherlands Institute for Fisheries Research. IJmuiden. Report Nr. CVO 03.010. 73 pp.
- Böttcher, U., Oeberst, R. & Mieske, B., 1998, Daily vertical migration patterns of Baltic 0-group cod., ICES CM1998/J:9, 17pp.Collie, J.S., S.J. Hall, M.J. Kaiser & I.R. Poiner. 2000. A quantitative analysis of fishing impacts on shelf sea benthos. J. Anim. Ecol. 69: 785-798.
- Buisman, E., Van Oostenbrugge, J. A. E., Craeymaersch, J. A., Piet, G. J. and Quirijns, F. 2003. Directe effecten van het demonstratiewindpark NSW voor de visserijsector. LEI, RIVO. Report Nr. 36 pp.
- Collie, J.S., S.J. Hall, M.J. Kaiser & I.R. Poiner. 2000. A quantitative analysis of fishing impacts on shelf sea benthos. J. Anim. Ecol. 69: 785-798.
- Couperus, A.S., Ybema, M.S. and Grift, R. (2003) Base line studies North Sea wind farms: pelagic fish field work report 1. RIVO Report C039/03. RIVO, IJmuiden.
- Creutzberg, F. and Witte, J. J. 1989. An attempt to estimate the predatory pressure exerted by the lesser weever, Trachurus vipera Cuvier, in the southern North Sea. Journal of Fish Biology, 34: 429-449.
- Daan, N., Bromley, P. J., Hislop, J. R. G. and Nielsen, N. A. 1990. Ecology of North Sea fish. Netherlands Journal of Sea Research, 26: 343-386.
- Grift, R. and Tien, N. (2003) Strategy of Approach Demersal Fish Fauna. Project number 9M9237.01 Reference 9M9237.01/R0001/LA/Nijm
- Grift, R. E., H. C. Welleman, A. D. Rijnsdorp, and H. W. Van der Veer. 2001. De visgemeenschap en de visserij in het Nederlandse kustgebied en de Westelijke Waddenzee. Pp. 90. RIVO, IJmuiden.
- Grift, R., Tulp, I., Ybema, M.S. & Couperus, A.S. (2004) Base line studies North Sea wind farms: Final report pelagic fish. Report nr C047/04. 77 p.
- Heessen, HJL 1996. Time-series data for a selection of forty fish species caught during the International Bottom Trawl Survey. ICES Journal of Marine Science, 53: 1079-1084.
- Jager, Z., 1999, Floundering: processes of tidal transport and acumulatin of larval flounder (Platichthys flesus L.) in the Ems-Dollard estuary., Doctoral thesis, University of Amsterdam, 192pp.
- Jager, Z., Kleef, H. L. and Tydeman, P. 1993. The distribution of 0-group flatfish in relation to abiotic factors on the tidal flats in the brackish Dollard (Ems estuary, Wadden Sea). Journal of Fish Biology, 43: 31-43.
- Jarvis, S, Allen, J, Proctor, N, Crossfield, A, Dawes, O, Leighton, A, McNeil, L and Musk, W (2004) North sea wind farms: NSW Lot 1 Benthic fauna. Final report. 607.2-F-2004
- Jennings, S., J.K. Pinnegar, N.V.C Polunin & K.J. Warr. 2001.Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series: 213: 127-142.

- Jennings, S., J.K. Pinnegar, N.V.C Polunin & K.J. Warr. 2001.Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series: 213: 127-142.
- Jennings, S., M.D. Nicholson, T.A. Dinmore & J.E. Lancaster. 2002. Effects of chronic trawling disturbance on the production of infaunal communities. Marine Ecology Progress Series: 243: 251-260.
- Jongman, R.H.G., C.J.F. ter Braak and O.F.R. van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press.
- Kaiser, M.J. & S.J. de Groot 2000 (eds) 2000. The effects of fishing non-target species and habitats: biological, conservation and socio-economic issues. Blackwell Science, Oxford.
- Kaiser, M.J., F.E. Spence & P.J.B. Hart. 2000b. Fishing-gear restrictions and conservation of benthic habitat complexity. Conservation Biology 14: 1512-1525.
- Kaiser, M.J., K. Ramsay, C.A. Richardson, F.E. Spence & A.R. Brand. 2000a. Chronic fishing disturbance has changed shelf sea benthic community structure. J. Anim. Ecol. 69: 494-503.
- Kühl, H. & Kuipers, B.R., 1978. Food relationships of Wadden Sea fishes. In: Dankers, N., Wolff, W.J. & Zijlstra, J.J. (Eds.). Fishes and fisheries of the Wadden Sea. Balkema Press Rotterdam, 112-123.
- Lindholm, J.B., P.J. Auster, M. Ruth & L. Kaufman. 2001. Modeling the effects of fishing and implications for the design of marine protected areas: juvenile fish responses to variations in seafloor habitat. Conservation Biology 15: 424-437.
- Muus, B.J., Nielsen, J.G, Dahlstrom, P. & Nystrom, B.O. 1999. Zeevissen van Noord- en West-Europa. Schuyt&Co, Haarlem.
- Pihl, L. and Van der Veer, H. W. 1992. Importance of exposure and habitat structure for the population density of 0-group plaice, Pleuronectes platessa L., in coastal nursery areas. Netherlands Journal of Sea Research, 29: 145-152.
- Rijnsdorp, A. D. and Vingerhoed, B. 2001. Feeding of plaice Pleuronectes platessa L. and sole Solea solea (L.) in relation to the effects of bottom trawling. Journal of Sea Research, 45: 219-229.
- Rogers, S.I., 1992, Environmental factors affecting the distribution of sole (Solea solea (L.)) within a nursery area., Netherlands Journal of Sea Research 29: 153-161.
- Tien, N., Bol, R and Grift R. (2003) Base line studies North Sea wind farms: demersal fish survey report 1. Royal Haskoning report 9M9237.01/THIE/Gron.
- Schratzberger, M. & S. Jennings 2002. impacts of chronic trawling disturbance on meiofaunal communities. Marine Biology 141: 991-1000.
- Ter Braak, C.J.F. and P. Šmilauer. 2002. CANOCO Reference manual and user's guide to Canoco for Windows: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca, NY, USA.
- Tien, N and Grift R. (2004) Base line studies North Sea wind farms: biological data demersal fish. Royal Haskoning report 9M9237/R0008/THIE/Gron
- Tien, N, Bol, R and Grift R. (2004) Base line studies North Sea wind farms: demersal fish survey. Fieldwork report 2. Royal Haskoning report 9M9237/R0007/THIE/Gron.

- Tien, N., Bol, R and Grift R. (2003) Base line studies North Sea wind farms: demersal fish survey report 1. Royal Haskoning report 9M9237.01/THIE/Gron.

- Van der Veer, H. W., Berghahn, R., Miller, J. M. and Rijnsdorp, A. R. 2000. Recruitment in flatfish, with special emphasis on North Atlantic species: progress made by the Flatfish Symposia. ICES Journal of Marine Science, 57: 202-215.

- Verver, S.W., Grift, R.E. and Quirijns, F.J. (2003) Beschrijving Nederlandse visserij in de Noordzee, EEZ en het Nederlandse kustgebied ten behoeve van Natuurbalans 2003. RIVO rapport nr C040/03.
- Verver, S.W., Grift, R.E. and Quirijns, F.J. (2003) Beschrijving Nederlandse visserij in de Noordzee, EEZ en het Nederlandse kustgebied ten behoeve van Natuurbalans 2003. RIVO rapport nr C040/03.
- Wheeler, A. 1969. The fishes of the British Isles and North-West Europe. Macmillan, London. 529 pp.

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Annex 2.1
Species list of species caught in Dutch coast between 1969-2004

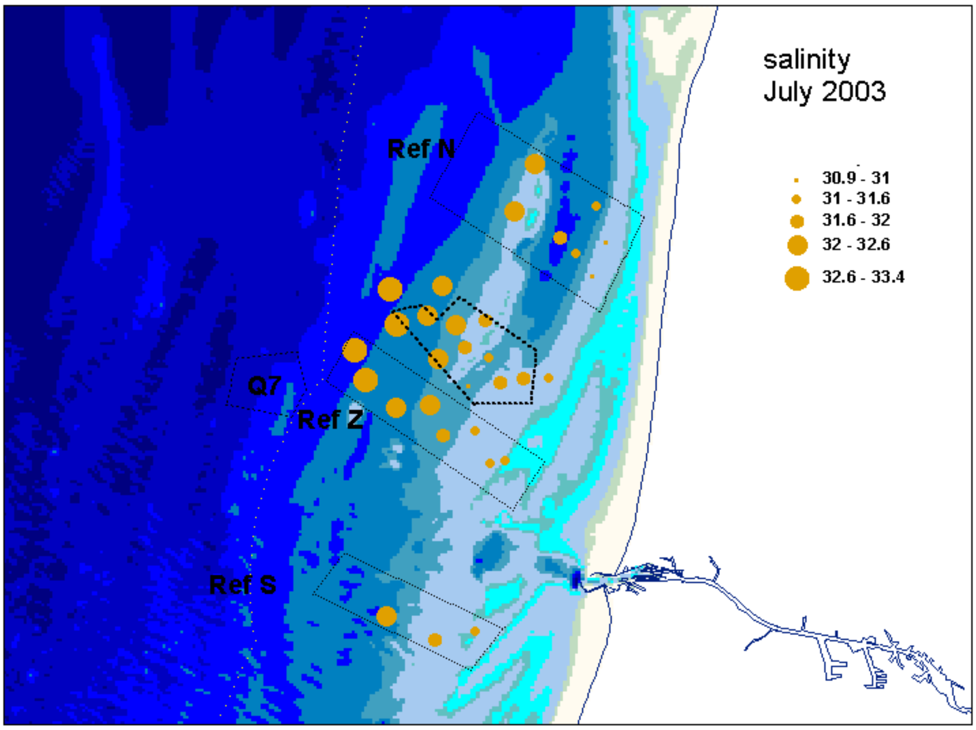
Annex 2.1 Species list of species caught in Dutch coast between 1969-2004

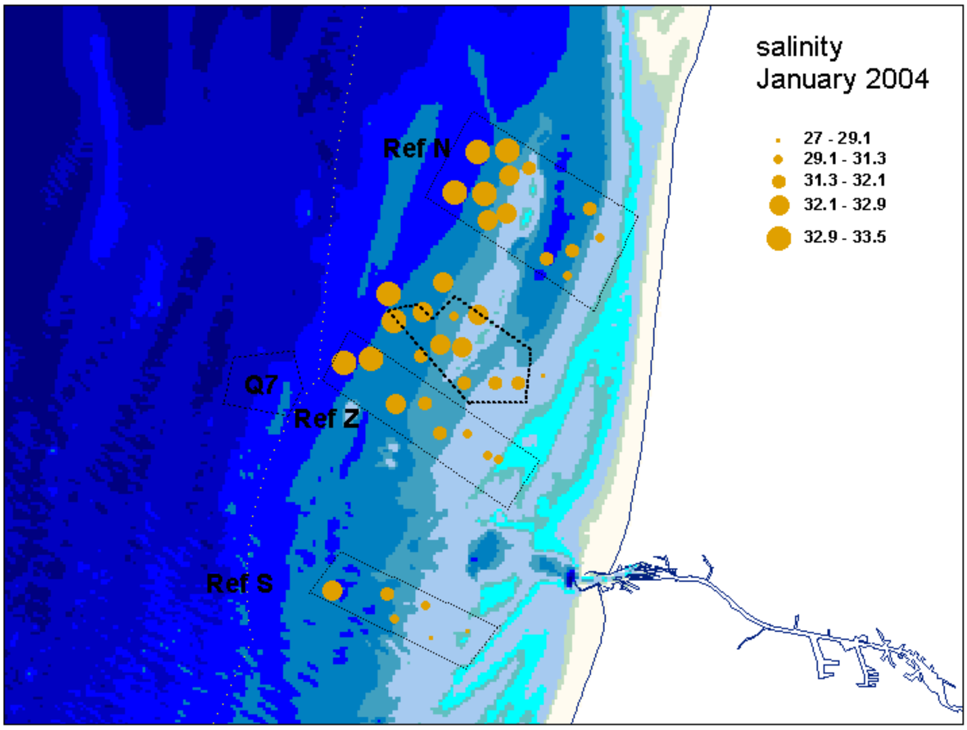
English, scientific, Dutch name, NODC code and the ecological group of the species are depicted. Data from the Baseline, SNS, BTS and Mare survey in the Dutch coast.

Species	Scientific name	Dutch name	NODC code	Ecological group
Allis shad	Alosa alosa	Elft	874701010700	Pelagic
Anchovy	Engraulis encrasicolus	Ansjovis	874702010400	Pelagic
Bass	Dicentrarchus labrax	Zeebaars	883575010100	Other
Bib	Trisopterus luscus	Steenbolk	879103170200	Roundfish
Brill	Scophthalmus rhombus	Griet	885703040300	Flatfish
Bull-rout	Myoxocephalus scorpius	Zeedonderpad	883102220700	Other
Butterfish	Pholis gunnellus	Botervis	884213020900	Other
Cod	Gadus morhua	Kabeljauw	879103040200	Roundfish
Dab	Limanda limanda	Schar	885704090400	Flatfish
Dragonet sp.	Callionymidae	Pitvis sp.	884601000000	Other
Eel	Anguilla anguilla	Aal	874101010200	Other
Fifteen-spined stickleback	Spinachia spinachia	Zeestekelbaars	881801050100	Other
Five-bearded rockling	Ciliata mustela	Vijfdradige meun	879103240100	Roundfish
Flounder	Platichthys flesus	Bot	885704140200	Flatfish
Four-bearded rockling	Enchelyopus cimbrius	Vierdradige meun	879103150100	Roundfish
Garfish	Belone belone	Geep	880302050200	Pelagic
Gobiids sp.	Gobiidae	Grondel sp.	884701000000	Other
Grey gurnard	Eutrigla gurnardus	Grauwe poon	882602060100	Other
Haddock	Melanogrammus aeglefinus	Schelvis	879103130100	Roundfish
Hagfish	Myxine glutinosa	Slijmprik	860601020100	Other
Hake	Merluccius merluccius	Heek	879104010500	Roundfish
Herring	Clupea harengus	Haring	874701020100	Pelagic
Hooknose	Agonus cataphractus	Harnasmannetje	883108080300	Other
Horse mackerel	Trachurus trachurus	Horsmakreel	883528010300	Pelagic
John Dory	Zeus faber	Zonnevis	881103030100	Other
Lamprey	Lampetra fluviatilis	Rivierprik	860301021700	Other
Lemon sole	Microstomus kitt	Tongschar	885704120200	Flatfish
Lesser spotted dogfish	Scyliorhinus canicula	Hondshaai	870801030600	Other
Lesser weever	Echiichthys vipera	Kleine pieterman	884006010100	Other
Long rough dab	Hippoglossoides platessoides	Lange schar	885704060300	Flatfish
Lumpsucker	Cyclopterus lumpus	Snotolf	883109150100	Other
Mackerel	Scomber scombrus	Makreel	885003030200	Pelagic
Mullet sp.	Mugilidae	Harder ongespecificeerd	883601000000	Other
Norway pout	Trisopterus esmarki	Kever	879103170300	Roundfish
Norwegian topknot	Phrynorhombus norvegicus	Dwergbot	885703220100	Flatfish
Pilchard	Sardina pilchardus	Pelser	874701220100	Pelagic
Pipefish sp.	Syngnathus sp.	Zeenaald sp.	882002210100	Other
Plaice	Pleuronectes platessa	Schol	885704150200	Flatfish
Pollack	Pollachius pollachius	Witte koolvis	879103090200	Roundfish
Poor cod	Trisopterus minutus	Dwergbolk	879103170100	Roundfish
Ray sp.	Raja sp.	Rog sp.	871304015900	Other
Red gurnard	Aspitrigla cuculus	Engelse poon	882602080100	Other
Saithe	Pollachius virens	Zwarte koolvis	879103090100	Roundfish
Sandeel sp.	Ammodytes sp.	Smelt	884501030100	Pelagic
Sand-smelt	Atherina presbyter	Grote koornaarvis	880502100300	Pelagic
Scaldfish	Arnoglossus laterna	Schurftvis	885703170200	Flatfish
Sea lamprey	Petromyzon marinus	Zeeprik	860301030100	Other
Sea-snail	Liparis liparis	Slakdolf	883109082800	Other
Silvery pout	Gadiculus argenteus	Zilverkabeljauw	879103210100	Roundfish
Smelt	Osmerus eperlanus	Spiering	875503030100	Pelagic
Smoothhound	Mustelus mustelus	Gladde haai	870802040900	Other
Sole	Solea vulgaris	Tong	885801060100	Flatfish
Solenette	Buglossidium luteum	Dwergtong	885801080100	Flatfish
Sprat	Sprattus sprattus	Sprot	874701170100	Pelagic
Starry smoothhound	Mustelus asterias	Gevlekte gladde haai	870802040800	Other
Stickleback	Gasterosteus aculeatus	Driedoornige stekelbaars	881801010100	Other
Striped red mullet	Mullus surmuletus	Mul	883545020200	Other
Thick-lipped grey mullet	Chelon labrosus	Diklipharder	883601070400	Other
Three-bearded rockling	Gaidropsurus vulgaris	Driedradige meun	879103200100	Roundfish
Tub gurnard	Trigla lucerna	Rode poon	882602050100	Other
Turbot	Psetta maxima	Tarbot	885703040200	Flatfish
Twaite shad	Alosa fallax	Fint	874701010900	Pelagic
Viviparous blenny	Zoarces viviparus	Puitaal	879301200100	Other
Whiting	Merlangius merlangus	Wijting	879103180100	Roundfish
Wrasse sp.	Labridae	Lipvis sp.	883901000000	Other

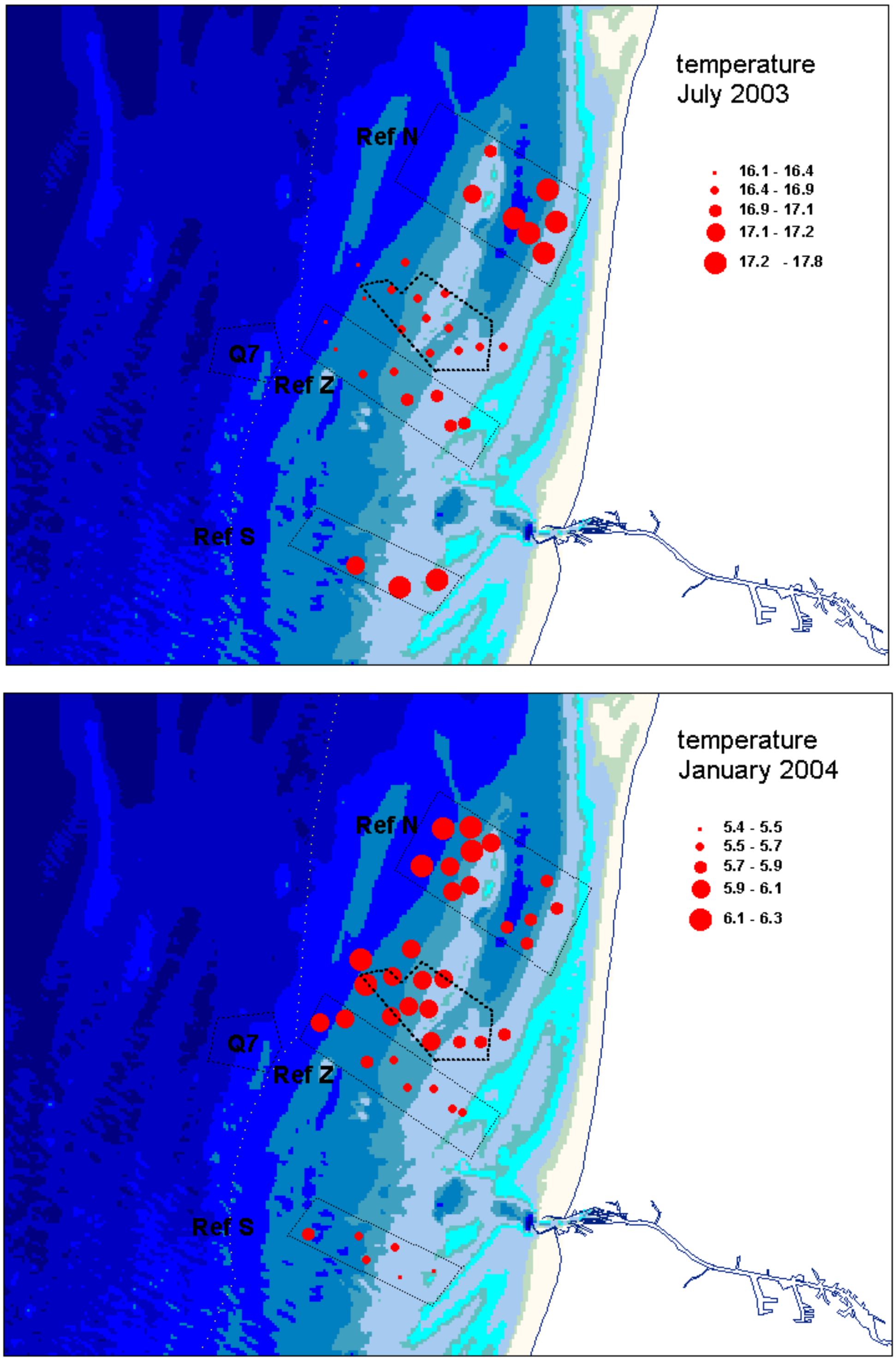
Annex 2.2
Environmental information per haul

Annex 2.2. Environmental information per haul

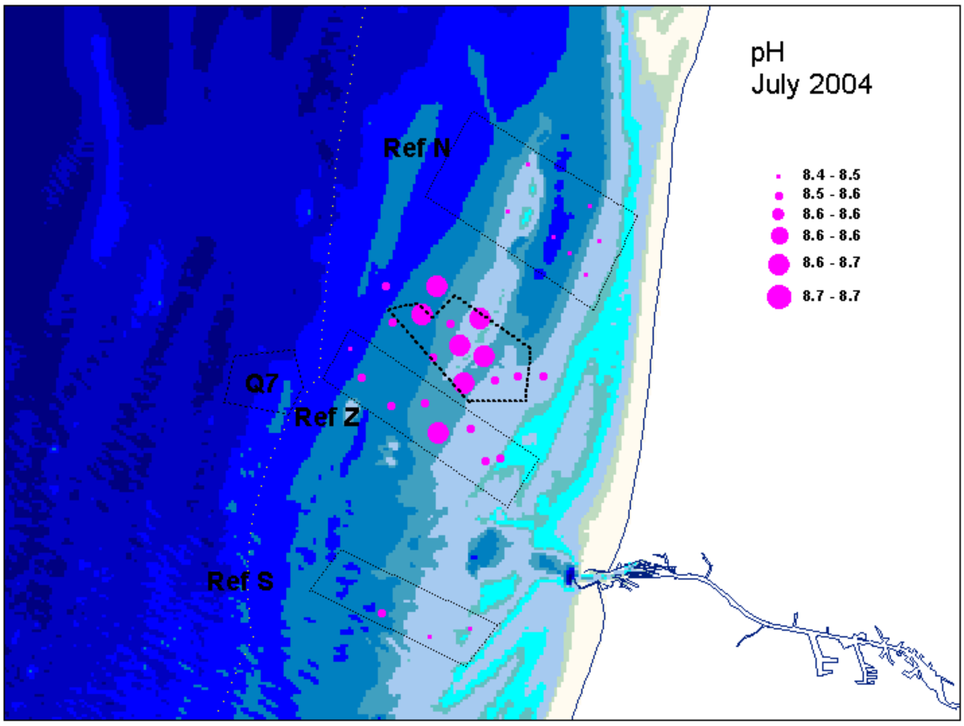


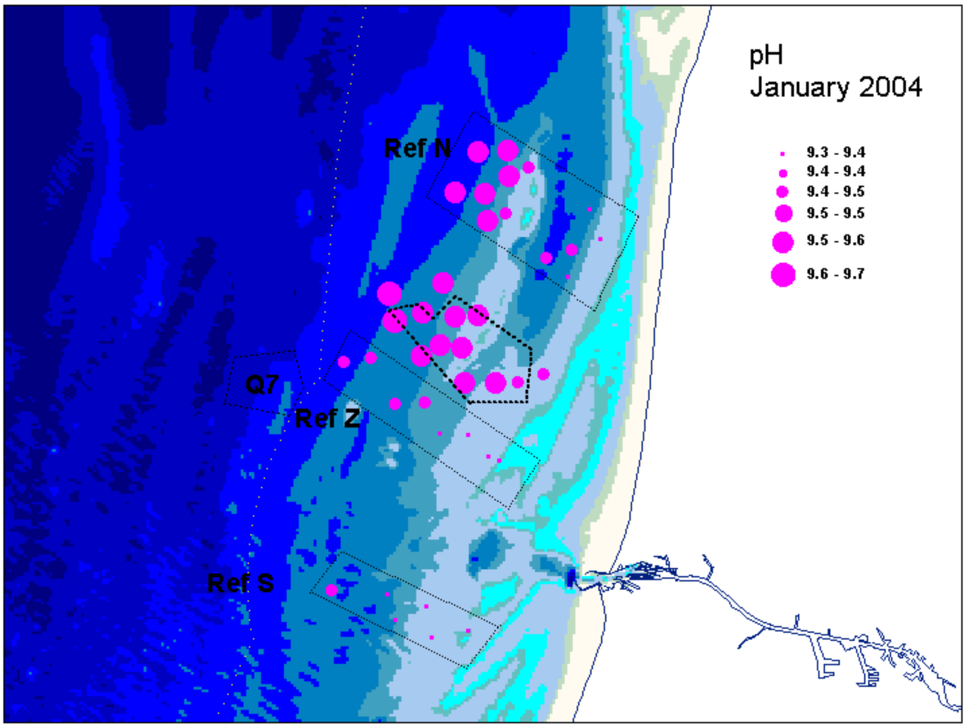


Salinity (ppm), average values per haul, measured with the CTD device.



Temperature (°C), average values per haul, measured with the CTD device.





PH (-), average values per haul, measured with the CTD device.

Annex 2.3
Statistical analyses

Annex 2.3. Statistical analyses

Analysis of variance for differences in fish biomass among areas

The variation between areas was investigated by using analysis of variance (ANOVA). This analysis investigates factors that cause variation in fish biomass. To test the effect of area (NSW, reference area) and period (summer 2003, winter 2004) on the fish biomass, a linear model was used:

$$\text{Log(catch weight)} \sim \text{Area}_i + \text{Period}_j, \qquad \text{(Model 1)}$$

where catch weight is the total weight of the catch, area is one of the four areas (I=4) and period is the survey period (June/July 2003 and January 2004, j=2). In fact, the model estimates average fish biomass and the variation for each combination of area and period. The averages from the combinations are compared, and it is tested if they differ statistically.

The analyses were performed for both mesh sizes separately. We used log-transformed catch weights in order to obtain normally distributed values. Before catches were analysed, they were thus log-transformed. The normality of the distribution was tested using a Wilk-Shapiro test. A normal distribution of the data is a basic assumption in this type of analysis. Statistical differences among areas were tested with a LSmeans procedure in which biomass estimates are compared pair wise after correction for the effect of sampling period (using a Tukey correction). This is important, because if you make many comparisons, there is always a probability that two averages differ by mere chance, and not because they are really different. Therefore, the Tukey correction is used.

Differences in the amount of biomass between areas were investigated using total biomass (over all species) as well as biomass per species. Both area and mesh size were investigated as explanatory variables in an ANOVA, after correcting for the sampling period (summer 2003 or winter 2004). This was done to answer the question if fish biomass varied among areas, not regarding periods.

The total biomass varies significantly ($P<0.05$, i.e. the probability that they do differ by chance alone is 5 %) among areas and between periods for both the 20 mm and the 40 mm net (Figure A). After correction for the effect of sampling period, there is, however, no statistical difference among areas for the 20 mm net; so, overall (not regarding sampling period), there is no significant difference in total biomass among areas in the 20 mm net. In the 40 mm net, the total biomass differed significantly among areas; it was lower in the NSW area than in the northern (RefN) and most southern reference area (RefS).

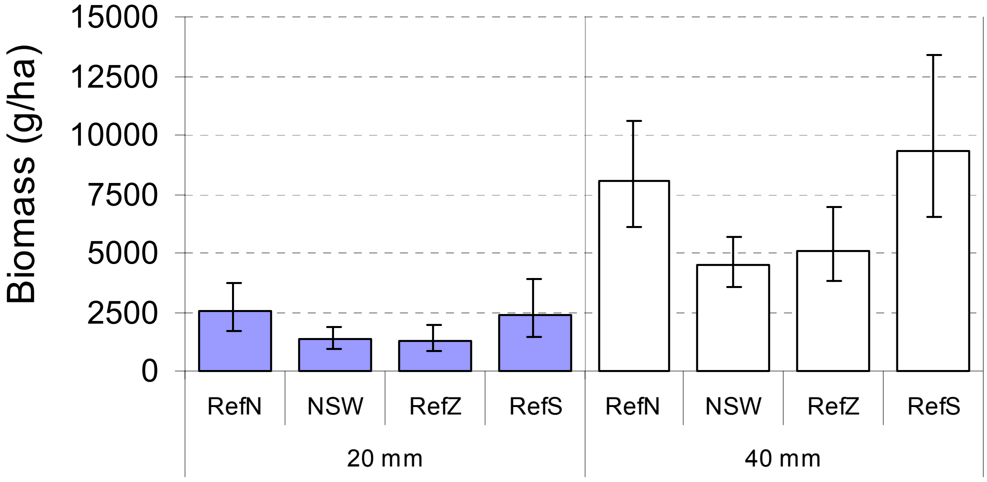


Figure A. Average total biomass (catch per unit effort, +/- 95% confidence limits of the mean) in each of the four areas per mesh size. These values are the result of model (1) and present the differences in total biomass among areas after the effect of the sampling period has been removed. The values per species are presented in Table A.

Table A. Results of the analysis of variance, for the Baseline biomass results. Predicted values (average catch per unit effort) from model (1). The table presents the biomass per species and for all species together (gram/hectare) in the four areas for each net after the effect of sampling period has been removed.

Mesh size	Species	RefN	NSW	RefZ	RefS
20 mm	Dab	1349	521	724	886
	Gobiids sp.	62	44	30	135
	Lesser weever	35	58	32	44
	Plaice	678	321	188	460
	Scaldfish	33	35	24	20
	Sole	62	78	25	46
	Solenette	56	74	63	50
	All species	2527	1327	1262	2347
40 mm	Dab	3325	1974	3163	3360
	Gobiids sp.	34	16	13	132
	Lesser weever	46	35	41	18
	Plaice	3120	1753	1263	2107
	Scaldfish	117	122	103	164
	Sole	384	114	63	492
	Solenette	27	60	60	54
	All species	8045	4530	5120	9342

Power analysis
With data collected in the baseline study the power of the sampling programme can be investigated. This power analysis addresses the question: to what extent are the results significant, and consequently, will this monitoring programme be able to detect possible ecological effects of future works? Also, the number of hauls can be estimated that are required to meet certain statistical precision levels.

The power analysis was started with exploring the statistical distribution of the data, i.e. are the data normally or Poisson distributed etc.. The results clearly show the immense variation in the total weight of fish caught per haul. For the analysis of total biomass per haul, observations range from 0.2 kg to over 48 kg per haul (the smallest haul was 0.2 kg and the largest one 48 kg). Nearly half this variation is attributable to structural differences, between areas, between seasons, between differences in experimental set-up (mesh size), but the other half ultimately ranks as random, local, incidental variation (Figure B). In other words, we can explain circa 50 % of the variation by the factors area, sampling period and mesh size. Statistically expected catches range from nearly 0.9 kg to 16.5 kg per haul, while individual hauls vary between 51 and 194% of these averages (this interval corresponds to ± 1 standard deviation around the mean). These statistically expected catches are based on averages (i.e. the average catch per haul in the NSW area with a 20 mm net).

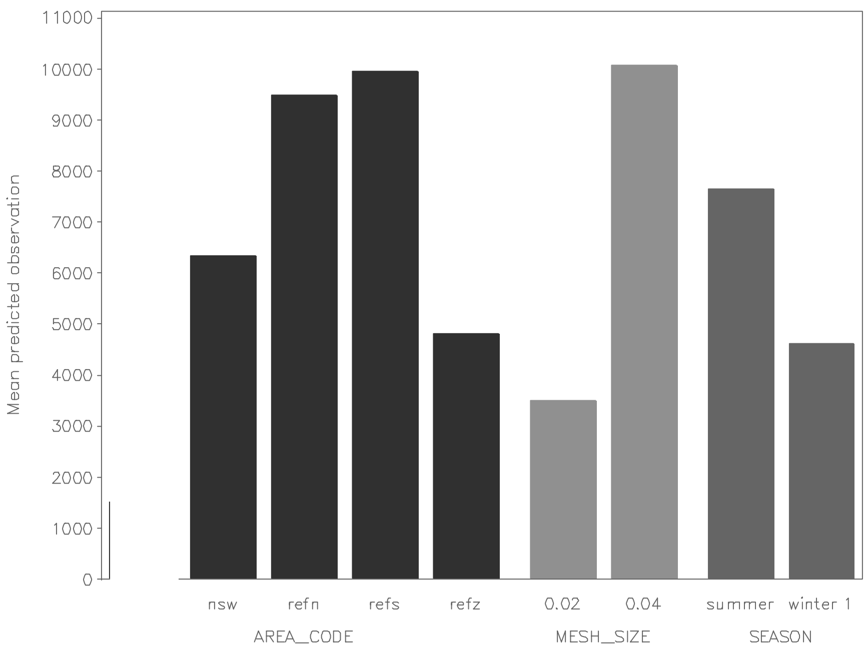


Figure B. Comparisons of statistically expected results (biomass in gr per haul), between areas, mesh sizes and seasons. Note that each comparison considers a single factor, that is: results have been corrected for the other factors. All factors combined results in an even wider range of expected catches. The bars show, for example, that the average catch in NSW is ~6000 gram/ha (averaged over all hauls, mesh sizes and periods). The graph clearly shows the difference in catch between the 20 and 40 mm net (3500 vs. 10000 gram per hectare averaged over all hauls). Also, in winter, catches were generally lower than in summer.

The random variation in catch between hauls blurs our perception of the underlying spatial and temporal patterns in fish abundance. The presented trends are based on statistical analyses in which the observed spatial and temporal variation is contrasted with random variance between hauls. Only if the odds of an accidental pattern are less than 5%, will a result be considered significant. Obviously, this statistical significance is linked to the number of observations: the more often a trend shows up, the less likely it is to be produced by mere chance. Inverting this line of reasoning, one can calculate the number of samples required to prove some pre-specified effect; this inverse analysis is known as a power-analysis.

Results power analysis

Figure C shows that, to prove a 50% reduction in fish biomass in the wind farm area, only three hauls will be required, while a 10% reduction requires more than 100 hauls to be statistically significant.

At the bottom line, the question arises, what sampling intensity will be required to detect considerable ecological effects of a future wind farm. As Figure C shows, this depends on the magnitude of what is considered a considerable effect. The sampling intensity from the current baseline study (13 hauls in the wind farm area) allows the detection of a 30% downward or 40% upward trend in fish biomass. Whether that is considered an adequate precision cannot be determined on purely statistical grounds.

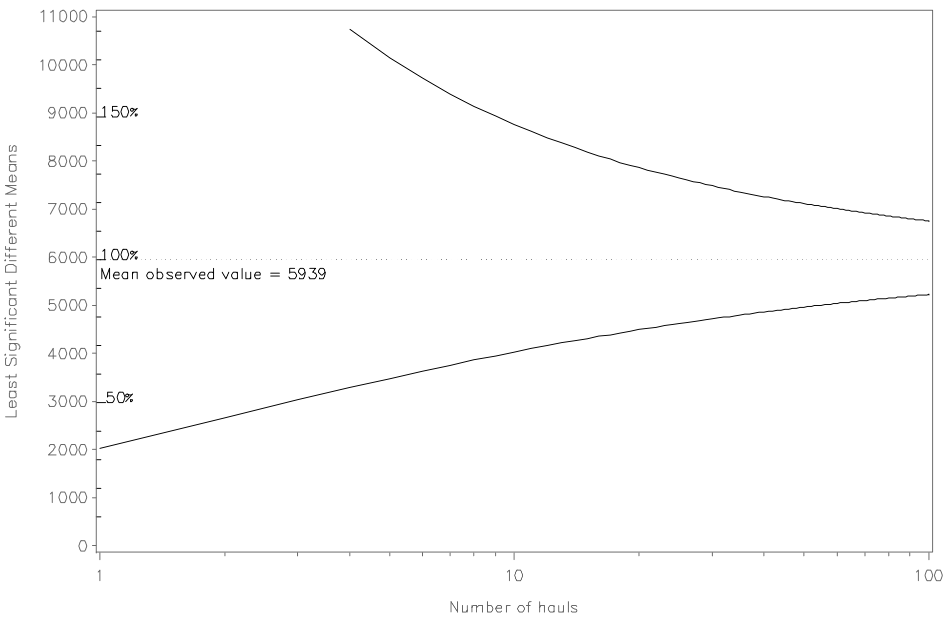


Figure C. The relationship between expected confidence intervals (vertical) and the number of hauls in a monitoring programme (horizontal), here shown for the mean value of all observations. Note the logarithmic nature of the horizontal axis. The average catch is always 5939 g/ha. With one haul (1 on the x-axis), the lower confidence limit of the estimate is 2000 g/ha, whereas the upper limit cannot be estimated. With 10 hauls, the lower confidence limit of the estimated biomass is ~4000 g/ha and the upper limit is ~8500 g/ha (around the average of 5939 g/ha). To detect a significant change in fish biomass, the new level of the fish biomass must be outside the confidence limits i.e.; when 10 hauls are executed, a change in fish biomass can be detected if it changes from 5939 g/ha to less than 400 g/ha, a reduction by more than 30 %.

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Annex 2.4
Length-weight relationships

Annex 2.4 Length-weight relationships

Standards length-weight relationships to predict weight from length: weight= a x Length^b (weight in grams, length in cm).

Species	Name	a	b
Agonus cataphractus	Hooknose	0.0196	2.6139
Alosa alosa	Allis shad	0.0096	2.9810
Ammodytes sp.	Sandeel sp.	0.0013	3.3200
Arnoglossus laterna	Scaldfish	0.0030	3.4023
Belone belone	Garfish	0.0002	3.4420
Buglossidium luteum	Solenette	0.9814	0.7590
Callionymidae	Dragonet sp.	0.0162	2.5781
Ciliata mustela	Five-bearded rockling	0.0108	2.9590
Clupea harengus	Herring	0.0060	3.0904
Echiichthys vipera	Lesser weever	0.0018	3.4099
Enchelyopus cimbrius	Four-bearded rockling	0.0035	3.1062
Eutrigla gurnardus	Grey gurnard	0.0062	3.1003
Gadus morhua	Cod	0.0049	3.1966
Gobiidae	Gobiids sp.	0.0098	2.9400
Limanda limanda	Dab	0.0074	3.1128
Liparis liparis	Sea-snail	0.0587	2.9390
Merlangius merlangus	Whiting	0.0042	3.0565
Mullus surmuletus	Striped red mullet	0.0047	3.3088
Mustelus asterias	Starry smoothhound	0.0049	2.9269
Myoxocephalus scorpius	Bull-rout	0.0126	3.1235
Osmerus eperlanus	Smelt	0.0053	3.0319
Platichthys flesus	Flounder	0.0087	3.0978
Pleuronectes platessa	Plaice	0.0082	3.0260
Psetta maxima	Turbot	0.0044	3.3862
Scomber scombrus	Mackerel	0.0030	3.2900
Scophthalmus rhombus	Brill	0.0055	3.3047
Solea vulgaris	Sole	0.0036	3.3133
Sprattus sprattus	Sprat	0.0021	3.4746
Syngnathus sp.	Pipefish sp.	0.0001	3.5270
Trachurus trachurus	Horse mackerel	0.0034	3.2943
Trigla lucerna	Tub gurnard	0.0080	3.0610
Trisopterus luscus	Bib	0.0038	3.3665
Trisopterus minutus	Poor cod	0.0092	3.0265

Annex 3.1
CpUE (number/ha) per species, net type and area for the Baseline study in June 2003

Annex 3.1 CpUE (number/ha) per species, net type and area for the Baseline study in June 2003

Zero catches are represented as '.'

English name / Area	20 mm net				40 mm net			
	NSW	REF N	REF S	REF Z	NSW	REF N	REF S	REF Z
Bib	.	.	.	0.3	0.1	.	.	0.1
Brill	.	0.3	.	.	0.4	0.7	.	0.4
Bull-rout	.	1.5	1	.	0.3	3.7	1.3	0.3
Cod	.	.	0.8	.	.	.	.	.
Dab	43.6	103	22.3	22.2	63.3	157.7	60.1	49.6
Dragonet	24.3	43.7	43.3	12.4	16.4	45.2	46.9	8.3
Flounder	1.4	0.4	1.2	.	5.3	3.4	5.1	0.1
Garfish	0.1	.	.	.	.	.	.	.
Greater sand-eel	0.3	.	.	0.4	0.2	.	0.2	.
Grey gurnard	0.2	0.4	.	.	.	0.7	0.2	0.1
Herring	.	0.6	.	.	.	0.3	.	.
Hooknose	2.4	0.6	0.6	0.6	3	18.2	3.1	0.9
Horse mackerel	0.2	.	.	0.1	0.2	.	.	0.1
Lesser sand-eel	5.3	9.2	0.3	3.6	0.2	.	.	.
Lesser weever	16.3	2.2	12.6	22.9	9.6	1.3	7.1	6.7
Lozano's goby	8.4	6.3	7.7	5.8	6.1	11.5	20.1	3.3
Mackerel	.	.	.	.	0.1	.	.	.
Painted goby	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0
Plaice	22.4	136.2	17.9	7.3	72.3	316.5	72.8	32.6
Poor cod	.	.	.	.	.	.	0.4	.
Raitt's sand-eel	6.1	4.2	.	1.4	0.9	.	.	0.3
Reticulated dragonet	0.6	.	2	1.2	0.2	.	.	0.3
Sand goby	4.7	9.4	3.6	1.5	0.9	15.2	3.8	0.9
Scaldfish	12.6	6.3	3.8	7.4	22.2	22.1	21.8	18.8
Sole	0.7	6.9	2.2	0.4	7.1	59.9	36.9	2.7
Solenette	62.4	19.9	28.3	46.3	49.3	10.4	29	43.8
Spotted dragonet	0.2	.	.	.	.	.	.	.
Sprat	.	.	.	.	0.1	.	.	.
Starry smoothhound	.	.	.	.	.	0.1	.	.
Striped red mullet	0.1	.	.	0.1	0.6	0.3	0.2	0.1
Transparent goby	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Tub gurnard	1	1.2	0.2	0.3	3.2	4.6	2	2.3
Turbot	.	.	.	0.1	0.2	.	0.2	0.3
Whiting	3.5	7.1	14.5	5.6	0.7	3.1	.	1.7

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Annex 3.2
CpUE (number/ha) per species, net type and area for the Baseline study in January 2004

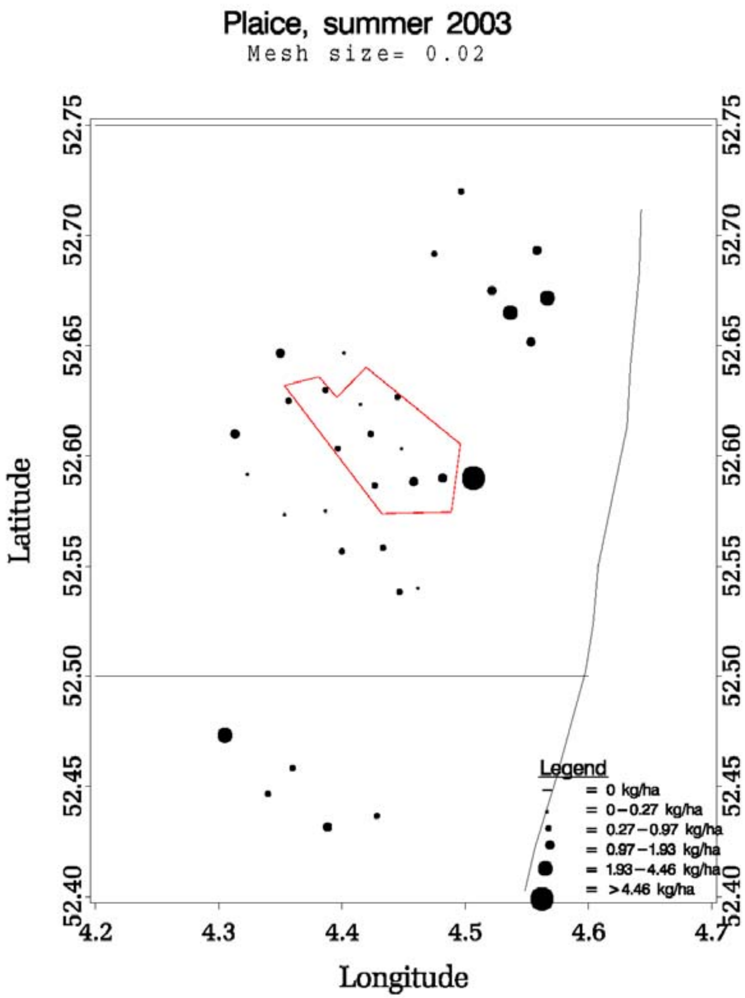
Annex 3.2 CpUE (number/ha) per species, net type and area for the Baseline study in January 2004

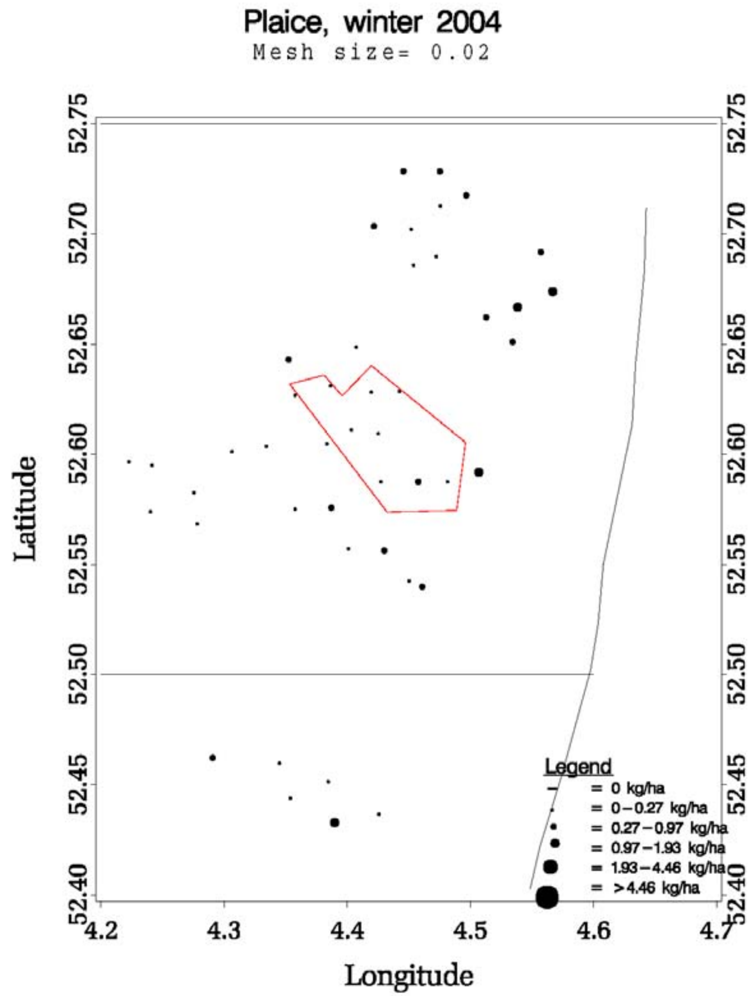
Zero catches are represented as '.'

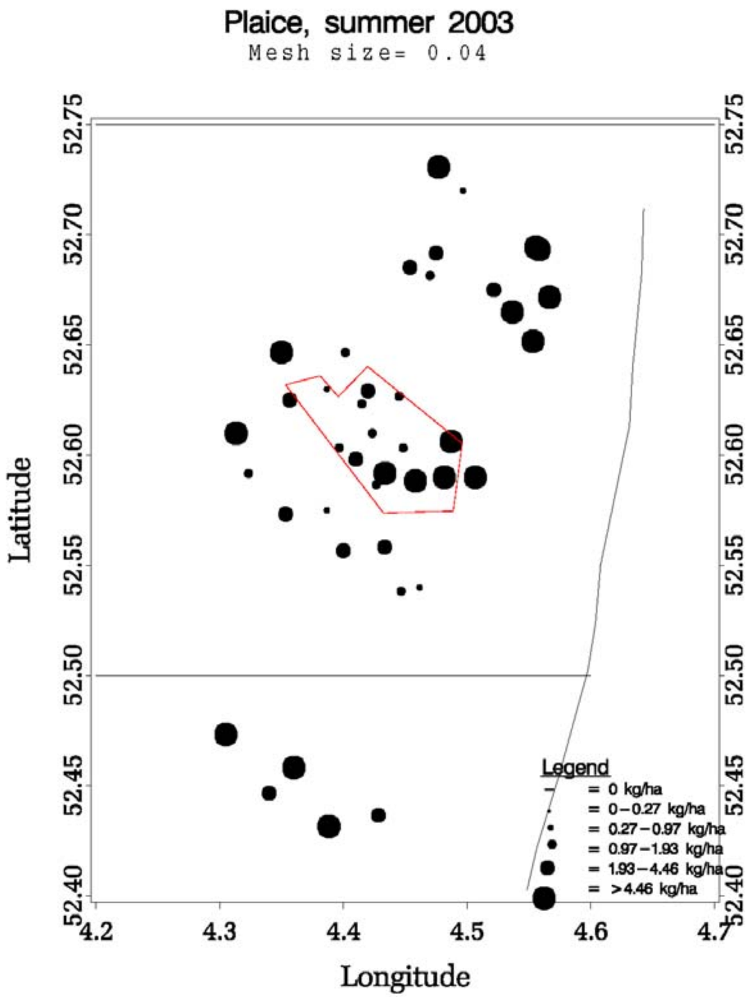
English name / Area	20 mm net				40 mm net			
	NSW	REF N	REF S	REF Z	NSW	REF N	REF S	REF Z
Allis shad	.	0.2	.	.	.	.	.	.
Bib	.	.	0.2	.	0.1	0.2	.	.
Brill	.	.	.	.	0.4	0.3	.	0.6
Bull-rout	0.2	0.7	3.4	0.3	0.3	2.0	2.5	0.2
Cod	0.4	0.4	0.3	.	0.3	0.3	0.2	0.2
Dab	86.7	189.5	107.4	42.5	77.9	144.7	260.2	93.3
Dragonet	10.2	26.3	27.6	7.4	3.3	9.3	17.2	4.8
Five-bearded rockling	0.3	0.3	0.8	0.3	0.1	0.5	0.7	.
Flounder	0.1	0.2	1.0	.	0.5	0.7	1.8	0.6
Four-bearded rockling	.	.	.	0.2	.	.	.	.
Greater sand-eel	.	.	0.3	.	.	.	.	.
Herring	34.5	46.6	29.9	70.3	1.8	3.7	13.7	0.7
Hooknose	0.9	0.7	0.2	0.4	1.8	2.4	0.3	1.6
Horse mackerel	0.1	.	.	.	.	.	.	.
Lesser sand-eel	.	0.1	.	0.1	.	.	0.2	0.2
Lesser weever	3.4	1.3	0.7	4.2	1.6	2.2	0.3	4.1
Lozano's goby	44.9	45.1	84.8	38.2	4.4	12.7	161.9	15.0
Painted goby	.	1.5	2.7	0.3	0.1	0.6	.	.
Plaice	23.7	51.3	21.4	16.6	101.1	179.4	86.8	65.6
Raitt's sand-eel	0.2	.	.	0.2	0.1	0.2	.	.
Reticulated dragonet	0.3	0.3	.	0.1	0.2	0.3	.	.
Sand goby	106.3	112.7	220.7	36.4	18.3	58.6	289.5	21.1
Scaldfish	1.2	0.7	0.7	0.7	3.9	3.5	3.0	3.6
Sea-snail	.	.	.	.	.	.	.	0.1
Smelt	.	0.1	.	0.1	.	.	.	.
Sole	0.1	0.3	.	.	1.1	5.7	1.0	0.4
Solenette	6.3	7.1	1.2	4.3	3.4	4.2	1.3	4.3
Sprat	26.7	23.4	14.4	34.4	0.6	0.8	7.3	0.8
Turbot	.	.	.	.	.	.	.	0.1
Whiting	41.8	5.1	0.7	0.3	33.5	4.4	0.8	1.0
Pipefish spp.	0.3	.	.	0.3	.	.	.	0.1

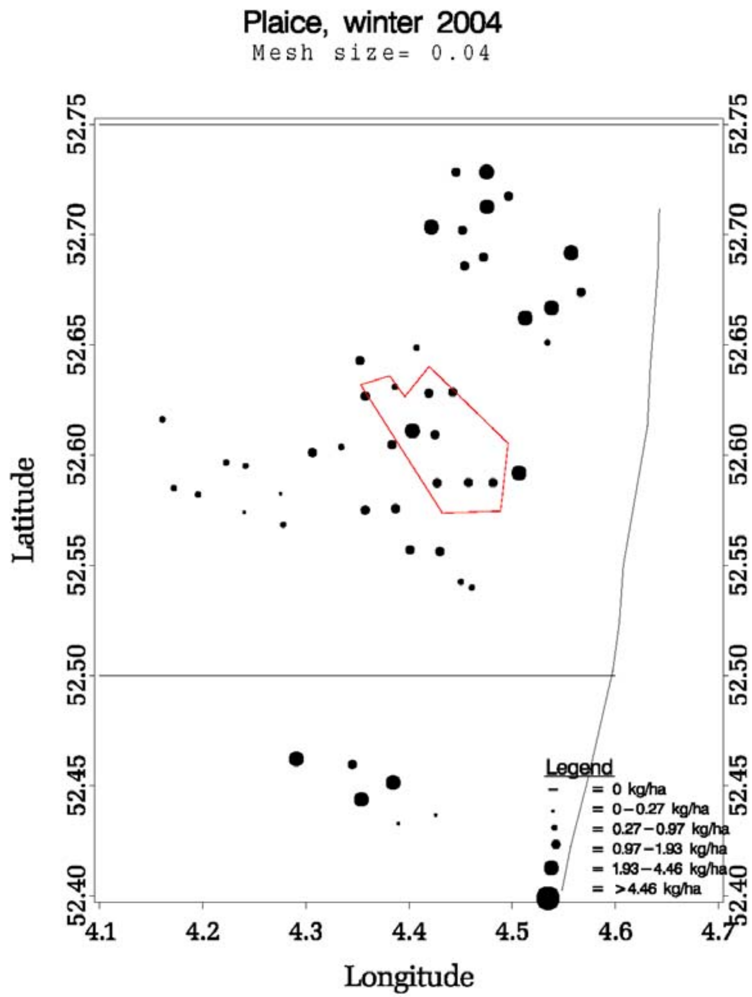
Annex 3.3
Spatial distribution of single species in the Baseline survey

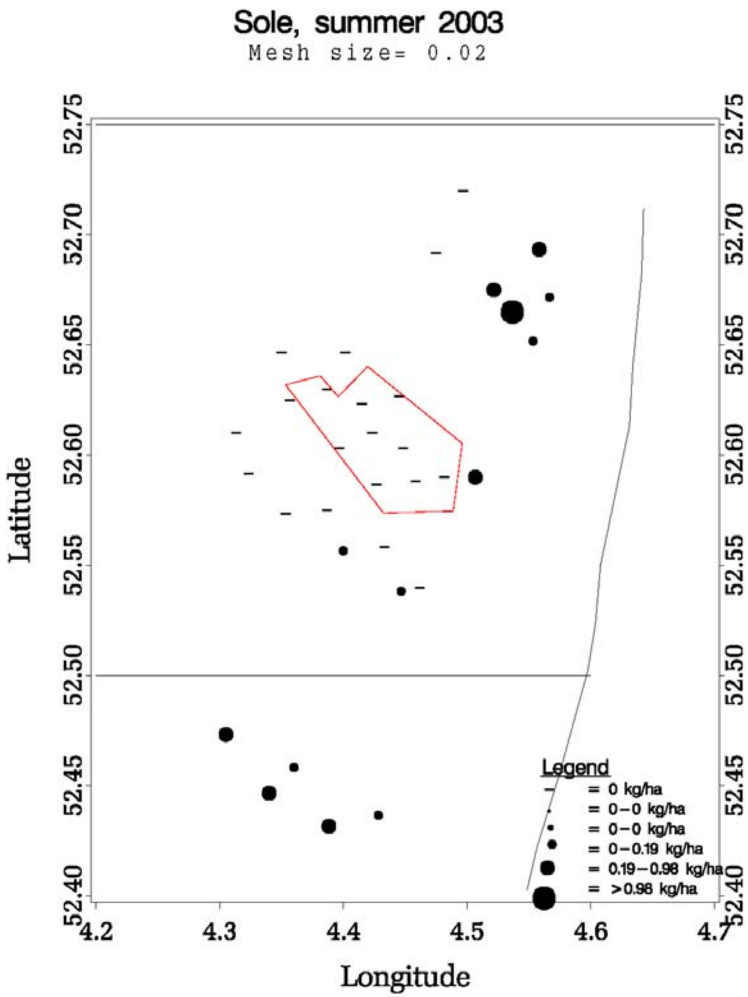
Annex 3.3 Spatial distribution of single species in the Baseline survey. Number per hectare is plotted per haul, per mesh size and per season. Top two figures represent the catches of the 20 mm net, the bottom two figures those of the 40 mm net.






Plaice, summer 2003
Mesh size= 0.04
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0 – 0.27 kg/ha
= 0.27 – 0.97 kg/ha
= 0.97 – 1.93 kg/ha
= 1.93 – 4.46 kg/ha
= >4.46 kg/ha


Plaice, winter 2004
Mesh size= 0.04
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.1
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0 – 0.27 kg/ha
= 0.27 – 0.97 kg/ha
= 0.97 – 1.93 kg/ha
= 1.93 – 4.46 kg/ha
= >4.46 kg/ha


Sole, summer 2003
Mesh size= 0.02
Latitude
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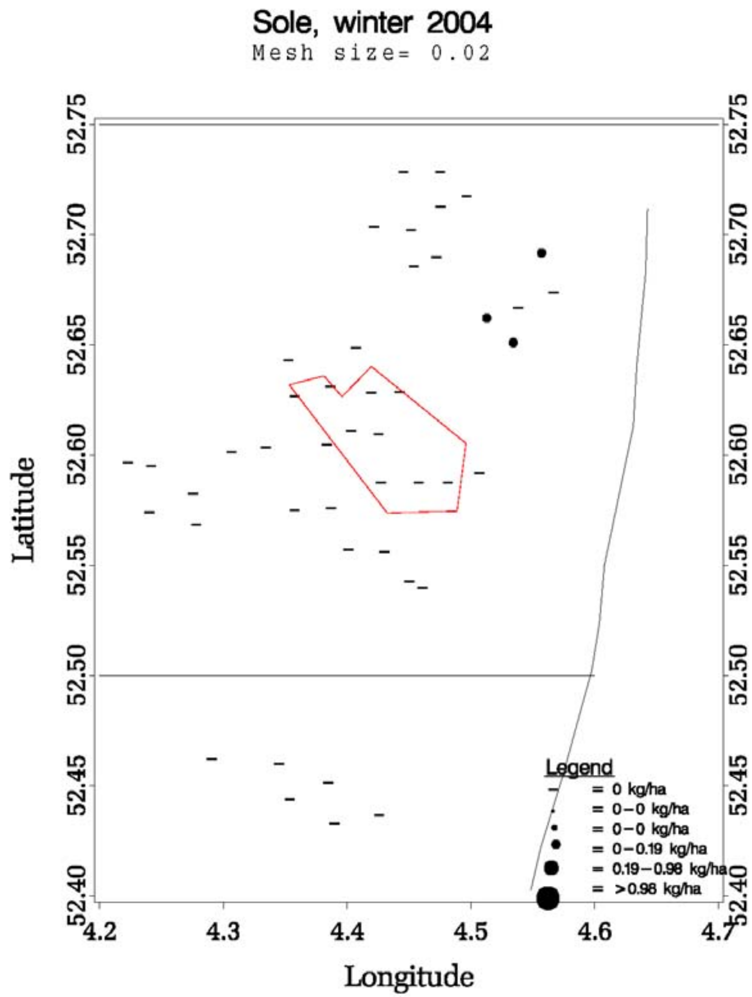
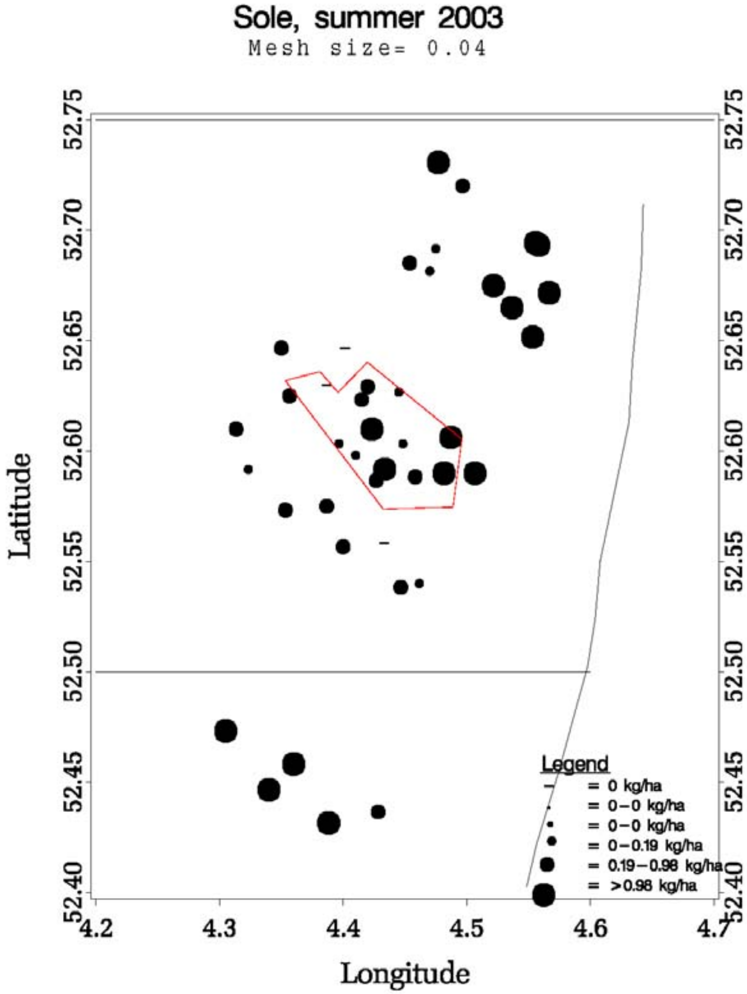
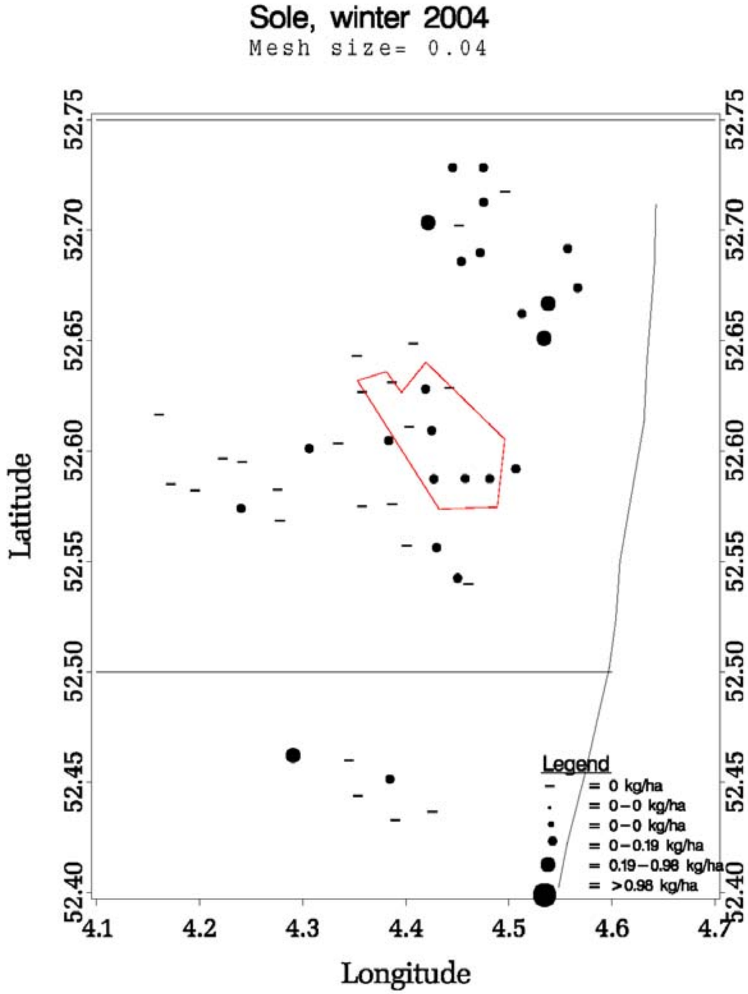
52.70
52.65
52.60
52.55
52.50
52.45
52.40
Longitude
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0−0 kg/ha
= 0−0 kg/ha
= 0−0.19 kg/ha
= 0.19−0.98 kg/ha
= >0.98 kg/ha


Sole, winter 2004
Mesh size= 0.02
Latitude
52.75
52.70
52.65
52.60
52.55
52.50
52.45
52.40
Longitude
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0−0 kg/ha
= 0−0 kg/ha
= 0−0.19 kg/ha
= 0.19−0.98 kg/ha
= >0.98 kg/ha


Sole, summer 2003
Mesh size= 0.04
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0-0 kg/ha
= 0-0 kg/ha
= 0-0.19 kg/ha
= 0.19-0.98 kg/ha
= >0.98 kg/ha


Sole, winter 2004
Mesh size= 0.04
Latitude
Longitude
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52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.1
4.2
4.3
4.4
4.5
4.6
4.7
Legend
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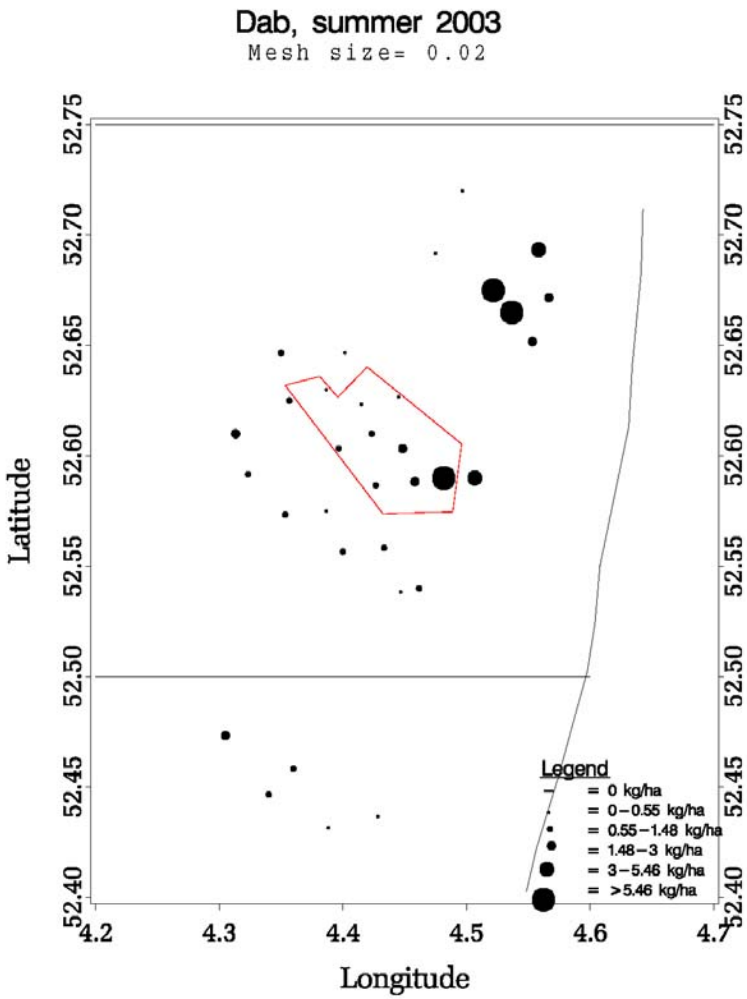
= 0-0 kg/ha
= 0-0 kg/ha
= 0-0.19 kg/ha
= 0.19-0.98 kg/ha
= >0.98 kg/ha


Dab, summer 2003
Mesh size= 0.02
Latitude
Longitude
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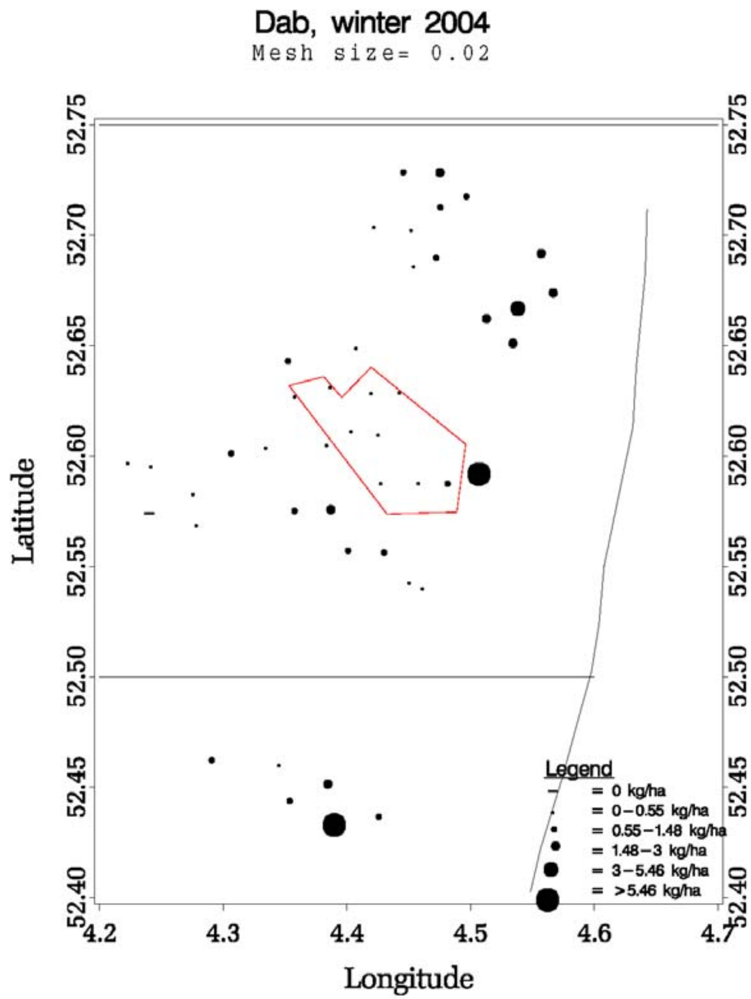
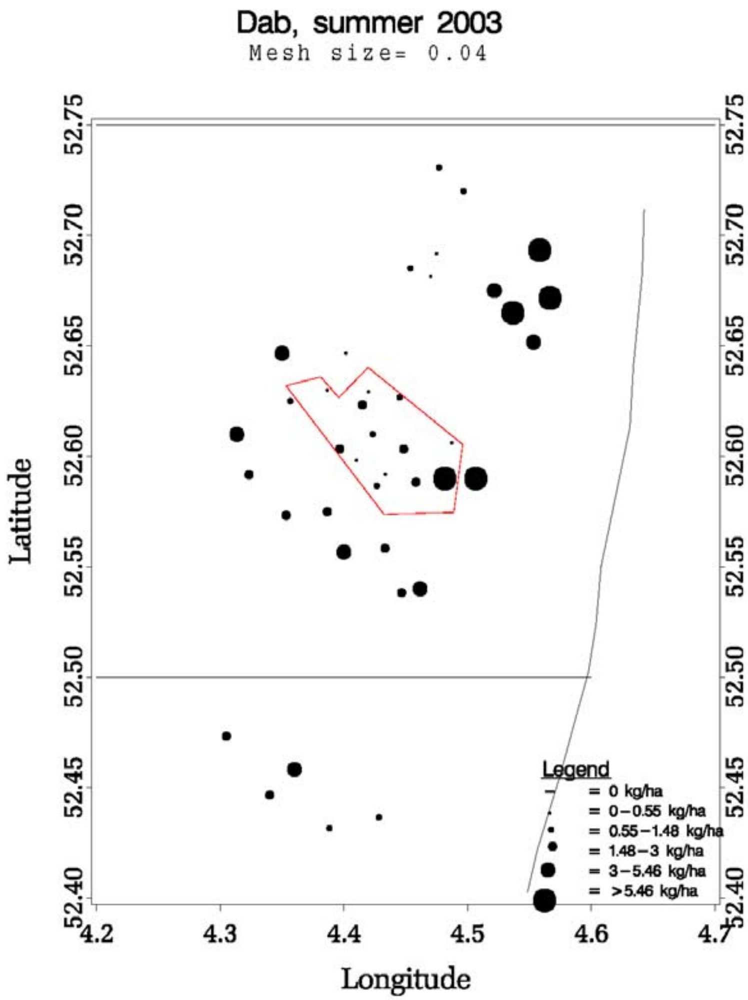
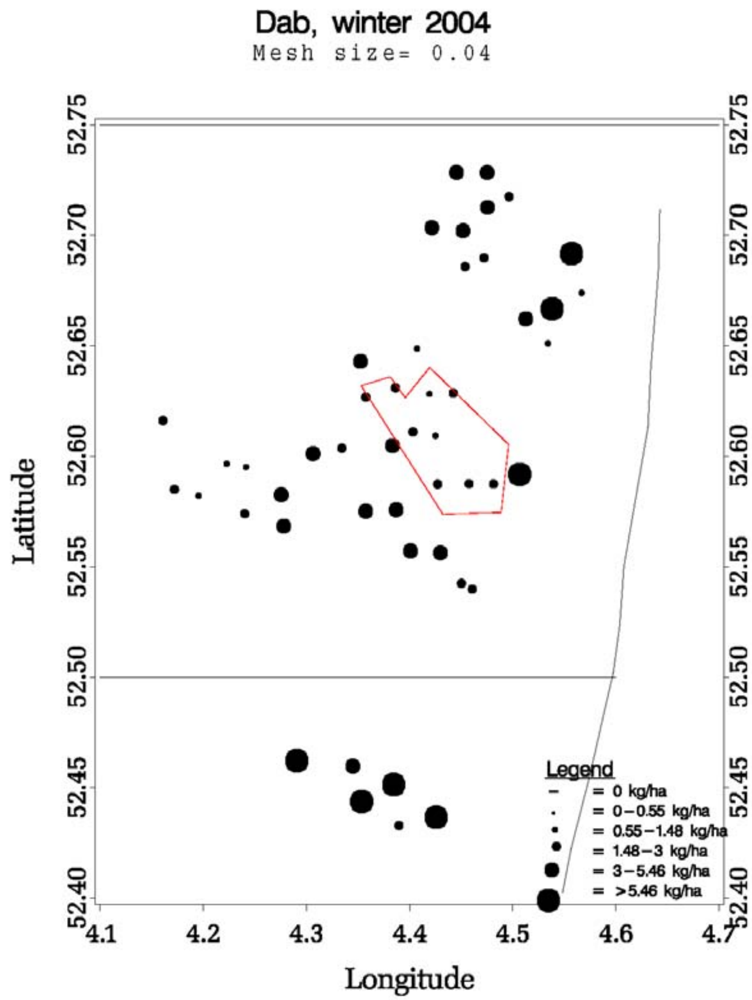
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0-0.55 kg/ha
= 0.55-1.48 kg/ha
= 1.48-3 kg/ha
= 3-5.46 kg/ha
= >5.46 kg/ha


Dab, winter 2004
Mesh size= 0.02
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0-0.55 kg/ha
= 0.55-1.48 kg/ha
= 1.48-3 kg/ha
= 3-5.46 kg/ha
= >5.46 kg/ha



Dab, summer 2003
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.55 kg/ha
= 0.55-1.48 kg/ha
= 1.48-3 kg/ha
= 3-5.46 kg/ha
= >5.46 kg/ha



Dab, winter 2004
Mesh size= 0.04
Latitude
Longitude
Legend
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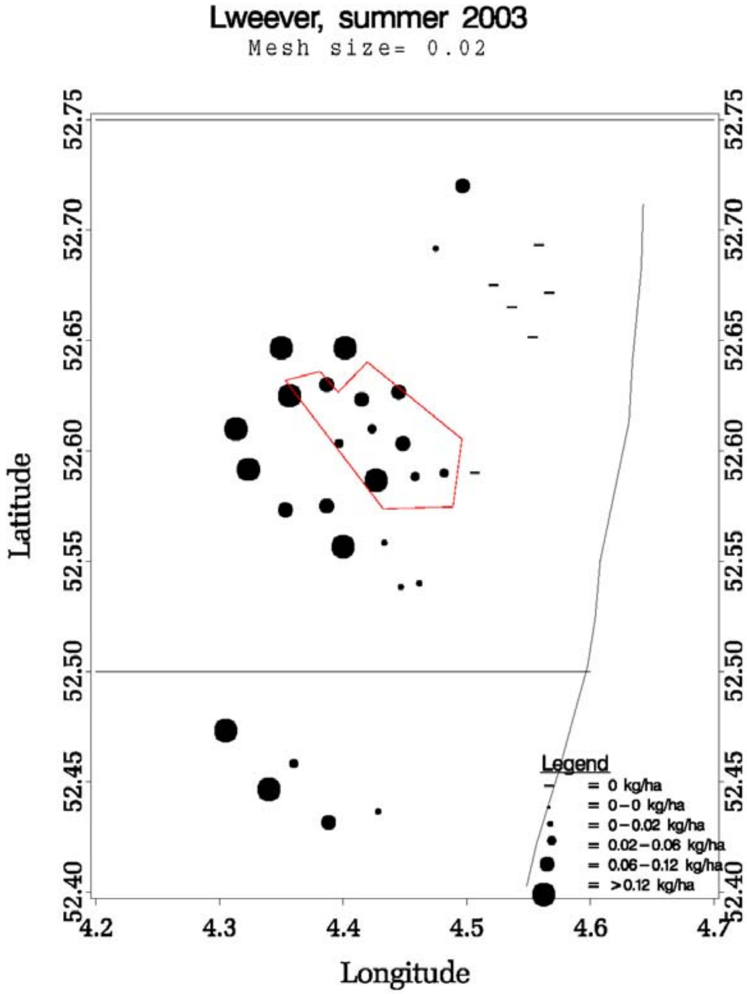
= 0-0.55 kg/ha
= 0.55-1.48 kg/ha
= 1.48-3 kg/ha
= 3-5.46 kg/ha
= >5.46 kg/ha


Lweever, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
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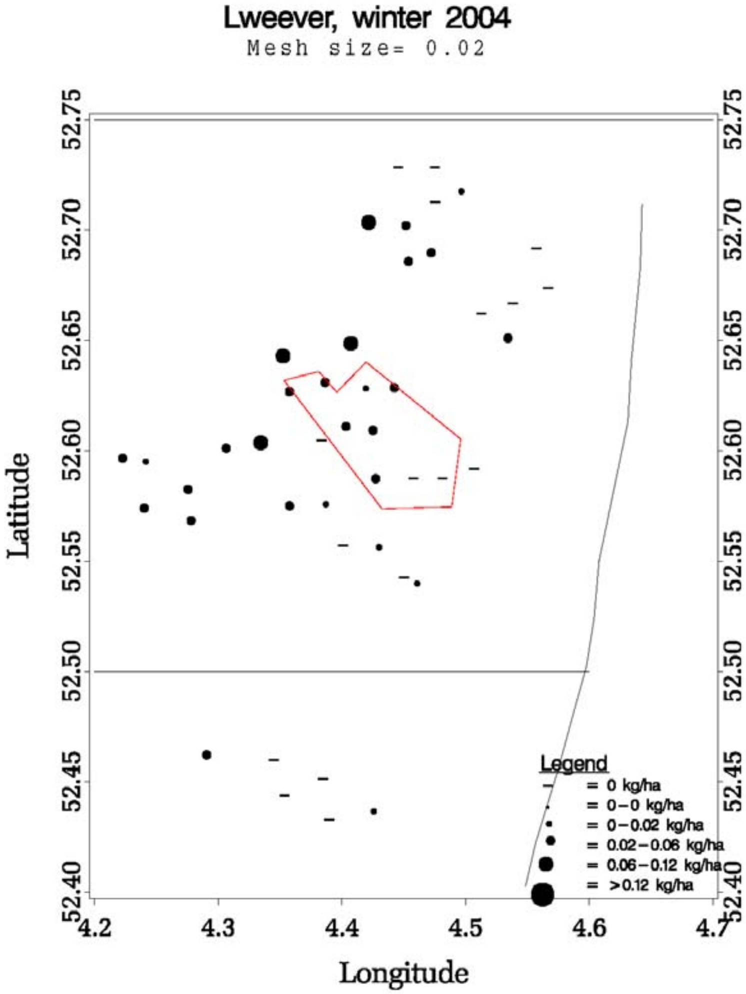
= 0-0 kg/ha
= 0-0.02 kg/ha
= 0.02-0.06 kg/ha
= 0.06-0.12 kg/ha
= >0.12 kg/ha


Lweever, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
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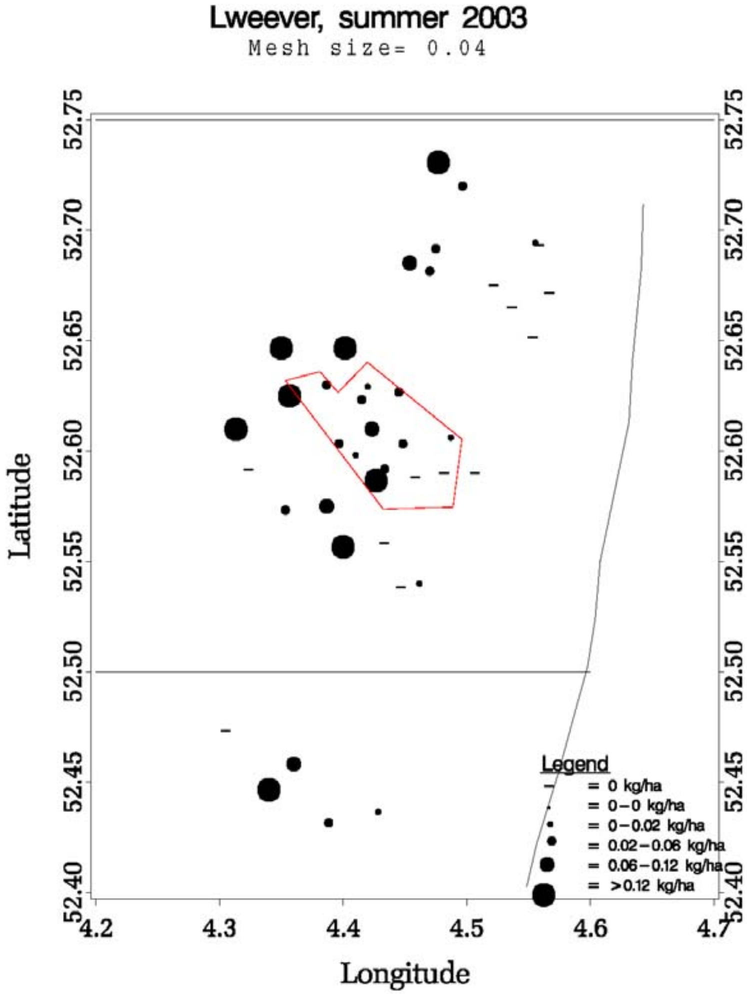
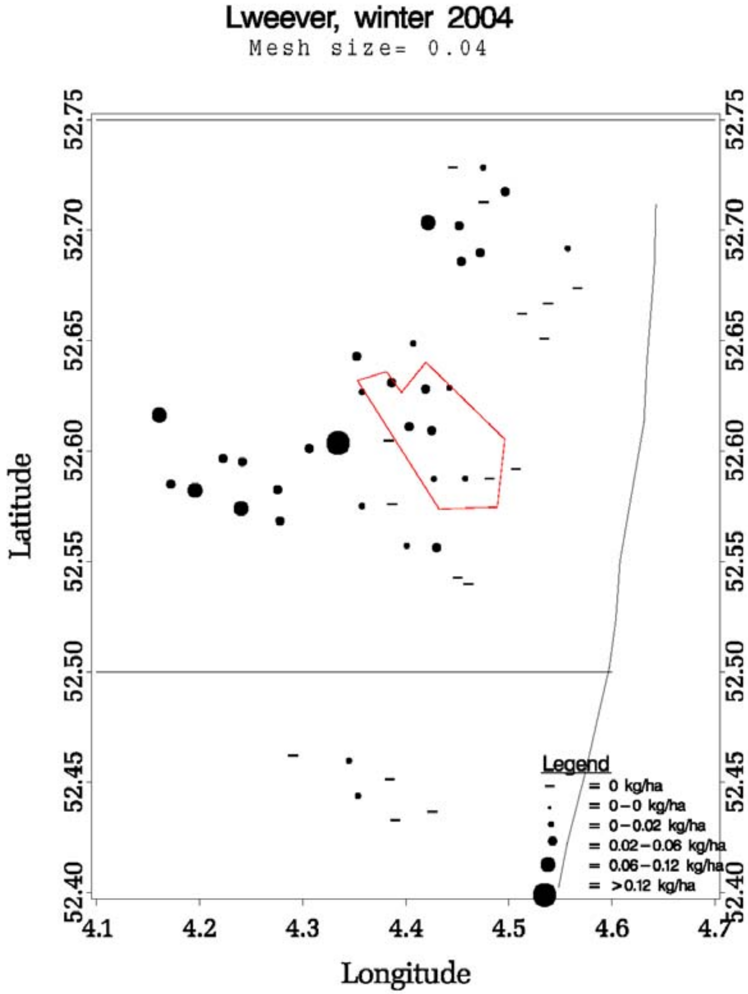
= 0-0 kg/ha
= 0-0.02 kg/ha
= 0.02-0.06 kg/ha
= 0.06-0.12 kg/ha
= >0.12 kg/ha


Lweever, summer 2003
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0 kg/ha
= 0-0.02 kg/ha
= 0.02-0.06 kg/ha
= 0.06-0.12 kg/ha
= >0.12 kg/ha


Lweever, winter 2004
Mesh size= 0.04
Latitude
Longitude
Legend
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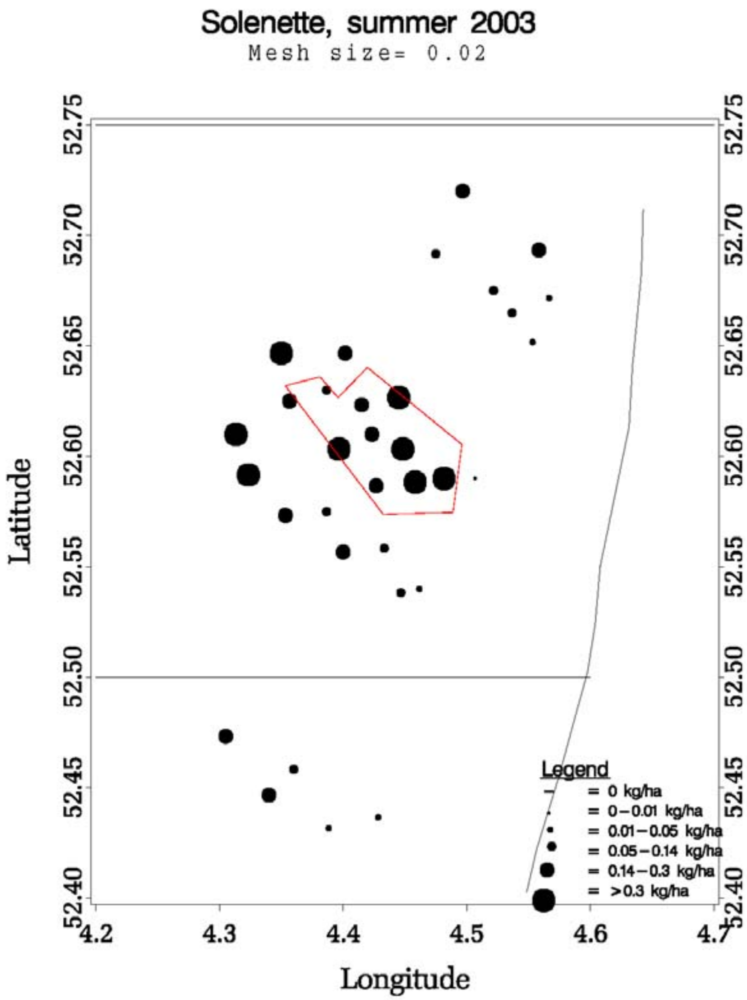
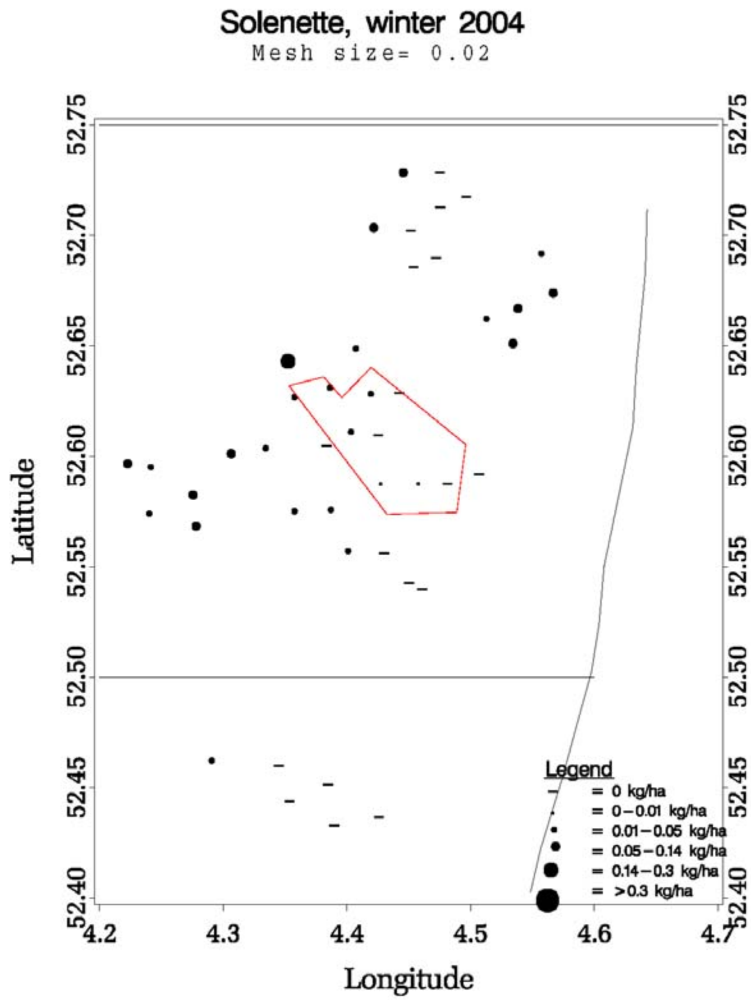
= 0-0 kg/ha
= 0-0.02 kg/ha
= 0.02-0.06 kg/ha
= 0.06-0.12 kg/ha
= >0.12 kg/ha


Solenette, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.14 kg/ha
= 0.14-0.3 kg/ha
= >0.3 kg/ha


Solenette, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.14 kg/ha
= 0.14-0.3 kg/ha
= >0.3 kg/ha

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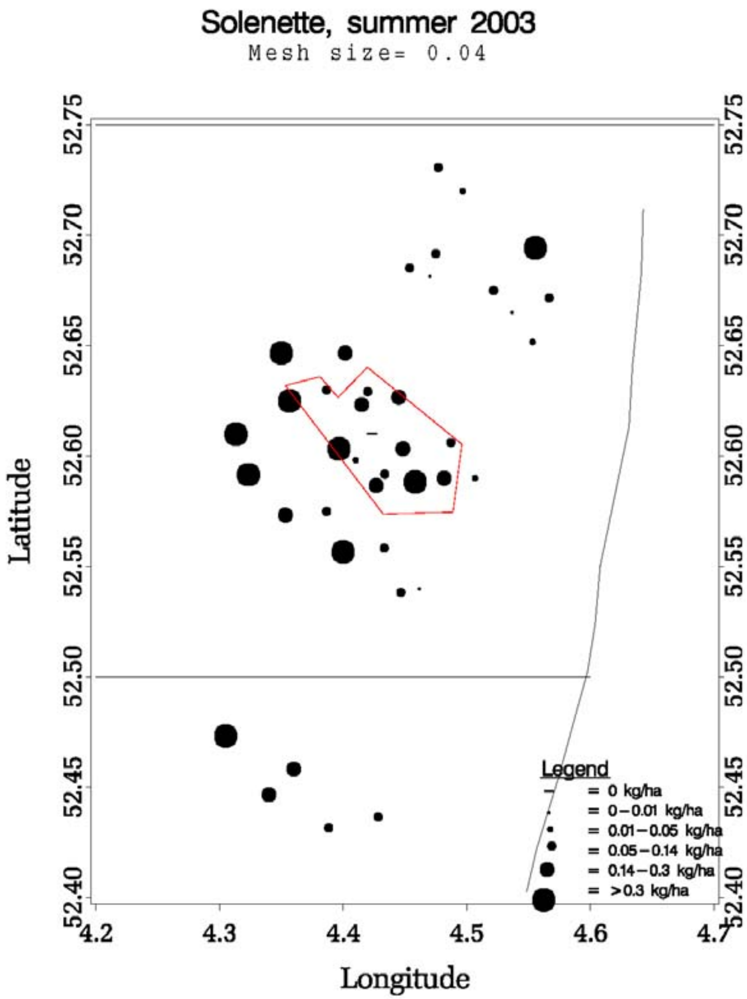
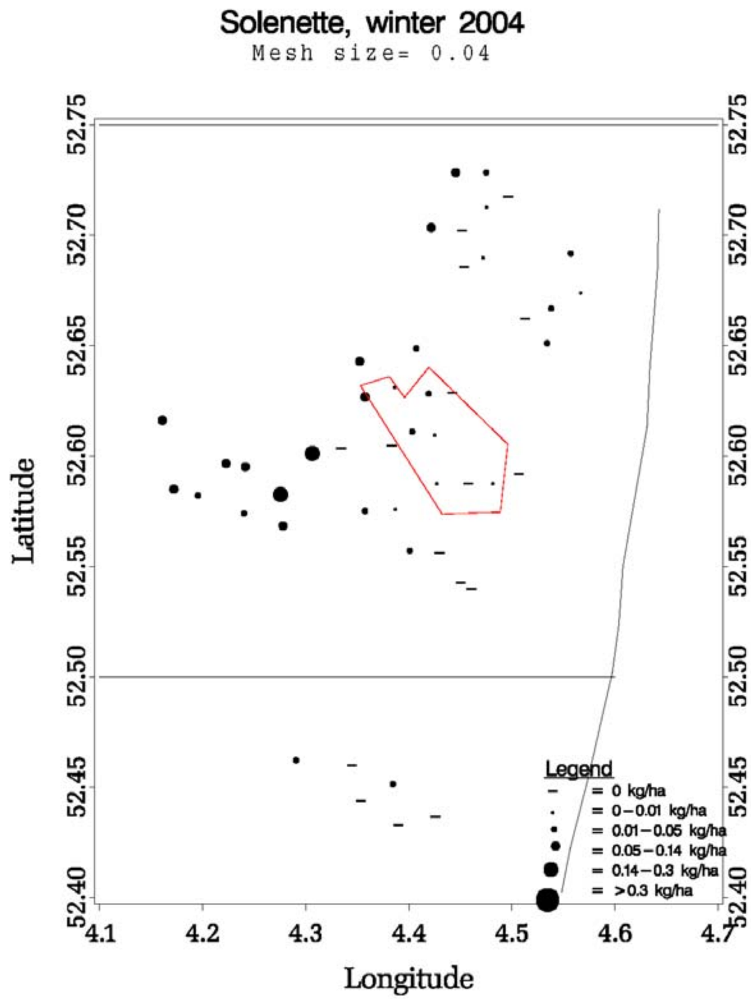
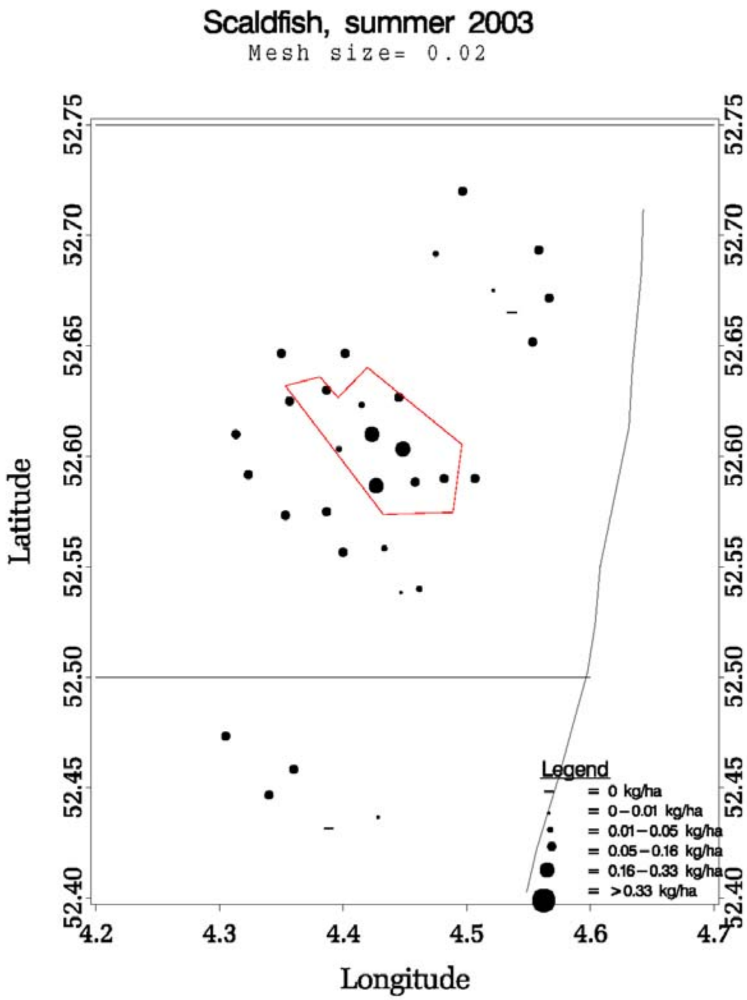
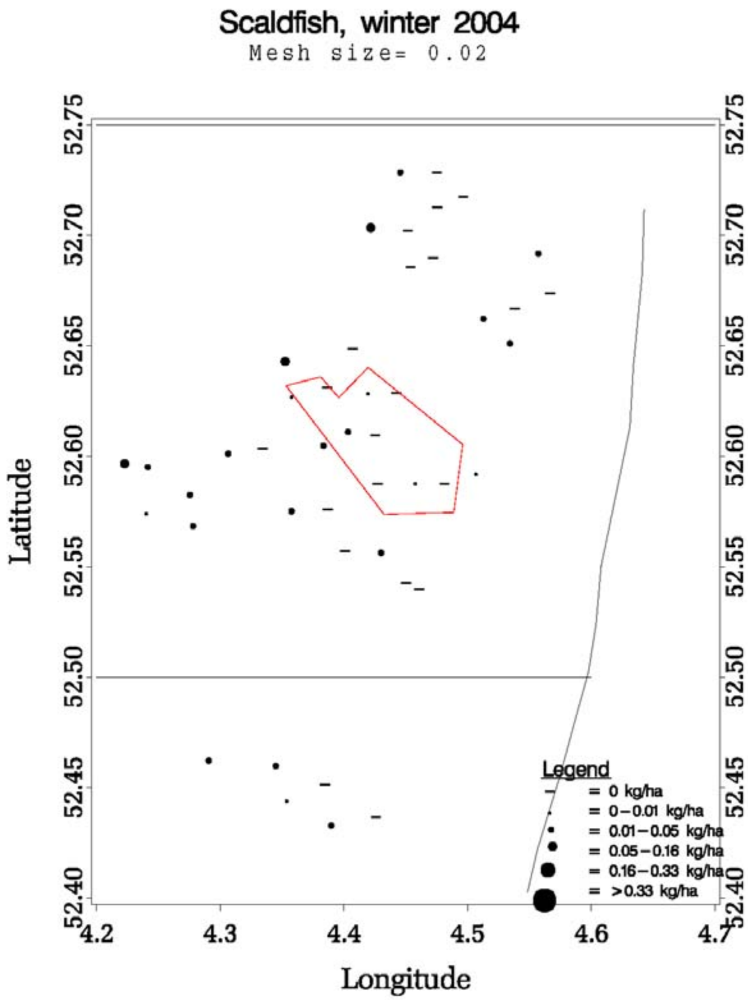
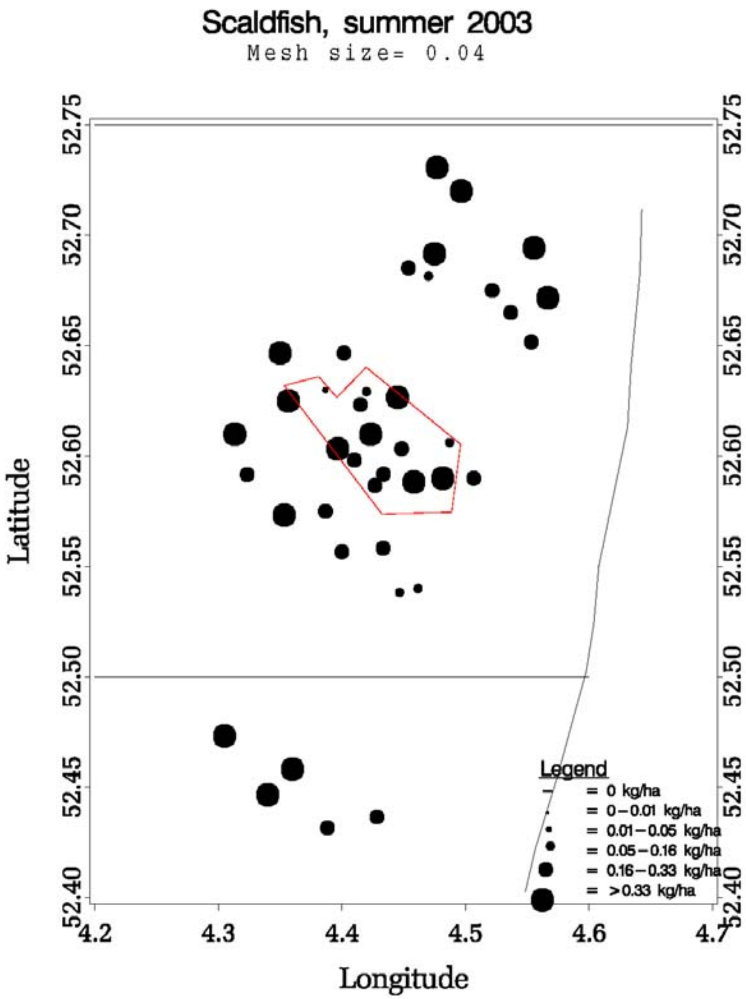
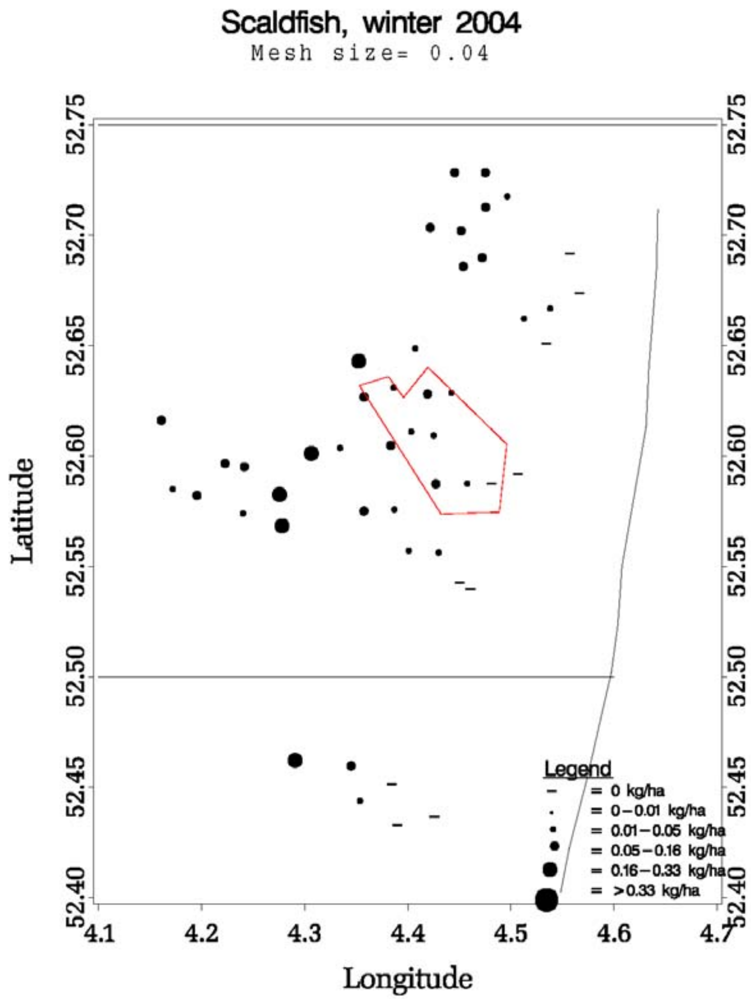


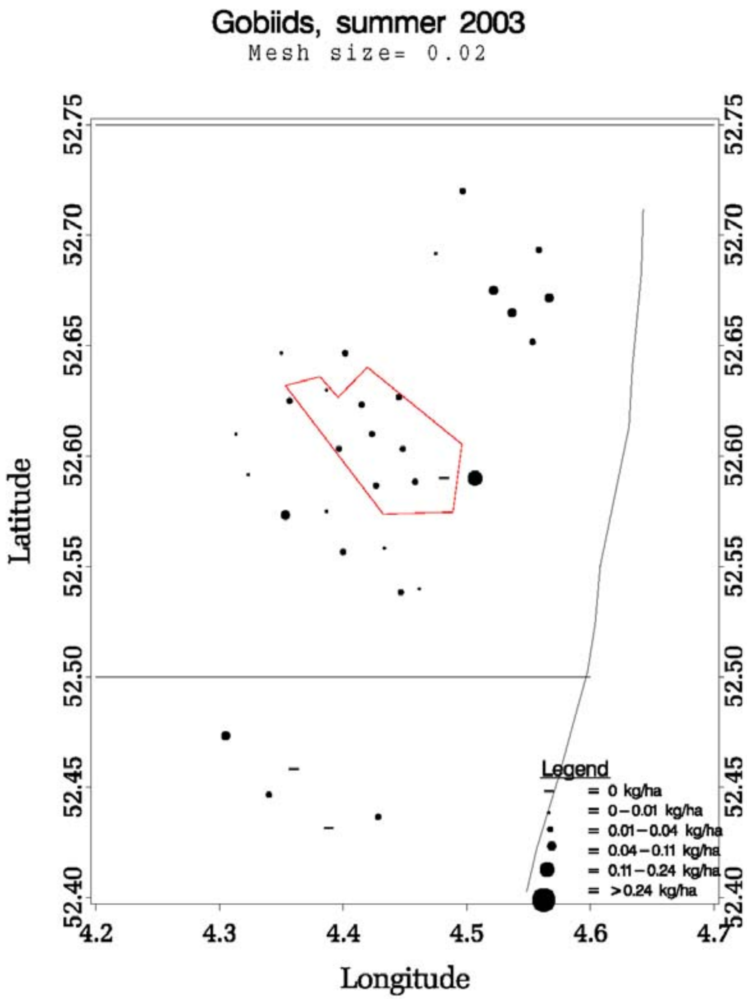


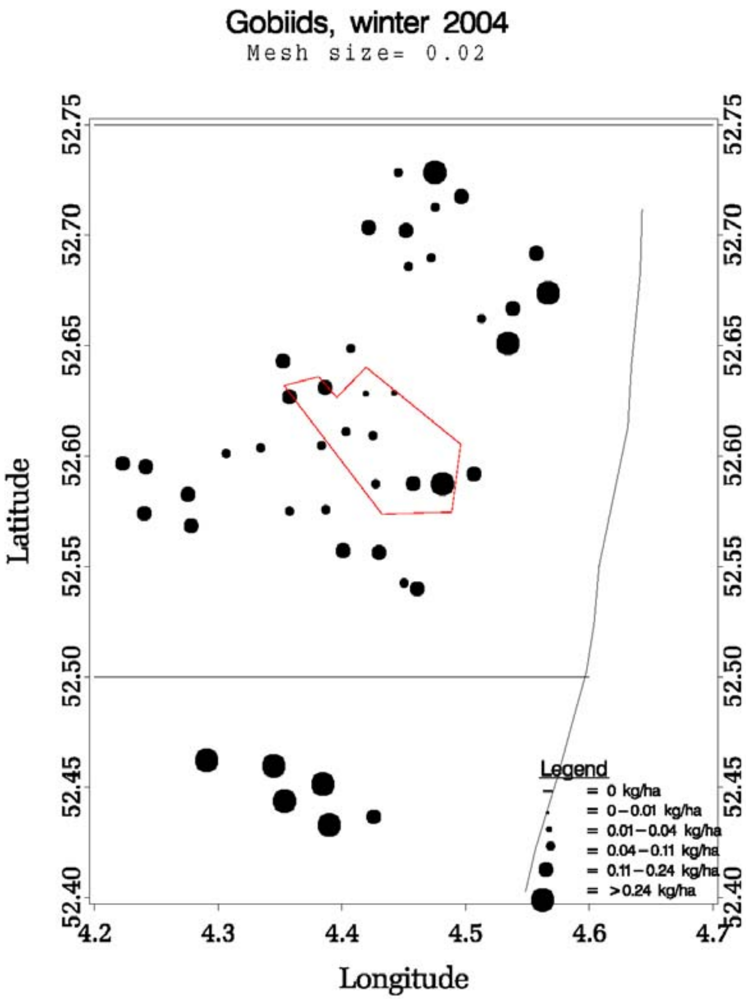

Scaldfish, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.16 kg/ha
= 0.16-0.33 kg/ha
= >0.33 kg/ha

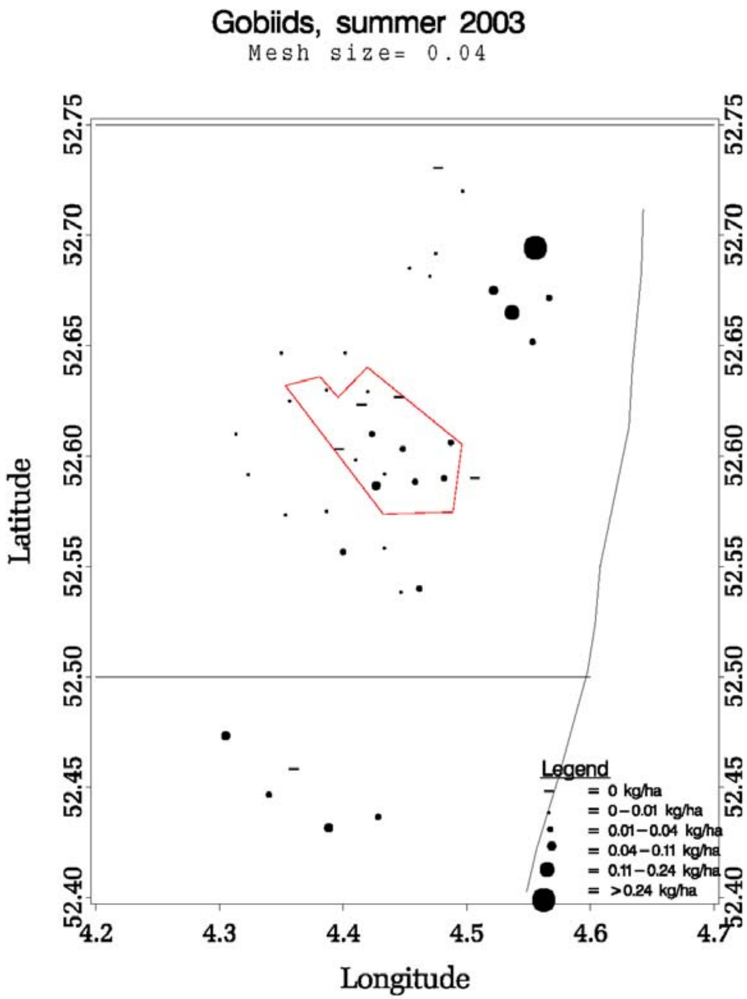

Scaldfish, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.16 kg/ha
= 0.16-0.33 kg/ha
= >0.33 kg/ha


Scaldfish, summer 2003
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.16 kg/ha
= 0.16-0.33 kg/ha
= >0.33 kg/ha

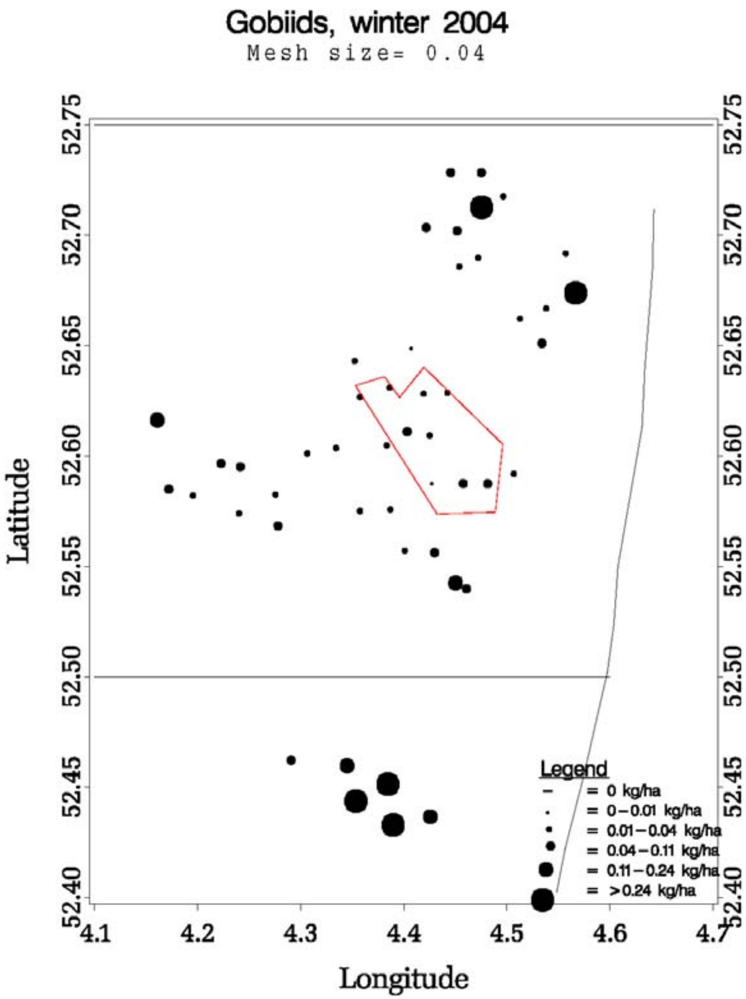

Scaldfish, winter 2004
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.05 kg/ha
= 0.05-0.16 kg/ha
= 0.16-0.33 kg/ha
= >0.33 kg/ha


Gobiids, summer 2003
Mesh size= 0.02
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.04 kg/ha
= 0.04-0.11 kg/ha
= 0.11-0.24 kg/ha
= >0.24 kg/ha


Gobiids, winter 2004
Mesh size= 0.02
Latitude
Longitude
52.40
52.45
52.50
52.55
52.60
52.65
52.70
52.75
4.2
4.3
4.4
4.5
4.6
4.7
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.04 kg/ha
= 0.04-0.11 kg/ha
= 0.11-0.24 kg/ha
= >0.24 kg/ha

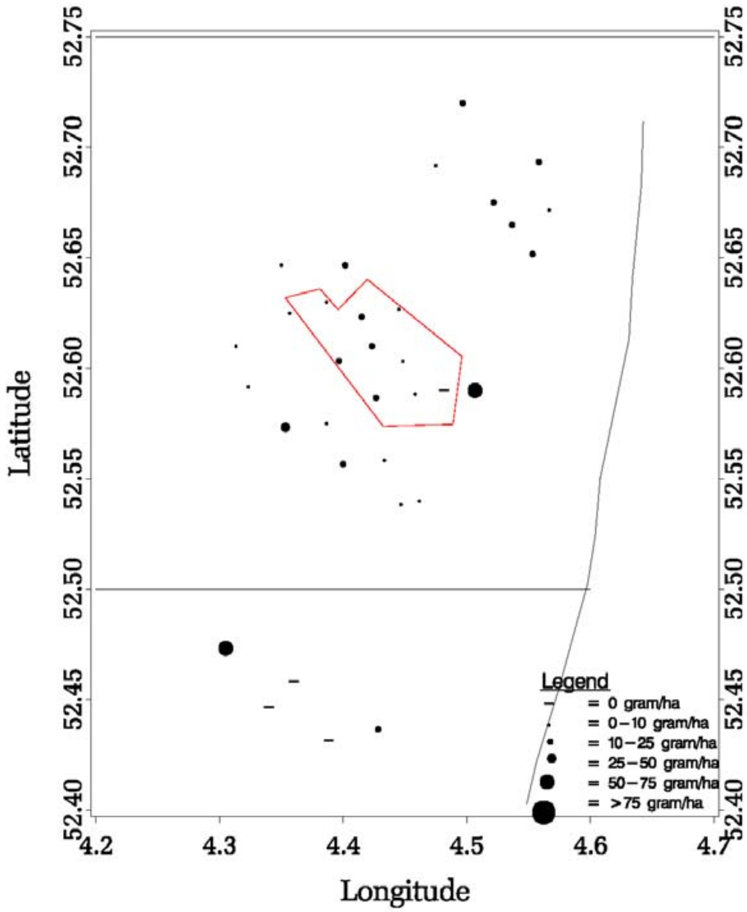


Gobiids, summer 2003
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.04 kg/ha
= 0.04-0.11 kg/ha
= 0.11-0.24 kg/ha
= >0.24 kg/ha

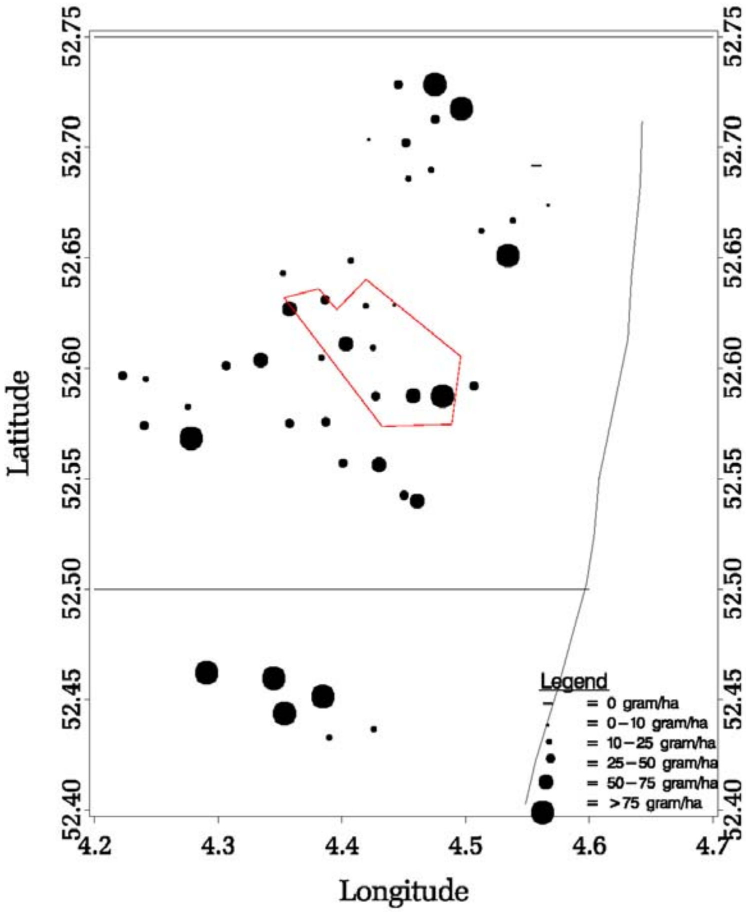


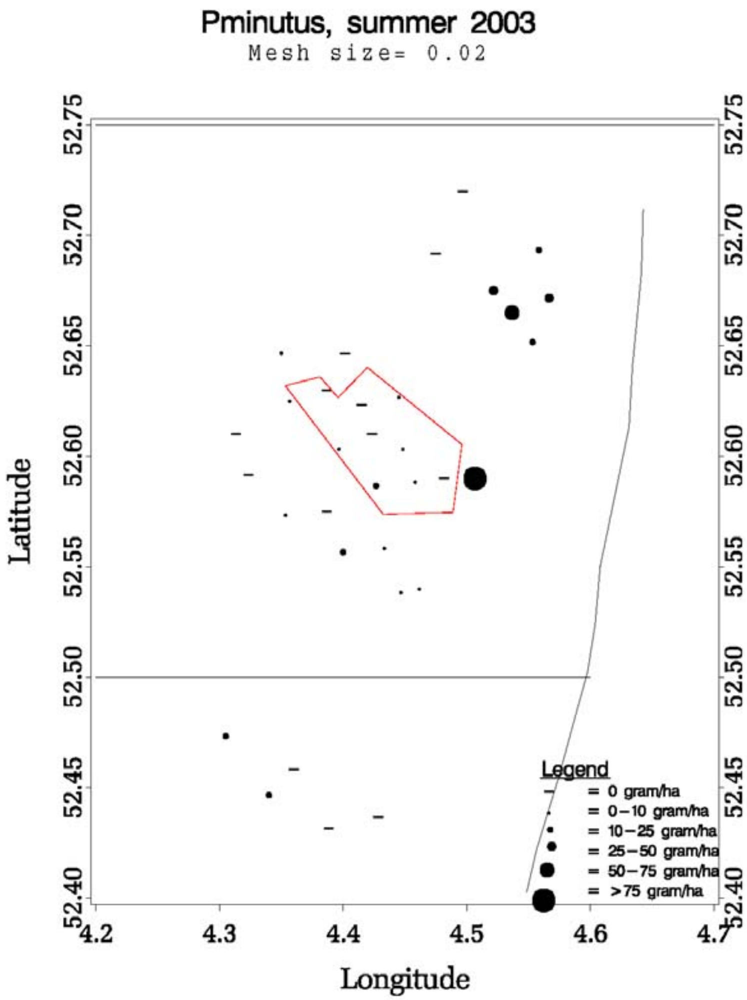
Gobiids, winter 2004
Mesh size= 0.04
Latitude
Longitude
Legend
= 0 kg/ha
= 0-0.01 kg/ha
= 0.01-0.04 kg/ha
= 0.04-0.11 kg/ha
= 0.11-0.24 kg/ha
= >0.24 kg/ha

Plozanoi, summer 2003
Mesh size= 0.02

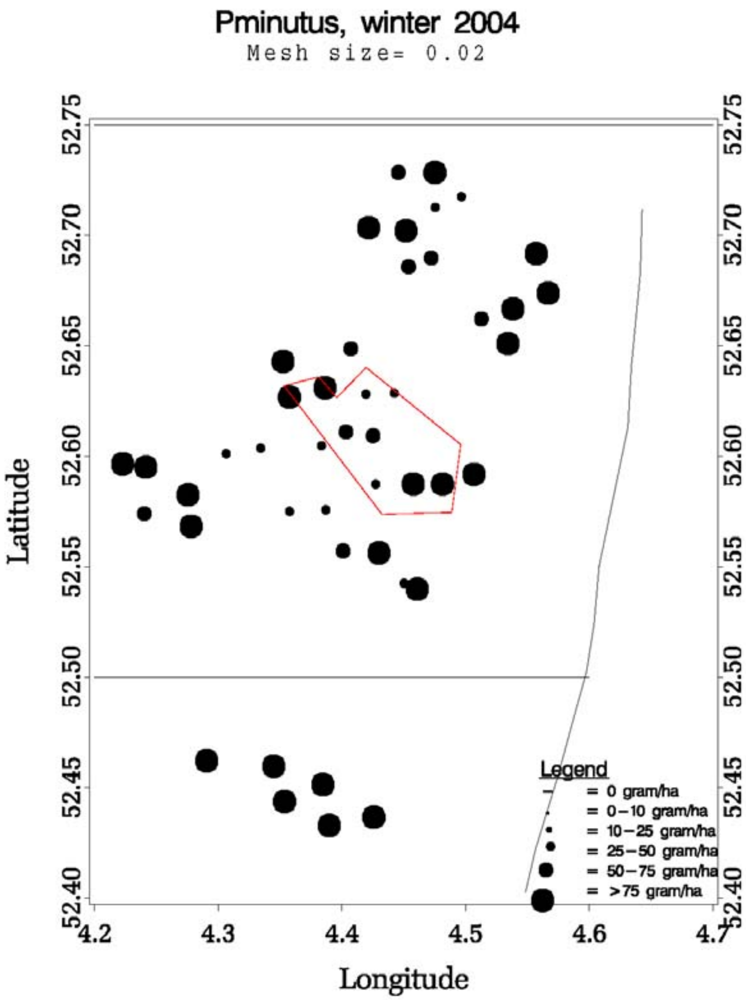


Plozanoi, winter 2004
Mesh size= 0.02

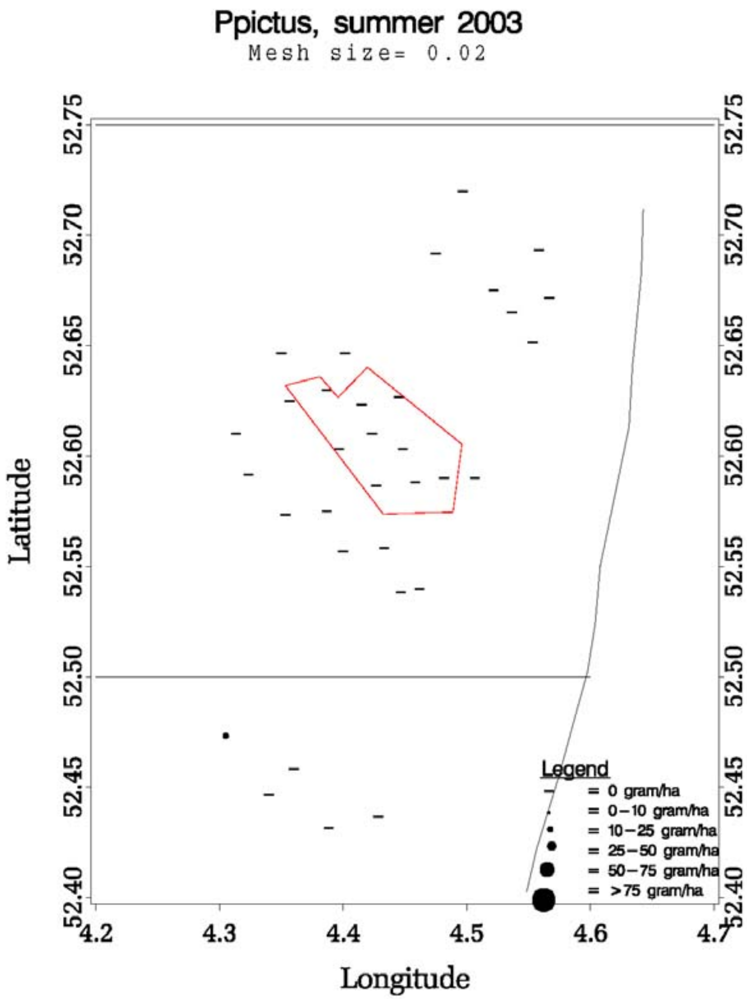


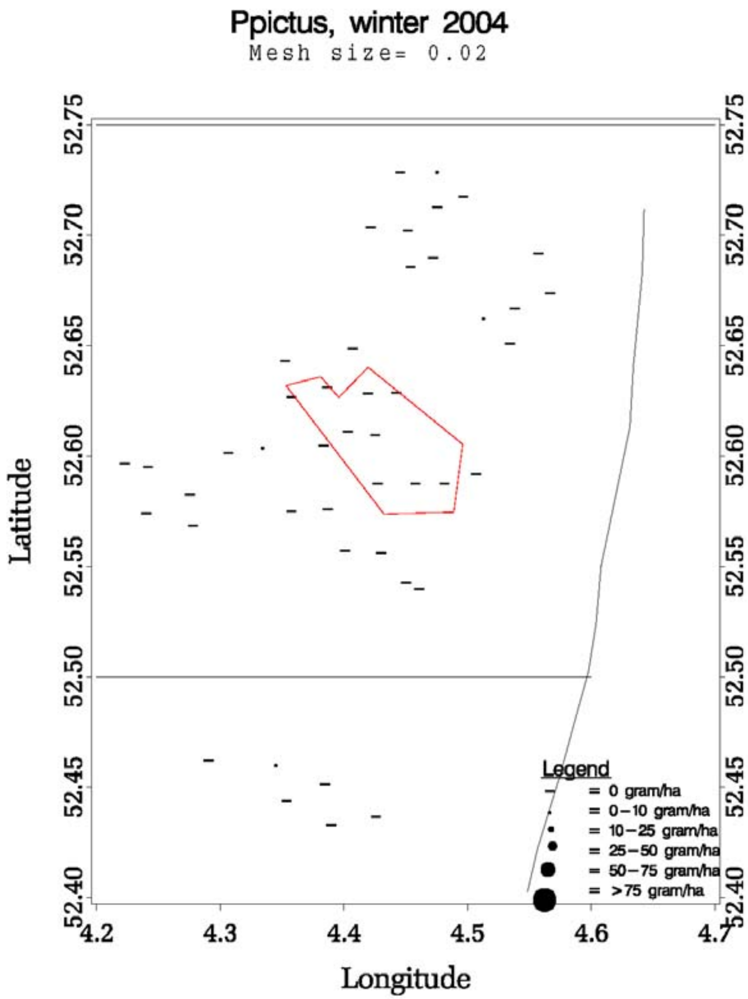


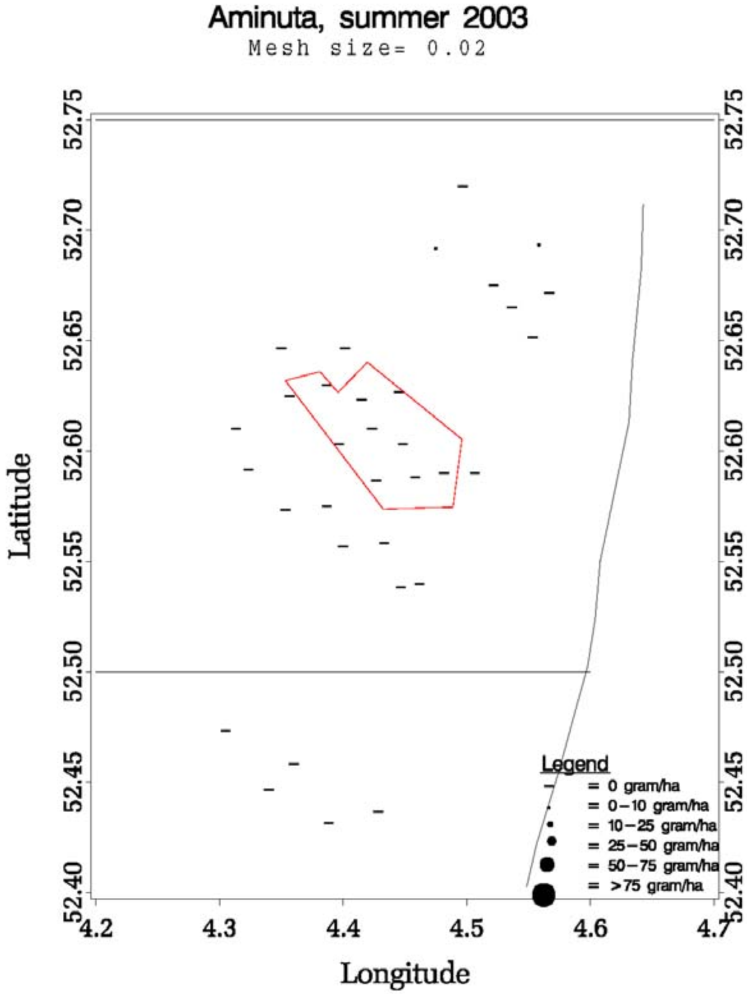
Pminutus, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha

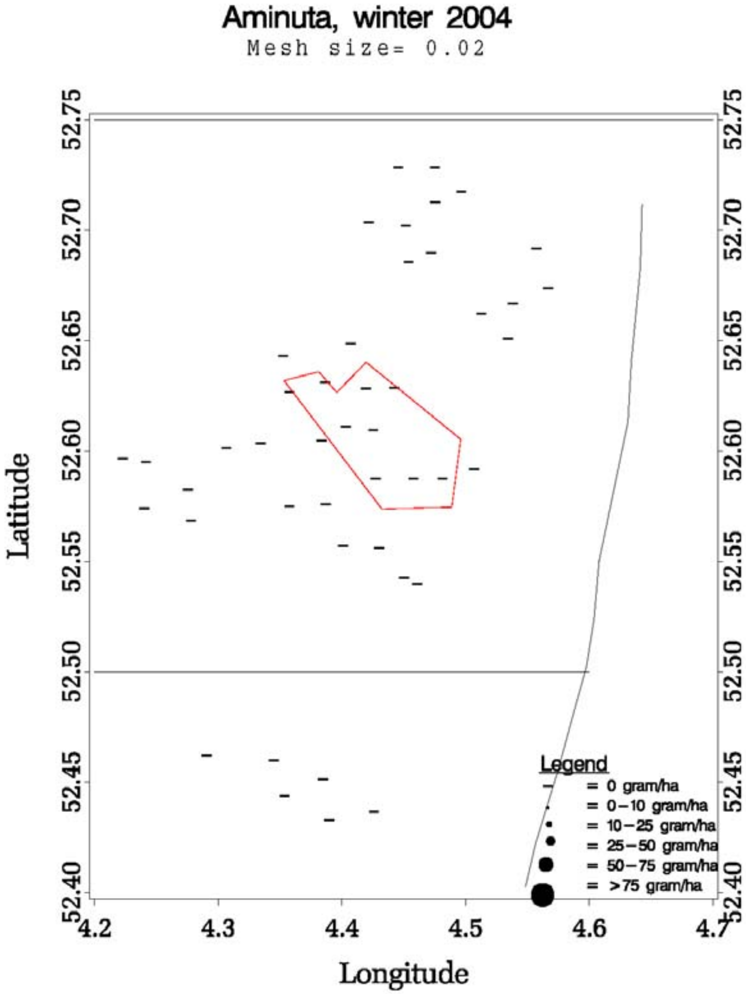


Pminutus, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha


Ppictus, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha


Ppictus, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha


Aminuta, summer 2003
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha


Aminuta, winter 2004
Mesh size= 0.02
Latitude
Longitude
Legend
= 0 gram/ha
= 0-10 gram/ha
= 10-25 gram/ha
= 25-50 gram/ha
= 50-75 gram/ha
= >75 gram/ha

Annex 3.4
Results of Redundancy Analysis of the Baseline 2003/ 2004 data

Annex 3.4 Results of Redundancy Analysis of the Baseline data of July 2003 and January 2004 data

Only significant variables are included.

July 2003

	axis 1	axis 2
mesh size 20mm		
summary statistics for first two axes		
eigenvalue	0.285	0.070
species-environment correlation	0.782	0.723
percentage of variance explained	28.5	7.0
correlations with first two axes		
temperature	0.57	-0.47
water depth	-0.06	0.62
pH	-0.55	0.02
mesh size 40mm		
summary statistics for first two axes		
eigenvalue	0.360	0.065
species-environment correlation	0.871	0.758
percentage of variance explained	36.0	6.5
correlations with first two axes		
temperature	0.68	-0.36
water depth	-0.14	0.56
pH	-0.66	-0.11

January 2004

	axis 1	axis 2
mesh size 20mm		
summary statistics for first two axes		
eigenvalue	0.196	0.072
species-environment correlation	0.716	0.765
percentage of variance explained	19.6	7.2
correlations with first two axes		
salinity	-0.39	0.54
temperature	-0.17	0.46
pH	-0.34	0.21
water depth	-0.03	0.71
mesh size 40mm		
summary statistics for first two axes		
eigenvalue	0.174	0.071
species-environment correlation	0.883	0.634
percentage of variance explained	17.4	7.1
correlations with first two axes		
salinity	-0.79	-0.09
water depth	-0.72	0.26
pH	-0.64	-0.32
temperature	-0.78	-0.08

Annex 3.5
The occurrence of the species or species groups per season, caught in the Baseline, SNS, BTS and Mare surveys between 2001-2004

Annex 3.5 The occurrence of the species or species groups per season, caught in the Baseline, SNS, BTS and Mare surveys between 2001-2004

Occurrence is defined by at least one individual caught. Yellow indicates that the species is only caught with a 40 mm net, blue a 20 mm net and green in both type of nets. In the right hand table, the average number of species per haul is shown per season and mesh size, together with the standard error of that mean.

	Season		
Species	spring	summer	winter
Allis shad			blue
Bass	yellow		
Bib	yellow	green	green
Brill	yellow	green	yellow
Bull-rout	yellow	green	green
Cod	yellow	green	green
Dab	yellow	green	green
Dragonet sp.	yellow	green	green
Eel	yellow		
Five-bearded rockling	yellow		green
Flounder	yellow	green	green
Four-bearded rockling	yellow		blue
Garfish	yellow	green	
Gobiids sp.	yellow	green	green
Grey gurnard	yellow	green	yellow
Herring	yellow	green	green
Hooknose	yellow	green	green
Horse mackerel	yellow	green	blue
Lemon sole	yellow	yellow	yellow
Lesser weever	yellow	green	green
Lumpsucker		yellow	
Mackerel	yellow	yellow	
Pilchard		yellow	
Pipefish sp.	yellow	yellow	green
Plaice	yellow	green	green
Poor cod	yellow	yellow	yellow
Sandeel sp.	yellow	green	green
Scaldfish	yellow	green	green
Sea-snail		yellow	yellow
Smelt			green
Sole	yellow	green	green
Solenette	yellow	green	green
Sprat	yellow	yellow	green
Starry smoothhound		yellow	
Stickleback			yellow
Striped red mullet	yellow	green	
Tub gurnard	yellow	green	yellow
Turbot	yellow	green	yellow
Twaite shad	yellow		yellow
Viviparous blenny	yellow		yellow
Whiting	yellow	green	green
n trawl 20 mm		33	48
n trawl 40 mm	66	98	122

		spring	summer	winter
20 mm	mean n species		10.00	9.56
	SE of mean		0.20	0.27
40 mm	mean n species	11.64	12.03	10.16
	SE of mean	0.28	0.24	0.21

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Annex 3.6
Average catch per unit effort
of the species caught in the Baseline, SNS, BTS and Mare surveys between 2001-2004

Annex 3.6 Average catch per unit effort

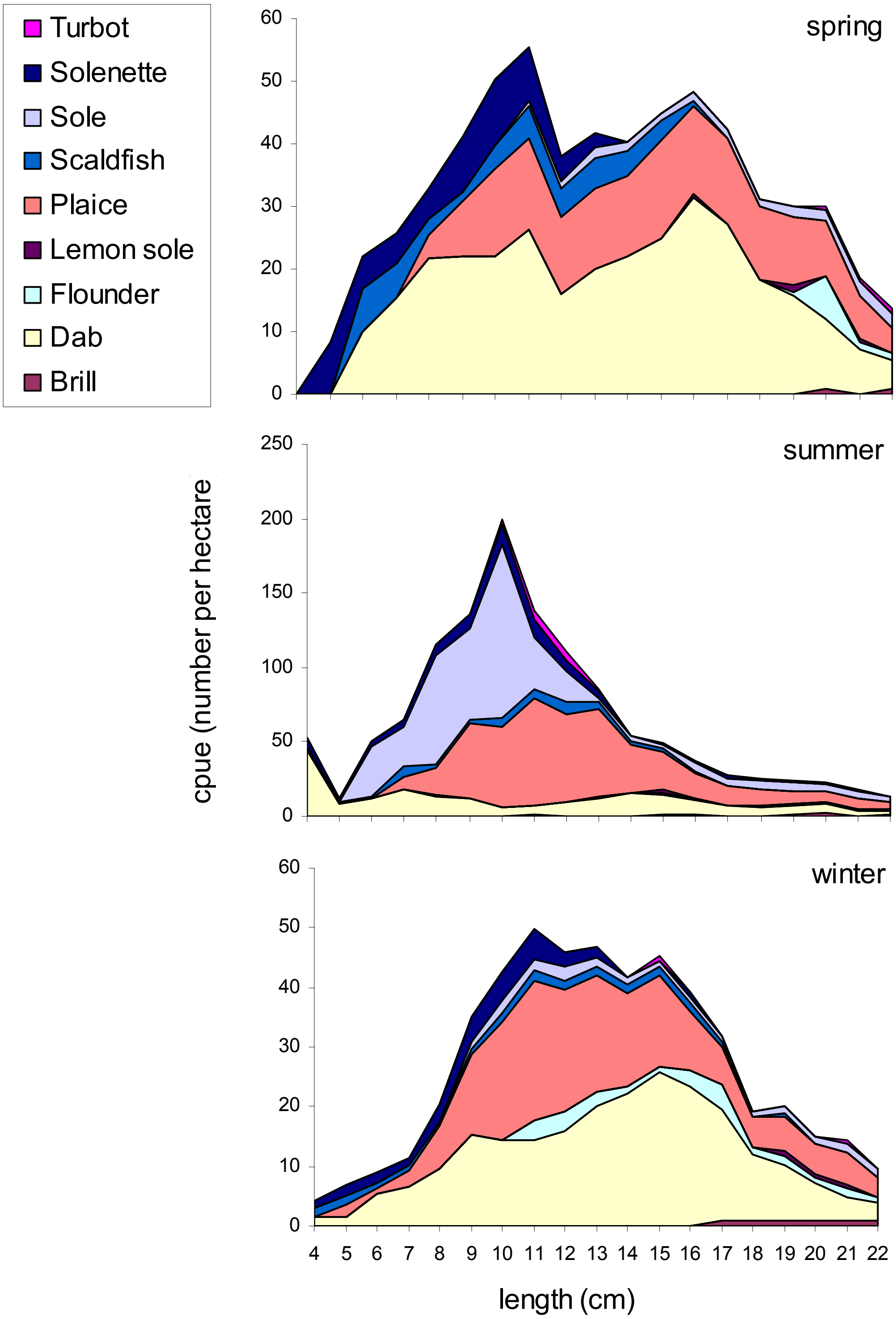
CpUe (numbers per hectare) and its standard error per species, season and mesh size. Cpue is averaged over selected hauls of the Baseline, SNS, BTS and Mare survey, (with a depth of 5-30 metres) between 2001-2004. The first nine species constitute at least 1% of the total average catch (in descending order of percentage of total average catch).

Mesh size	20 mm				40 mm					
Season	summer		winter		spring		summer		winter	
	mean cpue	se	mean cpue	se	mean cpue	se	mean cpue	se	mean cpue	se
Dab	47.79	10.09	94.48	21.86	212.72	31.38	84.77	9.52	183.27	29.87
Gobiids sp.	12.87	2.84	161.74	23.32	5.61	1.29	47.31	18.20	42.86	14.53
Plaice	42.19	12.79	25.62	4.32	120.16	21.34	209.83	47.04	127.67	22.57
Solenette	44.33	7.30	7.49	1.53	22.69	2.94	36.91	4.80	9.32	1.34
Dragonet sp.	29.32	5.57	15.46	2.55	17.70	3.77	32.92	7.71	4.01	0.55
Lesser weever	14.36	3.55	2.97	0.50	20.82	3.43	24.08	3.81	5.57	1.00
Whiting	6.41	2.21	13.67	11.61	22.45	4.20	5.30	1.53	7.28	3.73
Sole	2.16	0.95	0.08	0.05	8.96	1.18	30.57	8.13	2.78	0.38
Scaldfish	8.67	1.04	1.04	0.20	10.03	1.55	24.27	2.70	3.25	0.35
Allis shad	.	.	0.04	0.04	.	.	.	.	.	.
Bass	.	.	.	.	0.01	0.01	.	.	.	.
Bib	0.06	0.04	0.02	0.02	0.04	0.02	2.09	1.09	0.04	0.02
Brill	0.06	0.04	.	.	0.34	0.07	0.40	0.07	0.32	0.06
Bull-rout	0.47	0.26	0.70	0.29	0.42	0.17	0.78	0.18	0.52	0.10
Cod	0.13	0.13	0.26	0.09	0.07	0.03	0.02	0.02	0.18	0.04
Eel	.	.	.	.	0.01	0.01	.	.	.	.
Five-bearded rockling	.	.	0.29	0.09	0.05	0.03	.	.	0.20	0.04
Flounder	0.84	0.40	0.21	0.10	2.28	1.14	1.95	0.68	2.36	0.48
Four-bearded rockling	.	.	0.04	0.03	0.05	0.04	.	.	.	.
Garfish	0.03	0.03	.	.	0.34	0.26	0.02	0.01	.	.
Grey gurnard	0.16	0.08	.	.	2.26	0.47	0.93	0.39	0.02	0.01
Herring	0.12	0.09	37.27	6.08	0.32	0.20	0.05	0.03	4.62	2.82
Hooknose	1.33	0.80	0.53	0.19	0.87	0.29	6.16	1.65	0.87	0.18
Horse mackerel	0.10	0.05	0.02	0.02	1.26	0.51	4.87	2.14	.	.
Lemon sole	.	.	.	.	0.06	0.03	0.07	0.04	0.02	0.01
Lumpsucker	.	.	.	.	.	.	0.01	0.01	.	.
Mackerel	.	.	.	.	0.07	0.05	0.03	0.02	.	.
Pilchard	.	.	.	.	.	.	0.00	0.00	.	.
Pipefish sp.	.	.	0.17	0.08	0.13	0.06	0.17	0.10	0.05	0.03
Poor cod	.	.	.	.	0.04	0.03	0.50	0.23	0.01	0.01
Sea-snail	.	.	.	.	.	.	0.06	0.06	0.03	0.02
Smelt	.	.	0.04	0.03	.	.	.	.	0.01	0.01
Sandeel sp.	8.82	2.71	0.21	0.08	2.73	1.05	0.77	0.16	0.96	0.20
Sprat	.	.	21.34	3.01	6.28	2.87	3.99	2.83	4.02	0.93
Starry smoothhound	.	.	.	.	.	.	0.01	0.01	.	.
Stickleback	.	.	.	.	.	.	.	.	0.01	0.01
Striped red mullet	0.06	0.04	.	.	0.07	0.03	1.21	0.32	.	.
Tub gurnard	0.73	0.18	.	.	1.28	0.29	2.45	0.61	0.01	0.01
Turbot	0.03	0.03	.	.	0.26	0.05	0.54	0.18	0.06	0.02
Twaite shad	.	.	.	.	0.01	0.01	.	.	0.01	0.01
Viviparous blenny	.	.	.	.	0.01	0.01	.	.	0.01	0.01

Annex 3.7
Length frequency distribution of the flatfish species of 4-22 cm for the 40 mm net, caught in the Baseline, SNS, BTS and Mare surveys between 2001-2004

Annex 3.7 Length frequency distribution of the flatfish of 4-22 cm, per season for the 40 mm net.

See section 3.1.4 for an explanation of the chosen selection. Based on data from the Baseline, SNS, BTS and Mare surveys from 2001-2004.

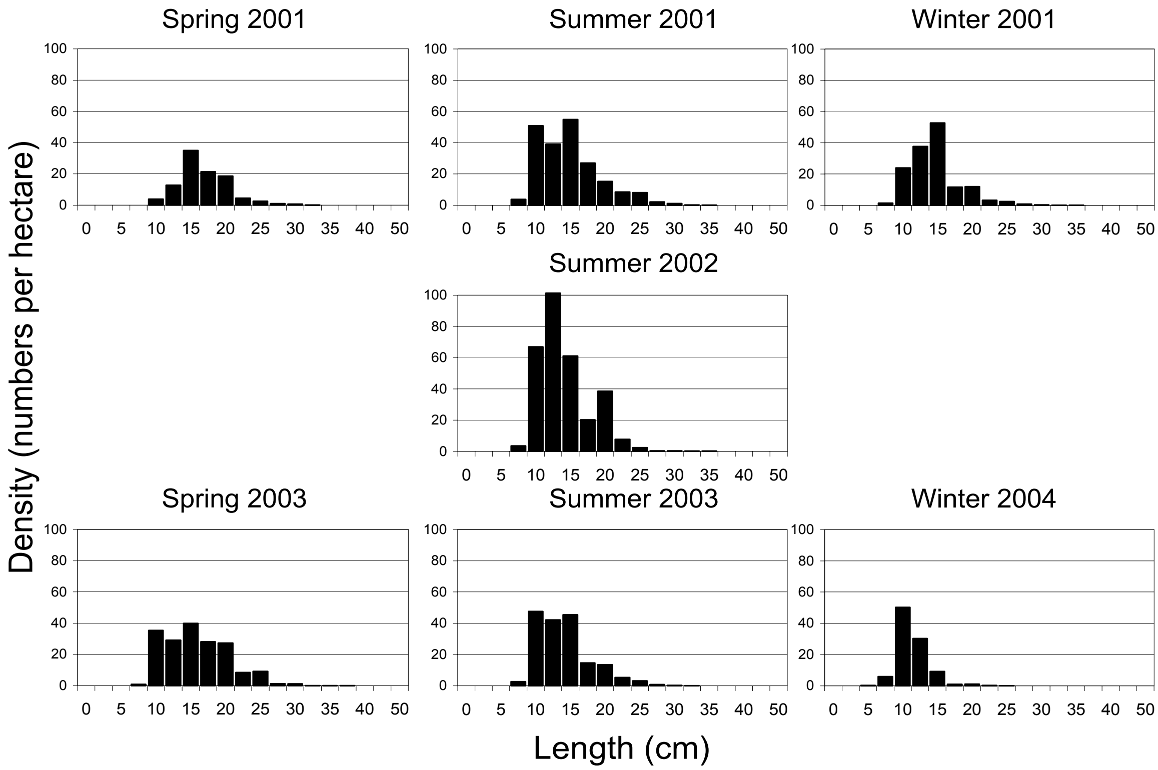


Annex 3.8
Length frequency distribution per species, caught in the Baseline, SNS, BTS and Mare surveys between 2001-2004

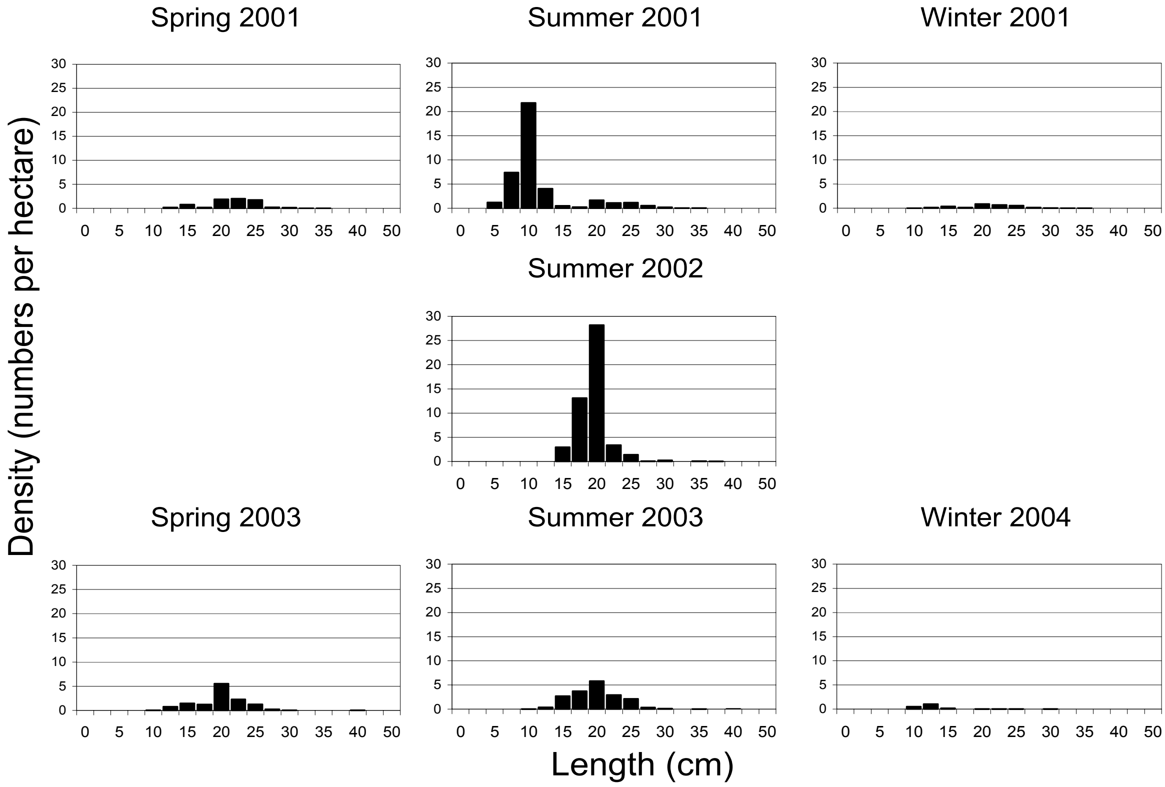
Annex 3.8 Length frequency distribution per species, year and season

Data collected with a 40 mm net. Based on data from the Baseline, SNS, BTS and Mare surveys from 2001-2004.

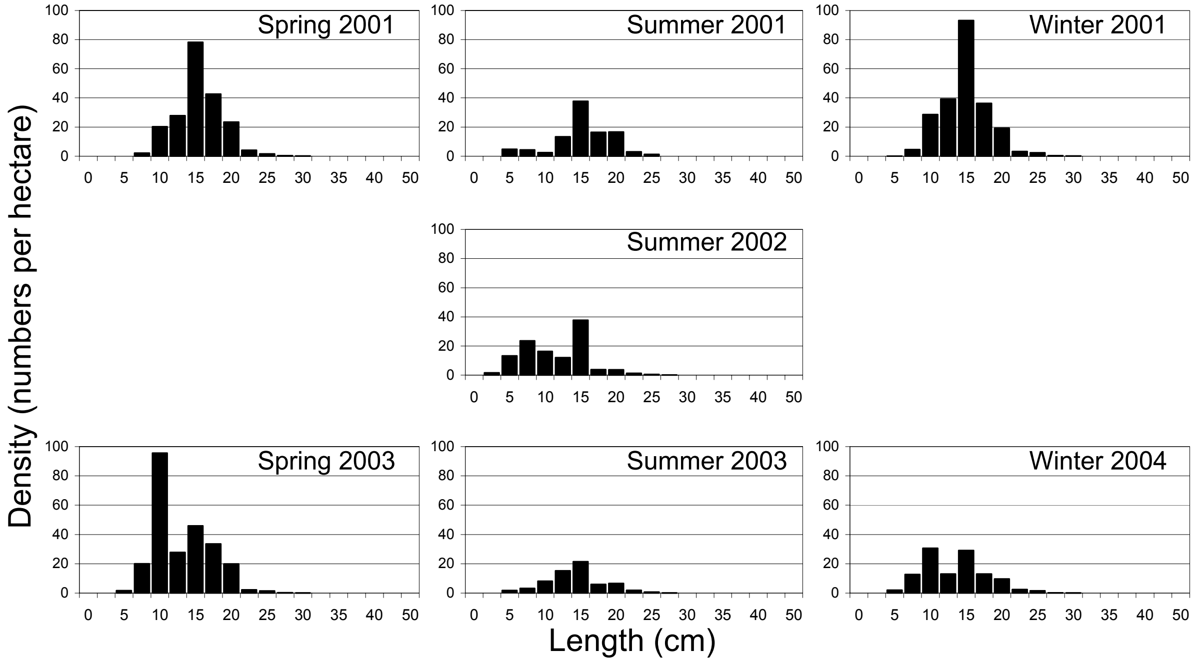
Plaice



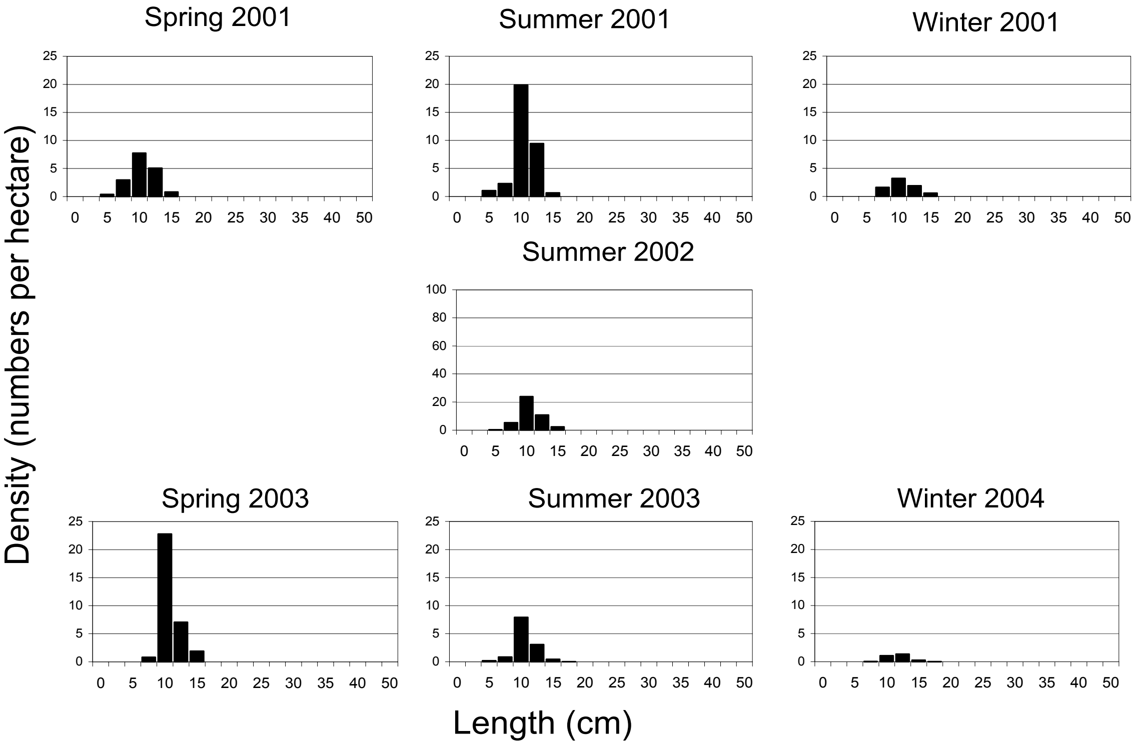
Sole


Spring 2001
Summer 2001
Winter 2001
Summer 2002
Spring 2003
Summer 2003
Winter 2004
Density (numbers per hectare)
Length (cm)

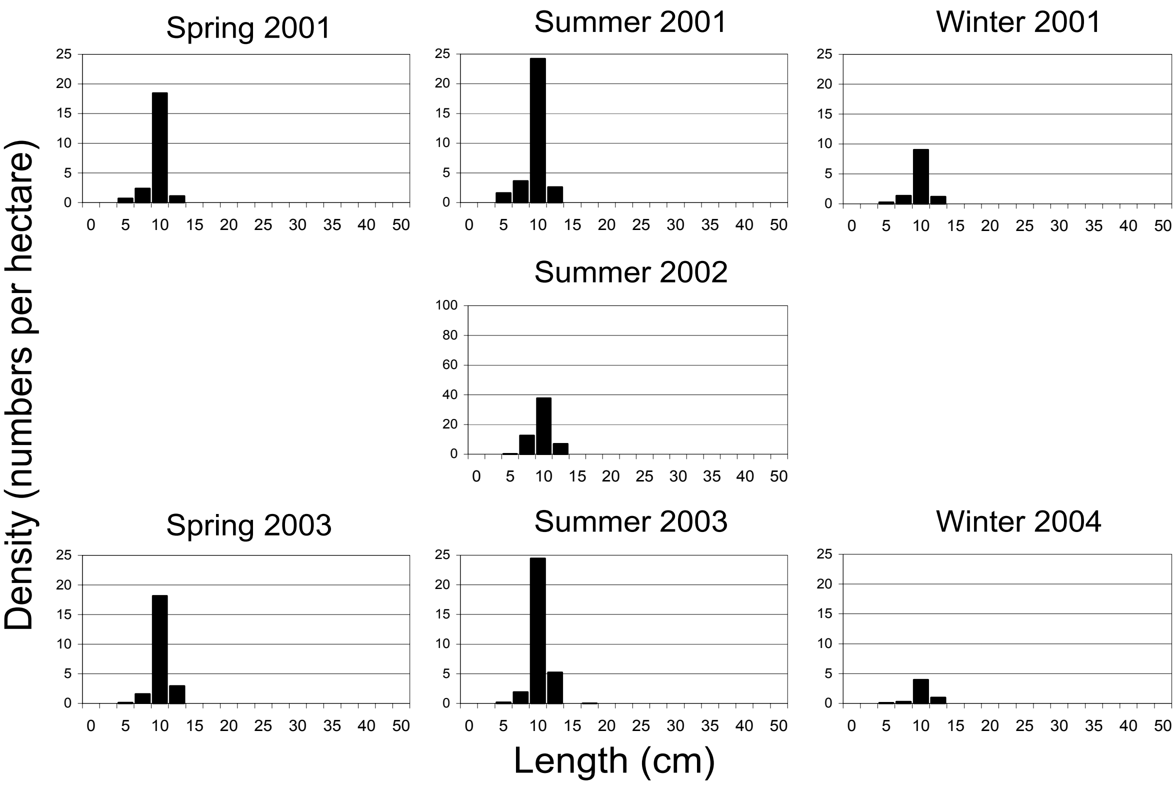
Dab


Spring 2001
Summer 2001
Winter 2001
Summer 2002
Spring 2003
Summer 2003
Winter 2004
Density (numbers per hectare)
Length (cm)

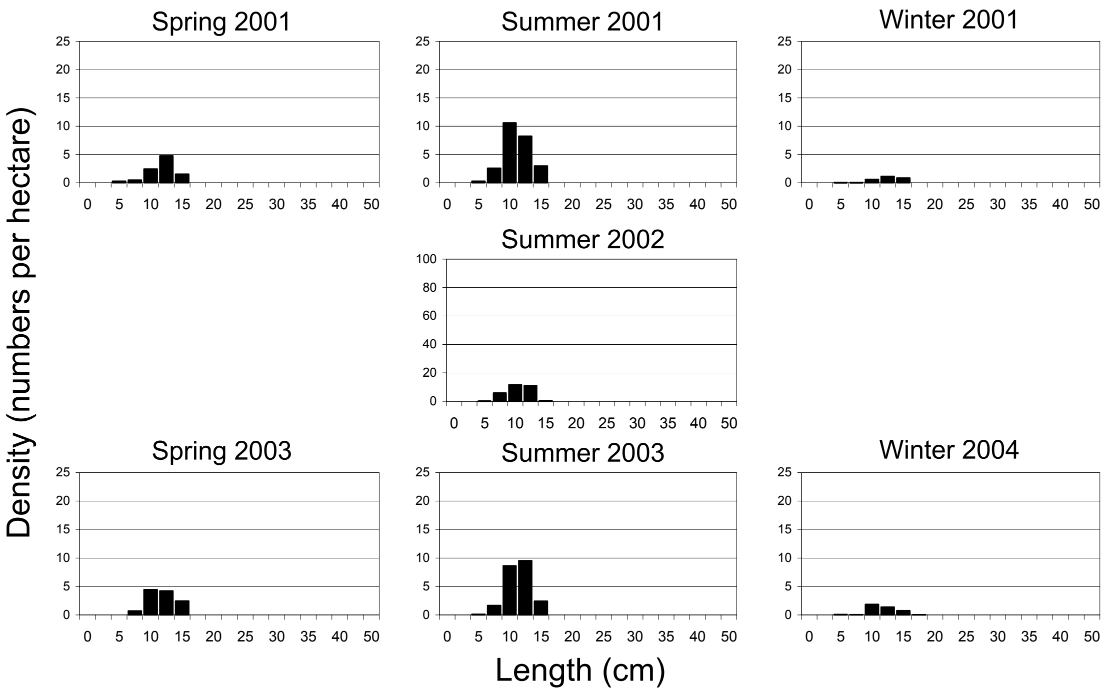
Lesser weever



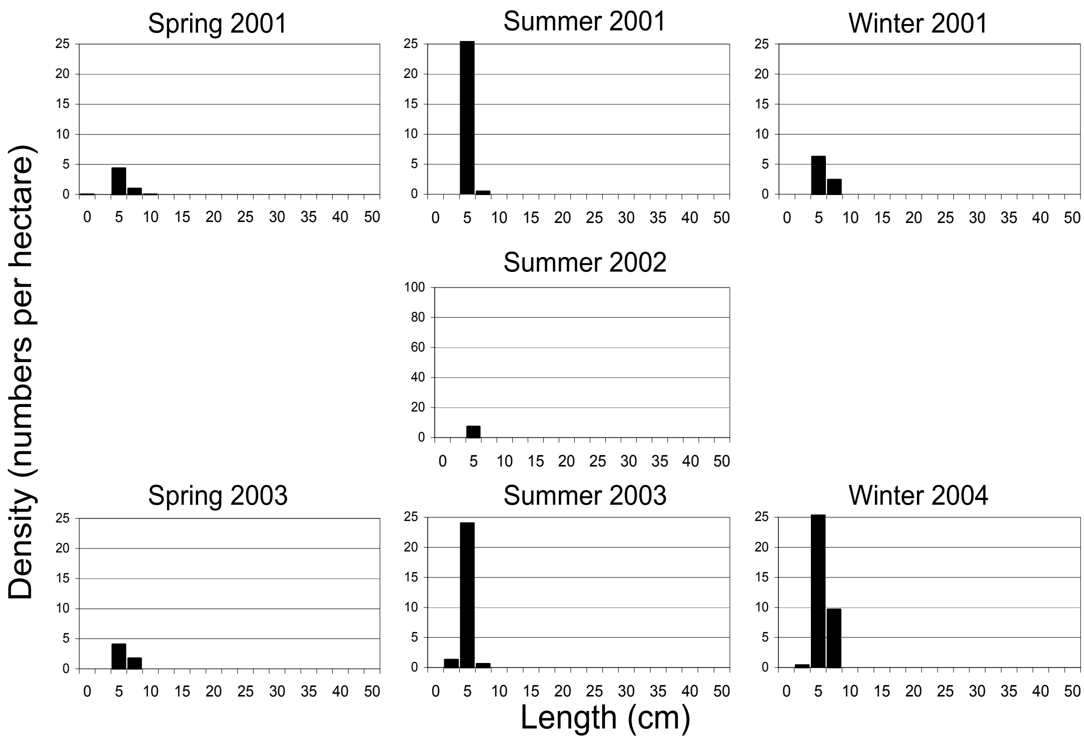
Solenette



Scaldfish



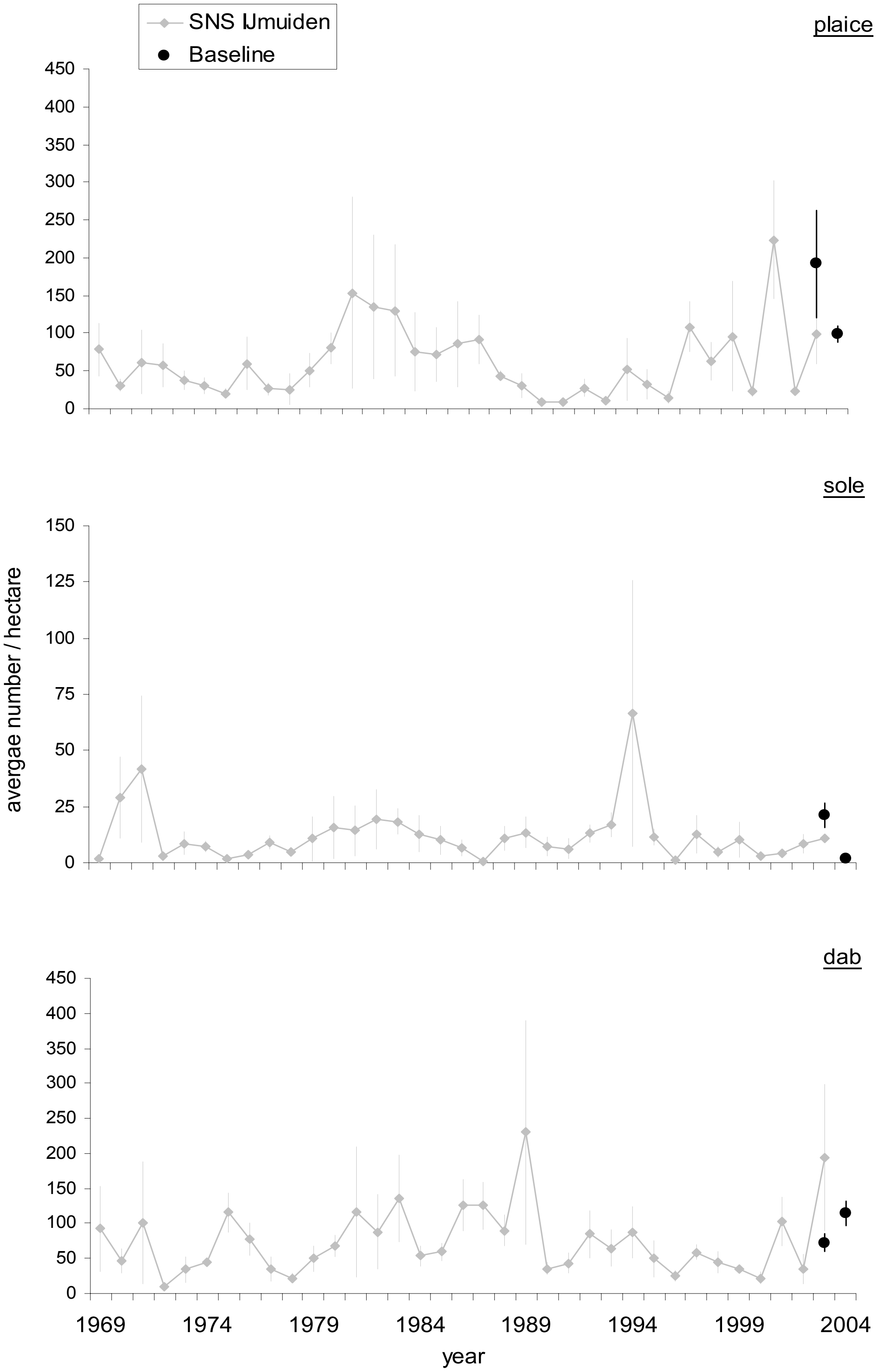
Gobiids



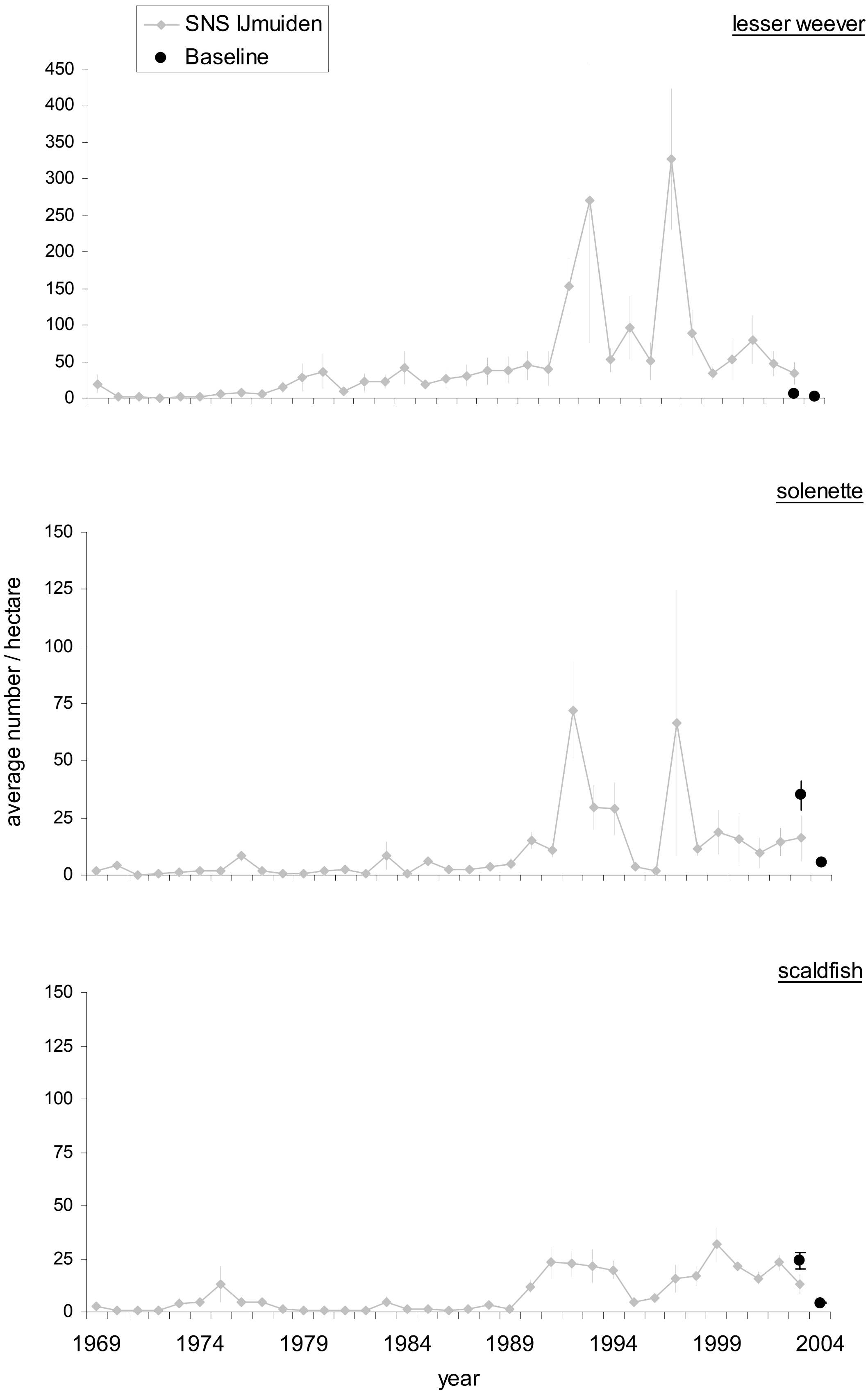
Annex 3.9
The annual variation in mean CpUE of 7 selected species, based SNS and Baseline data of 1969-2004

Annex 3.9. The annual variation in mean CpUE (number per hectare) of 7 selected species

Caught during the SNS hauls conducted in the wind farm area. Vertical bars are the standard error of the mean. In black, the mean CpUE of the two Baseline surveys are shown.



Annex 3.9 continued



Annex 3.9 continued