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Report Number: C075/03

Base line studies North Sea wind farms: pelagic fish survey report 2

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Commissioned by: Ministry of Transport, Public Works and Water Management
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Project number: 3161268002

Contract number: RKZ-1273

Approved by: E. Jagtman
Head of the Department

Signature: _____

Date: 18th December 2003

Number of copies: 10
Number of pages: 41
Number of tables: 2
Number of figures: 4
Number of annexes: 8

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Summary

The Dutch Government has decided to allow the construction of a Near Shore Wind Farm (NSW) demonstration project under the condition that a monitoring programme on - among other things - the ecological impacts is carried out. The Dutch government is responsible for providing a thorough description of the present ecological situation in order to evaluate future effects of planned wind farms. The Netherlands Institute for Fisheries Research is responsible for the baseline study on pelagic fish. Within this study, the pelagic fish community was sampled twice in 2003. It was sampled with a high spatial resolution in the planned location of the wind farm and in two reference sites, and with a low spatial resolution in a larger area along the coast. The first fieldwork report was published in July 2003. The present report describes the second survey that was carried out in September/October 2003. It reports on the execution of the monitoring programme, including a description of the circumstances (days, weather conditions, specific situations, etc.), facilities and materials used, and other relevant information. It also describes preliminary results on the occurrence of species and sizes. It does not, however, contain information on biological data, and densities and biomass data per age and sex because this information will be delivered at the end of the second phase of the project. Finally, the progress of the project is discussed. Apart from some minor problems, the survey was executed well. The preliminary results of the present survey are compared to the results of the spring survey.

Acknowledgements

The fieldwork described in this report was executed on board of the GO58 and we thank Koos de Visser and his crew for the pleasant and professional co-operation. Kees Bakker contributed to the execution of the cruise and Mario Stoker processed the fish at the lab of the institute.

1. Introduction

The Dutch Government has decided to allow the construction of the Near Shore Wind Farm (NSW) demonstration project under the condition that a monitoring programme on - among other things - the ecological impacts is carried out. The most important objective of monitoring is to acquire knowledge and practical experience in the construction and operation of large offshore wind farms in the North Sea[1]. Both the private party that constructs the wind farm as well as authorities (ministries) need this information for future wind farm projects: for construction as well as for developing policy on this topic. Therefore, the (ecological) knowledge acquired with monitoring programmes for NSW must be made available to all parties involved in the realisation of such large-scale wind farms.

The Dutch government is responsible for providing a thorough description of the present ecological situation as a reference for evaluation of future effects. 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 base line study on the North Sea situation for 2003. This study will be on behalf of the Monitoring and Evaluation Programme Near Shore Wind Farm (MEP-NSW) in the North Sea. The baseline study must provide data on the occurrence and density of benthic fauna, demersal fish, pelagic fish, sea mammals, marine birds and non-marine migratory birds. The Netherlands Institute for Fisheries Research of the Animal Sciences Group of Wageningen UR is responsible for the baseline study on pelagic fish.

The baseline study for pelagic fish should establish the occurrence, density, population structure and migration patterns of pelagic fish fauna in the reference situation. Also, the spatial variation of pelagic fish fauna in the reference situation has to be described. This has to be done in such a way that later (outside this assignment) quantitative evaluation is possible of the impact of a wind farm on the occurrence, density, population structure and migration patterns of the pelagic fish fauna. The design of the monitoring programme is justified to meet these goals. The objectives and the sampling design of this study are described in a detailed strategy of approach (Grift et al. 2003). Within this study, the pelagic fish community was sampled twice: in April and September 2003. In April 2003 it was sampled with a high spatial resolution in the planned location of the wind farm and in two reference sites, and with a low spatial resolution in a larger area to provide representative data of the pelagic fish community in the Dutch coastal zone. This report describes the second survey that was carried out in September 2003.

Apart from some adaptations, the September survey was similar to the one carried out in April. The most important adaptation was the lower resolution with which the NSW and reference areas were sampled. The first survey proved that completing the sampling programme with a very high resolution was not feasible and required two weeks of perfect weather conditions. It was expected that in September weather conditions would be worse than in April. Moreover, the results showed that there was no reason to sample these areas with such resolution. Therefore, it was decided, after discussion with RIKZ, that the resolution should be lowered.

[1] We define offshore wind farms as wind farms at sea outside the 12 miles zone (22 km offshore).

As discussed with RIKZ during the kick off meeting, both field work reports will contain data on the occurrence of species and sizes, and a separate report will be delivered at the end of Phase 2 that contains all biological data, and data on densities and biomass per age and sex. These data can best be analysed after the second fieldwork period when age-length keys for all fish species have been established. Both fieldwork reports present preliminary results that give a first impression of the pelagic fish community and also the progress of the project will be discussed.

Chapter 2 summarises the set-up of the survey and describes the adaptations to the April survey. A report of the execution of the survey is given in Chapter 3. Preliminary results are discussed in Chapter 4 and in Chapter 5 the progress of the project is briefly discussed. Tables and Figures of the results are presented in the Appendix, as well as copies of the field forms that were filled out during the survey and lab work.

2. Set-up of the sampling programme

In order to be able to assess temporal variation in the pelagic fish community, pelagic fish were sampled twice within the current project, in April and September 2003 (weeks 16,17 and 40, 41). The sampling design is discussed in detail in the strategy of approach (Grift et al. 2003) and will be summarised here.

Sampling sites were selected such that they cover the planned location of the Near Shore Wind farm, cover reference sites and provide representative data of the pelagic fish community in the Dutch coastal zone. The reference sites have the same size as the wind farm area, and are similar to the wind farm area regarding species community, water currents, water depth and seabed morphology.

Evaluation of the first survey lead to an adapted sampling programme for the second survey (Figure 1). Not all transects could be sampled in the planned two weeks in April and as a result, the survey resolution of the planned location of the wind farm and in the reference sites were reduced by half. This adaptation was discussed with and approved by RIKZ during a meeting in August 2003. The arguments for the adaptation of the sampling programme were:

- Completion of the high resolution programme is only possible under perfect weather conditions;
- Expected worse weather conditions during the second survey in September;
- The spatial distribution of pelagic fish in the wind farm and reference areas showed no differences on the scale of half a mile distance between transects. Consequently, we saw no reason to sample with a very high resolution.

The principle of the survey was, however similar: pelagic fish were sampled with a high spatial resolution in the planned location of the wind farm and in the reference sites, and with a low spatial resolution in a larger area in the coastal zone. This resolution is required to be able to detect possible effects of the wind farm on the occurrence of fish in the impact study. If these effects occur, they are small-scaled and a high-resolution sampling scheme is needed. Additional sampling with a lower resolution in a larger area is required to get an overview of the position of the NSW and reference sites in a larger coastal system and to judge the collected data in the perspective of the observed patchiness over a larger area.

In addition to the adaptation to the sampling programme, the sampling of environmental data with the CTD device was also adapted because of problems experienced in April: the CTD probe was now attached to the net and data were only collected during trawling. During the April survey, turbidity was not measured correctly and we thought this was because the probe was towed at insufficient depth.

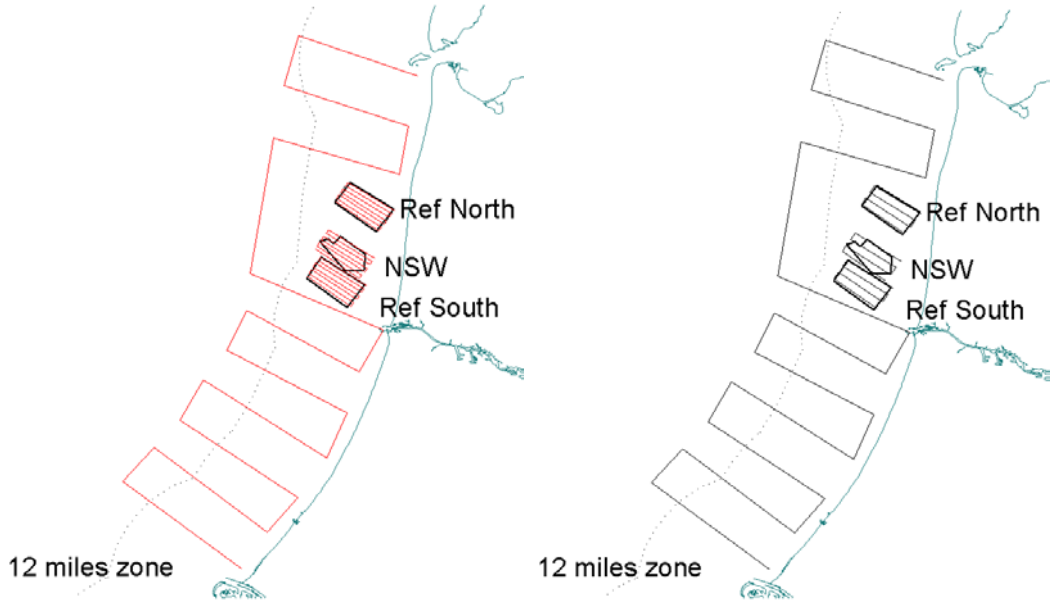

***Figure 1**. Survey design to describe the reference situation of the pelagic fish community in the Dutch coastal zone with the planned acoustic transects in April (left panel) and September (right panel) 2003. The NSW and both reference areas are indicates as well as the 12 miles zone. In April only the perpendicular transects were sampled.*

The data presented here will be supplemented with data from a survey in November, in which two ornithologists and one colleague of the fisheries institute will sample fish and birds during a two-week period. This survey is part of the RIKZ, Waardenburg and RIVO cooperation project 'Birds and Fish'.

3. Survey report

3.1 Introduction

The survey was planned to be carried out in weeks 40 and 41 (29th September - 10th October) of 2003. Owing to adverse weather conditions, sampling was impossible in week 41. At the end of the first week it was quite clear that it would not be possible to survey in the second week. Therefore, it was decided to do as much work as possible during the first week, and the survey was extended to Friday evening. Apart from logistic considerations, there were also scientific reasons that made us decide that it was permissible to finish the survey at the end of the first week:

- The distribution of pelagic fish may rapidly change in time; therefore a hydro acoustic survey aims to cover the studied population as quickly as possible. If an interruption is unavoidable, it should be kept as short as possible and a break of one week between surveys in such a small area is not optimal. Moreover, the sudden change to bad weather conditions could rapidly change the spatial distribution of pelagic fish;
- The NSW and reference areas were sampled as planned (Figure 2);
- A large part of the larger transects was sampled;
- We judged that enough data were collected to adequately describe the baseline situation in September.

In addition, it was foreseen that data from the low-resolution sampling transects in the coastal zone would be completed with data from a similar survey, planned for November 2003 in the 'Birds and Fish' project in cooperation with Waardenburg consultants.

In total, 21 trawls hauls were made and in addition to the regular daytime trawls, two nocturnal trawls were made to study dial variation in catchability (Figure 3).

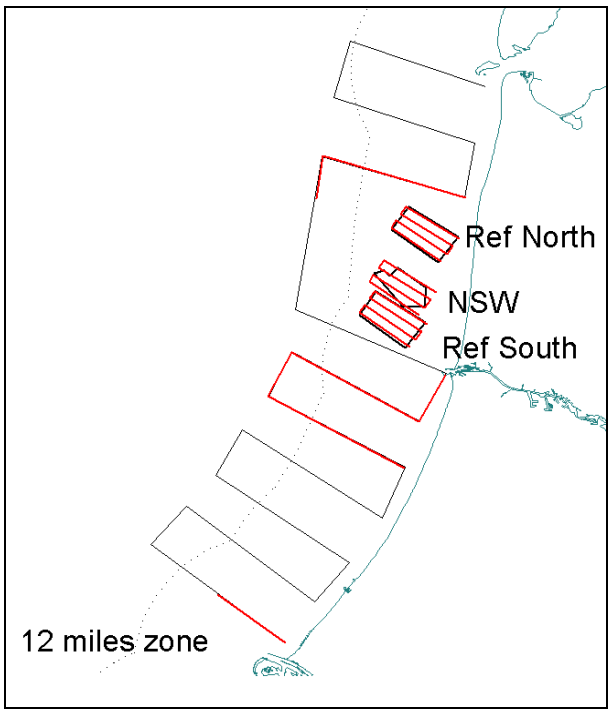

Figure 2. *Planned and executed transects of the acoustic survey in September 2003. The executed transects are red.*

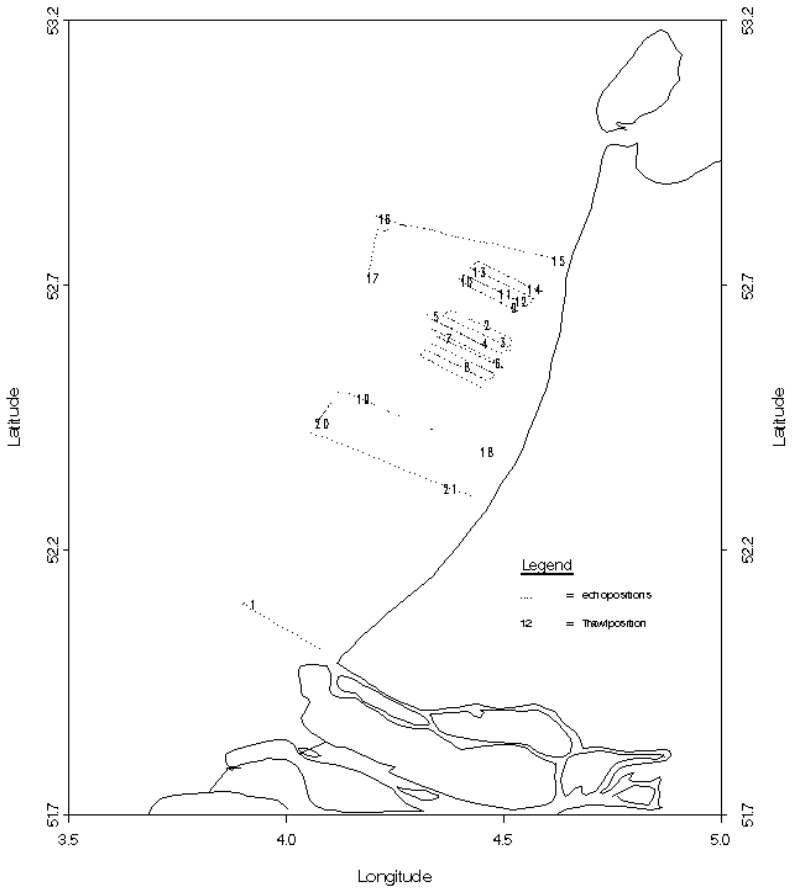

Figure 3. *Positions of the echo survey (dotted line) and of the 21 trawl hauls (numbers) in September 2003. In this plot, positions where no fish were detected are left out. The complete programme is presented in Figure 1.*

3.2 Description of the sampling procedure

3.2.1 Week 40

The survey was planned to be executed week 40 and 41. The weather forecast for week 40 was very good but the conditions were expected to worsen in week 41. Therefore most of the work had to be done by the end of the first week.

On Monday morning the 29th of September, the acoustic and laboratory equipment required for the survey was transported to the chartered vessel GO58 "Jakoriwi" in Stellendam. In the afternoon the acoustic equipment was installed. After installation the vessel steamed up to the Europahaven, port of Rotterdam. By the time the vessel arrived and the crew had their supper, it was already dark. Nevertheless a calibration was performed with the 200 kHz transducer. The results were poor, so it was decided to continue calibration in the morning.

Next morning (30th of September) the vessel was anchored at the edge of the "Offshoreput" by means of the ships anchor on the bow side and with a cable attached on a fixed buoy on the rear. The weather conditions were good. The 38 kHz transducer was successfully calibrated (after having some start-up difficulties with new acoustic software) before 09.00. After this calibration the 200 kHz was calibrated again but without success. Consequently, the 200 KHz transducer could be used to identify species but the estimation of biomass of species would depend on the 38 KHz transducer. Since the results of the April survey are based on the 38 kHz transducer only it was decided to use the 200 kHz transducer for scrutinizing purposes only and to exclude it from precise biomass estimations. After calibration, an ornithologist of Bureau Waardenburg was collected nearby and the survey started at 14.00 sailing along the most southern transect. Halfway through this transect, a haul was made just before dusk. The GO58 headed for IJmuiden to spend the night. Backups of the raw acoustic data and the log post processing-data were made. The data from the CTD-logger were downloaded. It turned out that the turbidity data had not been logged correctly just as in April. A solution for this problem has still not been found although we had adapted the construction and the use of the CTD probe. Temperature and conductivity, pH and oxygen content were measured correctly. During the rest of the trip, turbidity could not be measured correctly.

On the morning of Wednesday, 1st of October, the survey started with sailing the transects of the NSW-area. The planned transects of this area were conducted, including 4 trawl hauls. In the afternoon, the transects of the northern reference area were surveyed and 3 trawl hauls were made. The vessel arrived in IJmuiden, at 21.00. The fish collected for the biological samples was brought to the cold store at RIVO. Backups of the raw acoustic data and the log post processing-data were made and CTD data were downloaded from the logger.

On Thursday, 2nd of October, the transects of the northern reference area were surveyed and 6 trawl hauls were made. In the afternoon only one transect of the low resolution area was surveyed and 1 trawl haul was made. On the way back to IJmuiden an extra short transect was surveyed and trawled shortly after dusk to get some information on catchability differences between day and night time. This transect was executed offshore, not far from the offshore ending point of that day. At 24.00 the vessel arrived in IJmuiden again. The collected fish-

samples were brought to RIVO, backups were made and CTD data were downloaded from the logger.

On Friday, the 3rd of October, 2 transects of the low resolution area were surveyed and 3 trawl hauls were made, of which the first one was, again, a nocturnal haul but this time near shore. Due to heavy weather forecasts for the next week, it was decided to use this week as optimal as possible, so instead of 12.00 we ended the survey at 17.00 With 3½ transects of the whole programme not sampled, we headed back to the port of Schevingen, where we made backups from all collected acoustic, biological and CTD data of this week.

3.2.2 Week 41

On Monday, 6th of October, it took the whole morning and the afternoon to unload and put away the equipment from the vessel in the port of Stellendam to our warehouse in IJmuiden.

3.3 Methods

3.3.1 Acoustics

Raw data were collected using a Simrad EK60 echosounder with a 38 kHz- and 200 kHz-split beam transducer fixed to a towed body, which was towed from the bow of the trawler. The depth of the towed body was approximately 2.5 - 3 meter below the water surface. Data were logged and integrated by 0.5 nautical mile intervals with Echoview software.

3.3.2 Processing of fish

Fish samples were taken with a small half-pelagic trawl, with a 1-cm cod end lining. In total 21 trawl hauls were conducted: 4 in NSW, 3 in the southern reference area, 6 in the northern reference area and 8 in the rest of the coastal zone (Appendix I). From the catch, species could be identified and biological data (length, weight, sex, maturity and otoliths) could be collected.

For each haul, the total weight per species was measured or calculated according a length-weight relationship. For each species[2], length-frequency distributions were assessed with a precision of 0.5 cm for sprat, herring, anchovy and pilchard and of 1 cm for other species. Individuals of species, for which biological data were collected, were stored on ice for later processing at the institute. Biological data were collected for 82 fish of four species (Table 1, below). Following the strategy of approach (Grift *et al.* 2003), no biological data from sprat and herring were collected because these data are collected in other surveys.

[2] A table with all species names (English, Dutch and scientific) is presented Table IV in the Appendix.

Intermezzo: Acoustic data processing

Acoustic data are collected with a transducer and displayed along the cruise track as shown in figure A. From the trawl catches, acoustic signals were allocated to fish species, and with data from the literature these signals were transformed into numbers and biomass (Figure B).
The data are stored by a specified interval, i.e. 0.5, 1.0 or 5.0 nautical mile (Figure C).

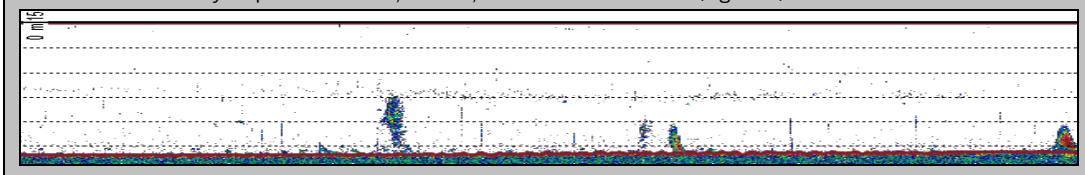

Figure A. *Raw acoustic signals from the echo sounder presented as a vertical slice through the water column.*

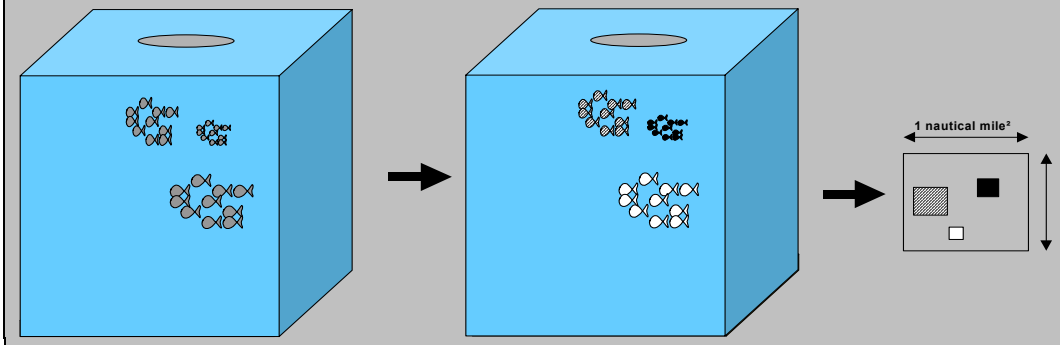

Figure B. *Transformation of raw acoustic signals into acoustic backscattered area per square nautical mile.*

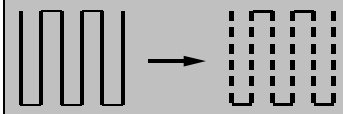

Figure C. *Acoustic back scattered area (in m²/nm²) along the cruise track is integrated per 0.5 nautical miles.*

For an average fish within a species group, an acoustic cross section (sigma, σ) was calculated, using a target strength-length relationship of TS = 20logL - β. (Where TS is the target strength of a single fish, L is the mean length of the fish in the school observed and β is a known, species-dependent constant).

Subsequently the total back-scattered acoustic area of that species within the integrated 0.5 nautical miles is divided by the acoustic area of the one fish to calculate the numbers of fish (Figure D).

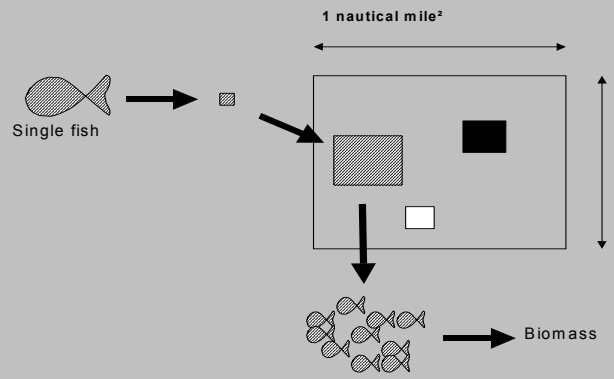

Figure D. *Deriving biomass per nautical mile by dividing total acoustic area by the calculated acoustic area of 1 fish.*

Table 1. *Numbers of fish of which biological data were collected (length, weight, sex, maturity and otoliths). A table with all English, Dutch and scientific names is presented in Appendix IV.*

Name	Dutch name	Numbers processed April/May	Numbers processed September/October
Anchovy	Ansjovis	104	39
Greater sandeel	Smelt	47	9
Herring	Haring	141	-
Lesser sandeel	Kleine zandspiering	45	2
Pilchard	Pelser	53	32
Raitt's sandeel	Noorse zandspiering	109	-
Sprat	Sprot	66	-
Total		**565**	**82**

Sandeels were hardly caught and consequently a limited number was available for the collection of biological data. Length-frequency distributions of the fish processed for biological data are presented in Appendix V (Figure IX).

3.3.3 Hydrography

Temperature, salinity (derived from conductivity), oxygen content (% saturation), pH, time and depth, were recorded by a Hydrolab data logger (CTD device) that was fitted in a netting envelope on the head rope of the trawl during fishing. Turbidity could not be logged due to unsolved problems with the CTD device.

3.3.4 Data processing

The acoustic signals were translated into densities per species group by assigning acoustic data (Nautical Area Scattering Coefficient's; NASC's) to different species/groups on the basis of the trawl information and specific characteristics on the echogram. NASC's were assigned to the following groups:

- Clupeids;
- Horse mackerel;
- Whiting;
- Mackerel
- Plankton and noise.

All data were saved at a -70 dB sv threshold level. Unlike the April survey, it appeared to be possible to allocate NASC's to mackerel.

Although some sandeel showed up in the catches, it was impossible to recognize any marks on the echogram that may belong to (one of) these species because their abundance was too low. Abundance and biomass of sandeel was thus too low to be estimated.

4. Preliminary results

4.1 Trawl catches

In total, ca. 112,000 fish of 16 species were caught (Appendix II). Compared to the survey in April, the catch per unit of effort (time of trawling) in September was much higher (186 fish/minute in April and 304 fish/minute in September). This difference may have multiple causes and cannot be easily related to the density of the fish in the coastal area because the sampling is not random. The table shows numerous demersal species appearing in the catches in low numbers. In contrast to the survey in April 2003, sandeel was caught in very low numbers and lesser sandeel was even not observed at all. Average lengths of each species per haul are presented in Appendix III.

Pelagic species were most important, both in terms of biomass and numbers. Herring, sprat and mackerel were important pelagic species (Figure 4 and Appendix VI). In the NSW area, herring and mackerel were most important and the species composition in terms of biomass resembled that of the southern reference area. The species composition in the northern reference area was different and resembled more that of the larger coastal zone. In the northern area, other species were relatively important.

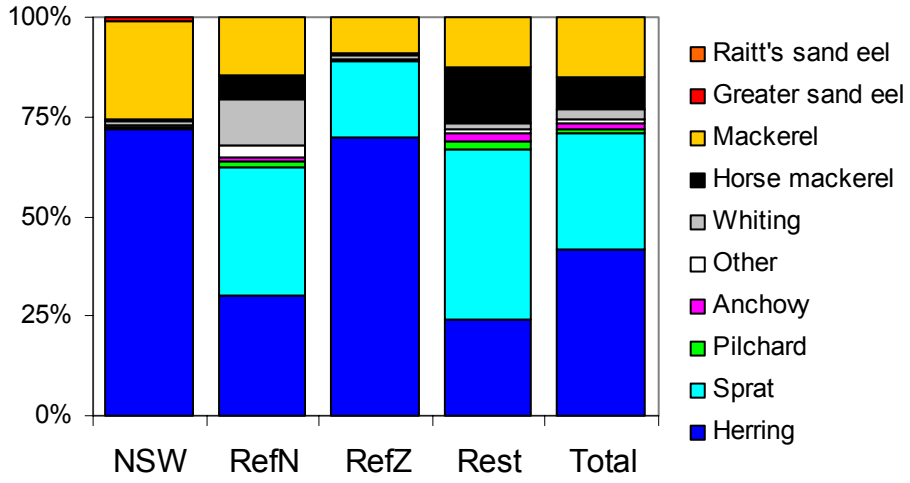

Figure 4. *Species composition in trawl catches in terms of biomass. Pelagic fish are presented per species, other species are grouped as 'other'.*

Appendix V presents the length-frequency distributions of the main pelagic species and these distributions will be discussed below. The bulk of the caught **anchovy** measures 7.5 to 10.5 cm, a group that was not observed in April. Two specimens of 16.5 and 17.5 cm most probably belong to the year class 2002. **Herring** consisted of specimens in the range of 8 - 17 cm. In the NSW – and the reference area's the length peaked at 10-11 cm, whereas in the low-resolution coastal area, two size-groups can be recognized: 8-11 and 11-17 cm. According to data available from RIVO surveys, they were probably from the year class 2002 (0 winter-ring) and 2001 (1 winter-ring). The **pilchards** in the catches ranged from 7 to 12 cm, probably 0-group fish originating from the 2003 spawning season (Knijn et al., 1993). **Sprat** ranged from 9

to 14 cm. Compared to the April survey it looks like the group that had sizes 6.5 – 11 cm in April has now grown to sizes of 10-14 cm. **Greater sandeel**, of which only some tens were caught, were all between 23 and 30 cm.

The main pelagic species – clupeids, horse mackerel and mackerel – were more or less evenly distributed over the coastal area. The clupeid-group may be slightly more abundant at near-shore, whereas horse mackerel was not observed close to the coast. At first sight, no large differences in species distribution and size compositions were revealed between the larger coastal zone and the three other areas.

As in the April survey, these first results indicate that the reference areas have comparable pelagic fish communities and seem to be chosen well.

4.2 Spatial distribution of species

The data can be used to get a first impression of the spatial distribution of pelagic fish in the coastal zone. The figures presented in Appendix VII are very preliminary. From the acoustic information, three groups could be recognized: “clupeids”, consisting of herring, pilchard, sprat and anchovy, mackerel and horse mackerel. The clupeid-group can later be split into species, based on the weight proportions from trawl-information. At present, however, these data were not analysed sufficiently.

The preliminary results are presented in Appendix VII as NASC post plots for the different species (groups). The distribution is similar to the findings from the trawl catches. This is not surprising, because the scrutiny of the echograms is based on the trawl information. At first sight clupeids (herring, sprat, pilchard and anchovy), mackerel and horse mackerel are randomly distributed over all four area's (Figures XI, XII and XIII in Appendix VII). Horse mackerel may have a more offshore distribution, whereas the clupeid group is more shore bound.

4.3 Hydrography

Hydrographic data (temperature and salinity) have been recorded during trawling. These data were linked to geographical positions (Table I in Appendix I) At the time of preparing this report, no spatial distribution patterns or relationships to the fish community could be generated yet. These relationships will we be explored in the final report.

4.4. Otoliths

Age of individual fish will be determined by counting growth zones in the otoliths in order to assemble age-length keys. We examined otoliths that were collected in the first survey and ages of herring and sprat were read successfully. The Netherlands Institute for Fisheries Research has ample experience with both species. For the other species, however (Anchovy, Greater sandeel, Lesser sandeel, Pilchard and Raitt's sandeel) we have no experience and it turned out to be very difficult to determine their ages. Therefore, we consulted experts from other

research institutes abroad and sent the otoliths of these species to institutes in three different countries. The otoliths collected during the second survey were sent to these institutes too. At present, we received the age readings of anchovy and expect to receive the other species by the end of November.

5. Discussion

The second survey of the baseline study for pelagic fish was carried out reasonably successfully. In our opinion the baseline situation of pelagic fish in the autumn can be described well. The high-resolution NSW area and both reference areas could be sampled as planned. However, less than 40% of the high-resolution transects were skipped due to very poor weather conditions in the second week.

Both surveys for this project were not executed as planned but our first impression of the data collected is that the pelagic fish in the coastal zone was sampled well in both periods. The additional data collected in the 'birds and fish' project, and 2002 data from the Flyland project are, however, very welcome. The set up of the baseline study for pelagic fish was based on additional sampling within the Flyland programme in January and July 2003. The January survey for the Flyland project was cancelled because of bad weather and the July survey was cancelled because the project was stopped. Data from four surveys have now become available that should, altogether, form a basis to describe the baseline situation of pelagic fish (Table 2).

Table 2. *Overview of data available on the pelagic fish community in the Dutch coastal zone.*

Period	Project	Observations
June 2002	Flyland	Fish, birds, zooplankton
April 2003	Baseline wind farms	Fish
September 2003	Baseline wind farms	Fish, birds
November 2003	Birds and fish	Fish, birds

Despite trials with new methods of attachment to the trawl, the logging of turbidity data failed again. Therefore the conclusion must be that the used CTD device is not designed to be towed at speeds of 8 knots (attached on the towed body, April survey) or at 4 knots (attached on the head rope of the trawl). Probably, the water is either too clear or the CTD is towed at an insufficient depth to sample turbidity well. Because we think that turbidity is an important environmental factor, we will try to obtain satellite data from the periods we surveyed with which the spatial distribution of turbidity can be reconstructed. At present, we have requested this type of data from Dutch experts.

The calibration of the 200 kHz failed again. At the time of writing this report the transducer had been sent to the manufacturer, who did not find any problems and returned it without repairing it. However in a new test at RIVO, it turned out that one of the electrical cables was broken and the transducer was sent back to the manufacturer again. At present, we are hiring a transducer to carry out the survey for the birds and fisheries project. For this project, the transducer was calibrated reasonably successfully in the basin of the Netherlands Institute for Fisheries Research.

The 38 kHz will be used for echo integration while the 200 kHz, together with the 38 kHz, is being used for distinguish among different species.

The scrutiny of the acoustic data revealed numerous small diffuse schools consisting of four species of clupeids. Since it was not possible to distinguish between these species yet, they were grouped into a group called "clupeids". In future analyses the species distribution will be estimated on the basis of the compositions of the trawl catches.

The amount of sandeel (three species) in the catches was very low and there were no distinct schools recorded. The acoustic response of these species is very low compared to clupeids and gadoids. From the perspective of the clupeids, they belong to the "noise". In summary, it was not possible to assign NASC's to this group of species because their densities were too low.

Although systematic recordings of the turbidity were not available, it was evident to the crew and the scientists that the visibility was high. This may influence the catchability of fast swimming fish, like bigger-sized mackerel, horse mackerel and clupeids. The two trawl catches performed at night-time, however did not differ significantly from the daytime catches in terms of species composition and length distributions.

Compared to the preliminary results from the April survey the current survey reveals a more patchy distribution for the main swim-bladdered species (Clupeids and horse mackerel). Raitt's sandeel and lesser sandeel were almost absent from the catches in September whereas they were abundant in April. An explanation may be that sandeels are believed to over winter buried in the sand (Macer, 1966). Another explanation is that the sandeel in September had a more offshore distribution compared to April. It is worth noting here that the bulk of the sandeel in the Flyland survey was caught more than 15 nautical miles offshore (RIVO, unpublished).

This may also be true for greater sandeel of which only a few more specimens showed up in the catches. The group of 7-11 cm found in April, seems to have grown to about 26 cm which implies a monthly growth increment of slightly less than 3 cm. This increment is comparable to the growth rate observed by Macer (1966): 3.3 cm.

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Appendix

Appendix I. Trawl list

Table I. *List of trawl hauls with position, date, time, haul duration, dissolved oxygen (% saturation), pH (-), water temperature (°C) and salinity (ppm) from the CTD.*

Area	Sample ID	haul no.	date	position	time UTC	haul duration (min)	DO	pH	temp	salinity
Coastal zone	5000034	1	30/09/03	52 05N 03 54E	14:13	27	60.74	9.2	17.75	33.118
NSW	5000035	2	01/10/03	52 37N 04 26E	04:52	15	57.15	9.3	17.04	32.498
	5000036	3	01/10/03	52 35N 04 28E	08:35	18	52.62	9.3	17.00	31.918
	5000037	4	01/10/03	52 35N 04 26E	09:55	17	49.76	9.3	17.05	32.091
	5000038	5	01/10/03	52 38N 04 19E	11:19	17	49.14	9.3	17.31	33.808
	5000039	6	01/10/03	52 33N 04 28E	13:03	13	45.92	9.2	17.02	31.604
Reference area South	5000040	7	01/10/03	52 36N 04 21E	14:19	25	47.65	9.3	17.25	33.559
	5000041	8	01/10/03	52 32N 04 23E	16:20	34	44.77	9.3	17.07	32.264
	5000042	9	02/10/03	52 39N 04 30E	07:03	13	52.18	9.0	16.90	32.029
Reference area North	5000043	10	02/10/03	52 42N 04 24E	08:10	18	49.61	9.2	17.05	33.359
	5000044	11	02/10/03	52 41N 04 29E	09:25	13	47.13	9.1	16.90	32.232
	5000045	12	02/10/03	52 40N 04 31E	10:15	21	46.05	9.2	16.95	32.216
	5000046	13	02/10/03	52 43N 04 26E	12:03	10	45.48	9.2	17.13	33.323
	5000047	14	02/10/03	52 41N 04 33E	13:19	22	43.65	9.1	16.96	31.964
Coastal zone	5000048	15	02/10/03	52 45N 04 37E	14:55	15			no data	no data
	5000049	16	02/10/03	52 49N 04 12E	17:13	11	42.81	9.2	17.23	33.098
	5000050	17	02/10/03	52 43N 04 11E	18:35	12	42.47	9.2	17.22	34.913
	5000051	18	03/10/03	52 23N 04 27E	06:08	14	41.43	9.1	16.89	30.477
	5000052	19	03/10/03	52 29N 04 09E	08:18	11	41.40	9.2	17.31	33.258
	5000053	20	03/10/03	52 26N 04 04E	09:37	23	41.01	9.2	17.33	34.042
	5000054	21	03/10/03	52 19N 04 22E	12:20	19	37.75	9.2	17.05	31.026

Appendix II. Numbers caught

Table II *Total numbers of pelagic fish caught.*

Haul	Sample ID	Total	Anchovy	Herring	Pilchard	Sprat	Horse mackerel	Mackerel	Greater sandeel	Raitt's sandeel
1	5000034	9255	2056	4612	1005	1553	25	4	0	0
2	5000035	64	24	3	5	0	30	2	0	0
3	5000036	1854	0	1792	0	0	14	14	32	2
4	5000037	12856	0	12802	0	0	12	41	0	1
5	5000038	524	24	31	6	5	88	368	1	1
6	5000039	9306	0	6315	0	2987	0	4	0	0
7	5000040	214	13	84	12	63	29	13	0	0
8	5000041	10457	1	9599	1	748	21	87	0	0
9	5000042	3416	465	1440	260	1248	0	3	0	0
10	5000043	288	64	5	0	76	124	17	1	1
11	5000044	497	41	164	184	44	17	47	0	0
12	5000045	276	5	131	22	11	23	84	0	0
13	5000046	89	0	40	2	0	46	0	1	0
14	5000047	8731	0	3574	0	5120	36	1	0	0
15	5000048	26662	56	5135	1665	19800	0	2	4	0
16	5000049	635	0	0	2	0	81	552	0	0
17	5000050	2375	0	1856	0	0	517	2	0	0
18	5000051	14051	120	361	120	13440	8	1	1	0
19	5000052	929	0	0	0	0	928	1	0	0
20	5000053	8114	0	0	0	0	8064	47	2	1
21	5000054	169	30	5	6	0	128	0	0	0

Table II*. Total number of other fish caught per haul.*

Haul	Sample ID	Total	Lesser weever	Dragonet	Dab	Whiting	Plaice	Red mullet	Grey gurnard	Transparent goby
1	5000034	176	4	1	1	170	0	0	0	0
2	5000035	1	1	0	0	0	0	0	0	0
3	5000036	32	2	0	5	23	2	0	0	0
4	5000037	53	0	0	4	48	1	0	0	0
5	5000038	25	1	2	7	3	0	12	0	0
6	5000039	2	0	0	0	1	0	1	0	0
7	5000040	9	0	1	3	4	0	1	0	0
8	5000041	56	3	0	2	45	4	2	0	0
9	5000042	0	0	0	0	0	0	0	0	0
10	5000043	19	1	0	11	0	0	7	0	0
11	5000044	9	1	0	4	3	1	0	0	0
12	5000045	496	0	12	55	406	18	4	1	0
13	5000046	27	3	3	10	4	3	4	0	0
14	5000047	35	1	1	6	22	3	2	0	0
15	5000048	0	0	0	0	0	0	0	0	0
16	5000049	14	5	0	3	2	1	3	0	0
17	5000050	167	54	0	24	8	10	58	1	12
18	5000051	4	0	0	0	0	1	3	0	0
19	5000052	99	16	5	1	68	0	9	0	0
20	5000053	70	25	10	1	26	0	8	0	0
21	5000054	47	0	20	2	20	4	1	0	0

Table II[c]. *Total number of other fauna caught per haul.*

Haul	Sample ID	Total	Crab	North Sea crab	Squid
1	5000034	358	0	0	358
2	5000035	52	20	0	32
3	5000036	362	256	0	106
4	5000037	198	0	0	198
5	5000038	60	24	0	36
6	5000039	82	20	0	62
7	5000040	62	0	0	62
8	5000041	176	60	0	116
9	5000042	12	12	0	
10	5000043	130	22	0	108
11	5000044	44	0	0	44
12	5000045	122	36	2	84
13	5000046	344	44	0	300
14	5000047	62	0	0	62
15	5000048	32	30	0	2
16	5000049	24	24	0	0
17	5000050	16	16	0	0
18	5000051	28	28	0	0
19	5000052	62	14	0	48
20	5000053	170	30	0	140
21	5000054	410	24	0	386

Appendix III. Average lengths.

***Table III*.** *Average length of pelagic species in each trawl haul (cm).*

Haul	Sample ID	Anchovy	Herring	Pilchard	Sprat	Horse mackerel	Mackerel	Greater sandeel	Raitt's sandeel
1	5000034	9.9	12.7	9.5	12.6	11.2	29.3		
2	5000035	9.5	20	10.5		11.3	31.5		
3	5000036		11.7			11.4	30.6	28	15
4	5000037		12.3			13	29.6		16
5	5000038	9.3	12.3	9.9	12.3	10.3	27.2	29	14
6	5000039		10.6		12.1		27.8		
7	5000040	10	10.6	8	12	11.5	28.8		
8	5000041	10.5	11.5	12	12	12.1	29.8		
9	5000042	8.7	11.9	10	11.8		31.7		
10	5000043	9.2	11.8		11.8	11.1	28.2	14	17
11	5000044	9.3	13.4	10.7	12	12	28.6		
12	5000045	9.2	12.6	10.7	12	25.5	29.5		
13	5000046		9.5	11		12.3		27	
14	5000047		11.4		11.4	25.8	34		
15	5000048	8.4	10.9	9.2	11.1		24	25.5	
16	5000049			24		21.7	27.1		
17	5000050		15.6			15.6	24		
18	5000051	8	9.7	10.5	11.1	21.3	23	24	
19	5000052					10.6	25		
20	5000053					10.5	28.8	28	15.5
21	5000054	9.8	10.9	10		10.2			

Table III'. *Average length of other species in each trawl haul (cm).*

Haul	Sample ID	Lesser weever	Dragonet	Dab	Whiting	Plaice	Red mullet	Grey gurnard	Transparent goby
1	5000034	12.5	18	26	17.4				
2	5000035	16							
3	5000036	13		12.6	20.2	23			
4	5000037			20.5	20	26			
5	5000038	11	17	18.9	23.7		12.5		
6	5000039				20		13		
7	5000040		18	17.7	17		25		
8	5000041	12.3		15	22.4	18.8	11.5		
9	5000042								
10	5000043	15		17.2			11.4		
11	5000044	12		16.5	20.7	18			
12	5000045		18.2	15.9	21.7	19.7	12.8	19	
13	5000046	11.7	18	15.2	18	17.7	10.5		
14	5000047	14	20	15.7	19.9	22.3	10.5		
15	5000048								
16	5000049	10.4		15	28	22	11.7		
17	5000050	11.3		15.9	24.3	20.1	11.9	8	4.4
18	5000051					21	11.3		
19	5000052	11.6	17	17	22.4		11		
20	5000053	11.4	17.6	21	21.1		12.1		
21	5000054		17.2	14.5	19.2	25.8	10		

Appendix IV. Species names

Table IV. *English, Dutch and scientific names of fish species.*

Name	Dutch name	Species	Family
Allis shad	Elft	Alosa alosa	Clupeidae
Anchovy	Ansjovis	Engraulis encrasicolus	Engraulidae
Bib	Steenbolk	Trisopterus luscus	Gadidae
Bull-rout	Zeedonderpad	*Myoxocephalus scorpius*	Cottidae
Cod	Kabeljauw	*Gadus morhua*	Gadidae
Dab	Schar	*Limanda limanda*	Pleuronectidae
Dragonet	Pitvis	*Callionymus lyra*	Callionymidae
Flounder	Bot	*Platichthys flesus*	Pleuronectidae
Four-bearded rockling	Vierdradige meun	*Enchelyopus cimbrius*	Gadidae
Greater sandeel	Smelt	*Hyperoplus lanceolatus*	Ammodytidae
Grey gurnard	Grauwe poon	*Eutrigla gurnardus*	Triglidae
Herring	Haring	*Clupea harengus*	Clupeidae
Horse mackerel	Horsmakreel	*Trachurus trachurus*	Carangidae
Lamprey	Rivierprik	*Lampetra fluviatilis*	Petromyzonidae
Lesser sandeel	Kleine zandspiering	*Ammodytes tobianus*	Ammodytidae
Lesser weever	Kleine pieterman	*Echiichthys vipera*	Trachinidae
Mackerel	Makreel	*Scomber scombrus*	Scombridae
Pilchard	Pelser	*Sardina Pilchardus*	Clupeidae
Plaice	Schol	*Pleuronectes platessa*	Pleuronectidae
Poor cod	Dwergbolk	*Trisopterus minutus*	Gadidae
Raitt's sandeel	Noorse zandspiering	*Ammodytes marinus*	Ammodytidae
Reticulated dragonet	Rasterpitvis	*Callionymus reticulatus*	Callionymidae
Scaldfish	Schurftvis	*Arnoglossus laterna*	Bothidae
Sole	Tong	*Solea vulgaris*	Soleidae
Solenette	Dwergtong	*Buglossidium luteum*	Soleidae
Sprat	Sprot	*Sprattus Sprattus*	Clupeidae
Transparent goby	Glasgrondel	*Aphia minuta*	Gobiidae
Tub gurnard	Rode poon	*Trigla lucerna*	Triglidae
Whiting	Wijting	*Merlangius merlangus*	Gadidae

Appendix V. LF distributions

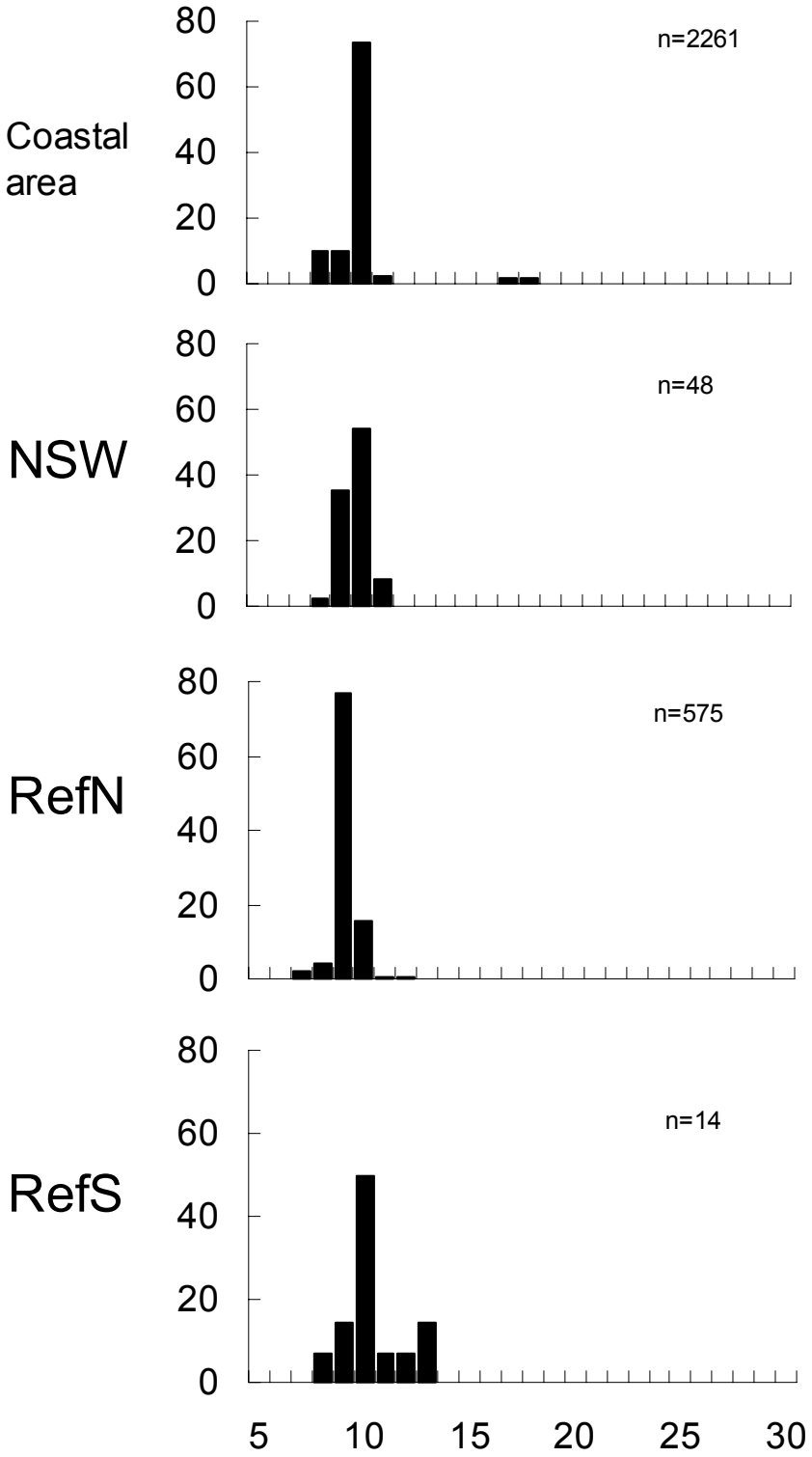

Figure I. *Length frequency distributions of anchovy from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

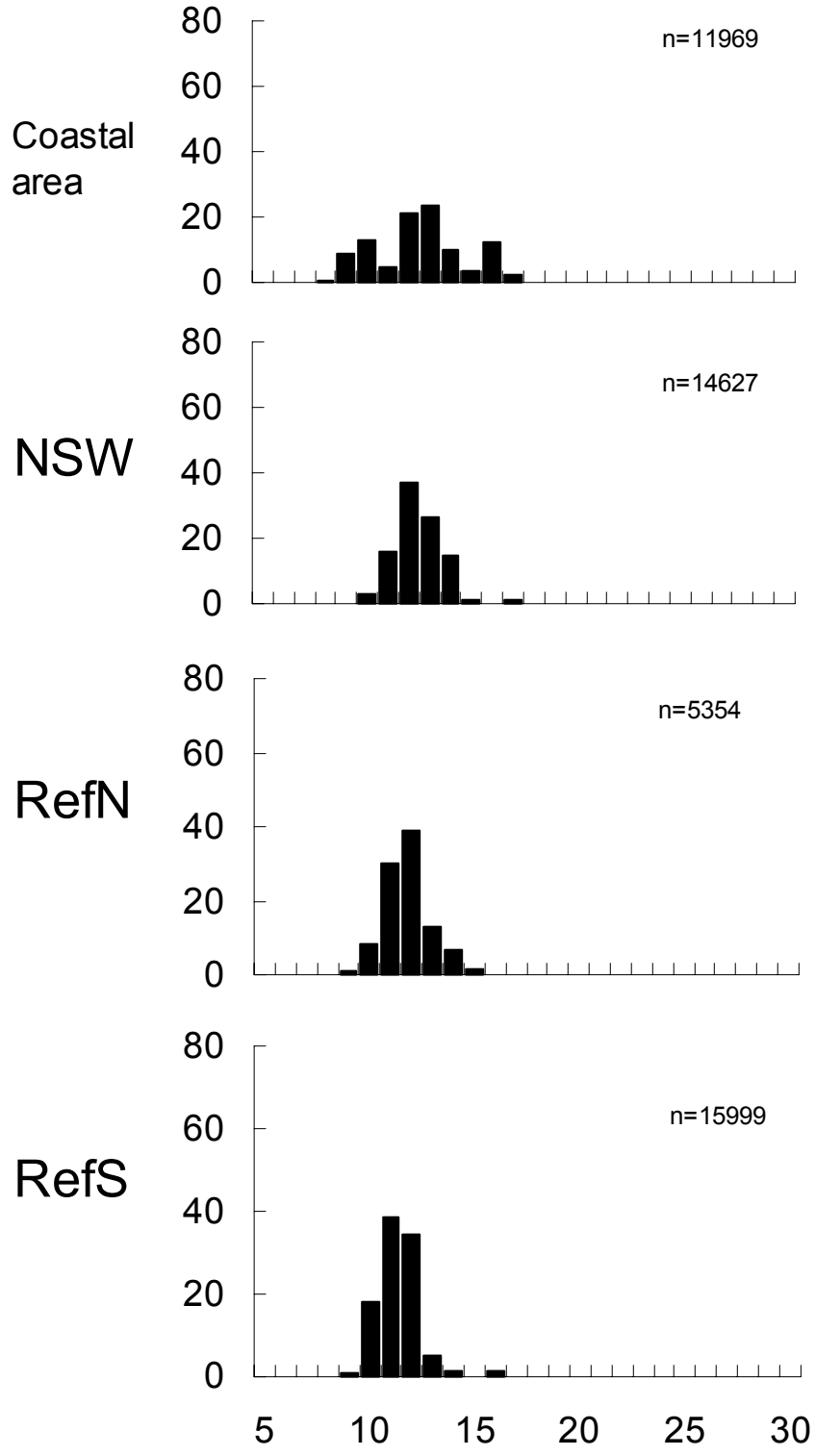

***Figure II**. Length frequency distributions of herring from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

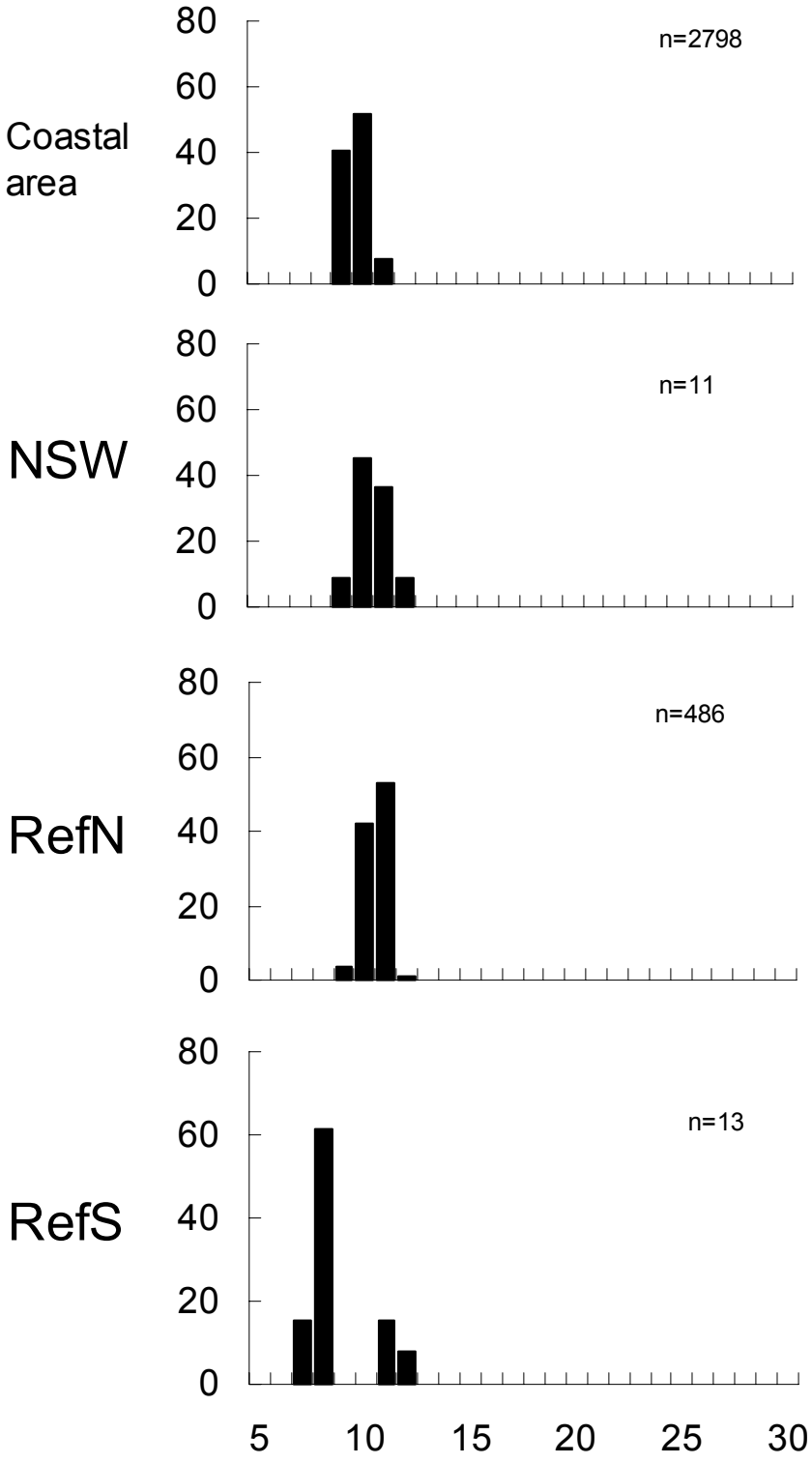

Figure III*. Length frequency distributions of pilchard from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

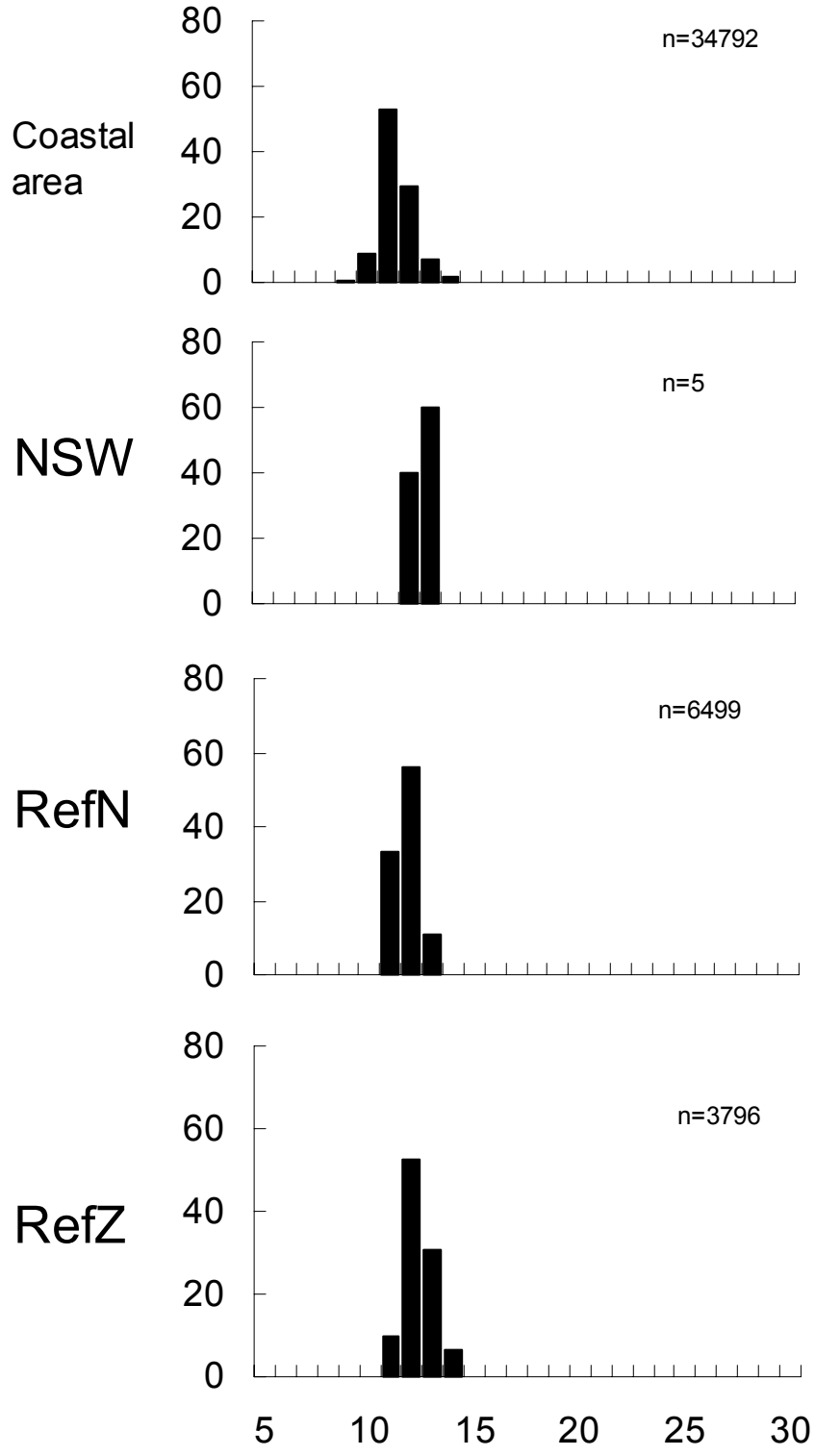

Figure IV. *Length frequency distributions of sprat from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

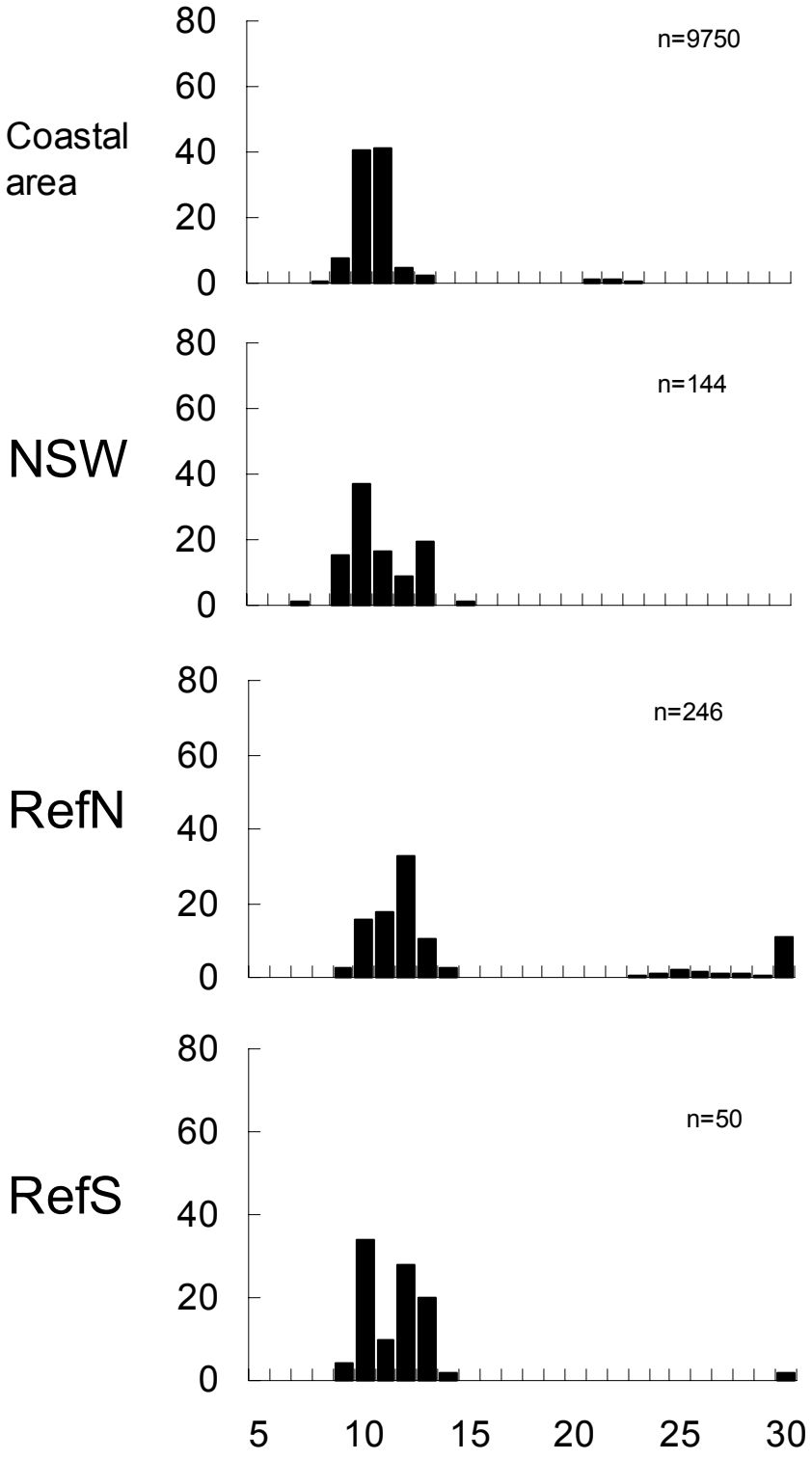

***Figure V**. Length frequency distributions of horse mackerel from the trawl catches.Total length on the x-axis (cm and a 30+cm group) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

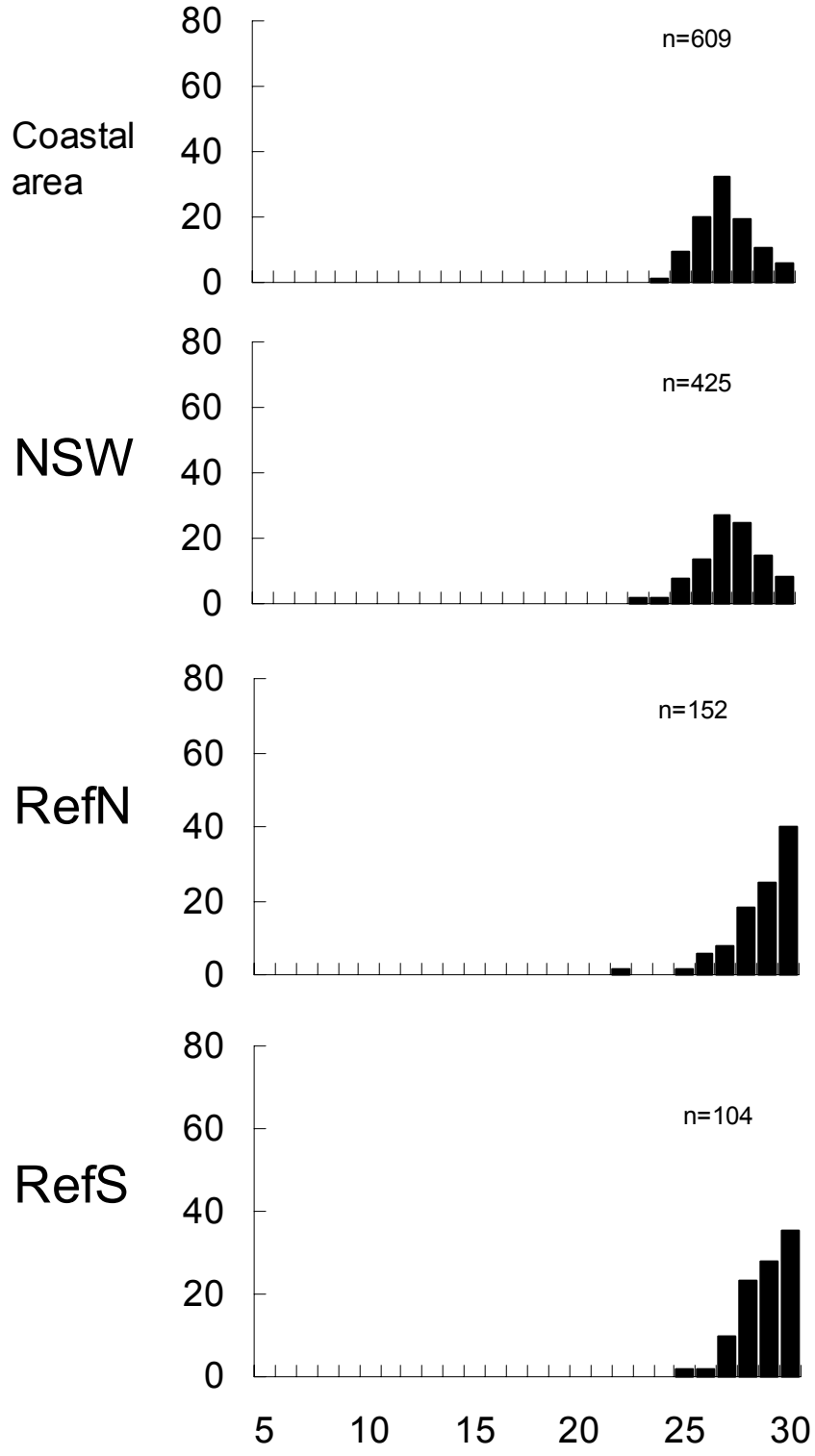

Figure VI. *Length frequency distributions of mackerel from the trawl catches. Total length on the x-axis (cm and a 30+cm group) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

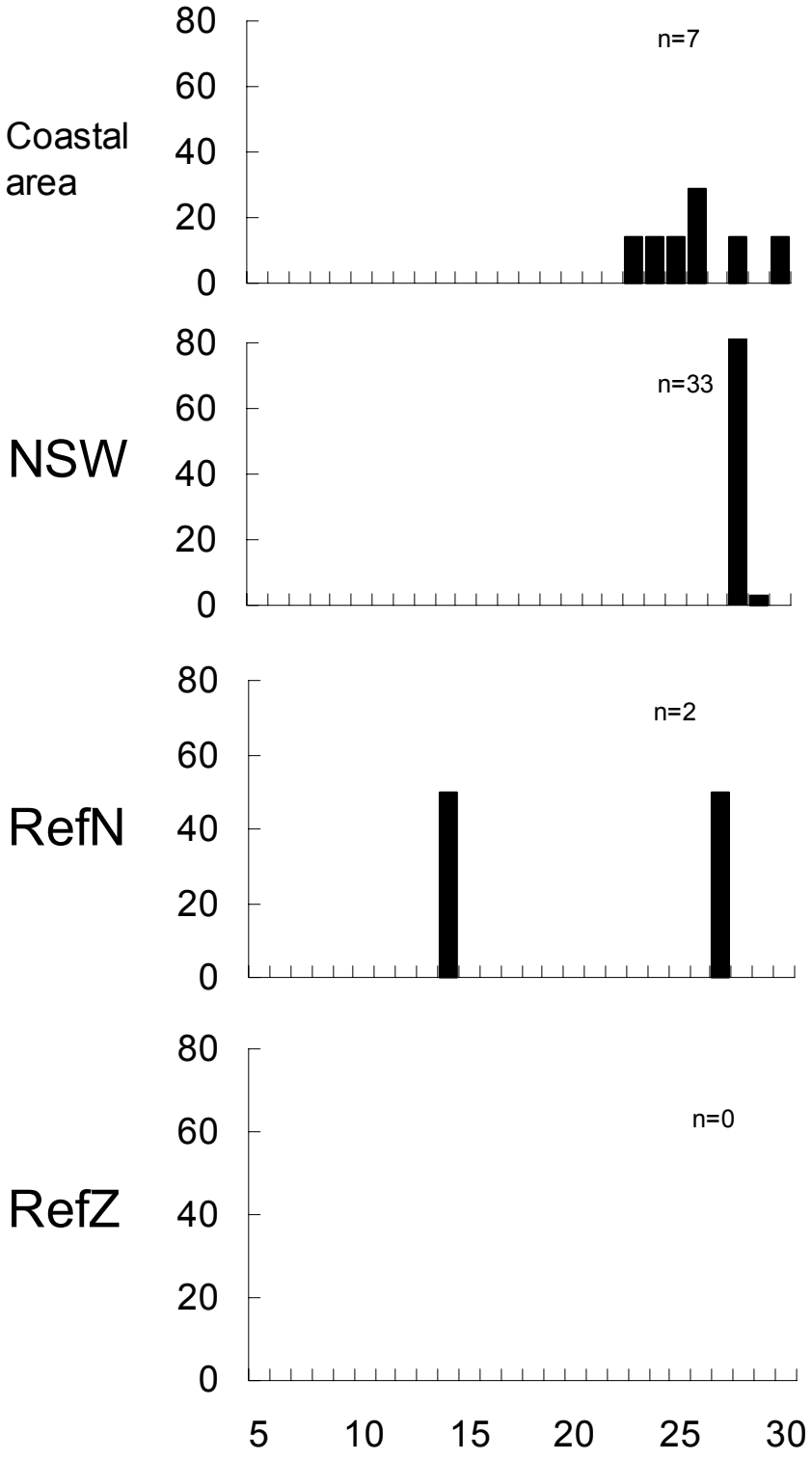

Figure VII. *Length frequency distributions of greater sandeel from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

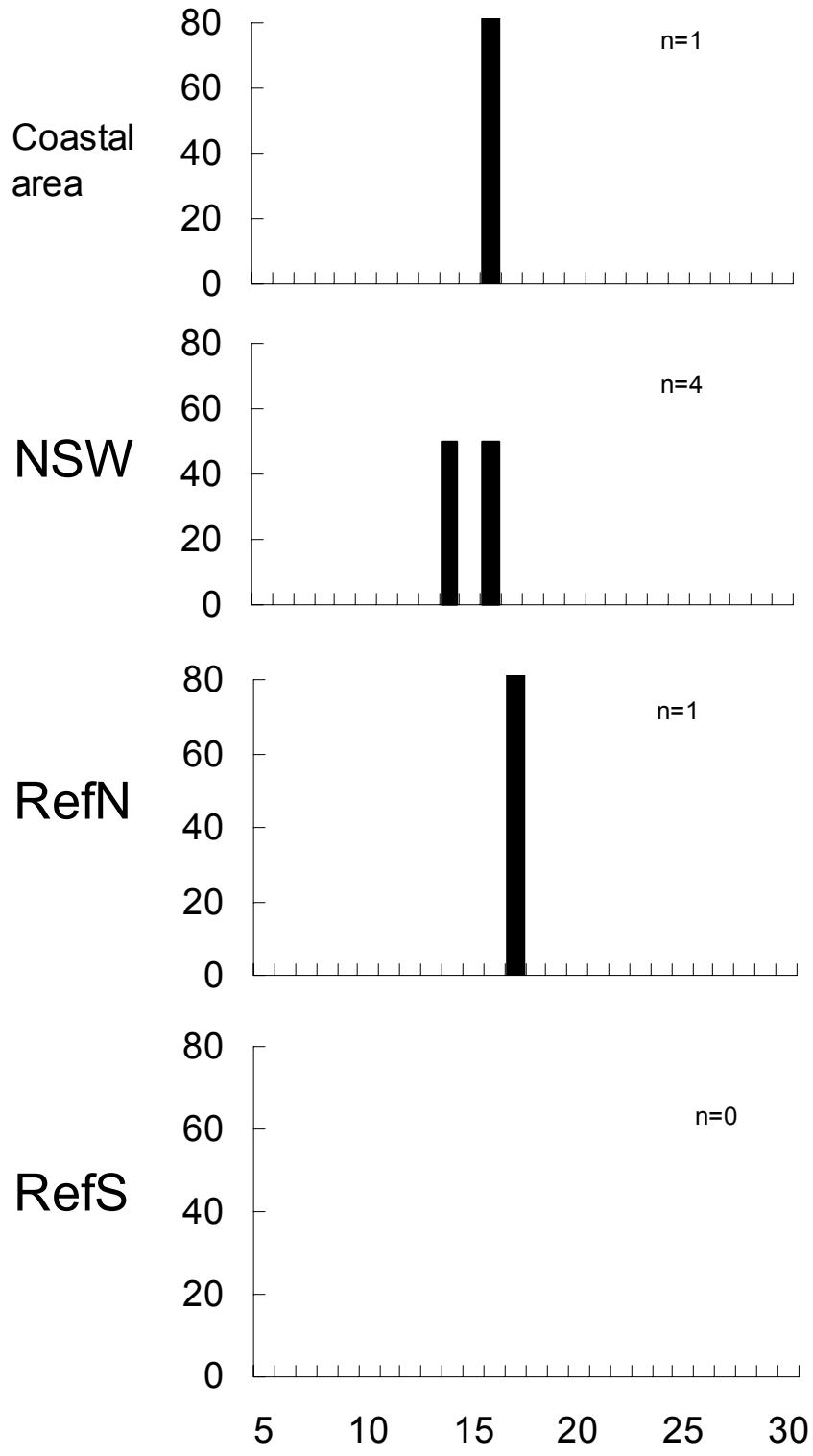

Figure VIII*. Length frequency distributions of Raitt's sandeel from the trawl catches. Total length on the x-axis (cm) and percentage of fish in each length class on the y-axis. N is the total number of fish caught.*

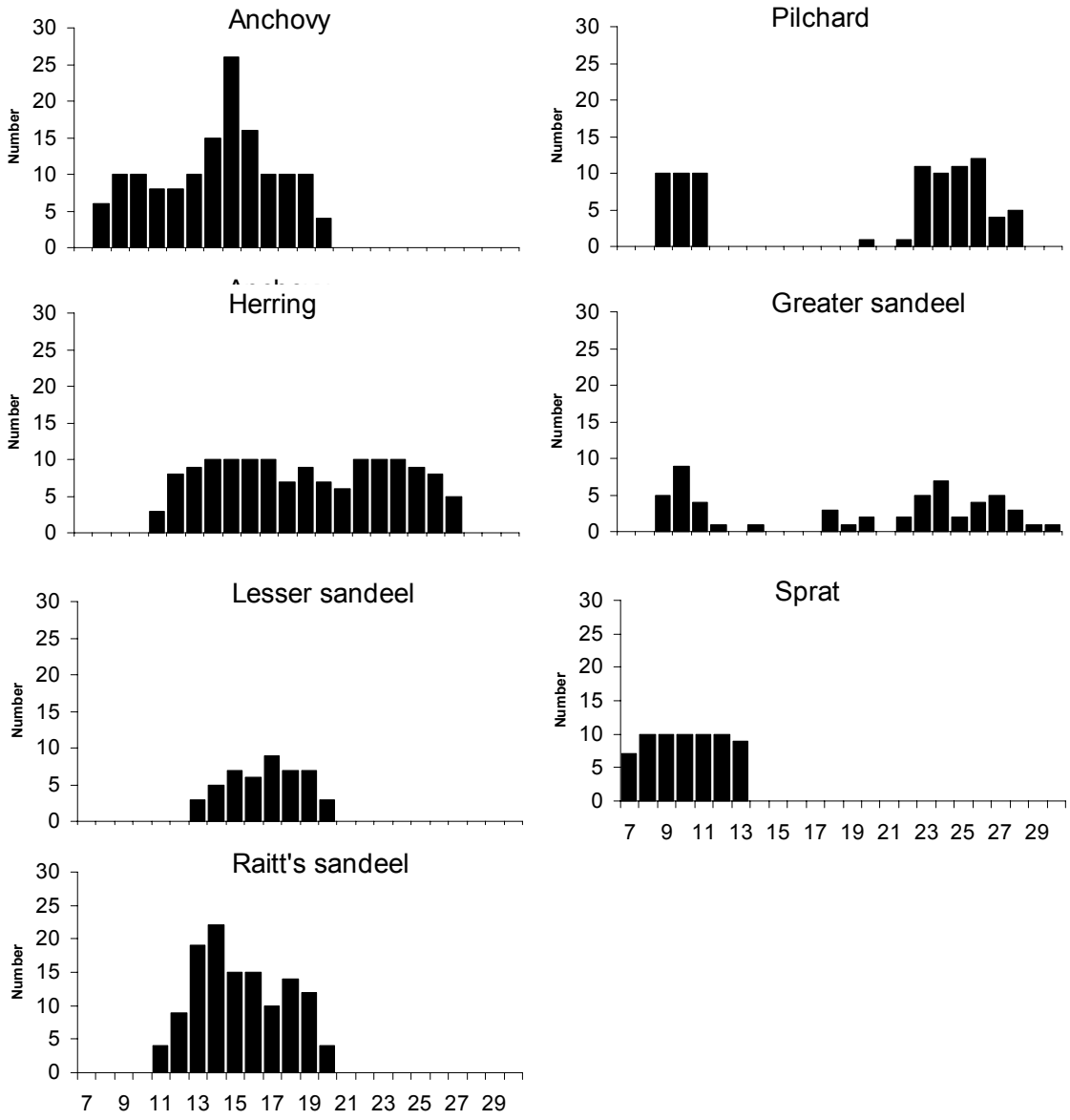

Figure IX. *Length frequency distributions of fish of which biological data were collected in the first and second survey combined. Total length on the x-axis (cm) and total number of fish of which data were collected on the y-axis (-).*

Appendix VI. Abundance of fish

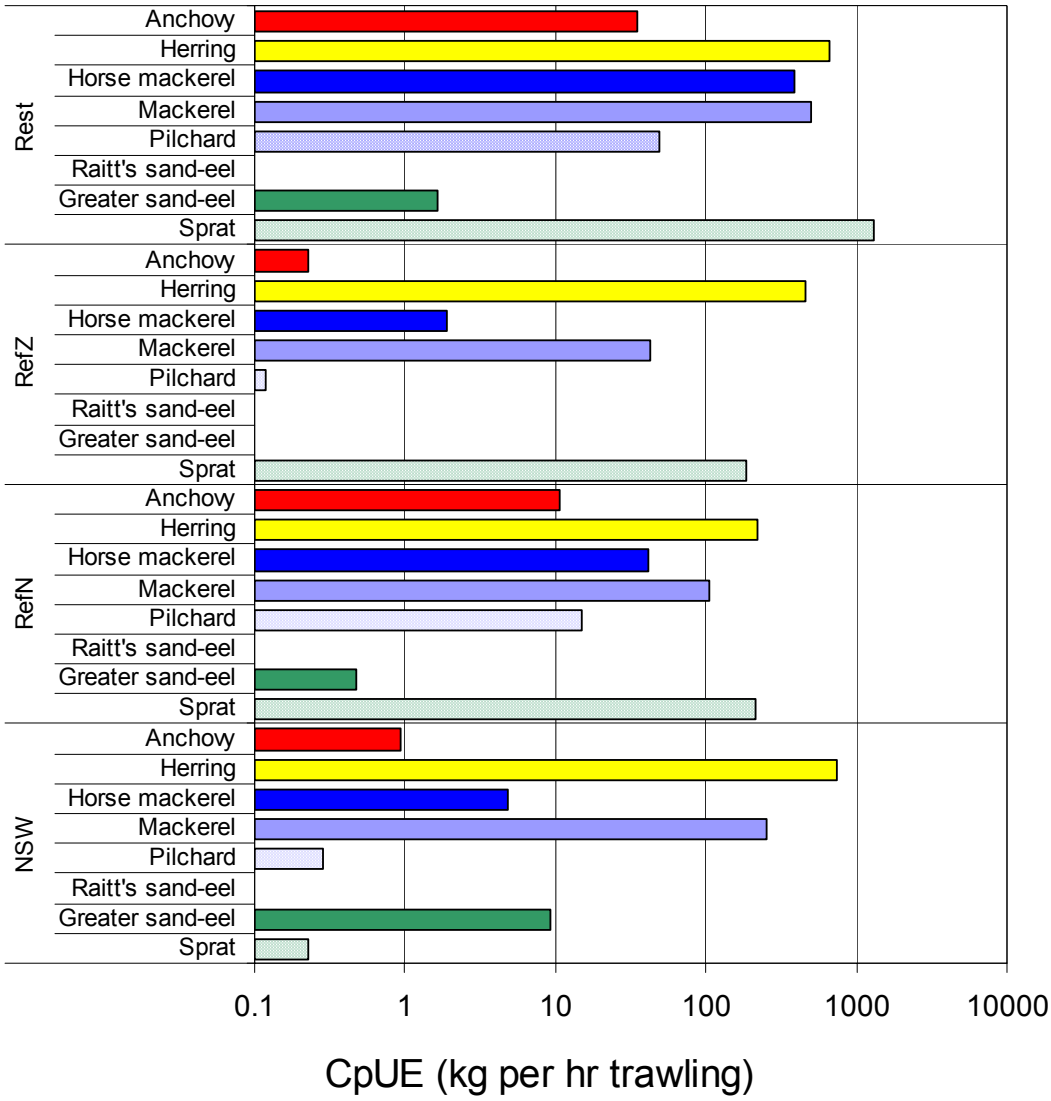

Figure X. *Abundance of eight pelagic species in terms of biomass in four areas: Near Shore Wind park area (NSW); northern reference area (RefN); southern reference area (RefZ) and the larger coastal area (rest). The weight on the x-axis is the trawl catch in kg per hour trawling.*

Appendix VII. Spatial distribution of pelagic species.

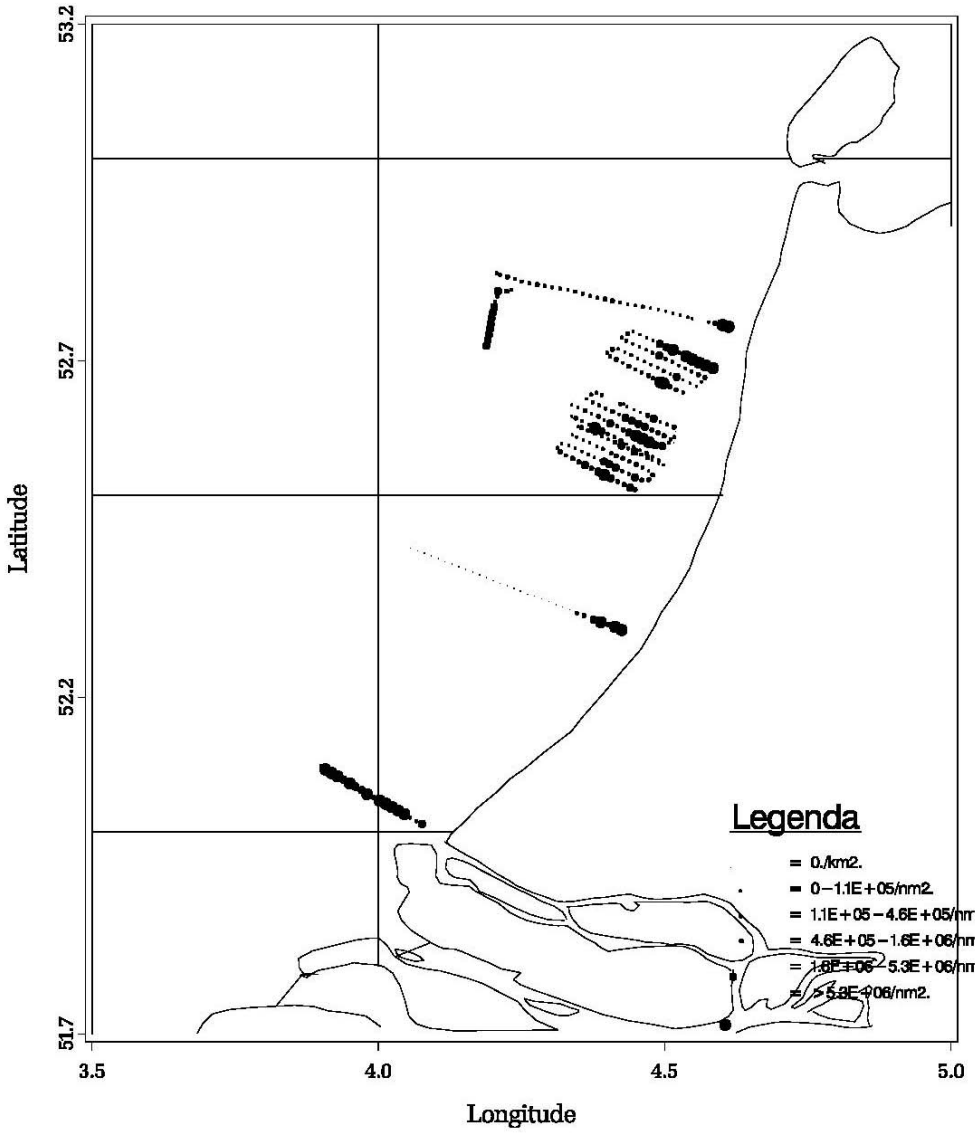

Figure XI. *Spatial distribution of clupeids (herring, sprat, anchovy and pilchard). This group could not be discerned further at the time of writing this report. In the final report, however, density per species will be presented. The bubbles representing densities of fish are plotted at the start positions of half nautical miles.*

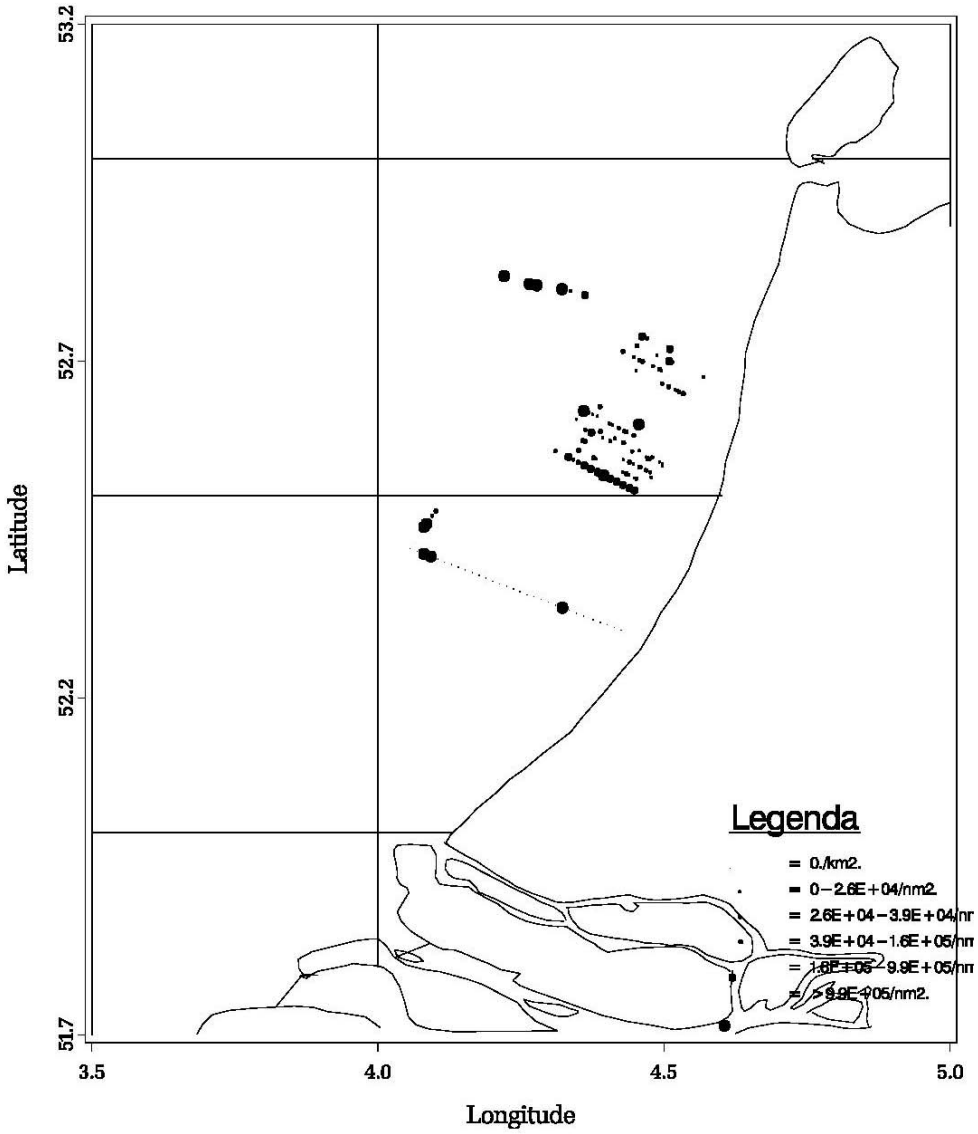

Figure XII. *Spatial distribution of mackerel.*

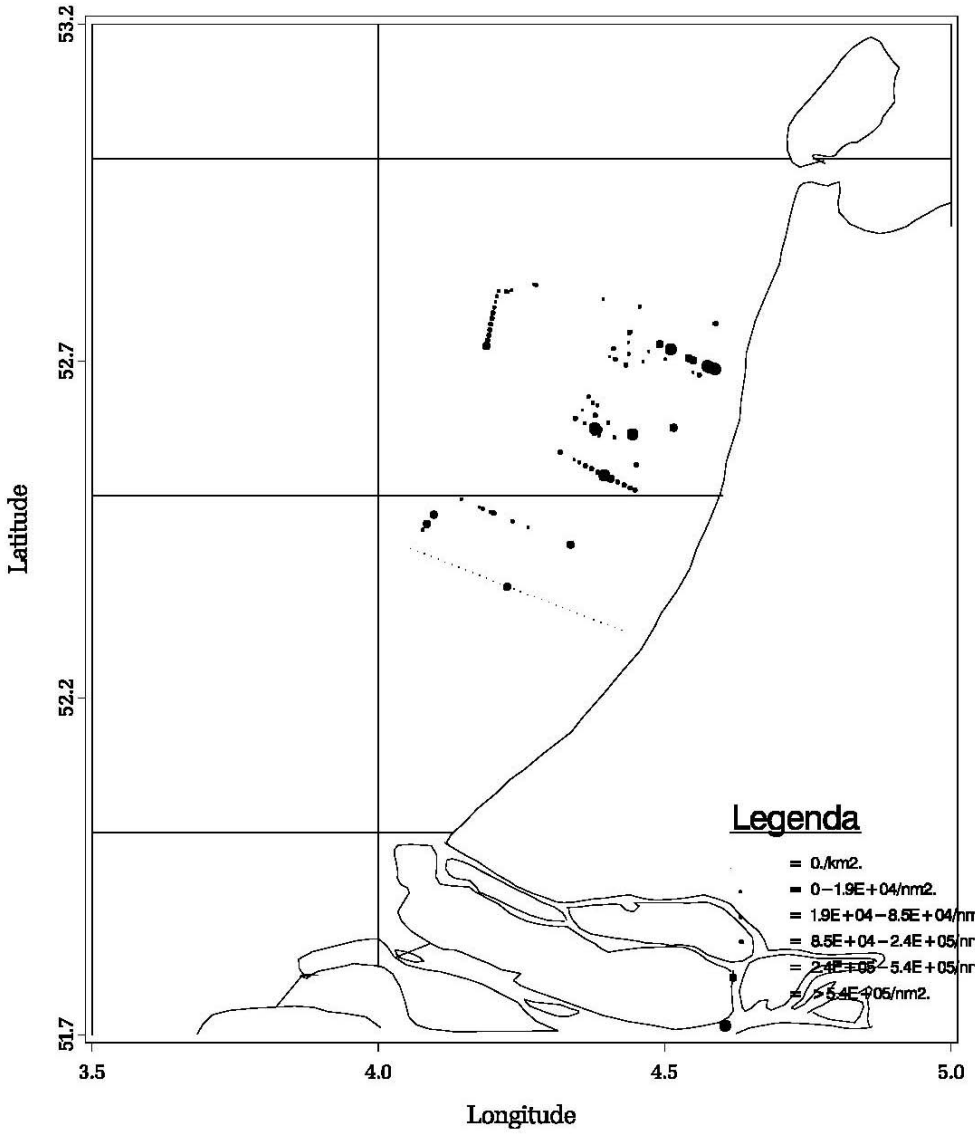

Figure XIII. *Spatial distribution of horse mackerel.*

Appendix VIII. Copies of the field forms used

Three types of field form used are included in this report:

1. Field forms on which information on the trawl hauls (position, time etc.) was recorded;

2. Field forms on which length frequency distributions were recorded;
   These forms were filled out aboard the trawler where length frequency distributions of all species were assessed. Also the total weight caught per species were filled out at the forms.

3. Field forms on which biological data were recorded;
   These forms were filled out at the lab where length, weight, sex and maturity were assessed and otoliths were collected.