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Combined Fish and Birds survey in the Dutch coastal zone

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Summary

Knowledge on the relationship between birds and fish is important when assessing the impact of infrastructural development on birds and fish in the coastal zone. It can have a direct effect on bird migration routes and resting areas. It can also have an indirect effect by changing the fish community and hence food availability for the bird community. RIKZ assigned Bureau Waardenburg a continuation of the prematurely terminated Flyland project in which the relationship between fish and birds should have been studied. This renewed project aims at describing the ecological relationships between marine birds and their food sources, mainly pelagic fish. The present report describes the results of a study on the relationship between fish and birds in the Dutch coastal zone. With this knowledge, impact of future infrastructural development on birds and their food (fish) can be better assessed.

For this report, one survey was executed in November 2003. Information from other surveys was used to get better insight in the pelagic fish community. The occurrence, density, spatial variation and size distribution of the pelagic fish fauna in this survey were assessed by means of echo integration and reference trawl hauls during acoustic surveys. Two frequencies were used to distinguish species better. The survey was carried out during daytime, apart from one transect. For the first time in RIVO acoustic surveys, information on school size and geographical position together with the vertical position of these schools in the water column were collected. Also nocturnal schooling behaviour was recorded for the first time at a single transect. Environmental conditions at sampling locations were measured using a CTD measuring device and a Secchi disk. The CTD device recorded its measuring depth, water temperature, conductivity and oxygen saturation at each trawl location. In addition to the CTD, transparency was measured with a Secchi-disk at all trawl stations.

In total, 17 species were caught. Herring and Sprat made out 98% of the total catch weight. Fish was detected almost throughout the entire study area with locally higher concentrations. Density of schooling fish was remarkable high at the beginning of the Frisian Front, an area with a relatively high silt concentration, 37 kilometres off shore. The majority of Sprat consisted of year class 1 in the near shore area. In the rest of the area, Sprat consisted of 1 and 2 year old specimens. In all areas, Herring occurred in two distinctive groups: many 1-year-old fish and a mixture of older, larger specimens. All Pilchards and Anchovy were newly hatched (0-group). During dusk, schools gradually dispersed and most of the fish were found in the lower water layers.

Absence of sandeels, Mackerel and Horse mackerel make birds rely on clupeid fish species as their main food items during winter. Since Herring and Sprat were certainly living very close together and may even have occurred in mixed schools, it is likely that their presence was caused by a common reason such as avoidance of predators or feeding on similar prey items. Aggregations related to spawning are unlikely in this time of the year. The presence of these small clupeids is likely to be explained by the increased transparency in an area with a comparatively high food supply. However since the prey concentration is not measured and no stomach contents were examined, this remains a subject for further research.

Acknowledgements

1. Introduction

Knowledge on the relationship between birds and fish is important when assessing the impact of infrastructural development on birds and fish in the coastal zone. A wind farm, for example, can have a direct effect on bird migration routes and resting areas. It can also have an indirect effect by changing the fish community and hence food availability for the bird community. Still, little information is available on the behaviour of (pelagic) prey fish, the structure and dynamics of these stocks and their availability as a food source for birds in the Dutch coastal area. The present report describes the results of a study on the relationships between fish and birds in the Dutch coastal zone. The approach that was chosen was to sample fish and birds simultaneously on board the same vessel. This was done during a single survey in November 2003. Fish were sampled with hydro acoustic equipment. Birds were counted by routine visual observation. Before this survey was conducted, the pelagic fish community in the coastal area was only sampled three times: during the Flyland study (June 2002) and during the baseline study for the near shore wind farm (April and September 2003). Both fish and birds were sampled simultaneously during two of these surveys (Flyland and Baseline September 2003; Grift et al. 2004).

The aim of the Flyland research was to predict the effects of an airport island in the Dutch coastal zone. Within this project, Bureau Waardenburg and the Netherlands Institute for Fisheries Research studied the ecological impact of this infrastructural development on pelagic fish and birds. One of the research issues was to examine the relationships between birds and fish in order to assess the effect of such an airport. This resulted in a combined birds and fish survey in 2002. Information collected within this survey, on species occurrence, species distributions and community structures was a valuable addition to other routine surveys and commercial market samplings from this area. Distribution of zooplankton, birds and fish were studied in a unique way by simultaneously sampling these groups in the coastal area. Premature termination of the Flyland project in February 2003 resulted in an unfinished combined bird and fish project. Results were, however, analysed and presented in the baseline study wind farms for pelagic fish (Grift et al. 2004).

However, RIKZ assigned Bureau Waardenburg a continuation of this project to assess the relationships between birds and fish. This renewed project aims at increasing knowledge of the ecological relationships between marine birds and their food sources, especially in order to explain bird/fish relationships in the Dutch Economic Exclusive Zone (EEZ). Relationships between spatial distributions, densities, behaviour, food availability and abiotic parameters will become clearer for different ecological groups.

The survey for this research was executed during the first two weeks of November 2003. Both pelagic fish and marine birds were sampled simultaneously. The Netherlands Institute for Fisheries Research was contracted by Bureau Waardenburg for this research. In addition to the survey from the Flyland project and this bird fish project, birds were counted during the October survey within the Near Shore Wind farm baseline study.

All together, information on birds and pelagic fish is available from 3 surveys executed in the Dutch Exclusive Economical Zone:
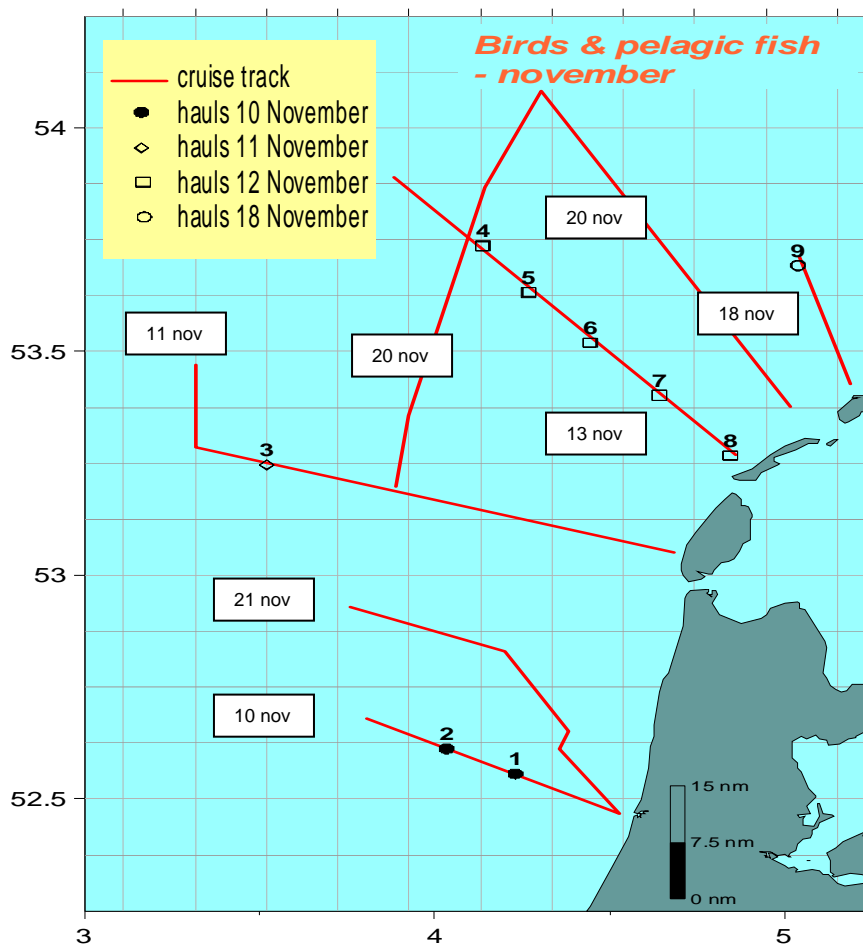
Period	Project	Sampled
June 2002	Flyland	Birds, fish, zooplankton, physical characteristics
September 2003	Baseline wind farm	Fish, birds, physical characteristics
November 2003	Bird – Fish	Fish, birds, physical characteristics

This report will describe the results of the November 2003 survey for pelagic fish and discusses the structure and behaviour of the pelagic fish community off the Dutch coast during winter months. Furthermore, it describes the availability of pelagic fish as food items for seabirds. The sampling details are described in Chapter 2 after which the results for pelagic fish are given in Chapter 3. In the discussion (Chapter 4), the results and sampling program are discussed.
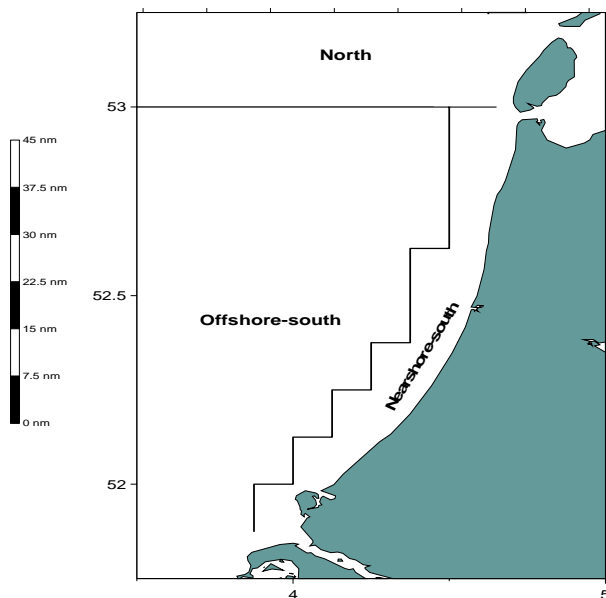
2. Set-up of the sampling program

2.1 Sampling strategy of the study

In November 2003, pelagic fish were sampled by the use of hydro acoustics. The transects layd perpendicular to the coast and were defined in advance for an optimal survey of bird distribution (Figure 2.1). The other coastal surveys from which data was used were executed more south (Annex III) and have a small overlap with the area covered in this study.

Figure 2.1. Executed transects of the acoustic survey in the Birds-Fish study in November 2003. Transects are red. Symbols indicate trawl stations. All tracks were sampled during daytime except on the 20th of November; this North-South transect was sampled during the night.

The coastal zone was divided in three areas: South offshore, South near shore and North (Fig. 2.2). The near shore area was defined as an area shallower than 20 meters and is generally situated in the coastal river (Fisher et al., 2002). We used a grid compatible with the ICES grid to define these areas. As a result the border between offshore and near shore is not smooth. During this survey the emphasis was put on a more northern part of the Dutch North Sea, but it also comprised a part of the coastal zone.

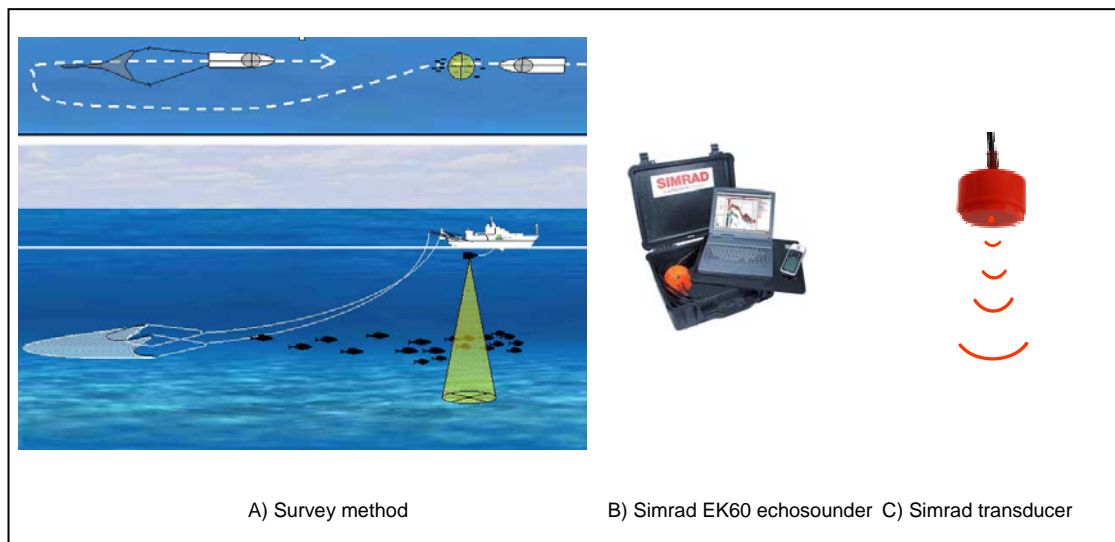**Figure 2.2.** Used areas within the data analysis.

2.2 Details of the acoustic survey

The occurrence, density, spatial variation and size distribution of the pelagic fish fauna in this survey were assessed by means of echo integration and reference trawl hauls during hydro-acoustic surveys. Hydro-acoustic surveys are an efficient tool in describing spatial distribution (both horizontally and vertically) and biomass estimates of pelagic fish over large areas. However, additional trawl hauls are required to validate the acoustic observations on fish density, distribution and species composition and to assess length frequency distributions. In this survey only length measurements were taken because information on sex, maturity, age and weight of the relevant species was collected in the month previous to this survey (Couperus et al. 2003). These data were used to translate lengths into ages. When an undefined school of fish is observed with the acoustic equipment, a trawl haul is made to investigate species composition and length distribution. The net is shot within 15 to 20 minutes after detection of the school. Hauls can therefore never be planned in advance and are not randomly spread. More detailed information can be found in Grift et al. (2004).

Acoustic equipment
Raw acoustic 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 side of the trawler (Fig. 2.3). Two frequencies were used to distinguish species better. To ensure a continuous vertical position of the acoustic beam, a heel and pitch sensor was connected to the towed body. The depth of the towed body was approximately 2.5 to 3 meter below the water surface. Data were logged per 0.3-second ping intervals with Simrad ER60 software.
The 38 kHz transducer has a view angle of 7º, which makes the detection range diameter 2 ½ meters at a depth of 20 meters (7tan*20m=2.5m). All animals with a different structure than water will appear on the screen. Even individual small fish can be detected close to the bottom.

A) Survey method   B) Simrad EK60 echosounder C) Simrad transducer

Figure 2.3. *Scheme of the sampling method for pelagic fish. When an undefined school of fish is detected on the echosounder (B), the vessel turns and shoots a pelagic trawl within 15 to 20 minutes. During this manoeuvre the transducer (C) will be used to track the school (Figure from Grift et al. 2004).*

Acoustic theory

The acoustic equipment transmits and receives acoustic signals that are reflected by objects in the water column such as fish, plankton and the seafloor. This detection method is called *Echolocation*. The strength of the reflection of the signal is a measure for the structure of the object and in fish: the size of the swim bladder. The time between the transmitted and incoming signal is a measure for the distance between the transducer and the fish. To identify species, assess length distributions and collect fish length data, a sample of the fish is taken with a pelagic trawl.

Calibration of equipment

For the November) survey we have used the calibration of the Baseline study executed in October 2003 (Appendix I). The hydrographical environment, which influences the calibration, is assumed to be similar in October and November. The 38 kHz split beam transducers was calibrated at the beginning of that sampling period. During the October survey the 200 kHz transducer was calibrated with poor results. Calibration of the 200 kHz transducer failed because one of the electrical cables proved to be partly broken. For this project we hired a 200kHz transducer from the manufacturer that was calibrated satisfactory in the basin of the Netherlands Institute for Fisheries Research. We only used the data from the 38 kHz transducer to estimate fish numbers and biomass because this transducer was employed successfully in other similar surveys. As a consequence, the 200 kHz transducer was additionally used to better distinguish species.

Survey characteristics

The survey was carried out during daytime, apart from one transect on 20 November (the transect in North-South direction (Fig. 2.1). By each haul, the total catch weight per species was measured and for each species, 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.

For this survey a vessel was chartered that used a specially designed trawl for small pelagic fish (Table 2.1).

Table. 2.1. *Characteristics of the half pelagic trawl used in this survey.*

Characteristic	Value	Unit
Upper rope	23.5	Meter
Bottom rope	29.7	Meter
Standing rope	19.4	Meter
Mesh width at cod end	6.0	Millimetre
Vertical net opening	5 - 8	Meter

Environmental conditions at sampling locations were measured using a CTD measuring device and a Secchi disk. The CTD device recorded its measuring depth, water temperature, conductivity, oxygen saturation and turbidity at each trawl location. In addition to the CTD, at all trawl stations transparency was measured with a Secchi-disk. Results of satellite observations were provided by the 'Vrije Universiteit Amsterdam' (Annex VI) and are not discussed in this report because it was beyond the scope of the research.

Intermezzo: Difference between turbidity and transparency

Solar radiation is the major source of light energy in an aquatic system, governing the primary productivity. **Transparency** is a characteristic of water that varies with the combined effect of colour and turbidity. It measures the light penetrating through the water body and is determined using Secchi disc.

Turbidity is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer. Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter; plankton and other microscopic organisms cause turbidity in water. Turbidity affects light scattering, absorption properties and aesthetic appearance in a water body. Increase in the intensity of scattered light results in higher values of turbidity.

2.4 Acoustic data processing

Raw acoustic data were transformed into estimates of numbers per fish species per km² following two basic steps: 1) assign acoustic signals to species or groups of species based on the appearance of signals on the screen (scrutinizing) and 2) derive densities from acoustic signals using relations on target strength (species specific reflection) and length information from trawl catches. More detailed information can be found in Grift et al. 2004.

2.4.1 Scrutinizing acoustic data

Acoustic data were displayed in so called 'echograms' and live-viewed along the cruise track using Sonardata 'Echoview' software. After the survey, in the lab, echograms were scrutinized with Echoview and with the Simrad BI500 post processing software. Scrutinizing is the translation of acoustic signals into densities per species. It is mostly based on species-specific acoustic characteristics shown in the echograms and this manual process requires many years of experience. Based on these species-specific characteristics, we assigned all observed pelagic species to the group of clupeids because we only observed four species that were also acoustically similar. Other groups were not distinguished, because no other pelagic species were observed.

Output of the scrutinizing process are acoustic signals called *NASC's* or Sa-value for each species or species group per square nautical mile. The data were then stored by 0.5 nautical miles intervals. So each 0.5 nautical mile we stored an acoustic density in numbers per square nautical mile.

Results on vertical distribution will not be presented or discussed in this report. Vertical distribution of pelagic fish is often influenced by the presence of the research vessel (Mismund and Aglen, 1992). Especially in shallow waters such as in the Dutch coastal zone, fish will dive to the bottom or try to avoid the vessel. This effect is not yet quantified in the coastal zone.

2.4.2 Analysing acoustic data

Densities per species were estimated by translating the scrutinized data with the SAS software package following three steps:

1. Assignment of strata;
2. Translate acoustic signals to density per species;
3. Split numbers per species into length class per species.

1. Assignment of strata

To account for spatial variation in length frequency distributions we assigned strata. Based on the patterns in length frequency distribution geographical strata were assigned according to the division in areas (Fig. 2.2). As explained, in paragraph 2.2, the information from the trawl catches is required to translate the acoustic signals into densities per species group and size class. Strata are areas in which (schools of) fish are assumed to have equal length distributions. Here, we pooled trawl data from each stratum to the acoustic data in that stratum (Fig. 2.1 and fig. 2.2). So all acoustic recordings in an area are related to the mean of trawl compositions in that area.

2. From acoustic signal to density

Acoustic signals per species group were translated into densities using the mean length of all the fish from this group. The length of a fish is directly related to the body shape and therefore to the amount of acoustic reflection of an individual fish. All fish from one group e.g. clupeids, have the same body shape and therefore they have the same acoustic reflection at a certain length. Acoustic signals have been translated by stratum.

When trawl information within a stratum was lacking, the mean length over all the hauls in the entire survey was taken instead. Subsequently, the total back-scattered acoustic area of a species group within the 0.5 nautical miles was divided by the acoustic area of one fish. In this way, total densities of fish were estimated.

3. Splitting numbers of fish into length classes.

Finally, total densities of fish from assigned groups of species were split up per length class according to mean length-frequency-distribution over all catches within a stratum.

3. Results

In this chapter, the occurrence, density along the cruise track and size distributions of the most common pelagic fish species in the northern part of the Dutch coastal area in November will be described (area 'north' in fig. 2.2). The emphasis will be on the description of the presence and behaviour patterns of Herring, Sprat, Anchovy and Pilchard during winter. The other pelagic species that were observed are of less importance to the project: because of their low densities they are considered not to be important food items for birds. Results of physical measurements and schooling behaviour will be presented and discussed in more detail in the final Bird-Fish report produced by Waardenburg.

First, spatial distribution patterns of Herring and Sprat will be described. Next, the size structure of these species will be described by presenting length-frequency distributions per species.

Length frequency distributions and spatial patterns used in the Baseline studies North Sea wind farms are included in Annex IV and Annex V. These results will not be discussed in this report.

Table 3.1. *Trawl list of the Fish-Bird survey in 2004.*

sample_id	haul	date	Time GMT	Position	Haul Duration (min)	Depth (m)	Wind direction (degrees)	Wind force (m/sec)	Decimal latitude	Decimal longitude
5000084	1	10/11/2003	12:23	52 33N 04 13E	26	19	158	2	52.5565	4.230
5000085	2	10/11/2003	14:25	52 36N 04 02E	14	23	45	2	52.6123	4.034
5000086	3	11/11/2003	13:11	53 14N 03 31E	22	27	135	4	53.2475	3.520
5000087	4	12/11/2003	06:59	53 44N 04 08E	22	39	158	9	53.7356	4.137
5000088	5	12/11/2003	08:30	53 37N 04 16E	20	36	158	9	53.6331	4.270
5000089	6	12/11/2003	10:09	53 31N 04 26E	22	26	158	9	53.5198	4.443
5000090	7	12/11/2003	11:56	53 24N 04 38E	13	27	158	9	53.4021	4.642
5000091	8	12/11/2003	13:43	53 16N 04 50E	23	15	158	9	53.2676	4.846
5000092	9	18/11/2003	14:57	53 41N 05 02E	17	31	248	7	53.6921	5.039

In total, 9 hauls were made (Table 3.1). Strong winds made it impossible to trawl more frequently. On the 12th of November, the wind was too strong to operate the acoustic equipment and it was decided to survey this transect merely by trawling. Since the species composition from the trawl hauls on that day consisted mainly of Herring and Sprat, we decided to survey this transect back the next day using the echo sounder. We assumed that the pelagic fish assemblage in this transect had remained the same because hauls on the previous day and other hauls on 11 November and 8 November in 'Offshore south' had yielded comparable species compositions.

In total 17 fish species of fish were caught (Table 3.2). Herring and Sprat made out 98% of the total catch weight.

Table 3.2. *Total catch (numbers in trawl catches) of all species in the Fish-Bird survey in 2003)[1].*

English name	Haul number									
	1	2	3	4	5	6	7	8	9	**total**
Herring	10333	3	2076	248	1950	4000	1764	3500	1830	**25704**
Sprat	26666	1472	2048	608	7400	51840	1862	3280	16384	**111560**
Anchovy		1	416		50				4	**471**
Cod									1	**1**
Dab			2	6	2	2	1	2	1	**16**
Greater sand-eel							16			**16**
Grey gurnard			1							**1**
Horse mackerel		37	11						1	**49**
Lesser weever	2	21	4					1		**28**
Mackerel	8									**8**
Nilsson's pipefish								180		**180**
Pilchard	205	1024								**1229**
Raitt's sand-eel		3						40		**43**
Sea lamprey								1	1	**2**
Striped red mullet			1		1	3	1			**6**
Turbot				1						**1**
Whiting	23		3	208	20	2	1	5	16	**278**
Total	**37253**	**2961**	**4578**	**1071**	**9423**	**55847**	**3645**	**7009**	**18238**	**140025**

3.1 Spatial patterns of most abundant species

In general, the pelagic fish community was completely dominated by Herring and Sprat (Table 3.2). According to the trawl information, Anchovy was distributed more southerly while Pilchard was distributed more northerly but no distinction could be made among the clupeid species and Anchovy from the acoustic data. Therefore all fish echoes were assigned to the group of fish which includes Herring, Sprat, Anchovy and Pilchard.

Fish were detected almost throughout the entire study area with locally higher concentrations (Fig. 3.1). The most notable concentration was observed in an area approximately 30-40 km northwest off the Frisian coast on 18 and 20 November. This area is known as the Frisian Front and is defined as an area with a relatively high silt concentration (higher than 20%) (de Gee et al. 1991). During the survey, the observation of an increase of fish on the echo sounder was accompanied by observations of an increase in the abundance of birds and a decrease in turbidity. These results will be presented and discussed in the Birds-Fish report of Waardenburg.

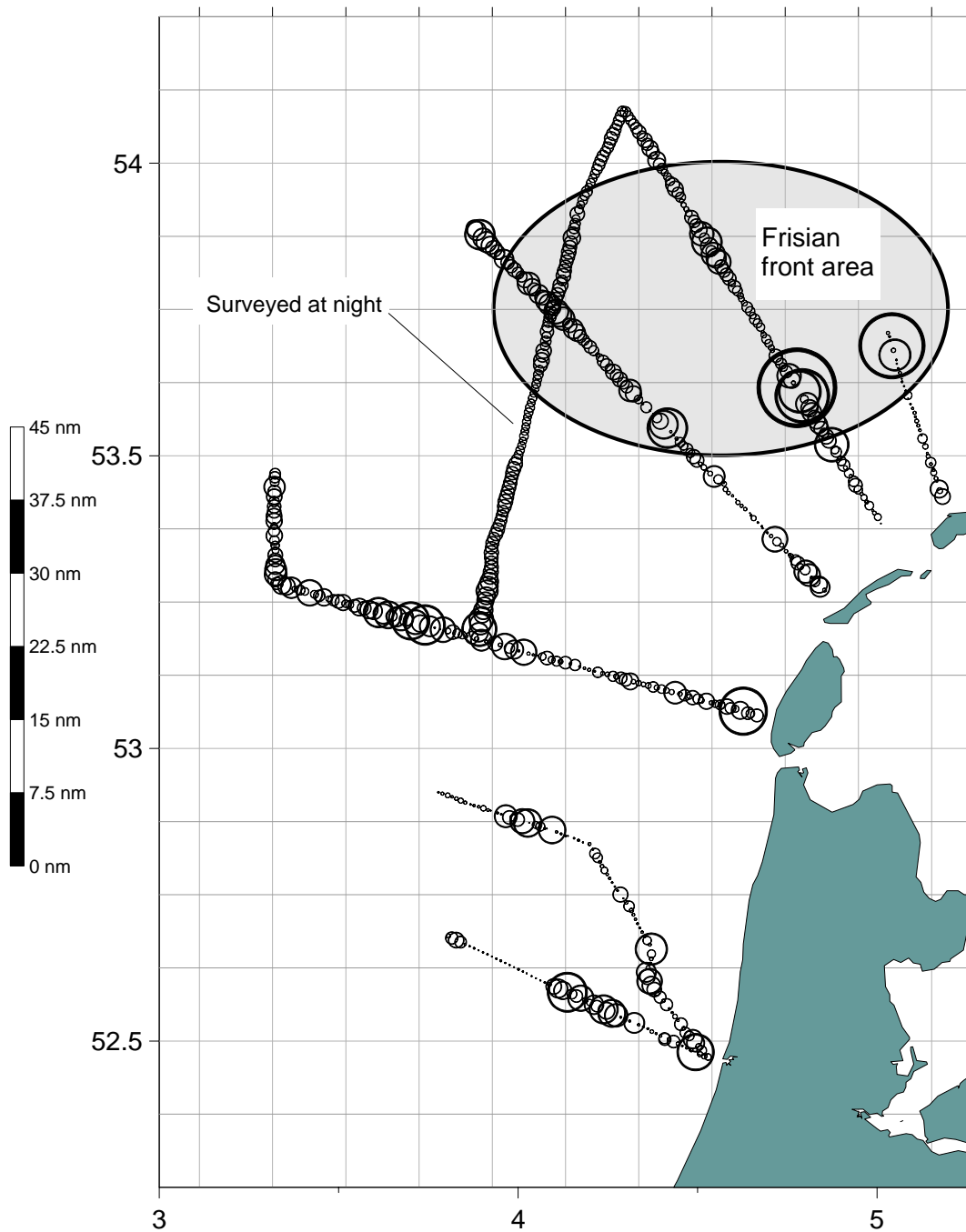[1] Numbers are not corrected for fishing effort and can thereforee not be compared directly.
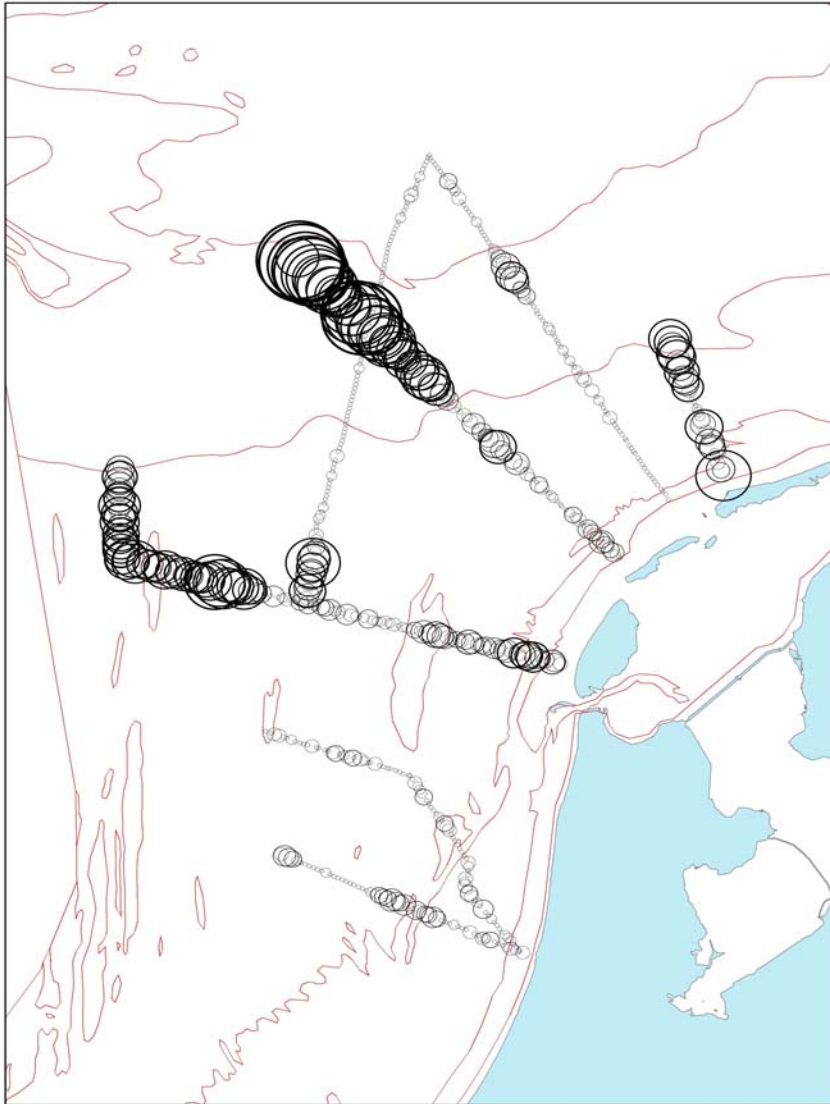
Figure 3.1A. Distributions of Anchovy and three clupeid species in the Fish-Bird survey, GO58, November 2003. The north/south transect was experimentally sampled acoustically during night and is not comparable with the other transects . Bubble size is related to a proportional square root scale relative to the largest value 21.6*10E6 kg/km². The Frisian Front is indicated as the grey area. An exact location on the Friesian Front is given in de Gee et al. 1991.

Figure 3.1B. *Distributions of schools of Anchovy and three clupeid species in the Fish-Bird survey, GO58, November 2003. The north/south transect was experimentally sampled acoustically during night and is not comparable with the other transects . Bubble size is related to a proportional square root scale relative to the largest value 73 schools of fish per half nautical mile.*

3.2 Size distributions of most abundant species

The majority of Sprat consisted of year class 1 in the near shore area. In the rest of the area Sprat consisted of 1 and 2 year old specimens (Fig. 3.2). In all areas Herring occurred in two distinctive groups: many 1-year-old fish and a mixture of older, larger specimens. All Pilchards and Anchovy were newly hatched (0-group).

Only 2 hauls were made in the southern part of the research area. Therefore results are not comparable between sub areas (Fig. 3.2). However, since fish was less schooling in the southern area, trawl catches here were assumed to reflect the overall length frequency distribution.
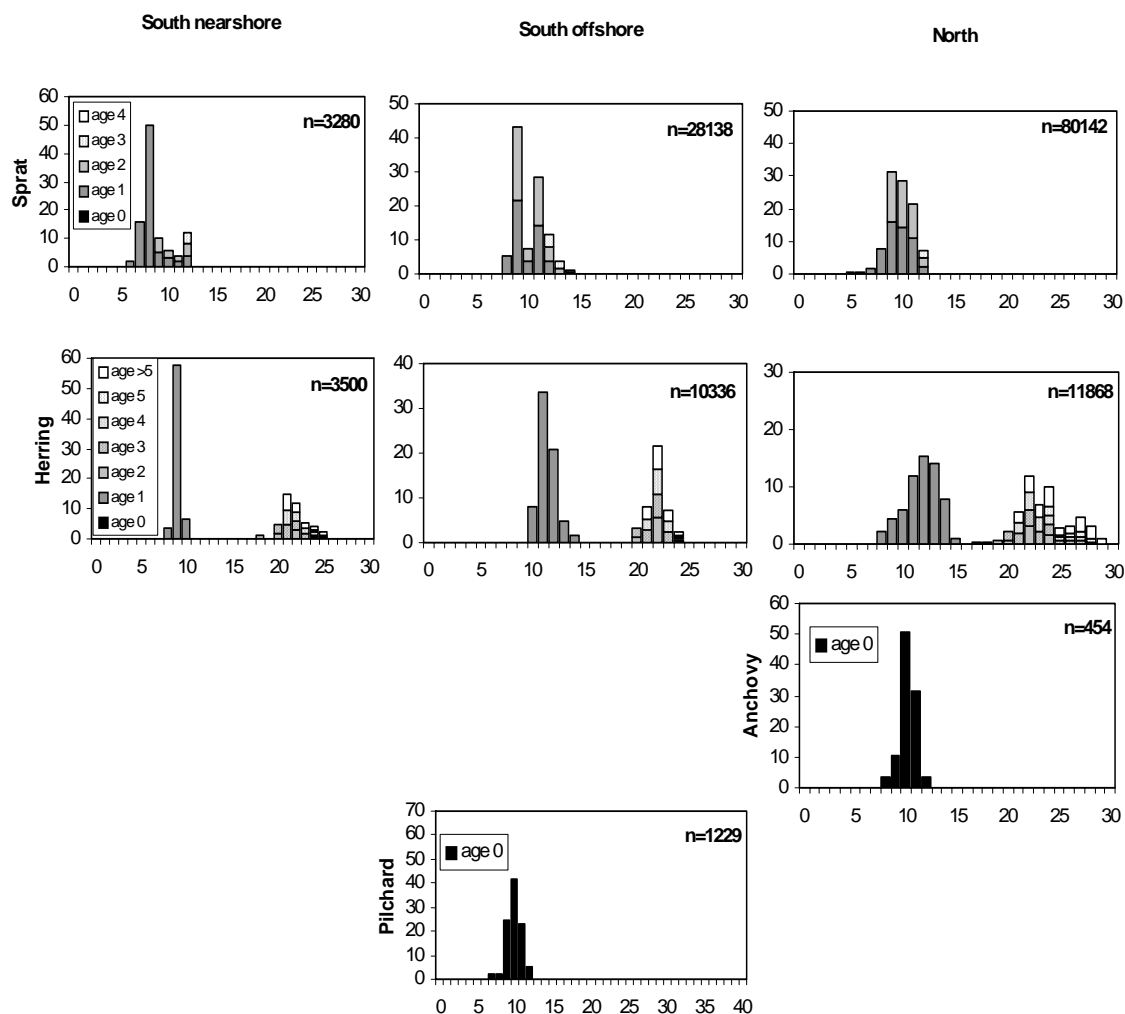

Figure 3.2. Length frequency distributions (in cm) of Anchovy and three clupeid species per age group in the Fish-Bird survey, GO58, November 2003. Length-age relations from Grift et al. 2004.

3.3 Experimental nocturnal transect

Nocturnal schooling behaviour was recorded during the night of 20 November while sailing from one planned transect in the north to another in the south. This north south transect was sailed without trawling. During dusk schools gradually dispersed (Photo1) and most of the fish was found in the lower water layers.
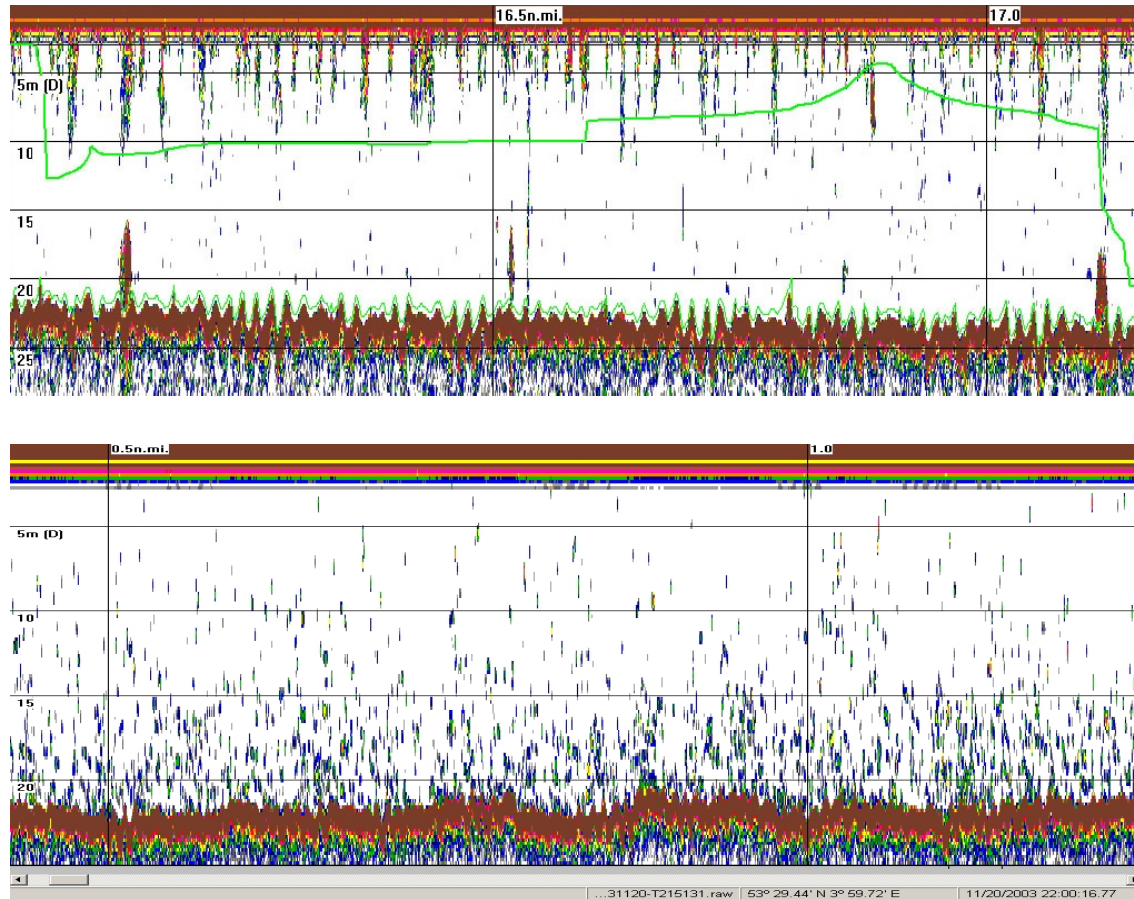

Photo 1. Typical echogram of pelagic fish in the coastal zone during day (13.00h upper photo) and during night (21.00h lower photo). *Schools are clearly visible at the day photo as elongated aggregations. The spikes at the surface in the upper photo(above the green line) indicate air turbulence and have been excluded from analysis. GO58, November 2003.*

3.4 Physical parameters

The turbidity sensor did not work properly and therefore results are not presented here.

In general transparency, pH, salinity and temperature increased in offshore direction and stabilised at a distance of about 40 kilometres offshore. Transparency increased towards a maximum 20 km offshore, after which it decreased again towards a minimum 40 km offshore, indicating the presence of a different water package.

Density of schooling fish was remarkable high at the beginning of the Frisian Front, 37 kilometres off shore (Fig. 3.1). Figure 3.3 shows all environmental parameters along the cruise track on the 20th of November during daytime. This typical pattern was seen also at 13 and 18 November.
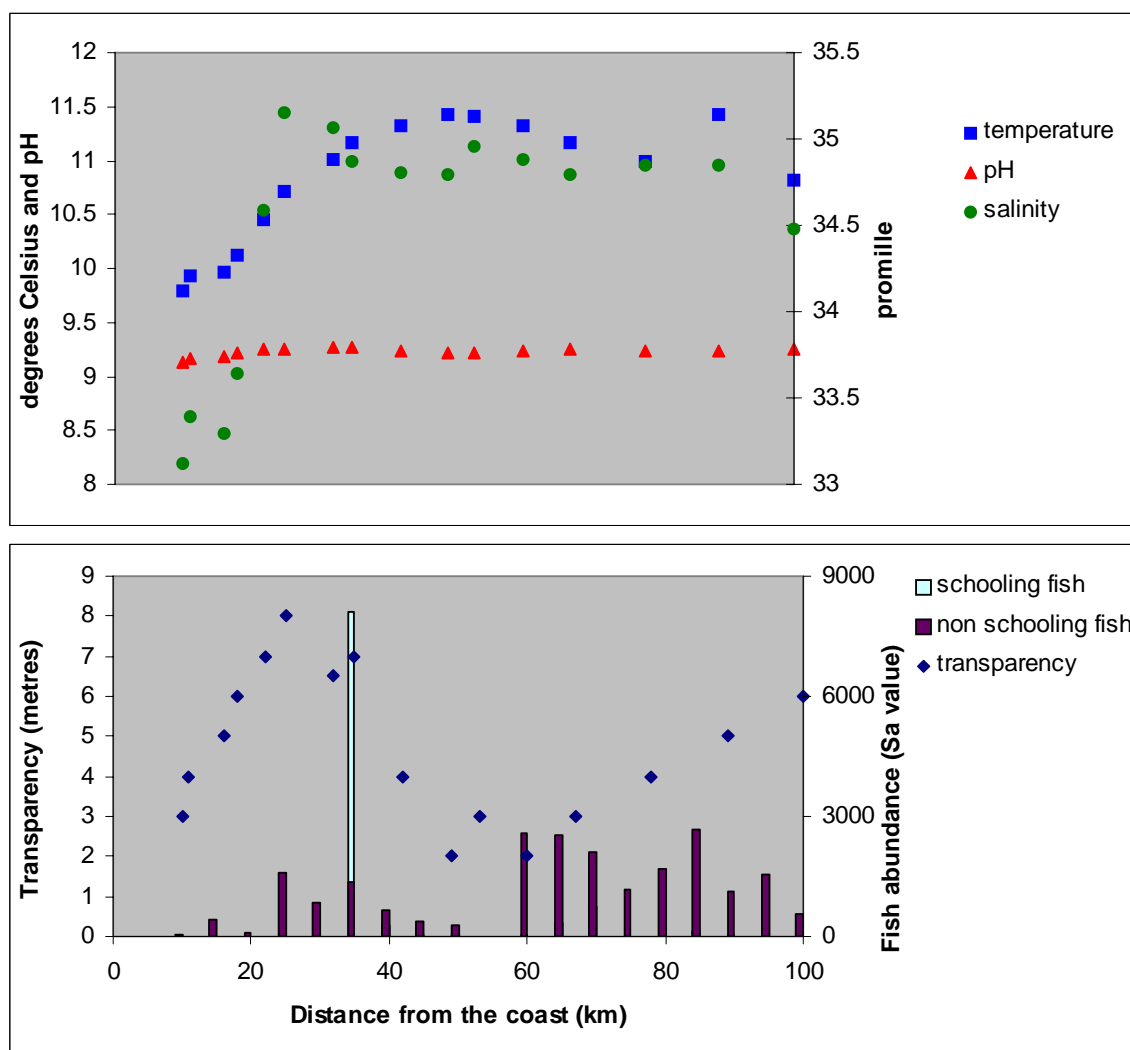

Figure 3.3. Typical physical gradients along a transect from nearshore to a distance of 100 kilometres offshore. Fish densities are presented as their total acoustic reflection value (Sa value). GO58, November 2003.

4. Discussion

This survey belongs to the very few in which fish and bird behaviour studies in the Dutch coastal zone were combined. Information on schooling patterns of pelagic fish was never collected before in this area. This chapter will discuss the occurrence and densities of pelagic fish during winter months in the northern Dutch coastal area and will translate this to the availability of fish as a food item for birds.

4.1 The situation of the pelagic fish community during winter months.

Juvenile Herring and mature Sprat dominate the pelagic fish community in the northern coastal zone of the Netherlands, in November. Sandeels were not encountered during this survey, but were dominating in spring and early summer but not in October (in particular *Ammodytes marinus* and to a lesser extent *A. tobianus* and *Hyperoplus lanceolatus*)(Grift et al., 2004). This is not surprising, as sandeels spend the winter buried in the sand (Macer, 1966; Winslade 1974) and are thus not a part of the pelagic fish community and cannot be detected by acoustic surveys. Mackerel and Horse mackerel are known to migrate out of the North Sea during winter. As a consequence, diving birds rely on clupeid fish species as their main food item (Blake, 1984).

The Dutch coast, together with the German bight, is known as a nursery areas for pelagic fish such as clupeids. The Dutch coast provides shelter and food in spring and summer for larvae hatched in the Channel in winter. These larvae origin from Herring that have spawned in the Channel in December (Down's Herring). The larvae arrive approximately in February and metamorphose in spring. The small Herrings grow up during the summer in the warm, turbid and nutrient rich near shore waters. In autumn they leave the coastal water and migrate in deeper water, mainly in western direction. Two years later they take part in the spawning process, either in the Channel or in one of the spawning area's in the western central and the northern North Sea.

The near shore acoustic surveys conducted by Grift et al. (2004) off the Dutch coast in April, June and October and the survey dealt with here, give information of the whereabouts of small clupeids on a small scale. The distribution of Herring and Sprat in November is less concentrated at the coast and is therefore more comparable with the Baseline survey conducted in March than with the survey conducted in June and October when small clupeids were distributed very close to shore, probably largely outside of the detection range of the echo sounder but accidentally trawled on (Grift et al., 2004). However, the areas of these surveys were situated more to the south and are only partly overlapping with the survey dealt with here.

Interestingly, the highest concentrations of clupeids were found in a biologically enriched zone, known as the *Frisian Front* (de Gee et al. 1991). In this area, the tidal current velocity drops below a critical value, enabling fine-grained material to settle from the water column (Creutzberg et al., 1984), while favourable conditions generate a vigorous spring phytoplankton bloom and a stronger primary production in summer, resulting in an enriched benthos and hyperbenthos fauna at the end of the summer (Baars et al., 1991; Dewicke et al., 2002). In this area, during summer, schools of Sprat had been detected by Sprong et al. (1990) that were probably feeding on copepods. While birds, in particular Guillemots, are feeding on the Sprat (Baars et al., 1991). In winter this effect of local enrichment is absent, partly because water masses are mixed due to the impact of gales. Last (1987) found that Sprat stopped feeding in the period of December-February, in November feeding started to cease, while young Herring continues to feed during winter. Since Herring and Sprat were certainly living very close together in this survey and may even have occurred in mixed schools, it is likely that

their presence was caused by a common reason. One may speculate that both the influence of the summer enrichment is still valid and both Herring and Sprat were schooling in the area for feeding.

The appearance in schools in itself may also be caused by predation by birds, although the highest bird densities may not necessarily be found in the direct vicinity of the fish concentrations due to intra specific competition and disturbance of the fish by their predators (Camphuysen in prep.). De Gee discusses the possibility of schools of Sprat to disappear during winter, but the present survey seems to indicate that, also in late autumn, the Frisian Front is also an area where concentrations of small pelagic fish are comparatively high.

Spawning aggregations of Sprat are considered unlikely in November. Although most specimens of this species were mature, Van der Land (1990) found a spawning period for Sprat in the southern North Sea from February till July.

The presence of 0-group Anchovy and Pilchard during this survey period is in line with the findings of Grift et al. (2004), who found adults of these species predominating in April and June, followed by a 0-group in October. The occurrence of Anchovy and Pilchard is surprising because both were only observed occasionally in previous sampling programmes. Pilchard is known to migrate from the Channel into the North Sea in summer (Knijn et al., 1993), but the occurrence of newly hatched Pilchards in autumn has not been described before. Anchovy, another southern species, is known to occur along the Dutch coast. This species used to spawn in the former Zuiderzee and still small numbers are known to spawn in the eastern Oosterschelde. However, Anchovy was observed only in very small numbers in the IBTS catches in the 1980s (Knijn et al., 1993). The occurrence of Anchovy and Pilchard are also in accordance with the observed trend of more southern species in the North Sea (i.e. Red Mullet and the cephalopod Sepia officinalis: data RIVO database). In addition, the year 2003 was an exceptionally warm year. The metamorphosed Pilchard, caught during this survey and in October by Grift et al. (2004) may origin from larvae hatched in the Channel and carried to the Dutch coast by the current. One may speculate that normally these larvae do not survive at the comparatively low temperatures along the Dutch coast, but metamorphosed in 2003 because of the warm coastal water. It is not likely that the presence of these two southern species has a direct impact on the abundance and distribution of seabird. However it may be an indication for long-term shifts in the North Sea fauna, which are not easy to study.

4.2 Feeding habits of pelagic fish during winter in relation to their occurrence

Whether the increased concentration of Herring and Sprat 30 to 40 km off the Frisian coast is caused by a preference of clupeids for one of - or a combination - of environmental features is not easy to answer. Fish concentrations in this area fell together with a remarkable dip in the transparency and a change in salinity and temperature regime. Dewicke et al. (2002) reported high concentrations of copepods and mysids at the end of the summer at the Frisian Front. These groups are known to be important preys for young Herring and Sprat (Last, 1987). Turbidity is an important environmental factor for the distribution of young fish, in particular clupeids, as pointed out by Blaber and Blaber (1980) and Cyrus and Blaber (1992). A high turbidity provides protection from visual predators and is often connected with a comparatively high food supply of small prey items such as juvenile fish. The effects of turbidity on abundance of several fish species were negligible at high turbidity levels in the Humber area (approximately 80 NTU; Marshall and Elliot, 1998), but seem to be an important factor at lower turbidity (0-15 NTU; Blaber and Blaber, 1980).

Herring and Sprat are known to use different methods for feeding. Normally they use their eyes to hunt for preys and will bite for individual prey, but if food concentrations are very high they will switch to filter feeding (Gibson and Ezzi, 1990). In the dark they will switch to filter feeding (Batty et al., 1990). However, the removal rate at light when biting at individual preys is much higher and it is assumed that if nighttime filter feeding takes place, it will only be of importance when exploiting dense patches of food (Batty et al., 1986). Gibson and Ezzi (1992) found that at the same capture rates in both feeding methods, less than 50% of the Herring were filter feeding, which suggest that filtering is more costly than biting. They estimated that the energy cost of filter feeding might be 1.4 to 4.6 times higher than that of biting. Even at high concentrations of particles they will succeed in filter feeding (Cyrus and Blaber, 1987).

Since visibility includes turbidity, and turbidity has not been measured during this survey, only indicative conclusions can be drawn from the visibility measurements in relation to turbidity. Assuming that the turbidity ranges in the North Sea are much lower than in the Humber area, which is known as one of the most turbid area's along the North Sea coast, maximum turbidity or transparency ranges as seen during this survey will not have an negative effect on filter feeding. Levels of turbidity found to have a physiological effect on fish are reported to be 14 g/l, while Marshall and Elliot (1998) found a maximum concentration of 5 g/l. No plankton samples were taken during this survey, but we suspect that Herring and Sprat will not use filter feeding in clear water like we have seen at the Frisian Front. Likely the presence of these small clupeids is explained by the increased transparency in an area with a comparatively high food supply.

However since the prey concentration is not measured and no stomach contents were examined, this remains a subject for further research.

4.3 Schooling behaviour of pelagic fish during winter.

Information on spatial schooling patterns, diurnal vertical distribution and school size was gathered within this project but analyses of this data were not a part of the initial research question. Nevertheless, primarily analysis indicates a different behaviour of schooling fish in the area of the Frisian Front. Diurnal migrations were clearly visible although the influence of the approaching ship is unclear. In 1991, De Gee describes similar behaviour of pelagic fish in the area of the Frisian Front and also found adult Sprat and juvenile Herring to be the species causing the echoes. It was the first time data on the schooling behaviour of pelagic fish in the Dutch coastal zone were collected. Although a more thorough analysis was beyond the scope of this research, we think the data collected in this survey are very suitable for future analysis of the ecology of pelagic fish.

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Annex I. Calibration settings of Simrad EK60

```
#  Calibration  Version   1.0.0.9
#  Date:  9/30/2003
#  Comments:
#  Baseline 2003 oktober offshore put
#
#  Reference Target:
#    TS                    -33.60 dB       Min. Distance       10.00 m
#    TS Deviation          8.0 dB       Max. Distance       15.00 m
#
#  Transducer:  ES38B  Serial No.   28887
#    Frequency           38000 Hz        Beamtype                        Split
#    Gain                      26.50 dB       Two Way Beam Angle    -20.6 dB
#    Athw. Angle Sens.         21.90                     Along. Angle Sens.      21.90
#    Athw. Beam Angle   7.10 deg      Along. Beam Angle        7.10 deg
#    Athw. Offset Angle  0.00 deg      Along. Offset Angle            0.00 deg
#    SaCorrection          0.00 dB       Depth                        0.00  m
#
#  Transceiver:  GPT  38 kHz 009072017a3b 1 ES38B
#    Pulse Duration   1.024 ms      Sample Interval     0.194   m
#    Power                 2000  W        Receiver Bandwidth   2.43 kHz
#
#  Sounder Type:
#    EK60 Version   ComSounder
#
#  TS Detection:
#    Min. Value          -50.0 dB
#    Max. Beam Comp.      6.0 dB       Min. Echolength        80 %
#    Max. Phase Dev.        8.0      Max. Echolength       180 %
#
#  Environment:
#    Absorption Coeff.   7.9 dB/km      Sound Velocity     1515.0 m/s
#
#  Beam Model results:
#    Transducer Gain      = 25.14 dB       SaCorrection            = -0.62 dB
#    Athw. Beam Angle    = 6.84 deg      Along. Beam Angle        = 6.90 deg
#    Athw. Offset Angle   =-0.00 deg      Along. Offset Angle        =-0.05 deg
#
#  Data deviation from beam model:
#    RMS =    0.20 dB
#    Max =    0.70 dB  No. =   115          Athw. =  2.9 deg  Along =  3.7 deg
#    Min =   -0.52 dB  No. =   80 Athw. =  -1.3 deg  Along =  4.6 deg


#  Data deviation from polynomial model:
#    RMS =    0.09 dB
#    Max =    0.30 dB  No. =   99          Athw. = -3.2 deg  Along =  2.2 deg
#    Min =   -0.31 dB  No. =   40          Athw. = -3.6 deg  Along =  0.1 deg#
```
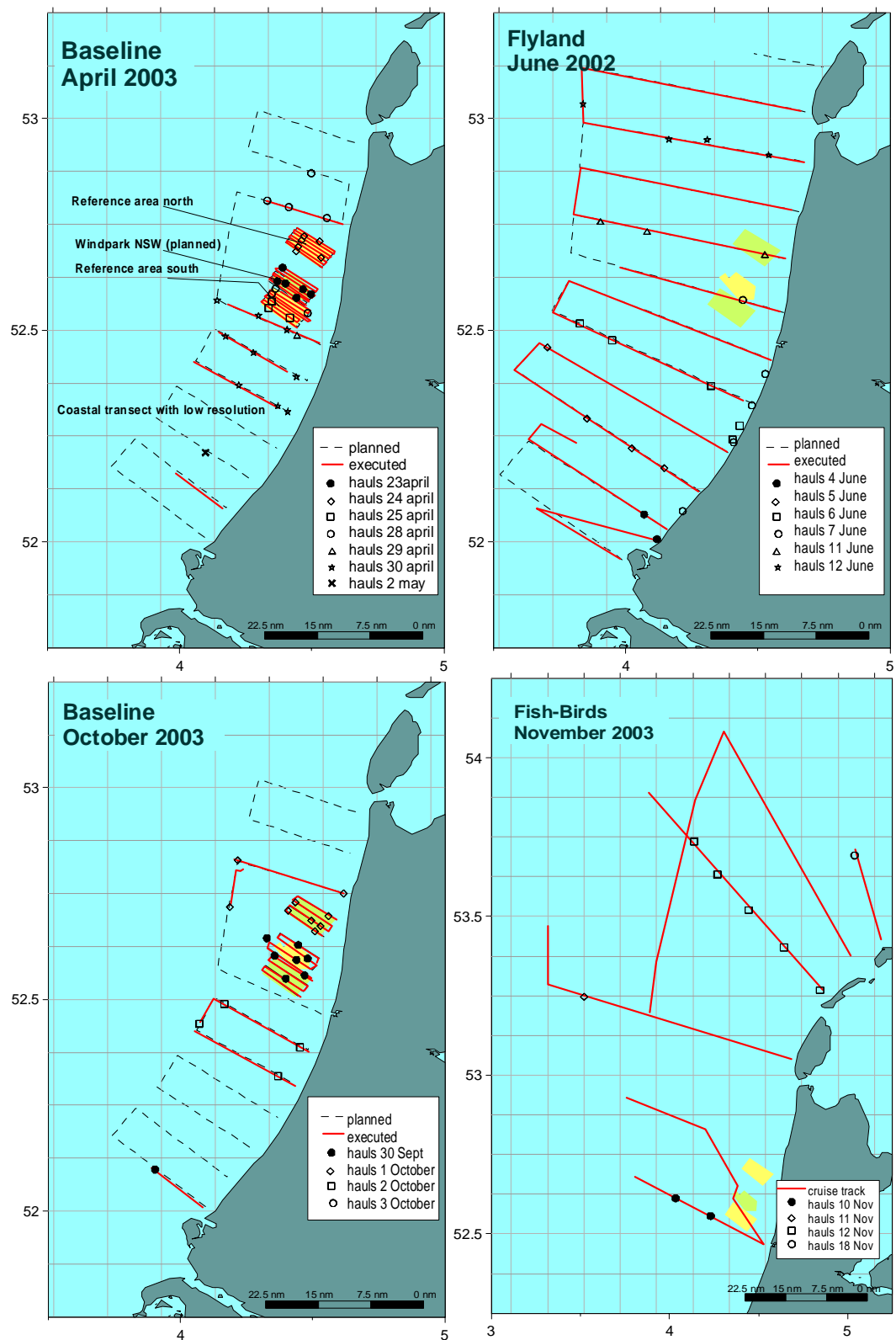
Annex II. Species names

Table I.1. English, Dutch and scientific names of fish species.
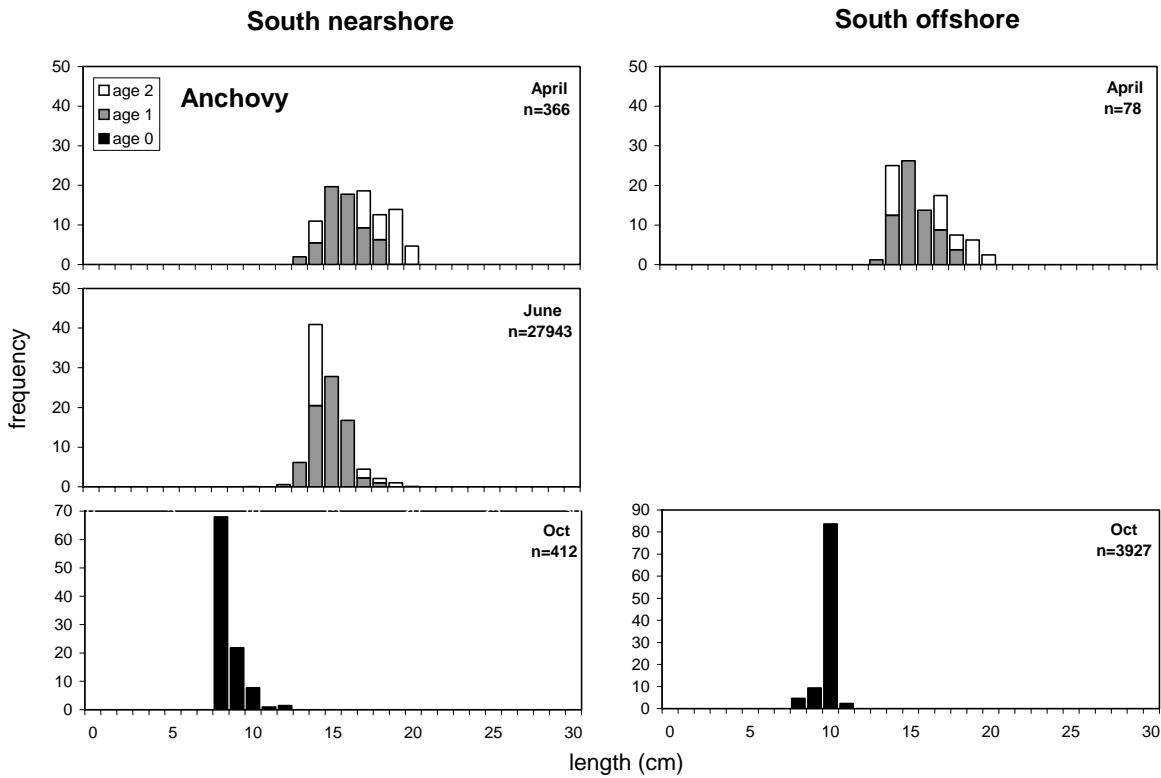
Name	Dutch name	Species	Family
Anchovy	Ansjovis	Engraulis encrasicolus	Engraulidae
Cod	Kabeljauw	*Gadus morhua*	Gadidae
Dab	Schar	*Limanda limanda*	Pleuronectidae
Greater Sandeel	Smelt	*Hyperoplus lanceolatus*	Ammodytidae
Hagfish	Slijmprik		
Grey Gurnard	Grauwe poon	*Eutrigla gurnardus*	Triglidae
Herring	Haring	*Clupea harengus*	Clupeidae
Horse mackerel	Horsmakreel	*Trachurus trachurus*	Carangidae
Lesser Weever	Kleine pieterman	*Echiichthys vipera*	Trachinidae
Mackerel	Makreel	*Scomber scombrus*	Scombridae
Nilssons Pipefish	Zeenaald		
Pilchard	Pelser	*Sardina Pilchardus*	Clupeidae
Raitt's Sandeel	Noorse zandspiering	*Ammodytes marinus*	Ammodytidae
Sprat	Sprot	*Sprattus Sprattus*	Clupeidae
Striped Red Mullet	Mul		
Turbot	Tarbot		
Whiting	Wijting	*Merlangius merlangus*	Gadidae

Annex III. Planned and executed transects during the coastal surveys in 2002 and 2003

Figures from Grift et al. (2004).

Annex IV. Length frequency distributions of pelagic fish species from the Baseline wind farm project
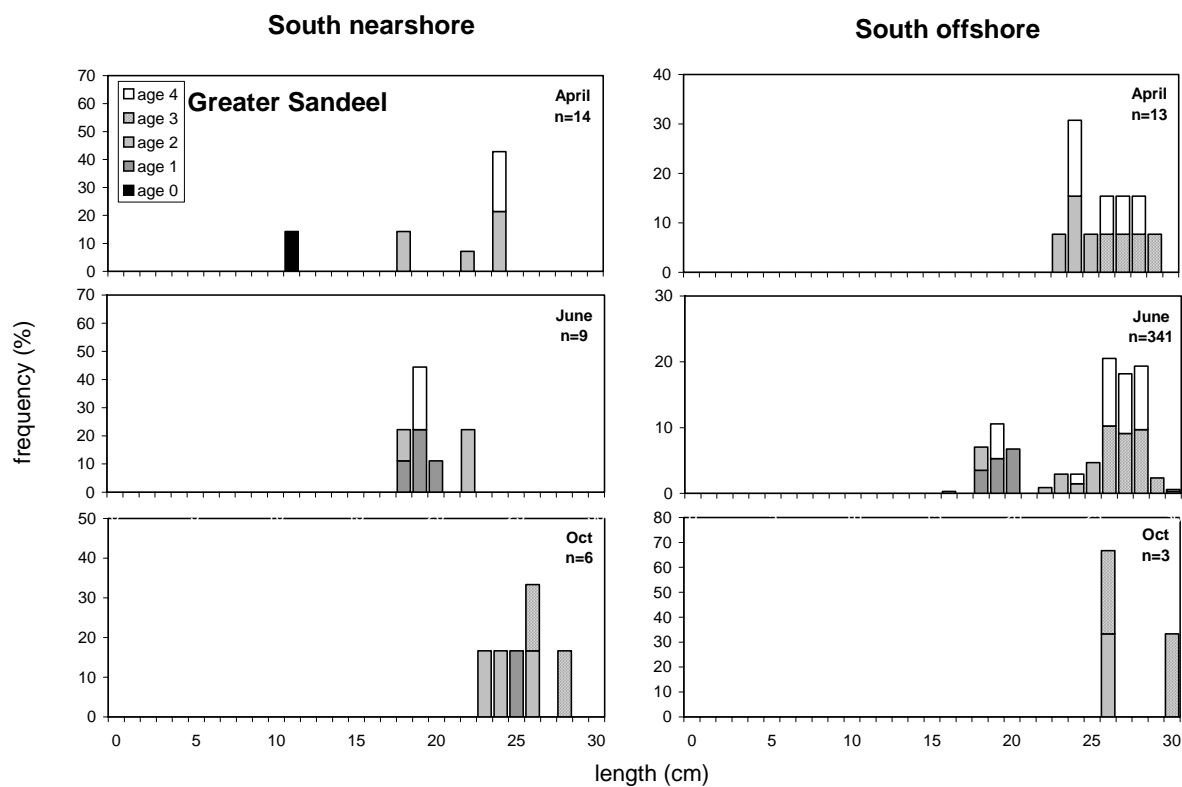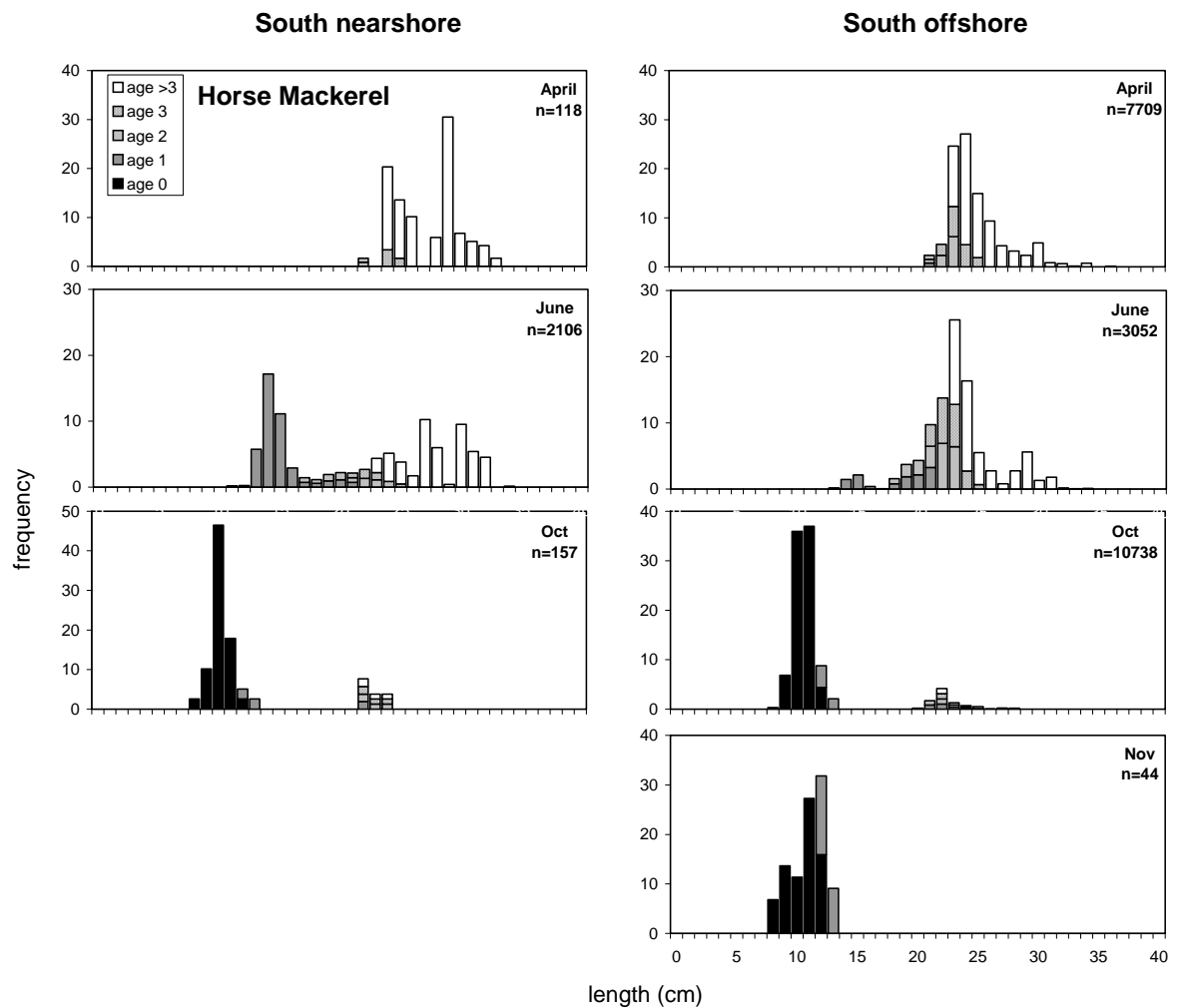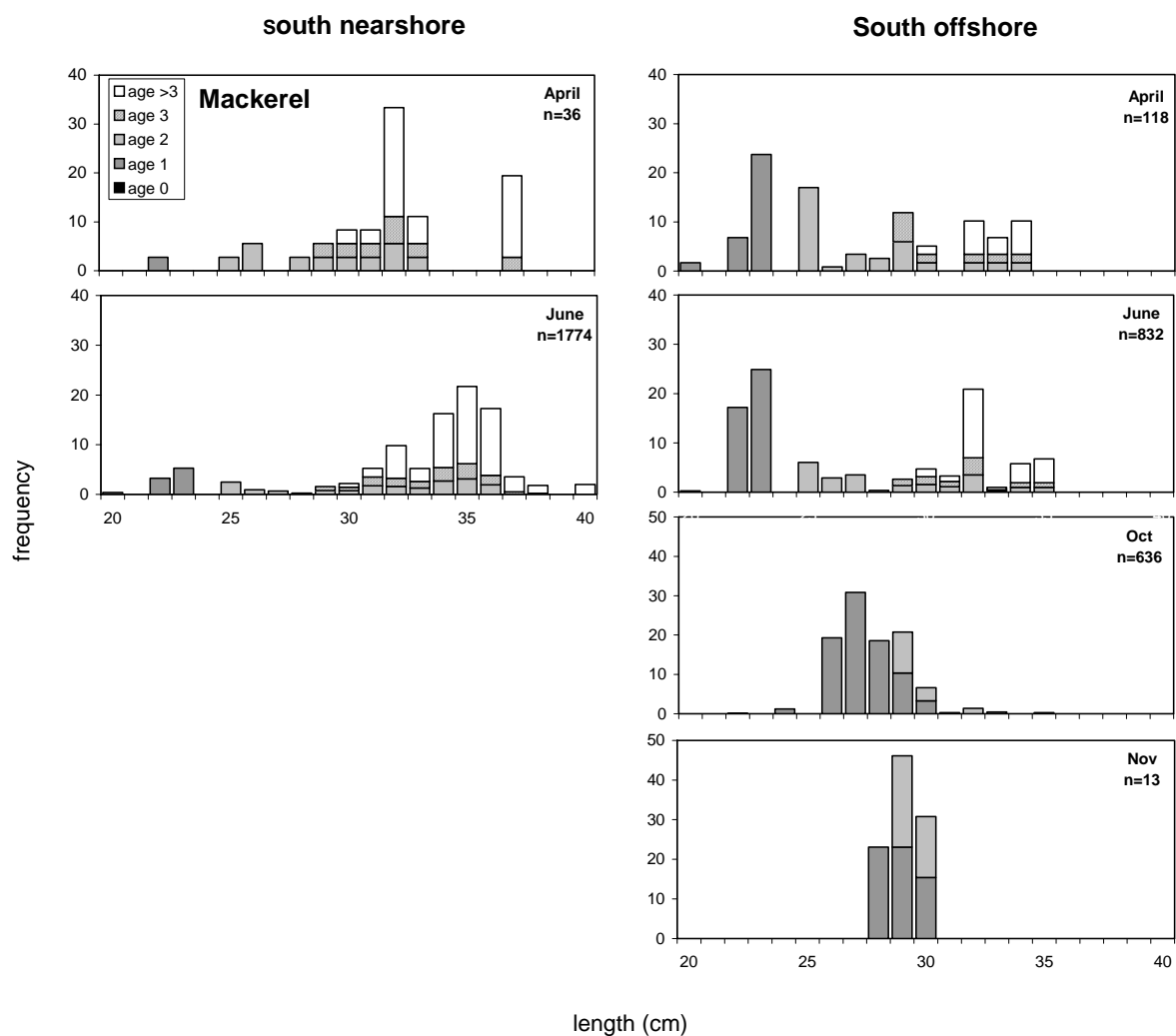

Figure IV.1. *LF distributions of Anchovy per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Anchovy was not caught in November during the Fish-bird survey. Figures from Grift et al. (2004).*

Figure IV.2. *LF distributions of Pilchard per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Anchovy was not caught in November during the Fish-bird survey. Figures from Grift et al. (2004).*

Figure IV.3. *LF distributions of Herring per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Figures from Grift et al. (2004).*
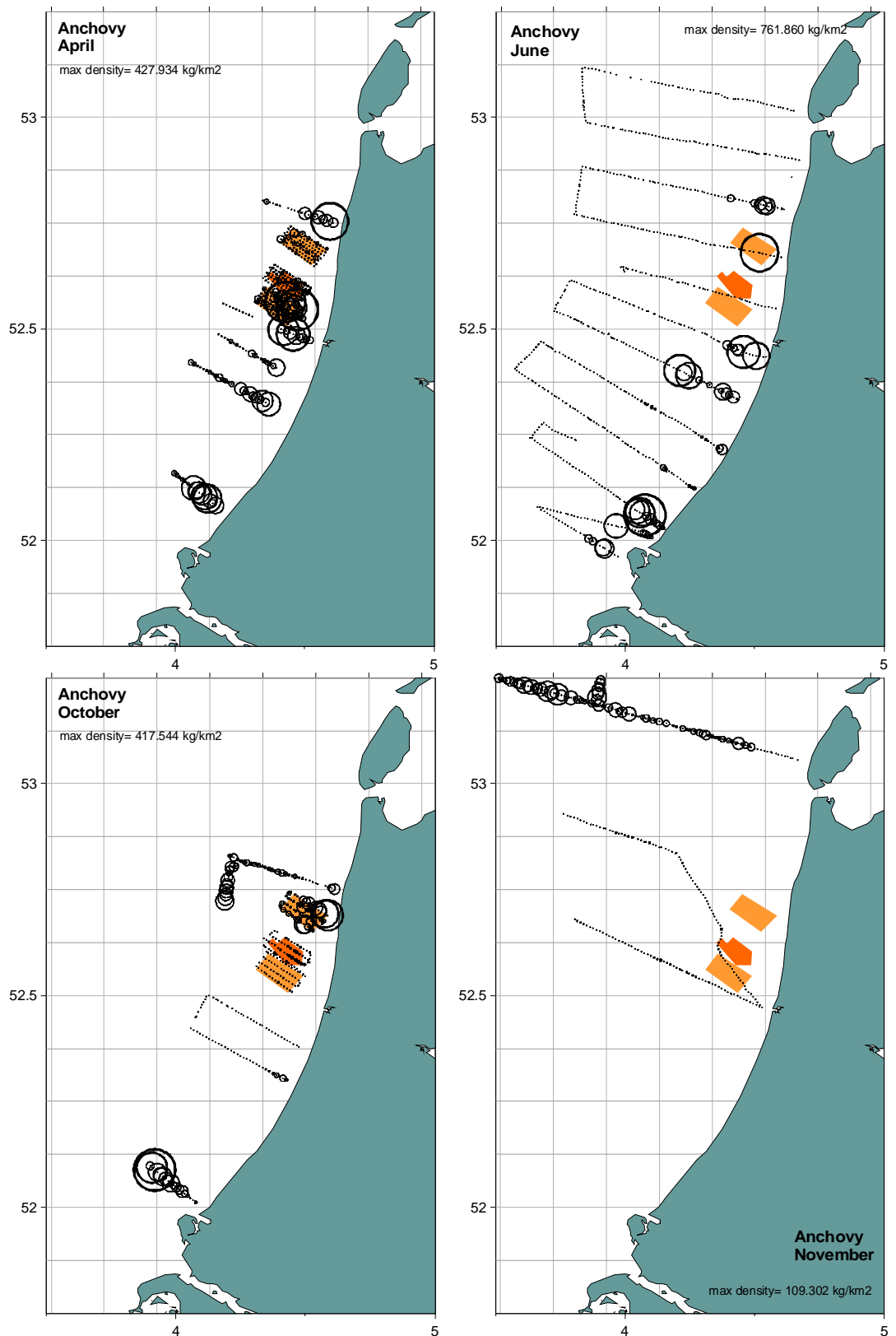
Figure IV.4. *LF distributions of Sprat per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Figures from Grift et al. (2004).*
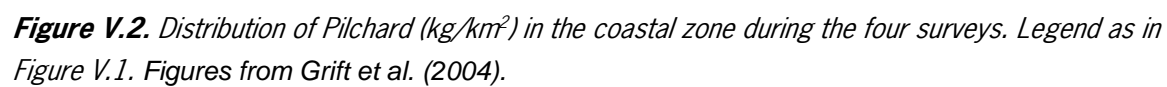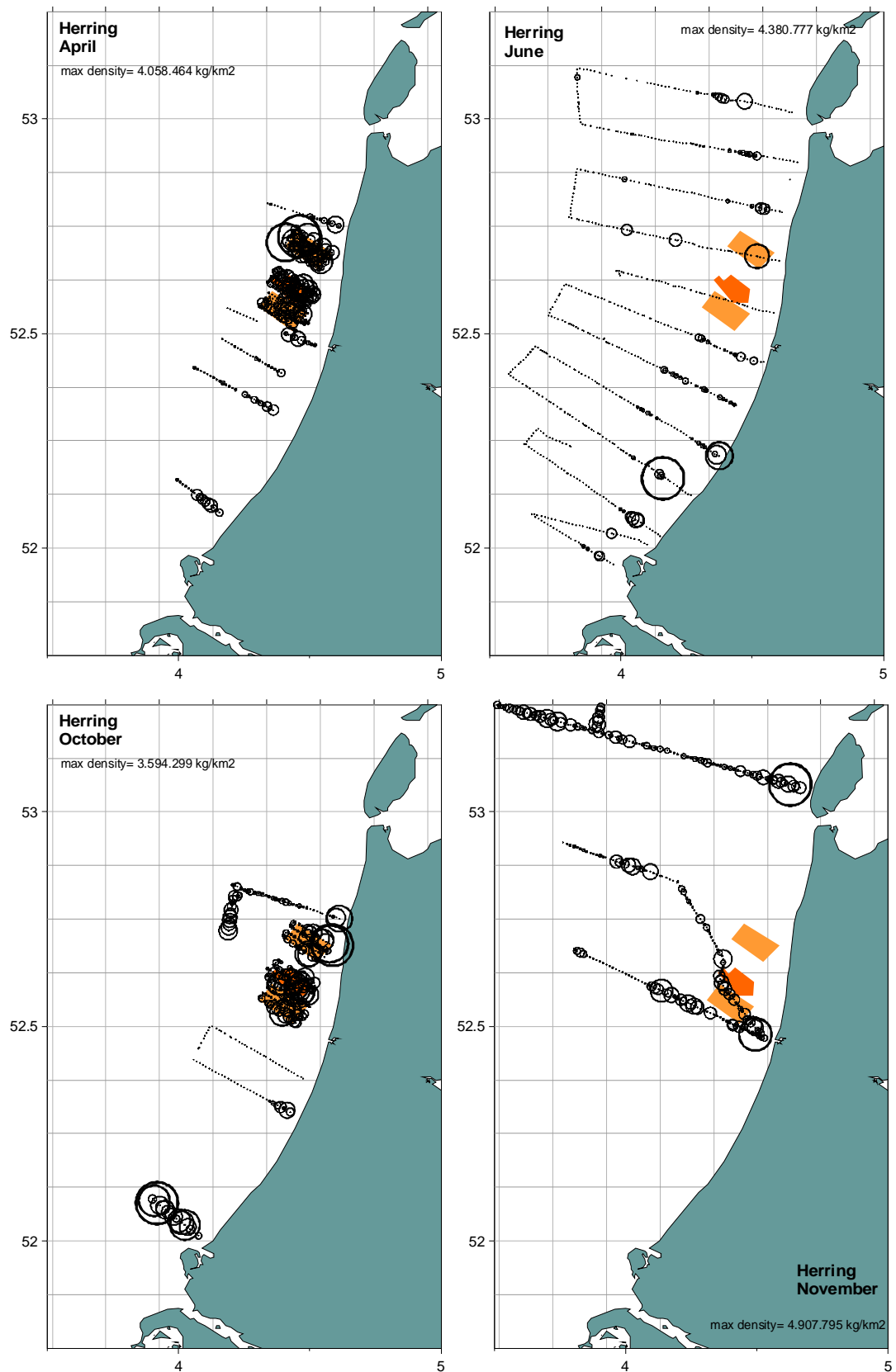
Figure IV.5. *LF distributions of Greater sandeel per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Figures from Grift et al. (2004).*

Figure IV.6. *LF distributions of Horse mackerel per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Figures from Grift et al. (2004).*

Figure IV.7. *LF distributions of Mackerel per age group and period, offshore and near shore. The percentage in the catch on the y-axis, length on the x-axis. The total number caught (n) is indicated. Figures from Grift et al. (2004).*

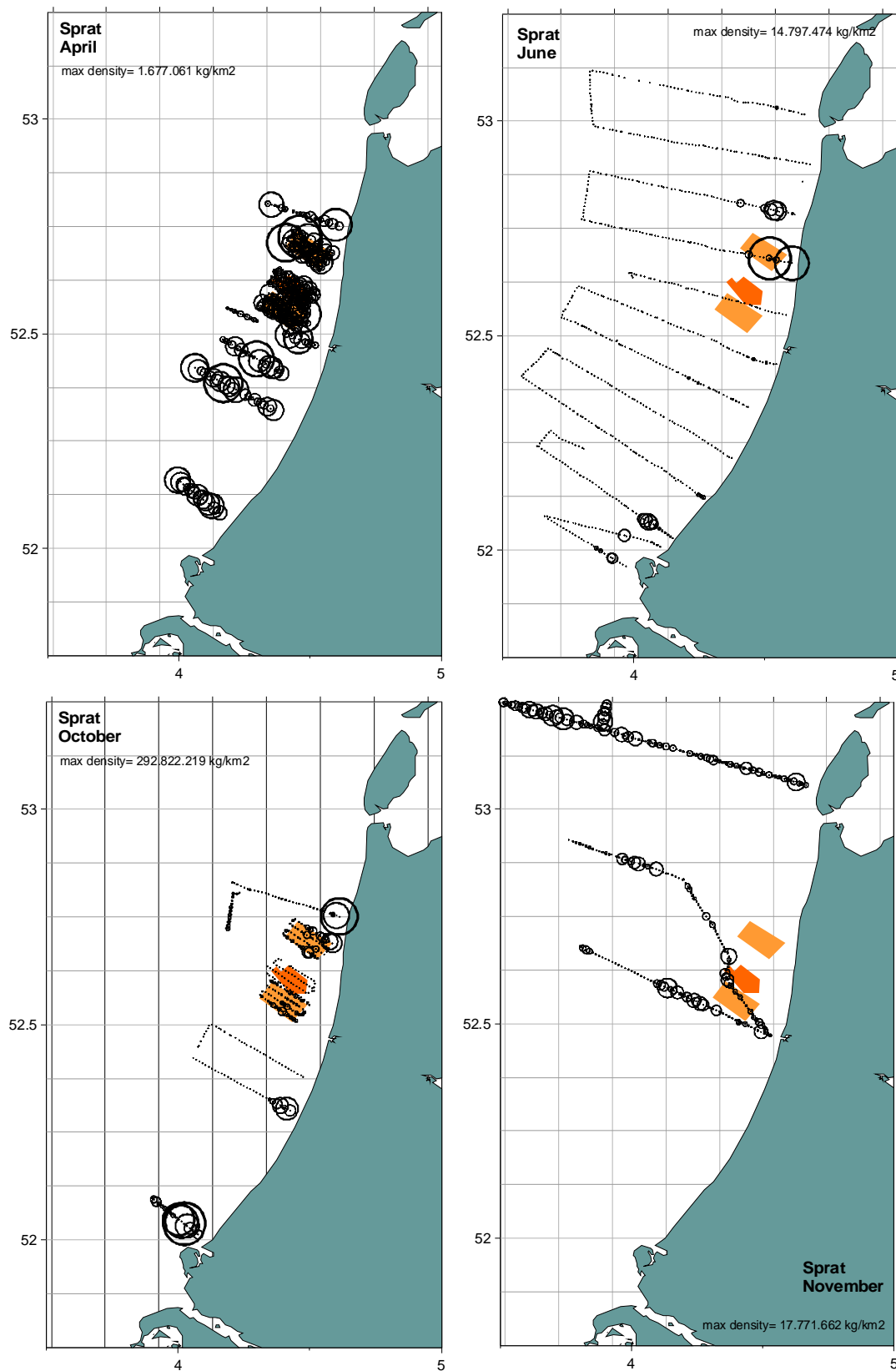Annex V. Spatial distribution of pelagic fish species from the Baseline wind farm project.

Figure V.1. *Distribution of Anchovy (kg/km^2) in the coastal zone during the four surveys (April + October: baseline, June: Flyland, November: Fish-Birds). The size of the largest bubble is indicated by the maximum density and bubble size increases with square root of the densities. The sizes of the other bubbles decrease not linearly. A '+' indicates zero values. Figures from Grift et al. (2004).*
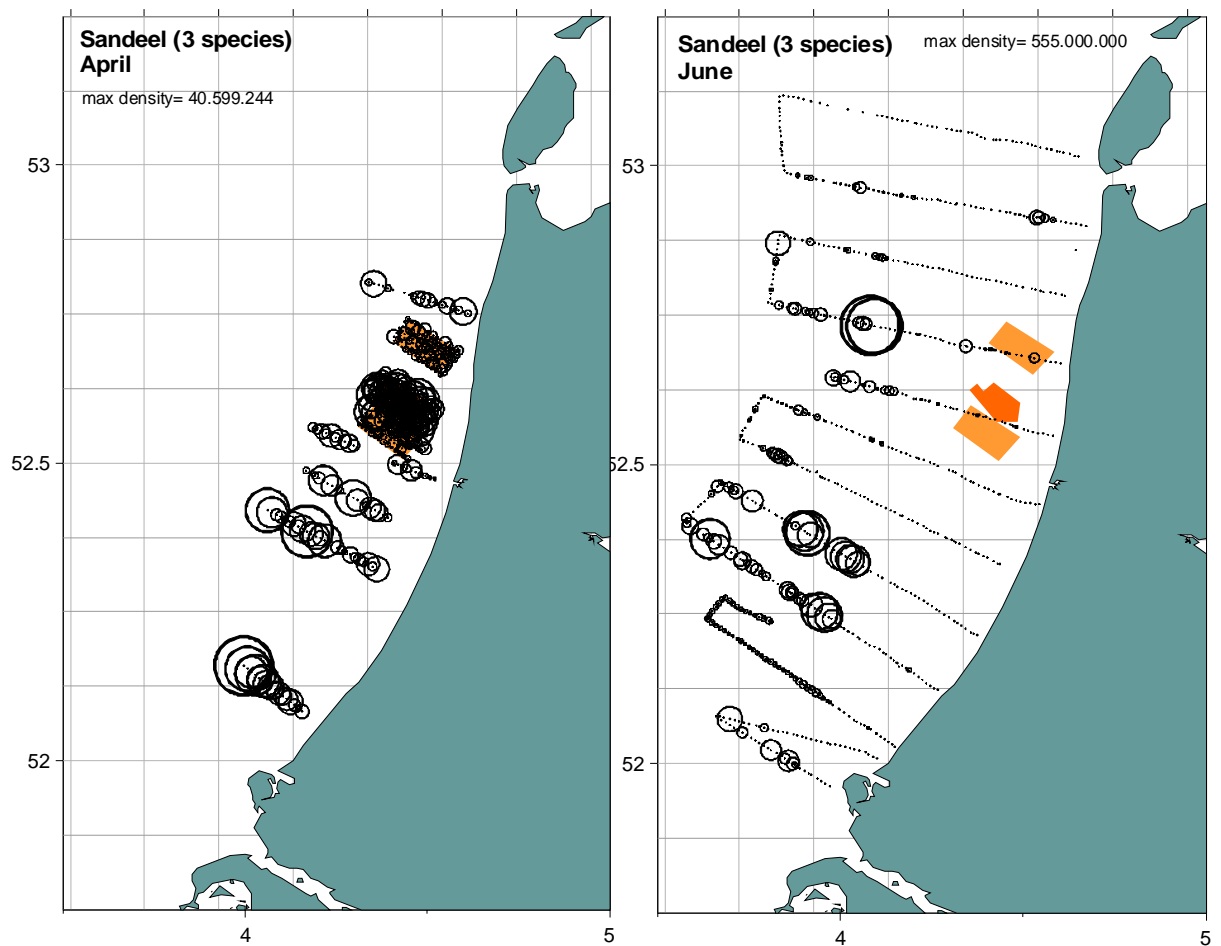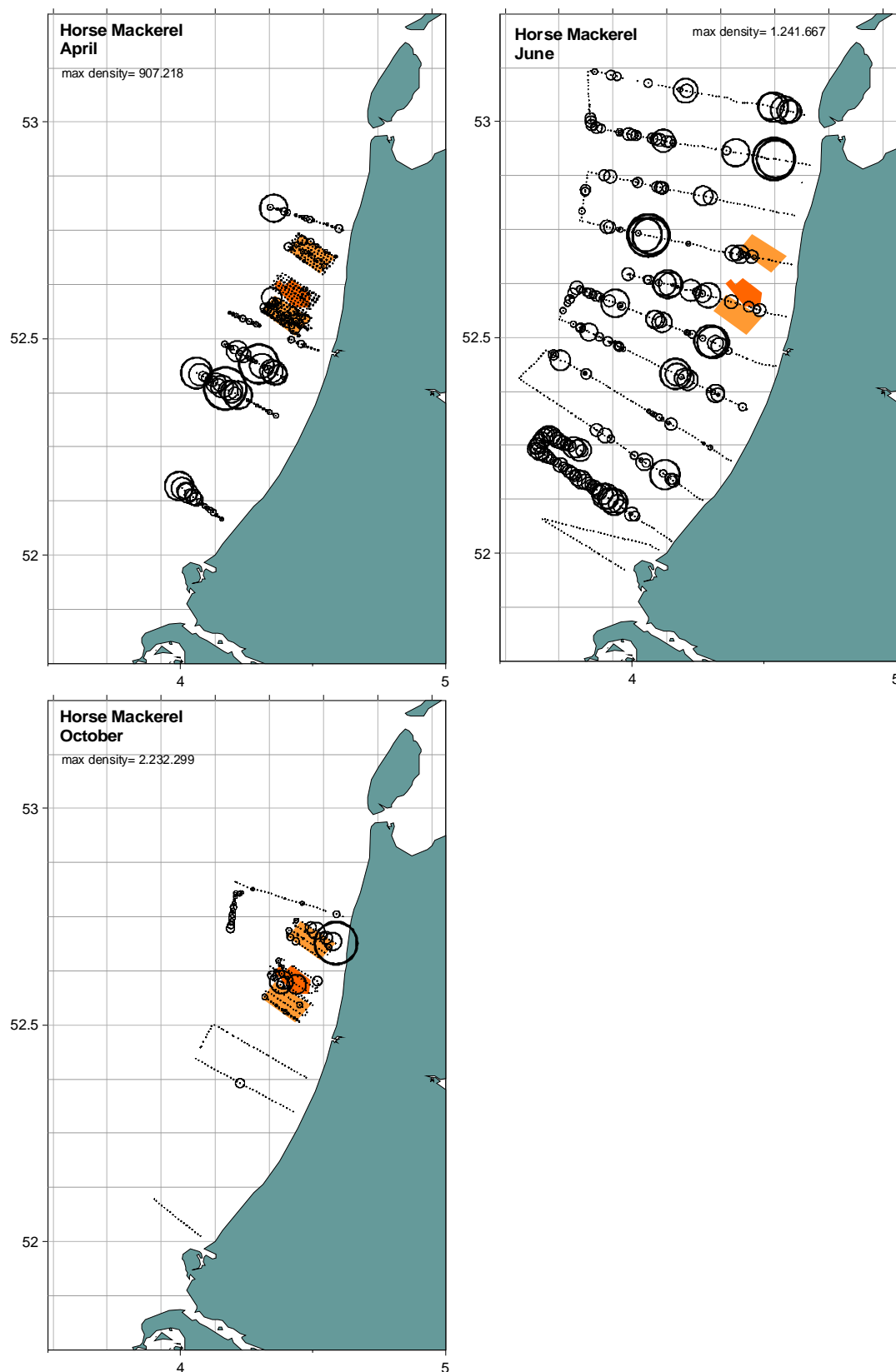
Figure V.2. *Distribution of Pilchard (kg/km²) in the coastal zone during the four surveys. Legend as in Figure V.1. Figures from Grift et al. (2004).*

Figure V.3. *Distribution of Herring (kg/km²) in the coastal zone during the four surveys. Legend as in Figure V.1. Figures from Grift et al. (2004).*
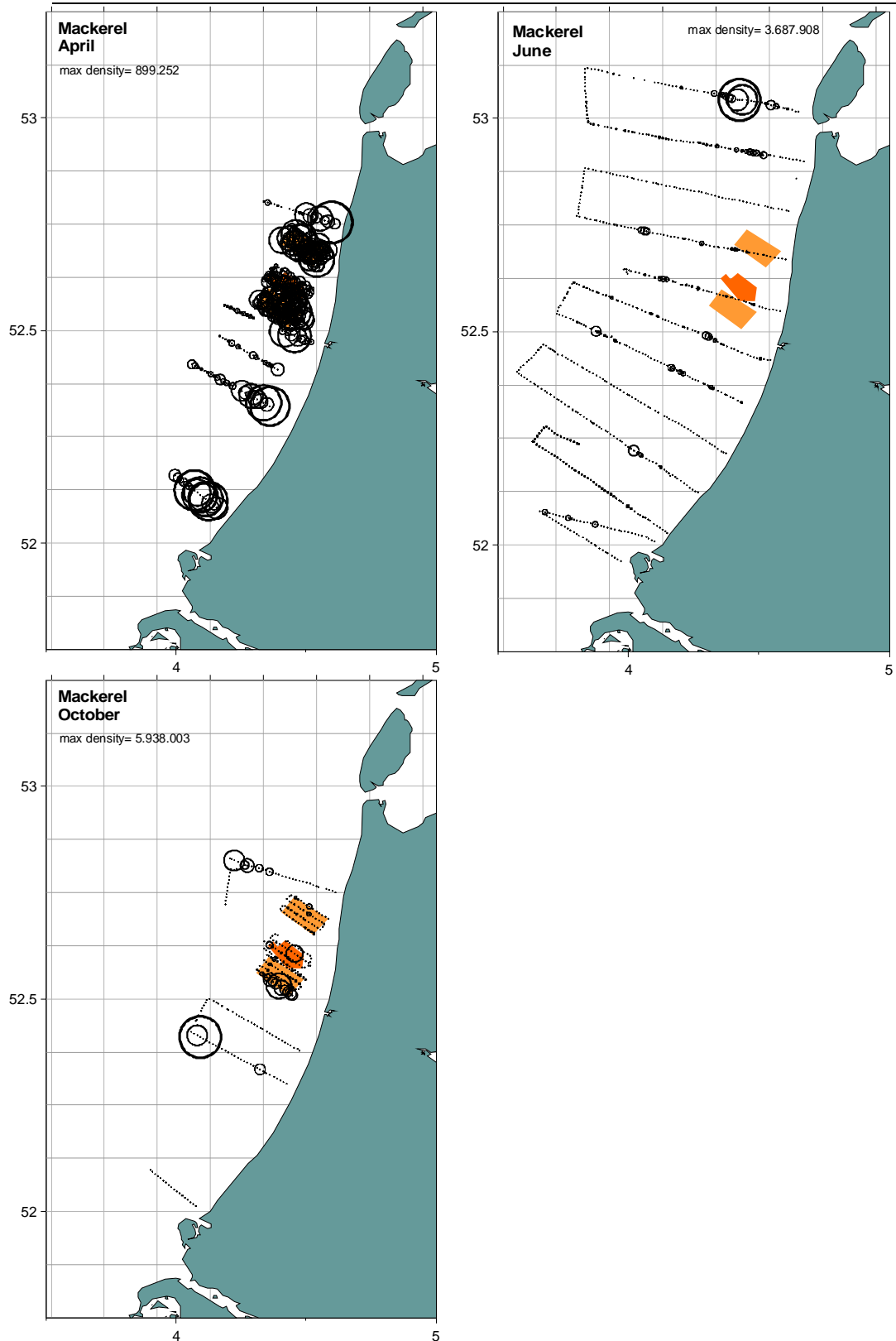
Figure V.4. *Distribution of Sprat (kg/km²) in the coastal zone during the four surveys. Legend as in Figure V.1. Figures from Grift et al. (2004).*

Figure V.5. *Distribution of Sandeel sp. (kg/km²) in the coastal zone during the four surveys. Legend as in Figure V.1. Sandeel species were only caught in very small numbers in autumn and therefore distribution maps of this period are not presented. Figures from Grift et al. (2004).*

Figure V.6. *Distribution of Horse mackerel (kg/km²) in the coastal zone during the four surveys. Legend as in Figure V.1. Figures from Grift et al. (2004).*

Figure V.7. *Distribution of Mackerel (kg/km^2) in the coastal zone during the four surveys. Legend as in Figure V.1. In November very few Mackerel were observed and showing distribution maps was not relevant. Figures from Grift et al. (2004).*

Annex VI. Satellite observation on total suspended matter (TSM), November 6, 2003