Toktrapport/Havforskningsinstituttet/ISSN 1503-6294/Nr.3 – 2008

SURVEY REPORT

ABUNDANCE ESTMATION OF SANDEEL, PLANKTON SURVAILANCE AND RADIOACTIVITY MEASUREMENTS IN THE NORTH SEA IN APRIL/MAY 2007

by

Anne Lene Brungot (radioactivity), Tone Falkenhaug (plankton and hydrography)
and Tore Johannessen (sandeel, ed.)

Research vessel: **JOHAN HJORT**		**Cruise no.: 2007 205** **Sandeel, plankton, radioactivity**
Departure: **11.04.07**	Departure port: **Bergen**	
Arrival: **13.05.07**	Arrival port: **Bergen**	
Survey areas: The North Sea, Utsira, Hanstholm, Aberdeen, main sandeel grounds.		
Objectives: Acoustic abundance estimation of sandeel, bottom substrate sampling for radioactive analyses, plankton sampling and hydrographical transects.		
Deltakernavn:	**Gruppenr:**	**Tidsrom:**
Tone Falkenhaug (toktleder)	434 Plankton	11.04.07 - 20.04.07
Hege Øverbø Hansen	423 Dyphavsarter	11.04.07 - 20.04.07
Julio Erices	431 Plankton	11.04.07 - 20.04.07
Ingvald Svellingen	431 Observasjonsmetodikk	20.04.07 – 29.04.07
Roar Skeide	425 Fangst	20.04.07 - 29.04.07
Ronald Pedersen	430 NMD	20.04.07 - 13.05.07
Alf Harbitz	431 Observasjonsmetodikk	28.04.07 – 13.05.07
Tore Johannesen (toktleder)	435 Pop.gen. og økologi	20.04.07 - 13.05.07
Knut Hansen	433 Pelagisk fisk	20.04.07 - 13.05.07
Inger Henriksen	422 Bunnhabitat og skalldyr	20.04.07 - 13.05.07
Harald Larsen	421 Bunnfisk	20.04.07 - 13.05.07
Jarle Kristiansen	620 Instrumentering	11.04.07 - 13.05.07
Jan Erik Nygaard	620 Instrumentering	11.04.07 - 13.05.07
Cruise leader: Tone Falkenhaug : 11.04.07 - 20.04.07, Tore Johannessen: 20.04.07 - 13.05.07		
Guest: Statens Strålevern: Anne Lene Brungot 11.04.07 – 20.04.07		

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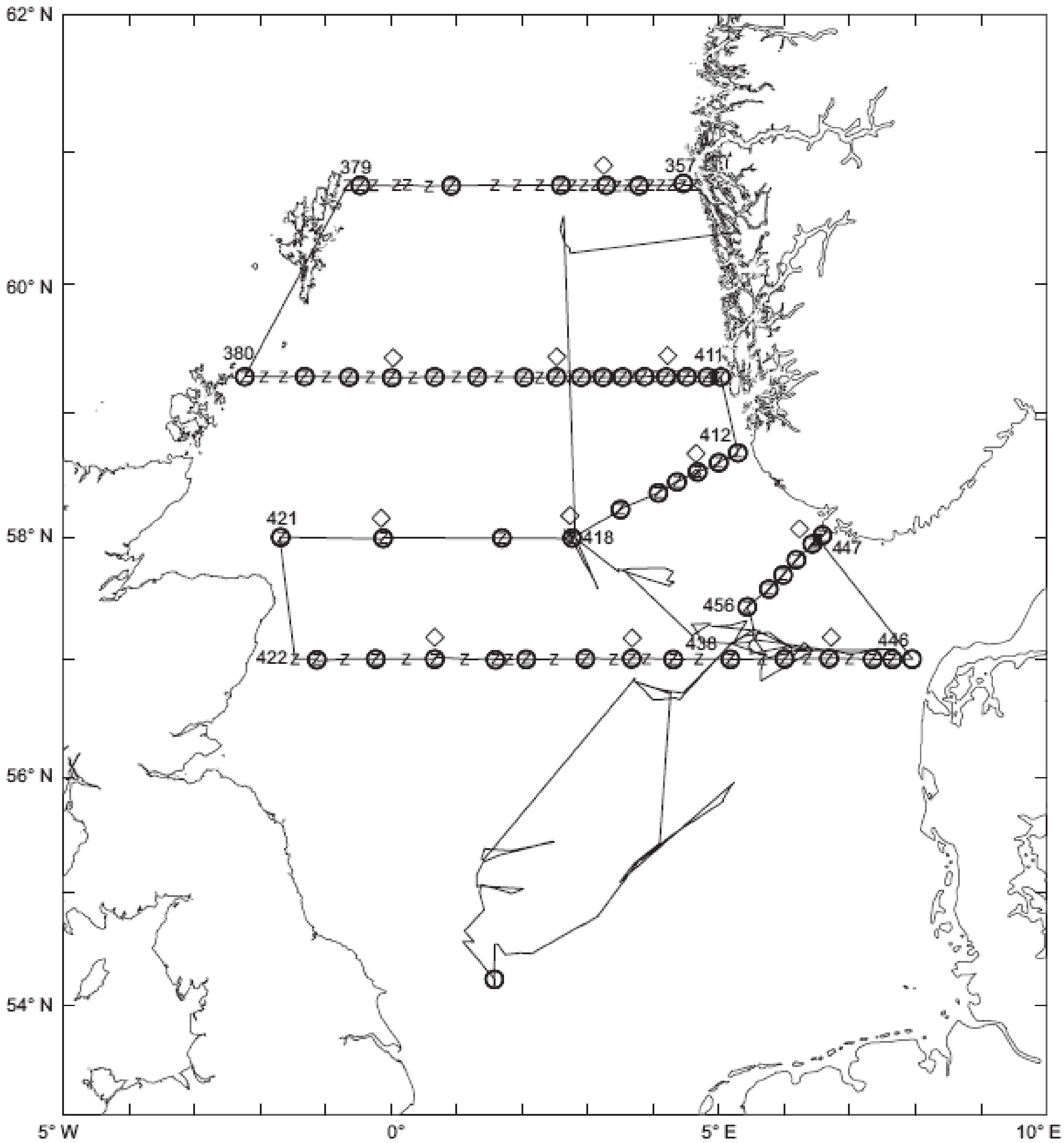
Introduction

This report gives an overview of activities and some preliminary results from survey no. 2007205, “Sandeel, plankton and radioactivity in the North Sea”.

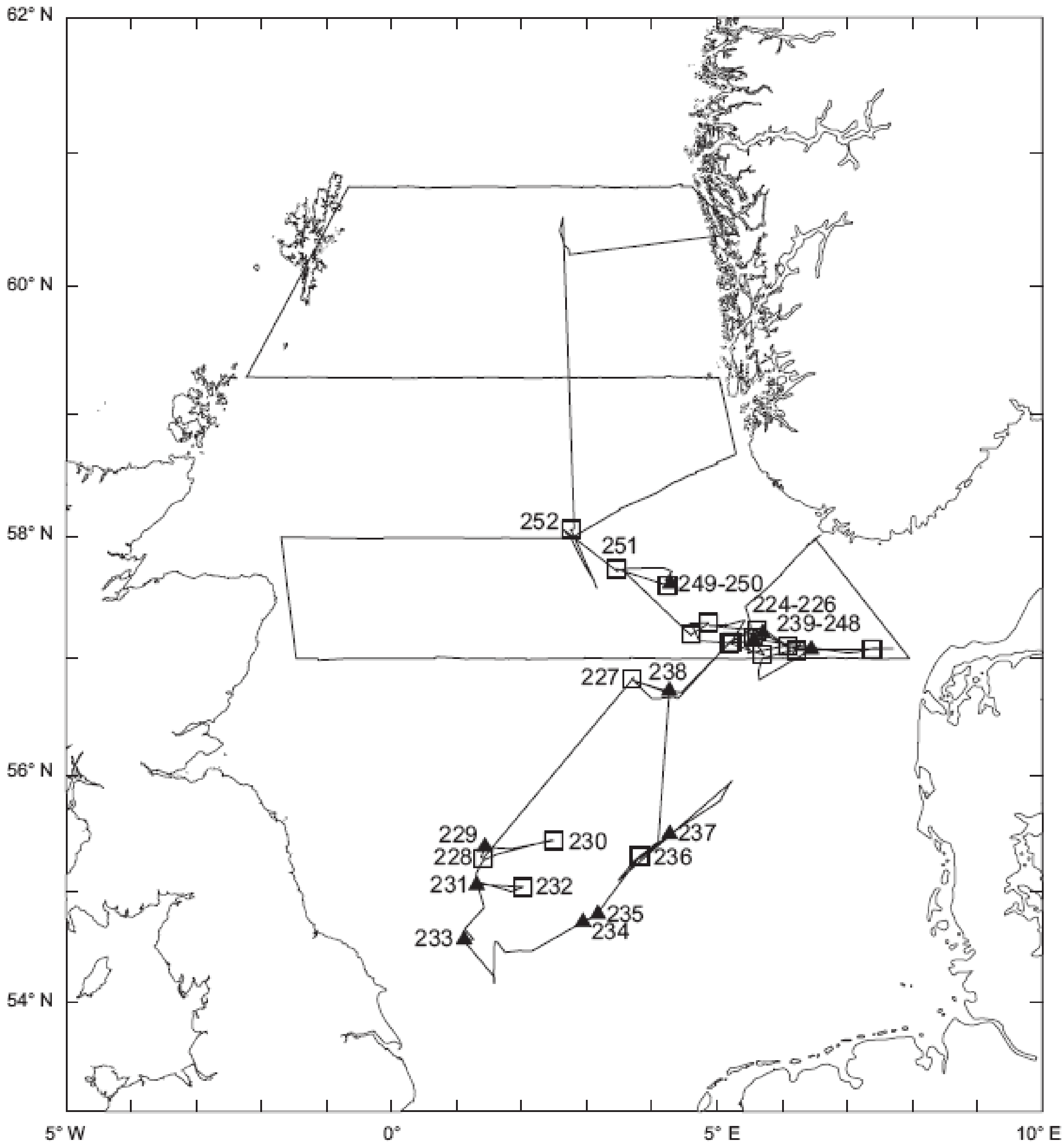
Between the April 11 and 20 the main activity was plankton sampling, hydrographical transects and collection of bottom substrate and water samples for radioactivity analyses. Between April 20 and May 13 the main activity was acoustic abundance estimation of sandeel on all major sandeel grounds in the North Sea, including in situ target strength measurements of sandeel. The figures below indicate surveyed area, transects and position of various types of sampling stations.



11 April–13 May 2007
Cruise no 2007205

z CTD st.no 357-456
○ Plankton st. (WP-II-net)
◇ Mocness st.

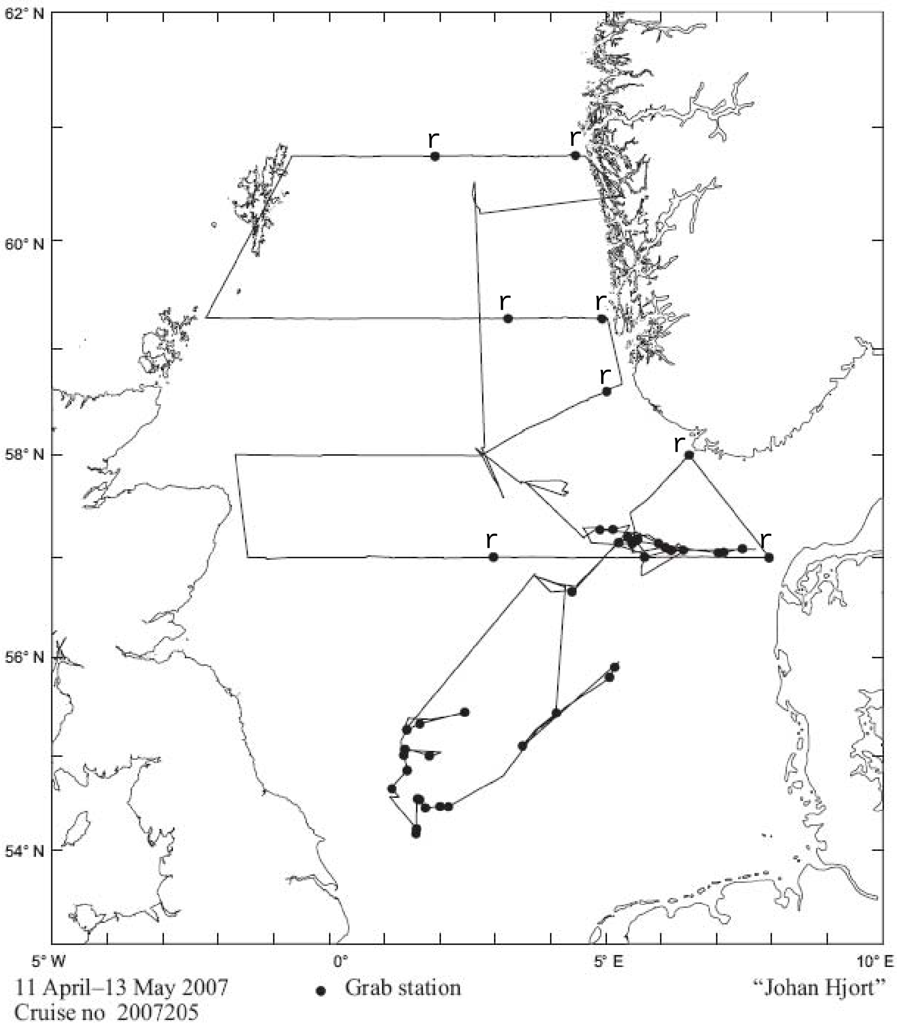
"Johan Hjort"



11 April–13 May 2007
Cruise no 2007205

Trawl st.no 224-252
□Bottom trawl
▲Pelagic trawl

"Johan Hjort"



r – indicates radioactivity sampling station
The other stations are grab sampling stations for sandeel

Plankton and hydrography

The aim of the sampling of plankton and hydrography was:

a) To describe the spatial variation in hydrography and plankton in the northern North Sea. A specific task was to collect data on plankton and hydrography as part of the project 11974, "Monitoring of climate and plankton in the North Sea and Skagerrak".

b) To perform zooplankton sampling in conjunction with the monitoring of sandeel: Due to time constraints however, no zooplankton sampling were made during the sandeel investigations.

Sampling

Sampling of hydrography and plankton were made on pre-selected stations along five transects according to Table 1.

Table 1.

	Number of stations							
Name of transect	CTD	Nutrients	Chl*a*	Mixed algal sample	Algae -net 10µm	WP-2 180µm	MOC-NESS	Egg-net
Feie-Shetland	23	23	23	6	6	6	1	3
Utsira-StartPoint	32	32	32	9	9	16	3	2
Jærens rev mot SW og W	10	10	10	8	8	10	3	2
Hanstholm-Aberdeen	26	26	26	7	7	13	3	2
Lista mot SW	6	6	6	1	1	6	1	0

On each station, a CTD cast with water bottles were made. The CTD is equipped with temperature-, conductivity and oxygen sensors. Water samples from the whole profile were drawn and conserved with chloroform for nutrient analysis in the chemistry laboratory at Institute of Marine Research after the cruise. Water samples from 0, 5, 10, 20, 30 and 50 m, were filtered and the filters frozen for chlorophyll analysis in the laboratory. Samples for algal cell counts were sampled by mixing equal amounts of water from 5, 10, 20 and 30 m depth and fixed on lugol. Samples were also drawn for salinity calibration.

Vertical net tows were made with the "**Algae-net**" (10 µm) from 30-0 m on selected stations. 1/2 of the sample was fixed on 2 ml lugol, and one 1/2 on 2,5 ml 0,5% formaldehyde. Secchi-depth was recorded at each station during daytime.

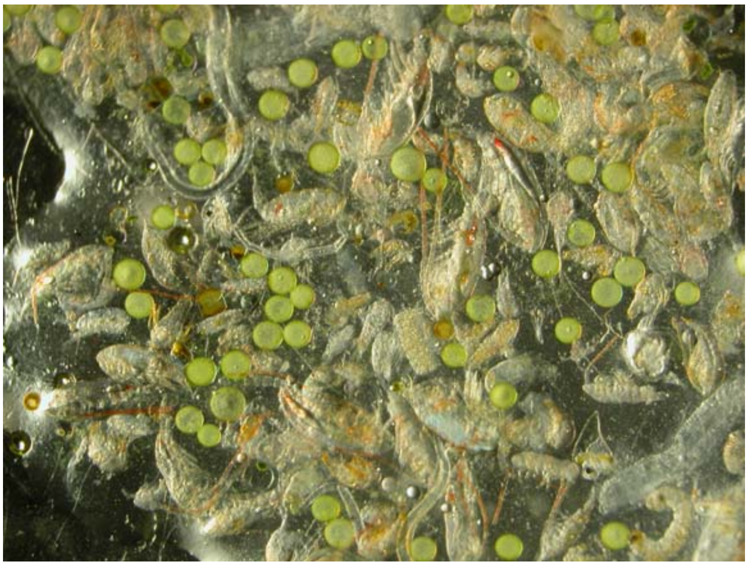
Zooplankton was sampled by a WP-2 net (180 µm, 0,25 m^2) and the MOCNESS (180µm, 1m^2). Vertical tows (0,5 m/s) with the **WP-2** were made from the bottom to the surface, and from 200-0 m, bottom depth permitting.

Oblique tows with the **MOCNESS** were made from 5m above bottom to the surface (Table 2). On stations with shallow bottom depth (<100 m, Hanstholm-Aberdeen) the first net was towed horizontally 5m above bottom for 1 minute.

Table 2: Standard sampling depths, MOCNESS:

On deep stations:	On shallow stations (<100 m):
500-400 m	Net 1: horizontal tow 5 m above bottom, 1 minute
400-300 m	Net 2: oblique bottom-50m
300-200 m	Net 3: oblique 50-25 m
200-150 m	Net4: oblique 25-0 m
150-100 m	
100-50 m	
50-25 m	
25-0 m	

In addition to the standard sampling program, a large "**egg-net**" was used in order to observe possible presence of the invasive ctenophore "*Mnemiopsis leidyi*". The egg-net (1m^2 , 300µm mesh-size) was equipped with a large, non-filtering cod-end, and towed vertically at low speed (0,2 m/s) from 30-0m. All ctenophores from this net were sorted out, identified and discarded.



A typical North Sea spring zooplankton sample. Halosphaera, Pseudocalanus and Calanus copepodites.

Sample treatment, zooplankton

Large medusae and ctenophores were sorted out from whole samples. The sample was split in two parts by a Motoda plankton splitter: one part was fixed on 4% borax buffered formaldehyde. The other half was used for estimation of biomass (dry weight): samples were fractionated into three fractions (180-1000µm, 1000-2000µm and >2000µm) and placed on pre-weighted aluminum trays, and dried at 60°C for 24 hours.
Samples were not split on the transect Hanstholm-Aberdeen, due to shallow depths and small sampling volumes. Instead, two WP2-tows were made: 1/1 sample was fixed on formaldehyde, and 1/1 sample was fractionated and dried for later biomass measurements.

Onboard zooplankton analysis

Enumeration, species identification and stage determination of *Calanus* spp, were made onboard on a limited number of samples. In order to determine the proportion of Calanus finmarchicus/C. helgolandicus in the sample, 20 Calanus V /VI were sorted out and identified into species, based on the shape of the 5th leg, according to:

> Fleminger A. and Hulsemann 1977. Geographical range and taxonimic divergence in North Atlantic Calanus (C. helgolandicus, C. finmarchicus and C. glacialis). Marine Biology, 40: 232-248.

A qualitative determination of the species composition in the fractionated samples were made prior to drying.

Calanus finmarchicus (left) and *C. helgolandicus* (right). Do you see the difference?

Preliminary results- Phytoplankton

Satellite image from the period 3 – 10 April shows that a bloom was emerging during the first days of the cruise in the southern North Sea. High chlorophyll values are shown along the western coast of Denmark and in a small area on the Norwegian west coast (Fig1). The dominant algae observed was the large *Halosphaera*, which may contribute significantly to the smallest size fraction (180-1000 µm) of the zooplankton samples.

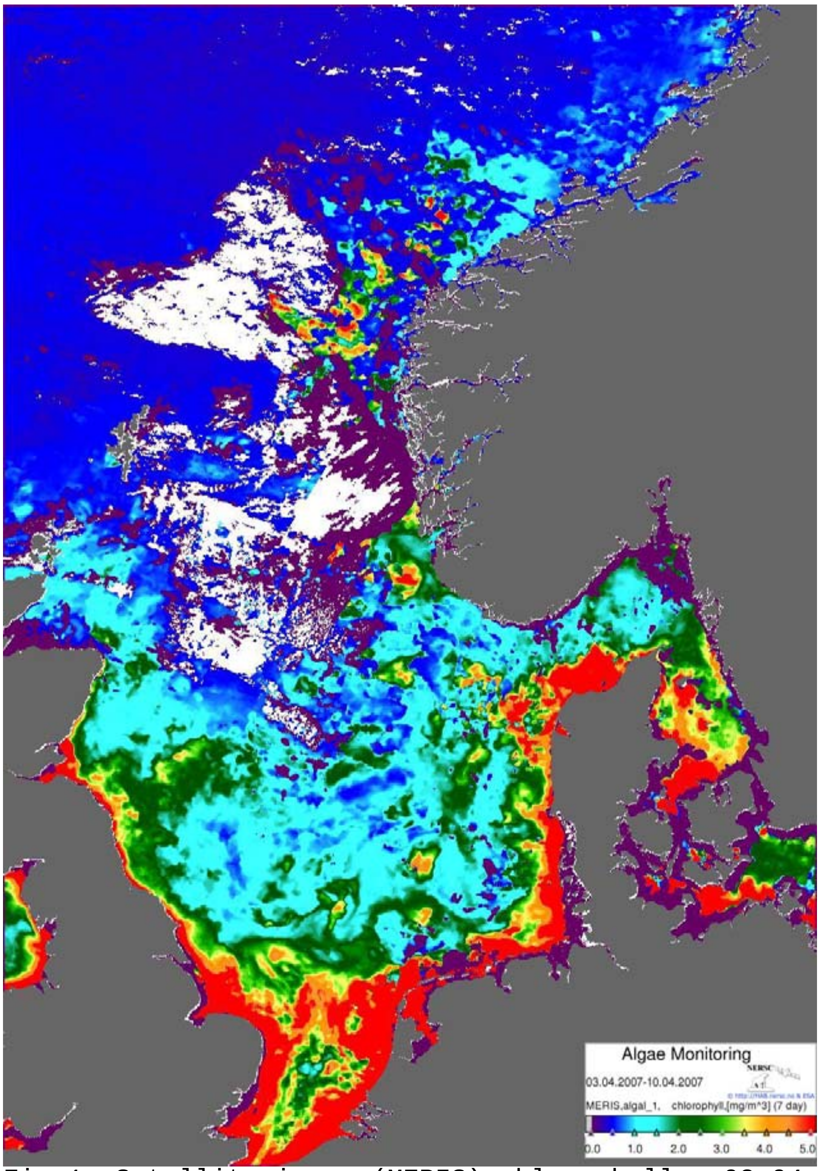


Fig 1: Satellite image (MERIS) chlorophyll a 03.04-10.04.2006

Preliminary results- Zooplankton
The preliminary results from the *Calanus* identification indicates that large geographical variations exists both in abundances and species composition (Fig 2).
The highest numbers of *Calanus spp* were found in the eastern part of the sampling area, over the Norwegian trench, dominated by *C. finmarchicus* (Fig 2 and 3). Low proportions of *C. helgolanidcus* was found on the easternmost stations (Fig 2). The stage composition in these areas was dominated by small copepodite- stages, indicating production of the first generation of the year (Fig 4). *C. helgolandicus* was dominating in the western North Sea. The numbers were lower, and the stage composition showed a different pattern compared to eastern stations. In general, the proportion of *C. helgolandicus* showed an increasing trend towards west, and towards south in the sampling area (Fig2).

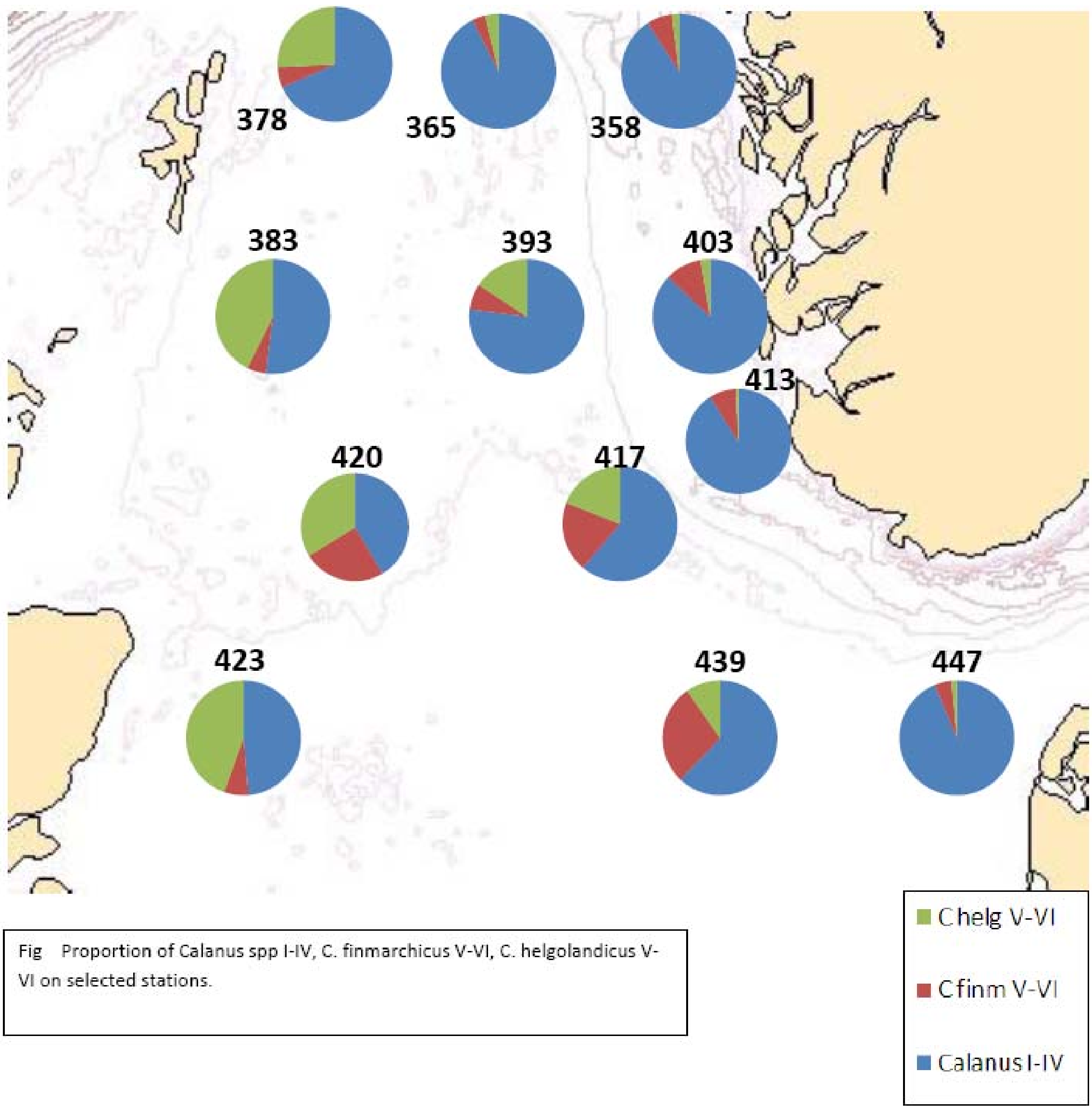


Fig Proportion of Calanus spp I-IV, C. finmarchicus V-VI, C. helgolandicus V-VI on selected stations.

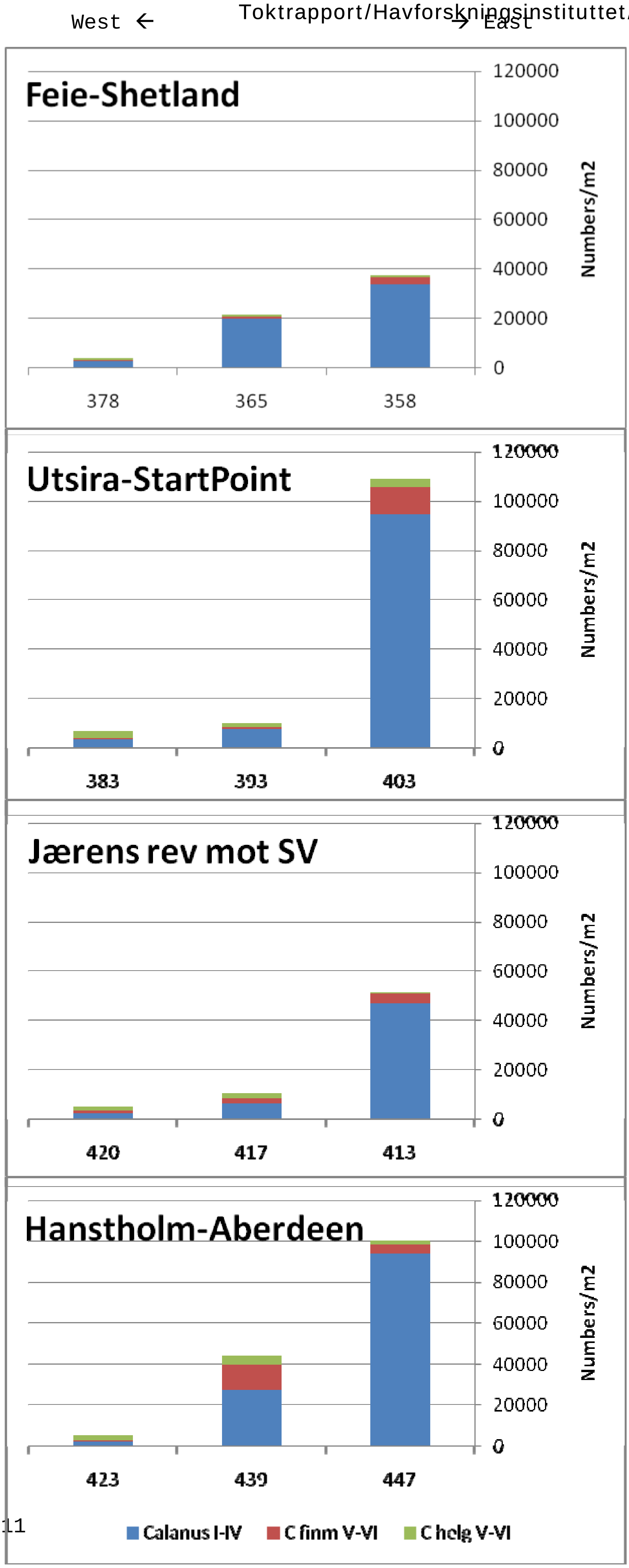


Fig 3. Abundances of *Calanus* spp (*Calanus finmarchicus and C. helgolandicus*, as Numbers per m^2) along four transects. X-axis refers to CTD station numbers. Stations in the western part of the transect, to the left in figure.

West ←

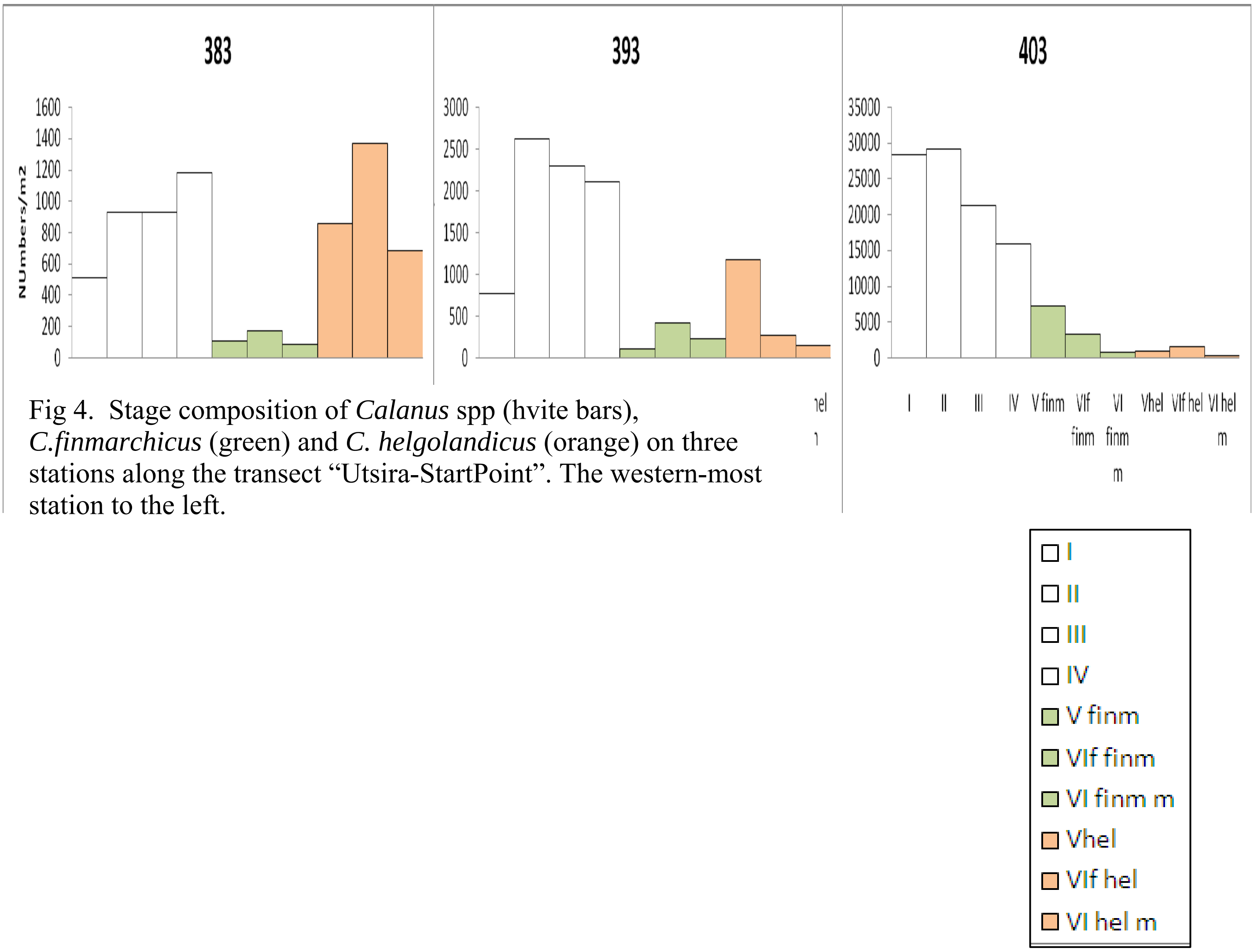
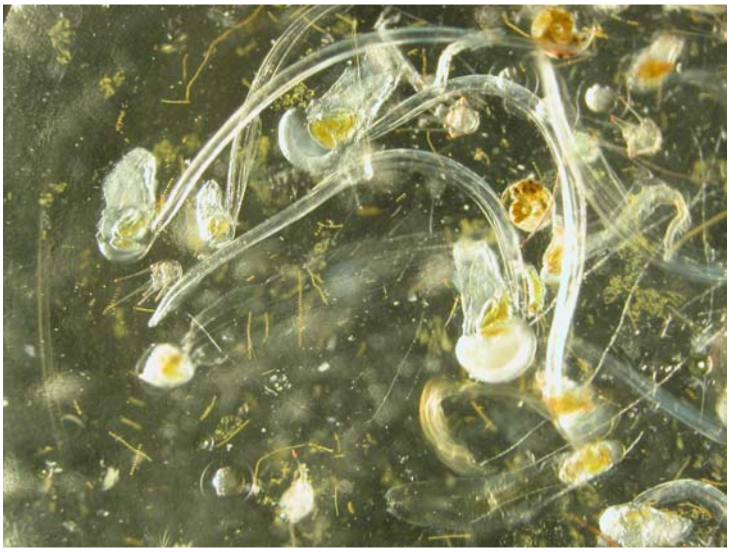


Fig 4. Stage composition of *Calanus* spp (hvite bars), *C.finmarchicus* (green) and *C. helgolandicus* (orange) on three stations along the transect “Utsira-StartPoint”. The western-most station to the left.

Relatively high numbers of the oceanic, warm-temperate species *Mesocalanus tenuicornis* was observed on the westernmost stations. This may indicate inflow of water with Atlantic origin, which is further supported by the high proportion of *C. helgolanidus* in these areas.

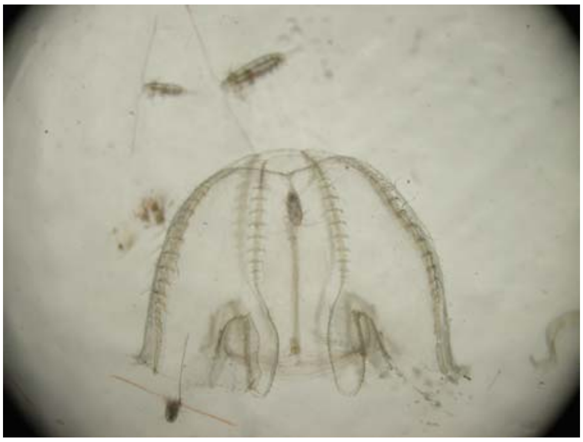
High abundances of appendicularians (*Oikopleura*) was observed on the Hanstholm-Aberdeen transect. The gelatinous houses caused clogging of the nets.

Mesocalanus tenuiocornis



Oikopleura sp

Ctenophores were sorted out and identified in all nets (WP2, “egg-net” and MOCNESS”). No observation was made of the invasive species *Mnemiopsis leidyi*. However, numerous small individuals of *Bolinopsis infundibulum* was observed south of 60°N, on the eastern stations close to the Norwegian and Danish coasts.



Bolinopsis infundibulum

Mnemiopsis leidyi
(not observed during the cruise)

Radioactivity

The issue of potential and radioactive contamination in the marine environment has received considerable attention in Norway in recent years. Due to the vulnerability to contamination as well as any rumours of radioactive contamination, one of the main objectives for this cruise was to document levels and trends of radionuclides in the Norwegian marine environment. The survey is part of a programme that is co-ordinated by the Norwegian Radiation Protection Authority (NRPA). RAME is funded by the Ministry of Environment (MD), and the main collaborating partner in the programme is the Institute of Marine Research (IMR).

Each year, a cruise with collection of seawater, sediments and marine organisms in Norwegian coastal waters and adjacent seas is performed. The cruise regarding RAME is rolling between the Barents Sea, Norwegian Sea and the North Sea /Skagerrak.

In 2007 the cruise was carried out in the North Sea with the research vessel RV Johan Hjort during the period April 10 to April 20. This cruise report gives an overview of the sampling and detailed information on the number and kind of samples obtained (see table below).

During the cruise 72 samples of seawater (mainly surface- but in one station also subsurface water) and sediments from the seabed were collected. In addition, 10 water samples were collected for analysis of Neptunium at Risø, Denmark, and 5 samples of sediments for analysis of Neptonium at to IMR.

All samples will be analysed in laboratories on shore, and the results will be presented in forthcoming report from the Norwegian National Monitoring Programme. The data will also be published on the web site: www.nrpa.no

Stations

Feie – Shetland, stations. Utsira West, 3 stations and Aberdeen - Hanstholm it is also 3 stations.

On each station it was planning to take:

- 350 liter surface water (technetium, plutonium, americium, strontium, radium and neptunium).
- Cs-filtration.
- Surface sediment.
-

One station outside Lista:

- 350 liter surface water water (Tecnetium, Plutonium, Americium, Strontium, Radium and Neptunium).
- Cs-filtration.
- Surface sediment.
- 200 litre water from 100 m.
- 200 litre water from floor (bottom)

Sampling

Surface water collected on board the ship. Analyses will be carried out on land.

Boxcorer, with sediment from station 7.

CTD – we use this for collecting water from the deep.

Sampling of bottom sediments using van Veen grab.

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Table. Information on radioactivity sampling.

				Koordinater ikke regnet om		Koordinater regnet om					
Dato	Stasjon	CTD stasjon	Saltholdighet	Breddegrad	Lengdegrad	Breddegrad	Lengdegrad	Prøve parameter	Mengde/volum	Analyse	Opparbeidelse om bord
12.04.2007	1	358	32,8400	60,45	4,27	60,75	4,45	Vann	25	Np	Ingen
12.04.2007	1	358	32,8400	60,45	4,27	60,75	4,45	Vann	50	Sr	Saltsyre
12.04.2007	1	358	32,8400	60,45	4,27	60,75	4,45	Vann	50	Tc	Ingen
12.04.2007	1	358	32,8400	60,45	4,27	60,75	4,45	Vann	200	Pu/Am	Felling
12.04.2007	1	358	32,8400	60,45	4,27	60,75	4,45	Vann	314	Cs	Tørking av filter
12.04.2007	1	358	35,2651	60,45	4,27	60,75	4,45	Sediment	Overflate		Ingen-fryses
12.04.2007	1	358	35,2651	60,45	4,27	60,75	4,45	Sediment	Corer	HI-geo	Ingen-fryses
12.04.2007	2	371	35,2874	60,45	1,55	60,75	1,92	Vann	25	Np	Ingen
12.04.2007	2	371	35,2874	60,45	1,55	60,75	1,92	Vann	50	Sr	Saltsyre
12.04.2007	2	371	35,2874	60,45	1,55	60,75	1,92	Vann	50	Tc	Ingen
12.04.2007	2	371	35,2874	60,45	1,55	60,75	1,92	Vann	200	Pu/Am	Felling
12.04.2007	2	371	35,2874	60,45	1,55	60,75	1,92	Vann	397	Cs	Tørking av filter
12.04.2007	2	371	35,2847	60,45	1,55	60,75	1,92	Sediment	Overflate		Ingen-fryses
12.04.2007	2	371	35,2847	60,45	1,55	60,75	1,92	Sediment	Corer	HI-geo	Ingen-fryses
13.04.2007	3	379	35,3322	60,45	-0,4	60,75	-0,67	Vann	25	Np	Ingen
13.04.2007	3	379	35,3322	60,45	-0,4	60,75	-0,67	Vann	50	Sr	Saltsyre
13.04.2007	3	379	35,3322	60,45	-0,4	60,75	-0,67	Vann	50	Tc	Ingen
13.04.2007	3	379	35,3322	60,45	-0,4	60,75	-0,67	Vann	200	Pu/Am	Felling
13.04.2007	3	379	35,3322	60,45	-0,4	60,75	-0,67	Vann	347	Cs	Tørking av filter
13.04.2007	3	379	35,3207	60,45	-0,4	60,75	-0,67	Sediment	Overflate		Ingen-fryses
13.04.2007	3	379	35,3207	60,45	-0,4	60,75	-0,67	Sediment	Corer	HI-geo	Ingen-fryses
13.04.2007	4	380	34,7182	59,17	-2,14	59,28	-2,23	Vann	25	Np	Ingen
13.04.2007	4	380	34,7182	59,17	-2,14	59,28	-2,23	Vann	50	Sr	Saltsyre
13.04.2007	4	380	34,7182	59,17	-2,14	59,28	-2,23	Vann	50	Tc	Ingen
13.04.2007	4	380	34,7182	59,17	-2,14	59,28	-2,23	Vann	200	Pu/Am	Felling
13.04.2007	4	380	34,7182	59,17	-2,14	59,28	-2,23	Vann	456	Cs	Tørking av filter
13.04.2007	4	380	34,7393	59,17	-2,14	59,28	-2,23	Sediment	Overflate		Ingen-fryses
13.04.2007	4	380	34,7393	59,17	-2,14	59,28	-2,23	Sediment	Corer	HI-geo	Ingen-fryses

14.04.2007	5	390	35,2119	59,17	1	59,28	1	Vann	25	Np	Ingen
14.04.2007	5	390	35,2119	59,17	1	59,28	1	Vann	50	Sr	Saltsyre
14.04.2007	5	390	35,2119	59,17	1	59,28	1	Vann	50	Tc	Ingen
14.04.2007	5	390	35,2119	59,17	1	59,28	1	Vann	200	Pu/Am	Felling
14.04.2007	5	390	35,2119	59,17	1	59,28	1	Vann	367	Cs	Tørking av filter
14.04.2007	5	390	35,2651	59,17	1	59,28	1	Sediment	Overflate		Ingen-fryses
14.04.2007	5	390	35,2651	59,17	1	59,28	1	Sediment	Corer	HI-geo	Ingen-fryses
14.04.2007	5-2.	399	35,3057	59,17	3,13	59,28	3,22	Sediment	Overflate		Ingen-fryses
14.04.2007	5-2.	399	35,3057	59,17	3,13	59,28	3,22	Sediment	Corer	HI-geo	Ingen-fryses
15.04.2007	6	411	32,6882	59,17	5,02	59,28	5,03	Vann	25	Np	Ingen
15.04.2007	6	411	32,6882	59,17	5,02	59,28	5,03	Vann	50	Sr	Saltsyre
15.04.2007	6	411	32,6882	59,17	5,02	59,28	5,03	Vann	50	Tc	Ingen
15.04.2007	6	411	32,6882	59,17	5,02	59,28	5,03	Vann	200	Pu/Am	Felling
15.04.2007	6	411	32,6882	59,17	5,02	59,28	5,03	Vann	397	Cs	Tørking av filter
15.04.2007	6	410	35,0034	59,17	4,56	59,28	4,93	Sediment	Overflate		Ingen-fryses
15.04.2007	6	410	35,0034	59,17	4,56	59,28	4,93	Sediment	Corer	HI-geo	Ingen-fryses
15.04.2007	11	413	35,1642	58,37	5	58,62	5	Sediment	Overflate		Ingen-fryses
15.04.2007	11	413	35,1642	58,37	5	58,62	5	Sediment	Corer	HI-geo	Ingen-fryses
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Vann	25	Np	Ingen
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Vann	50	Sr	Saltsyre
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Vann	50	Tc	Ingen
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Vann	200	Pu/Am	Felling
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Filter	353	Cs	Tørking av filter
17.04.2007	7	423	34,5630	57	-1,08	57	-1,13	Filter	404	Ra	Tørking av filter
17.04.2007	7	422	34,5258	57	-1,28	57	-1,47	Vann	25	Ra	Saltsyre
17.04.2007	7	422	34,5388	57	-1,28	57	-1,47	Sediment	Overflate		Ingen-fryses
17.04.2007	7	422	34,5388	57	-1,28	57	-1,47	Sediment	Corer	HI-geo	Ingen-fryses
17.04.2007	8	431	35,0465	57	2,04	57	2,07	Filter	610	Ra	Tørking av filter
17.04.2007	8	431	35,0465	57	2,04	57	2,07	Vann	25	Ra	Saltsyre
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Vann	25	Np	Ingen
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Vann	50	Sr	Saltsyre
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Vann	50	Tc	Ingen

17.04.2007	9	433	35,0876	57	2,58	57	2,97	Vann	200	Pu/Am	Felling
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Filter	384	Cs	Tørking av filter
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Filter	801	Ra	Tørking av filter
17.04.2007	9	433	35,0876	57	2,58	57	2,97	Vann	25	Ra	Saltsyre
17.04.2007	9	433	35,1054	57	2,58	57	2,97	Sediment	Overflate		Ingen-fryses
17.04.2007	9	433	35,1054	57	2,58	57	2,97	Sediment	Corer	HI-geo	Ingen-fryses
18.04.2007	10	447	-	57	7,57	57	7,95	Vann	25	Np	Ingen
18.04.2007	10	447	-	57	7,57	57	7,95	Vann	50	Sr	Saltsyre
18.04.2007	10	447	Measuring lab	57	7,57	57	7,95	Vann	50	Tc	Ingen
18.04.2007	10	447	-	57	7,57	57	7,95	Vann	200	Pu/Am	Felling
18.04.2007	10	446	-	57	7,65	57	7,39	Filter	486	Cs	Tørking av filter
18.04.2007	10	447	-	57	7,57	57	7,95	Filter	469	Ra	Tørking av filter
18.04.2007	10	447	-	57	7,57	57	7,95	Vann	25	Ra	Saltsyre
18.04.2007	10	447	-	57	7,57	57	7,95	Sediment	Overflate		Ingen-fryses
18.04.2007	10	447	-	57	7,57	57	7,95	Sediment	Corer	HI-geo	Ingen-fryses
19.04.2007	12	448	-	57,59	6,3	57,97	6,5	Vann-overflate	25	Np	Ingen
19.04.2007	12	448	-	57,59	6,3	57,97	6,5	Vann-overflate	50	Sr	Saltsyre
19.04.2007	12	448	-	57,59	6,3	57,97	6,5	Vann-overflate	50	Tc	Ingen
19.04.2007	12	448	Measuring lab	57,59	6,3	57,97	6,5	Vann-overflate	200	Pu/Am	Felling
19.04.2007	12	448	-	57,59	6,3	57,97	6,5	Filter	509	Cs	Tørking av filter
19.04.2007	12	448	-	57,59	6,3	57,97	6,5	Vann-overflate	25	Ra	Saltsyre
19.04.2007	12	448	35,1801	57,59	6,3	57,97	6,5	Sediment	Overflate		Ingen-fryses
19.04.2007	12	448	35,1801	57,59	6,3	57,97	6,5	Sediment	Corer	HI-geo	Ingen-fryses
19.04.2007	13	448	35,1801	57,59	6,3	57,97	6,5	Vann-bunn	172	Pu/Am	Felling
19.04.2007	14	450	34,989	57,59	6,3	57,97	6,5	Vann-100m	160	Pu/Am	Felling

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Sandeel

Between April 20 and May 13 the main activity was directed towards estimating the distribution and abundance of sandeel on all major sandeel grounds in the North Sea (Figure 5). Simultaneously, between April 1 and May 6, an experimental fishery using commercial sandeel vessels was carried out under the supervision of ICES in order to estimate the abundance of I-group sandeel as a basis for setting a TAC for the rest of the year. ICES uses catch per unit effort (CPUE) to estimate the abundance of sandeel. In order to evaluate the robustness of the CPUE methodology and the potential impact of fishery on local sandeel stocks, results from the survey are discussed in relation to the experimental fishery. In addition, some experimental studies were carried out during the survey, e.g. in situ measurements of target strength of sandeel by trapping sandeel in a net pen placed on the bottom where sandeel bury.

In spring sandeel feed on plankton during daytime and bury in sand during night. However, there is evidence to suggest that part of the population may bury in sand also during daytime. This peculiar behaviour makes abundance estimation of sandeel problematic. Therefore, an important part of the sandeel survey is to develop a robust methodology for survey based estimations of sandeel abundance. Consequently, results presented here are preliminary and should be interpreted with caution. Focus is on the Norwegian economical zone (NEEZ).

Material and methods

Sandeel fishing grounds in the North Sea have been identified from WMS data (satellite tracking data) of the Danish and Norwegian sandeel fleets. In addition, several Norwegian vessels have generously provided trawl trajectories from the sandeel fishing grounds obtained the last 8-10 years. The fishing grounds form a patchwork of clearly defined areas spread all over the North Sea at depths between 20-70 m, except at the Viking bank were sandeel are found between 90 and 110 m.

Sandeel bury in sandy bottom substrate during night, and emerge from their bottom habitat during daytime to feed. Between 700 and 2100 hours the abundance of sandeel was measured using a multi-frequency echo sounder and during night between 2200 and 600 hours the same areas were sampled using a modified scallop dredge (Danish model) and a 0.2 m van Veen grab. Dredge sampling was carried out in accordance to the Danish method (10 min., 2 knots). Three grab samples (one station) were obtained if sandeel were caught in the dredge. During day time sandeel was sampled using standard bottom trawl (code 3270) and standard pelagic trawl (code 3513, Harstadtrål uten blåser).

Table. No. of stations (see Figs. page 2-4).

Gear	Bottom trawl	Pelagic trawl	van Veen grab	Dredge
No. of stations	18	11	36	68

Sandeel schools were identified from the frequency response of the multi-frequency echo sounder, 18, 38, 120 and 200 kHz. In this report area backscatter coefficients (s_A) have not been converted into biomass.

Methodological studies

In situ target strength of sandeel was measured in a 9 m^3 net pen (see picture below) placed on the bottom where sandeel bury. The net pen was equipped with a scientific echo sounder, EK60 200kHz, and a video camera. The target strength measurements are being analyzed. Presently, it is too early to conclude whether the results will change the abundance estimates. However, the results confirm earlier findings that target strength of sandeel is weak for both 38 and 120 kHz. In addition, measurements indicate that is it possible to separate I and II-group sandeel based on the changes in the frequency response of 18, 38, 120 and 200 kHz.

Preliminary studies of a new survey design were carried out. The basic idea of the new methodology is to increase acoustic coverage where dense concentrations of sandeel are observed. This so-called adaptive survey design may be necessary to improve the precision of the abundance estimates due to the extreme patchiness of sandeel.

Figure. Net pen for in situ measurements of target strength of sandeel.

Historical background

The spatial distribution of sandeel landings is considered as a good representation of stock distribution (ICES 2005). Annual landings for the period 1995-2005 distributed by ICES rectangles are shown in Figure 6. The highest landings from a single statistical square were taken in 1995 at the Viking Bank (162 000 t), the most northerly fishing gorund in the North Sea (Figure 7). However, in 1996 landings from the Viking Bank dropped substantially, and since 1997 have been close to null. Gradually, also other areas in the northern part of the North Sea dropped out of the fishery. Since 2000 the fishery in NEEZ has mainly been carried out in the Vestbank area in the southern part of NEEZ. In this area landings remained high in 2001 and 2002 due to the strong 2001 year-class. However, the 2001 year-class was only abundant in the Vestbank area, which resulted in a highly concentrated fishery and the decimation of the year-class before reach maturity in 2003. This, in turn, resulted in the collapse of the sandeel fishery in NEEZ. It should be noted that despite very good recruitment in the Vestbank area in 2001, other areas in NEEZ where the fishery had already collapsed, did not have sufficient recruitment to sustain a fishery. Since 2003 a very limited fishery in NEEZ has taken palace in the Vestbank area.

In contrast to the northern assessment area (north of 57°N) where the fishery has contracted, the fishery in the southern area seems to have spread out (Figure 6). This may be due to reduced abundance in the Dogger Bank area which has sustained the highest landings in the southern part. This in turn may have resulted in the fishermen exploiting fishing grounds with generally lower abundance.

Annual landings of sandeel in EU EEZ and NEEZ during the period 1995-2005 are presented in Figure 7. In NEEZ landings decreased by ~90% in 2003 and 2004, and by 94% in 2005. In 2006 there was only a limited experimental fishery in NEEZ In the EU EEZ the decrease in landings was less severe compared to NEEZ. In 2006 ~260000 t of a TAC of 300000 t were landed from the EU EEZ.

In the northern part of the North Sea the sandeel fishery contracted substantially and eventually collapsed. In the southern part of the North Sea the decrease in landings were also accompanied by marked changes in the fishing pattern. In 2001 extraordinary high numbers of 0-group sandeel were landed from the southern North Sea (which was also the case in the northern North Sea). In 2002 the 2001 year-class contributed to the highest number of I-group ever landed. (Figure 8b). Hence, in terms of total number landed of a single year-class (all age groups), the 2001 year-class is the highest on records (Figure 8d). From 1998 to 2002 there was a substantial increase in landings of I-group sandeel (Figure 8b). II^+-group sandeel which comprise the spawning stock, on the other hand, decreased during the same period (Figure 8d). This resulted in a decrease in SSB from well above b_{pa} in the late 1990s to below b_{lim} in 2001 (ICES 2006). Since 2004 SSB has been approximately half b_{lim}. The simultaneous increase in landings of I-group sandeel and the collapse of SSB, suggest that fishing mortality has been an important factor for the poor state of sandeel in the North Sea in recent years.

Surveys and experimental fishery in NEEZ in 2006.

Two sandeel surveys were carried out in 2006, one in April/May to estimate the abundance I^+-group sandeel and one in early August to estimate the abundance and distribution of 0-group sandeel. The methodology was the same as during the 2007 survey, except that only

NEEZ was covered in 2006. In addition, in April/May an experimental fishery using 6 commercial sandeel trawlers was carried out to estimate the abundance of the I-group sandeel (the 2005 year-class). The experimental fishery lasted for three weeks. Each trawler was allowed to fish without restrictions during two weeks, but had to fish and visit all know sandeel grounds in NEEZ during one week in order to describe the distribution of sandeel in NEEZ. Results from both the IMR survey and the experimental fishery were in agreement with the distribution in recent years as depicted in Figure 6, with the main concentration appearing around the Vestbank area. However, there were some promising results from Inner Shoal, an area which comprises two closely situated fishing grounds in 42F3 and 42F4 (see Figure 9), respectively. Inner Shoal has not sustained a significant fishery since 1998 (Figure 6). The 2005 year-class was neither sufficiently abundant nor the distribution sufficiently wide distribution for a regular fishery to be opened in NEEZ in 2006.

I^+-group sandeel typically go into hibernation in the latter half of June. 0-group, on the other hand, continue to feed until September/October. However, in the beginning of August 2006 relatively few schools of 0-group sandeel were observed during daytime. Therefore, the distribution of 0-group was described on the basis of dredge and grab sampling during night. In Figure 9 the average catch per of 0-group sandeel per ICES quadrants are presented. Because sandeel only bury in suitable habitats which may vary substantially on relatively small spatial scales, the average number per dredge haul should only be considered as a rough estimate of relative abundance.

The highest abundances of 0-group were found in the Vestbank area with an average of 437 sandeel per haul (10 min, 2 knots) in quadrant 43F3 and 94 in 43F6. In addition to lower abundance in the latter quadrant, only a small part of Vestbanken lies within 43F6l. Also at Inner Shoal East (42F4) there was relatively high abundance of 0-group sandeel, but no older sandeel. No I^+sandeelwere observed at Inner Shoal East during April/May survey either during daytime using echo sounder or in 6 dredge hauls during the night. The commercial fleet that participated in the experimental fishery did not report landings from this area in April/May. This suggests that Inner Shoal East had new recruitment in 2006 after several years without a fishery at this fishing ground. At Inner Shoal West, which is a small fishing ground in 42F3 where much of the bottom is too rough to allow sandeel trawling, we observed some sandeel schools during the April/May survey. The commercial fleet landed ~1000 t from this area, which the fishermen considered promising as there had been no extensive fishery at Inner Shoal since 1998.

All other areas in NEEZ had very low abundance of 0-group sandeel during the August survey. As there is no time seriesdredging from this time of the year, one cannot conclude whether the abundances observed at Vestbanken and Inner Shoal represent high concentrations. However, the survey do confirm that also the abundance of 0-group sandeel in 2006 is in accordance with the pattern of distribution in NEEZ the last 7-12 years with relatively high abundance at Vestbanken and low abundance elsewhere in NEEZ, except for Inner Shoal East where 0-group sandeel were abundant.

The experimental fishery in 2007

The common experimental fishery for sandeel between EU and Norway to estimate the abundance of the 2006 year-class was carried out between April 1 and May 6. During this period fishing effort was limited to 30% of deployed effort in 2005. EU regulated this according kW days, whereas Norway regulated effort to 25 trips, corresponding to 30% of trips in 2005. 25 Norwegian vessels did one trip each spread over the experimental fishing period. The different parties (EU and Norway) could fish up to 20 000 t in the other party's EEZ. This report focuses on two sandeel fishing grounds in NEEZ, Inner Shoal East in 42F4 and Diana-Charles Vann (Snorrehalet) in the Vestbank area (43F5). Most of the sandeel landed from NEEZ were caught at these fishing grounds. In addition, during the survey we carried out detailed mapping of these fishing grounds during and after the experimental fishery.

Norwegian vessels landed 15570 tonnes. during the experimental fishery, of which 700 tonnes were taken in the EU EEZ. 2000 tonnes were taken at Inner Shoal East, and the rest at Vestbanken (almost exclusively in 43F5). Already at the start of the fishery CPUE was very high in NEEZ. This attracted a relatively high number of Danish vessels to NEEZ, of which a majority were fishing at Inner Shoal East. Between April 5 and 21 (mainly before April 17) Danish vessel landed 8835 t from Inner Shoal East. Hence, ~11000 t were landed from Inner Shoal East, which correspond to the highest landings from a single ICES rectangle in the North Sea during the experimental fishery. The last Norwegian vessel left Inner Shoal East April 23. In agreement with new recruitment at Inner Shoal East in 2006, landings consisted almost exclusively of I-group sandeel.

Figure 10 shows landings per day during the fishery at Inner Shoal East in 2007. There was no trend in daily landings from the beginning of the fishery until the last vessel left the area (nor was there a trend in vessel size, Figure 11; hence, no trend in CPUE). The fleet never returned to Inner Shoal after April 23, except for one vessel searching for half a day.

Norwegian vessels landed about 8000 t from the fishing ground Diana-Charles Vann. It is a small fishing ground that consists of two separate areas with a total length ~13 nautical miles and average width slightly more than 1 nautical mile, except for an narrow extension of about 3 nautical miles (1 n mile – 1852 m). These fishing grounds are surrounded by rough bottom that does not allow trawling with commercial sandeel trawls. The relatively high concentration of 0-group sandeel from the Vestbank area in August 2006 (Figure 9) was sampled at Diana, Charles Vann and at nearby small fishing grounds. There was commercial fishing activity at Diana and Charles Vann during most of the experimental fishery. In between, the vessels left the Diana and Charles Vann for 2 to5 days, before returning. Hence, the fishing patter at this fishing ground was very different from that at Inner Shoal East, where fishing went on continuously until the fleet left area for good.

When not fishing at Diana and Charles Vann, the fleet was mainly fishing at nearby fishing grounds where relatively high concentrations of 0-group sandeel were observed in August 2006. Consequently, all sandeel fishing in NEEZ was carried out at fishing ground that had high abundances of 0-group sandeel in 2006.

As an indication of the fishing intensity at sandeel grounds, trawl trajectories from two days of fishing is plotted in Figure 12. Fishing like this can go on for weeks.

Sandeel survey in 2007
Mainly results relevant to the experimental fishery are presented in this survey report, with focus on the fishing grounds Inner Shoal East and Diana and Charles Vann where most of the sandeel in NEEZ were caught.

Average area backscatter coefficient values (s_A) per nautical mile for the various areas are presented in Figure 13. The s_A values should be interpreted with caution and only taken as an indication of relative abundance. Highest concentrations were observed at Vestbanken, Inner Shoal West and English Klondyke in NEEZ, and in the Dogger Bank area and Jyske Rev in the EU EEZ. In agreement with this, most of the landings in the EU EEZ were taken at Dogger, which is a large fishing ground, and Jyske Rev, whereas there were reported no landings from the Elbow Spit North. It should be noted that the acoustic registrations at Inner Shoal East was carried out after the fleet had stopped fishing there, in the EU EEZ close to 50% of the total landings in 2007 had been taken, whereas only about 20% of the total landings at Vestbanken had been taken. At sandeel grounds north of Vestbanken there was no fishing before the survey.

It is interesting to note that that at Outer Shoal and English Klondyke, where there has been very little fishing activity for last 6 and 8 years, respectively, relative high concentrations of sandeel were recorded in 2007. During the ordinary fishery from May 16 onwards, approximately 11 000 tonnes were landed from Outer Shoal, whereas Norwegian authorities closed English Klondyke in hope that this area may contribute to new recruitment farther northeast where sandeel abundance still was very low. The highest landings in NEEZ were taken at Vestbanken, where also the highest densities were recorded.

Inner Shoal was surveyed twice, on April 26-27 and on May 5, after fishing had stopped (last vessel left the area on April 23). During the first survey, only two small sandeel schools were observed at Inner Shoal East (see Figure 14). In agreement with the low abundance observe during daytime using echo sounder, only one of 7 dredge hauls contained sandeel (avg. 3.5 per haul). The second coverage at Inner Shoal East confirmed the very low abundance, with only 5 small schools observed. At Inner Shoal West, which is a much smaller fishing ground, much higher s_A values were obtained (Figure 13). All schools in this area were observed over rough bottom where sandeel trawls cannot be operated. These observations suggest that the experimental fishery almost completely decimated the sandeel stock at Inner Shoal East. Last timer there was a significant fishery at Inner Shoal was in 1998, i.e. 9 years ago. The Norwegian landings from Inner Shoal East consisted almost entirely of I-group sandeel. Hence, the new recruiting sandeel at Inner Shoal East in 2006 were probably fished down before reaching maturity (II-group).

Position of sandeel schools observed during the acoustic survey at Diana and Charles Vann is shown in Figure 15. Based on WMS data and trawl trajectories from the fleet, the area that allows trawling, is indicated in the figure. The survey was not designed to cover all potential sandeel habitats in the area, but to study the distribution of sandeel inside and outside the area that had been trawled during the experimental fishery. There were only a few sandeel school where trawling had taken place, whereas there were relatively high abundance of sandeel over rough bottom just outside. The behaviour of the fleet by leaving the area and then returning a couple of days later, suggest that sandeel from the rough ground gradually immigrate into the smoother area that allows trawling.

On the other hand, two sandeel schools that we sampled over rough bottom using bottom trawl with rock hopper gear, consisted of extraordinary large and old (Figure 16) with 30% being 4^{+}-group. Such old sandeel are hardly ever seen in commercial landings. Sampling of

two schools on the two nearby fishing grounds (using the same trawl on smooth bottom) revealed the typical age for commercial landings in recent years with total dominance of I-group. Average length and weight of sandeel on rough bottom was 20.4 cm 28.5 g vs. 13.3 cm and 8.2 g on smooth bottom. Although these results may not accurately reflect the age distribution on rough bottom, they suggest that rough bottom do indeed serve as refuges. Interestingly, such old sandeel were sampled on an unexploited fishing ground on the west coast of Norway (Bergstad and Høines 2001, Arch. Fish. Mar. Res. 49; 3-18), which suggests that the fishery has a substantial influence on the age distribution of sandeel and that sandeel is a relatively long-lived species. In the Vestbank area there are several places with rough bottom that cannot be trawled. This may explain why there is still some sandeel left in this area, whereas at most fishing grounds in NEEZ sandeel have been decimated in recent years.
Vestbanken and Inner Shoal West are the only sandeel grounds in NEEZ that have natural refuges.

Summary and conclusion

1. All sandeel grounds in the North Sea have been identified.
2. There seems to be good correspondence between acoustic registrations of sandeel concentrations and where fishermen target sandeel.
3. Sandeel schools can be identified by the frequency response of 18, 38, 120 and 200 kHz echo sounders.
4. The approximate size of sandeels can probably be determined by changes in the frequency response.
5. The experimental fishery seems to have decimated the sandeel stock at Inner Shoal East at the I-group stage, before reaching maturity.
6. The fact that it has been 9 year since there was an extensive fishery at Inner Shoal, suggests that local depletion may severely affect the productivity of sandeel at a fishing ground. At the Viking Bank where the productivity potential for sandeel seems to be extraordinary high, there has been no fishery since 1996, after the highest landings on records in 1995.
7. There was no indication of decreasing CPUE during the decimation of sandeel at Inner Shoal East. This severely compromises the use of CPUE as a method for managing sandeel. It has been long recognized that CPUE is not an adequate method for managing schooling species as high efficiency can be maintained at low abundance. Sandeel might be particularly vulnerable as the distribution is confined to well know, distinct areas with suitable habitat.

Future challenges

The results so far are promising for using acoustic survey to measure the abundance of sandeel feeding in the water column during daytime. However, there is evidence to suggest that a proportion of sandeel may stay behind in the sand during daytime. To obtain a precise estimate the abundance using acoustic, it is essential to estimate how much sandeel that stay behind in the sand and how this proportion potentially varies on different time scales, e.g. between days and between years.

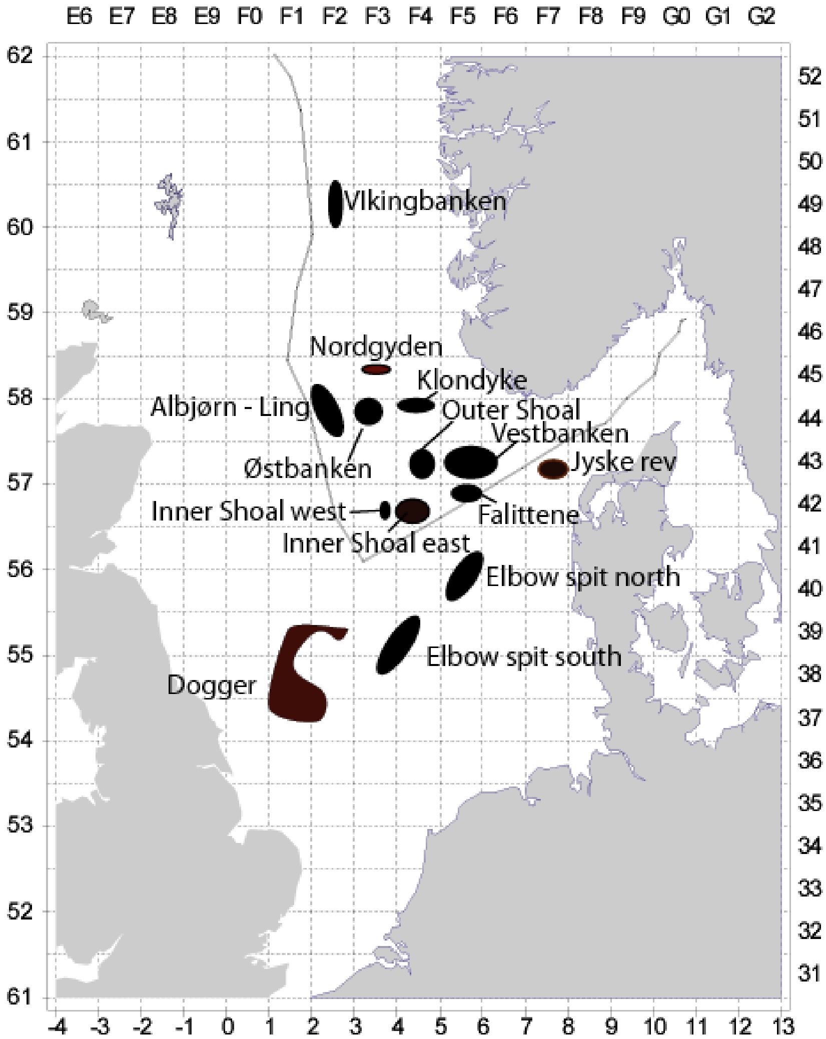

Figure 5. Indication of sandeel fishing grounds in the North Sea covered during the IMR survey in April-May 2007. Relative sandeel abundance was measured using echo sounder during daytime and dredge and van Veen grab during night.

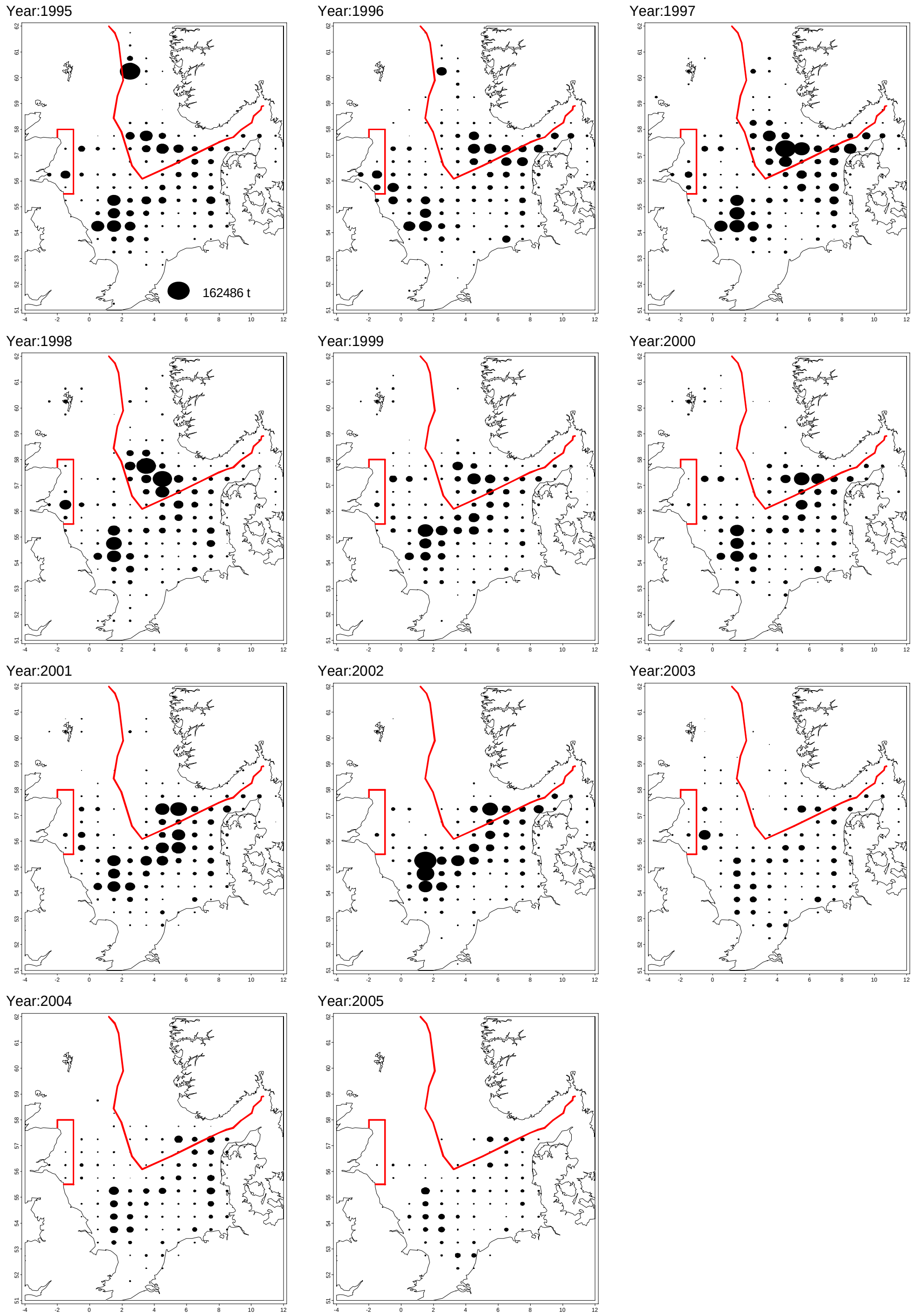

Figure 6. Landings of Sandeel by year and ICES rectangles for the period 1995-2005. The area of the circles corresponds to landings by rectangle. All rectangle landings are scaled to the largest rectangle landings shown at the 1995 map. The area that was closed to sandeel fishery on the east coast of Scotland in 2000 and the boundary between the EU and the Norwegian EEZ are shown in the map (modified from ICES 2006)

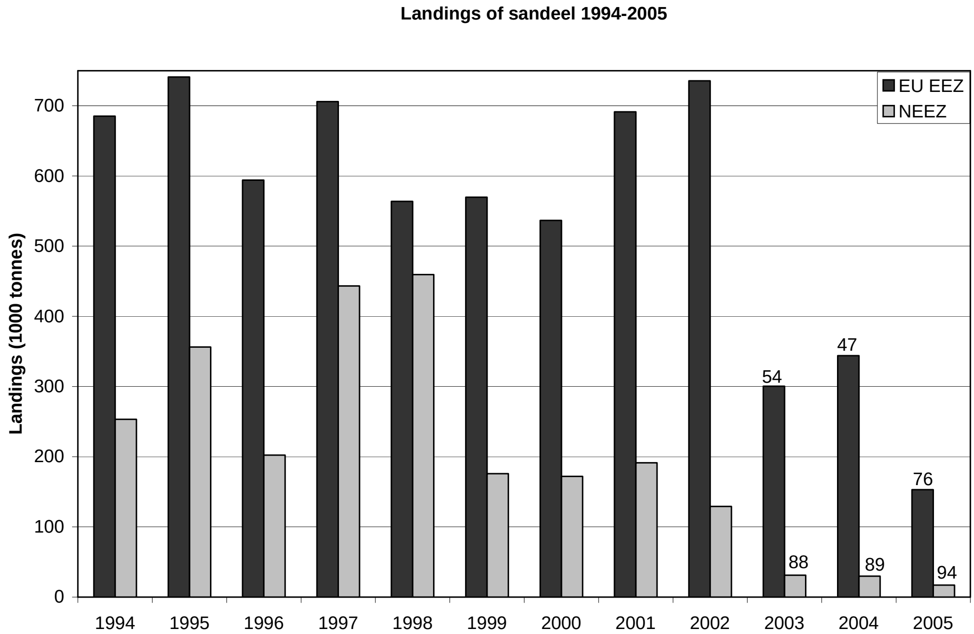

Figure 7. Landings of sandeel in the EU EEZ and NEEZ in 1994-2005. For 2003-2005 numbers indicate reduction in landings in the two zones compared to 1994-2002.

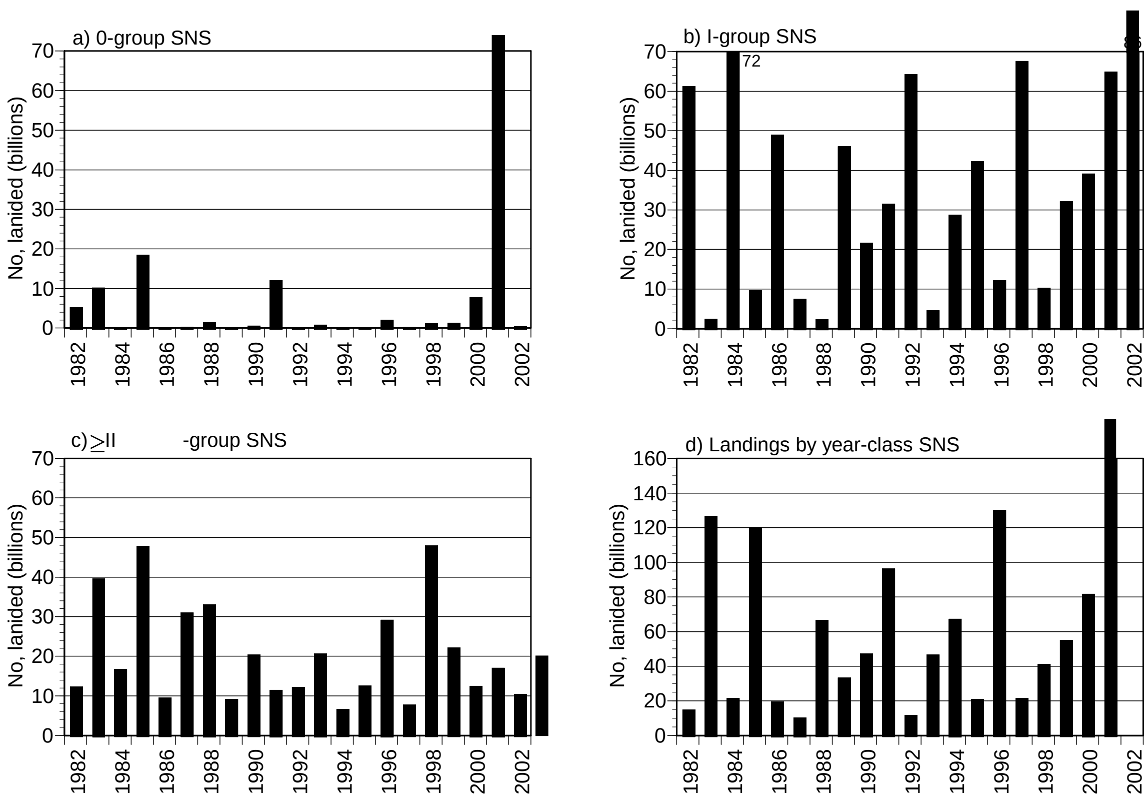

Figure 8. Landings of 0-group (a), I-group (b), ≥II-group (c) and per year-class (d) from the southern Norht Sea (SNS) between 1982 and 2003.

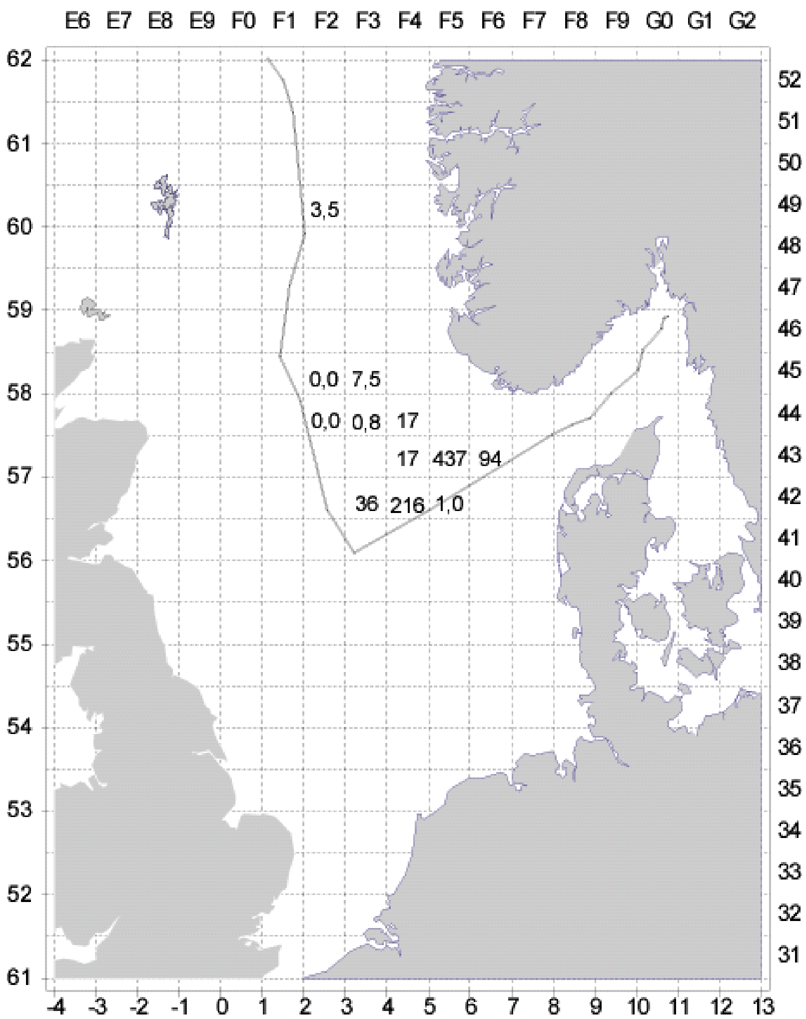

Figure 9. Average catch of 0-group sandeel per ICES quadrants in a modified scallop dredge (Danish type) in NEEZ in August 2006.

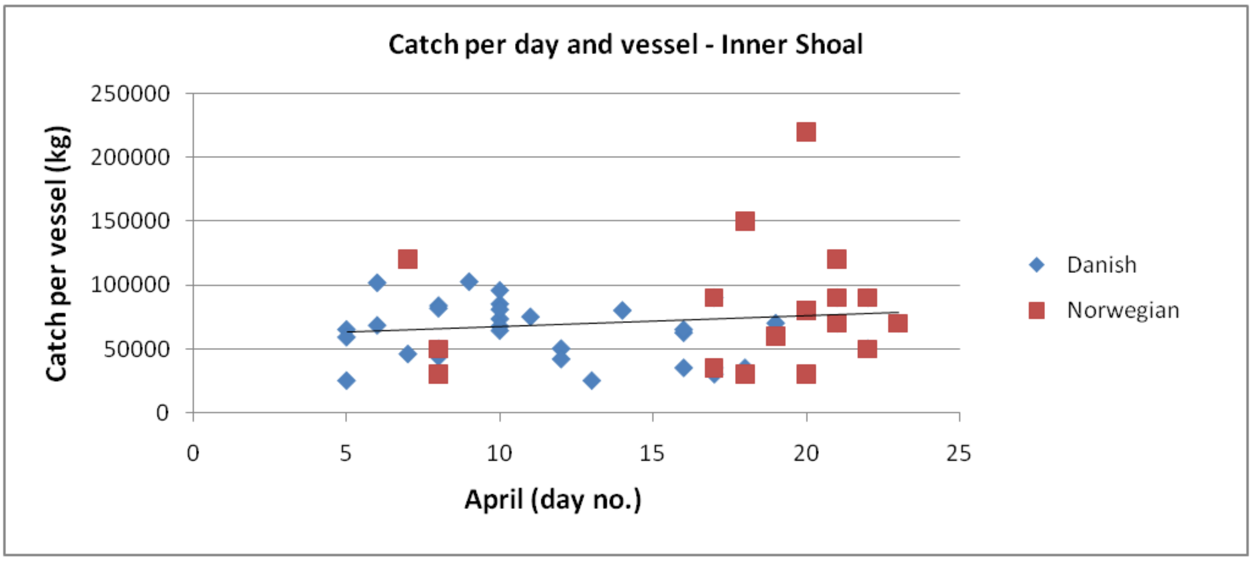

Figure 10. Sandeel catches at Inner Shoal East in April 2007. Norwegian data represent landings per day for each vessel, while Danish data are average catches per trip (e.g. if one Danish vessel spent 5 days on Inner Shoal, caught 500 t, left port April 2 and returned to port April 8, this would result in a catch of 100 t on April 5).

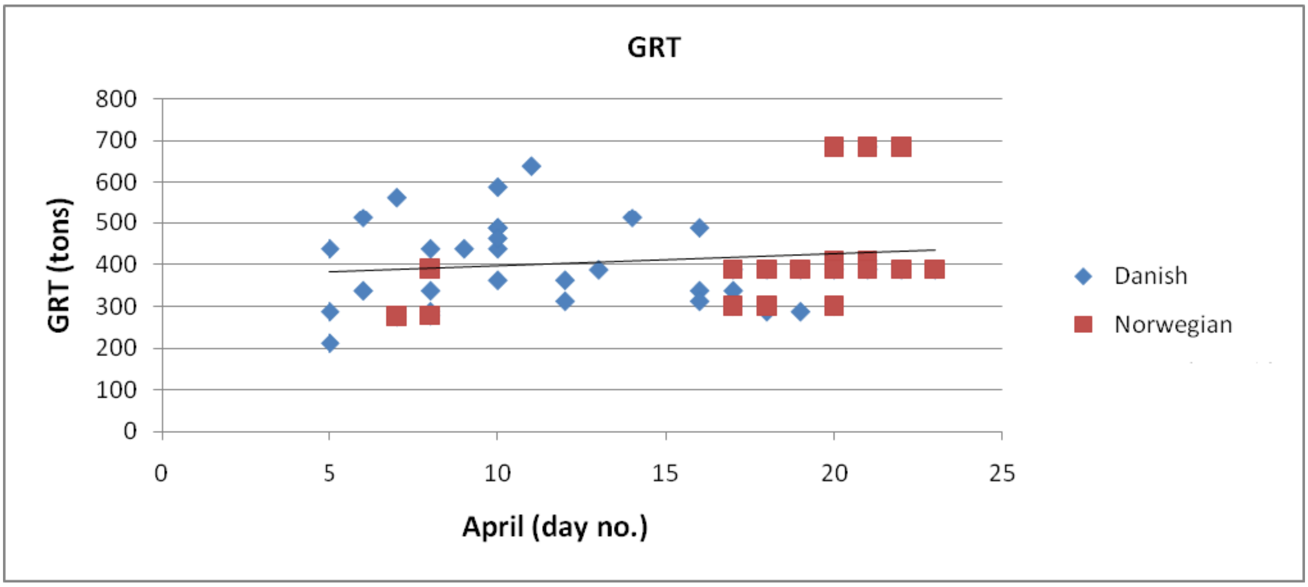

Figure 11 Size (GRT) of the vessels fishing at Inner Shoal East in April 2007. Two very large Norwegian vessels fishing in the end of the period were excluded (also in Fig. 5) because they contributed to a significant increase in vessel size over the period.

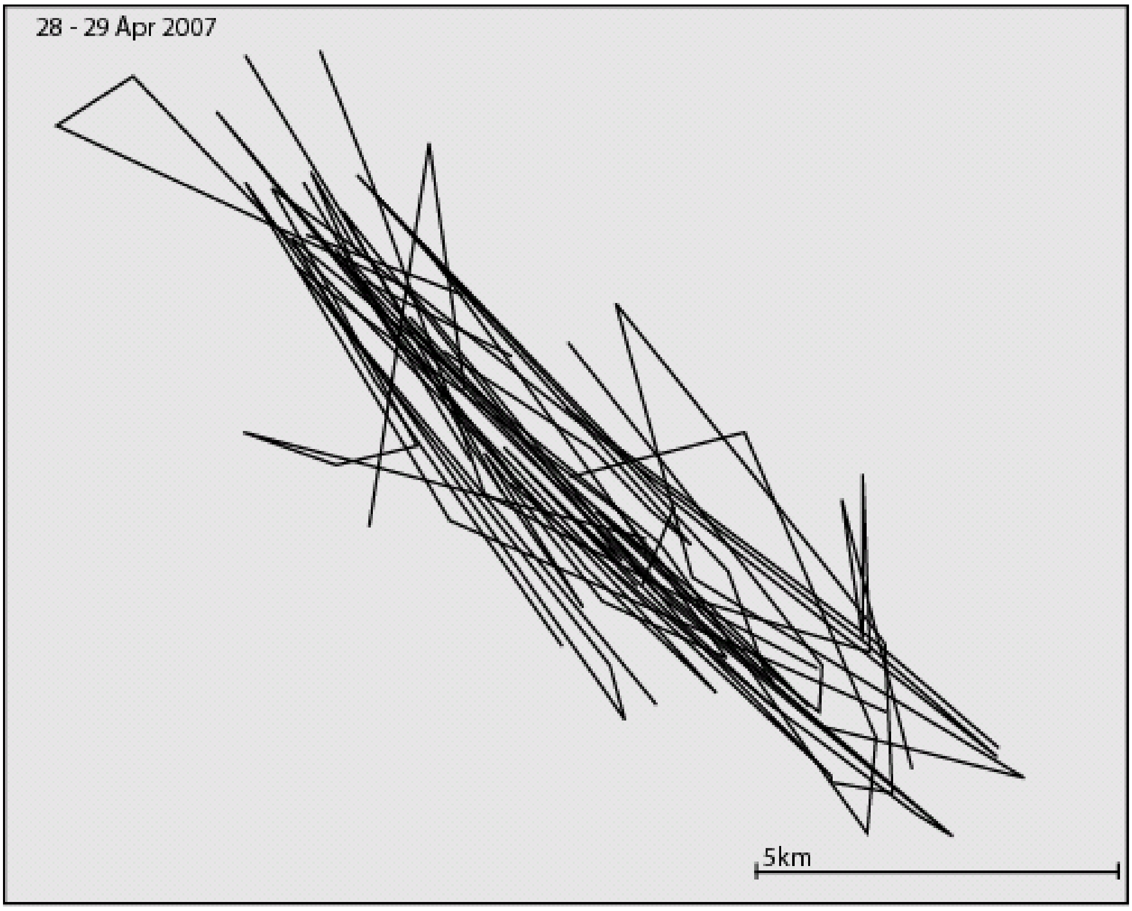

Figure 12. Trawl trajectories from two days of fishing at Vestbanken West. 5 vessels participated the first day and 3 vessels the second day.

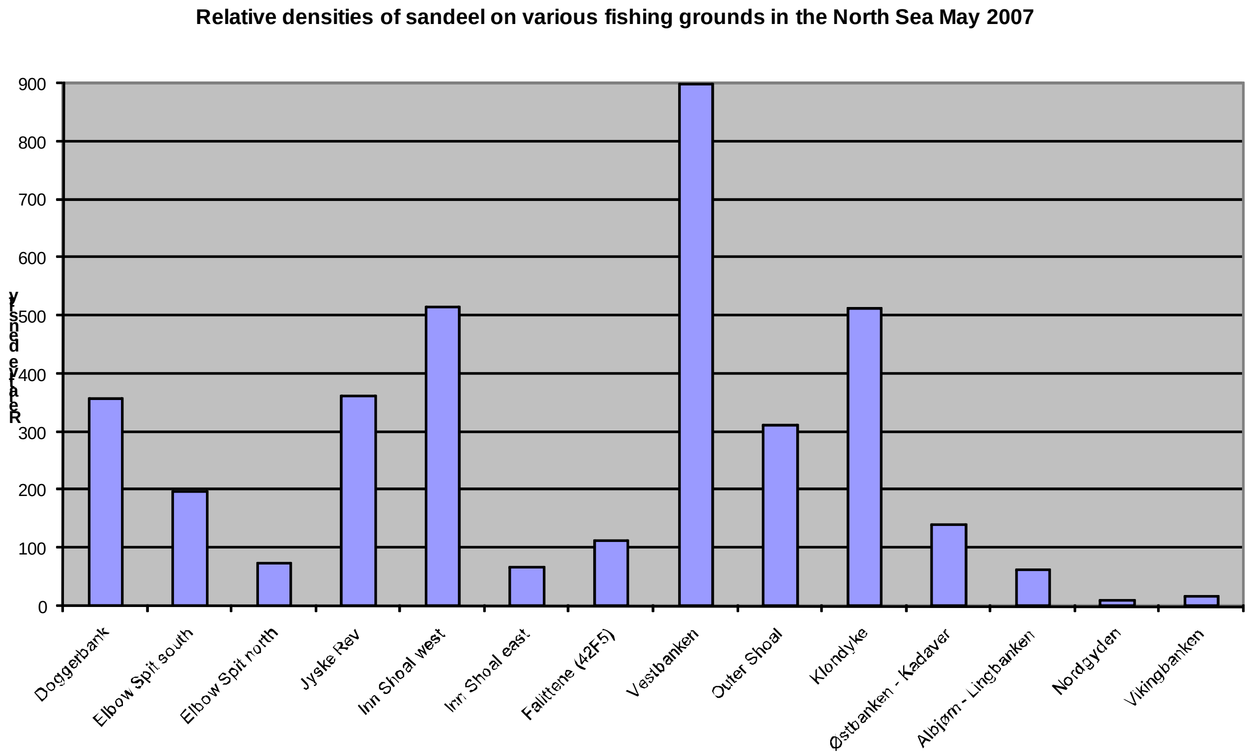

Figure 13. Relative densities (sA per nautical mile) of sandeel on various fishing grounds in the North Sea (Fig. 3) in May 2007 as measured by echosounder. The values should only be considered as indications of densities. Densities at Inner Shoal East and West are the averages of two surveys.

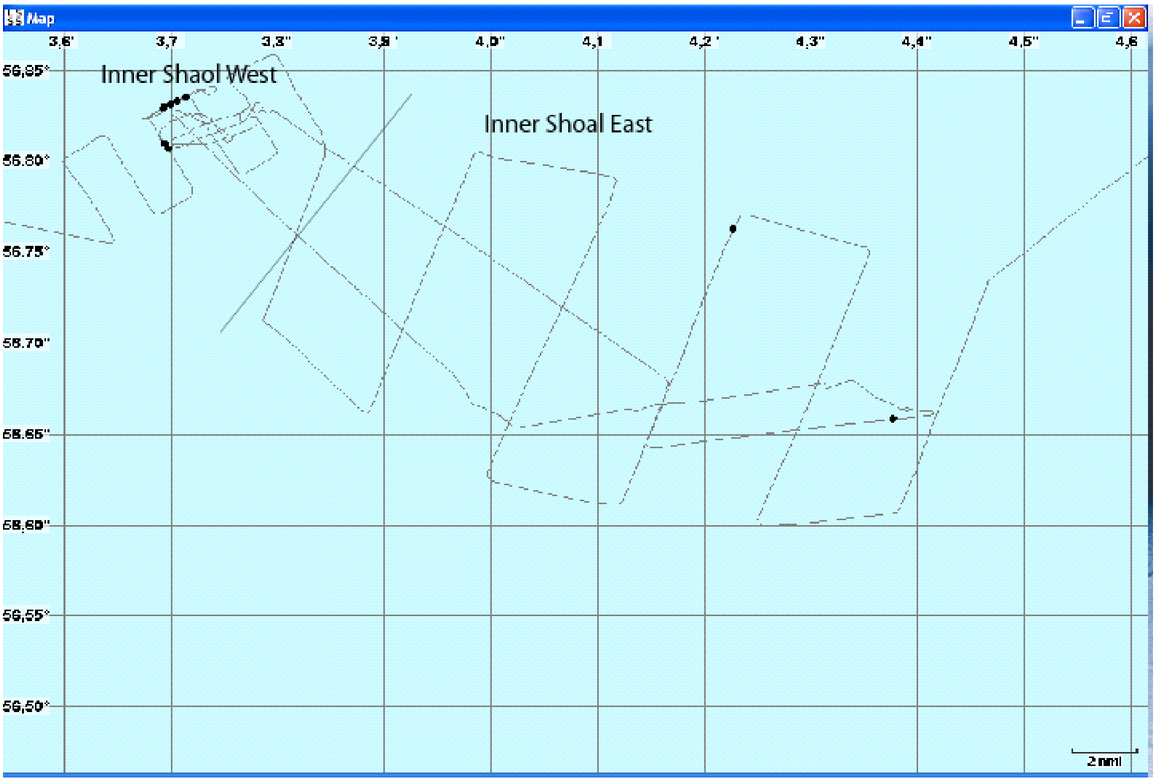

Figure 14. Acoustic survey at Inner Shoal East and West. Black dots indicate sandeel schools.

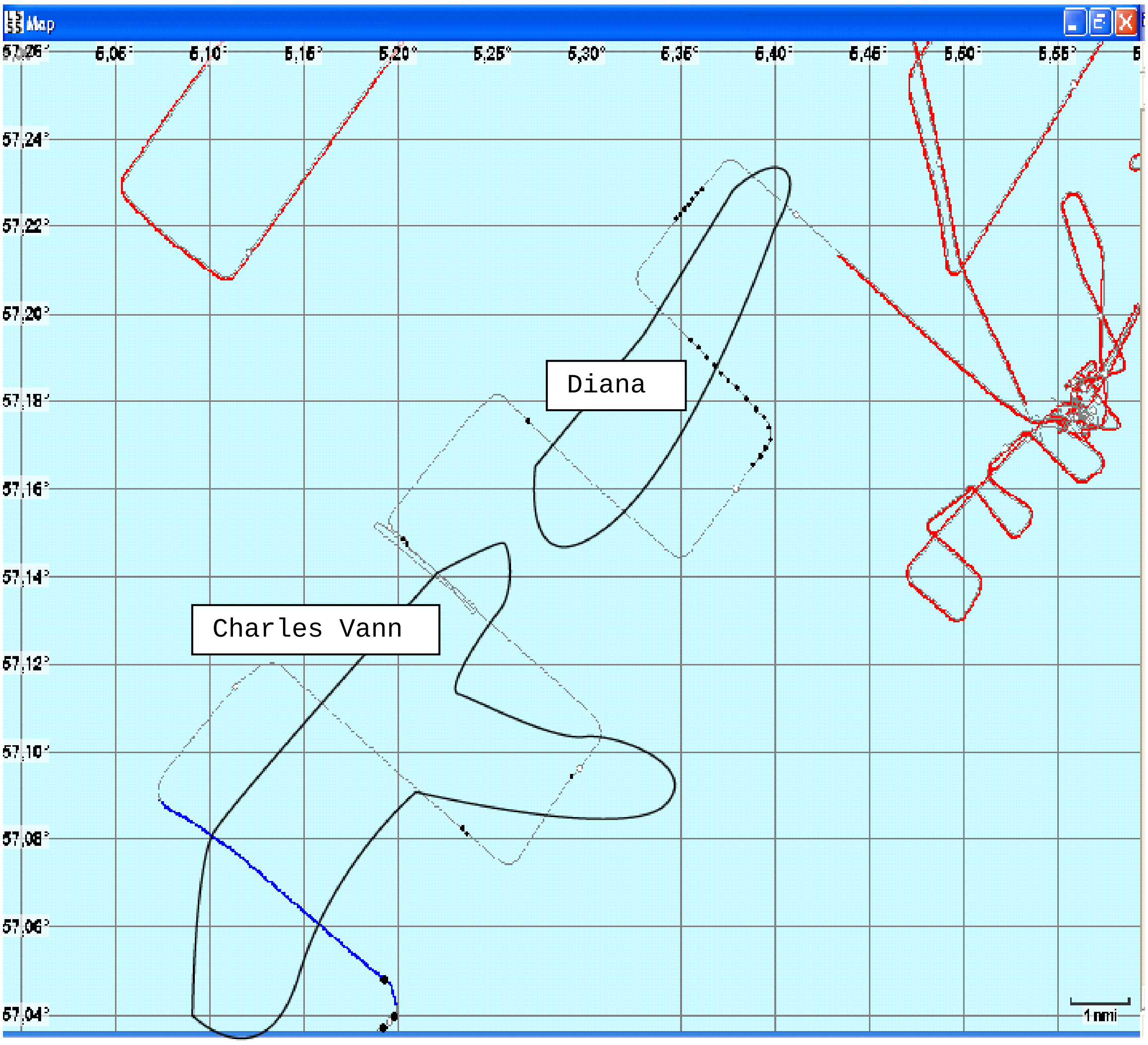

Figure 15. Acoustic survey at Diana and Charles Vann on Vestbanken. Black dots indicate sandeel schools. Areas that can be trawled are indicated.

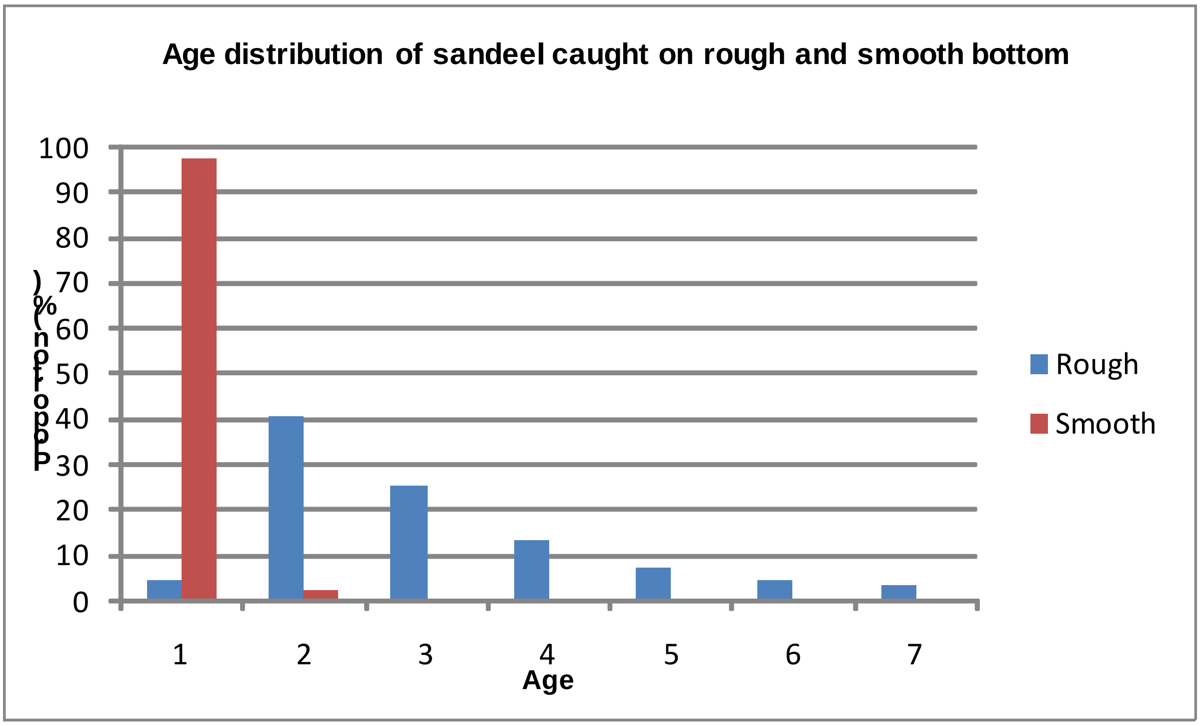

Figure 16. Age distribution of sandeel caught on rough and smooth bottom (outside and inside the fishing ground) on Vestbanken in May 2007.