Survey report

International Acoustic Herring Survey

Norwegian Sea

R/V "G.O. Sars", 28/4-2/6, 1999

Survey number 1999006

Introduction

This survey forms part of a coordinated effort organised under the auspices of ICES to undertake an international acoustic herring survey in the Norwegian Sea in April-May, 1999. The main aim of the survey was to obtain an acoustic estimate of the Norwegian spring spawning herring stock and to study the migration pattern of the herring stock in 1998. Hydrographic and plankton studies were included as an important part of the joint survey effort. The survey was planned under "The ICES planning group on Surveys on Pelagic Fish in the Norwegian Sea (PGSPFN)" which met in Lysekil in August 1998 (anon. 1997).

A total of four vessels, from Iceland, The Faroes, EU (German vessel) and Norway participated and carried out a coordinated survey effort, including a large scale coverage of the herring stock and ad-hoc mini-surveys in areas of high herring densities. The German R/V "Walther Herwig III" and the Norwegian R/V "G.O.Sars" carried out the coordinated large scale acoustic coverage of the eastern part of the Norwegain Sea, thus covering most of the herring stock. The Faroes and Icelandic vessel covered the western part of the Norwegian Sea and covered the westernmost parts of the stock, in particular from 66° to 68° N.

The present report gives an account of the survey as carried out by the R/V "G.O. Sars". The data collected by all the participating vessels will be brought together during a meeting to take place in Hamburg, Germany, 18-20 August 1999, with the aim to produce an official acoustic estimate of the herring stock and prepare associated results to be presented at the 1999 ICES Statutory meeting in Sweden, and to be reported to the "Northern Pelagics and Blue Whiting Working Group".

Participants

Valantine Anthonypillai	28/4-15/5	
Johan Blindheim	16/5-2/6	
Ole Gullaksen	16/5-2/6	
Terje Haugland	28/4-2/6	
Kjellrun Hiis Hauge	16/5-2/6	
Jens Christian Holst	28/4-24/5	Survey leader first period
Magnus Johannessen	21/4-21/5	
Tor Johansson	28/4-2/6	
Kåre Lauvås	28/4-15/5	
Kjell Arne Mork	28/4-15/5	
Jan Henrik Nilsen	16/5-2/6	
Annlaug Nøttvedt	28/4-15/5	
Egil Ona	25/4-2/6	Survey leader second period
Rolf Sundt	28/4-24/5	
Elna Meland Sælen	28/4-15/5	
Bente Skjold	16/5-2/6	

Methods

Acoustic registrations

Acoustic recordings were made by a 38 kHz Simrad EK500. Postprocessing and allocation of area backscattering strengths, Sa, to species or groups of species was done using the Bergen Echo Integrator (BEI).The following characteristics applied for the echo-sounder:

TRANSDUCER DEPTH	7.5m
ABSORBSION COEF	10db
TIME VARIED GAIN	20 log R
PULSE LENGTH	MEDIUM
BANDWITH	WIDE
MAX POWER	2000W
2 WAY-BEAM ANGLE	21.0db
Sv TRANSDUCER GAIN	27.2db
Ts TRANSDUCER GAIN	27.1db
ANGLE SENSIVITY	21.9
3db BEAMWITH	7.1deg
ALONGSHIP OFFSET	-0.08deg
ATHW OFFSET	0.05deg
PING INTERVAL	0.0
SOUND VELOCITY	1470m/s

Trawl sampling

Pelagic trawling was carried out using a "Åkra pelagic trawl" with a vertical opening varying from 25 to 30 meters depending on the mode of trawling and trawling depth. When hauled in the surface the trawl was fitted with two bouys on each of the fore ends of the wings which allowed sampling from the very surface and down to about 25 m. When hauled in the surface wirelengths of 250 m were used. When hauled at deep registrations, a Scanmar depth sensor and a Simrad trawl eye was fitted to the trawl.

Surface or deep trawl hauls of 30-60 minutes duration were in general performed to identify acoustic registrations and to obtain herring samples to be used in the acoustic estimate (Fig.1).

Fish sample analysis

Random samples of up to 100 specimens of herring and blue whiting were taken from the trawl catches. The samples were worked up according to the standard procedures of the IMR. Stomach samples were collected from the 30 first individuals in each sample.

Acoustic estimate

The acoustic registrations were allocated to 5 major groups: herring, blue-whiting, mesopelagic fish, plankton and a mix of mesopelgic fish and plankton, based on the characteristics of the echo registrations and the composition of the trawl catches made in the corresponding area and depth. In areas where herring and blue

whiting appeared in mixed registrations, herring was allocated a somewhat higher percentage of the total Sa value than indicated from the trawl catch composition. This was done due to a presumed higher catchability of the blue whiting.

The length dependent density coefficient: $C_f = 1.23*106*L^{-2.0}$ was used for conversion of Sa values into age stratified estimates of biomass of herring by statistical square. The computations were done using the standard IMR programmes PL042K, PL045K and PL043K.

CTD

The CTD probe was lowered to 1000 meters or to just above the bottom at shallow stations, except for some stations at the Svinøy and Gimsøy transects where hydrography was recorded to the bottom (Fig 2).

Nutrients samples and chlorophyll-a

The CTD probe was equipped with 12 five litres water samplers. Samples for analysis of nutrients were collected at 1000, 800, 500, 400, 300, 200, 150, 100, 75, 50, 30 and 10 meter depths, or with better depth resolution at shallower stations. Samples for analysis of chlorophyll-a were collected at 100, 70, 50, 30 and 10 meter. Information about nutrients and chlorophyll-a sampling is listed in table 1.

Zooplankton sampling

Zooplankton sampling was carried out using WPII ring and MOCNESS plankton trawl with 1^2 m opening equipped with 8 nets (Fig.3). WPII ring were deployed in vertical hauls 200-0 m (in addition bottom to 0 hauls were taken at selected stations at the Svinøy and Gimsøy transects) and MOCNESS in oblique hauls in the depth intervals 700-500-400-300-200-100-50-25-0. Information about zooplankton sampling is listed in table 1.
Samples were split for biomass and formaldehyde preservation. The biomass part was sieved through 2000,1000 and 180 µm mesh size and jellies, euphausiids, natatiniids and teleosts were sorted out for separate weighing
In order to get a preliminary idea of biomass distribution, dryweight was estimated onboard using a stabilised weight with 0.0000 kg level of accuracy. All samples were taken to IMR lab for more accurate measurements.

Results and discussion

Herring distribution.

Herring was observed in large parts of the surveyed area, but more northerly and westerly distributed than compared with the situation last year (Fig. 4). Based on the data from all participating vessels the zero line could be drawn in all areas except from in the north and NE towards the Barents sea.

Like in 1998 hardly any registrations were made close to the Norwegian coast between 62°N and 68° N

Herring abundance

Based on the acoustic registrations, the scrutinised acoustic integrator values (Fig. 5) and the analysed fish samples, an age structured estimate of the herring in the surveyed area was run (Table 2). The acoustic estimate presented here is based on the data collected by the F/F Walter Herwig, F/F G.O.Sars, F/F Arni Fridriksson and F/F Magnus Heinason.

In squares within the surveyed area not covered by any vessel, Sa values were interpolated from the neighbouring squares. A simple algorithm, weighting the four nearest neighbouring squares by 2, while the next second nearest four got a weight of 1, was applied.

Table 2. Age stratified estimate of Norwegian spring spawning herring in the Norwegian Sea, RV Árni Fridriksson, RV G.O.Sars, RV Magnus Heinason and RV Walther Herwig III, May, 1999. Numbers in millions, weight in thousand tonnes, length in cm, mean weight in grams.

Age	2	3	4	5	6	7	8	9	10	11	12	14	15	Total
Numbers	212	2191	322	965	3067	11763	6077	853	258	5	14	158	128	26013
Percent	0.8	8.4	1.2	3.7	11.8	45.2	23.4	3.28	1.0	0	0	0.6	0.5	100
Mean length	20.93	26.37	29.95	32.11	32.54	33.25	33.90	35.05	35.70	36.25	36.68	37.59	38.33	32.69
Weight	15.0	319.0	65.9	230.4	737.1	2964.6	1627.3	243.9	81.4	1.5	4.9	55.2	46.4	6392.9
Mean weight	71	146	205	239	240	252	268	286	315	298	351	350	363	246

Evaluation of the acoustic estimate.

Weather

Except for two short periods with wind of gale and storm force, the survey was run under favourable conditions in calm weather.

Herring samples

The obtained number of herring samples available was lower than last year. Unfortunately the F/F Walter Herwig was not able to obtain samples due to a defect winch. Partly the low numbers of samples available was compensated for by a fairly uniform size distribution throughout large parts of the surveyed area

Scrutinizing and mixed registrations

Like during the last year, herring and blue whiting appeared in mixed concentrations making the scrutinising process difficult in some areas.

This year the herring appeared either as dense schools close to the surface (eastern area) or as larger schools in the deep (western area).

Blue whiting distribution

Blue-whiting was distributed over large parts of the surveyed area (Fig. 6). As opposed to last year the blue whiting and the herring had a fairly good overlap in geographic distribution. The strong1996 yearclasses constituted most of the blue-whiting biomass, reflecting that the adults were out of this area on their southern spawning migration. Since last year much of the strong 1995 yearclass has matured and was out of the area at this time of the year.

Hydrography

The main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the south western Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate, Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last two to three decades that a similar layer has been observed all over the Norwegian Sea.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. Due to the influence from the EIC, the NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward, its western branch often reaching the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge.

It has been shown that the distribution of the water masses in the Nordic Seas is largely controlled by atmospheric forcing. Hence, the lateral extent of the NwAC, and consequently the position of the Arctic Front, is closely correlated with the large scale distribution of the atmospheric sea level pressure. This is clearly indicated for example by the correlation with the winter index of the North Atlantic Oscillation. As a result, the Atlantic water now has a far more easterly distribution than it had during the 1950s and 1960s when the herring had a more westward distribution during the feeding season, in western part of the Norwegian Sea, all the way over to Jan Mayen

and in the Iceland Sea (Which was favoured by larger supply of Atlantic Water to the North Icelandic branch of the Irminger Current) .

The observations from May 1999 are suggestive of a rather large influence from the EIC. This is indicated by relatively large volumes of the intermediate water of Arctic origin, lying under the Atlantic Water in the NwAC. In the Svinøy Section (Fig.) a core of water with salinities ranging below 34.85 represents a clear signal of the strong Arctic influence. Similar conditions have not been observed since 1978. It is further indicated by a somewhat more narrow NwAC in 1999 than in 1998.

In general, however, as observed in the Faroe-Shetland Channel, both temperature and salinity of the inflowing Atlantic water have been increasing during the last two to three decades. Conditions in May 1999 were in agreement with this, showing relatively high values in both temperature and salinity. In the surface layer the temperatures were, however, somewhat lower than in 1998. This is indicated by considerably less water warmer than 8°C in 1999 than in 1998. As seen in Fig.7, there was only a small area at around 66°N and 6°E with temperatures above 8°C in 1999, but still, the surface layer temperatures were between 6.5 and 7°C all the way to 72°N

Four sections across the area are shown in Figs 14, 15, 16 and 17, 1) the Svinøy Section toward NW from about 62°N on the Norwegian coast, 2) along 66.9°N, 3) the Gimsøy Section toward NW off the Lofoten Islands and 4) along 70,4°N. The Svinøy and Gimsøy lines are standard sections which have been observed regularly since 1978. These show that the Atlantic water was shallow in May 1999 and the Arctic intermediate waters were accordingly voluminous. Hence, the vertical extent of the Atlantic Water in the Gimsøy Section for instance, was only to between 500 and 600 m depth while its maximal observed extent is to about 1000 m.

Figure 18 shows profiles of the upper layer density at three stations respectively in the southern, central and northern part of the survey area. These are shown to indicate that a mixed surface layer has developed well during the spring of 1999. This may support a relatively successful spring bloom and consequently, good feeding conditions for zooplankton and next, for herring.

Table 1. Listing of CTD-stations, water bottles and plankton net hauls.

CTDst.	Lat	Long	Nutr. Chloro.	WPII (m)	MOC
601	62.367	5.200	X	120-0	
602	62.485	4.945	X	190-0	
603	62.602	4.690	X	170-0	
604	62.720	4.333	X	170-0	153-0
605	62.838	4.175	X	600-200-0	
606	62.957	3.917	X	200-0	700-0
607	63.073	3.657	X	950-200-0	
608	63.192	3.395	X	200-0	
609	63.310	3.133	X	1050-200-0	
610	63.427	2.868	X	200-0	
611	63.663	2.338	X	1400-200-0	699-0
612	63.898	1.802	X	200-0	
613	64.135	1.262	X	2316-200-0	
614	64.370	0.728	X	200-0	
615	64.667	0.000	X	200-0	
616	64.667	-0.333	X	2600-200-0	700-0
617	64.167	-0.333	X	200-0	
618	64.167	2.133	X	200-0	
619	64.167	4.583	X	200-0	701-0
620	64.167	6.000	X	200-0	
621	65.167	7.000	X	200-0	251-0
622	65.137	5.885	X	200-0	
623	65.167	4.600	X	200-0	
624	65.167	2.200	X	200-0	698-0
625	65.167	1.325	X	200-0	
626	65.167	-0.200	X	200-0	
627	65.167	-0.800	X	200-0	
628	65.167	-1.383	X	200-0	
629	65.167	-1.975	X	200-0	
630	65.167	-2.592	X	200-0	701-0
631	65.750	-2.583	X	200-0	
632	65.750	-1.167	X	200-0	
633	65.750	0.267	X	200-0	696-0
634	65.750	1.700	X	200-0	699-0
635	65.750	3.117	X	200-0	
636	65.750	4.550	X	200-0	708-0
637	65.750	6.000	X	200-0	
638	66.333	6.000	X	200-0	649-0
639	66.333	4.550	X	200-0	
640	66.333	3.117	X	200-0	702-0
641	66.333	1.700	X	200-0	
642	66.333	0.267	X	200-0	
643	66.333	-1.167	X	200-0	
644	66.333	-2.550	X	200-0	701-0
645	66.917	-2.550	X	200-0	
646	66.917	-1.158	X	200-0	
647	66.917	0.027	X	200-0	696-0
648	66.917	1.708	X	200-0	
649	66.917	3.117	X	200-0	
650	66.917	4.550	X	200-0	700-0

651	66.917	6.015	X	200-0	
652	66.917	7.467	X	200-0	
653	66.917	9.000	X	200-0	308-0
654	67.583	9.000	X	200-0	
655	67.583	6.817	X	200-0	702-0
656	67.583	4.633	X	200-0	
657	67.605	2.483	X	200-0	697-0
658	68.167	3.233	X	200-0	
659	68.167	5.000	X	200-0	
660	68.138	9.662	X	200-0	697-0
661	68.167	11.283	X	160-0	
662	68.167	13.000	X	130-0	
663	67.833	12.583	X	100-0	
664	67.650	13.517	X	200-0	
665	68.430	14.013	X	100-0	
666	68.512	13.783	X	100-0	121-0
667	68.568	13.583	X	128-0	
668	68.733	13.167	X	110-0	
669	68.850	12.800	X	200-0	
670	69.033	12.283	X	200-0	701-0
671	69.233	11.617	X	200-0	
672	69.483	10.950	X	200-0	
673	69.700	10.267	X	200-0	701-0
674	69.950	9.583	X	2800-200-0	
675	69.250	6.133	X	200-0	
676	69.250	2.608	X	200-0	
677	69.250	1.833	X	200-0	
678	69.250	-1.000	X	200-0	699-0
679	70.417	-1.000	X	200-0	
680	70.417	1.850	X	200-0	701-0
681	70.417	4.683	X	200-0	
682	70.417	7.500	X	200-0	
683	71.583	7.500	X	200-0	
684	71.583	5.000	X	200-0	693-0
685	72.083	6.067	X	200-0	
686	72.083	7.792	X	200-0	
687	72.083	9.583	X	200-0	
688	71.000	10.683	X	200-0	
689			X	200-0	702-0

Table 1. Continued.

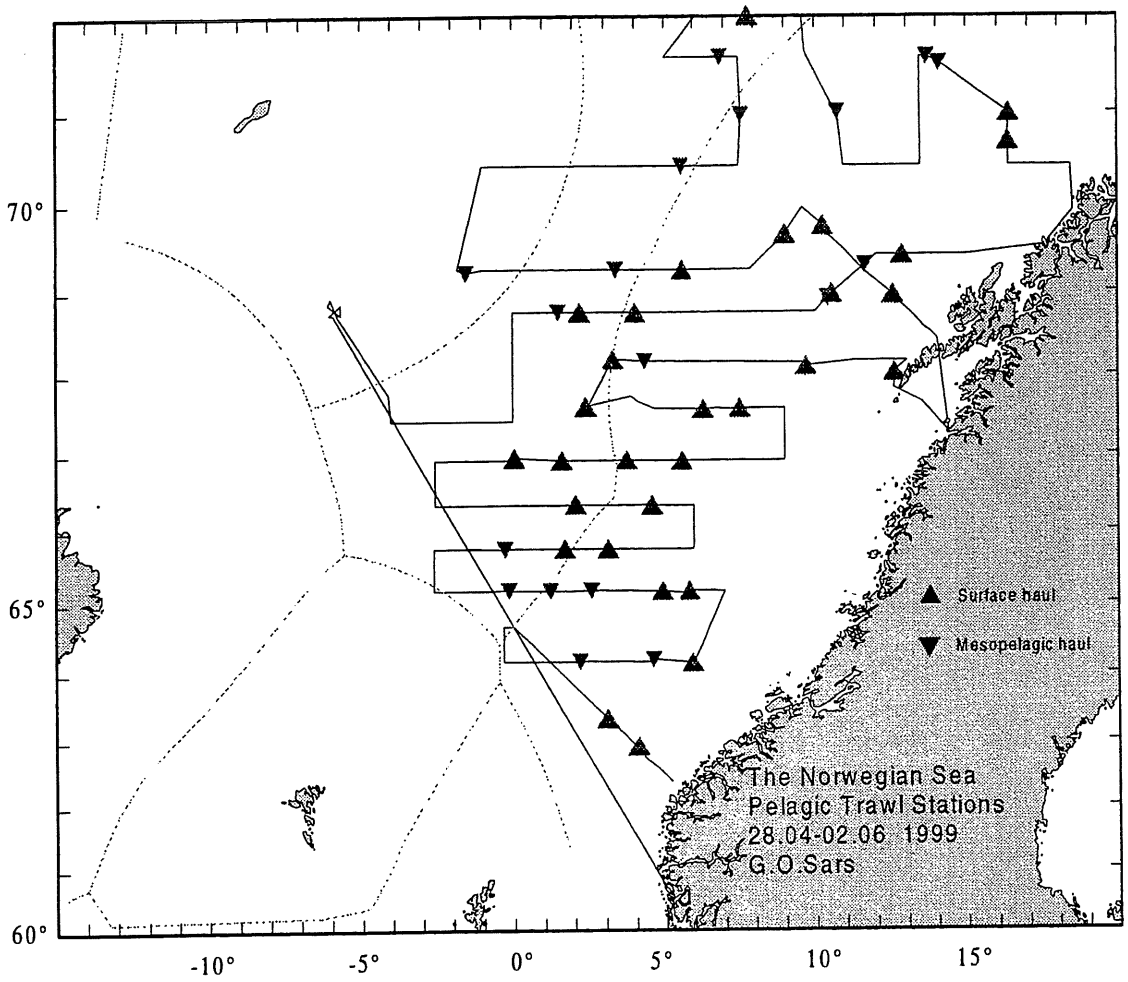

Figure 1. Survey transects and pelagic trawl stations of «G.O.Sars» during 29/4-2/6-1999.

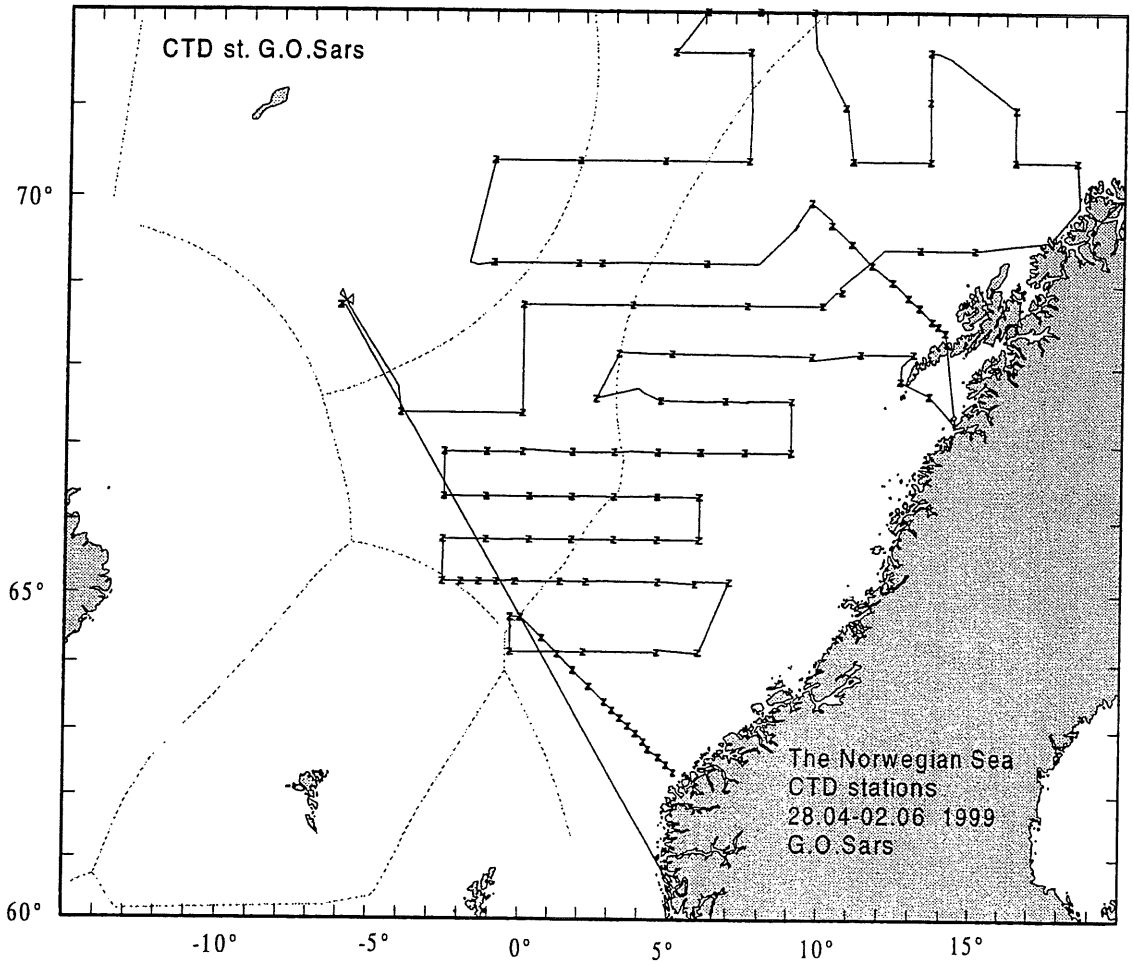

Figure 2. CTD-stations taken during the period 1/5-1/6, 1997.

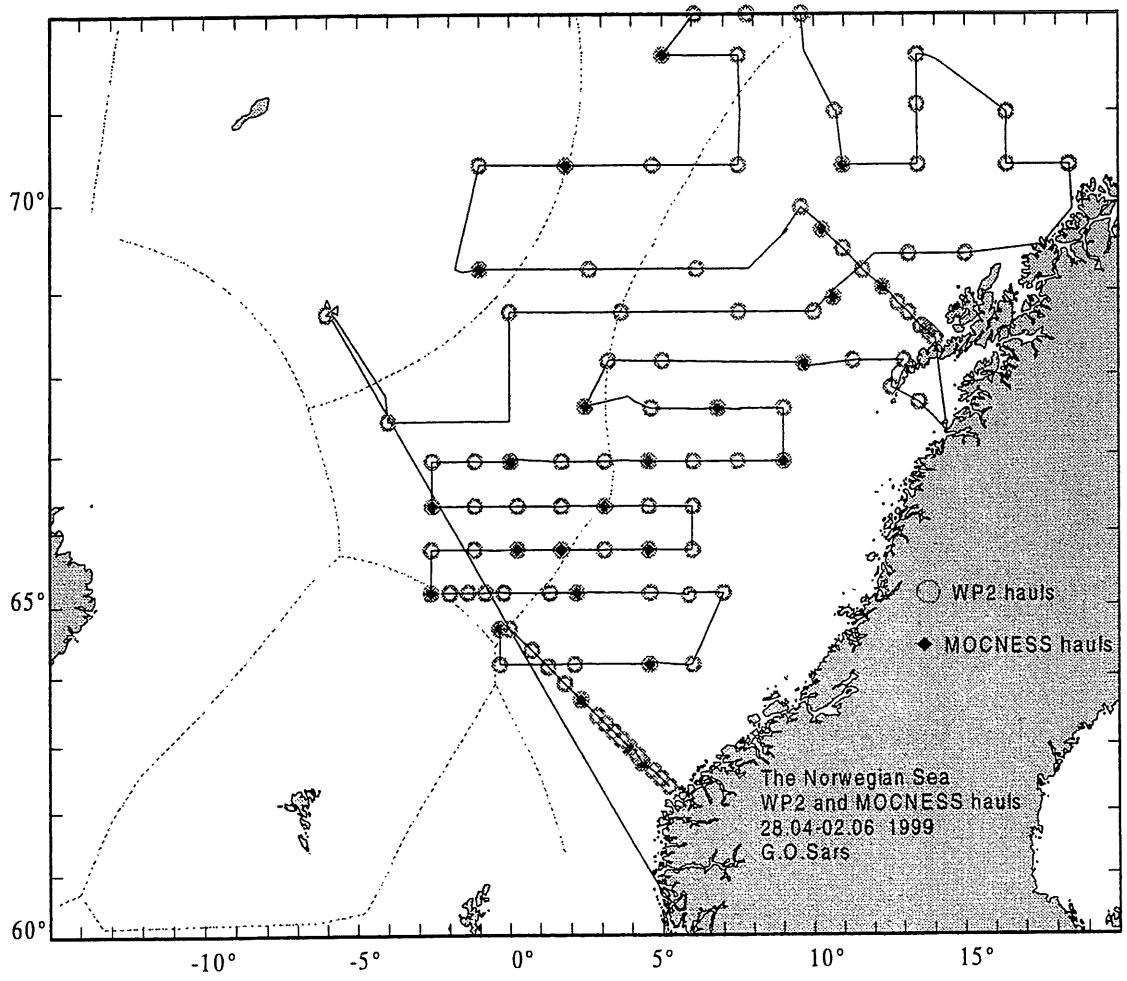

Figure 3. Mocness and WP2 hauls taken during the period 1/5-1/6, 1997.

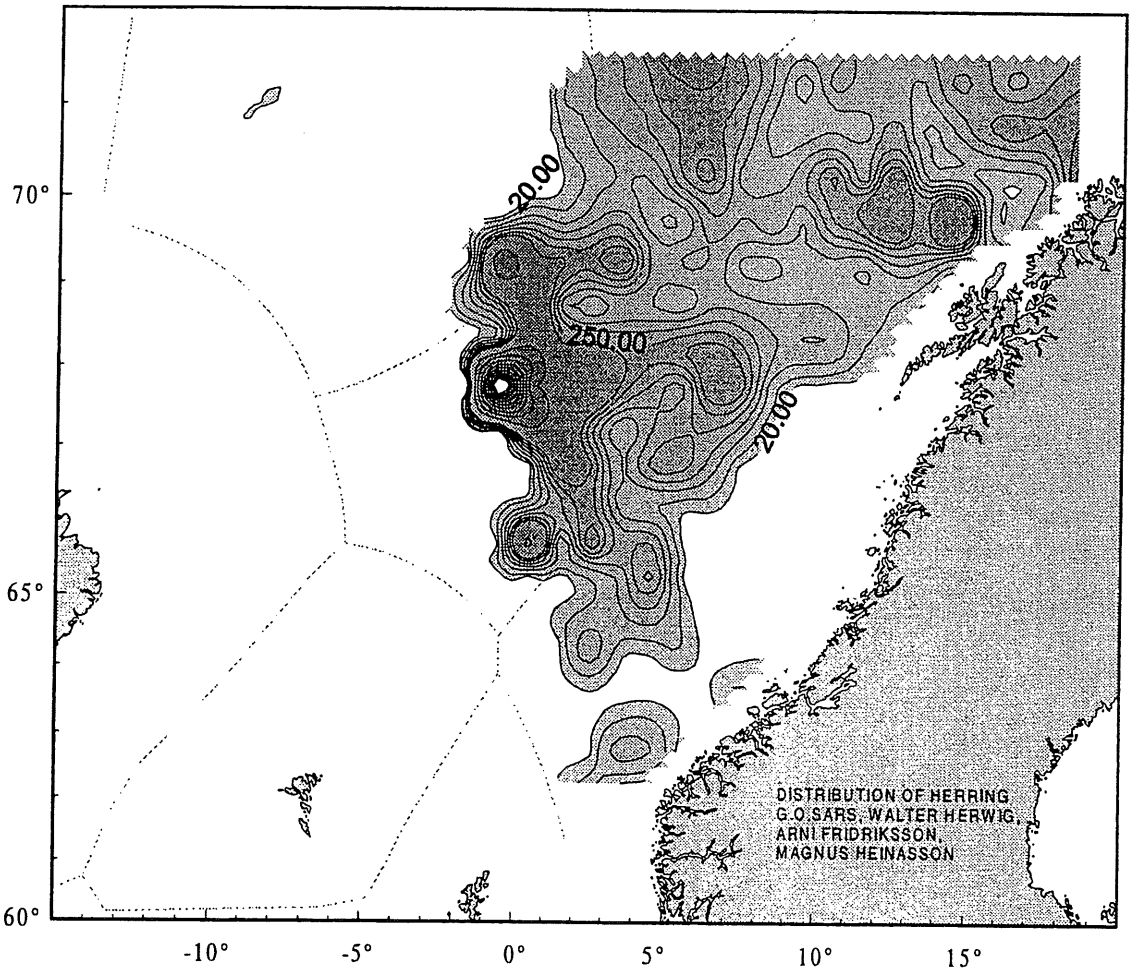

Figure 4. Relative distribution of herring as measured by the participating vessels, represented by isolines of smoothed Sa values.

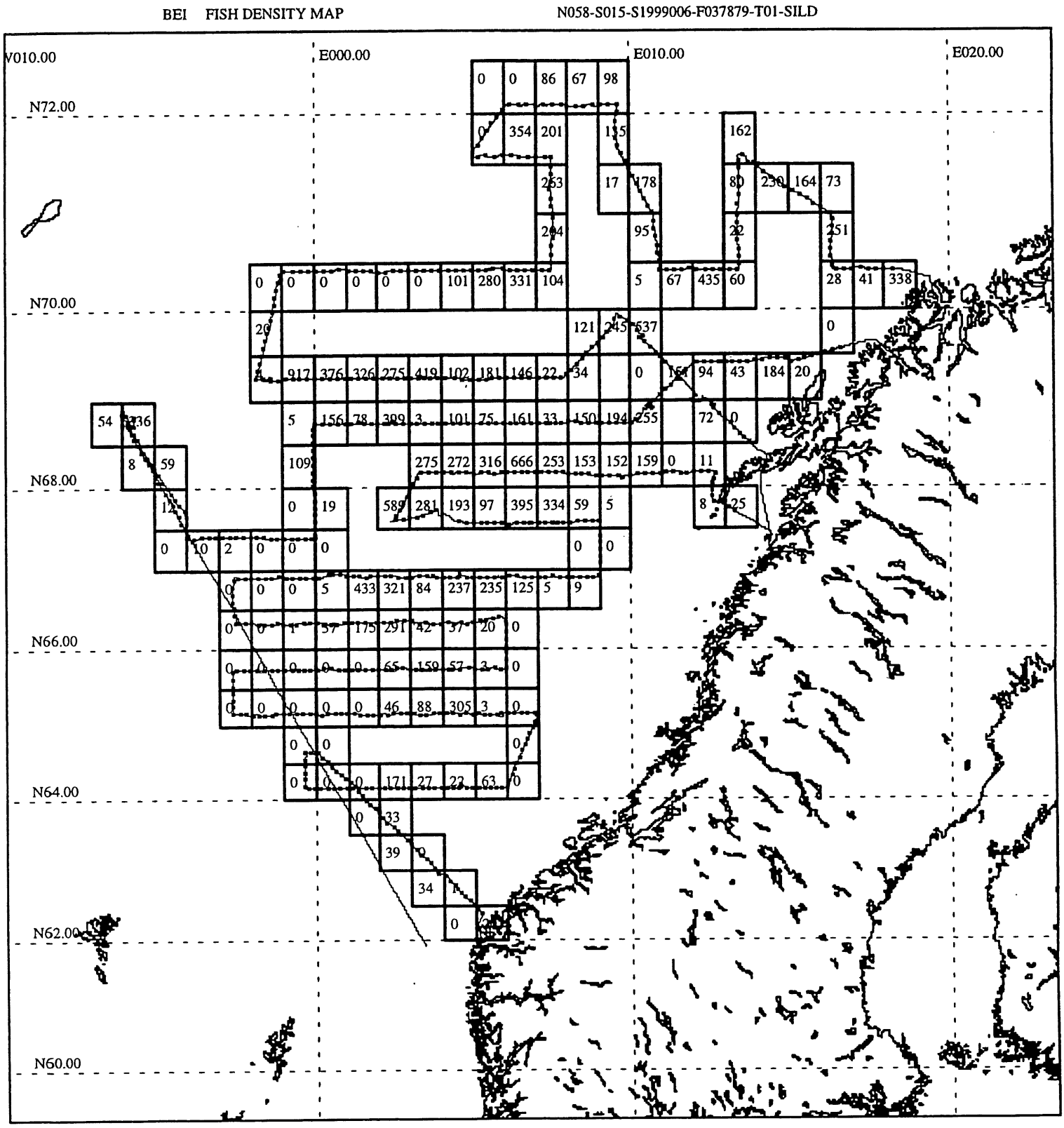

Figure 5. Mean Sa values allocated to herring by statistical square. G.O.Sars.

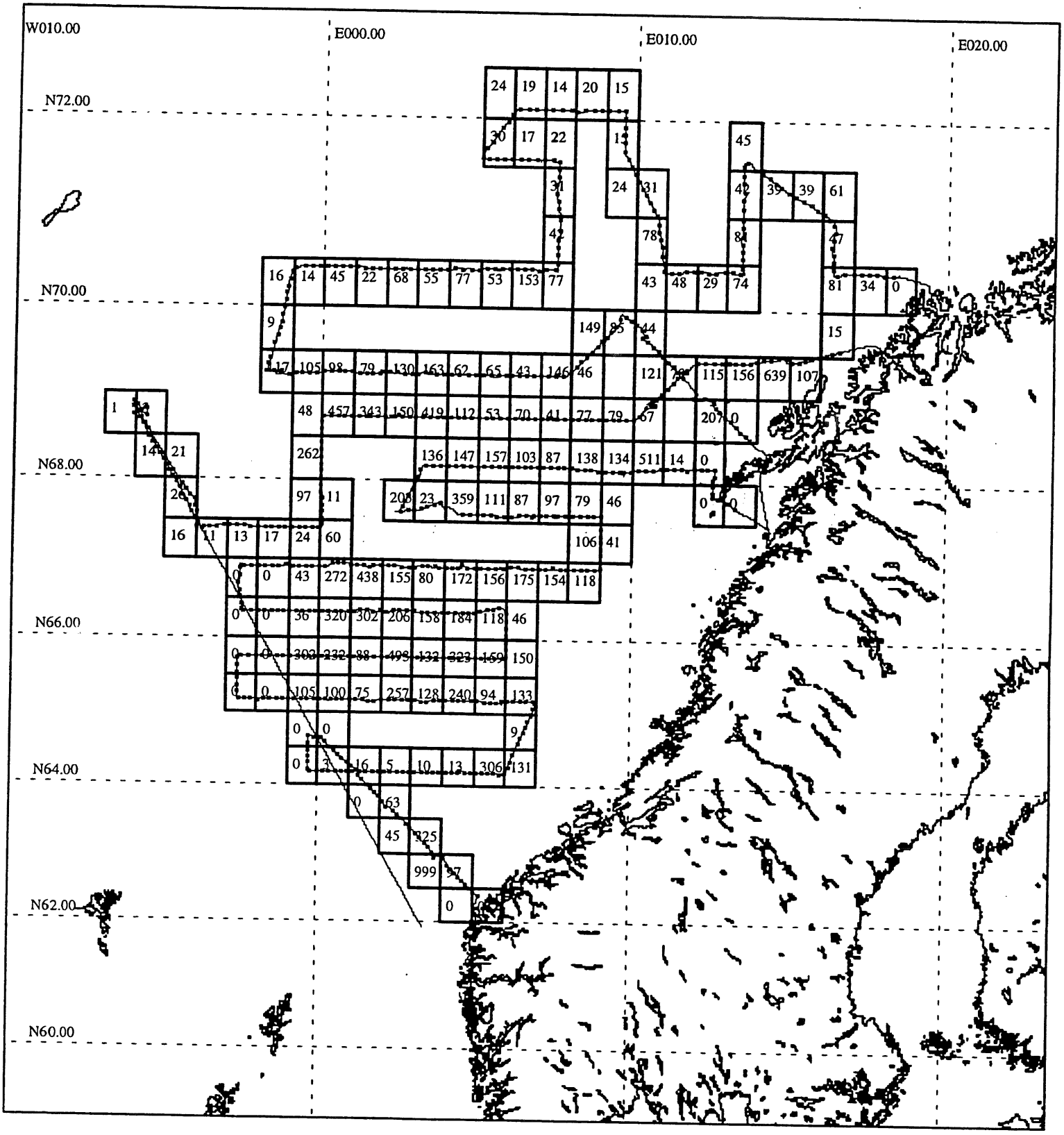

Figure 6. Relative distribution of blue whiting represented by Sa values per ICES square. G.O.Sars.

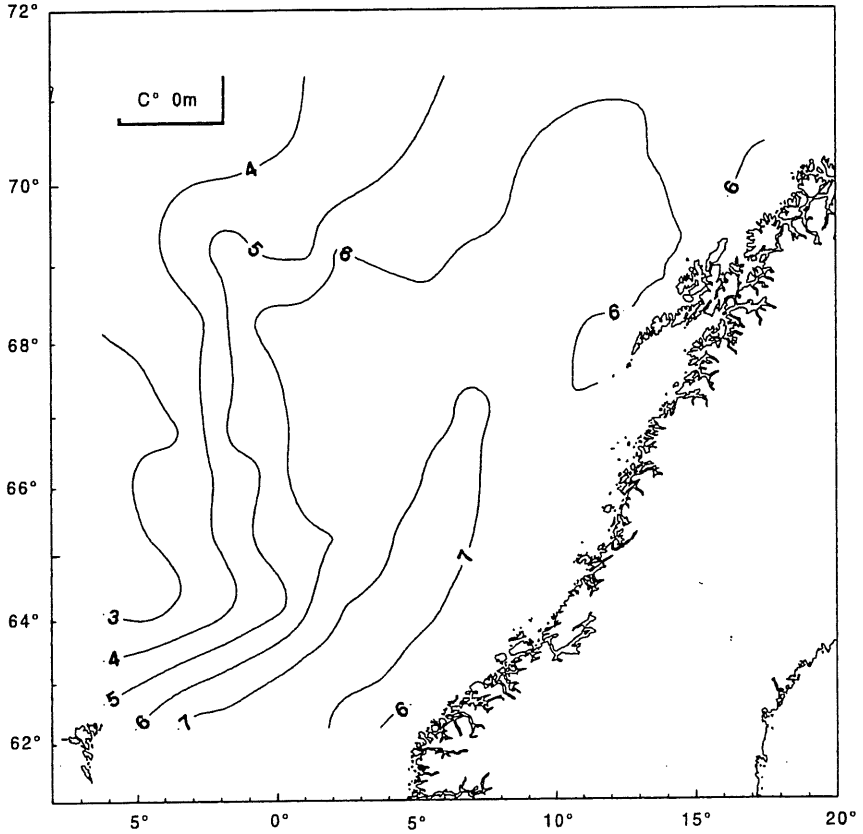

Figure 7. Temperatures at the surface during 1/5-1/6, 1997.

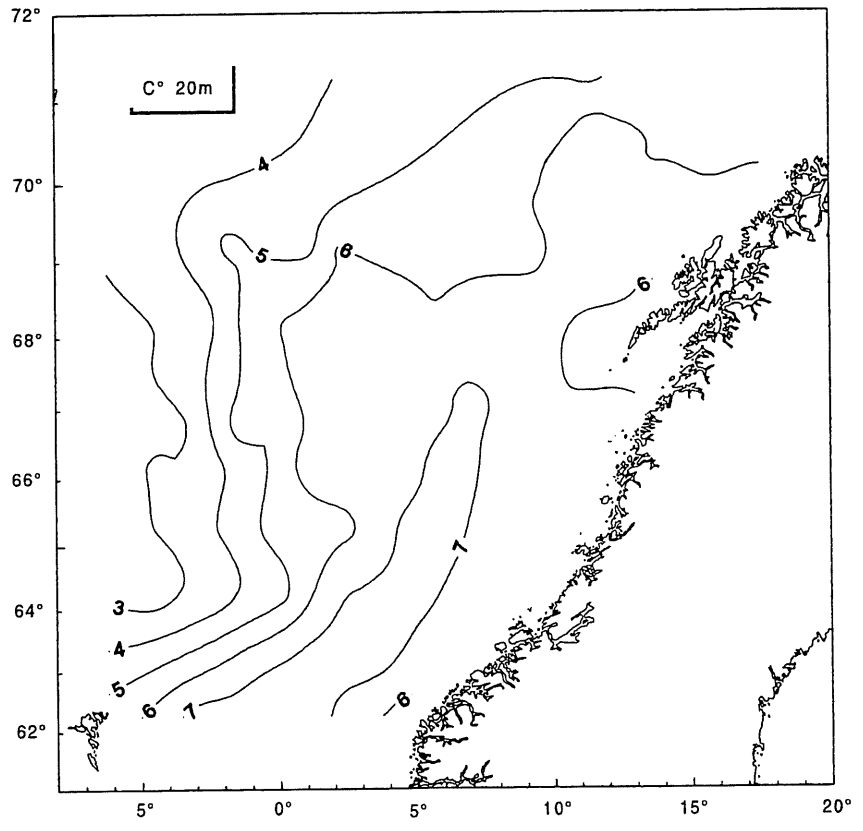

Figure 8. Temperatures at 20 m during 1/5-1/6, 1997.

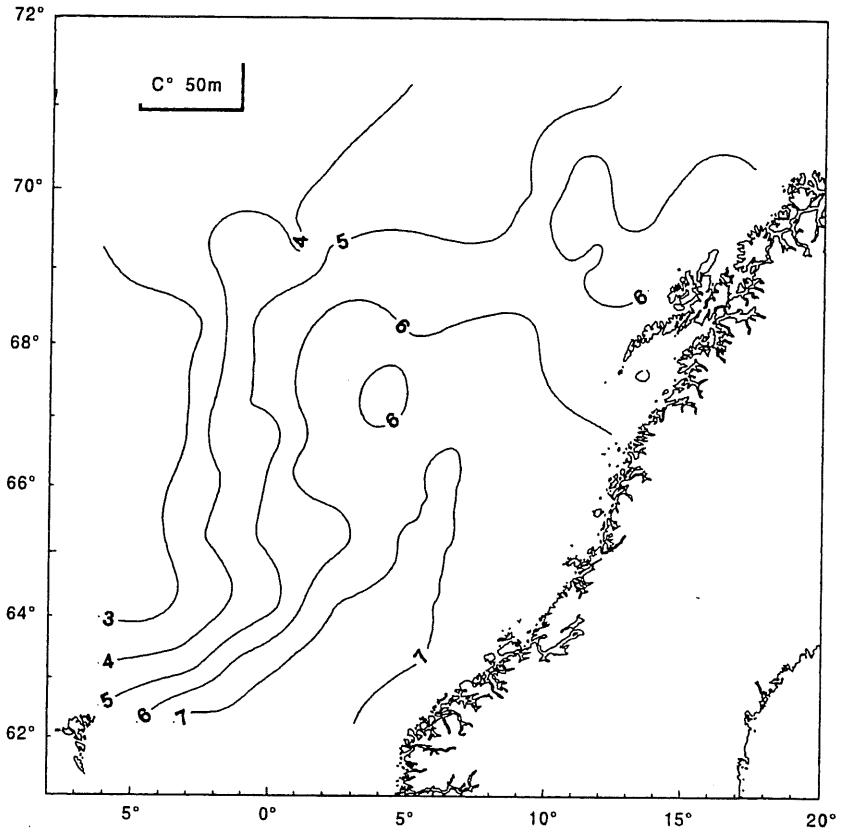

Figure 9. Temperatures at 50 m during 1/5-1/6, 1997.

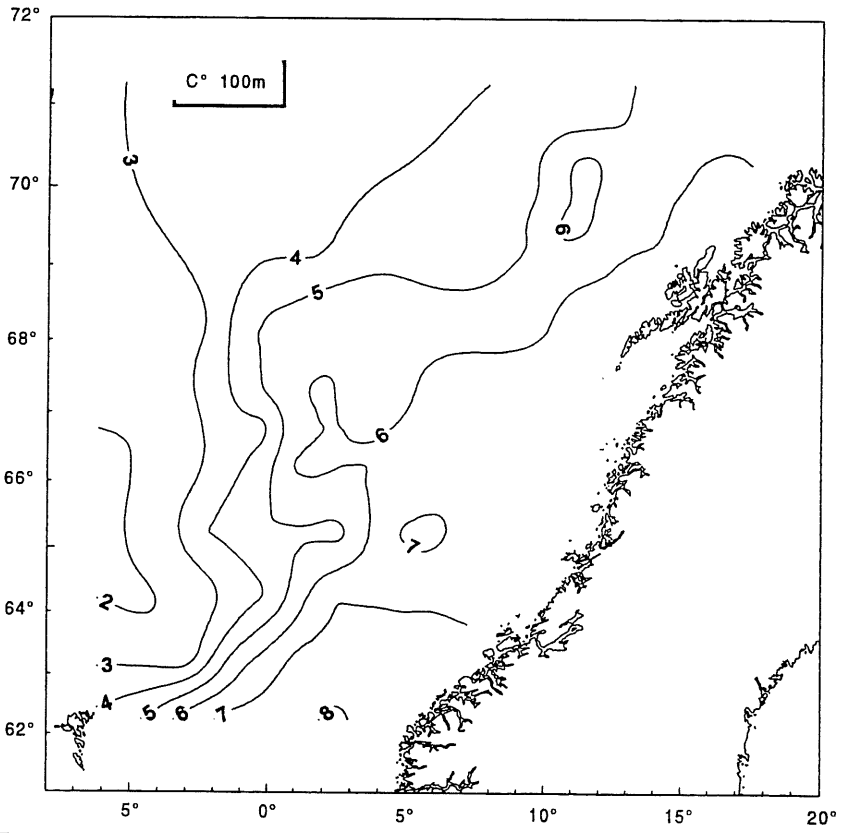

Figure 10. Temperatures at 100 m during 1/5-1/6, 1997.

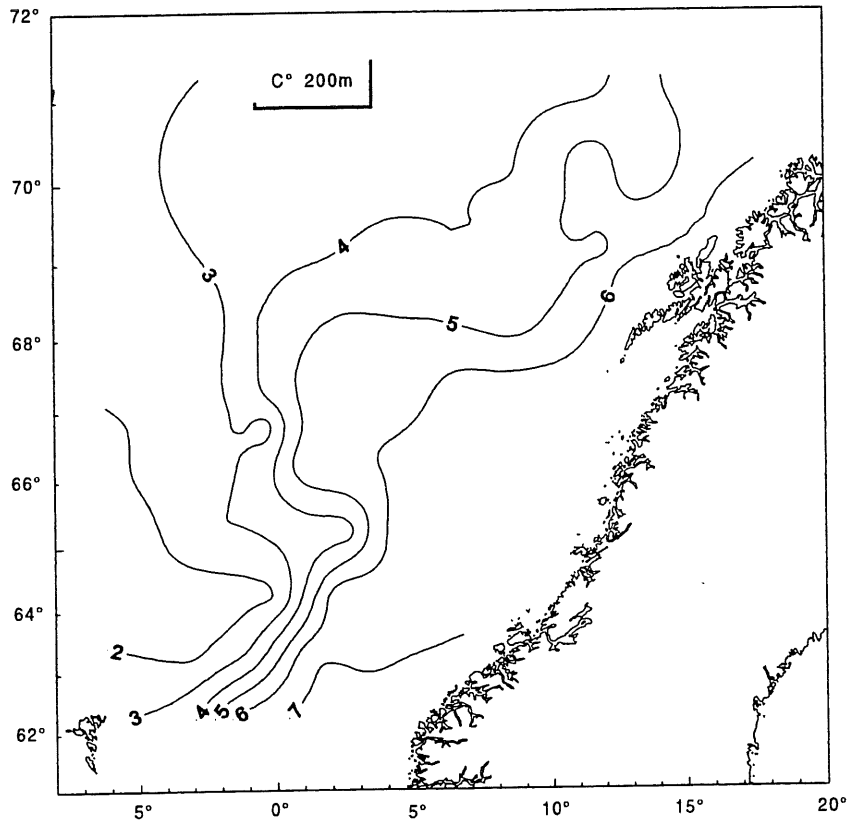

Figure 11. Temperatures at 200 m during 1/5-1/6, 1997.

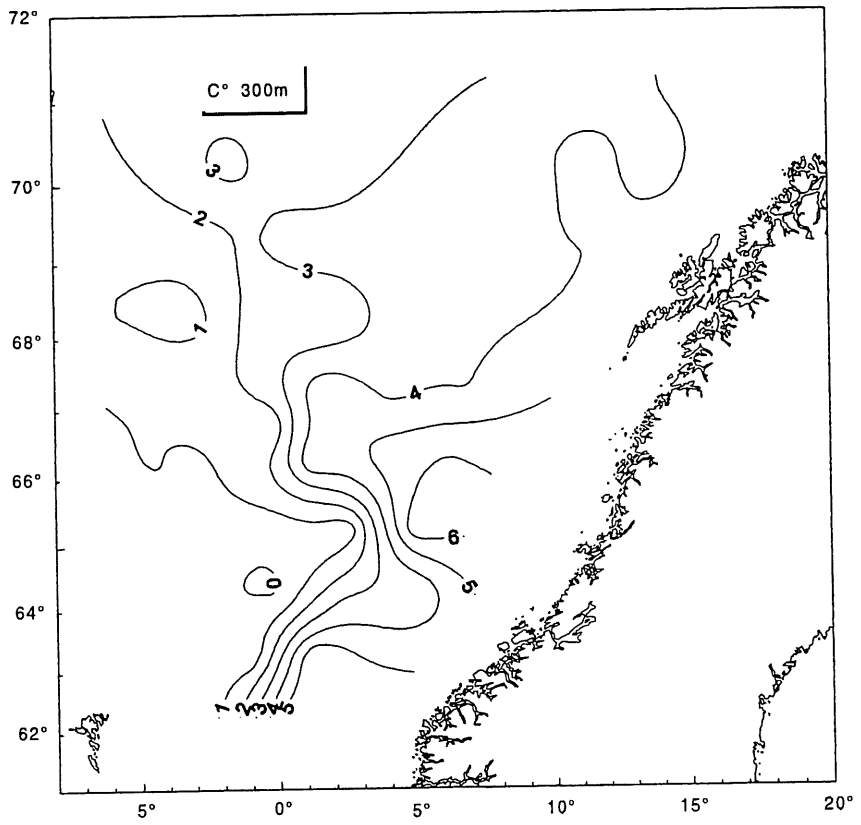

Figure 12. Temperatures at 300 m during 1/5-1/6, 1997.

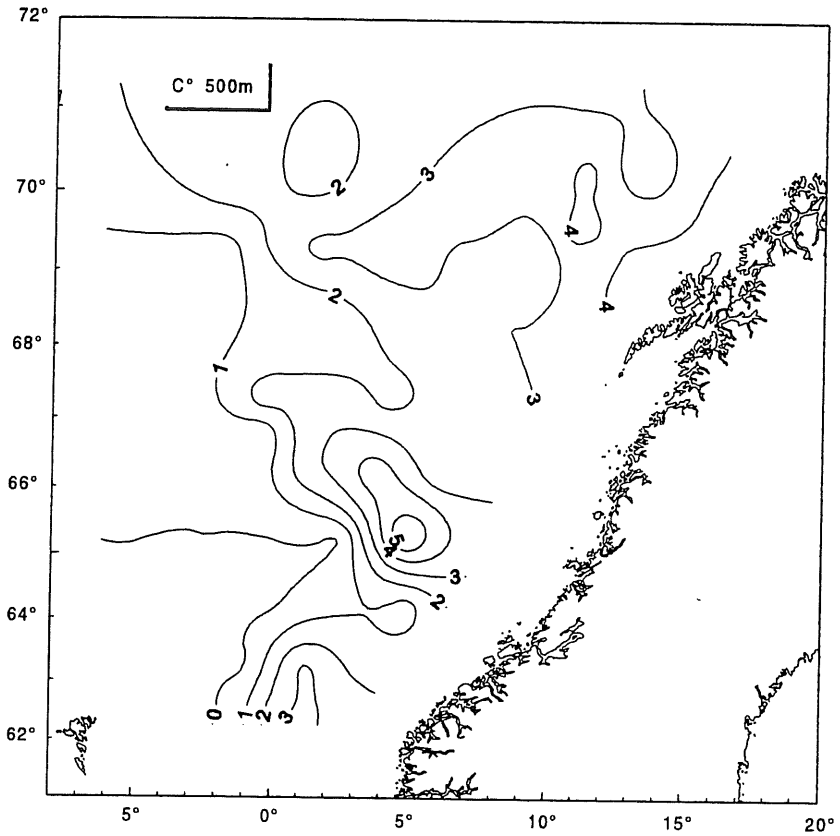

Figure 13. Temperatures at 500 m during 1/5-1/6, 1997.

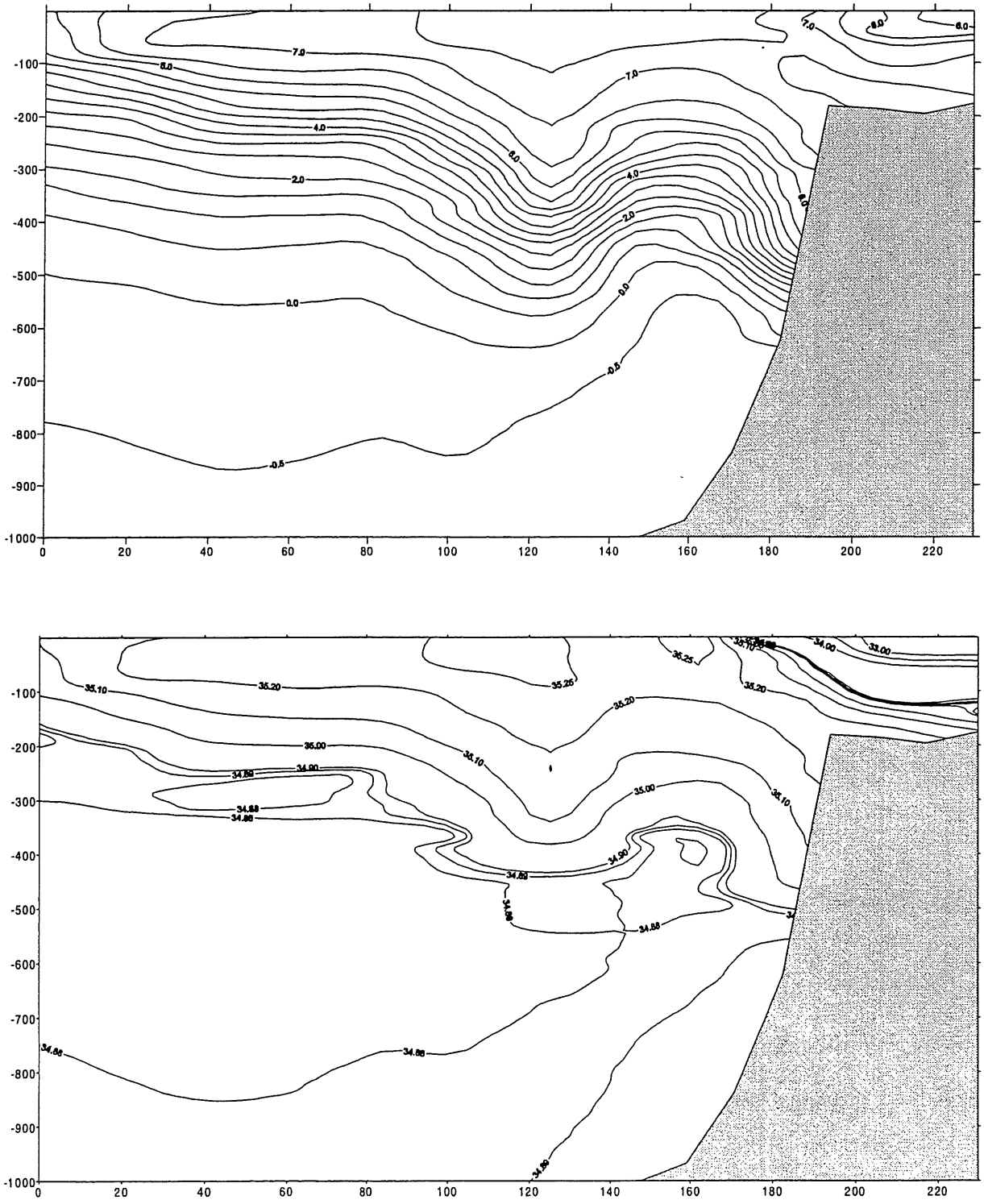

Fig. 14 Temperature and salinity in the section Svinøy - NW, between 62.37°N, 5.20°E and 64.66°N. 0.00°E.

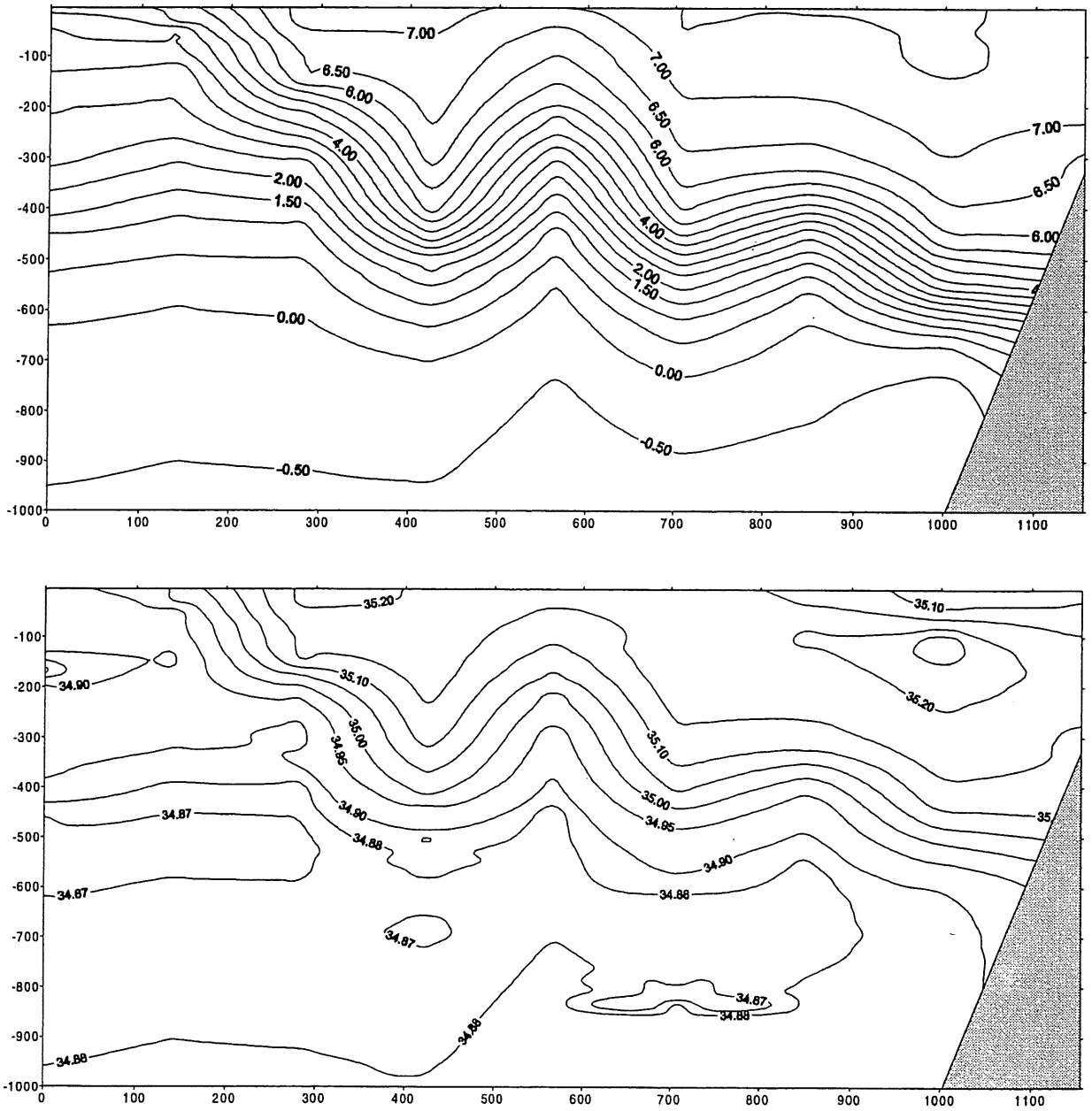

Fig. 15 Temperature and salinity along 66.9°N, between 2.55°W and 9.0°E. R.V. «G.O. Sars», May 1999.

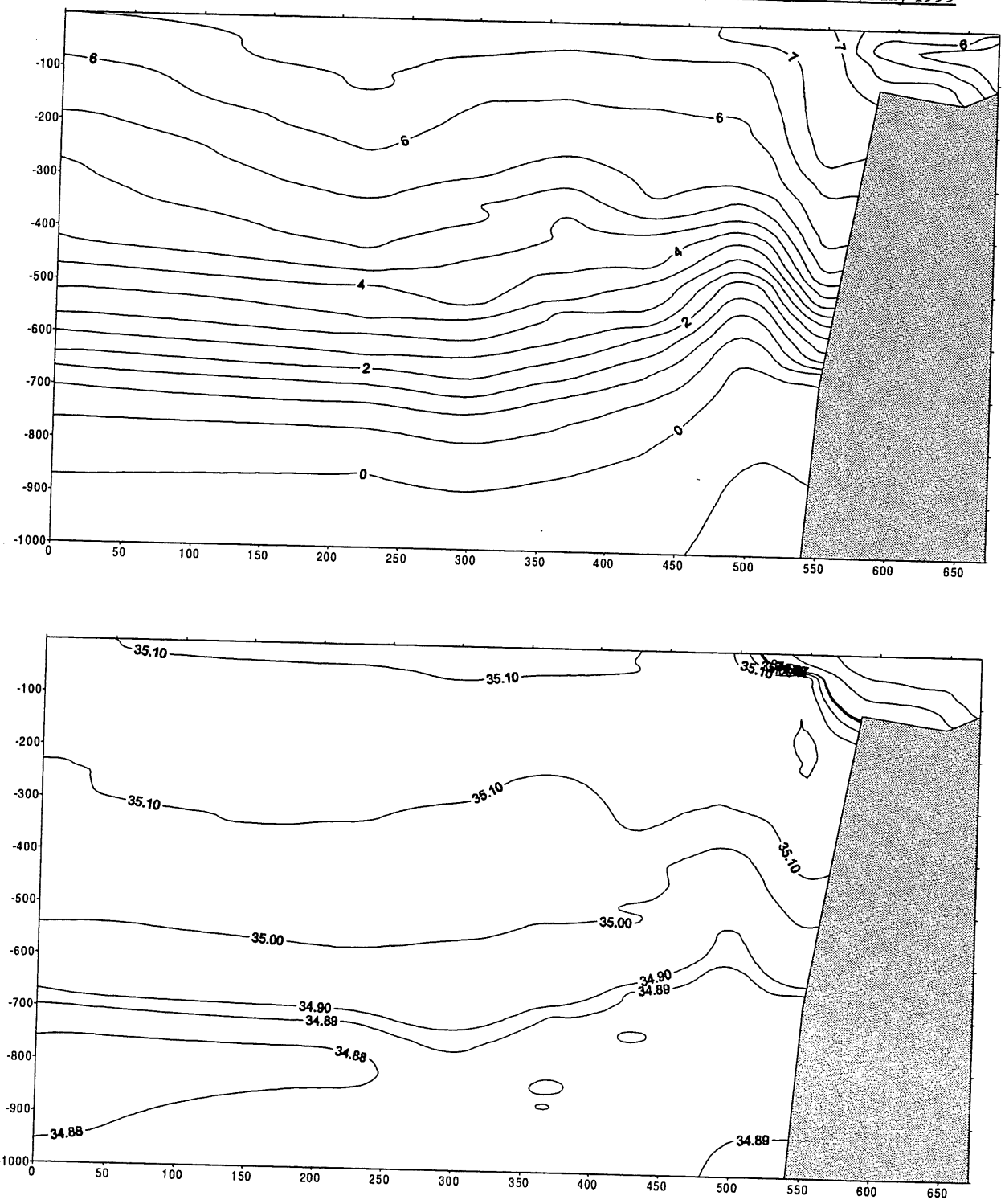

Fig. 16. Temperature and salinity in the section Gimsøy - NW, between 70,42° N, 7,30° E and 68,43° N, 14, 01°E. R.V. «G.O. Sars», May 1999.

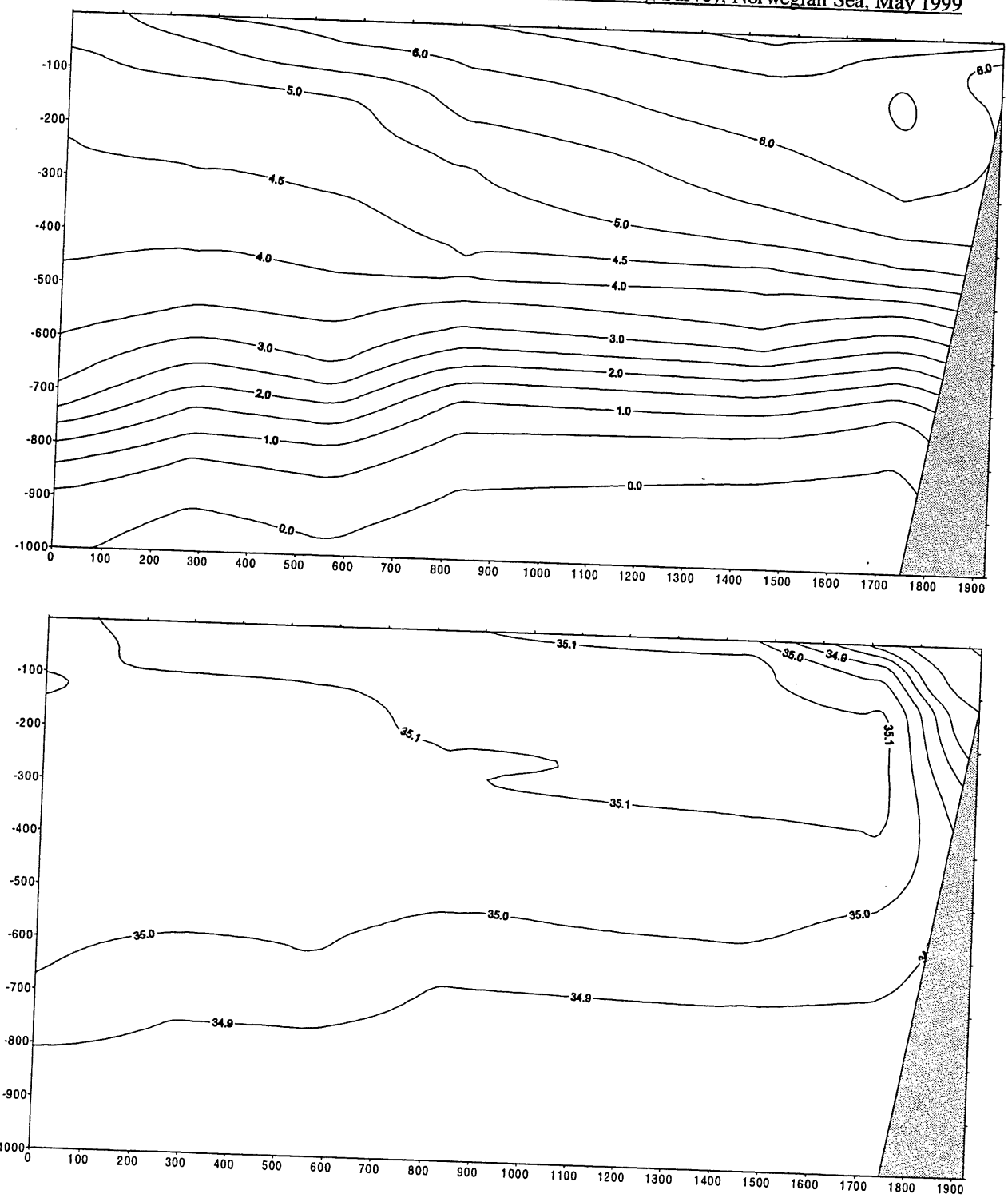

Fig. 17. Temperature and salinity between 1°W and 18.25°E along 70.4°N, R.V. «G.O. Sars», May 1999.

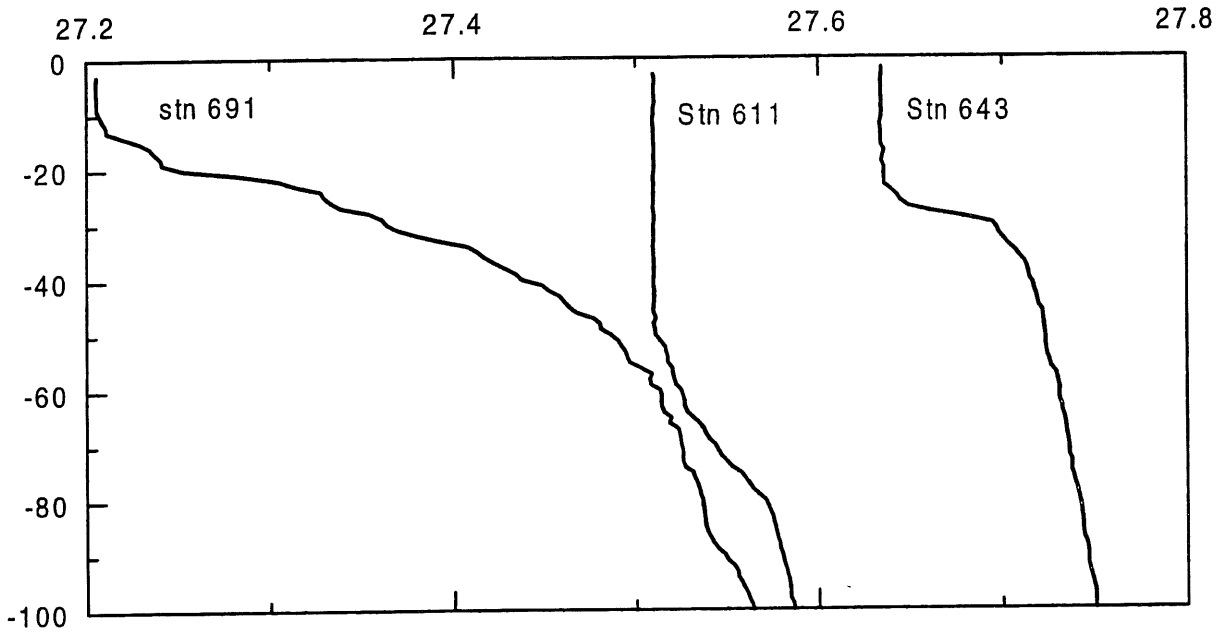

Fig 18. Density profiles from stations in the southern (Station 611), central (Stn 643) and northern (Stn 691) Norwegian Sea.