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A COMBINED FISH LARVAL, PHYTOPLANKTON AND OCEANOGRAPHIC SURVEY IN THE SKAGERRAK AND THE KATTEGAT IN APRIL 1983.

by

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ABSTRACT

The paper gives the distribution and abundance of larval fish in 61 hauls with a GULF-III sampler in the Skagerrak and the Kattegat in early April 1983.
Data on the hydrographic conditions in the area are presented.
An in-situ chlorophyll *a* fluorometer was used. The measurements were correlated to phytoplankton carbon estimates from samples taken simultaneously.
Data on the composition and abundance of the phytoplankton in the area are presented.

1. OBJECTIVES

The main objective of the survey reported here was to conduct a larval survey on the spring-spawning herring stocks in the Skagerrak and Kattegat.

The sizes of the spawning stocks and the localization of the spawning grounds in the area are not well known. The spawning appears, however, spread out along the coasts of Skagerrak and Kattegat and takes place close to the coasts, normally at 5 - 6 C. There may also be some spawning on the grounds in the Kattegat (Hagström, personal communication).

Another objective was to use an in-situ fluorescence meter in combination with the CTD and the GULF III, and to correlate the fluorescence with phytoplankton biomasses as measured from water samples taken simultaneously.

2. MATERIALS AND METHODS

The survey was conducted with the danish R/V DANA from 8 to 12 april 1983. A total of 65 stations were sampled during the survey. The programme for each station included:

2.1. Double oblique haul with a GULF-III high speed plankton sampler.
2.2. CTD-operation giving temperatures, conductivity and fluorescence profiles.
2.3. Water samples from the layers with maximum fluorescence.

2.1 Plankton hauls

The GULF-III sampler was equipped with an echo-sounder and a flow-meter. Both instruments were transmitting through cable to give readings on-deck during the haul. The sampler was towed double obliquely at 5 knots to within 5 metres of the bottom, or to a maximum depth of 100 metres. The sampler was continously lowered/raised 10 metres per 1 1/2 minutes. At depths of less than 20 metres the sampler was towed 5 minutes at 5, 10, and, if possible, 15 metres depth.

The samples were preserved in buffered 4 % formaldehyde. Fish larvae were identified and total lengths were measured to the nearest millimetre. The larvae of Limanda limanda and Platichtys flesus were not identified to species. Fish eggs were not removed from the samples.

The numbers in each sample (N) were converted to numbers per sq.metre using the formula:

$$No/m^2 = \frac{N * D * \cancel{E *} C}{\pi * R^2 * F * E}$$

where D is the water depth of the station.
E is the filtering efficiency = 0.83. (Scottish modification of GULF-III, see Nichols, 1982).
R is the radius of the aperture, and
F is the number of flowmeterrevolutions
C is the flowmetercalibration constant

2.2. CTD and Fluorescence.

The CTD was a Neil Brown Mark III CTD System.

The in-situ chlorophyll a fluorescence measurements were performed with the fluorometer developed at the Institute for Physical Oceanography, University of Copenhagen (Hundahl and Holck, 1980), which uses a chopped light source, a broad band excitation filter peaking at 500 nm, and a long wave pass filter with the edge at 665 nm for detection. The instrument was mounted on the CTD and the signals fed into the data retreiving system of the CTD.

2.3. Phytoplankton.

The vertical distribution of phytoplankton was traced at the CTD-stations by continuous measurements with the fluorometer. From depths with fluorescence peaks, samples were collected with a pump and preserved in neutral formaldehyde. Selected samples were concentrated by centrifugation and the dominating species of phytoplankton were identified and counted in a Palmer-Maloney slide. The cell numbers were converted to phytoplankton carbon via cell volume according to Stratmann (1967).

3. RESULTS AND DISCUSSION

3.1. Watermass conditions

The cruise covered the Norwegian and Swedish Skagerrak coasts, the Skagerrak-Kattegat boarder line, and the Kattegat (fig. 1). Basically, the area constitutes a transition zone between the oceanic North Sea and the brackish Baltic

Sea. Although considerable mixing takes place in the area between the Baltic outflow and the compensating inflow of North Sea water, the two watermasses can usually be distinguished throughout the area. The transition from the Skagerrak to the northern Kattegat is often marked by a strong salinity front and likewise the transition in the southern Kattegat to the Belt Sea is usually marked by a salinity front. The positions of the fronts and their sharpness as well as the intensity of the Baltic outflow depend strongly upon the meteorological conditions.

During the cruise the wind was moderate and varying. During the first half of the cruise the wind was westerly force 0 to 5. During the second half the wind was easterly force 2-6.

The cruise track (Fig.1) goes essentially parallel to the coast lines inside the Norwegian coastal current and the Baltic outflow as well as parallell to the frontal zone between Skagerrak and Kattegat. The minimum salinity along the Norwegian coast was about 25, whereas it was about 18 in middle May (Jensen et al. 1983). This shows that the Baltic outflow was rather weak and that the spring intensification of it had not started in April. The minimum salinity in eastern Skagerrak north of Göteborg was about 22, whereas it was considerably lower in May.

An analysis of the data in the form of sections does not appear ideal. Three Salinity/Temperature diagrammes have been made: for the Norwegian coastal zone and the eastern Skagerrak north of Göteborg (fig. 2); for the zone parallell to the Skagerrak -Kattegat transition and the Skaw, using stations in the Skagerrak part (fig. 3); for the Kattegat area, excluding the southernmost stations (fig. 4). The diagrammes are similar but nevertheless show clear differences between the waters in the three areas. The Norwegian coastal current water (fig. 2) is fairly distinct with low temperatures and high salinities while the eastern Skagerrak water forms a separate branch of slightly warmer water with salinities extending over a larger range than in the Norwegian case.

The water along the southern border of the Skagerrak shows a well-defined T-S curve (fig. 3), almost identical to the one defined by the eastern Skagerrak water in fig. 2. This shows that these waters have similar origin, namely the Jutland Current and the outflow from the Kattegat, and also suggests that the lather was weak during the observations.

The T-S diagramme for the Kattegat water (fig.4) shows larger scatter than in the other cases although with a quite narrow temperature range, considering that the salinity covers a range of about 18 units. The highest salinity was

present in the Skaw region and the lowest at Anholt. North of the Sound the salinity was about 19-20, again showing that the Baltic outflow was weak. The diagramme clearly shows the transitional nature of the area. In the Skagerrak the mixing has become more complete.

3.2. Phytoplankton

The dominating species of phytoplankton and their cell volume and cell carbon are shown in table 1. One cell of the large, Rhizosolenia setigera, contributes 200 times as much carbon as one cell of the small Chaetoceros socialis. Some large species of phytoplankton were occasionally observed in the GULF-net, e.g. Phaeocystis pouchetii, but not quantified and included in the calculation of the phytoplankton carbon.

In spite of the factors of uncertainty when counting phytoplankton and converting the number of cells to phytoplankton carbon, and of the fact that the carbon-chlorophyll ratio in phytoplankton may vary conciderably between species and within species according to environmental conditions such as temperature, light and nutrient supply (Eppley 1972), a correlation (0.72) between phytoplankton carbon and relative fluorescence (chlorophyll) was found (fig. 5).

The submersible fluorometer is thus a very useful tool for tracing the horizontal and vertical distribution of phytoplankton. The small peaks of phytoplankton with the depth shown in fig. 6, would hardly have been discovered by traditional sampling.

The horizontal distribution of phytoplankton in the area covered by the cruise is shown in fig. 7. The stratified Skagerrak water along the Swedish and Norwegian coast had only low concentrations of phytoplankton (table 2). The spring bloom of diatoms which, in these watermasses, normally occurs in March (Dahl and Danielssen, 1981) had finished.

In the southern part of the Skagerrak (The Jutland Current) the less stratified watermasses were very rich in diatoms (table 3). These watermasses were characterized by the presence of the two diatoms Asterionella glacialis and Thalassiosira nordenskioeldii. The latter also characterized the spring bloom in the same area in April 1980 (Dahl and Danielssen, 1981).

In the Kattegat the brackish surface layer was generally very rich in diatoms. The characteristic species were Nitzschia seriata, Rhizosolenia hebetata var. semispina and Thalassionema nitzschioides, while patches of Chaetoceros

socialis were found at a few stations in the more saline water beneath the surface layer (table 4). At station 40 and 41 (table 4), in the southern part of the Kattegat, *Thalassiosira* spp. contributed significantly to the phytoplankton biomass.

3.3 Fish larvae

Table 5 gives the numbers of fish larvae per sq.metre recorded for each species. The abundances of some of the more numerous species will be treated in the following sections.

3.3.1. Herring, *Clupea harengus.*

Herring larvae were only recorded at 7 stations (fig. 8). Four of these were in the northern Skagerrak, and three were in the southern Kattegat. All of the larvae were from 9 - 11 mm, and thus approximately two weeks old. This makes it very difficult to draw conclusions as to where the spawning grounds are situated.

From the results it is clear that it is not possible to conduct a standard herring larval survey as planned here. It was not possible to sample on the spawning grounds inside the skerries and at the shallow water at the Danish coast with a ship of the size of R/V DANA.

3.3.2 Cod, *Gadus morhua.*

Cod larvae were found mainly in the Oslofjord and in the Kattegat (fig. 9). Nearly all of the larvae were from 4 - 7 mm, and yolk sac larvae were recorded at only two stations in the Kattegat.

3.3.3 Sand eel, *Ammodytes marinus.*

Larvae of the sand eel were found to be the most abundant species on nearly all stations (fig. 10), apart from the southern Kattegat where the densitys were low. The highest numbers were recorded in the northern Kattegat close to the Jutland Current.

Numbers of larvae have earlier been found in spring in the Jutland and the Baltic Current (Lindquist, 1970), and on the Norwegian Skagerrak coast (Danielssen and Tveite, 1968).

The lengths of most larvae were 9 - 20 mm in the Skagerrak and the northern Kattegat, and 7 - 15 mm in the southern

Kattegat.

3.3.4. Dab, Limanda limanda,/Flounder, Platichtys flesus.

Most of the larvae in the samples were of *L. limanda*. The abundances were highest in the northern Kattegat (fig. 11). Nearly all larvae were 4 - 5 mm long.

3.3.5. Plaice, Pleuronectes platessa.

The larvae of the plaice were most abundant in the northern Kattegat, and hardly any were present in the central and southern Kattegat (fig. 12). Most larvae were from 7 - 10 mm.

3.3.6. The other commercial fish species.

Larvae of Sprat, *Sprattus sprattus* were found at 5 stations in the northern part of the area. The lengths of the few larvae caught were from 31 to 42 mm.

Haddock, *Melanogrammus aeglefinus* occured at 11 stations in the eastern Skagerrak and the northernmost Kattegat. The lengths were 4 - 5 mm in the southern part and 5 - 8 mm in the northern part.

Larvae of Saithe, *Pollachius virens* were found at 7 stations off the Norwegian coast and at 3 stations east of Jutland. The lengths were 4 mm in the southern and eastern stations, and 4 - 8 mm in the western.

Pollack, *Pollachius pollachius* was only found at 4 stations. The lengths were from 5 - 10 mm.

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TABLE 1. THE MOST COMMON SPECIES OF PHYTOPLANKTON OBSERVED DURING THE CRUISE AND THE CELL VOLUME AND CELL CARBON USED FOR CALCULATING PHYTOPLANKTON CARBON.

Taxa	cell volume (μm^3)	cell carbon (pg)
Asterionella glacialis	450	38
A. kariana	440	36
Biddulphia aurita var. minima	8300	316
Cerataulina pelagica	40000	1165
Chaetoceros socialis	40	7
Chaetoceros spp.	1200	82
Leptocylindrus danicus	960	69
Navicula sp.	1200	82
Nitzschia closterium	300	28
N. delicatissima	130	15
N. seriata	1100	76
Rhizosolenia hebetata var. semispina	6000	277
R. setigera	50000	1400
Skeletonema costatum	250	25
Thalassionema nitzschioides	800	60
Thalassiosira nordenskioeldii	3800	195
Thalassiosira spp.	22000	740
Gymnodinium sp.	1000	137

TABLE 2. THE MOST COMMON SPECIES OF PHYTOPLANKTON (AS THOUSANDS PER LITRE) IN THE NORTHERN PARTS OF THE SKAGERRAK.

Taxa		5	6	9	12	14	15	17	18	23
	Station :	5	6	9	12	14	15	17	18	23
	Depth (m) :	52	1	1	1	9	1	1	1	1
	Sal. ($^{o}/oo$) :	34.3	26.4[2]	25.8	26.1	25.6	25.7	27.1	30.2	34.2[3]
	Temp. (^{o}C) :	5.4	3.9[2]	3.9	4.3	4.2	4.3	4.6	4.9	4.8[3]
Asterionella glacialis						0.5				
Navicula sp.									0.5	
Nitzschia closterium		0.5								
N. delicatissima									0.5	1
N. seriata						1		0.5		1
Rhizosolenia hebetata [1]						1	1			
Skeletonema costatum		4							3	
Thalassiosira nordenskioeldii		0.5								
Gymnodinium sp.			1	1	1	0.5				1
Phytoplankton carbon ($\mu g/l$):		0.3	0.1	0.1	0.1	0.4	0.3	0.1	0.1	0.2
Relative fluorescence:		0.9	0.9	0.9	0.7	1.4	1.1	1.0	0.9	1.2

1: var. semispina
2: data from 3 m.
3: data from 2 m.

TABLE 3. THE MOST COMMON SPECIES OF PHYTOPLANKTON (AS THOUSANDS PER LITRE) IN THE HIGH SALINE JUTLAND CURRENT.

Station:	1	1	20	21	21	22	22	25	25	27	29	59	59	59	60	63	65
Depth (m):	3	30	20	1	30	1	51	6	40	9	7	6	18	25	50	18	6
Sal. (^{o}/oo):		33.7	34.2	33.6	33.8	33.0	33.2			33.8	20.9	21.7	33.2	33.3	33.6	33.8	33.4
Temp. (^{o}C):		4.7	4.8	4.6	4.6	4.5	4.5			4.7	4.3	4.7	4.6	4.5	4.7	4.7	4.9
Taxa																	
Asterionella glacialis	340	310	70	350	230	10	410	400	40	170	15	4	550	880	1400	700	1840
A. kariana									3								
Biddulphia aurita[1]															0.5	2	
Cerataulina pelagica											0.5						
Chaetoceros socialis				80	30					130							
Chaetoceros spp.	20						20			20							
Leptocylindrus danicus												1					
Navicula sp.				10			10	10	2		1	0.5	2	2		20	1
Nitzschia closterium	20		30		30	20			2				2	2	4	1	3
Rhizosolenia hebetata[2]											1				0.5		
R. setigera													0.5		0.5		
Skeletonema costatum				80		300	180		4	130	6	2	20				
Thalassionema nitzschioides		2											2		2		2
Thasassiosira nordenskioeldii	120	230	70	80	440	70	150	50	53	20	12		100	200	860	230	700
Gymnodinium sp.					10						1						
Phytoplankton carbon (μg/l):	39	57	17	32	96	22	52	26	12	16	4	1	43	73	222	92	206
Relative fluorescence:		3.7	1.8	3.5	4.6	2.4	4.5	2.7	1.3	2.7	1.1	1.5	3.6	2.4	>5.0	3.0	>5.0

1: var. minima.
2: var. semispina.

TABLE 4. THE MOST COMMON SPECIES OF PHYTOPLANKTON (AS THOUSANDS PER LITRE) IN THE KATTEGAT.

Taxa																
Station:	34	38	38	39	40	41	43	44	48	49	50	51	53	54	54	57
Depth (m):	1	1	23	1	10	7	1	12	6	10	20	9	1	1	12	6
Sal. ($^{o}/oo$):	19.8	18.9[2]	32.8	16.3	18.5	16.5	17.6	28.4	24.6	28.2	33.0	27.2	21.4	18.1	18.7	19.0
Temp. (^{o}C):	5.0	4.9[2]	4.6	5.0	4.1	4.7	4.6	4.6	4.8	4.4	4.8	4.8	5.0	4.6	4.4	4.5
Chaetoceros socialis			2800			10		1300	1800	200						
Chaetoceros spp.			10					15	1		40	5				
Leptocylindrus danicus						10	3				10	3				
Nitzschia seriata	110	140		220	100	110	150	30	20	40	4	20	0.5	50	40	40
Rhizosolenia hebetata[1]	40	40		10	140	40	40	20	2	10	60	40		40	50	30
R. setigera														0.5		
Skeletonema costatum					110						4					
Thalassionema nitzschioides	20		60		250	20	50	30	20	10	10		0.5	20	20	30
Thalassiosira nordenskioeldii									6			10				
Thalassiosira spp.	4				60	60	2									
Phytoplankton carbon (μg/l):	24	22	24	19	109	66	27	20	17	9	22	15	0.07	17	18	13
Relative fluorescence:	1.9	1.8[2]	3.7	3.2	5.0	4.3	2.5	5.0		2.8	3.4	2.6		2.7	2.6	2.4

1: var. hebetata
2: data from 2 m.

TABLE 5. THE NUMBER OF FISH LARVAE PER SQ.METRE RECORDED FOR EACH SPECIES.

POSITION	CLUPEA HARENGUS	SPRATTUS SPRATTUS	GADUS MORHUA	MELANOGRAMMUS AEGLEFINUS	POLLACHIUS POLLACHIUS	POLLACHIUS VIRENS	AMMODYTES MARINUS	LAMPHENUS LAMPRETAEFORMIS	PHOLIS GUNELLUS	POMATOSCHISTUS MINUTUS	MYOXOCEPHALUS SCORPIUS	TAURULUS LILLJEBORGI	LIPARIS LIPARIS	HIPPOGLOSSOIDES PLATESSOIDES	LIMANDA LIMANDA/ PLATICHTYS FLESUS	PLEURONECTES PLATESSA
58,02,0 N 08,13,5 E					5	7	66							2		2
58,09,7 N 08,29,2 E						3	11									
58,19,7 N 08,48,3 E						2	62									2
58,27,8 N 09,00,2 E						3	40						1	1		
58,37,6 N 09,15,1 E							30							1		2
58,48,3 N 09,36,4 E				2			17		2					2	2	6
58,54,9 N 09,47,8 E	4					7	5									1
58,54,7 N 10,02,4 E				5			24									5
59,05,6 N 10,32,5 E	1		1				6							1		
59,10,5 N 06,41,0 E	3		5				11									3
59,04,7 N 10,43,8 E	4		12	4			4	2						6	23	6
58,56,8 N 10,34,6 E				2		2	31								15	9
58,43,1 N 10,35,9 E		1		1		12	32							1	5	5
58,33,3 N 10,40,2 E			3	8			21	2							10	8
58,23,3 N 10,45,2 E		2					16									
58,13,5 N 10,49,4 E				2			26								10	
58,03,5 N 10,53,1 E							33							2		2
57,53,5 N 10,57,4 E		1		2		2	232	1							20	19
57,49,0 N 10,54,7 E			2				81								177	19
57,53,9 N 10,48,2 E							27							1	1	
57,58,1 N 10,56,8 E							32									4
57,53,7 N 11,04,8 E			2				96								44	20
57,49,3 N 11,04,6 E			1				32								107	2
57,44,4 N 10,48,0 E			4				72						3		113	4
57,35,2 N 11,08,4 E			11				98									14
57,28,2 N 11,03,7 E			5		1		6						1		28	1
57,28,0 N 11,18,0 E			9				5	1							13	
57,17,9 N 11,26,6 E			3				5							2	3	
57,10,8 N 11,27,7 E			3				25	1							6	
57,07,8 N 11,10,9 E			2				2					1		1	15	
56,56,6 N 11,45,4 E			7				11	2							13	2
56,48,0 N 11,42,9 E			6				4							1	4	
56,39,8 N 12,02,2 E	3		25				17	3							21	
56,36,5 N 11,33,0 E			10				4	1							4	
56,22,9 N 11,36,3 E			6				3								5	
56,12,0 N 12,18,9 E			4				3								9	
56,08,1 N 11,59,6 E			0				0								2	
56,02,2 N 11,36,0 E	0		0													
56,05,1 N 11,18,7 E			2				2								2	
56,15,2 N 10,53,0 E							2								6	
56,20,3 N 11,00,5 E			1				0								2	
56,36,4 N 11,00,1 E			0			1	1								2	
56,47,8 N 11,09,5 E			0				0	0							1	
56,44,5 N 10,39,7 E			1				1							0	4	0
56,57,1 N 10,52,1 E						0	0								0	
57,10,5 N 10,44,7 E			2				3								2	
57,22,3 N 10,47,5 E			7		1			1					1		10	2
57,28,3 N 10,41,6 E			6				17								6	
57,35,5 N 10,37,1 E		2	2	0			18			0				1	1	2
57,00,0 N 12,11,1 E	1		3					1							5	
57,07,5 N 12,01,9 E			3								1				6	1
57,17,0 N 11,45,9 E			3				19								9	[illegible]
57,24,5 N 11,42,5 E			5				3						2		8	2
57,52,7 N 11,35,0 E			9				75								170	8
57,41,7 N 11,28,7 E			1	1			62								57	5
59,52,6 N 11,20,2 E			4	1			112								141	13
58,01,4 N 11,16,8 E							38								26	13
58,09,8 N 11,11,0 E			3				33		1				1		25	27
58,19,1 N 11,03,2 E			2				48		1						11	19
57,43,1 N 10,21,0 E			2				63							2	35	27
57,39,4 N 10,10,5 E		0			1		85		0					1	8	7

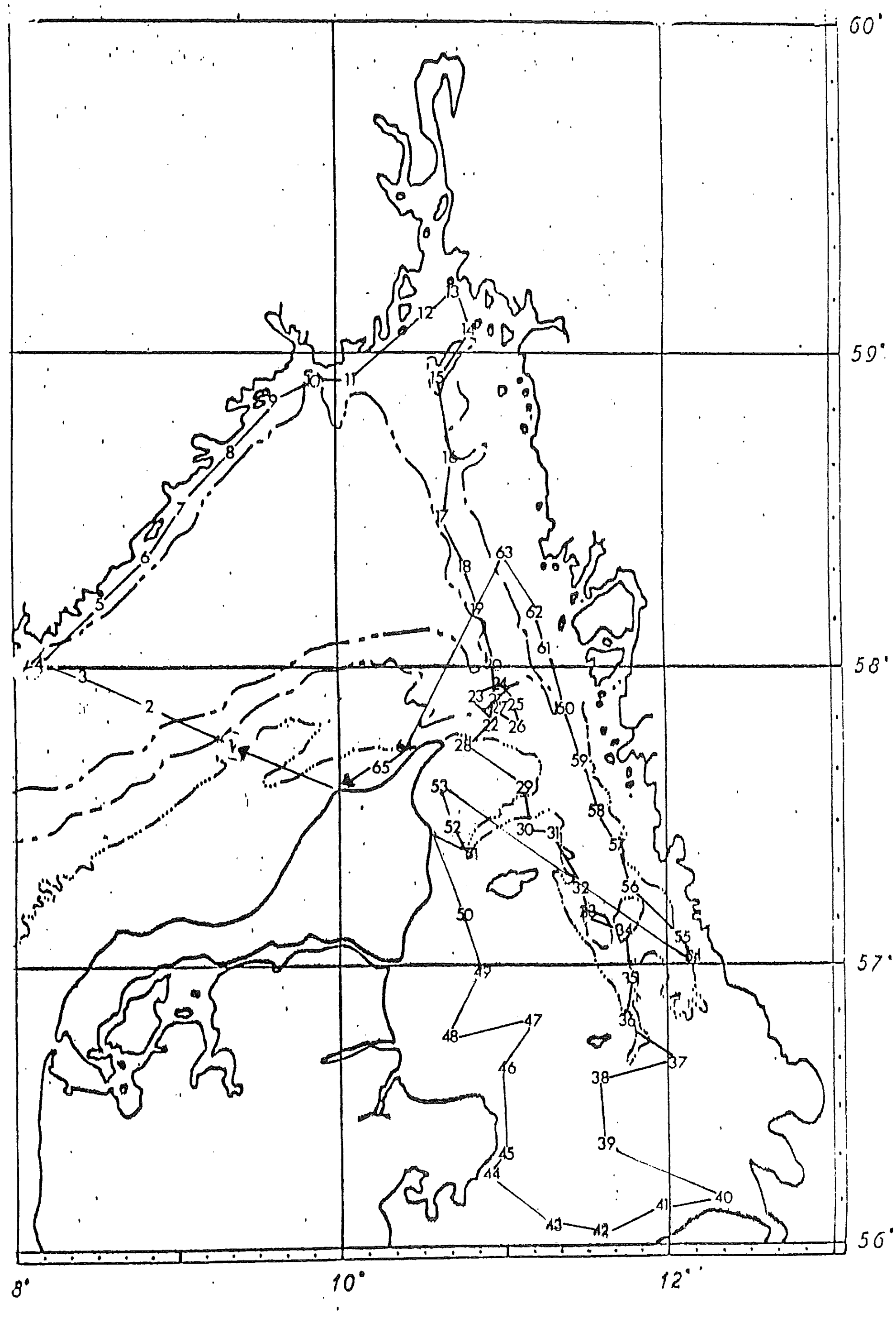

FIG. 1. AREA COVERED AND CRUISE TRACK.

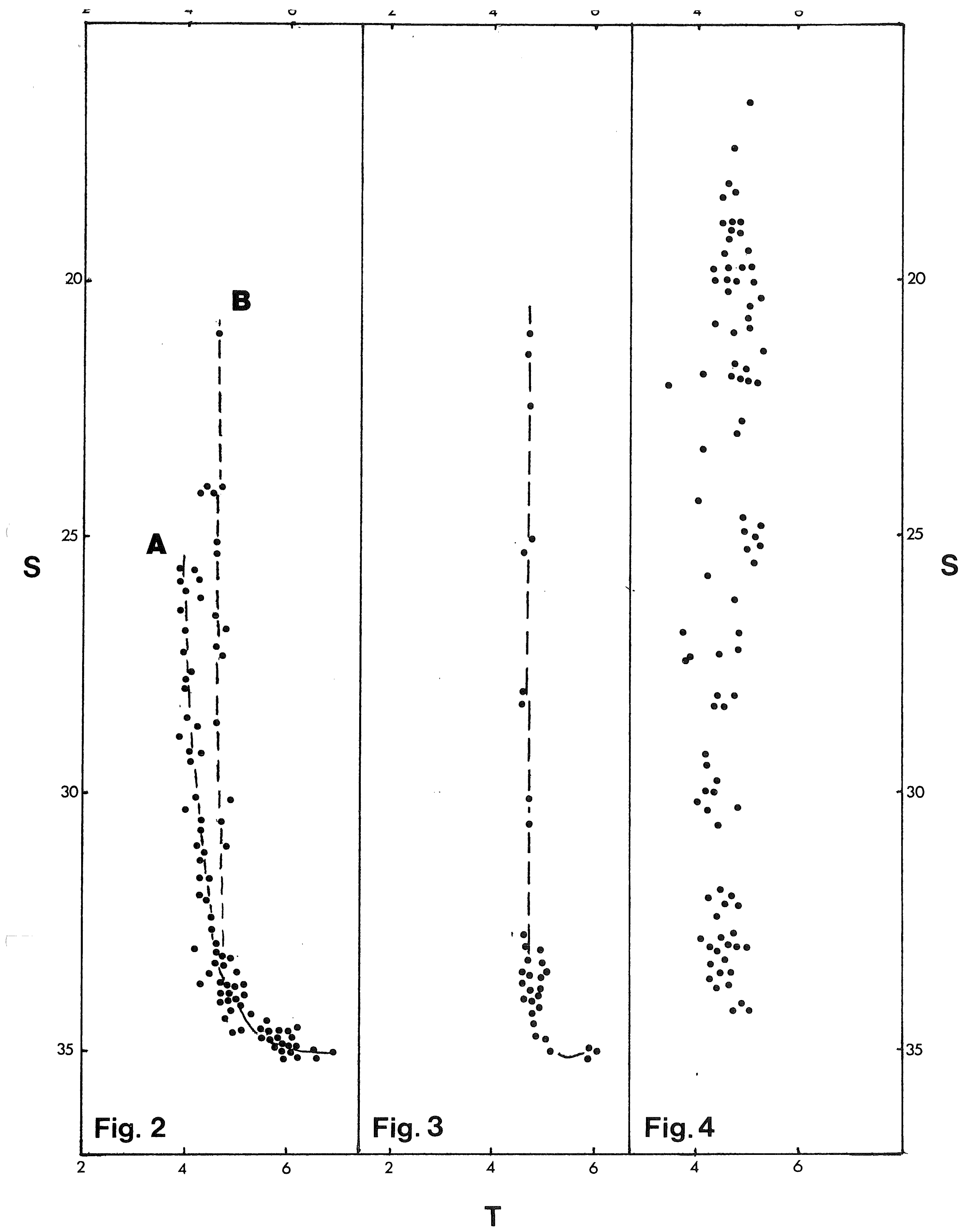

FIG. 2. SALINITY-TEMPERATURE (S-T) DIAGRAMME FOR NORTHERN AND EASTERN SKAGERRAK:
A. NORWEGIAN COASTAL ZONE,
B. EASTERN SKAGERRAK AND SWEDISH COASTAL ZONE.

FIG. 3. S-T DIAGRAMME FOR SOUTHERN SKAGERRAK: THE SKAW TO GOTEBORG NORTH.

FIG. 4. S-T DIAGRAMME FOR THE KATTEGAT STATIONS NORTH OF BOUNDARY TO THE BELT SEA.

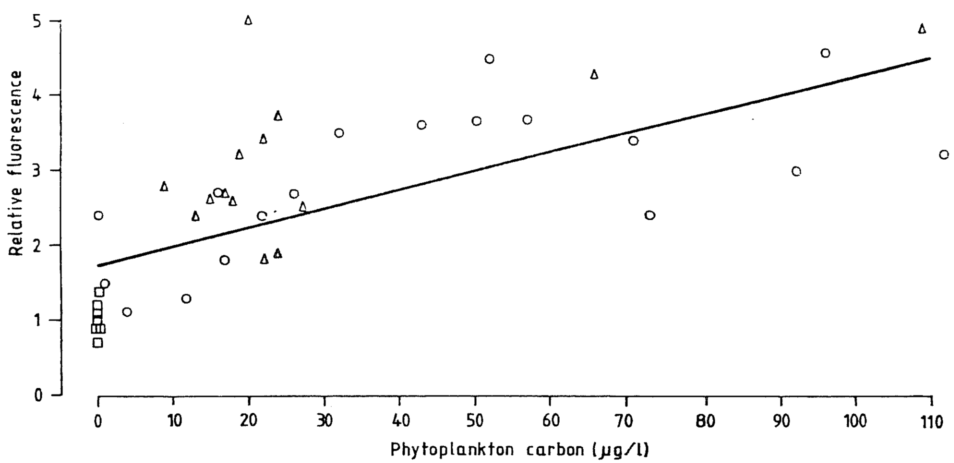

FIG. 5. CORRELATION BETWEEN PHYTOPLANKTON CARBON AND RELATIVE FLUORESCENCE. THE CORRELATION COEFFICIENT IS 0.72.

□ - DATA FROM TABLE 2
o - DATA FROM TABLE 3
Δ - DATA FROM TABLE 4

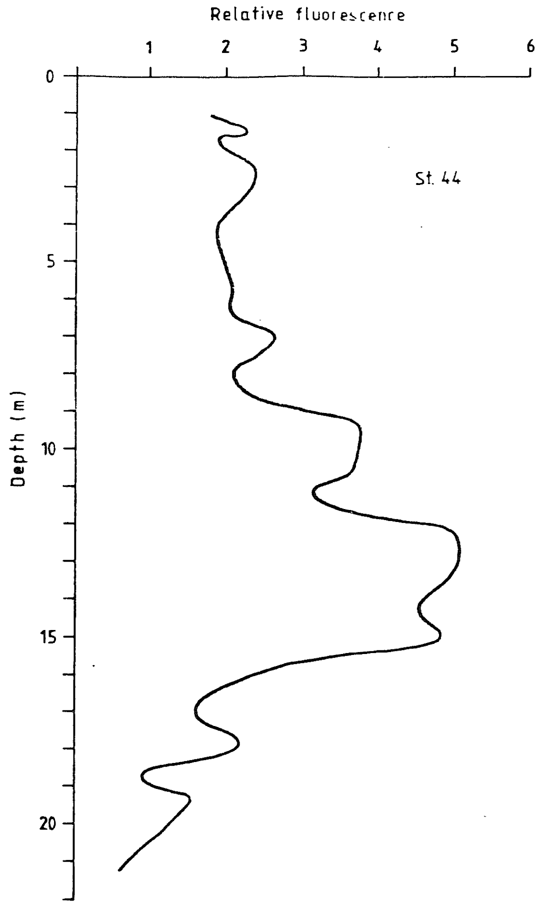

FIG. 6. THE RELATIVE FLUORESCENCE WITH DEPTH AT STATION 44.

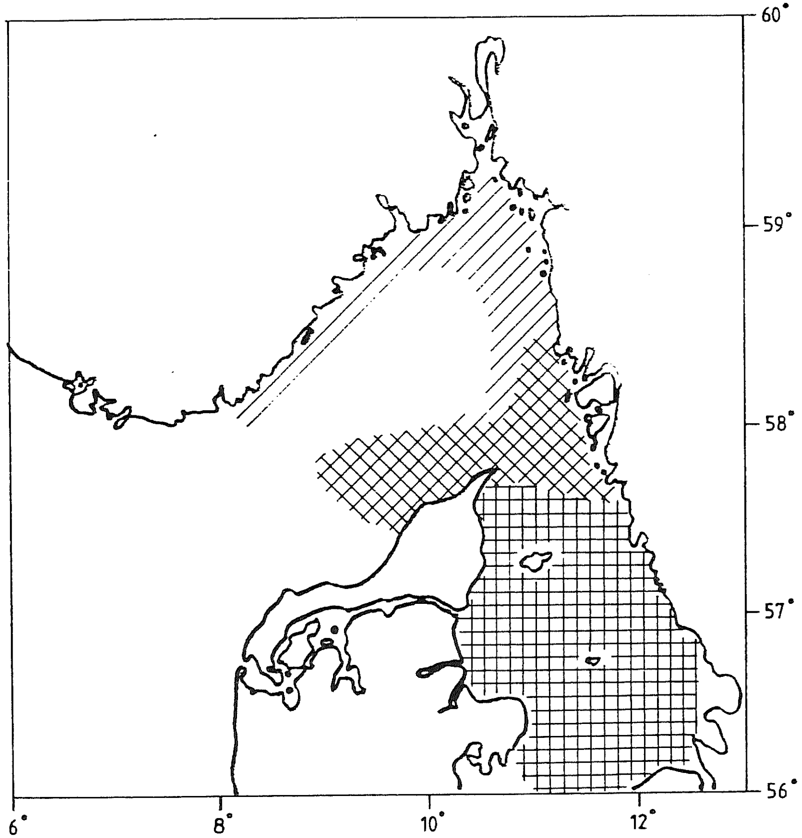

FIG. 7. WATERMASSES WITH DIFFERENT PHYTOPLANKTON POPULATIONS.

/// - WATERMASSES POOR IN PHYTOPLANKTON (TABLE 2)

- WATERMASSES RICH IN PHYTOPLANKTON, ASTERIONELLA GLACIALIS AND THALASSIOSIRA NORDENSKIOELDII DOMINATING (TABLE 3).

- WATERMASSES RICH IN PHYTOPLANKTON, NITZSCHIA SERIATA AND RHIZOSOLENIA HEBETATA VAR. SEMISPINA DOMINATING (TABLE 4).

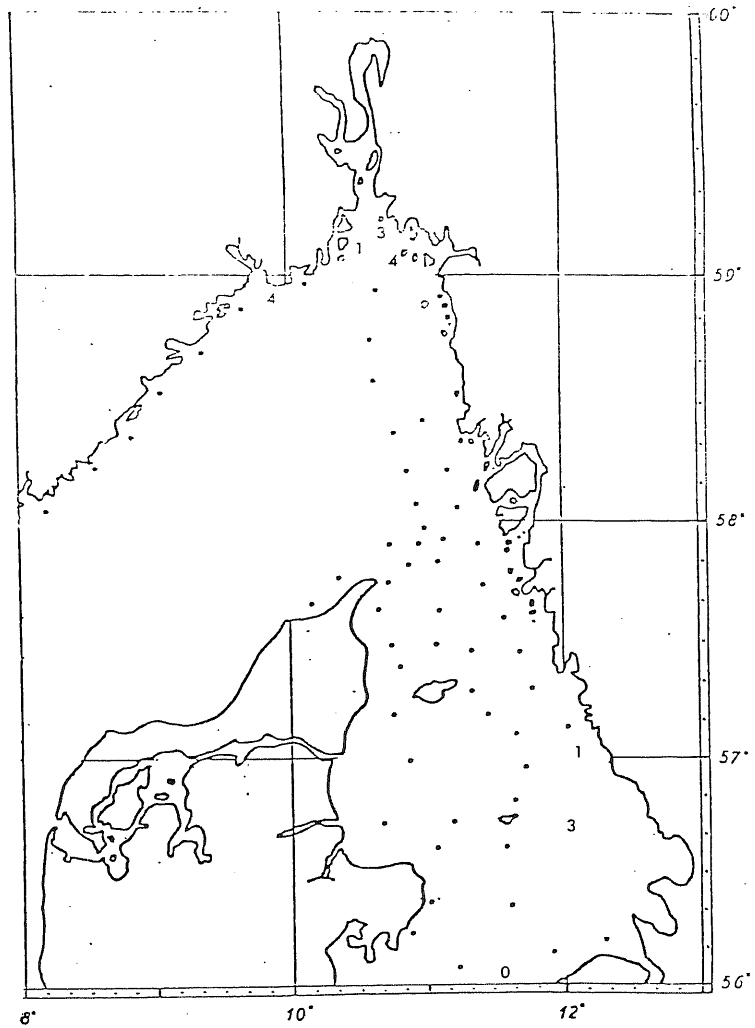

FIG. 8. NUMBERS OF HERRING LARVAE BELOW 1 M^2.
DANISH SURVEY 8/4 - 12/4 1983.

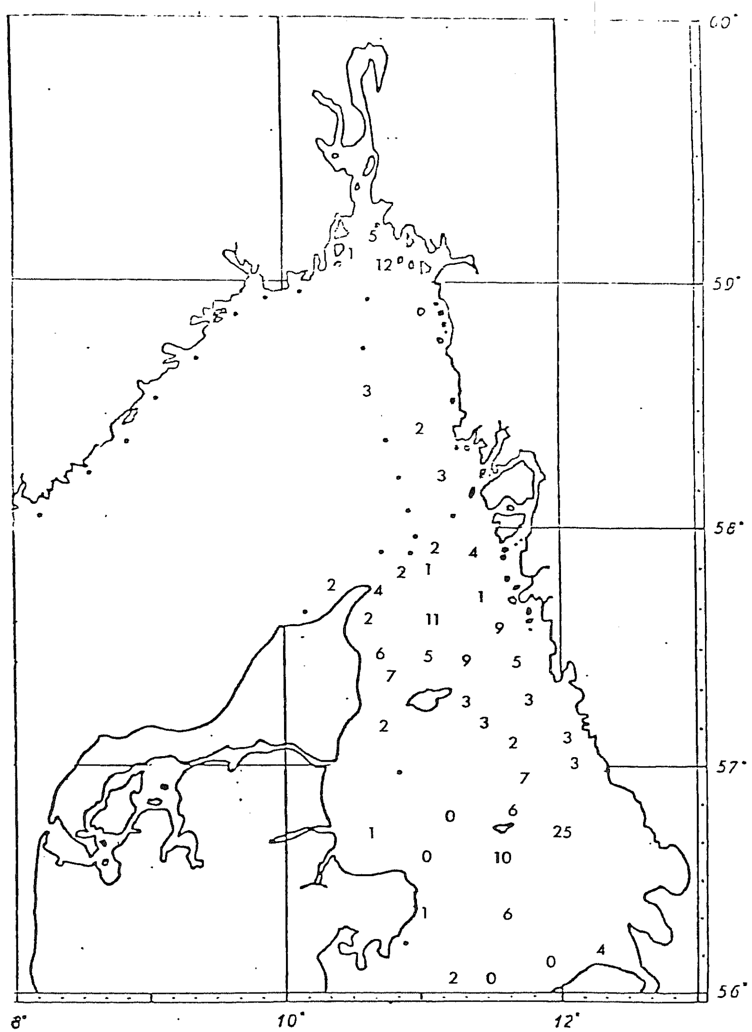

FIG. 9. NUMBERS OF COD LARVAE BELOW 1 M^2.
DANISH SURVEY 8/4 - 12/4 1983.

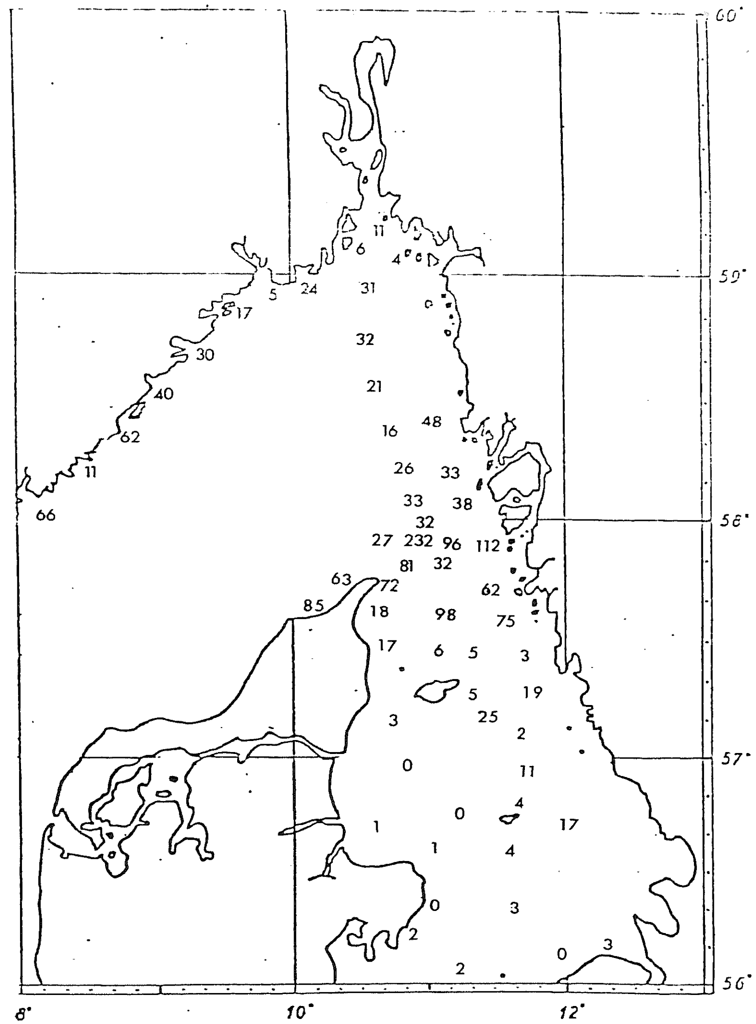

FIG. 10. NUMBERS OF SAND EEL LARVAE BELOW 1 M^2.
DANISH SURVEY 8/4 - 12/4 1983.

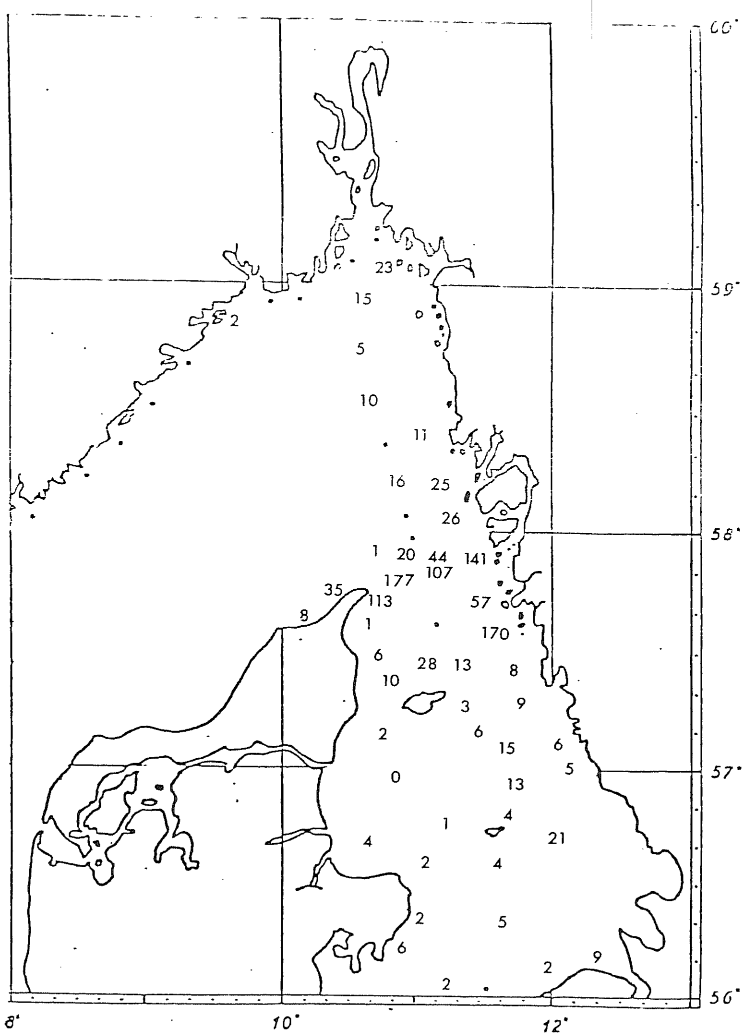

FIG. 11. NUMBERS OF DAB/FLOUNDER LARVAE BELOW 1 M^2. DANISH SURVEY 8/4 - 12/4 1983.

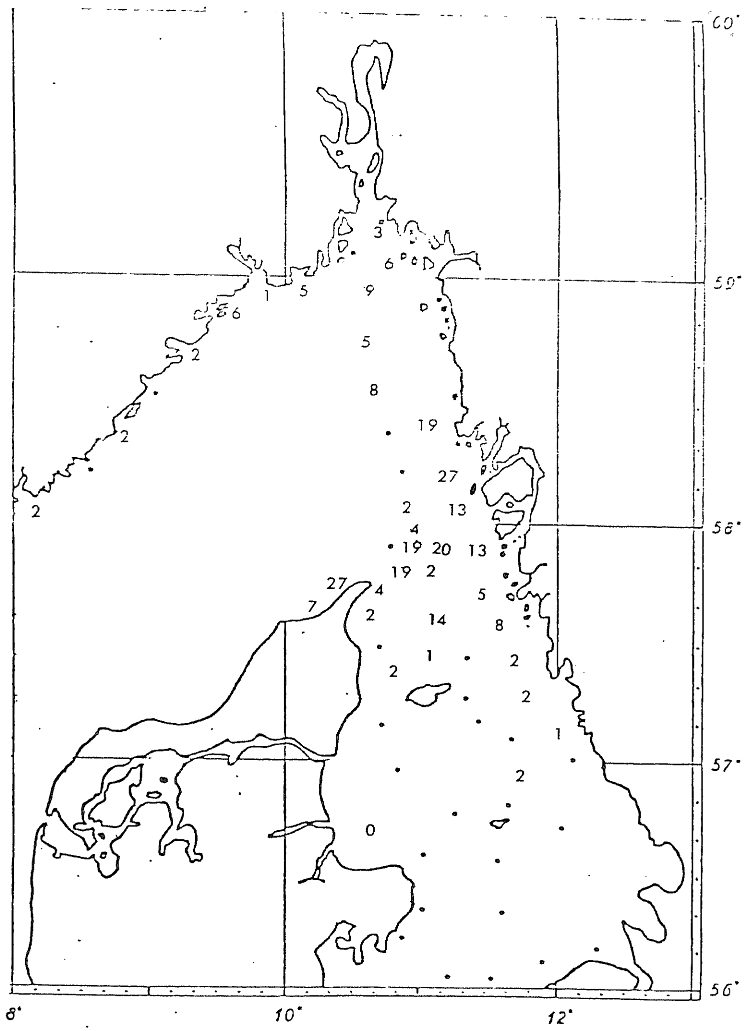

FIG. 12. NUMBERS OF PLAICE LARVAE BELOW 1 M^2. DANISH SURVEY 8/4 - 12/4 1983.

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Christensen, V. et al.:

"A combined fish larval, phytoplankton and oceanographic survey in the Skagerrak and the Kattegat in April 1983". ICES C.M. 1983/L:26.

The formula on page 3 should be:

$$No/m^2 = \frac{N * D * C}{\Pi * R^2 * F * E}$$