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NORTH SEA

SYNOPSIS OF INFORMATION ON THE OCEANOGRAPHY OF THE NORTH SEA

Prepared by

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FAO, Fisheries Division, Biology Branch August 1960

Purpose

This is one of a series of synopses on the oceanography of sea regions, aimed at summarizing the pertinent environmental factors affecting the fisheries. Whilst the primary purpose of these synopses is to contribute to the general work of the FAO Fisheries Biology Branch, on the appraisal of living aquatic resources, they also provide in concise form information necessary for briefing purposes, e.g. for the use of ETAP experts. They might also serve for assessing the general state of knowledge of different sea areas and might draw attention to the need for working up of accumulated data and serve as background material for designing research programmes.

These synopses are also compiled in accordance with recommendation No. 4, 1951 of the International Council for the Exploration of the Sea (Rapp.Cons.Int.Explor.Mer 131:5)

> "It is recommended that efforts should be made to encourage the writing of monographs describing the hydrographic conditions in the seas in which fishery research workers are interested".

Preparation

1st draft by Taivo Laevastu (11 August 1960)

Distribution

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1 INTRODUCTION

It is intended that this synopsis should be a collection of oceanographic and marine biological data for reference purposes mainly in graphic and tabular form with a minimal amount of descriptive material in the form of condensed summaries.

The present first draft contains data which was easily available. Notes are given on data being prepared, which will be added to following editions. It must be realized that the compilation of such a synopsis and the working up of individual data is a very large task, and the following should be considered mainly as an annotated outline with samples and comments on future processing of data.

In this synopsis it is intended to collect only data which is pertinent to the area. General information which can be found in textbooks is excluded and/or worked into special subject synopses.

This draft has been compiled hurriedly and may therefore contain occasional errors. The bibliography and data sources referred to will be added to the next edition, when the descriptive analyses will also be expanded.

1.1 Data and methods

(This chapter will contain information of national and international standard sections, routine observation routes and fixed stations. Availability of the time series data will be indicated together with notes on the extent to which these data have been worked up for various purposes. The list of institutions working in the area, their facilities and scientists specialized in different fields will facilitate the cooperative working up of data for the whole area as a unit. Reference list of the description of various routine and standard methods of observation and working up will also be added).

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1.2 Special aspects of data treatment

(This chapter will contain various conversion tables, notes on selection on sections etc. and suggestions on methods for further working up of accumulated data).

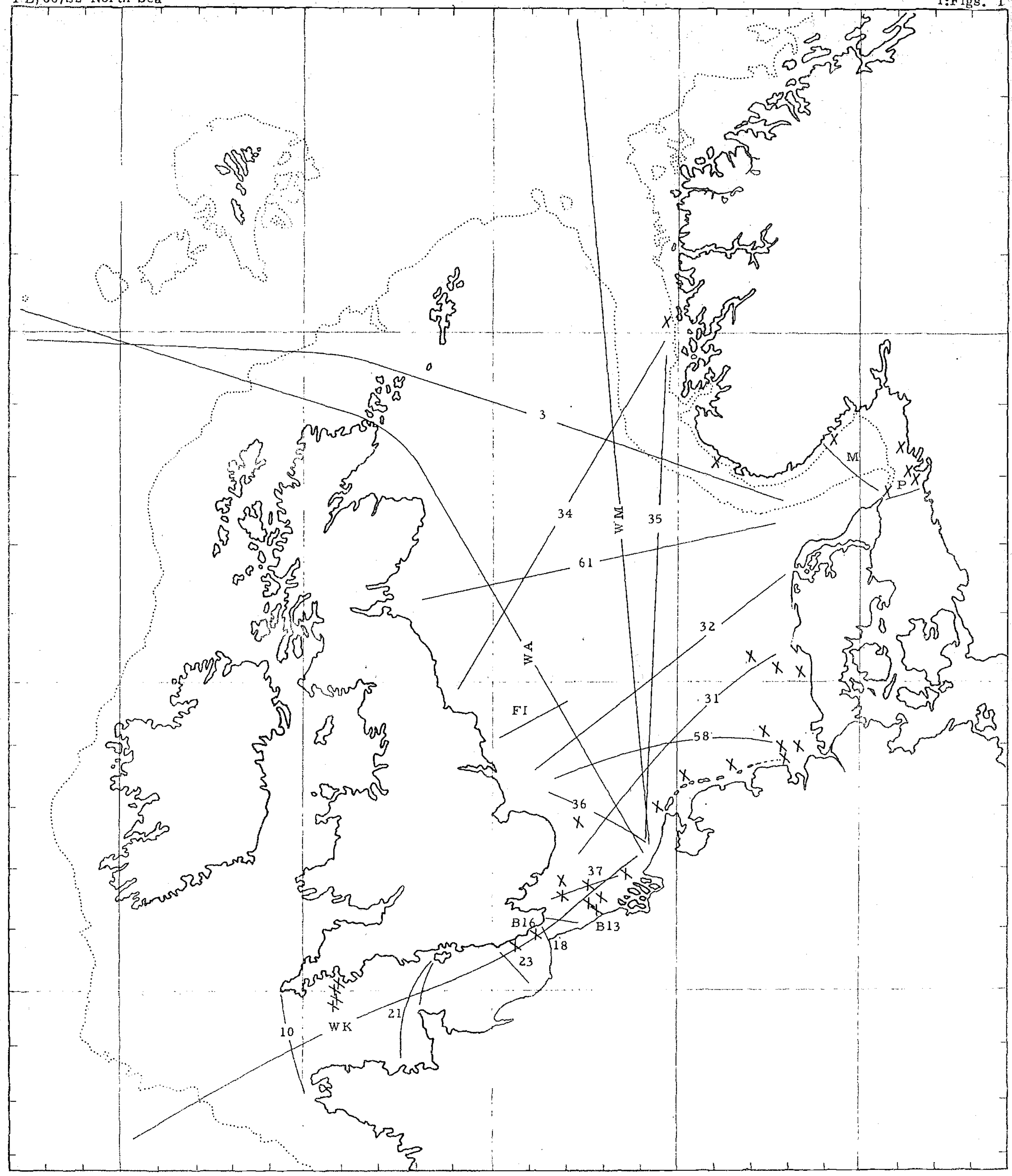

FIGURE 1.1 - ICES ROUTINE OBSERVATIONS IN THE NORTH SEA AND ADJACENT WATERS

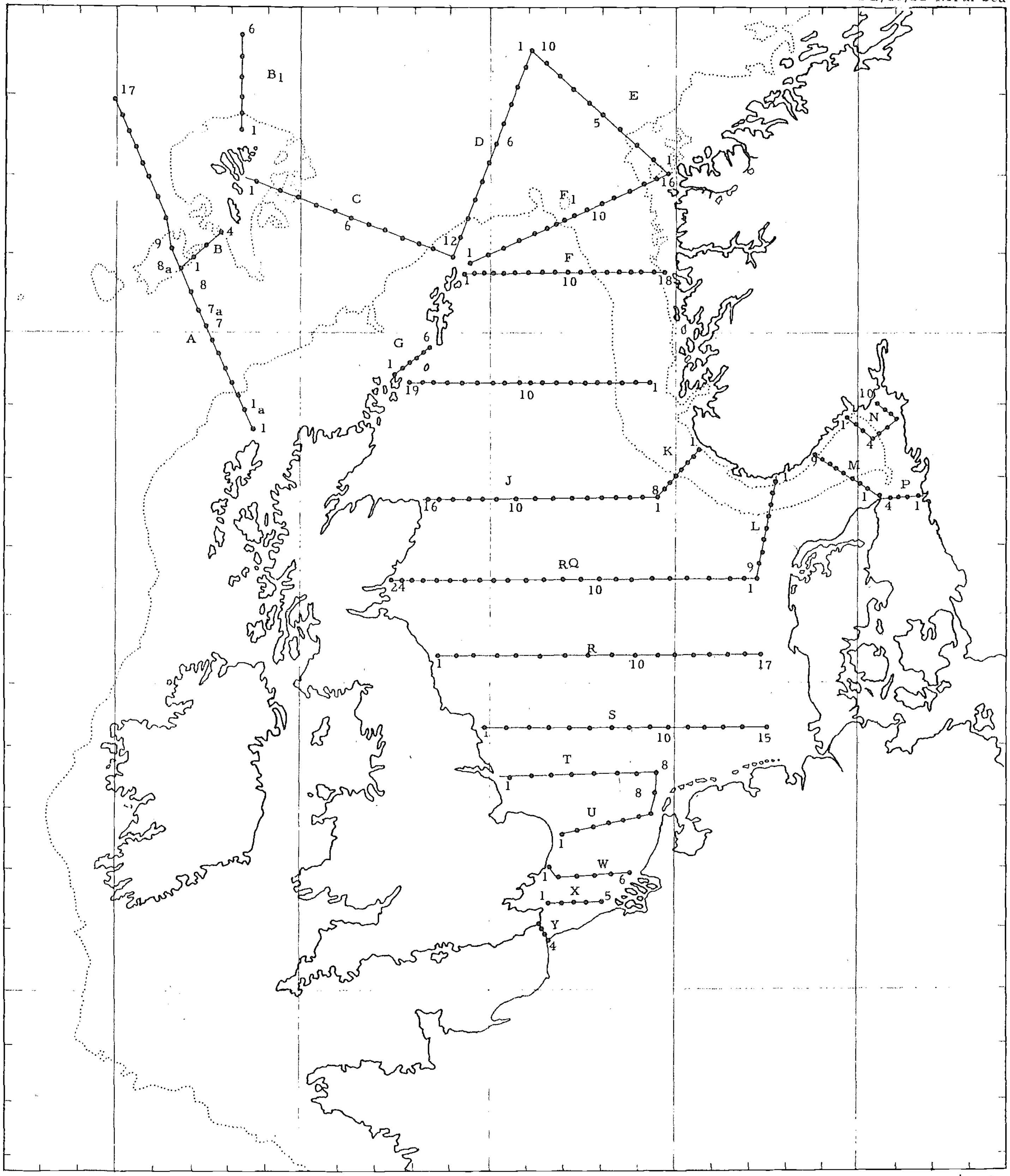

FIGURE 1.2 - ICES SECTIONS OF HYDROGRAPHICAL - BIOLOGICAL INVESTIGATIONS IN THT NORTH SEA

TABLE 1.1

Positions of routine observations from commercial vessels, light ships and fixed stations in the North Sea

North Sea, English Channel and Irish Sea

Routes and Sections

Bergen-New York	(Route 8)	Norway	Thermograph records. Salinity samples collected (intake pipe of the condenser) at fixed positions. Salinities determined by titration
Bergen-Newcastle	(" 34)	"	
Bergen-Rotterdam	(" 35)	"	
Bergen-Oslo	(" 9)	"	

The Skaw-Greenland (Route 3) Denmark. Surface observations, as often as sailings permit (i.e. about 30 times a year) of T$^{\circ}$ C and S ‰ at 13 points between 11°E. and 2°W. (fixed longitudes). Samples taken by bucket. Salinities: titration.

Leith-Copenhagen (Route 61) England. Weekly surface observations of T$^{\circ}$ C and S ‰ at 9 positions at approx. 40 mile intervals:-

56°17'N., 1°30'W.	Samples taken through the condenser intake in engine room at less than 5 m depths. Salinities determined by titration.
58°26'N., 0°19'W.	
56°35'N., 0°52'E.	
56°45'N., 2°03'E.	
56°54'N., 3°15'E.	
57°03'N., 4°25'E.	
57°12'N., 5°36'E.	
57°21'N., 6°47'E.	
57°30'N., 8°00'E.	

Hull-Hanstholm. (Route 32) England. Weekly surface observations of T$^{\circ}$ C and S ‰ at 9 positions:-

56°56'N., 8°00'E.
56°30'N., 7°00'E.
56°05'N., 6°00'E.
55°39'N., 5°00'E.
55°12'N., 4°00'E.
54°45'N., 3°00'E.
54°18'N., 2°00'E.
54°05'N., 1°30'E.
53°51'N., 1°00'E.

Samples taken through the condenser intake in engine room at less than 5 m depths. Salinities determined by titration.

Flamborough Line. (FL) England. Observations of T° C and S ‰ at 6 fixed positions:-

54°08'N., 0°00'	Surface observations from April to September taken by surface sampler. Sub-surface observations in June every 10 m taken by Nansen-Pettersson water bottle. Salinities determined by titration.
54°13'N., 0°19'E.	
54°18'N., 0°38'E.	
54°24'N., 0°57'E.	
54°29'N., 1°18'E.	
54°34'N., 1°38'E.	

Esbjerg-London. (Route 31) Denmark. Weekly surface observations, T° C and S ‰ at 6 fixed positions:- (Occasionally between Esbjerg and Grimsby)

55°24'N., 7°00'E.	55°23'N., 7°00'E.
54°54'N., 6°00'E.	55°09'N., 6°00'E.
54°24'N., 5°00'E.	54°52'N., 5°00'E.
53°49'N., 4°00'E.	54°35'N., 4°00'E.
52°54'N., 3°00'E.	54°20'N., 3°00'E.
52°10'N., 2°00'E.	54°02'N., 2°00'E.

Samples taken by bucket. Salinities determined by titration.

Ijmuiden-Hull. (Route 36) Netherlands. Weekly observations of T° C and S ‰ at the surface at 6 positions approximately:-

53°30'N., 1°50'E.
53°20'N., 2°20'E.
53°10'N., 2°50'E.
53°00'N., 3°20'E.
52°50'N., 3°40'E.
52°40'N., 4°00'E.

Samples taken by bucket. Salinities determined by titration.

Rotterdam-London. (Route 37) Netherlands. Weekly surface observations. of T°C and S ‰ at 4 positions approximately:-

51°51'N., 3°15'E.
51°45'N., 2°40'E.
51°36'N., 2°05'E.
51°27'N., 1°30'E.

Samples taken by the Lumby water sampler. Salinities determined by titration.

Hamburg-Hull. (Route 58) Germany. Frequency: 6 times per month. Observations at the surface of T° C and S ‰. Salinities determined by titration.

54°09'N., 7°32'E.
54°18'N., 6°12'E.
54°19'N., 5°21'E.
54°10'N., 4°26'E.
54°00'N., 3°32'E.
53°53'N., 2°43'E.
53°45'N., 1°54'E.

Gravelines-Deal. Belgium.

B 13	51°02'N., 2°03'E.	(8 times a year water samples by (frameless reversing bottle at the (surface, near the bottom and at (20 and 40 m T° C, S‰ and alkali- (nity. At 20 m observations of (oxygen, silicates, phosphates, (nitrates, calcium, magnesium and (sulphates. Salinities by titration.
B 14	51°07'N., 1°49'E.	
B 15	51°10'N., 1°36'E.	
B 16	51°12'N., 1°28'E.	

Folkestone-Boulogne. (Route 18) England and France. Weekly surface observations of T° and S ‰ at 3 fixed positions at intervals of 6 miles:-

51°00'N., 1°17'E.
50°55'N., 1°22'E.
50°50'N., 1°28'E.

Samples taken through the condenser intake in engine room at less than 5 m depths. Salinities determined by titration.

Newhaven-Dieppe. (Route 23) England. Weekly surface observations of T° C and S ‰ at 6 fixed positions at intervals of approximately 10 miles.

southbound	northbound
50°38'N., 0°11'E.	50°04'N., 0°56'E.
50°30'N., 0°20'E.	50°11'N., 0°48'E.
50°22'N., 0°30'E.	50°19'N., 0°39'E.
50°14'N., 0°39'E.	50°25'N., 0°30'E.
50°07'N., 0°49'E.	50°32'N., 0°21'E.
50°00'N., 0°58'E.	50°40'N., 0°12'E.

Samples taken through the condenser intake in engine room at less than 5 m depths. A thermograph is also used. Salinities determined by titration.

Southampton-St.Malo. (Route 21) England. Weekly surface observations of T° C and S ‰ at 9 positions at intervals of about 11 miles.

50°35'N.,	1°40'W.	(1°38'W.)
50°23'N.,	1°45'W.	(1°43'W.)
50°12'N.,	1°51'W.	(1°47.5'W.)
50°00'N.,	1°57'W.	(1°52'W.)
49°48'N.,	2°02'W.	(1°56'W.)
49°36'N.,	2°08'W.	(2°01'W.)
49°24'N.,	2°14'W.	
49°04'N.,	2°19'W.	
48°50'N.,	2°15'W.	

(An alternative route, occasionally used, is shown in brackets. The latitudes are the same for both routes).

Samples taken through the condenser intake in engine room at less than 5 m depths. A thermograph is also used. Salinities determined by titration.

Lands End-Ushant. (Route 10) England. Weekly surface observations of T° C and S ‰ at 9 positions at intervals of about 12.5 miles.

50°04'N., 5°55'W.
49°52'N., 5°50'W.
49°40'N., 5°45'W.
49°28'N., 5°40'W.
49°16'N., 5°35'W.
49°04'N., 5°30'W.
48°52'N., 5°25'W.
48°40'N., 5°20'W.
48°27'N., 5°15'W.

Samples taken through the condenser intake in engine room at less than 5 m depths. Salinities determined by titration.

Fishguard-Waterford. England. Surface observations 3 times a week, of T° C and S ‰ at one fixed position:-

52°04'N., 5°40'W. (L'p 4)

Samples taken by canvas bucket. Salinities determined by titration. (potentiometric).

Holyhead-Kish. England. Surface observations 3 times a week of T° C and S ‰ at 3 fixed positions:-

53°20'N., 4°44'W. (L'p 7)
53°20'N., 5°16'W. (L'p 6)
53°19'N., 5°52'W. (L'p 6)

Samples taken by canvas bucket. Salinities determined by titration. (potentiometric).

Larne-Stranraer. England. Surface observations 3 times a week of T° C and S ‰ at one fixed position:-

54°57'N., 5°28'W. (L'p 9)

Samples taken by canvas bucket. Salinities determined by titration (potentiometric).

Lightship Stations etc.

Vyl (Vy) Denmark 55°24.4'N., 7°34.3'E. (Daily observations at 8^h C.E.T.
ER (ER) " 55°23.6'N., 6°57.4'E. (of T° C and S ‰ (by hydrometer)
in 0 (or 1) m, near the bottom and in as many of the levels 0, 5, 10, 15, 20, 25, 30 and 35 m as permitted by the depth. Knudsen's insulating water bottle is used for temperature determination and water sampling including the surface (1 m). Every 4 hours (4^h, 8^h, etc. C.E.T.) the true direction of the current (by one of the 16 points of the compass) and the speed (in knots to the first decimal place) are estimated.

Noord Hinder (NH)	Netherlands.	51°39.0'N.,	2°34.0'E.
Terschellingerbank (TB)	"	53°29.0'N.,	5°07.0'E.
Texel (Tx)	"	53°01.4'N.,	4°21.7'E.
Goeree (Go)	"	51°55.7'N.,	3°39.7'E.

Surface observations of T° C every 3 hours at 00, 03 etc. G.M.T.; of surface S ‰ daily at 08^{00} G.M.T. Samples taken by bucket. Salinities determined by titration. Continuous current measurements by means of the vertical log with readings at 00, 01, 02 etc. G.M.T.

West Hinder (WH) Belgium. 51°22'25"N., 2°27'45"E.

Daily surface observations of T° C, every three days observations of S ‰ and alkalinity. Samples taken by bucket. Salinities determined by titration. Weekly observations of silicates, phosphates, nitrates. Monthly observations of calcium, magnesium and sulphates.

Dyck France 51°02.4'N., 1°53.0'E. Observations continues des courants à 6 mètres de profondeur par le "Vertical Log".

P 8	Germany	54°16.0'N.,	7°11.5'E.	(Daily at 08^{00}
P 12	"	54°00.0'N.,	7°51.5'E.	(measurements of
Elbe 1	"	54°00.0'N.,	8°10.7'E.	(surface T° C
Weser	"	53°51.6'N.,	7°53.3'E.	(and S ‰, and
Borkumriff	"	53°45.0'N.,	6°24.2'E.	(every 3 or 4 days
				(at high and low

water surface T° C and S ‰. Samples taken by bucket. Salinities determined by titration. Current measurements by cross-shaped log (Stromkreuz) every 2 hours. At Borkumriff: Once a week (at 08^{00} C.E.T.) T$^{\circ}$ C and S ‰ in 5, 10, 15 20 m. and at the bottom with the Pettersson sampler. Salinities determined by titration. Continuous current measurements by vertical log.

Varne (Va)	England	50°56'N., 1°17'E.	(Surface obser-
Seven Stones (SS)	"	50°03.7'N., 6°04.5'W.	(vations of T$^{\circ}$ C
Galloper (Ga)	"	51°44.5'N., 1°57.8'E.	(and S ‰ every

4 days. Samples taken by Engine Room Sampler at less than 5 m depths. Salinities determined by titration.

Smith's Knoll (SK) England. 52°43.5'N., 2°18.0'E. Samples taken by Surface Sampler until June 1958, and by Engine Room Sampler at less than 5 m depths thereafter, T$^{\circ}$ C and S ‰ every 4 days.

Conigsbeg (Co) Ireland 52°02'N., 6°40'W. Twice daily observations of T$^{\circ}$ C at the surface.

Liverpool Bar	(L'p 2)	England	53°31.4'N., 3°19.3'W.
Morecambe Bay	(L'p 1)	"	53°54.6'N., 3°28.9'W.

Surface observations 3 times a week of T$^{\circ}$ C and S ‰. Samples taken by canvas bucket. Salinities determined by titration (potentiometric).

Station L 2	England	50°20'N., 4°10'W.	(Monthly observations
" L 3	"	50°18'N., 4°11'W.	(of T$^{\circ}$ C and S ‰ at
" L 4	"	50°15'N., 4°13'W.	(surface. Salinity
" L 5	"	50°11'N., 4°18'W.	(determined by
" L 6	"	50°06'N., 4°21'W.	(titration.
" E 1	"	50°02'N., 4°22'W.	Monthly observations

of T$^{\circ}$ C, S ‰ and content of phosphorus and silicon at surface and sub-surface depths. Samples taken by Nansen-Pettersson water bottle. Salinities determined by titration.

Station at 3 nautical miles N65°W. of Port Erin. Weekly observations of surface T$^{\circ}$ C and S ‰. Temperatures taken by insulated thermometers, read to 0.1° C. Salinities determined by titration.

Coastal Stations.

Lista	Norway	58°05.1'N., 6°32.5'E.	(Observations
Utsira I	"	59°15.4'N., 4°55.7'E.	(every
Utsira II	"	59°15.2'N., 4°46.5'E.	(fortnight

Surface to bottom observations of T$^{\circ}$ C and S ‰. Samples collected by Nansen water bottles. Reversing deep-sea thermometers are used; salinities are determined by titration.

List (Isle of Sylt) Germany $55^{\circ}03'$N., $8^{\circ}27'$E. at the "Elbow". Daily surface observations of T$^{\circ}$ C, every 2 weeks salinities at high and low water.

List (Isle of Sylt) Germany. $55^{\circ}01'$N., $8^{\circ}27'$E. in the harbour. Every 10 days surface observations of T$^{\circ}$ C, S ‰, O_2 and pH.

B 22 Belgium. $51^{\circ}10'$N., $2^{\circ}38'$E. 8 times a year water samples collected by the "Frameless Reversing Bottle". Salinities determined by titration. Observations at the surface and near the bottom of T$^{\circ}$ C, S ‰, oxygen, alkalinity, silicates, phosphates, nitrates, calcium, magnesium and sulphates.

Roscoff France. Observations périodiques de T$^{\circ}$ C et S ‰ près l'ile de Bas.

Bardsey Island (L'p 3) England $52^{\circ}45'$N., $4^{\circ}48'$W. (T$^{\circ}$ C and S ‰ at
Chicken Rock (L'p 8) " $54^{\circ}02'$N., $4^{\circ}50'$W. (surface 3 times a
Salinities determined by titration. (week.

Port Erin Bay (Isle of Man) England. Daily observations of surface T$^{\circ}$ F at 9 a.m. and 4 p.m. GMT. Temperatures read to 0.5°F.

North Atlantic

Routes, Sections (and Ocean Weather Stations)

Reykjavik-New York Iceland. Thermograms, once or twice monthly.

Icelandic coastal routes " Thermograms, in summer twice, in winter four times monthly.

The Skaw-Greenland. (Route 3) Denmark. Surface observations as often as sailings permit (i.e. about 30 times a year), of T$^{\circ}$ C and S‰ at 21 points between 4° W. and 44° W. (fixed longitudes) and at 8 points along the west coast of Greenland. Samples taken by bucket. Salinities determined by titration.

Bergen-New York (Route 8) Norway. (Thermograph records. Samples col-
Bergen-Kirkenes " (lected [intake pipe in the condenser]
(at fixed positions. Salinities dete-
(rmined by titration.

Southampton-Canary Islands. " During winter: Thermograph records.

Ocean Weather Ship. Station A. (WA) Great Britain, France, Netherlands, Norway. 62°00'N., 33°00'W.
(Netherlands) every three hours at 00^{00}, 03^{00}, etc. GMT en route between Hoek van Holland and station and once daily at 12^{00} GMT during stay on station:- samples taken by bucket; daily BT observations only on station. Salinities determined by titration.

Ocean Weather Ship. Station I. (WI) Great Britain, Netherlands. 59°00'N., 19°00'W.
(Netherlands) every 3 hours at 00^{00}, 03^{00}, etc. GMT en route between Hoek van Holland and station and once daily at 12^{00} GMT during stay on station. Samples taken by bucket; daily BT observation only on station. Salinities determined by titration.

Ocean Weather Ship. Station J. (WJ) Great Britain, France and Netherlands. 52°30'N., 20°00'W.
(Netherlands) every 3 hours at 00^{00}, 03^{00} etc. GMT en route between Hoek van Holland and station and once daily at 12^{00} GMT during stay on station. Samples taken by bucket; daily BT observation only on station. Salinities determined by titration.

Ocean Weather Ship. Station K. (WK) Great Britain, France, Netherlands. 54°00'N., 16°00'W.
(Netherlands) every 3 hours at 00^{00}, 03^{00} etc. GMT en route between Hoek van Holland and station and once daily at 12^{00} GMT during stay on station. Samples taken by bucket; daily BT observations only on station. Salinities determined by titration.

Ocean Weather Ship. Station M. (WM) 66°00'N., 2°00'E. Norway, Netherlands.
(Netherlands) Observations of T° C and S ‰ at the surface every 3 hours at 00^{00}, 03^{00}, etc. GMT en route between Hoek van Holland and station and once daily at 12^{00} GMT during stay on station. Samples taken by bucket, salinities determined by titration. Daily BT observations only on station.

2. GEOGRAPHICAL AND GEOLOGICAL FEATURES OF THE NORTH SEA

2.1 General geographical characteristics of the North Sea

There are slight differences in the definitions of geographical boundaries of the North Sea and its subdivisions (see Figure 2.1). In certain quantitative comparative considerations it is necessary to determine areas and/or volumes of the regions. As the names of some geographical and statistical areas are identical, it is necessary to point out which divisions are used in these quantitative considerations. There is therefore a need to determine uniform boundaries in order to avoid confusion. In Figure 2.1 proposals have been made for uniform geographic boundaries of the area which are of course different from the ICES statistical boundaries (Figures 2.2 and 2.3) which should be maintained for present statistical purposes.

The general nature of the coastline is indicated in Figure 2.4. A list of geological maps, as well as national sea charts of the North Sea will be added later. The north and south coasts of the North Sea are basically different. In the north, the Scottish and Norwegian coasts are rocky and steep; the southern coasts are low, sandy and have extensive tidal flats.

The shipping in the North Sea is more intensive than in any other sea area. Some of the principle ports and their distances from each other are shown in Figure 2.5. More detailed information on harbours and shipping can be found in sailing directions and in G. Goodall, 1952, "The Mercantile Marine Atlas", published by G. Philip and Son Ltd., London.

A detailed description of the fishery falls outside the scope of this synopsis. A general idea of the intensity of fishing however, is given in Figure 2.5 and further general information on the types of vessels and gear used and the main commercial species will be added, partly to this chapter and partly to the last chapter of this synopsis.

2.1.1 Boundaries, areas and volumes of the North Sea and its subdivisions

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2.1.2 The coast

(The morphology of the coast - see Figure 2.5)

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2.1.3 Shipping and fishing (general)

List of figures

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2.2 Submarine geology

The bathymetry and distribution of sediments are shown in Figures 2.7 and 2.8. The shallowest depth in the northern North Sea is 73 m, on Viking Bank and the greatest depth is SW Bressay Shoal, 190 m. In the central North Sea the shallowest depth is 13 m on the Dogger Bank, and the greatest depth is 212 m - the Devil's Hole.

The sediments of the North Sea consist mainly of sand and gravel with occasional spots of mud in deeper holes. The average content of organic matter is 2 to 3 % but in some muds it can rise to 25 %. The content of $CaCO_3$ is usually below 7 % and is mainly caused by shell fragments and benthic forms. As the North Sea has sunk during the last glaciation, in some localities peat and tree trunks of earlier interglacial origin are found.

The rate of sedimentation varies locally, being greatest off the estuaries. Some sedimentation also occurs in deeper holes whereas on the shallow banks, erosion by wave action and tidal currents takes place.

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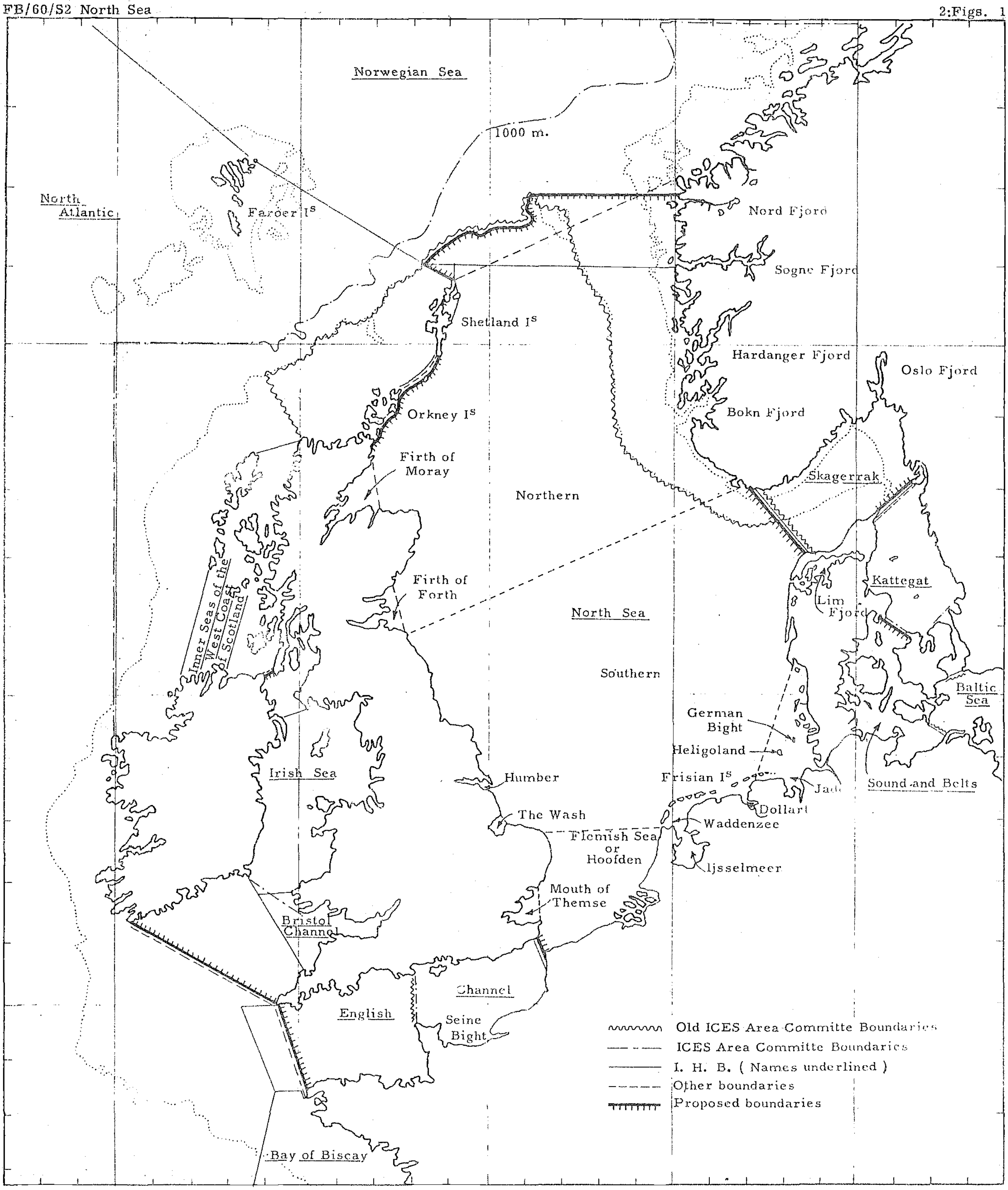

FIGURE 2.1 - BOUNDARIES OF THE NORTH SEA AND ITS SUBDIVISIONS

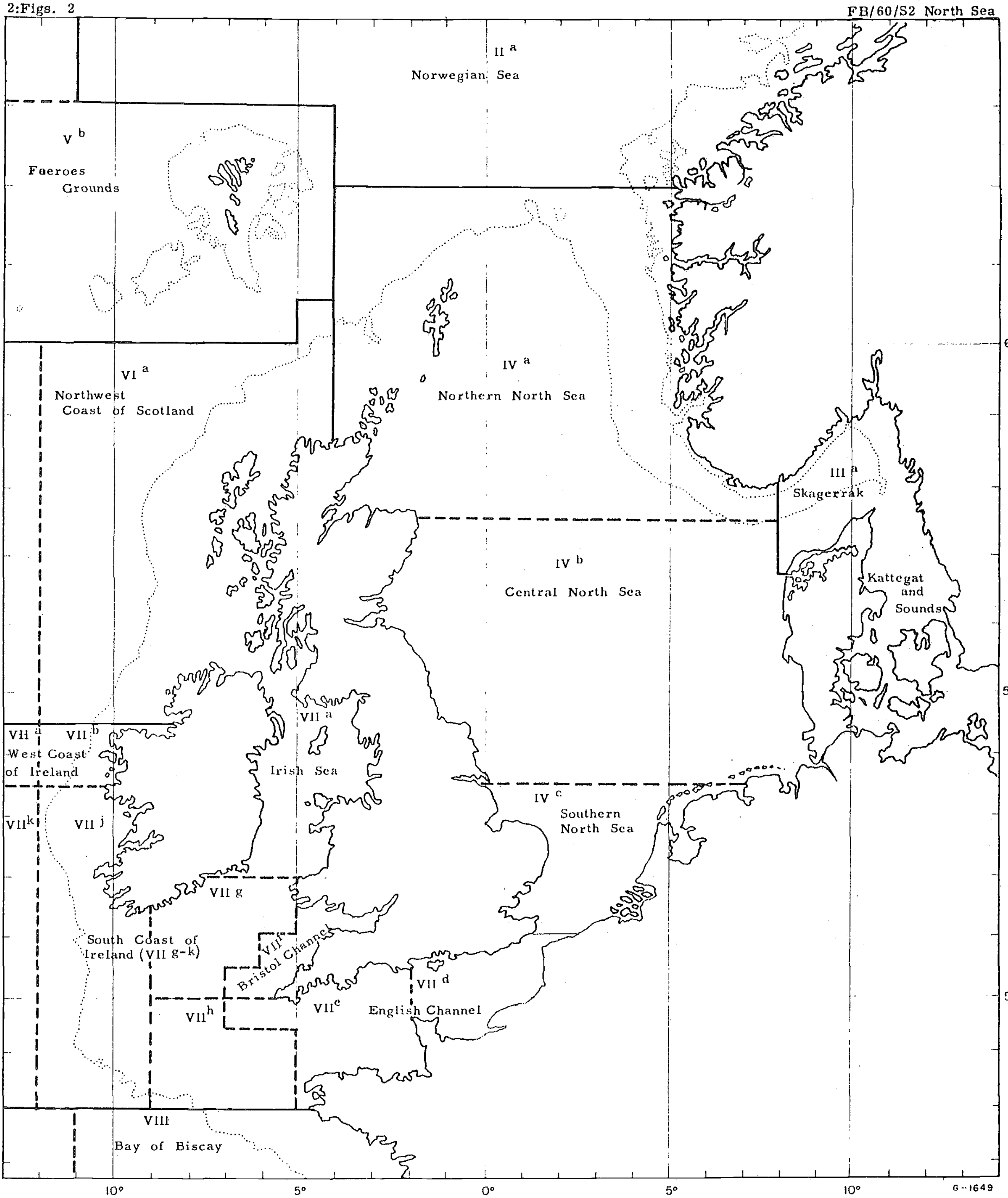

FIGURE 2.2 - STATISTICAL AREAS OF ICES

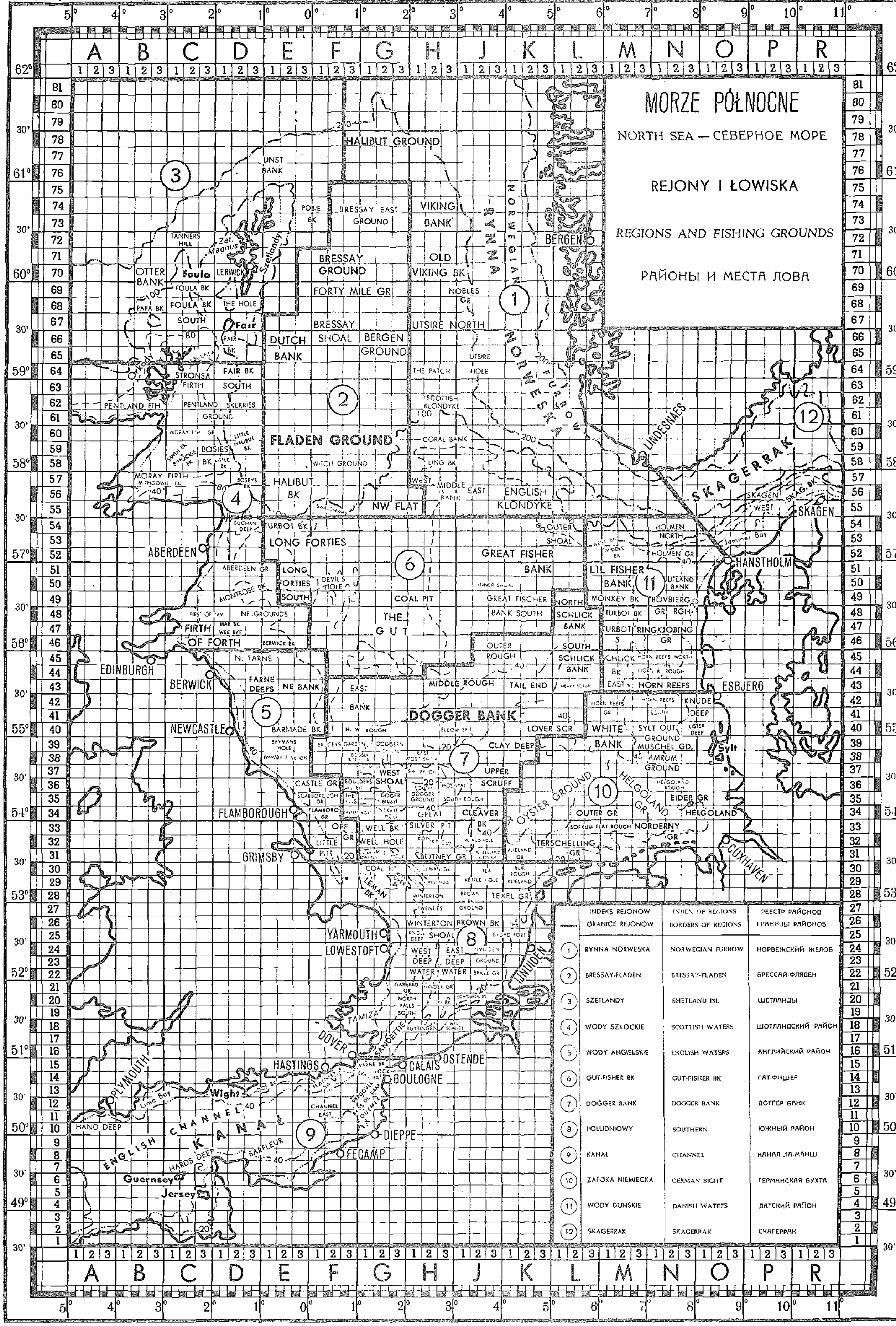

FIGURE 2.3 - REGIONS AND FISHING GROUNDS IN THE NORTH SEA
(from Klimaj and Rutkowicz, Fishing Atlas of the North Sea)

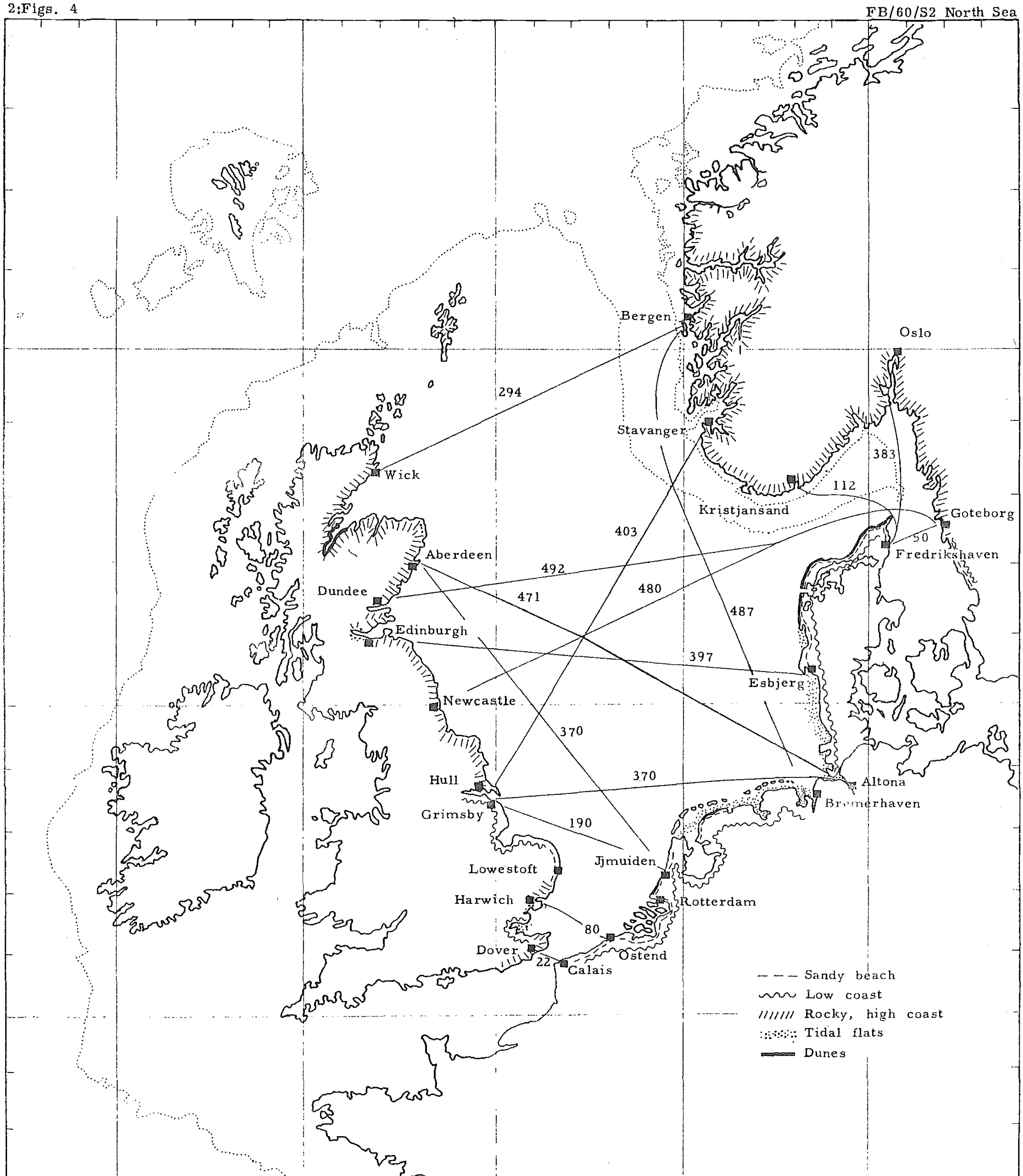

FIGURE 2.5 - SOME BIGGER HARBORS, DISTANCES BETWEEN THE PORTS AND NATURE OF THE COAST

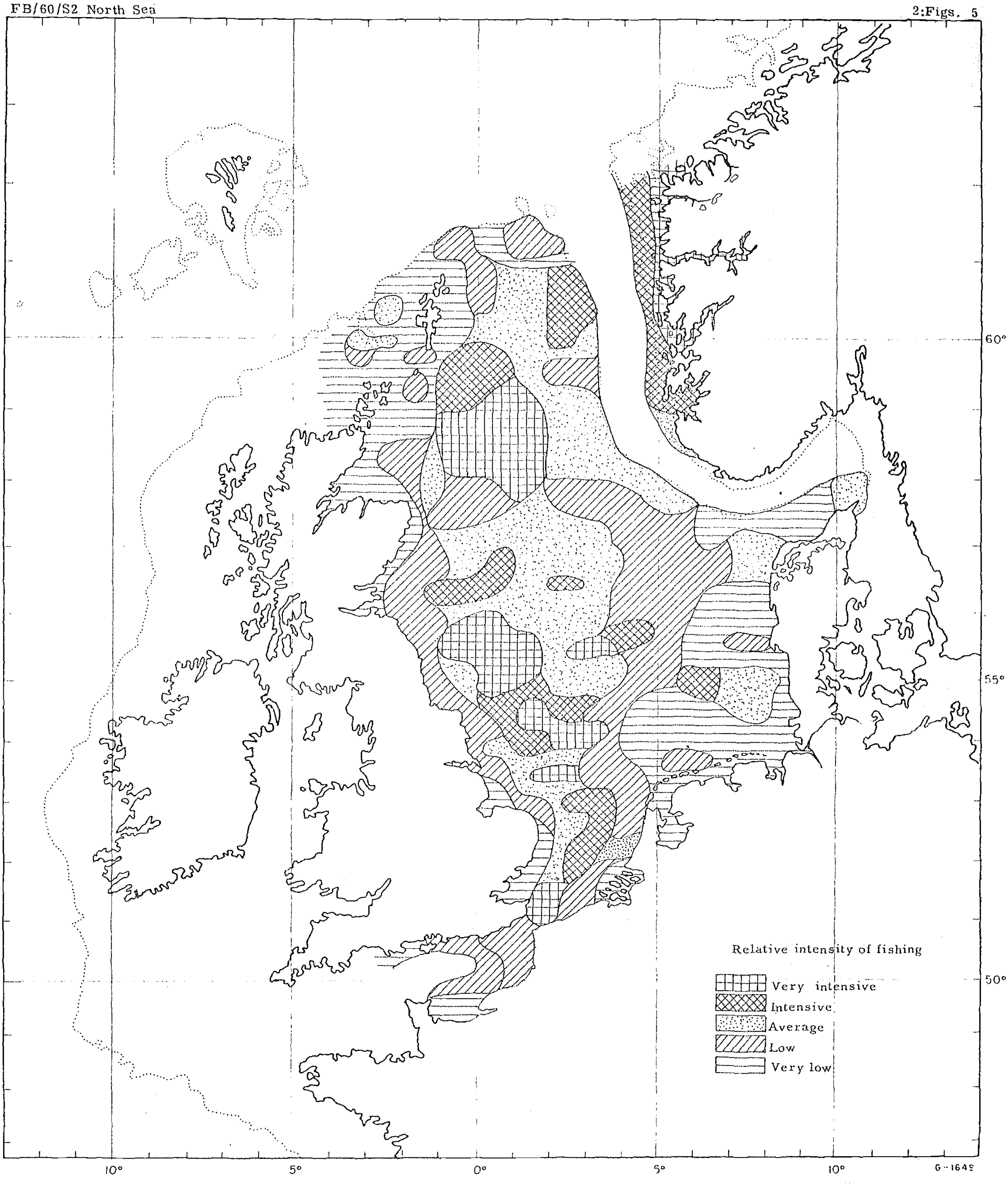

FIGURE 2.6 - RELATIVE INTENSITY OF FISHING IN THE NORTH SEA (after Klimaj and Rutkowicz)

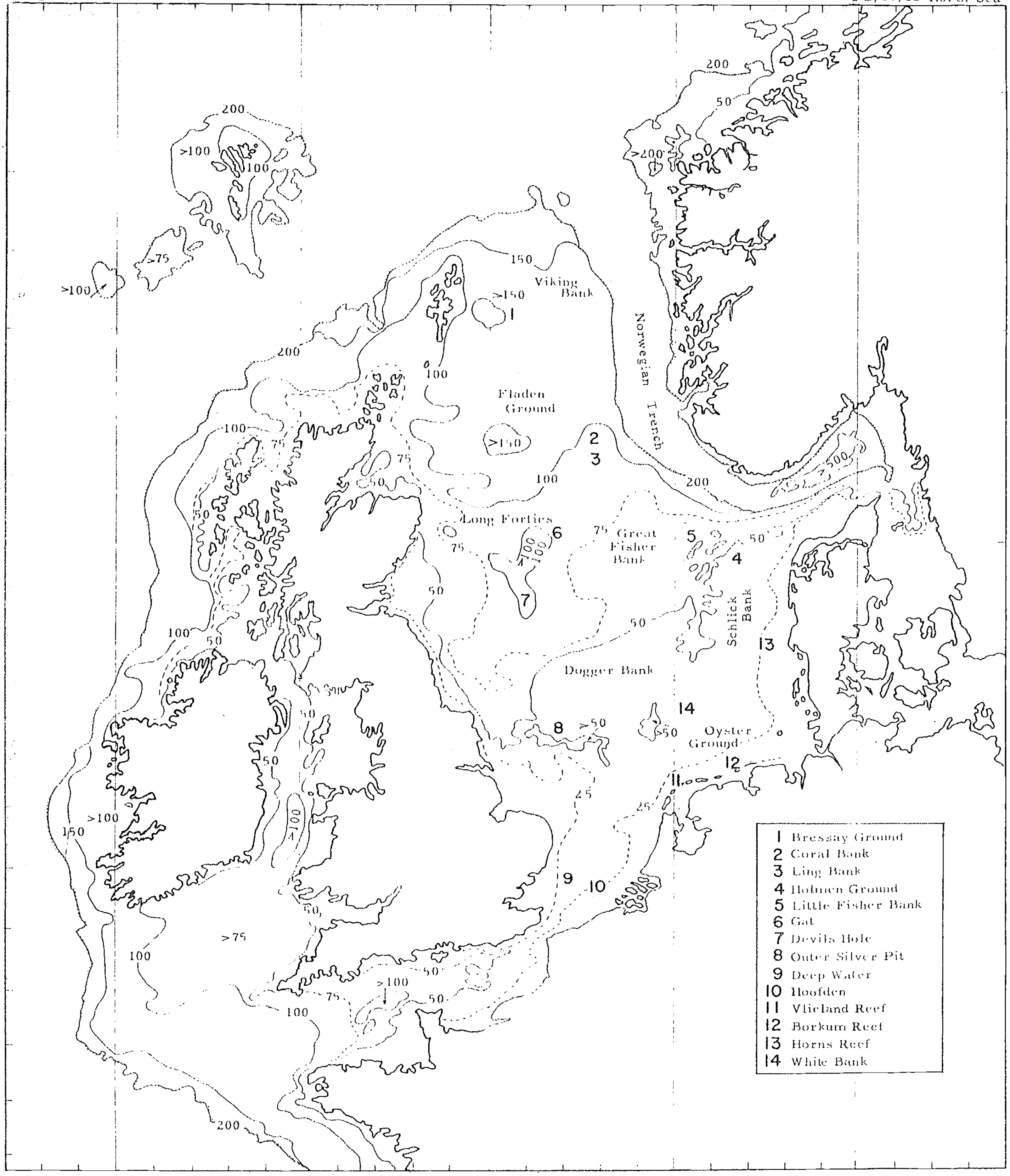

FIGURE 2.7 - BATHYMETRY AND NAMES OF THE BANKS AND GROUNDS

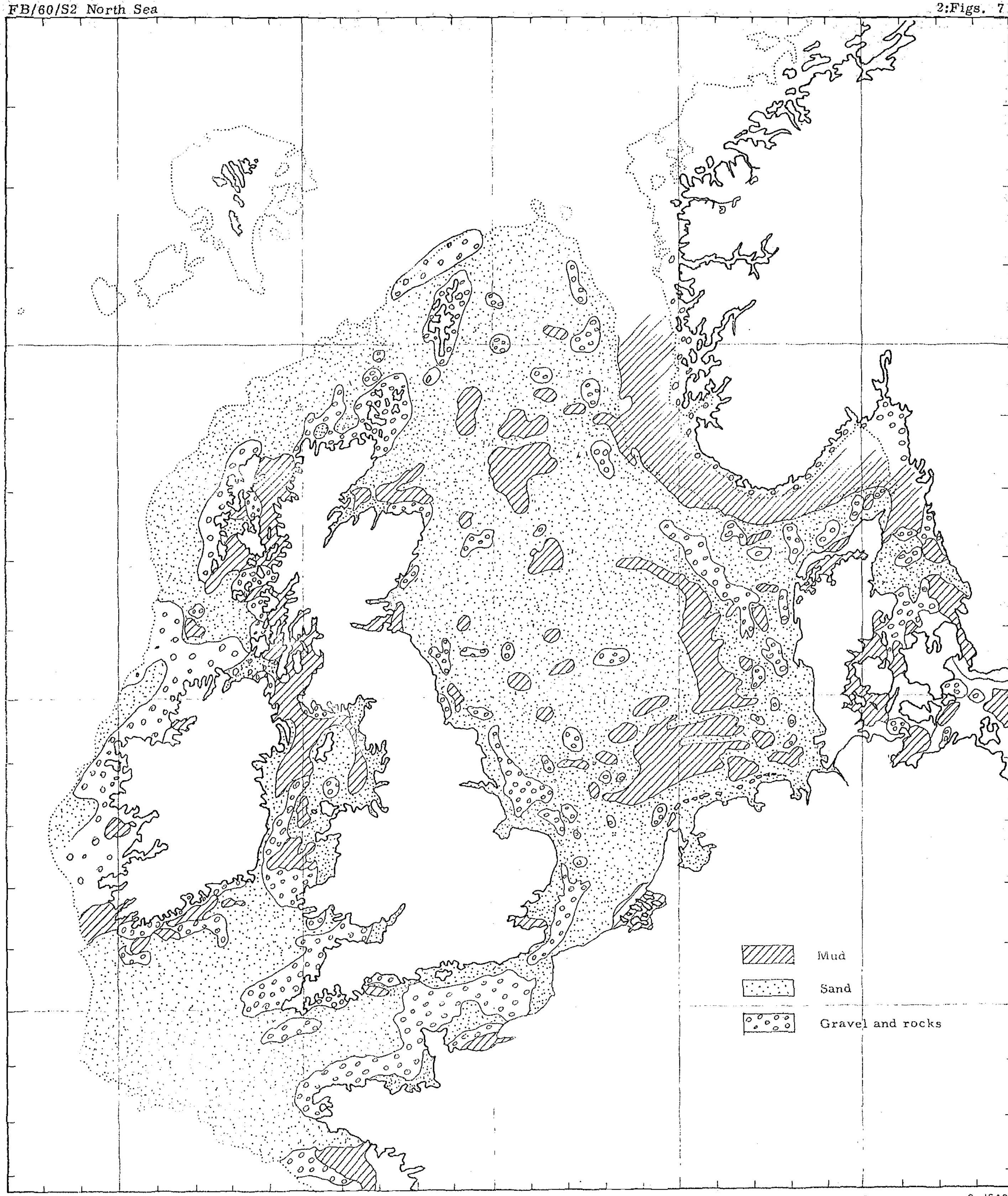

FIGURE 2.8 - NATURE OF THE BOTTOM (After Pratje)

TABLE 2·1

Areas, volumes and average depths of the North Sea and adjacent waters. (from Kalle 1949

		North Sea proper	English Channel	Irish Sea	Kattegat
Area	Depth 0-200 m	515.5	75.2	103.2	25.2
in	200 m	59.8		0.1	
1000 km^2	total	575.3	75.2	103.3	25.2
Volume in 1000 km^3		54	4.1	6.3	0.7
Depth, average, m		94	54	60	28

TABLE 2.2

Regions and fishing grounds and their approximate area, km.^{2} (see Figure 5)

Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq.km.
1. Norwegian Furrow							
Halibut Ground	5,600	Viking Bank	5,600	Old Viking Bank	4,200	Nobles Ground	2,100
The Patch	3,150	Utsire Hole	3,150	Utsire North	3,500	Scottish Klondyke	3,500
Coral Bank	3,500	Ling Bank	1,750	West Middle East,Bk	4,550	English Klondyke	5,250
2. Fladen Bressay							
Bressay E.Ground	7,000	Bressay Ground	4,900	Forty Mile	4,900	Dutch Bank	4,200
Bressay Shoal	3,150	Bergen Ground	3,150	Fladen Ground	18,550	Witch Ground	5,250
Halibut Bank	3,850	Swatchway	1,050	NW Flat	2,450		
3. The Shetlands							
Unst Bank	2,100	Pobie Bank	2,800	The Hole	1,050	Fair Bank	1,400
Fair Bank South	1,400	Tanners Hill	1,050	Foula Bank	1,050	Foula Bank South	2,100
Otter Bank	1,400	Papa Bank	1,400				
4. Scottish Waters							
Stronsa Firth	1,050	Pentland Skerries Ground	3,500	Moray Firth Gr.	1,400	Little Halibut Bk	2,100
Bossies-Little Bank	1,400	Smith-Bittockie Bk	1,400	Moray Firth	1,400	Berwick Bank	1,400
Boseys Bank	700	Buchan Deep	2,450	Aberdeen Ground	2,450	Montrose Bank	2,800
NE Grounds	3,150	Mar-Wee Bankie	700	Firth of Tay	1,050	Firth of Forth	2,100
Halibut Bank W	1,400						
5. English Waters							
Farne Deeps	2,100	North Farne Deep	1,400	NE Bank	5,250	Barmade Bank	1,750
Baymans Hole	1,050	Withby Fine Ground	1,050	Castle Ground	1,750	Scarborough Ground	1,050
Flaborough Gr.	700	Off Ground	1,050	Little Pit	2,100	Outer Dowsing	1,050

TABLE 2.2(contd)

Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.
6. The Gut-Fisher Bank							
Turbot Bank	1,050	Long Forties	5,250	Long Forties S.	4,050	Devils Hole	4,200
The Gut	28,000	Coal Pit	1,050	Great Fisher Bank	13,300	Inner Shoal	1,050
Outer Shoal	2,100						
7. Dogger Bank							
Dogger Bank	11,900	East Bank	4,200	NW Rough	1,050	Dogger N. Shoal	1,400
Bruceys Garden	2,450	Dogger North Gr.	700	Southern-most Gr.	1,050	Boulders Bk.	700
West Shoal	1,400	Dogger Bight	1,050	Skate Hole	700	The Hills	350
Eastmost Rough	700	Well Bank	1,050	Well Hole	1,050	NE Hole	700
Botney Ground	1,400	Botney Cut	1,050	Great Silver Pit	2,100	Outer Dowsing	350
S. Dogger Gr.	1,400	SW Patch	700	Elsmost Shoal	700	Hospital	700
South Rough	1,050	Cleaver Bank	2,450	W. Mud Hole	1,050	Upper Scruff	2,100
Clay Deep	2,100	Elbow Spit	700	Lower Scruff	2,800	Heavy Scruff	1,050
Tail End	1,050	Middle Rough	3,500	Outer Rough	3,900	Schlick Bank S	4,200
Schlick Bank N	2,800	N. Zeeland Ground	700				
8. Southern							
Coal Pit	1,050	Leman Ground	1,750	Leman Bank	1,050	Over Bank	700
West Hole	700	Tea Kettle Hole	1,750	Vlie Rough	1,400	Texel Ground	1,400
Brown Bank	1,400	Brown Bank Gr.	1,750	Winterton Twenties	2,100	Winterton Shoal	2,100
West Deep Water	2,100	East Deep Water	2,100	Ijmuiden Ground	2,100	The Broad Forth	1,400
Brille Gr.	700	Knoll Deep	700	Gabbard Gr.	700	Hinder Gr.	700
North Falls S	1,400	Bligh Bank	1,400	W. Shelde	700	Ruytingen	1,050
Sandettie	1,400	Schouven Bank	1,400				
9. The Channel							
Calais	700	Boulogne	2,100	Dieppe	1,400	Fécamp	2,100
Barfleur	2,800	Hooe Bank	2,100	Plymouth	2,100		

TABLE 2.2(contd)

Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.	Region and fishing ground	Surface sq. km.
10. German Bay							
Vlieland Gr.	1,400	Tersheling Gr.	2,800	Oyster Ground	11,650	White Bank	3,150
Outer Ground	1,400	Borkum Flat Rough	1,400	Norderny Ground	1,050	Helgoland Ground	3,150
Eider Ground	1,050	Helgoland Rough	1,050	Amrum Ground	2,800	Sylt Outer Gr.	2,450
Lister Deep	1,400	Horn Reef S. Gr.	2,100	Horn Reef Ground	2,100	Muschel Gr.	
11. Danish Waters							
Horn Reefs	1,400	Horn Reefs Rough	1,400	Horn Reef North Gr.	1,400	Ringkjobing Gr.	2,800
Turbot Bank	1,050	S Turbot Bank	1,400	Monkey Bank	1,400	Bovbierg Ground Rough	2,100
Jutland Bank	1,750	Holmen Ground	2,100	Little Fisher Bank	3,150	Schlick Bk East	2,100
Jubilee Bank	350	West Middle East Bk	3,850	Holmen North	2,100		
12. Skagerrak							
Zat. Jammer	3,500	Skagen Bank	2,800	Skagen West	1,750	Skagerrak	

TABLE 2.5

Fishing charts and atlases of the North Sea

	Author, year, title and publisher	Remarks
1.	Klimaj, A. and St. Rutkowicz 1952. Fishing Atlas of the North Sea. Morski Instytut Rybacki, Gdynia.	Charts on hydrographical and geological conditions with explanations in Polish, English and Russian and monthly charts on trawling and lugger fishery, with explanations and tabular data.
2.	U.K. Admiralty. 1953. Monthly fishery charts for the British Isles. Hydrogr.Dept. Admiralty, London.	Monthly charts with indication of fishing areas by type of fishery with short explanatory notes.
3.	I.C.E.S. 19?? Fisheries of the North-east Atlantic. Herring Atlas; Copenhagen	Monthly charts on occurrence of herring of different maturity stages, fishing grounds, landing ports and quality, with explanatory notes in English, French and Danish.
4.	Furnestin, J. et al. 1956 Atlas des pêche de la Mer du Nord. Inst.Scient.et.Techn. des Pêches Maritimes, Paris.	Monthly charts of fishing grounds for different species with short explanations.
5.	Close's Fishermans Charts. A. Close, London.	Sea charts with notes on type of bottom and fishing conditions.

3. CLIMATE AND HYDROLOGY

During the winter many barometric minima pass from southwest to northeast over the central North Sea. The higher the sea surface temperature in the North Atlantic during the winter, the more steady and strong are the southwest winds over the North Sea and the warmer remains the winter in general.

The frequency of storms increases towards the northern North Sea (see Table 3.1). Because of the northwest storms there is a rise in the high water level along the coast of the southern North Sea and many floods have occured especially but not exclusively during these storms.

Detailed climatological data are found in the atlases and charts listed in Table 3.2. Forecasts for shipping and fishery in the North Sea are given by most of the bordering states. However the forecast areas differ slightly (see Figures 3.1 and 3.2) and a unification of boundaries and nomenclatures of these forecast areas seems to be necessary. There is at present no good summary of the hydrological data available (precipitation, run-off and drainage areas) but some average run-offs are given in Table 3.3.

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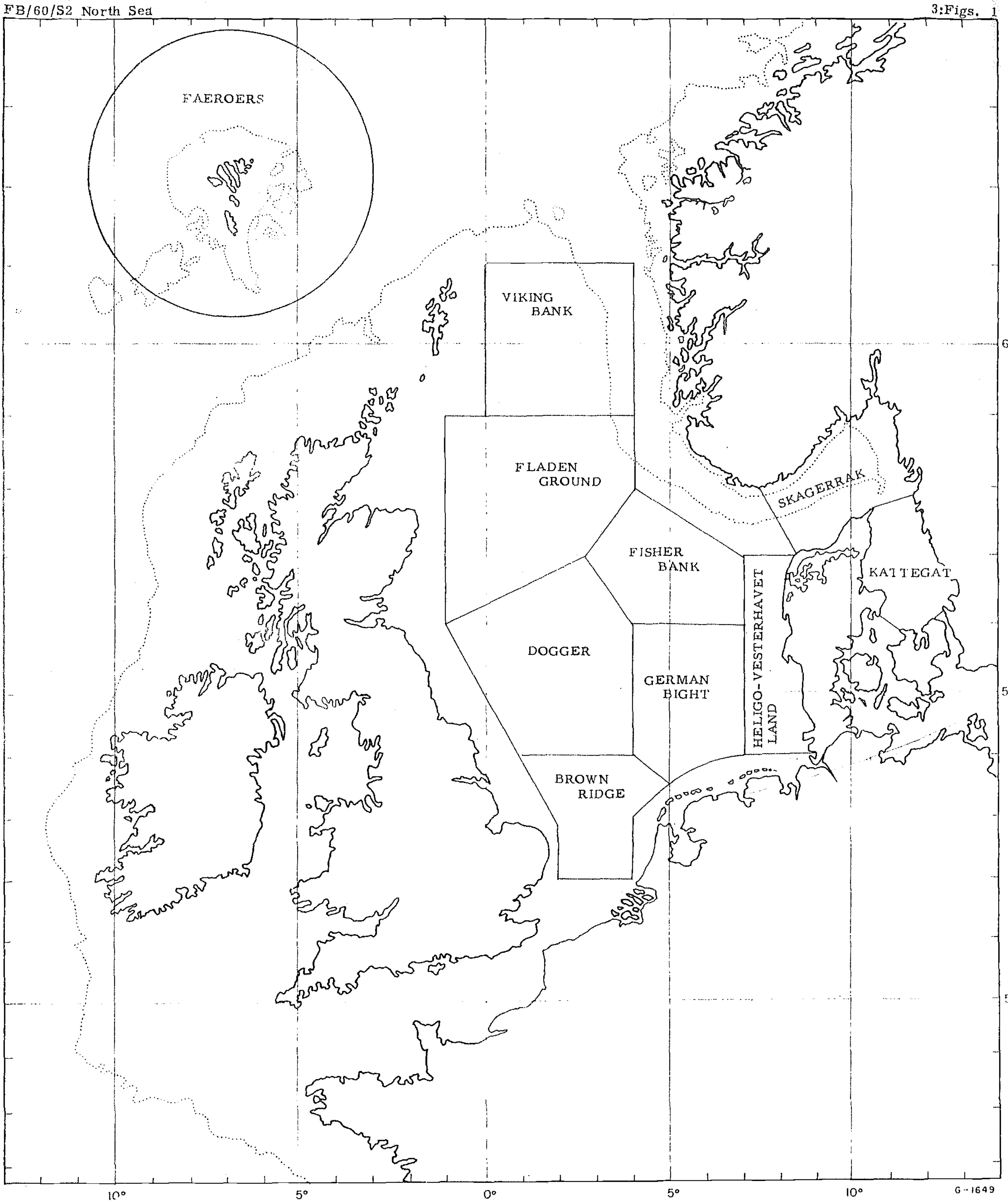

FIGURE 3.1 - METEOROLOGICAL FORECAST AREAS OF DANISH METEOROLOGICAL INSTITUTE

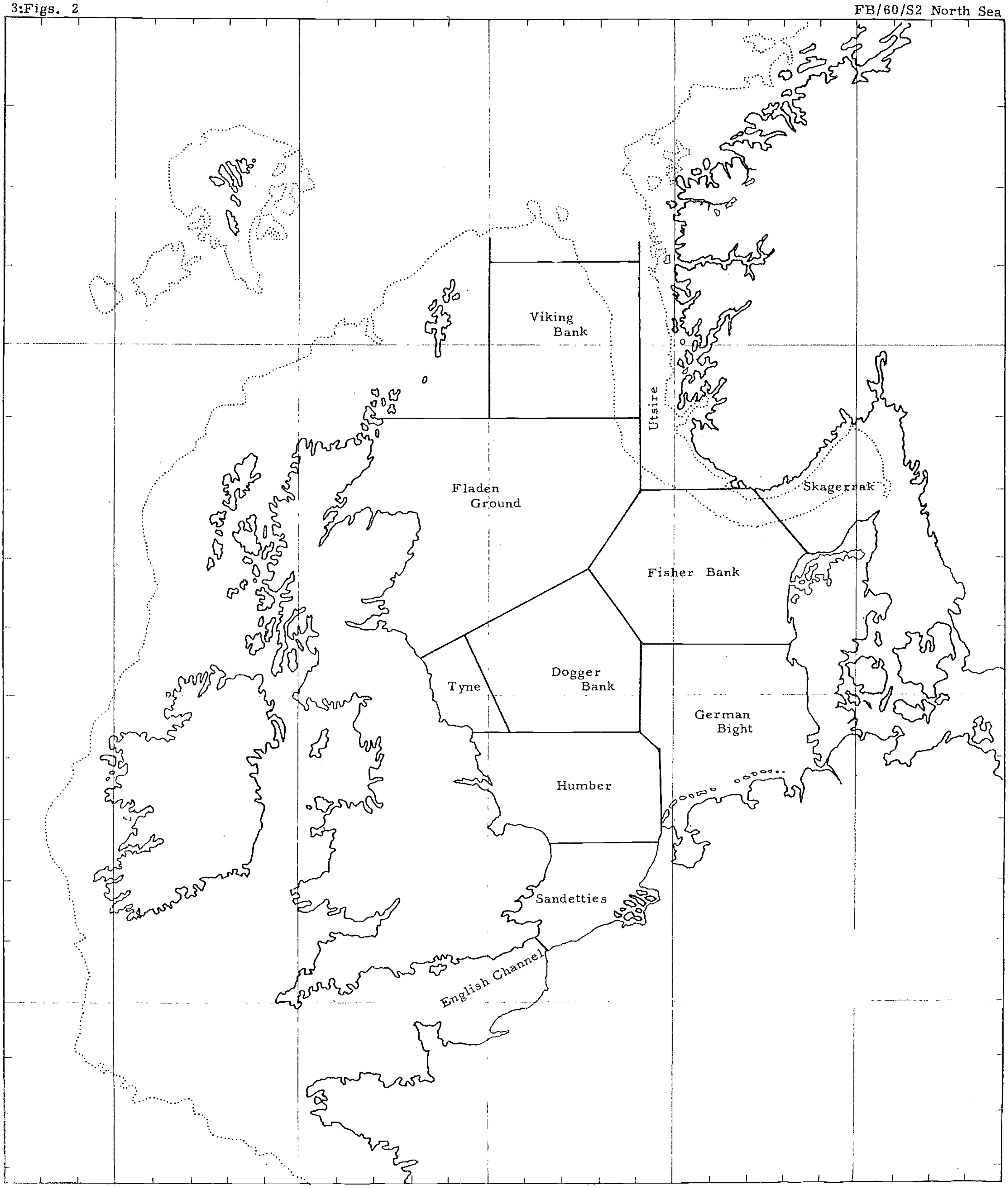

FIGURE 3.2 - METEOROLOGICAL FORECAST AREAS OF THE NETHERLANDS METEOROLOGICAL SERVICE

TABLE 3.1

Frequency of storms and fogs
in the North Sea

Season	North Sea Southern	Central	Northern
	Frequency of storms in %		
Winter	>5	10	20
Spring	1	5	10
Summer	<1	<1	1
Autumn	5	8	10
	Frequency of fogs in %		
Winter	>20	<10	<10
Spring	15	12	12
Summer	6	>15	>20
Autumn	15	10	10

TABLE 3.2

List of climatological atlases and charts
covering the North Sea

Author, year, title and publisher	Remarks
1. Deutscher Wetterdienst, Seewetteramt, Hamburg, 1954, 1956 Klimatologie der Nordwesteuropäischen Gewässer, Teil 1-2, 3	Three parts published by different authors. Detailed presentation of various properties as monthly averages, maximums and minimums and annual changes in selected localities.
2. International Council for the Exploration of the Sea (ICES) Serv.Hydrogr. Charlottenlund 1950 - Monthly wind charts.	Directions and average speeds of winds during 10-day periods in various localities.
3. Meteorological Office, London, 1948. Monthly meteorological charts of the Atlantic. M.O. 483.	
4. Deutsches Hydrographisches Institut, Hamburg, 1956. Monatskarten für den Nordatlantischen Ozeans.	
5. The Royal Netherlands Meteorological Institute. 1931. Climatological atlas of the Atlantic Ocean.	
6. U.S. Navy. 1955. Marine climatic atlas of the World. Vol. 1 North Atlantic Ocean.	

TABLE 3.3

Inflow of water to the North Sea
(from Kalle 1949)

Origin	Type of water	Amount in elevation of North Sea level im mm/year	Relation
English Channel	Atlantic	3140	10
Scheldt	Fresh	5	
Meuse	Fresh	12.6	
Rhine	Fresh	128	
Ems	Fresh	3.3	
Weser	Fresh	16.5	
Elbe	Fresh	39	
Kattegat	Baltic Sea W.	300	1
Glama	Fresh	43.5	
N.W. inflow	Atlantic	40,000	100
Thames	Fresh	3.7	
	Fresh water total	251.6	1

4. PHYSICAL AND DYNAMICAL OCEANOGRAPHIC CHARACTERISTICS OF THE NORTH SEA

The influence of tide generating forces on the tides within the North Sea is very minor and the tides in the area are determined by the oceanic tides entering through the English Channel and through the area between Scotland and Norway. The rotation of tidal currents is usually counterclockwise. The wind exercises great influence on the tidal currents and tidal heights. (see Figure 4.4) The form of tidal ellipses on the surface is slightly different from that close to the bottom. (see Figure 4.3)

The average net circulation is also greatly determined by the prevailing direction of winds. There are several more or less permanent centres of eddies which however change their positions slightly with the seasons. As seen from Figures 4.3, 4.7 and 4.8, the surface currents in the southern North Sea are approximately parallel to the coast, whereas the bottom water flows towards the coast, causing slow upwelling. In general the bottom currents are considerably different from the surface currents, as also indicated by the distribution of bottom temperatures. (see Figures 4.34 and 4.35) This circulation close to the bottom is controlled by the horizontal density differences close to the bottom (caused by cooling, warming and mixing processes) and by bottom topography.

The wave characteristics in various offshore localities in the North Sea are greatly determined by the length of the fetch. Average relations between the wave elements in the area are given in Figure 4.9 and Table 4.4, and the frequency of different sea conditions in Table 4.3. Maximum recorded wave heights are between 6 and 8 meters and the maximum length is ca. 150 meters.

In most cases it is possible to define six different water masses on the bases of different properties. (see Table 4.5) The distribution of these water masses also corresponds roughly to the distribution of different biological water masses. (see Figure 7.1) There are also some similarities between these water masses and the different hydrographical regions (see Figure 4.10) which are determined mainly by the mixing by tidal currents and the depth of the water. One of the determining characteristics of these hydrographical regions is the depth of the summer thermocline (see Figure 4.13) which is also an important ecological factor. The influence of the bottom topography on the stratification is recognizable from Figure 4.11 and 4.12.

As seen from Figures 4.19 to 4.30 the surface temperatures are mainly determined by the inflow of water, by mixing and to a lesser extent, by local cooling and warming in shallower water along the coasts (especially in the south). Monthly surface temperature charts with brief analyses are prepared by Serv. Hydrogr. of ICES.(Figure 4.31) There are some year to year variations in average monthly temperatures (Figure 4.32). These variations however differ from locality to locality (compare Figures 4.32 and 4.33), due to the differences of surface circulation pattern, and are especially influences by the intensity of inflow. The close correlation between the air and sea surface temperatures (see Figure 4.32) is determined by the sea surface temperatures and not vice versa.

There is no correspondence between the temperature variations of surface and deep water (see Figure 4.33), nor in the general distribution of surface and bottom temperatures (see Figures 4.34 and 4.35) as the surface and bottom water circulations are different from each other, as mentioned earlier.

No reliable heat budget calculations have been made for the North Sea.

The turbidity, caused by runoff, mixing and occasionally by intensive plankton blooms, follows the distribution and movement of water masses. (see Figure 4.39)

Ice is formed during severe winters on the shallow water along the coasts of Holland, Germany and Denmark. (see reference in ice atlas).

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4.9 Ice conditions

Reference:

Deutsches Hydrographisches Institut, Hamburg 1956
Atlas der Eisverhältnisse der Deutschen Bucht und Westlichen Ostsee

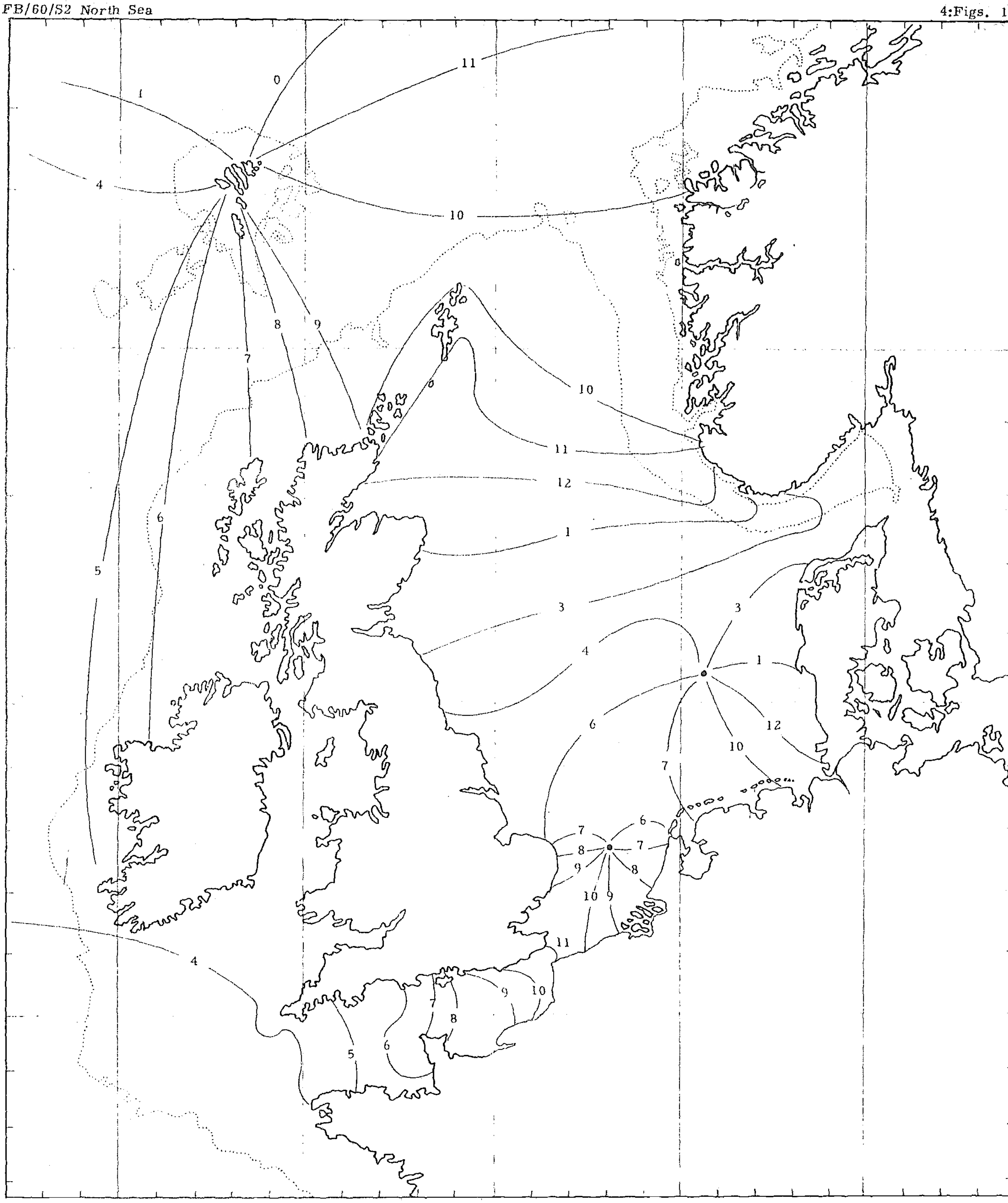


FIGURE 4.1 - COTIDAL LINES (G.M.T.)

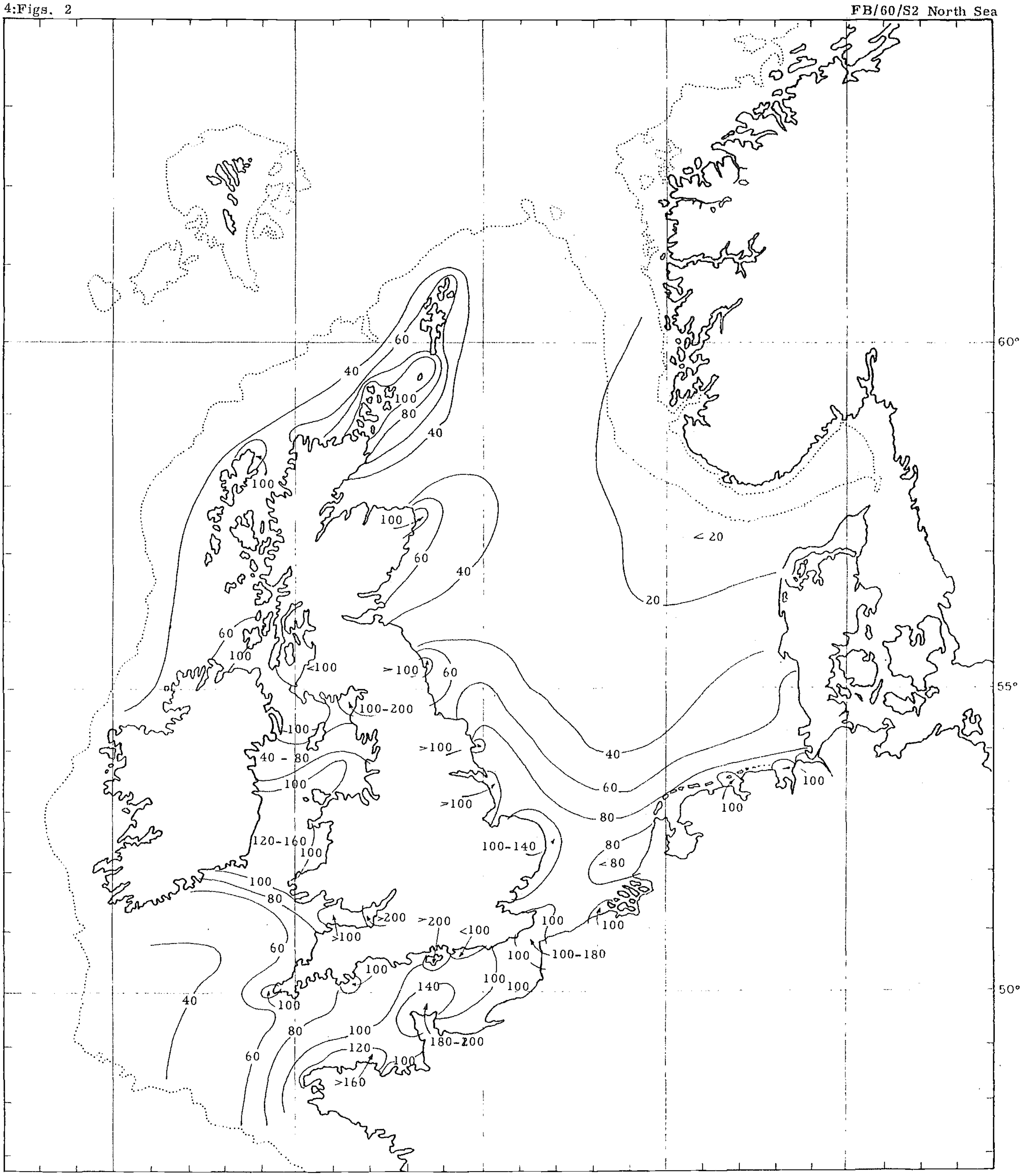


FIGURE 4.2 - DISTRIBUTION OF MAXIMUM VELOCITIES (cm sec^{-1}) OF TIDAL CURRENTS AT SPRING TIDE (after DIETRICH)

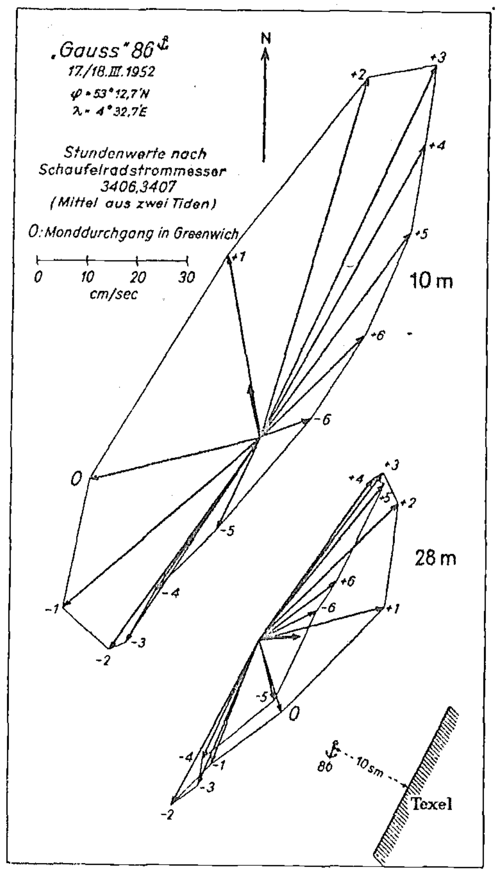
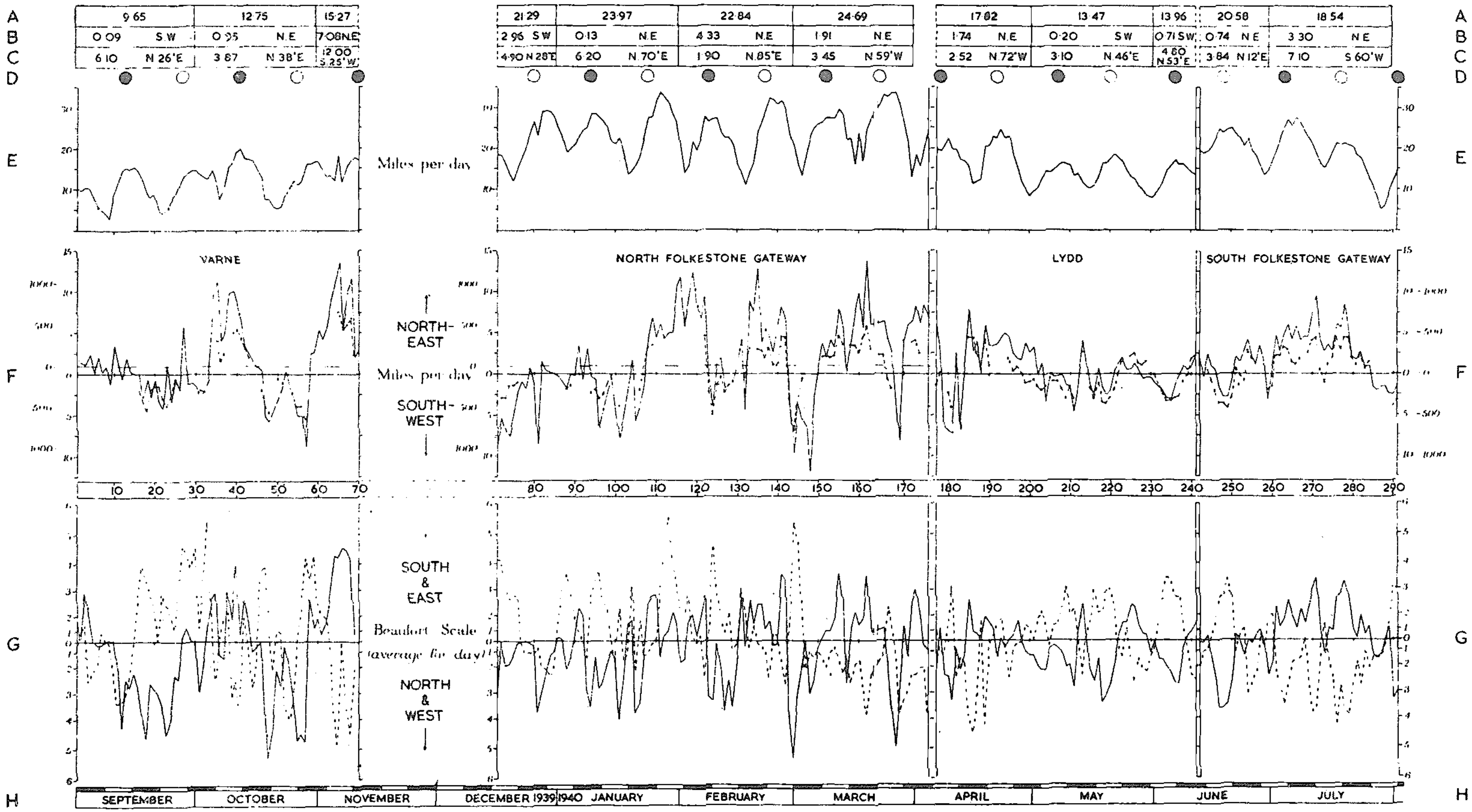


Figure 4.3

Hourly current vectors off Texel in 10 and 28 m depth
(after Dietrich)



Key

A Average monthly total water movement (the summed daily mileage, irrespective of direction) in miles per day.
B Average monthly residual water movement (the nett travel or "overall make" of the water) in miles per day and the octant in which it lay.
C Average monthly residual wind strength, in miles per hour, and direction.
D Full and new moon.
E Daily total water movement, in miles per day.
F Continuous line — Daily residual water movement, in miles per day. Pecked line — Mean daily SW. and NE. wind travel, in miles per day.
G Mean daily residual wind, in Beaufort scale. North and South components are drawn in full line, East and West components in pecked line.
H Calendar; black and white bars represent weeks of seven solar days.

Notes. (i) All days are lunar days of 24 hrs. 50 min., unless otherwise stated.
(ii) All miles are sea miles of 6080 feet.
(iii) All directions are magnetic. (Variation = 10° W.)

Figure 4.4

Water movements and winds in the Strait of Dover
September 1939 to August 1940
(after Carruthers, Lawford, Veley)

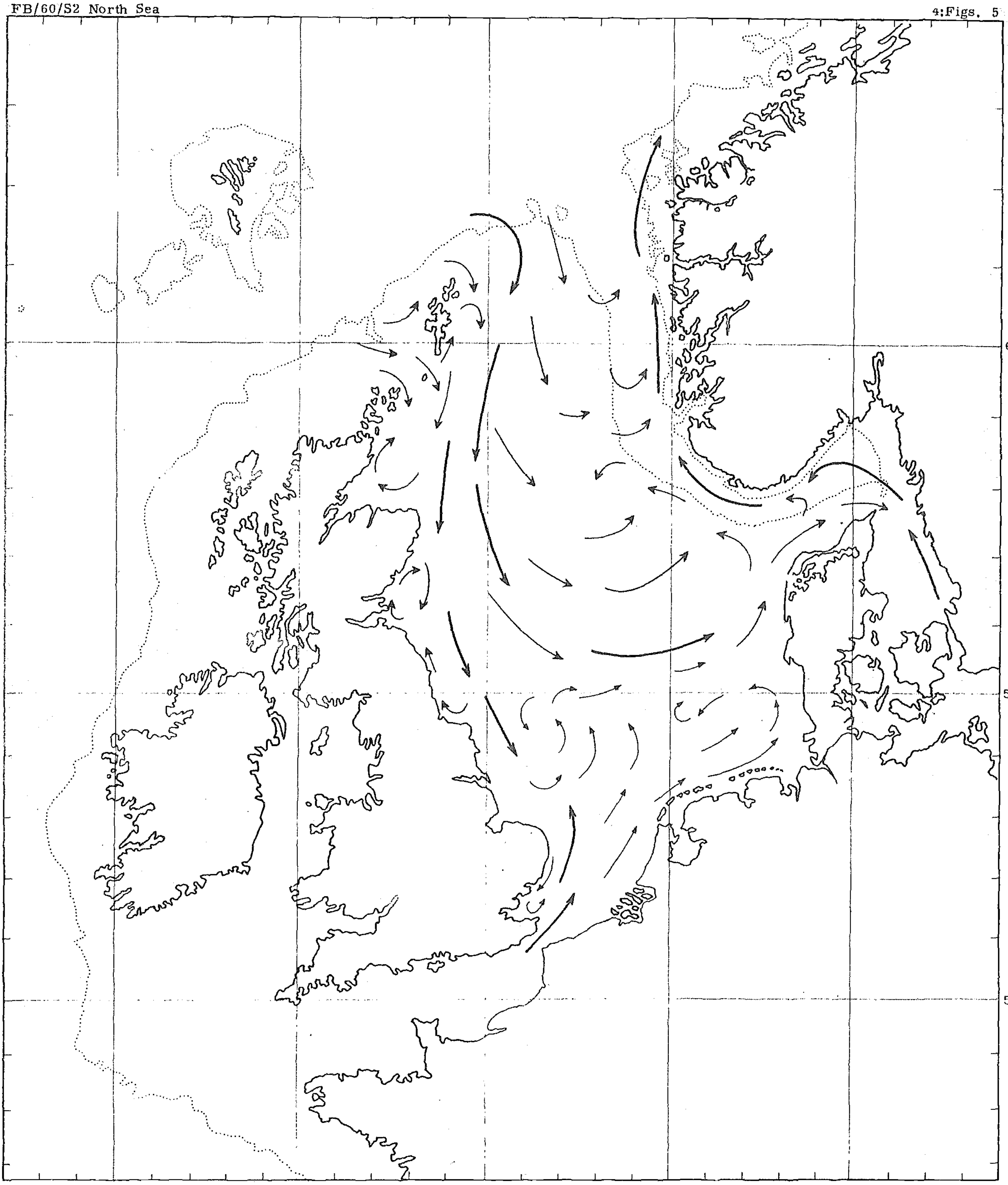
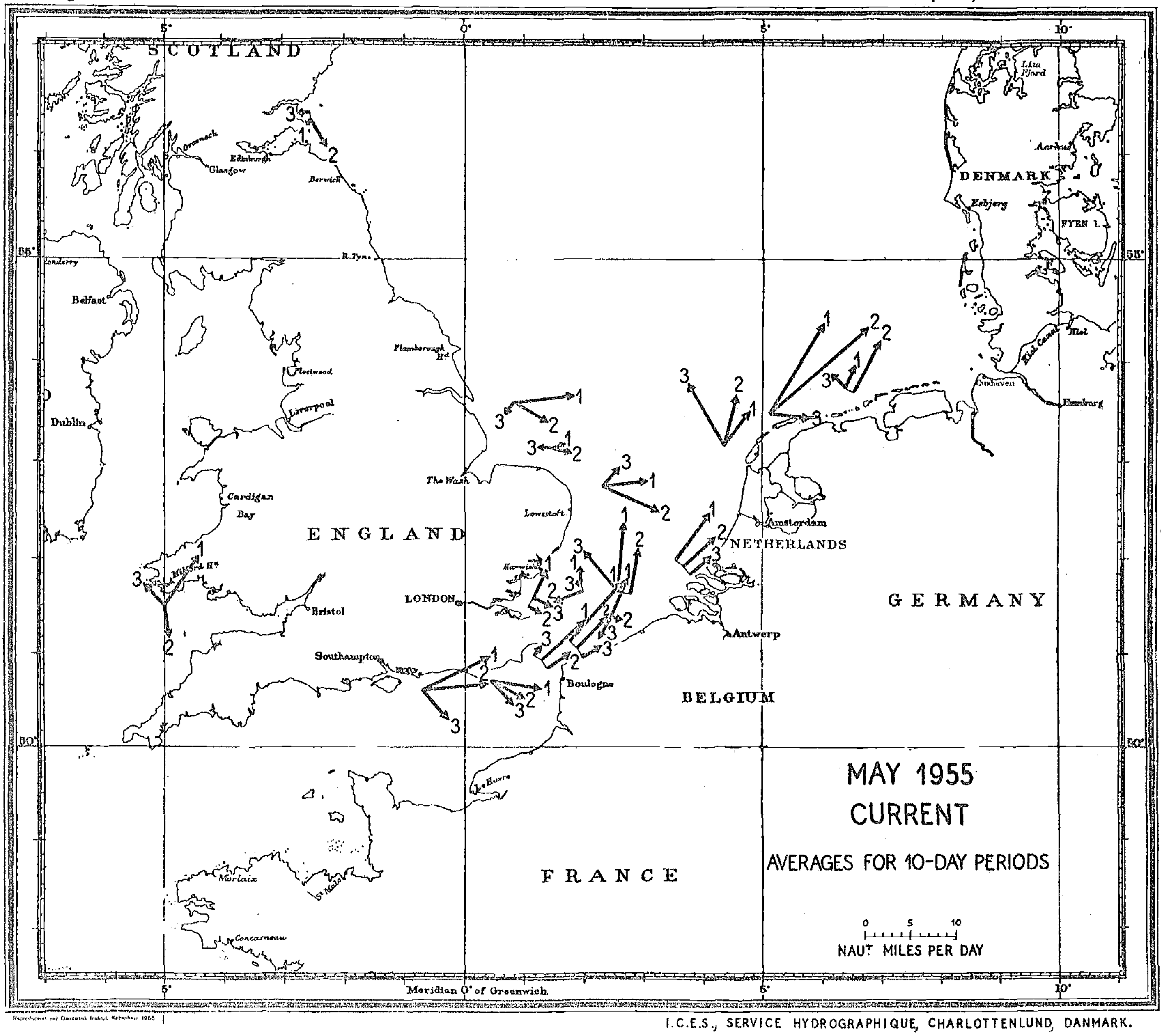


FIGURE 4.6 - AVERAGE NET SURFACE CIRCULATION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NETHERLANDS
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BELGIUM
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LONDON
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Belfast
Glasgow
Edinburgh
Berwick
Liverpool
Bristol
Southampton
Boulogne
Antwerp
Amsterdam
Esbjerg
Hamburg
Cuxhaven
Lowestoft
The Wash
Harwich
Cardigan Bay
Morlaix
Concarneau
Le Havre
Meridian 0° of Greenwich
MAY 1955
CURRENT
AVERAGES FOR 10-DAY PERIODS
NAUT MILES PER DAY
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.

Figure 4.7

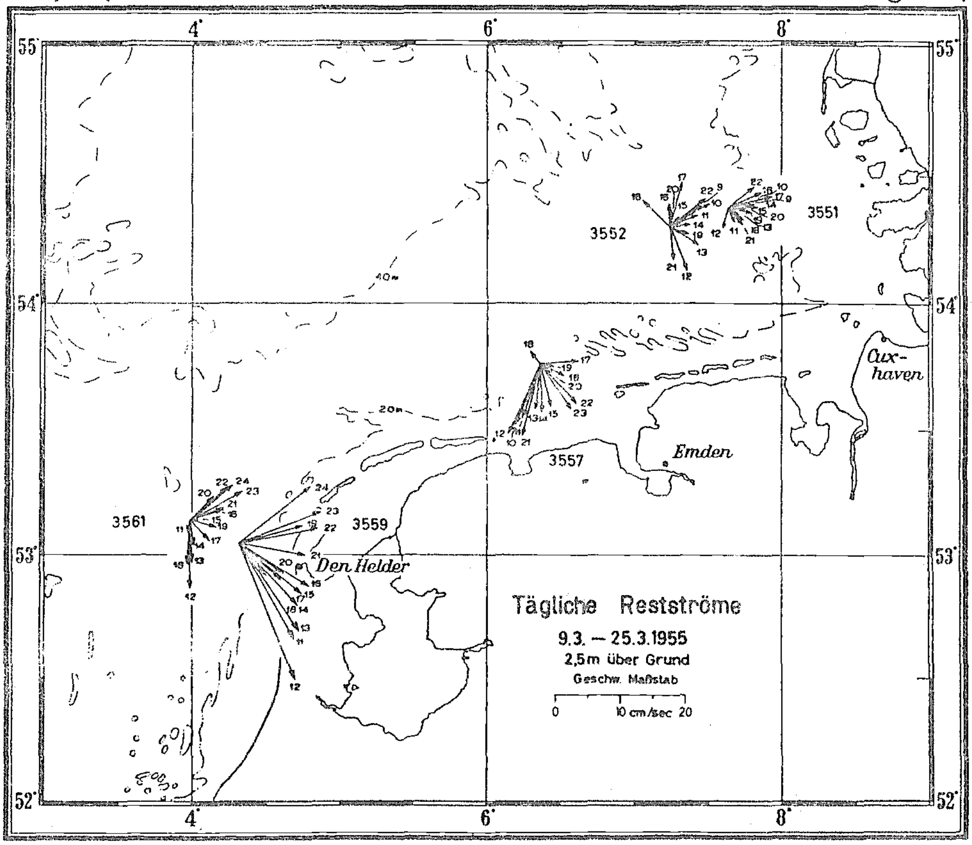


Figure 4.8

Daily residual current near the bottom in March 1955, based on measurements with 6 paddle wheel current-meters. (after Dietrich)

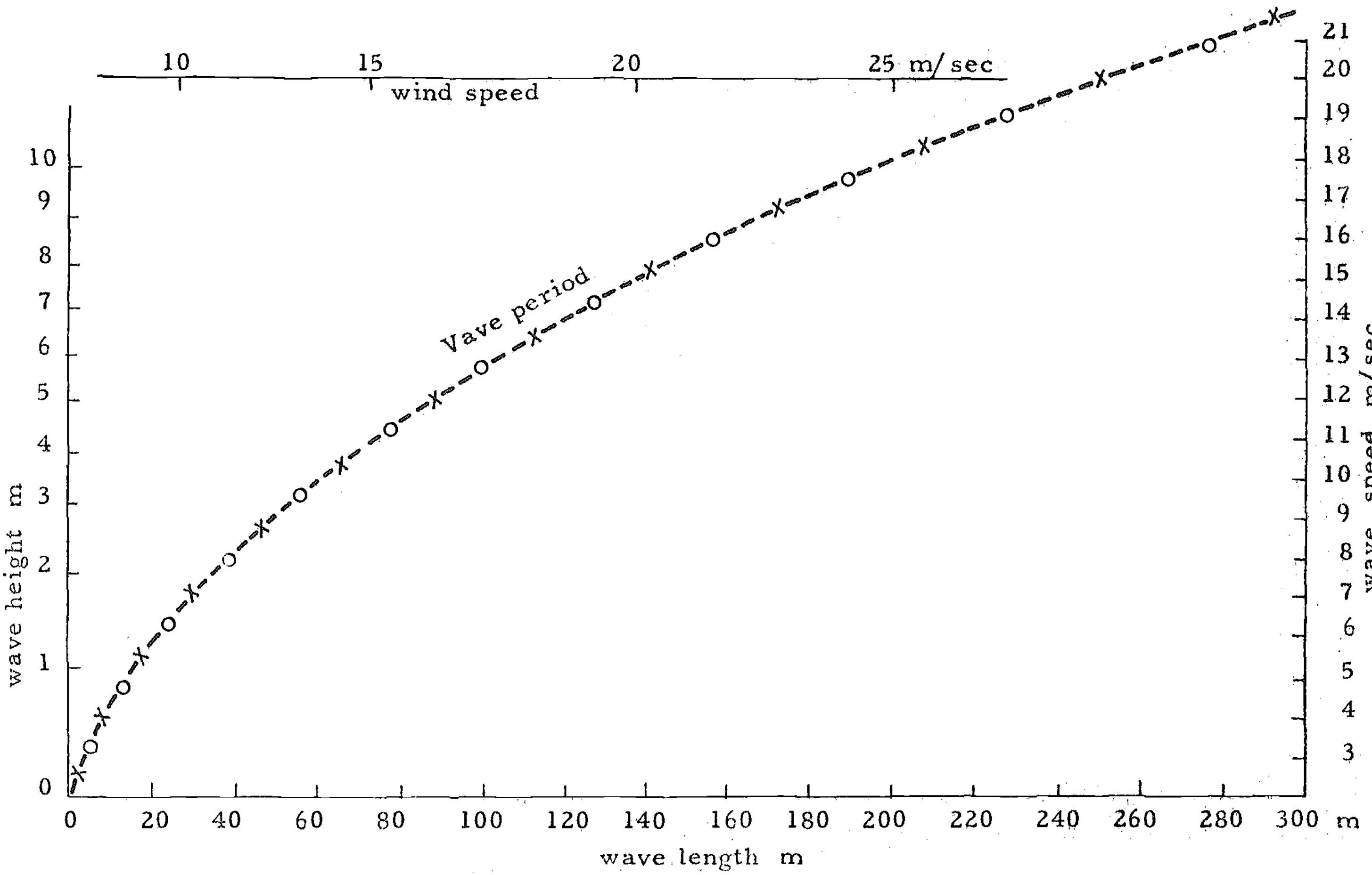


Figure 4.9

Average relations between wave length, height, period, speed and wind speed in the North Sea (after Schumacher)

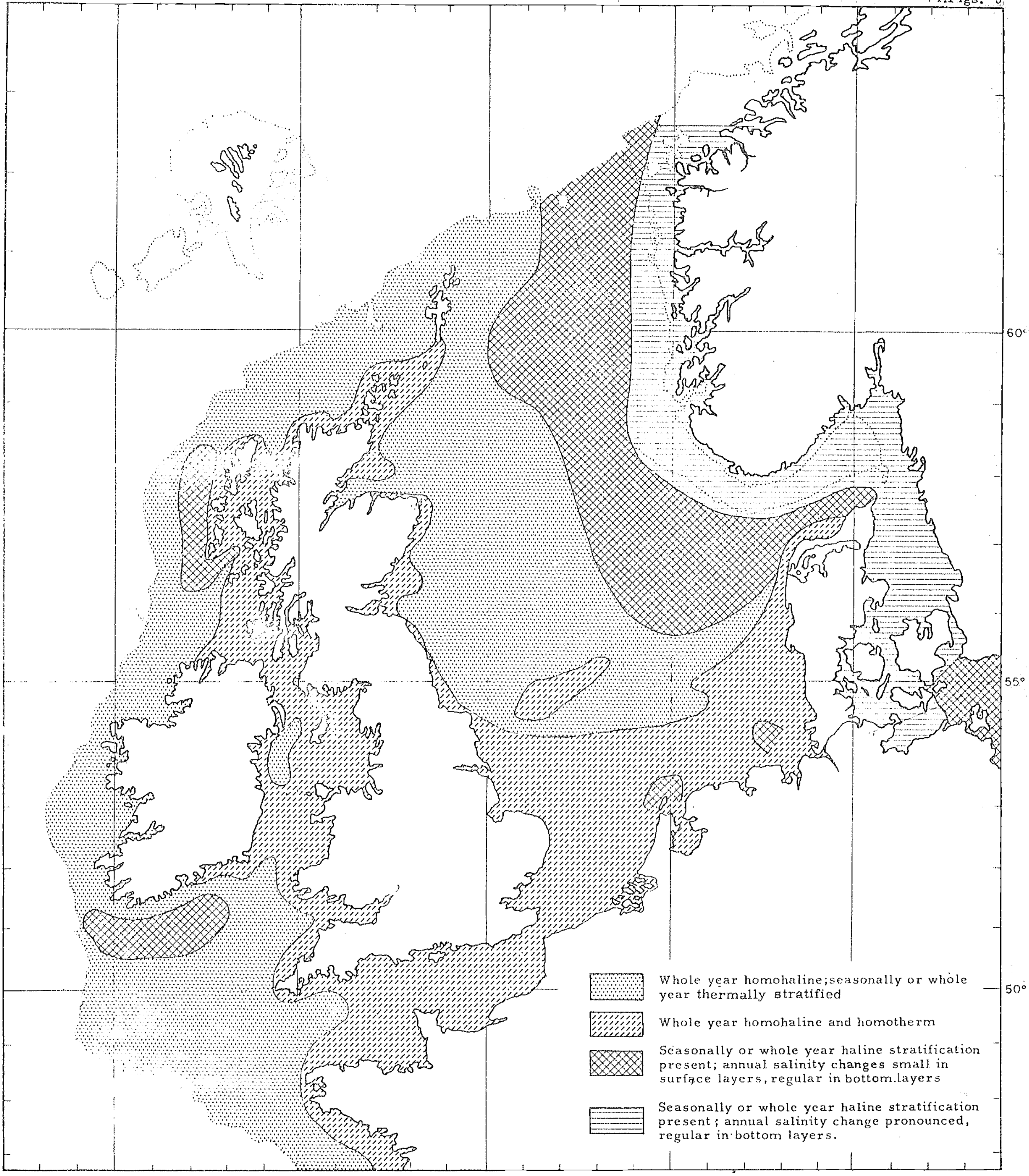
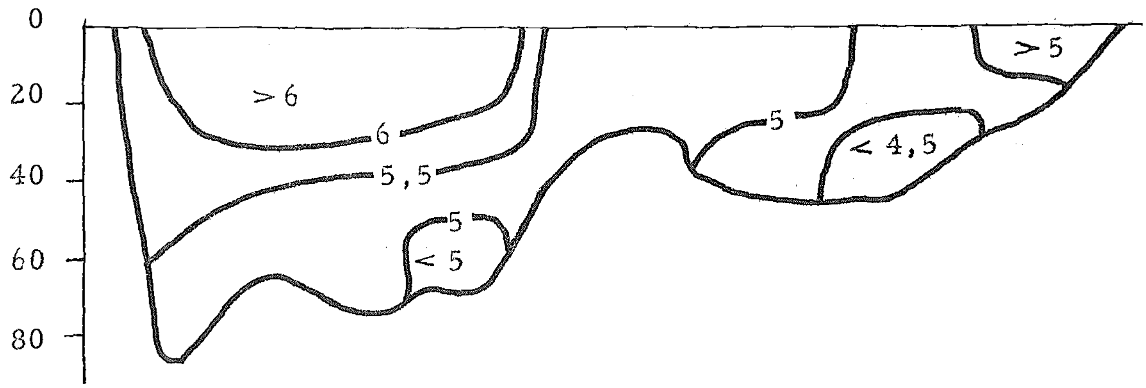


FIGURE 4.10 - HYDROGRAPHICAL REGIONS OF THE NORTH SEA (after Dietrich)



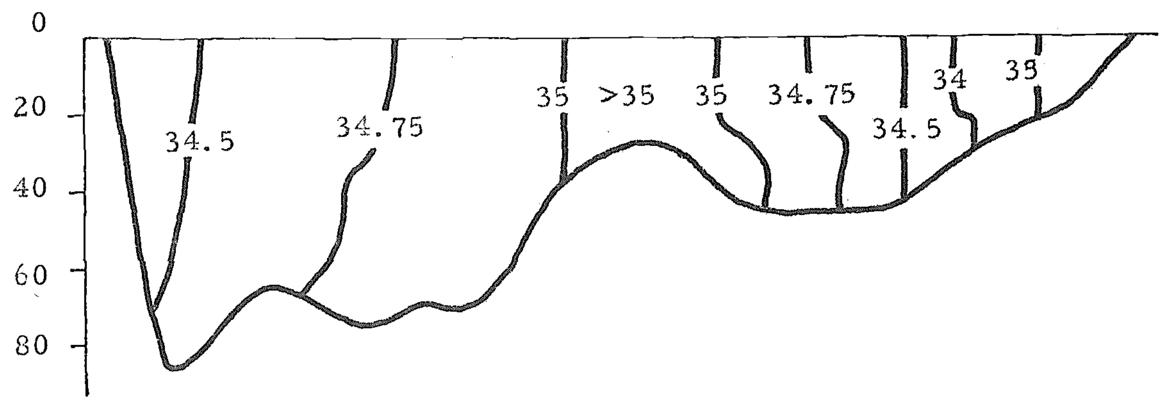


FIGURE 4.11

CHARACTERISTIC DISTRIBUTION OF T AND S IN INTERNATIONAL R SECTION DURING LAST PART OF APRIL

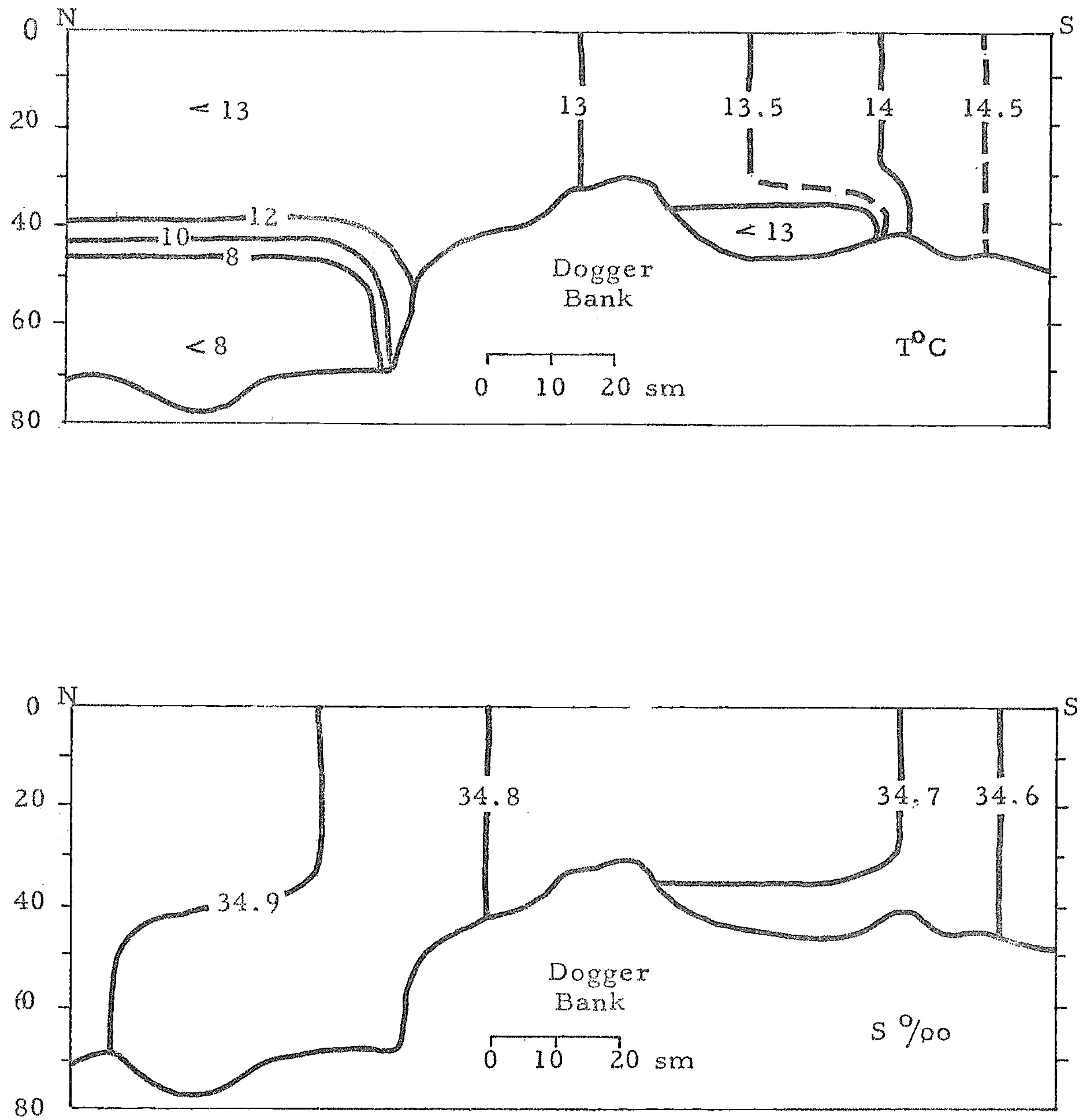


FIGURE 4.12

CHARACTERISTIC DISTRIBUTION OF T AND S IN a N.-S SECTION OVER THE DOGGER BANK ALONG 3° E DURING LAST PART OF SEPTEMBER

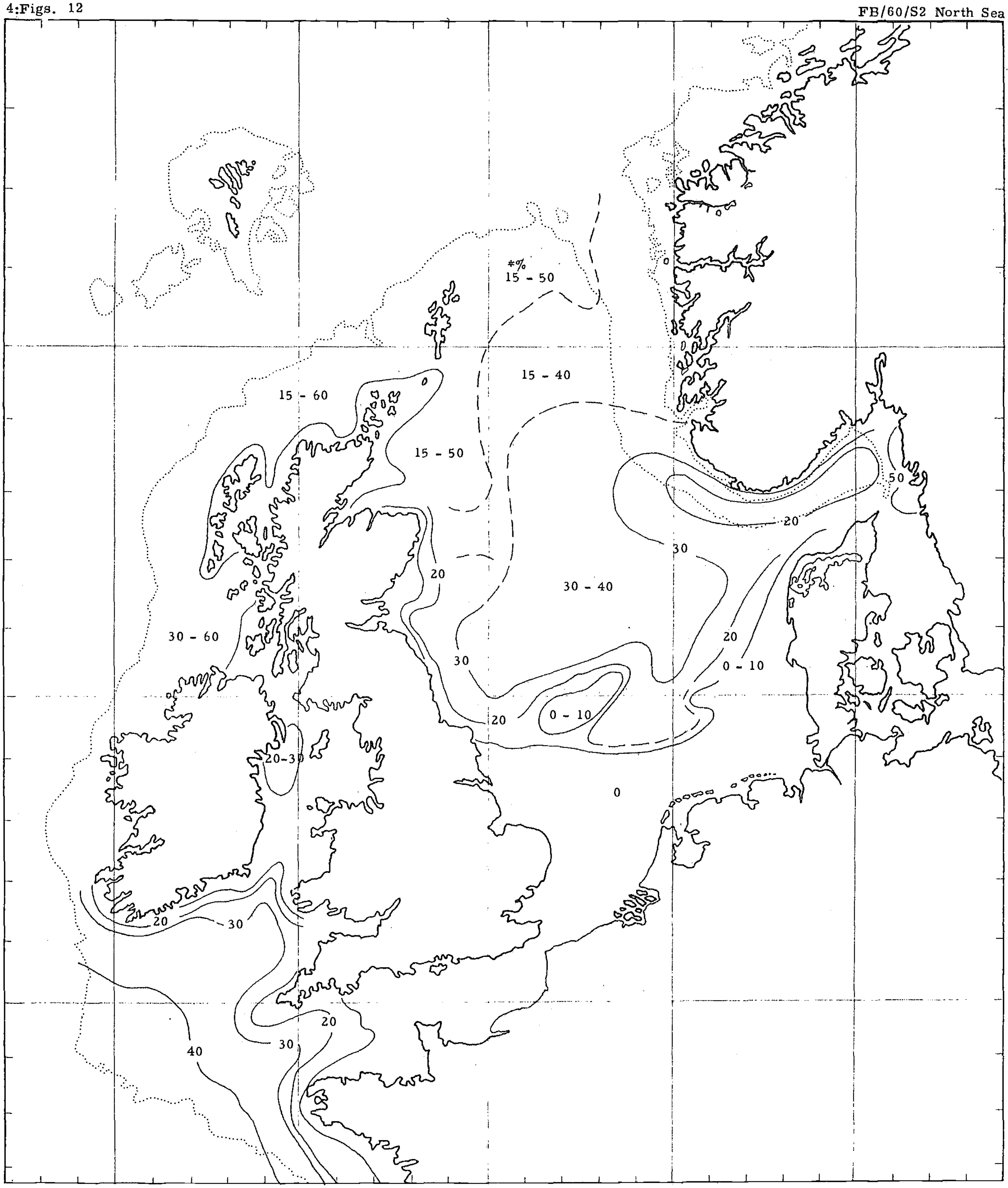
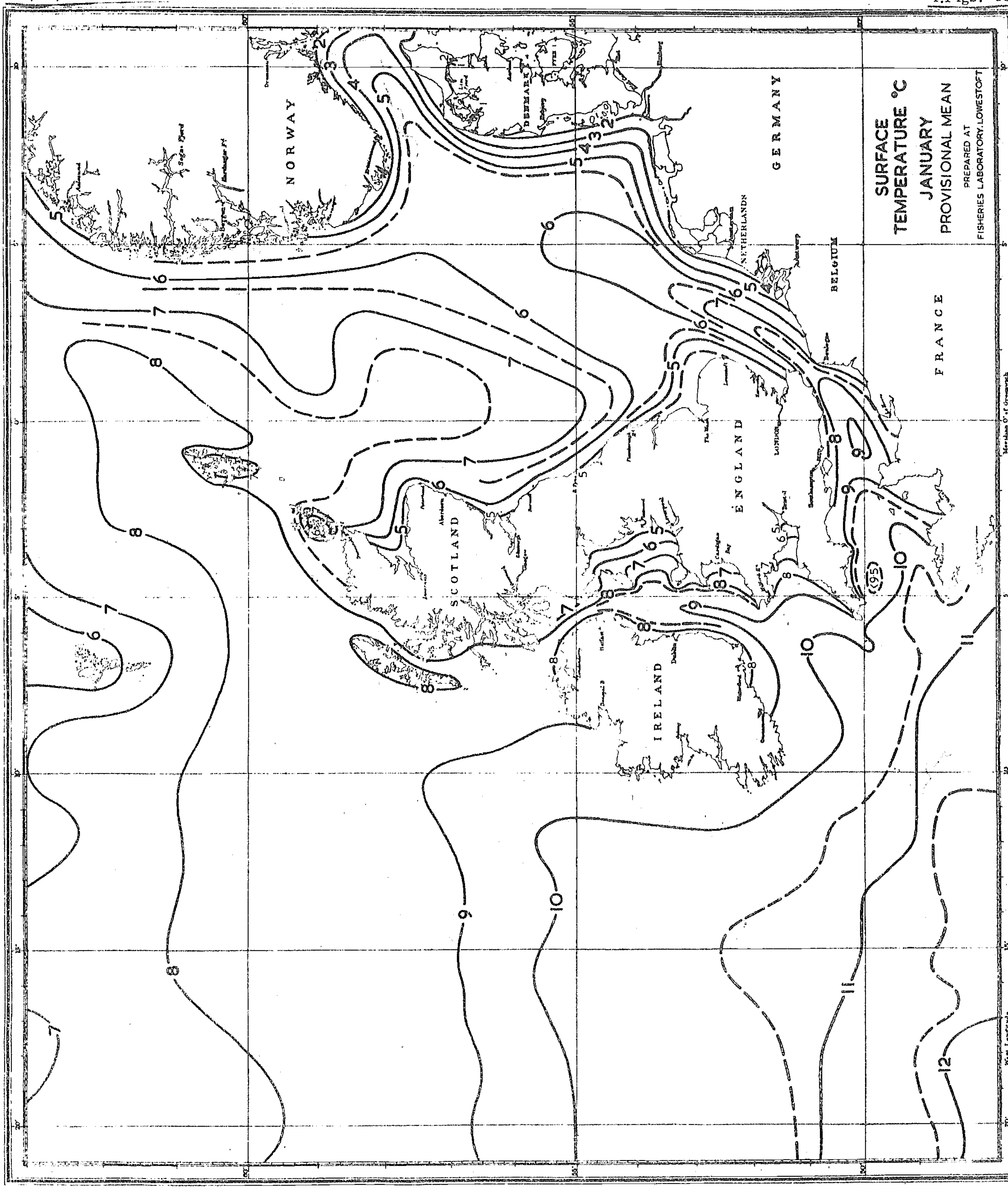


FIGURE 4.13 - AVERAGE DEPTH OF THE TERMOCLINE DURING THE SUMMER (in m) (after Dietrich)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TEMPERATURE °C
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PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
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NETHERLANDS
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IRELAND
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FIGURE 4.20

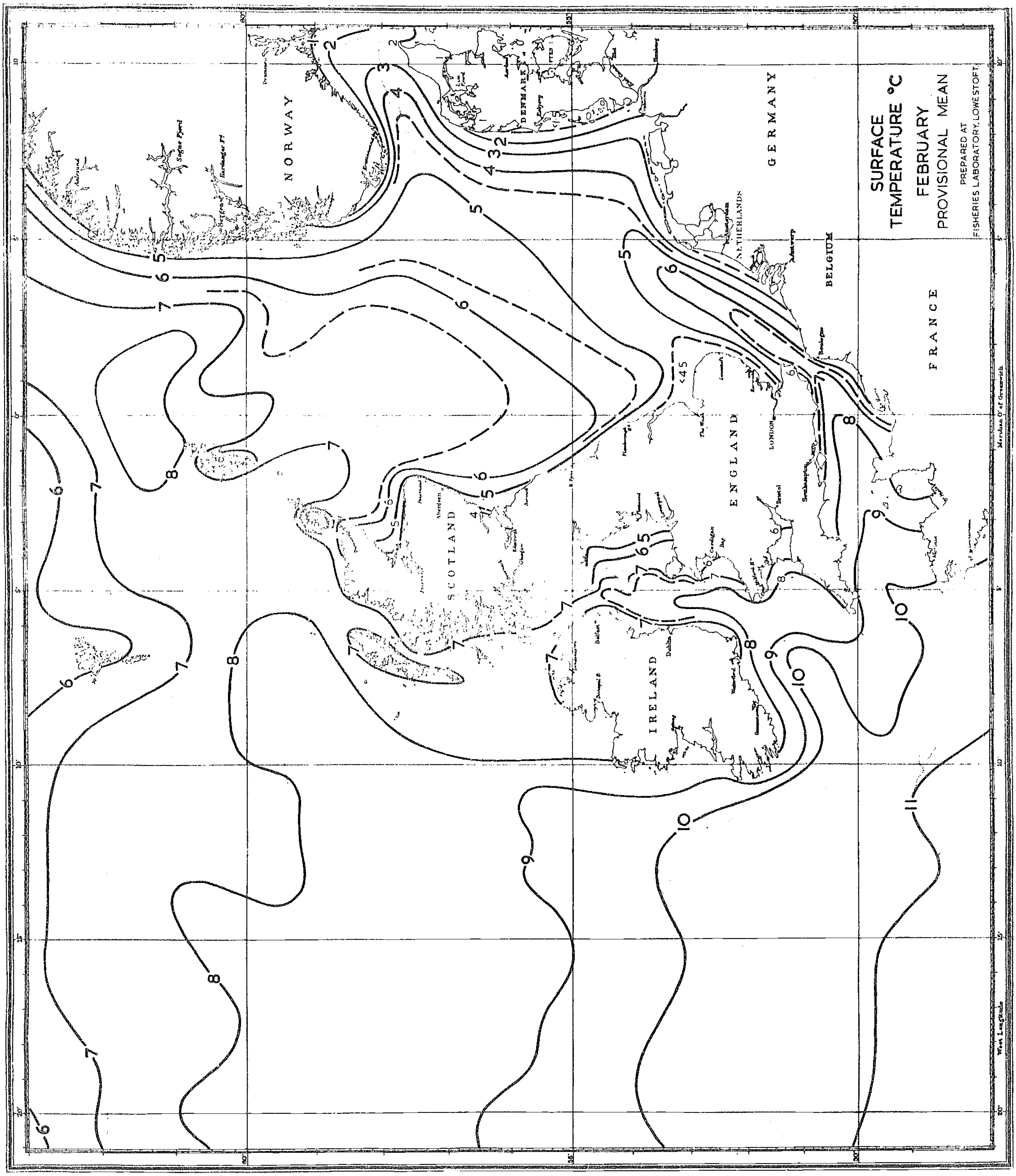
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FIGURE 4.21

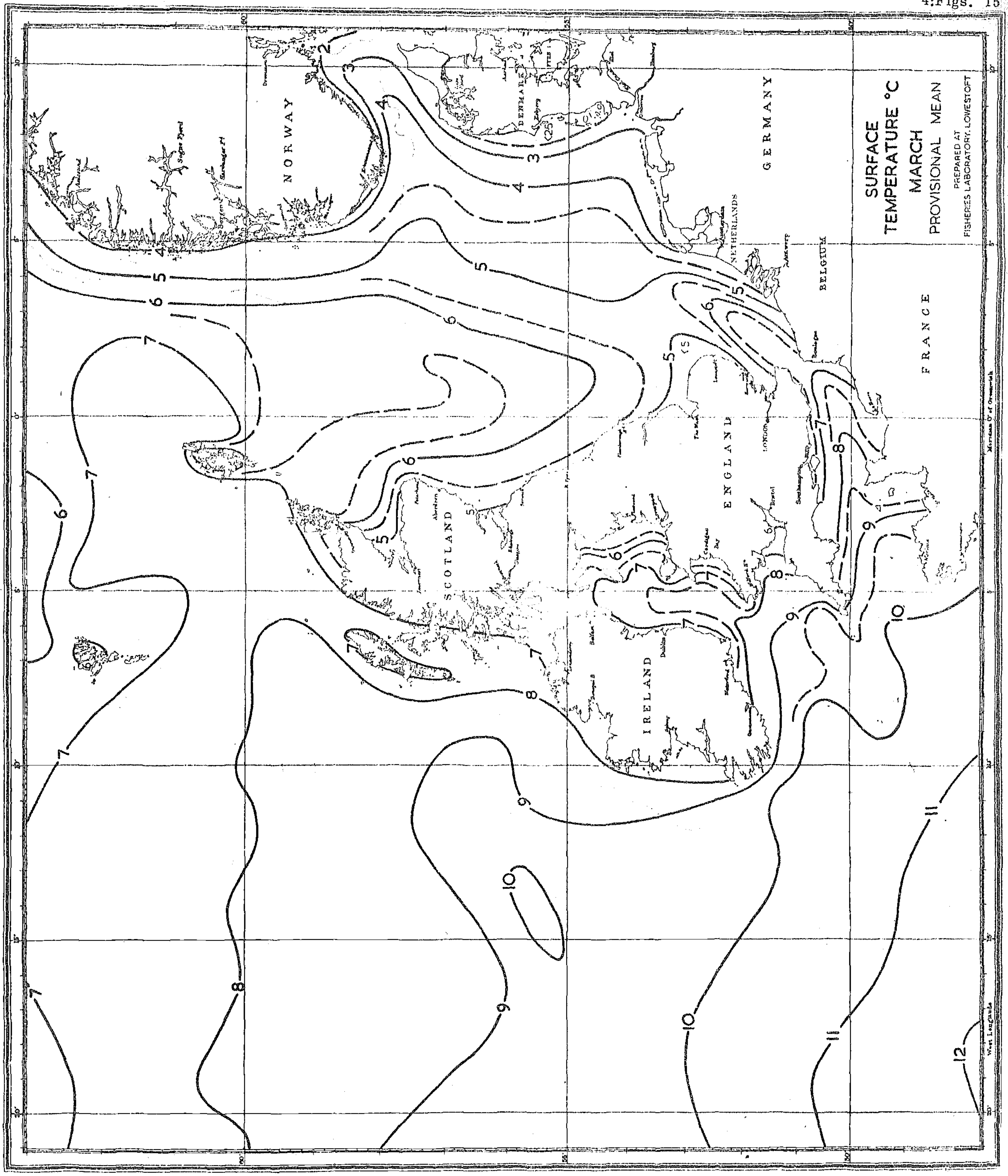
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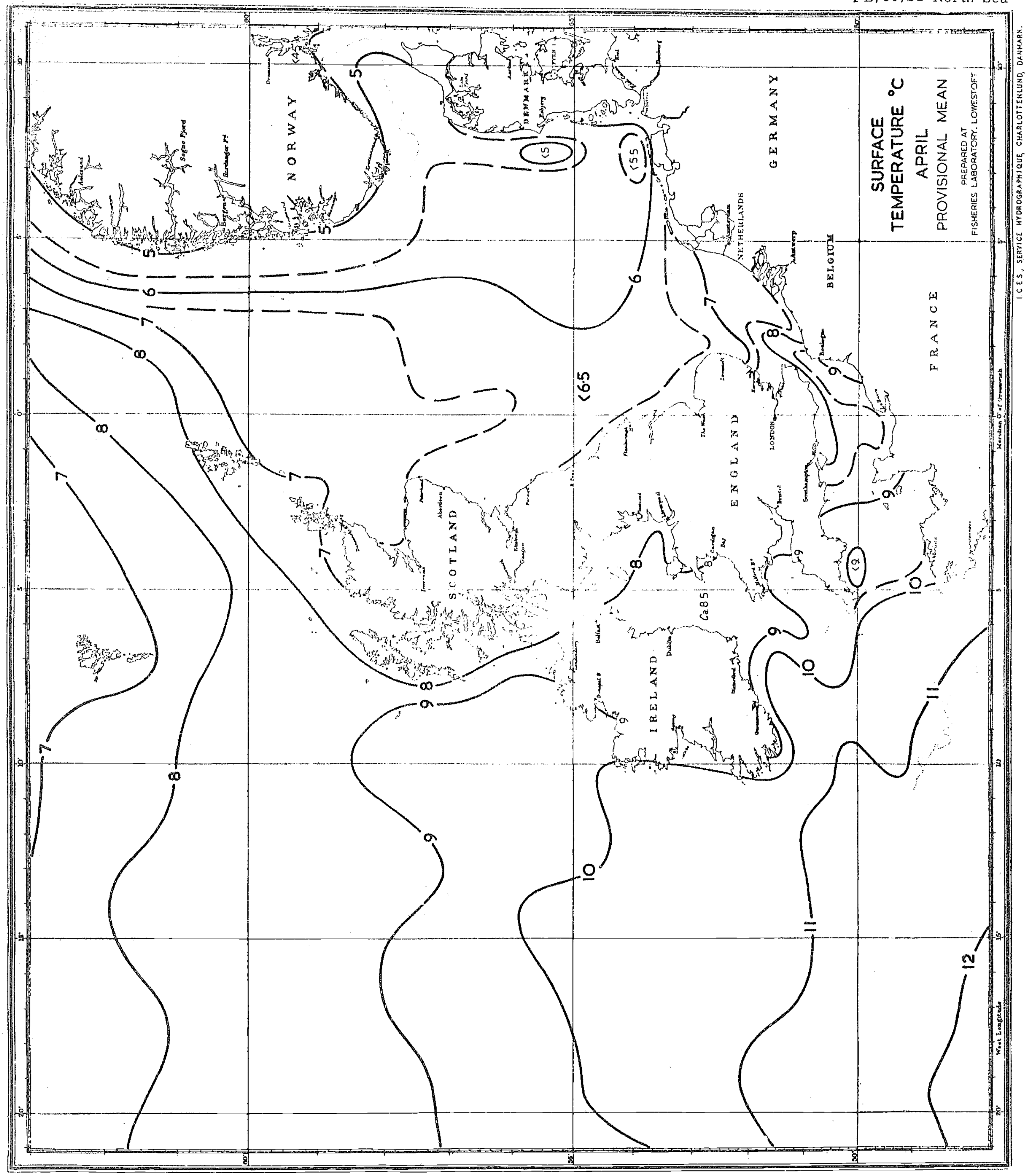
FIGURE 4.22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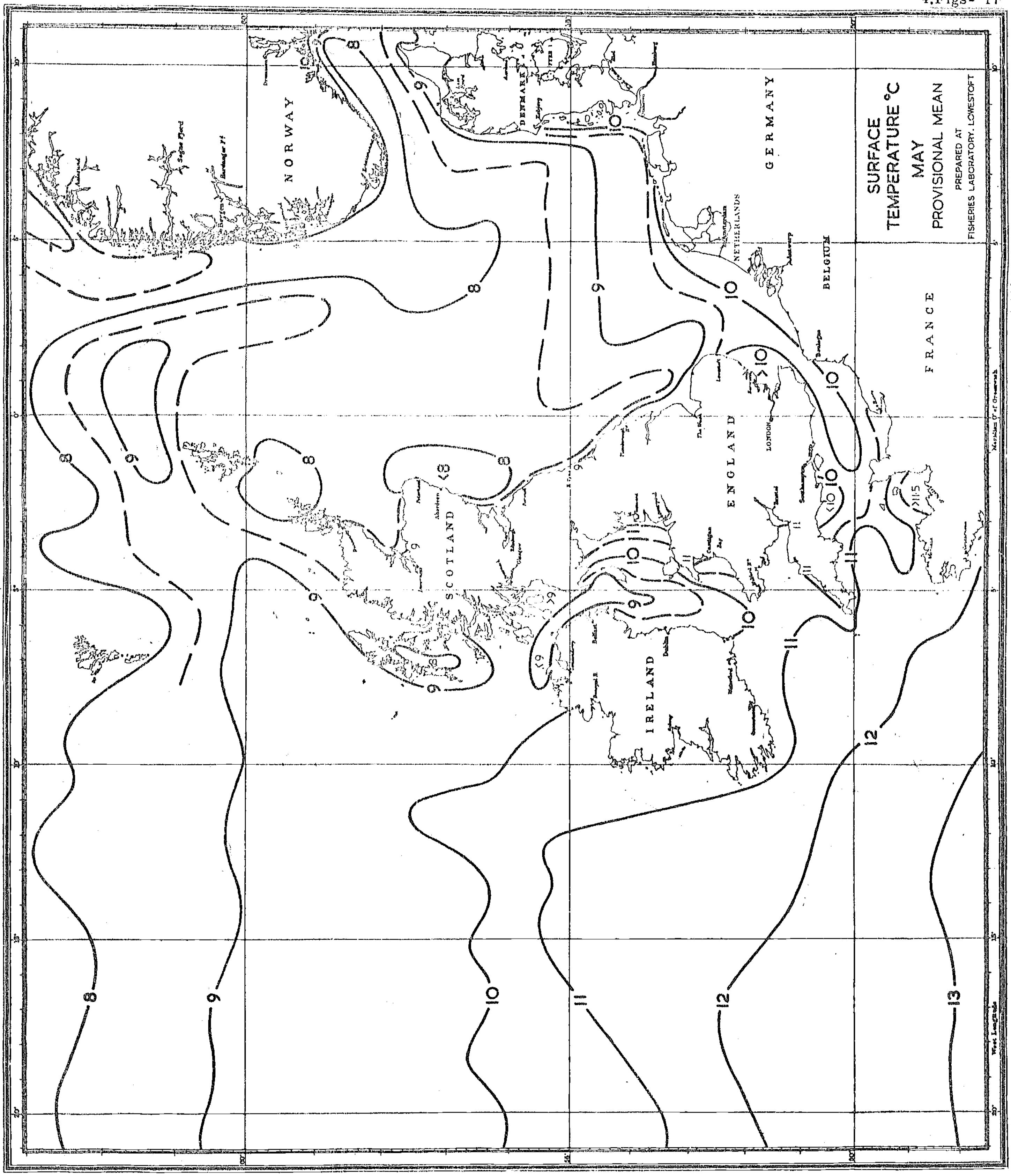
<9
Ca 8·5

FIGURE 4.23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NORWAY
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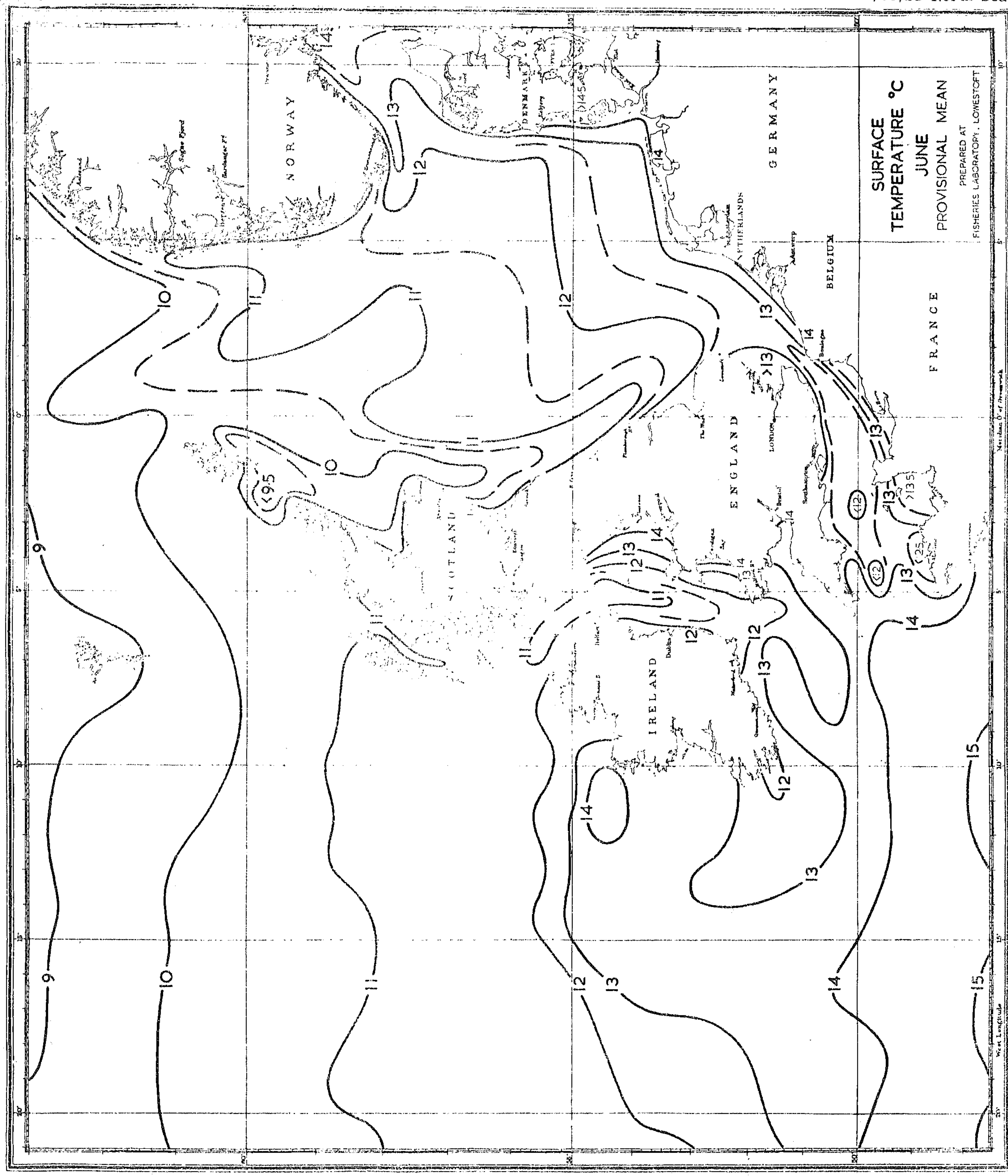
FIGURE 4.24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LONDON
ICES, SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.

FIGURE 4.25

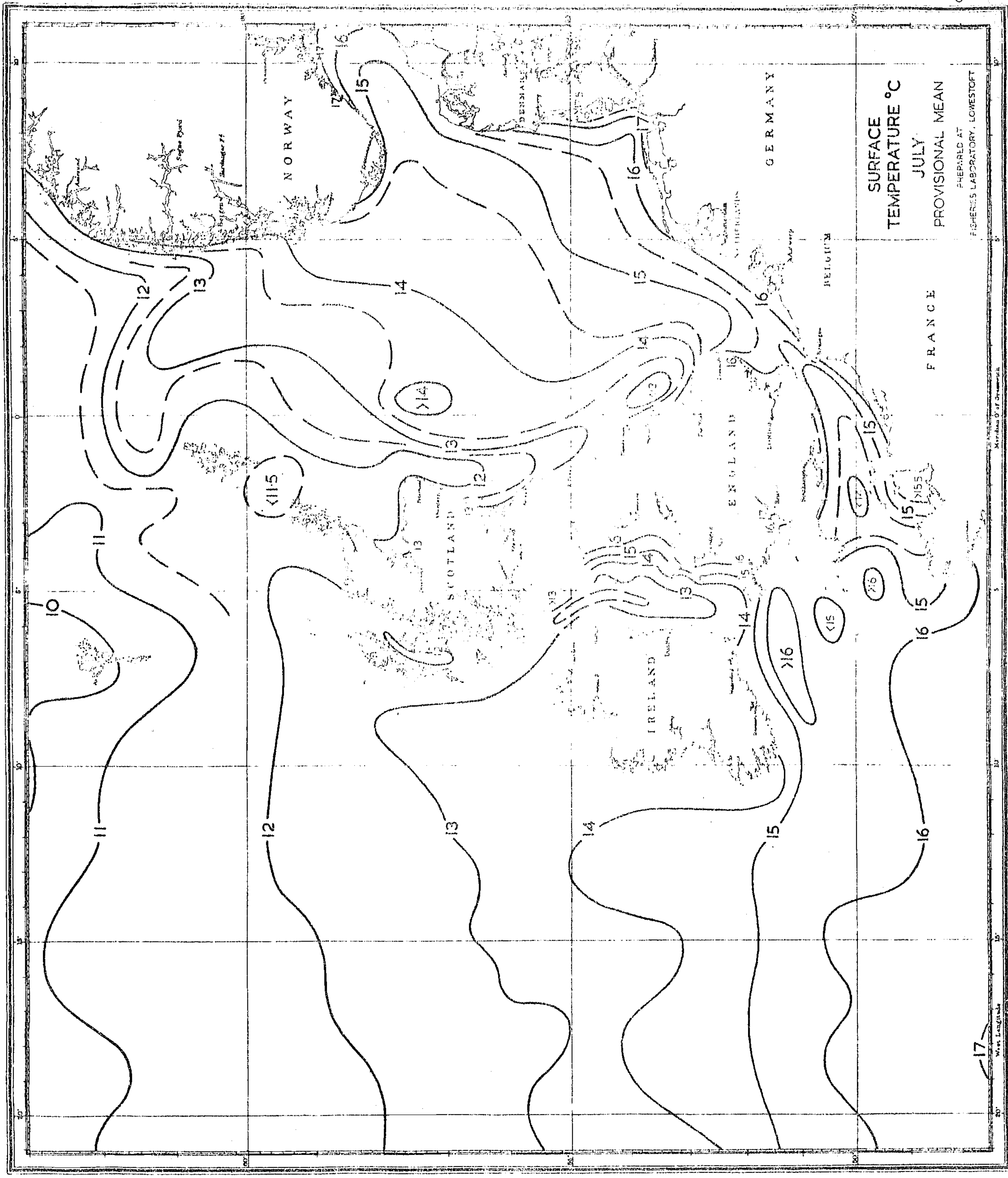
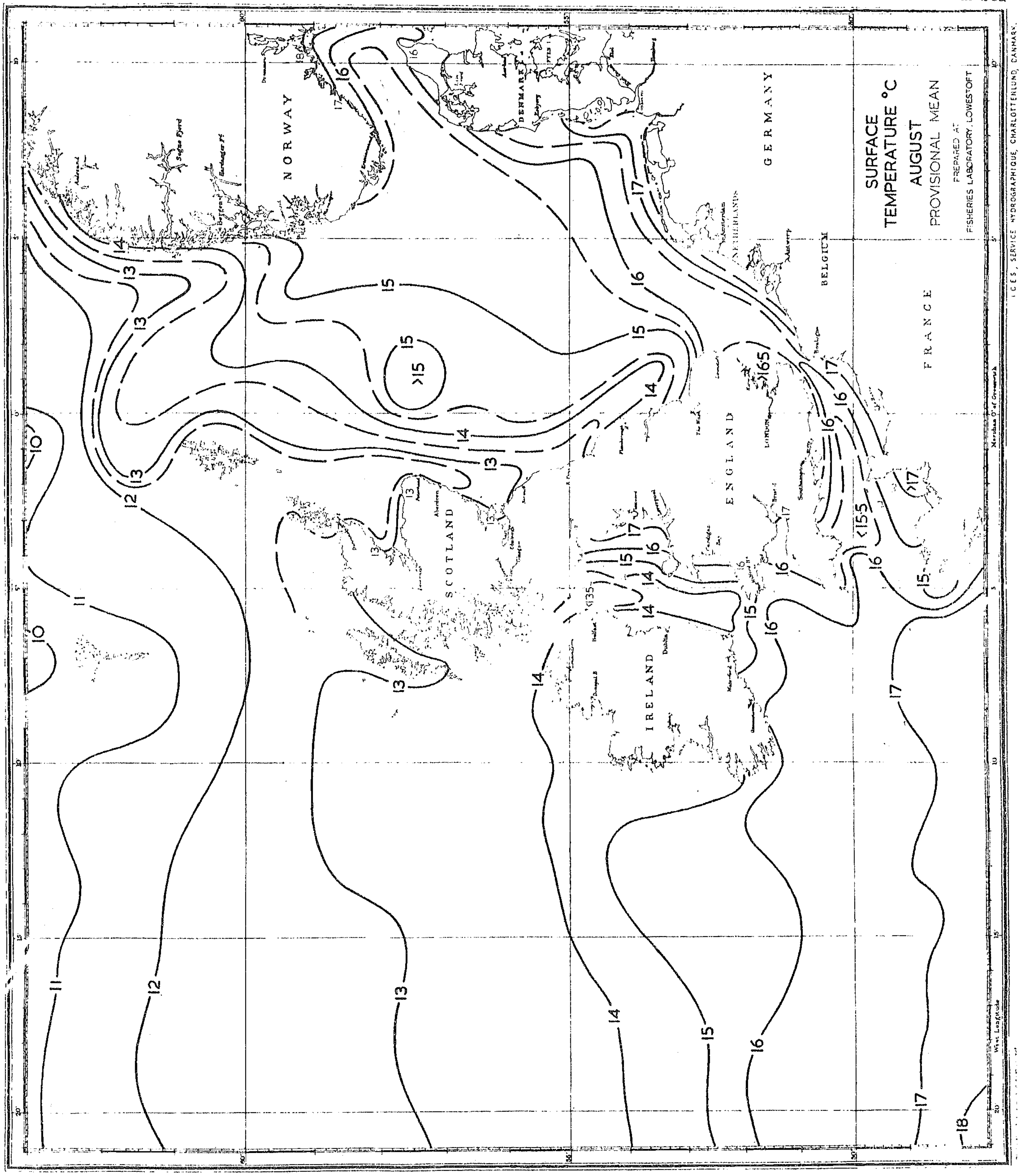


FIGURE 4.26

FIGURE 4.25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BELGIUM
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SCOTLAND
IRELAND
LONDON

FIGURE 4.27

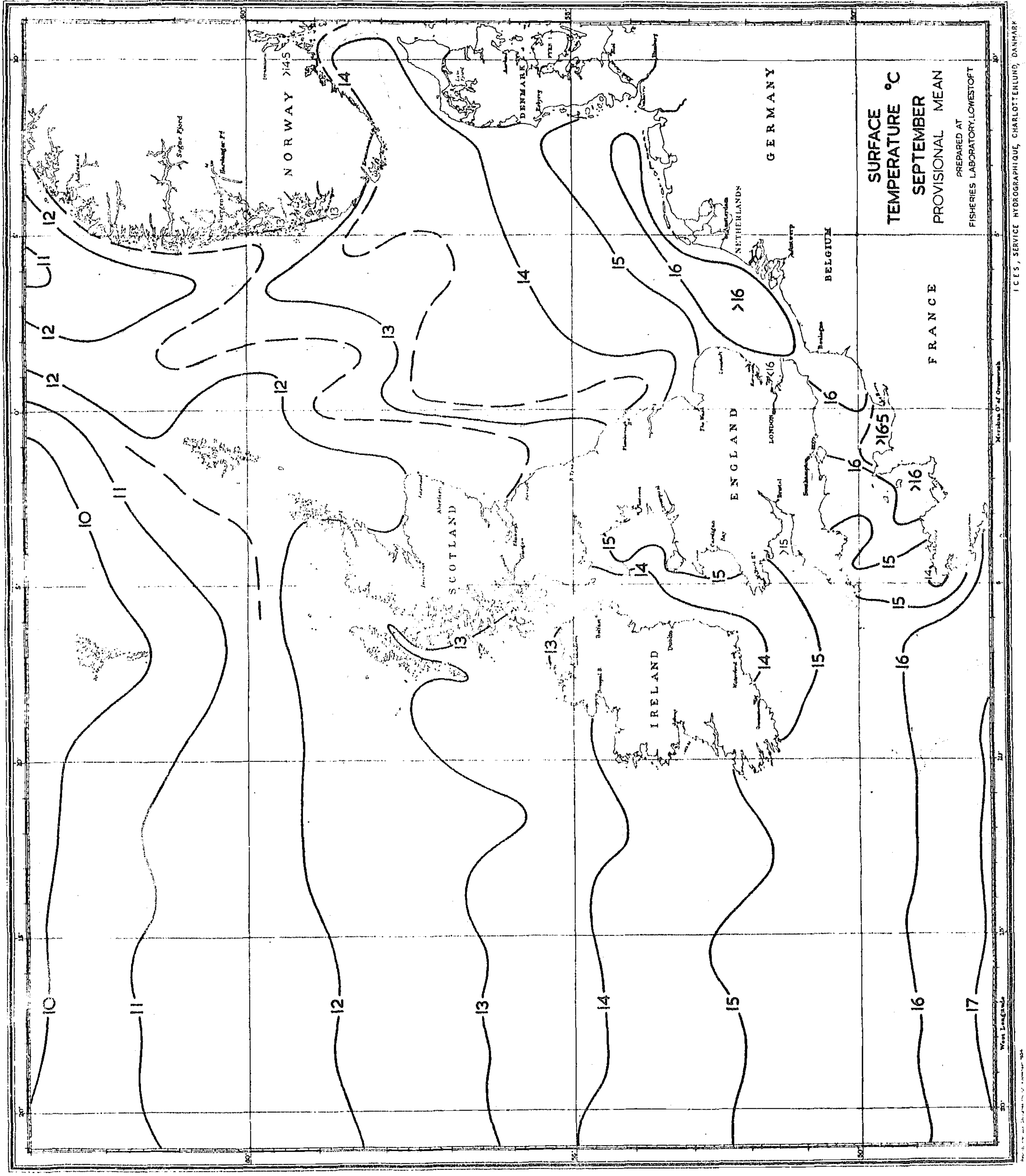

SURFACE
TEMPERATURE °C
SEPTEMBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON
>16
>16.5
>14.5
10
11
12
13
14
15
16
17

FIGURE 4.28

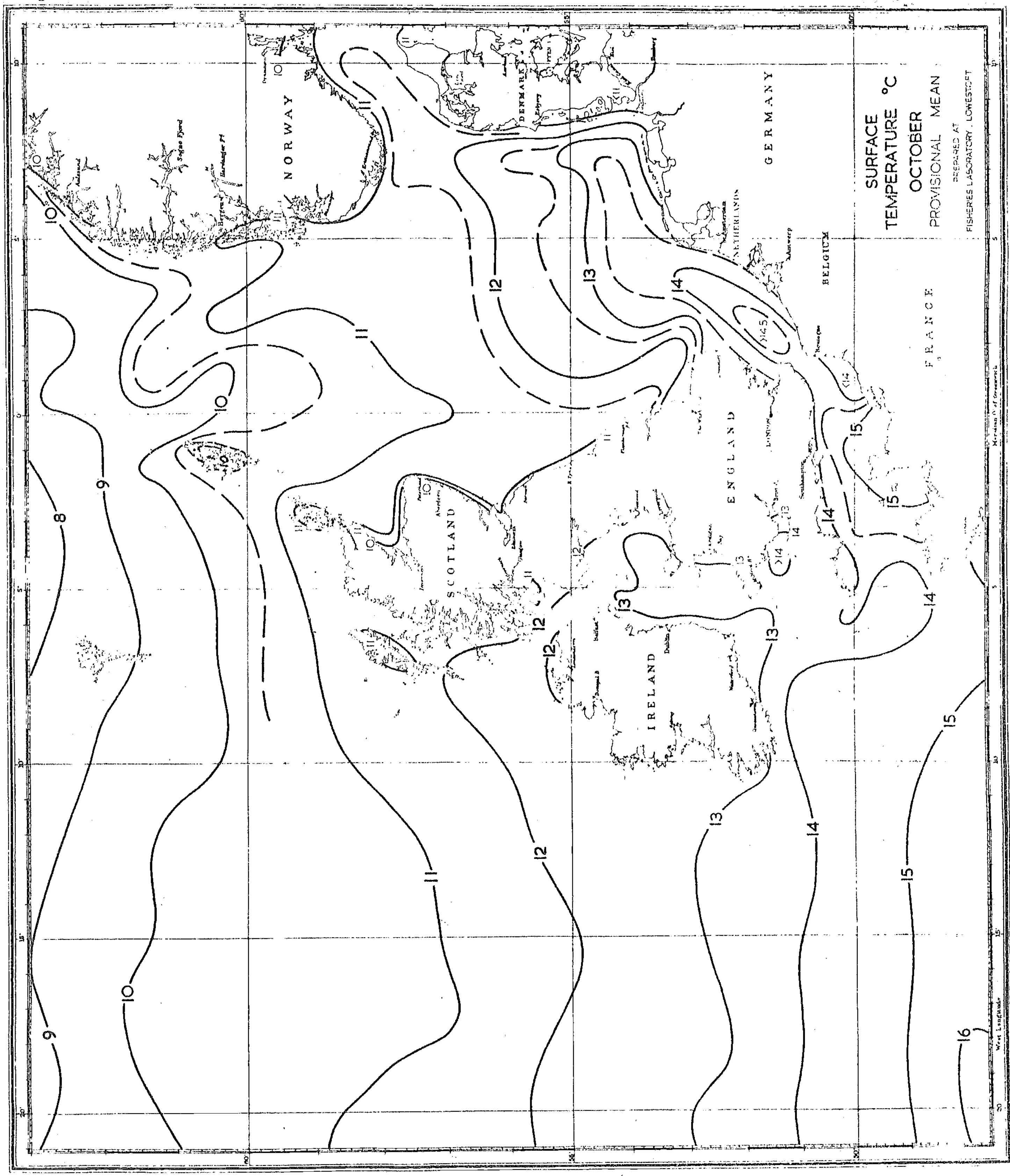

SURFACE
TEMPERATURE °C
OCTOBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND

FIGURE 4.29

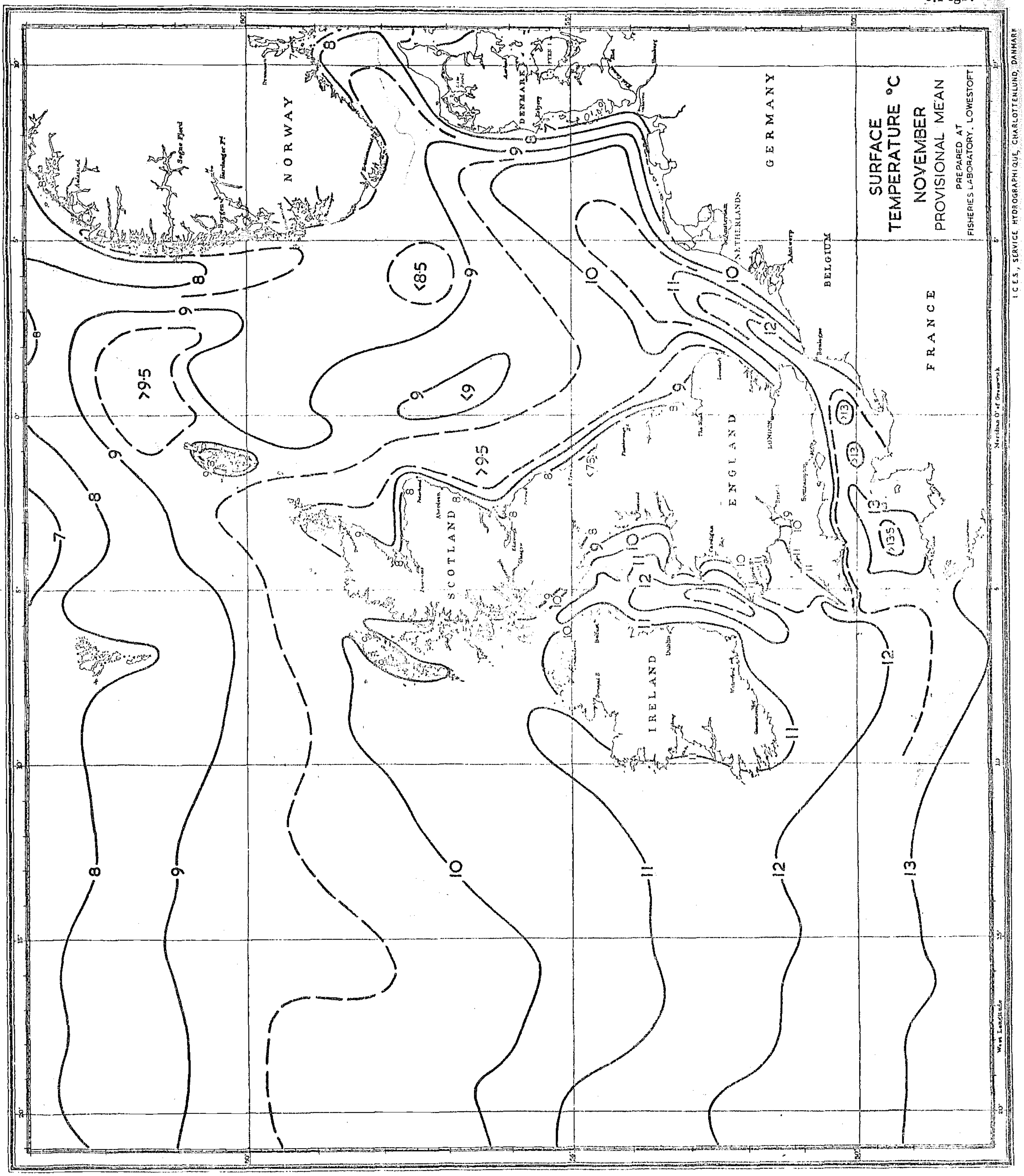

SURFACE TEMPERATURE °C
NOVEMBER
PROVISIONAL MEAN
PREPARED AT FISHERIES LABORATORY, LOWESTOFT
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
ICES, SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK

FIGURE 4.30

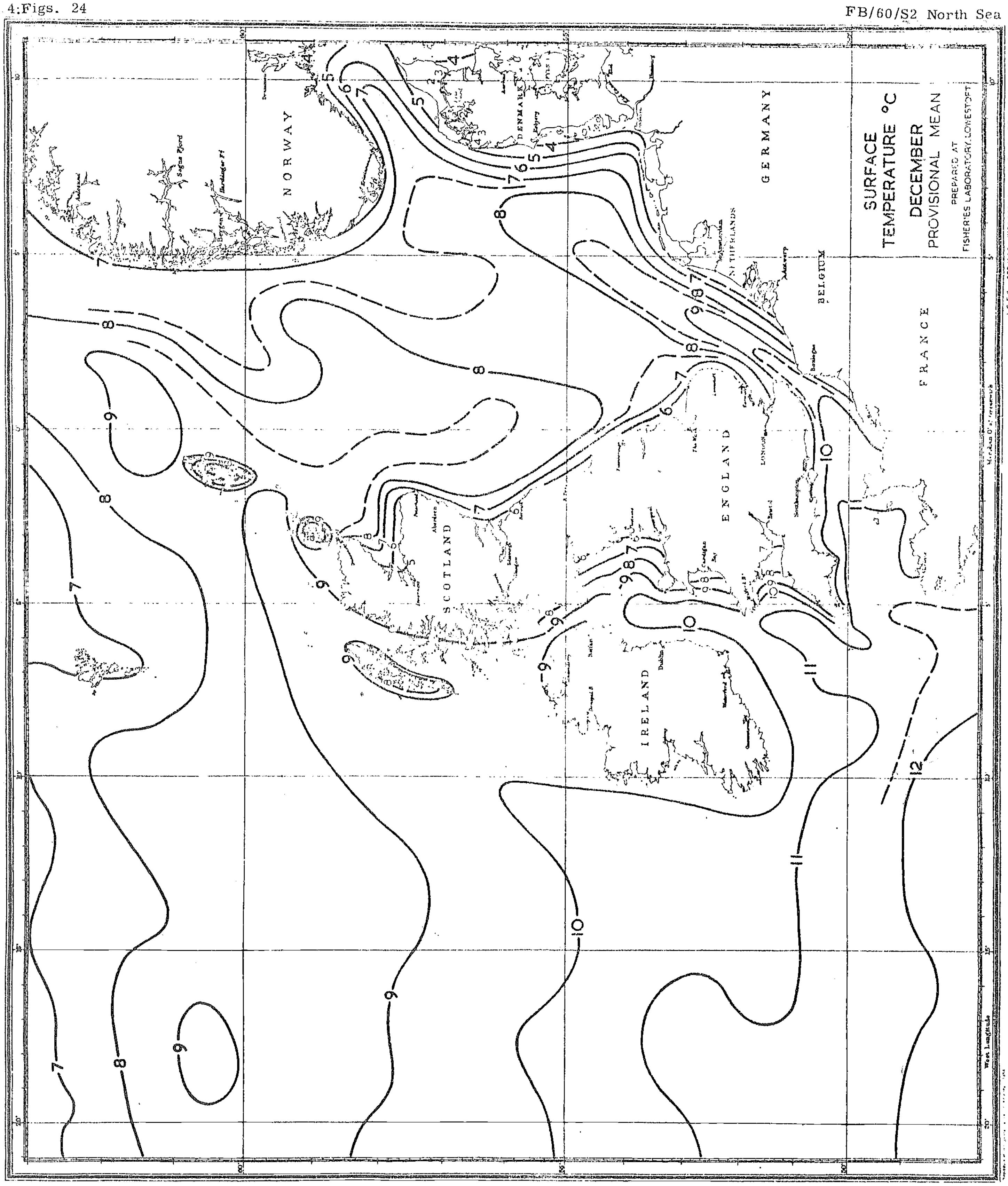

SURFACE
TEMPERATURE °C
DECEMBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
SCOTLAND
ENGLAND
IRELAND

FIGURE 4.31

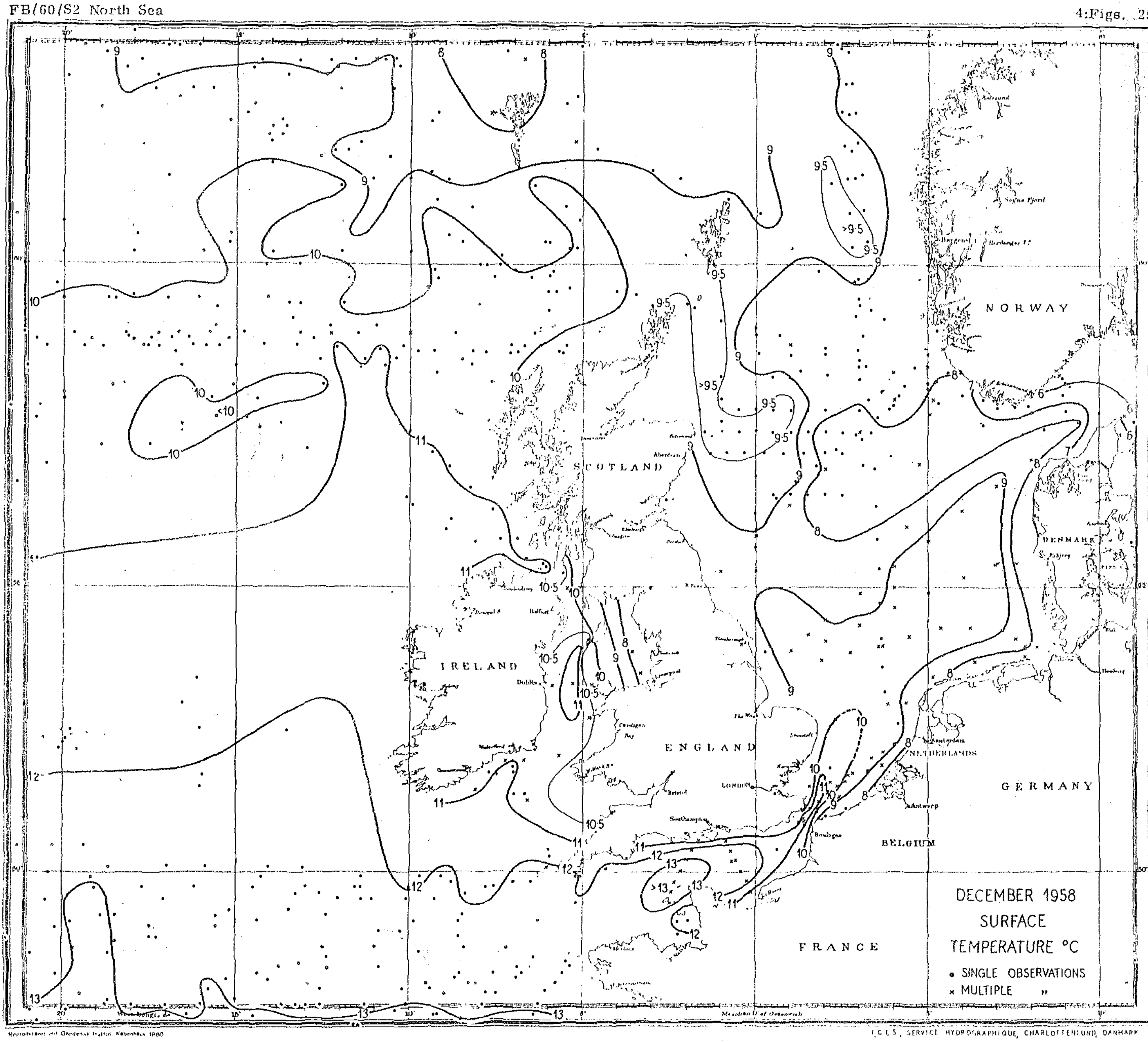

DECEMBER 1958
SURFACE
TEMPERATURE °C
• SINGLE OBSERVATIONS
× MULTIPLE "
NORWAY
SCOTLAND
IRELAND
ENGLAND
DENMARK
NETHERLANDS
GERMANY
BELGIUM
FRANCE
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK

FIGURE 4. 32

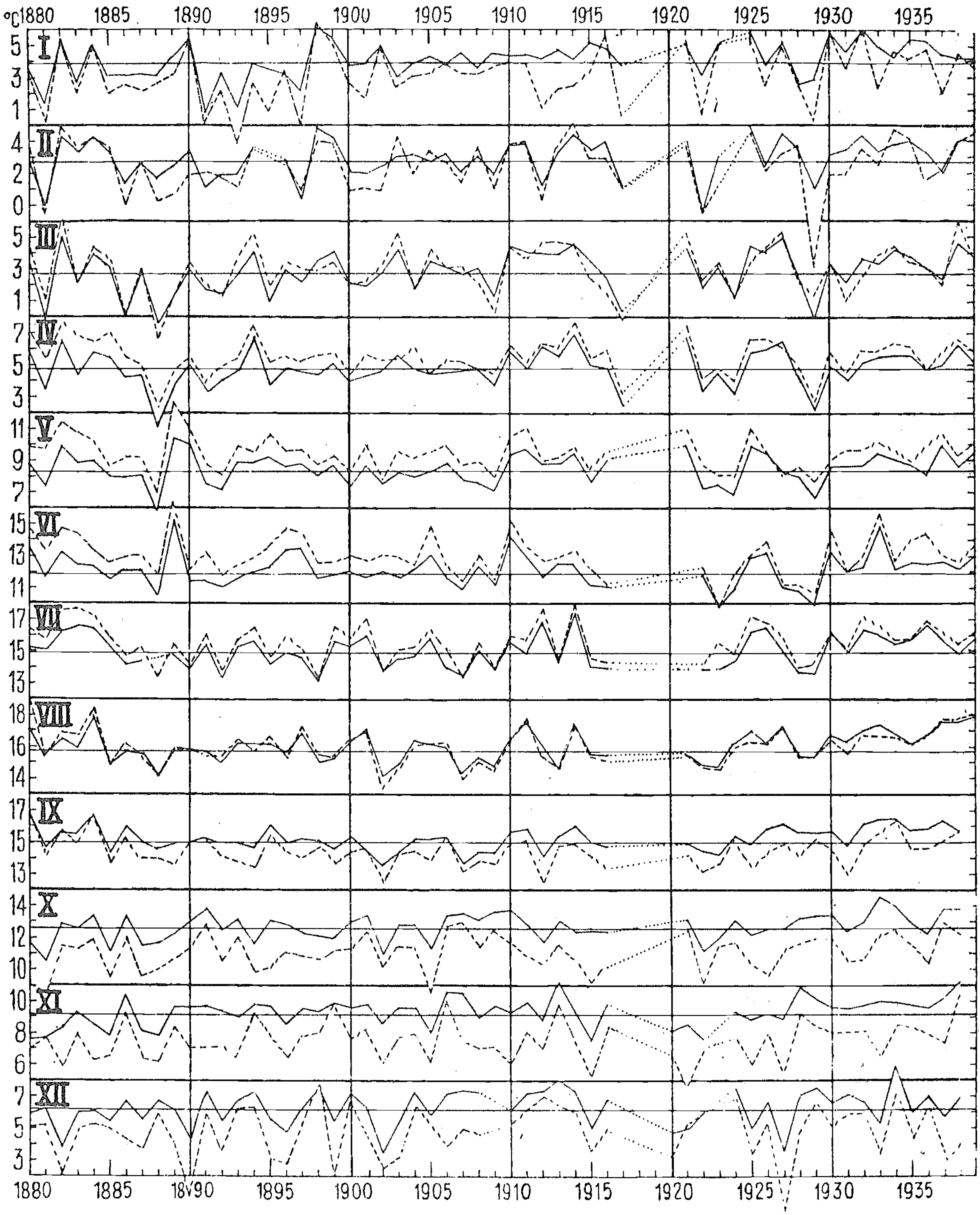


FIGURE 4.33

Monthly means of the surface temperature (solid lines) and of the air temperature (dashed lines) at Horns Rev Light-Vessel during the years 1880-1939 (after Smed)

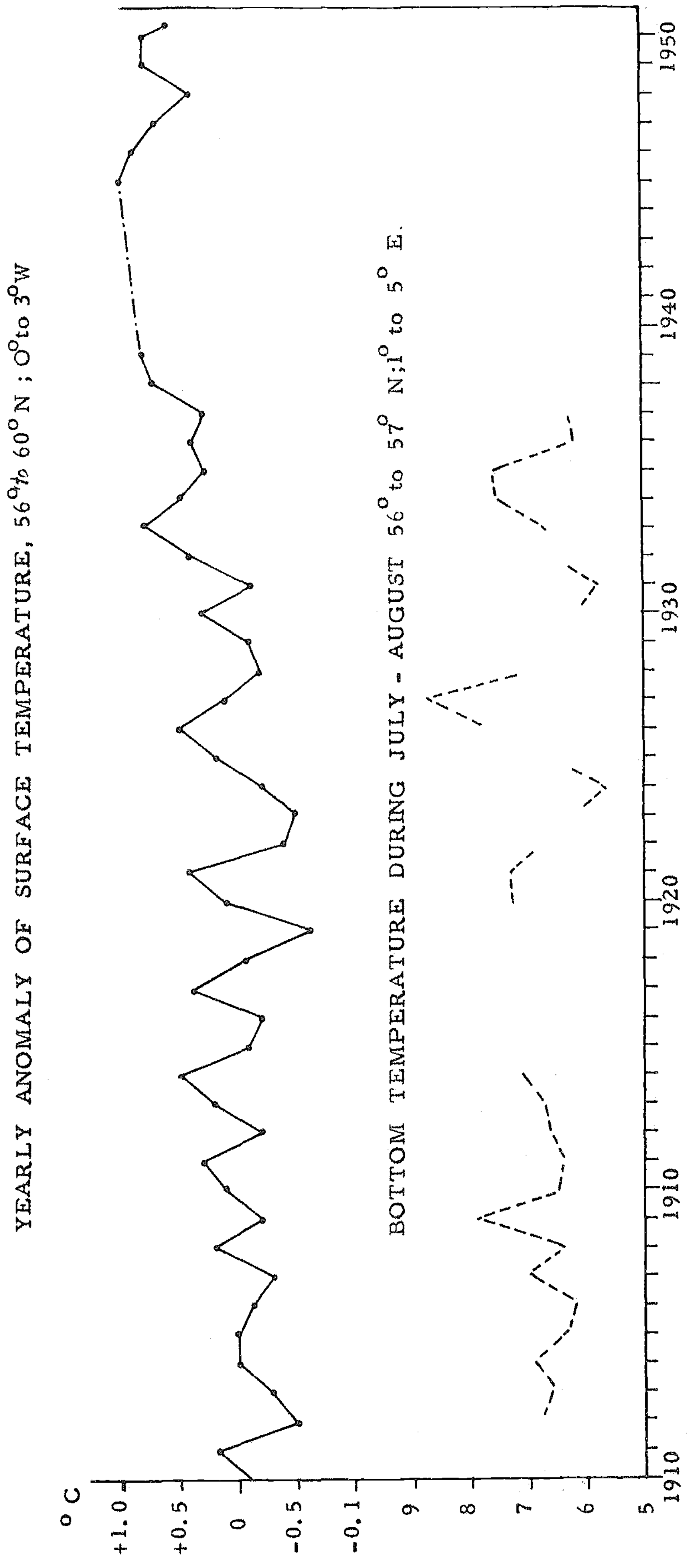

YEARLY ANOMALY OF SURFACE TEMPERATURE, 56° to 60° N ; 0° to 3°W
BOTTOM TEMPERATURE DURING JULY - AUGUST 56° to 57° N; 1° to 5° E.
° C
+1.0
+0.5
0
-0.5
-0.1
9
8
7
6
5
1910
1910
1920
1930
1940
1950

FIGURE 4.34

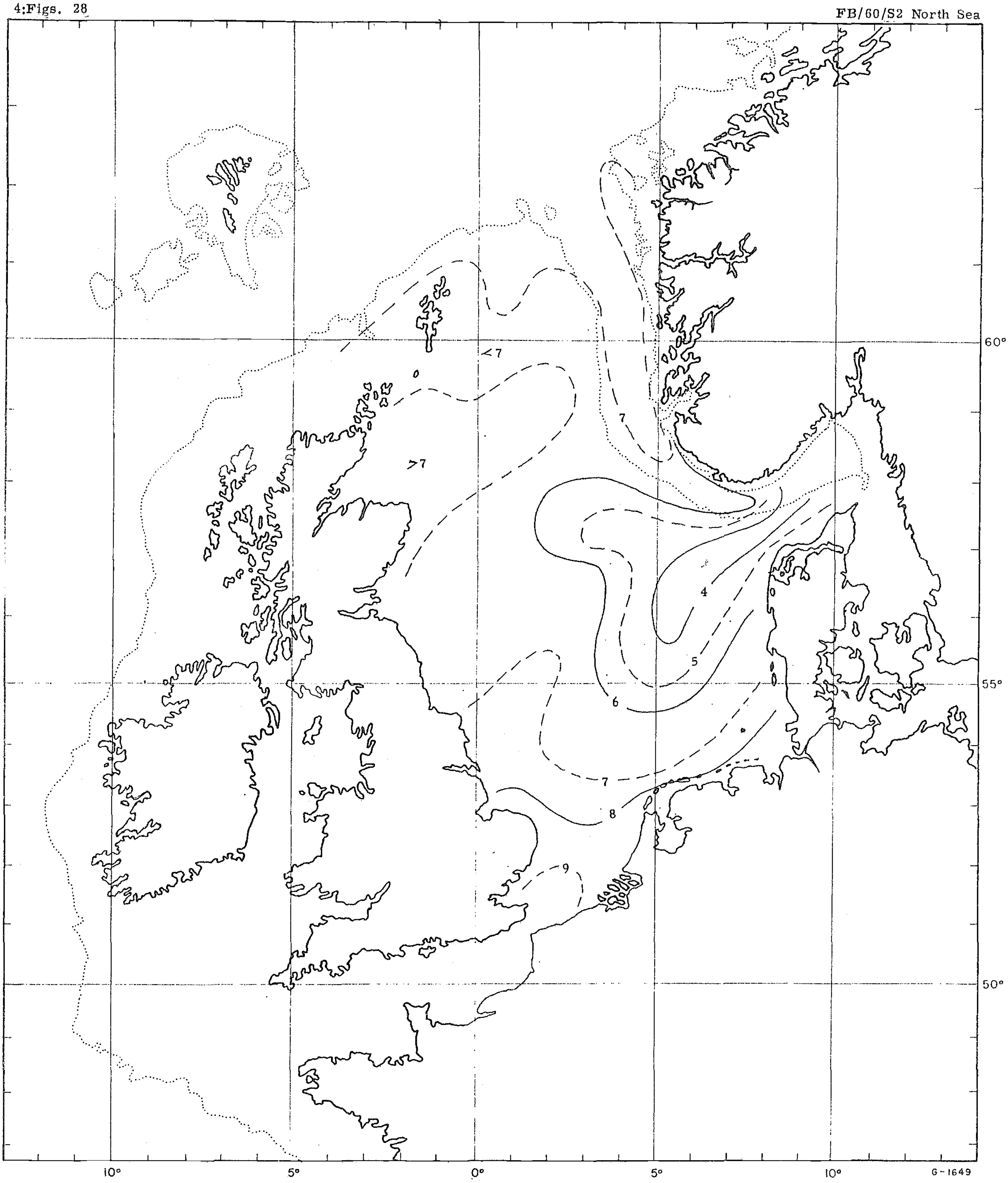


FIGURE 4.35 - CHARACTERISTIC DISTRIBUTION OF BOTTOM TEMPERATURES DURING LAST PART OF MAY

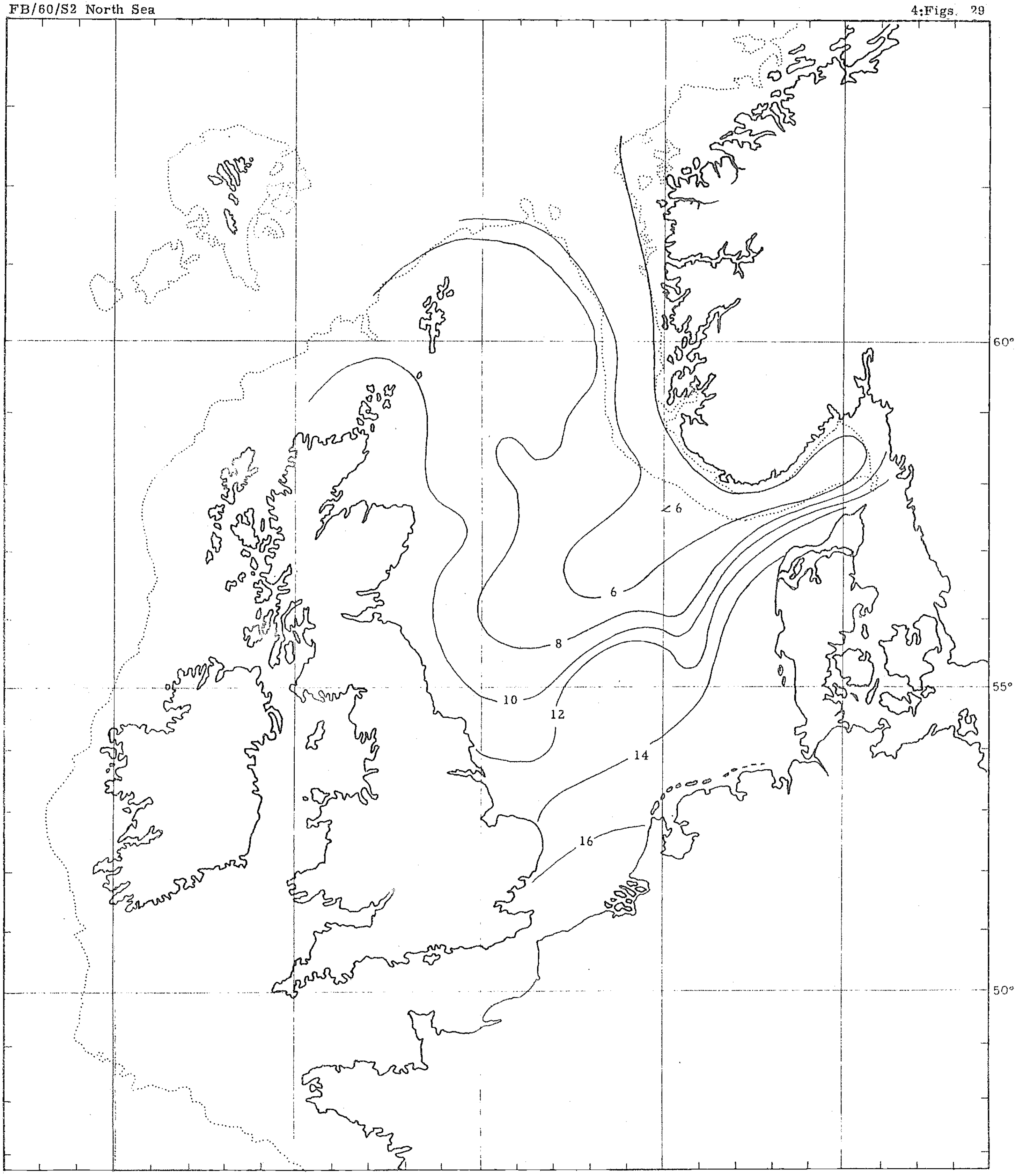


FIGURE 4.36 CHARACTERISTIC DISTRIBUTION OF BOTTOM TEMPERATURES AT THE BEGINNING OF SEPTEMBER

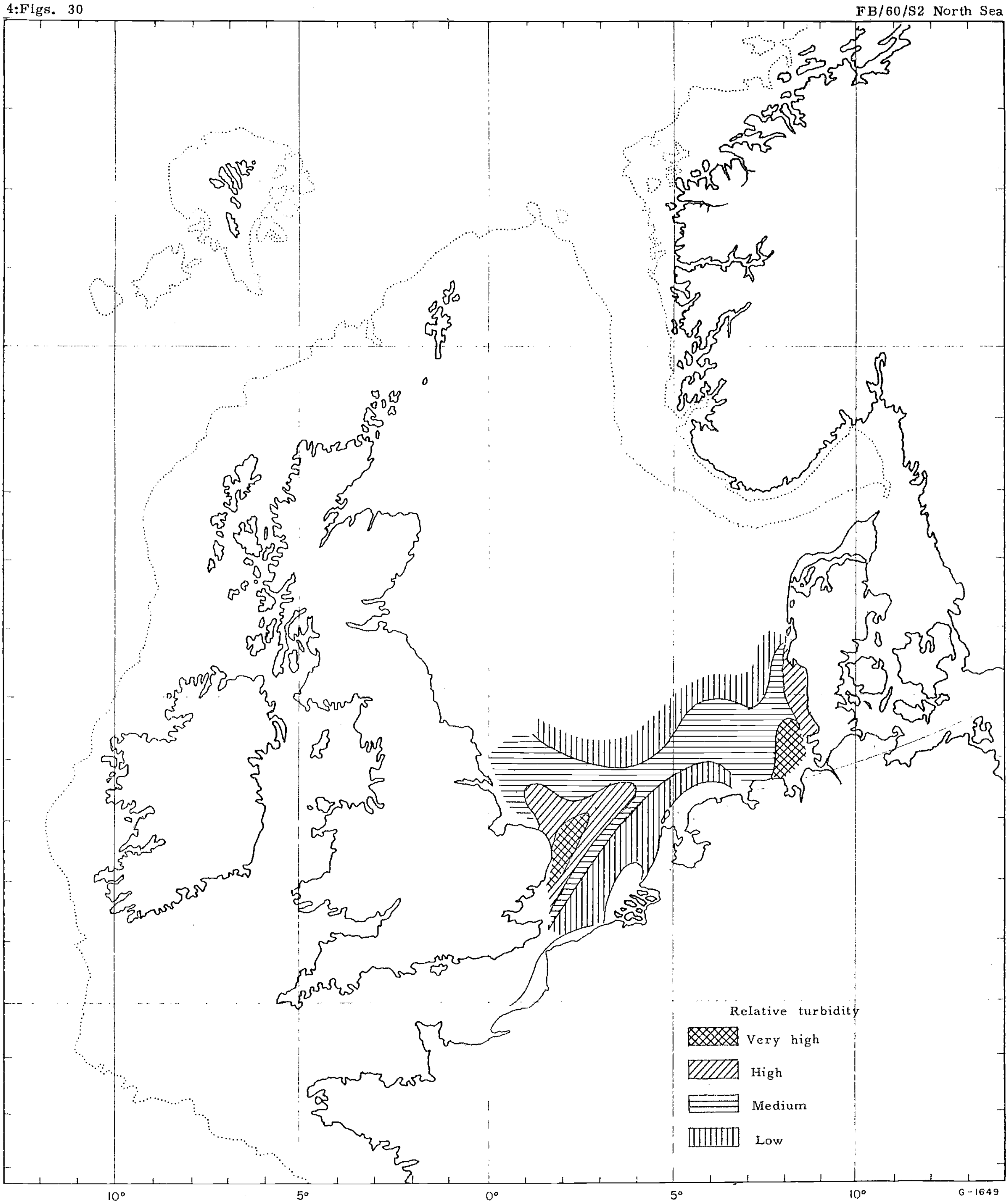


FIGURE 4.40 TURBIDITY OF THE WATER DURING SPRING (Incomplete)

TABLE 4.1

List of current charts, covering the North Sea
(incomplete)

1. International Council for the Exploration of the Sea. Serv. Hydrogr. Charlottenlund. 1950-

   Monthly charts of surface currents, averages for 10-day periods.

2. Böhnecke, G. 1922, Salzgehalt und Stromungen der Nordsee. Veröff.Inst.Meeresk. Berlin, NF. A.10.

3. Deutsche Seewarte, 1905. Atlas der Gezeiten und Gezeilenströme für das Gebiet der Nordsee und der Britischen Gewässer.

TABLE 4.3

Frequencies (in %) of different states of the sea in eastern and southern North Sea

Months	State of the sea code									
	0	1	2	3	4	5	6	7	8	9
	Eastern North Sea									
March-May	7	9	24	22	22	10	4	1.3	0.7	0
June-August	6	8	24	32	18	8	3	1.5	0	0
September-November	3	8	20	26	21	9	7	2.5	2.5	1.5
December-February	3	5	16	22	24	14	10	4	2	0.5
Average	5	8	21	26	21	10	6	2	1	0.5
	Southern North Sea									
March-May	9	11	24	23	18	12	2	0.5	0.5	0
June-August	8	15	23	28	18	5	2	1	0	0
September-November	7	6	19	28	18	12	6	2	1.5	0.5
December-February	3	6	17	21	25	14	10	2	1.5	0.5
Average	7	10	21	25	20	11	5	1.4	0.9	0.2

TABLE 4.4

Wave elements by various wind speeds at lightship "S2" (54°N, 3.5°E during 1949 (after Roll)

Wind speed Bft	Wind speed m sec^{-1}	State of the sea code	Measured wave height m	Computed wave length m	Number of observations
1-2	0.3 - 3.3	1 - 2	0.4	26	251
3	3.4 - 5.4	2	0.7	35	238
4	5.5 - 7.9	3	1.0	38	193
5	8.0 - 10.7	4	1.5	50	158
6	10.8 - 13.8	5	1.9	58	80
7	13.9 - 17.1	6	2.4	70	82
8	17.2 - 20.7	7	2.9	81	36
9	20.8 - 24.4	8	3.4	81	26
10	24.5 - 28.4	8	3.6	82	16

TABLE 4.5

Water masses, their characteristics and distribution in the North Sea (after Kalle 1953, modified)

Name	Characteristics	Distribution
North Atlantic Water	High salinity, poor in nutrients low turbidity, relatively warm in winter, cool in summer	Entering partly between Orkney and Shetland, but mainly north from Shetland, flowing to south along British East coast to Norfolk coast, turning to East and mixing in the three gyrals in the central part of the North Sea
Channel Water	High salinity, poor in nutrients, low turbidity, relatively warm	Entering through Dover-Calais strait, distributing in narrow strip to northeast, reaching the gyral in the northeast part of Dogger Bank
Central North Sea Water	Medium salinity, medium to poor in nutrients, medium turbidity	Covering the central North Sea, especially over Dogger Bank and northeast of it. A mixture of five other water masses
Skagerrak Water	Low salinity, poor in nutrients, low temperature and medium to low turbidity	A mixture of Baltic water, flowing out along the Norwegian coast. About 59°N a tongue of this water often reaches the central part of the northern North Sea and some mixing takes place also between 57-58°N
English Coastal Water	Low salinity, nutrient rich, high turbidity, low temperature in winter	Keel-shaped enclosure between Channel water and North Atlantic water, reaching the centre of a gyral south of Dogger Bank
Continental Coastal Water	Low salinity, nutrient rich, high turbidity, relatively cool in winter, warm in summer	Narrow strip off the continental coast. Mixed in the gyral in the German Bight and flowing North into Skagerrak-Kattegat along the Danish Coast

TABLE 4.7

List of hydrographic atlases of the North Sea

1. Böhnecke, G. and G. Dietrich, 1951. Monatskarten der Oberflächentemperatur für die Nord- und Ostsee. Dtsch.Hydrogr. Inst. Hamburg.

2. Bullig, H.J. and P. Bintig, 1954. Temperatur-Differenz Luft-Wasser. in Klimatologie der Nordwesteuropäischen Gewasser. Dtsch.Wetterdienst, Seewetteramt, Einzelverofentl.4., Hamburg.

3. Deutsche Seewarte, 1927. Atlas für Temperatur, Salzgehalt und Dichte der Nordsee und Ostsee, Hamburg.

4. ICES, Service Hydrographique. Monthly charts of surface temperature and salinity.

5. Lumby, J.R., 1935. Salinity and temperature of the English Channel (atlas of charts). Fisheries Invest. London. Ser. II, Vol. XIV No. 3

5. CHEMICAL OCEANOGRAPHY

There are very slight differences in the mean values of some major chemical constituents in the North Sea water (see Table 5.1) as compared to the recognized mean values for the oceans as a whole. The distribution of surface salinities is determined by inflow, run-off and mixing (see Figures 5.1 to 5.12). The inflow of Atlantic high salinity water is at a maximum in February and at a minimum in August. The inflow of low salinity Baltic water is at a maximum at the end of July and at a minimum in January. ICES issues monthly surface salinity charts with analyses similar to those for temperature (see Figure 5.13)

The surface water is slightly supersaturated with oxygen especially during May and the bottom waters are slightly undersaturated, especially during November. Otherwise no great differences in saturation between surface and bottom waters occurs, because of rather intensive mixing in the area by tides and waves.

The amounts of trace elements reported in the water from the North Sea are given in Table 5.3. Many of the data are unreliable because of the use of unreliable and improper methods of analysis. Average recognized values for sea water are also given in this table.

Although numerous individual data on nutrients in the North Sea are available, no systematic working up of these data has been done.

The $Si-O_2$ content is usually 0 from July to November and reaches a maximum usually in March to May with ca. 4.3 mg/l (caused mainly by run-off). Nitrates are usually at a maximum in January (360 mg NO_3/m^3) and at a minimum in September (90 mg NO_3/m^3). Phosphates are the main limiting nutrients in the North Sea, being at a maximum during the winter (ca 0.6 ug at/l) and almost exhausted during the summer. The phosphate/nitrate ratio varies with season, depending on the higher degeneration speed of phosphates. So also does the phosphate/silicate ratio, which in addition depends on the distance from the coast and estuaries.

There is some severe domestic and industrial pollution along several coasts, especially close to big cities and estuaries. Oil pollution is decreasing because of various regulations. At present, it is allowed to dump oil into a limited area in the central North Sea.

5.1 Salinity, major constituents

List of figures

List of tables

5.2 Oxygen and other dissolved gases

List of figures

List of tables

5.3 Trace elements

List of tables

5.4 Nutrient salts

List of figures

List of tables

5.5 Pollution

List of figures

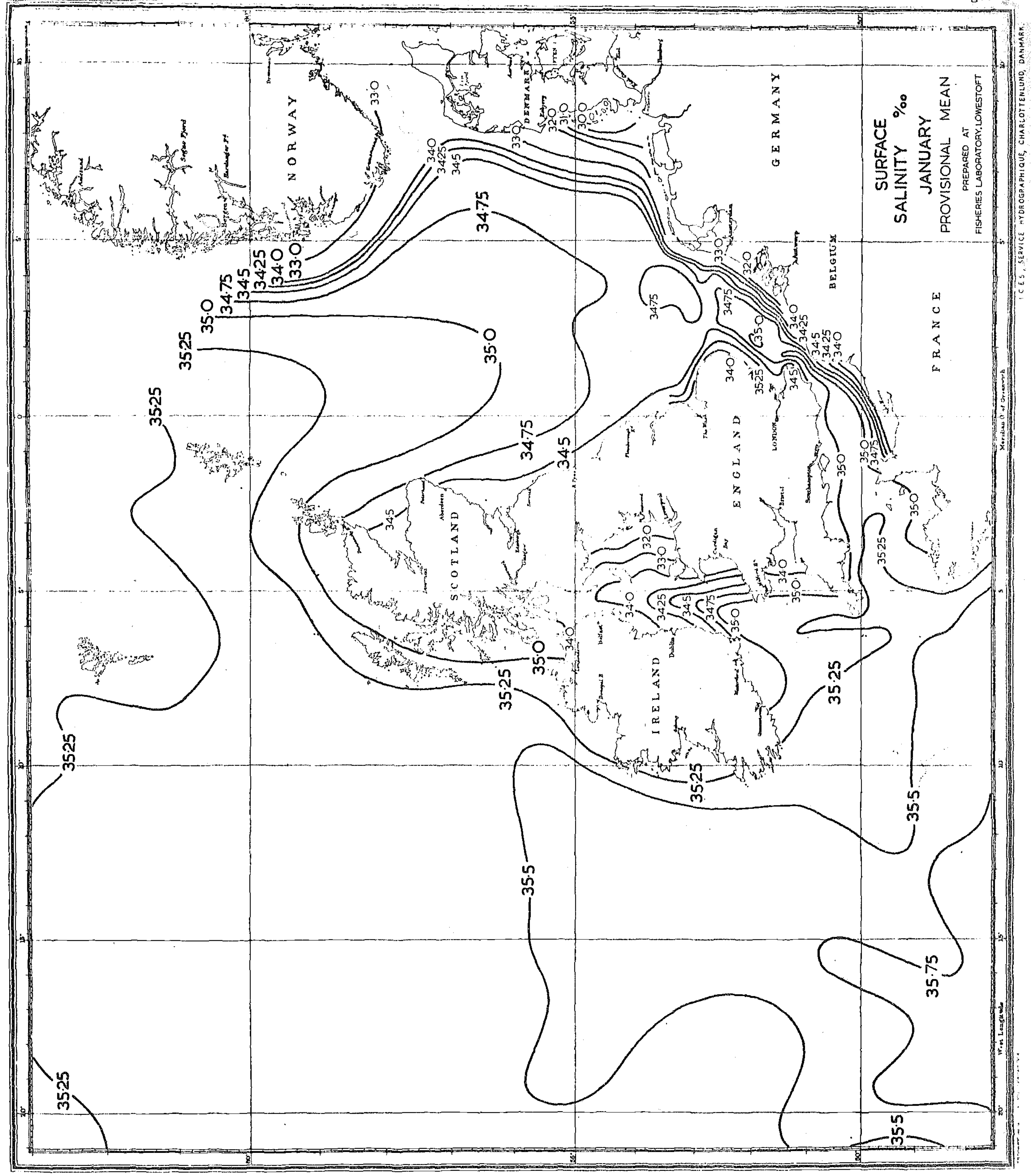

SURFACE
SALINITY ‰
JANUARY
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
NORWAY
DENMARK
GERMANY
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON
35·5
35·75
35·25
35·0
34·75
34·5
34·25
34·0
33·0
32·0
31·0
30·0

FIGURE 5.1

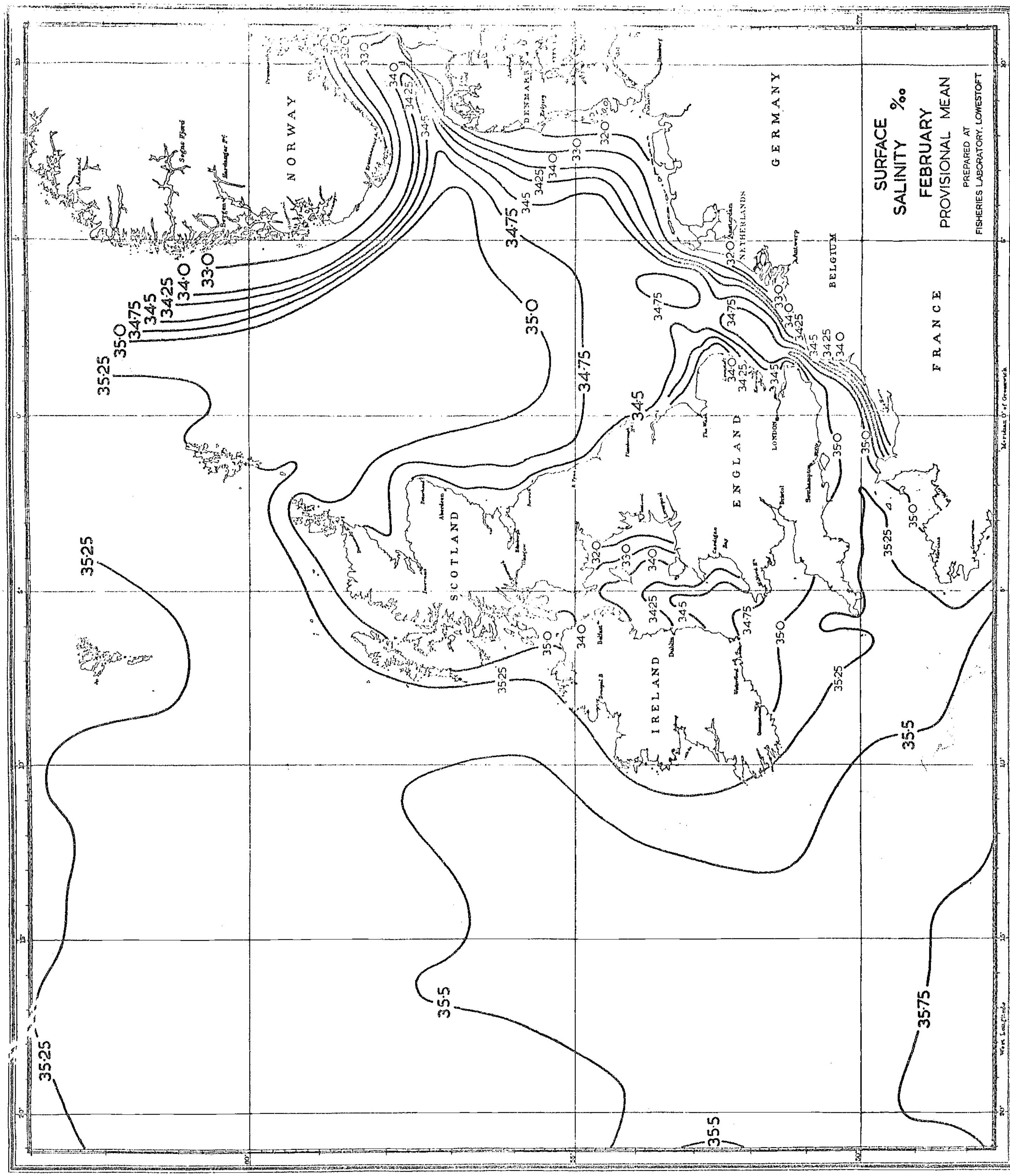

SURFACE
SALINITY ‰
FEBRUARY
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON
35·25
35·5
35·75

FIGURE 5.2

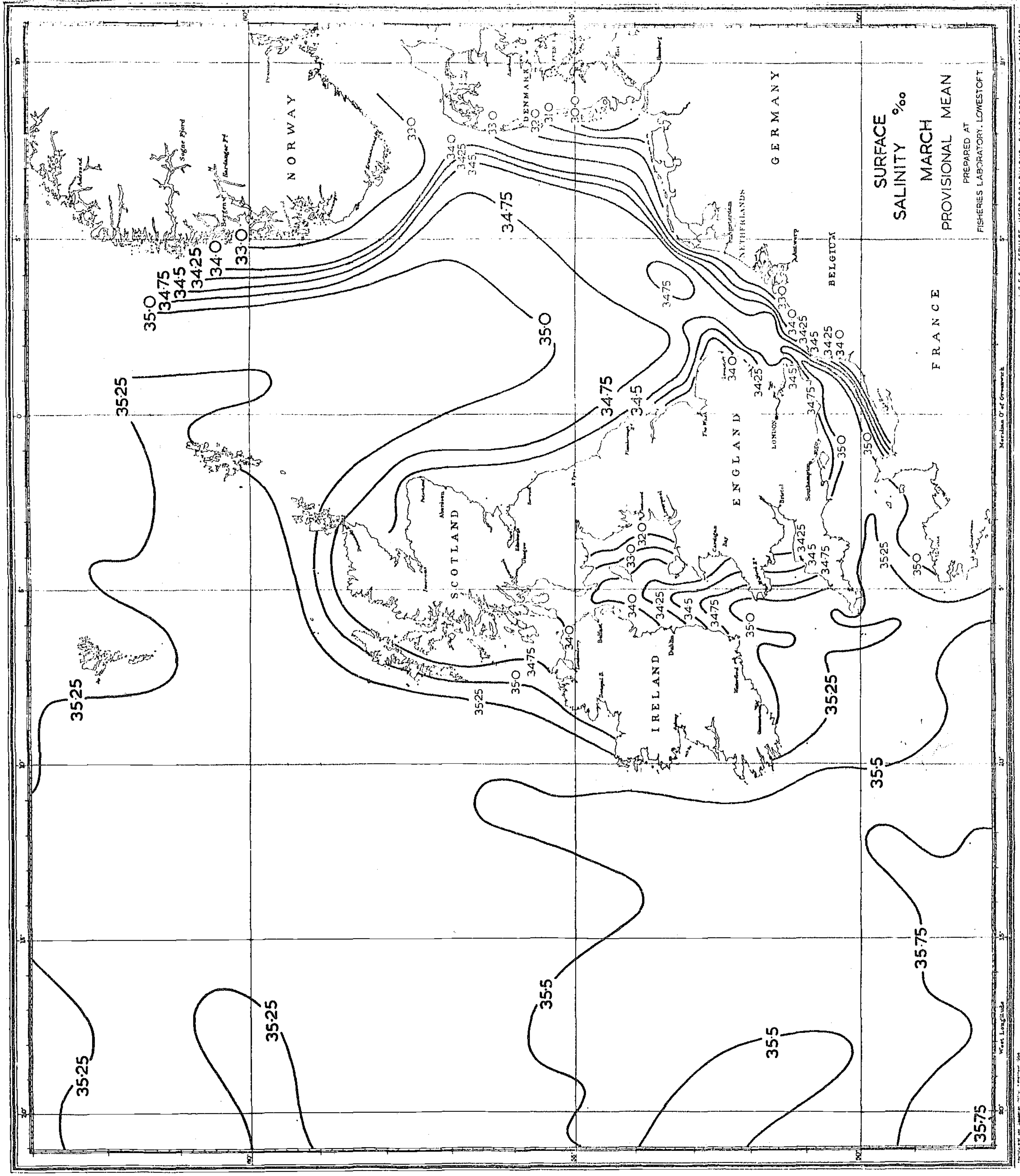

SURFACE
SALINITY ‰
MARCH
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
ICES, SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON

FIGURE 5.3

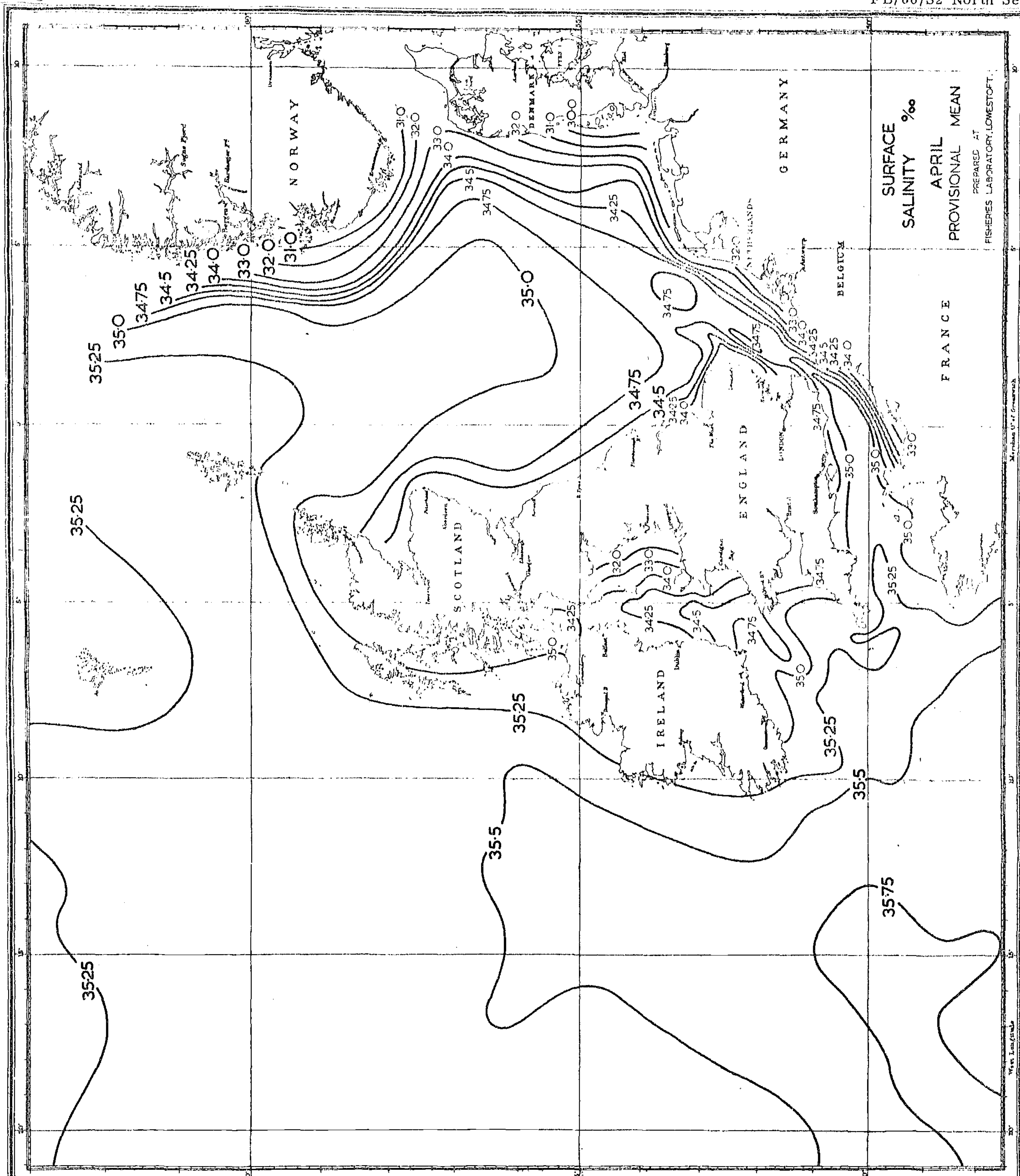
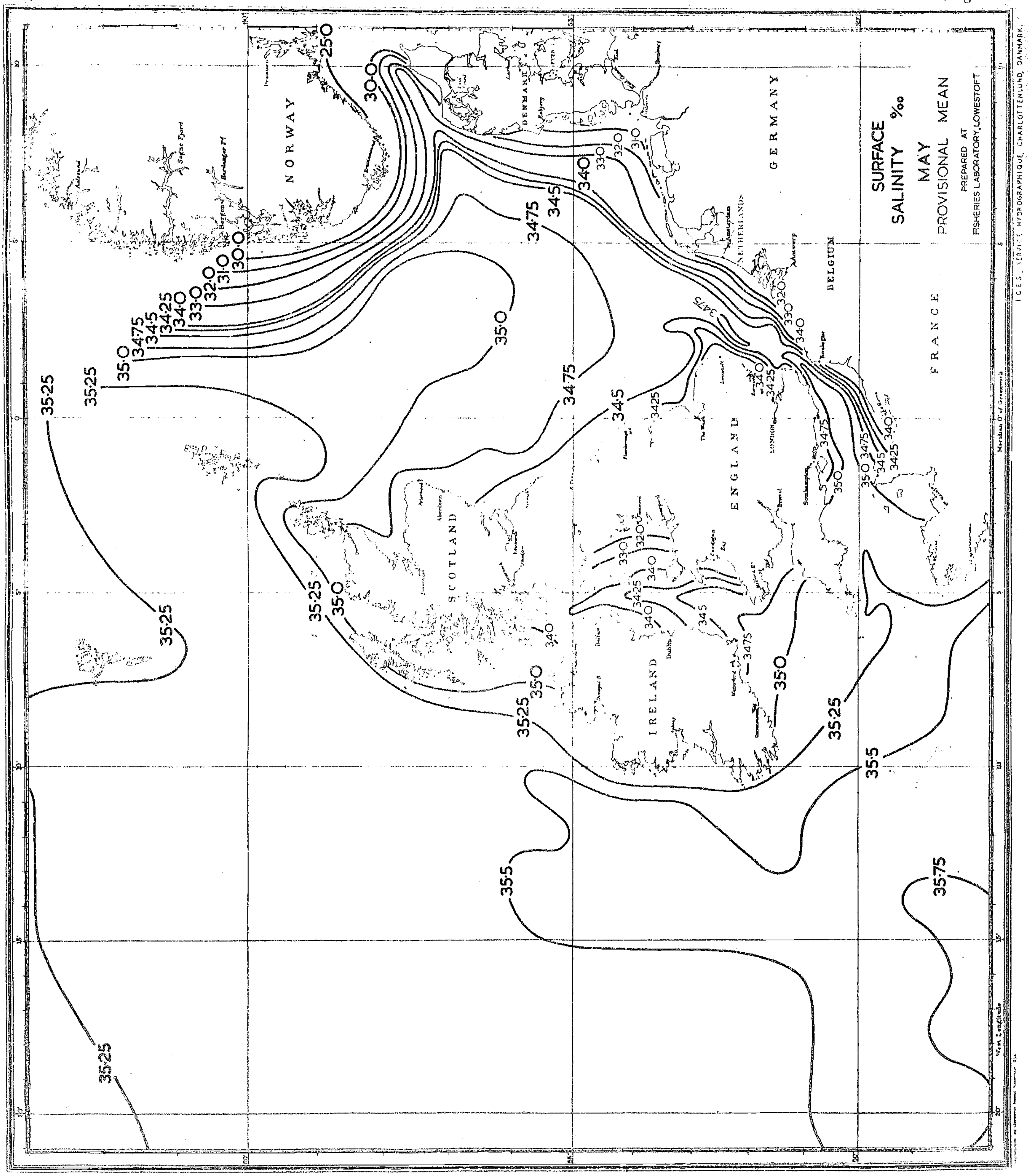

SURFACE
SALINITY ‰
APRIL
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT.
I.C.E.S. SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
DENMARK
GERMANY
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND

FIGURE 5.4


SURFACE
SALINITY ‰
MAY
PROVISIONAL MEAN
PREPARED AT
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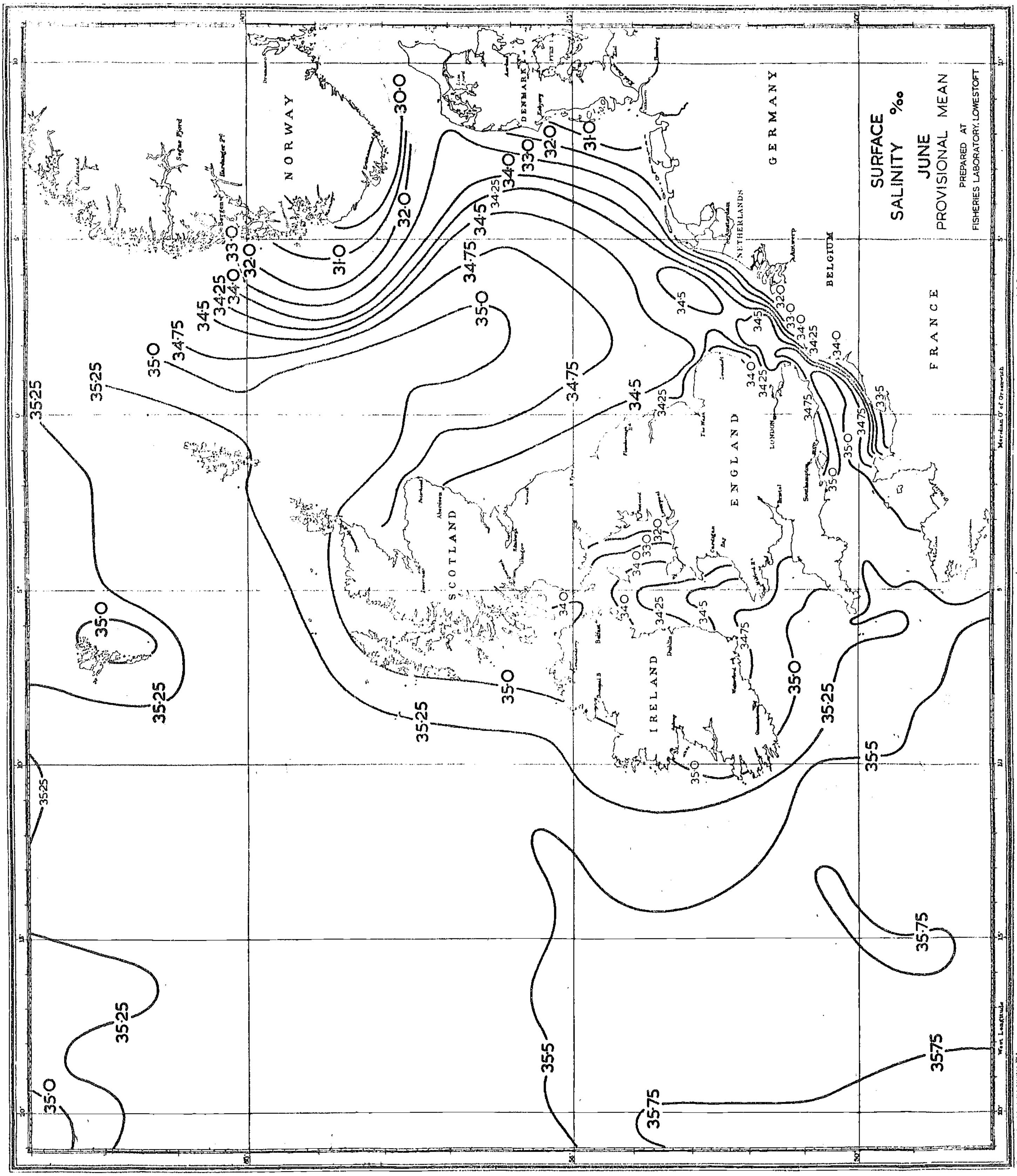
GERMANY
DENMARK
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND

FIGURE 5.5


SURFACE
SALINITY ‰
JUNE
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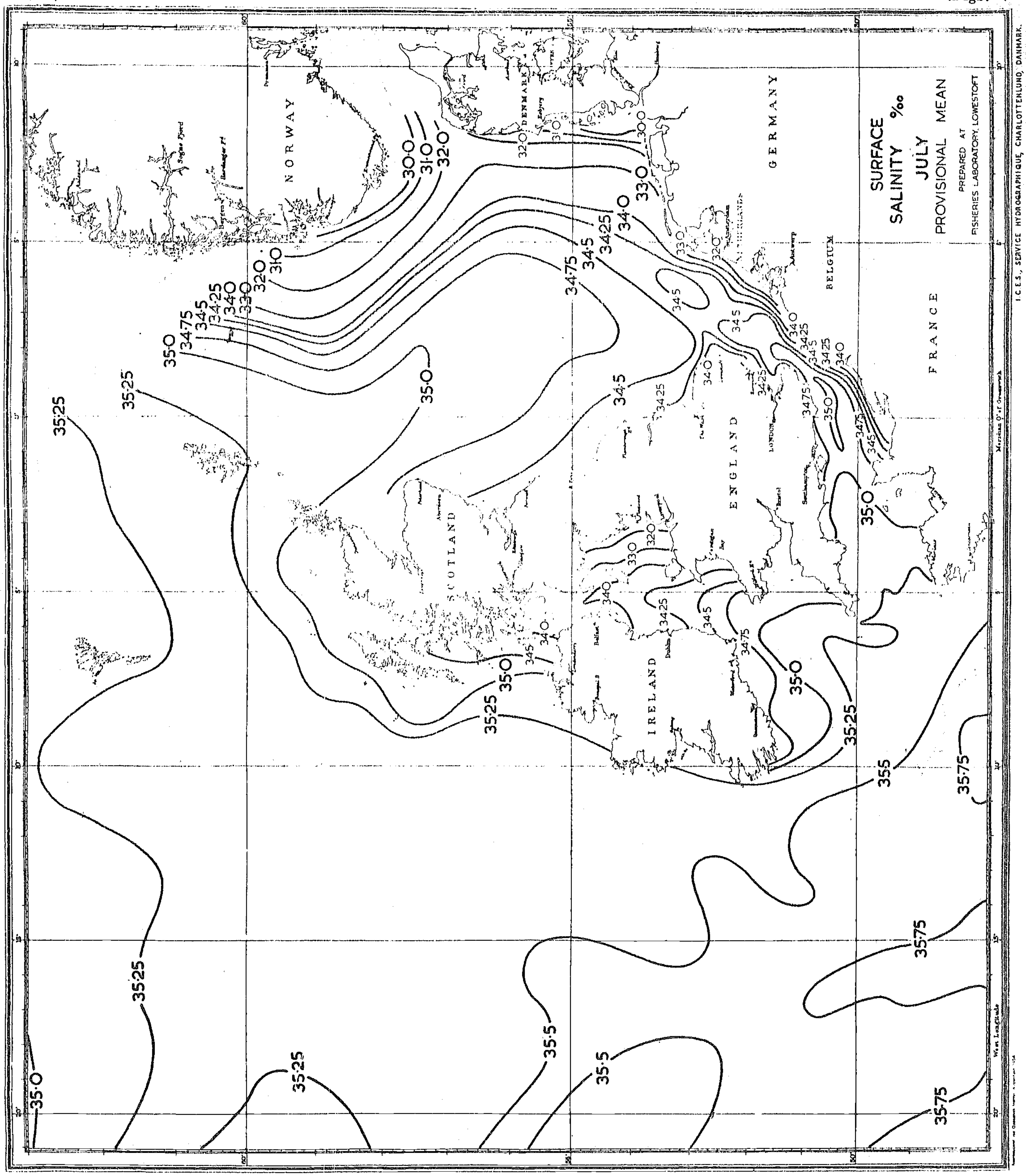
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON

FIGURE 5.6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SALINITY ‰
JULY
PROVISIONAL MEAN
PREPARED AT
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NORWAY
DENMARK
GERMANY
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.

FIGURE 5.7

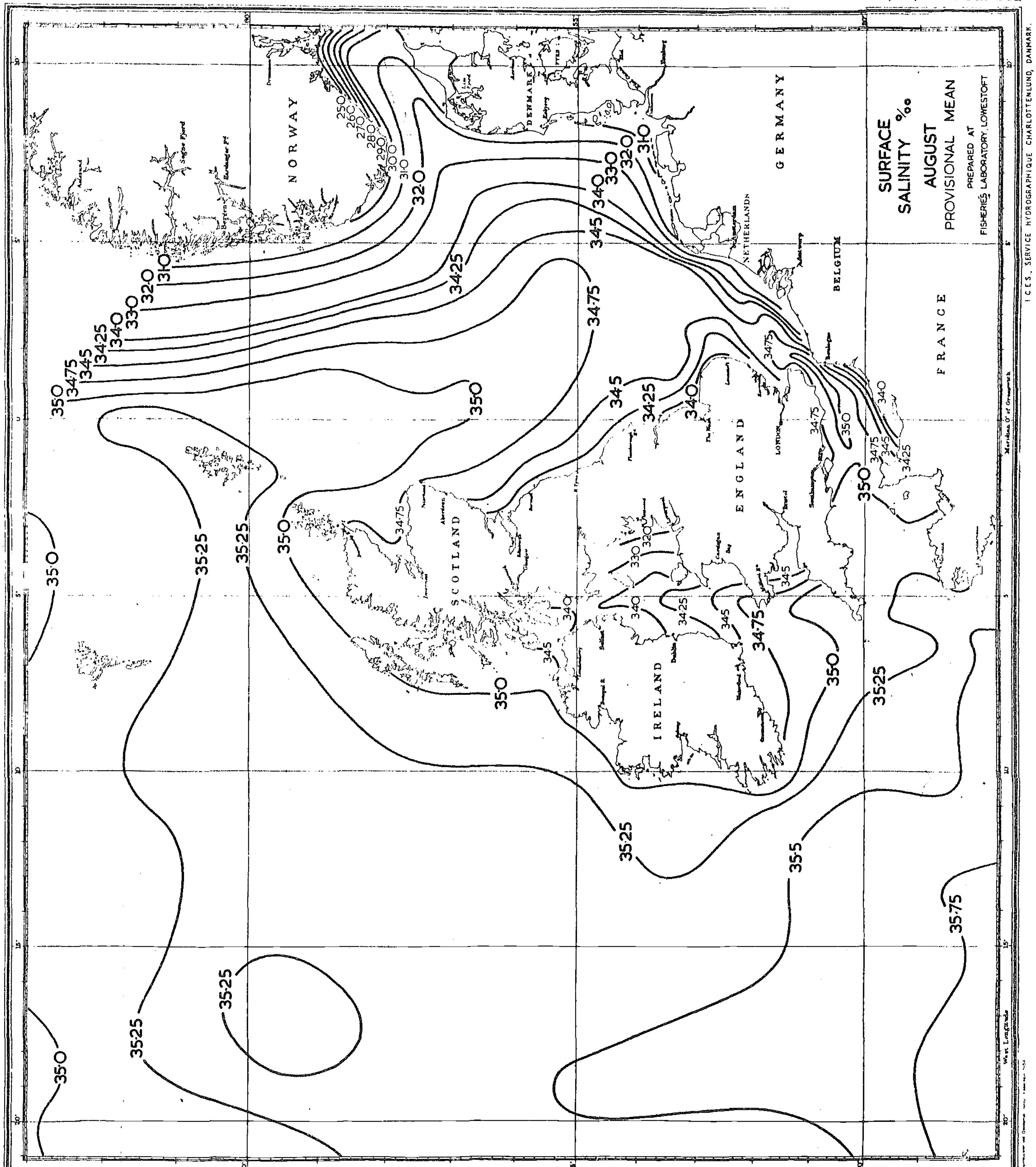


FIGURE 5.8

FIGURE 5.8

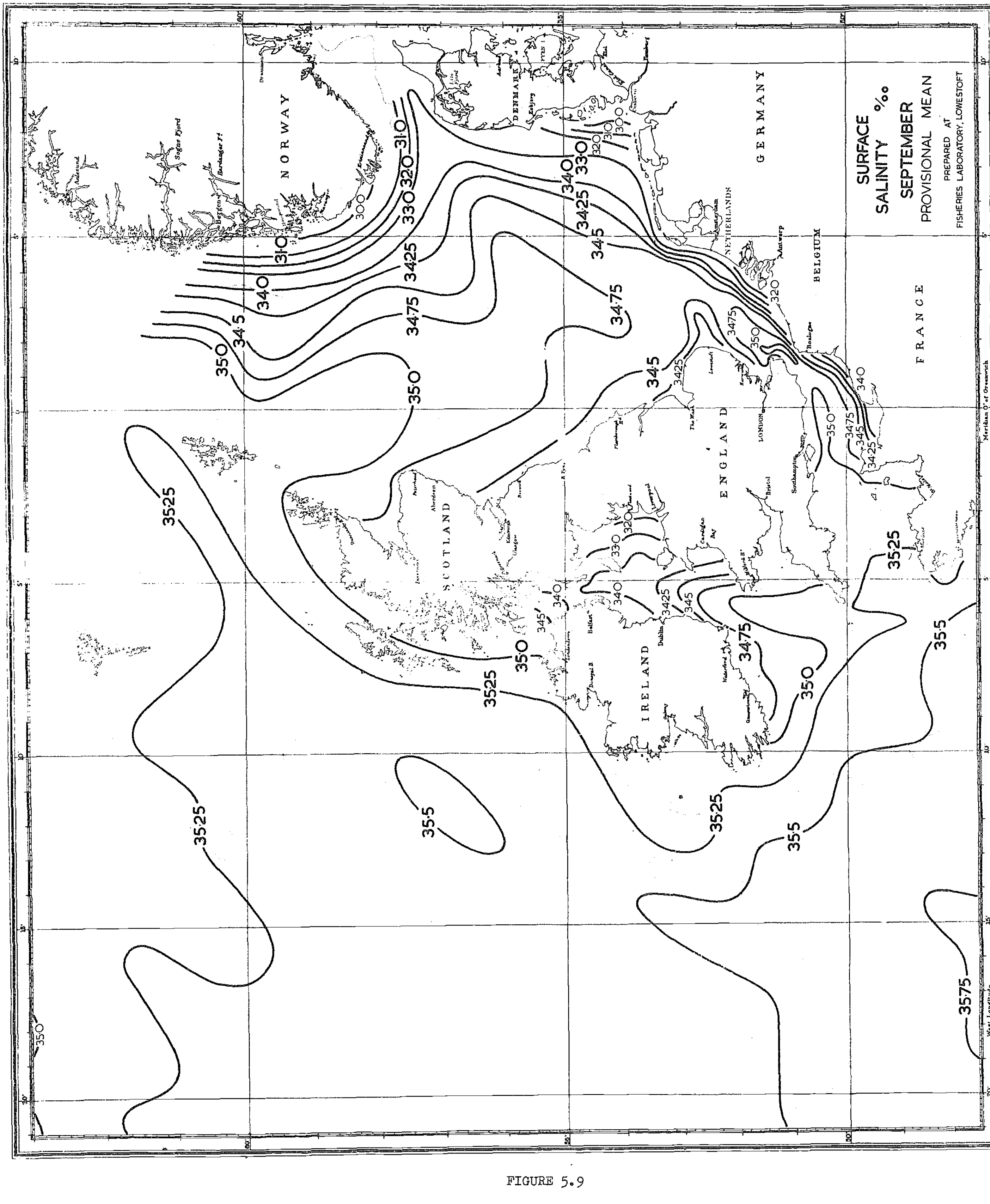

SURFACE
SALINITY ‰
SEPTEMBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
ICES, SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON
West Longitude
Meridian of Greenwich
30·0
31·0
32·0
33·0
34·0
34·25
34·5
34·75
35·0
35·25
35·5
35·75

FIGURE 5.9

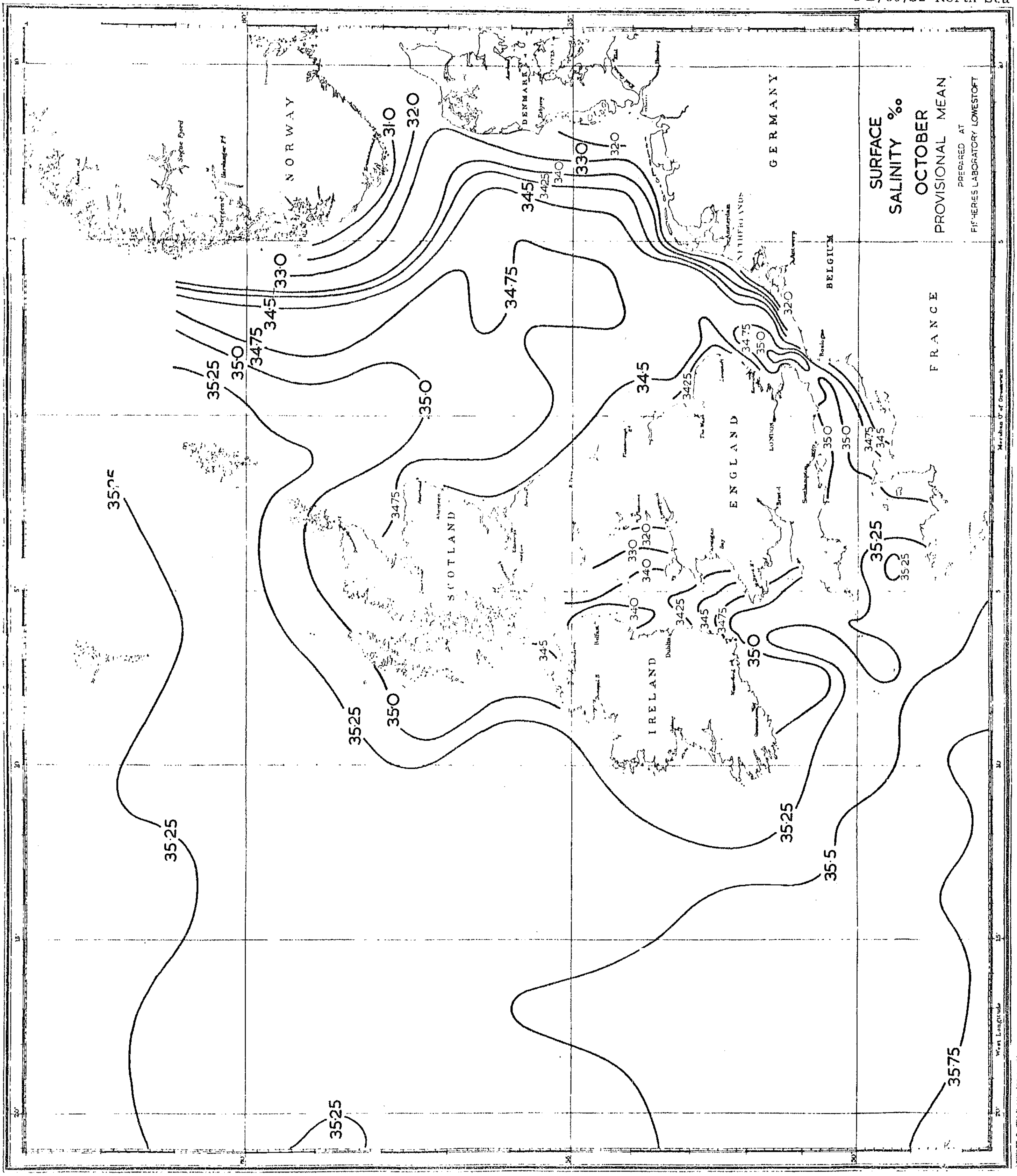

SURFACE
SALINITY ‰
OCTOBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY LOWESTOFT
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
LONDON
31·0
32·0
33·0
34·0
34·25
34·5
34·75
35·0
35·25
35·5
35·75

FIGURE 5.10

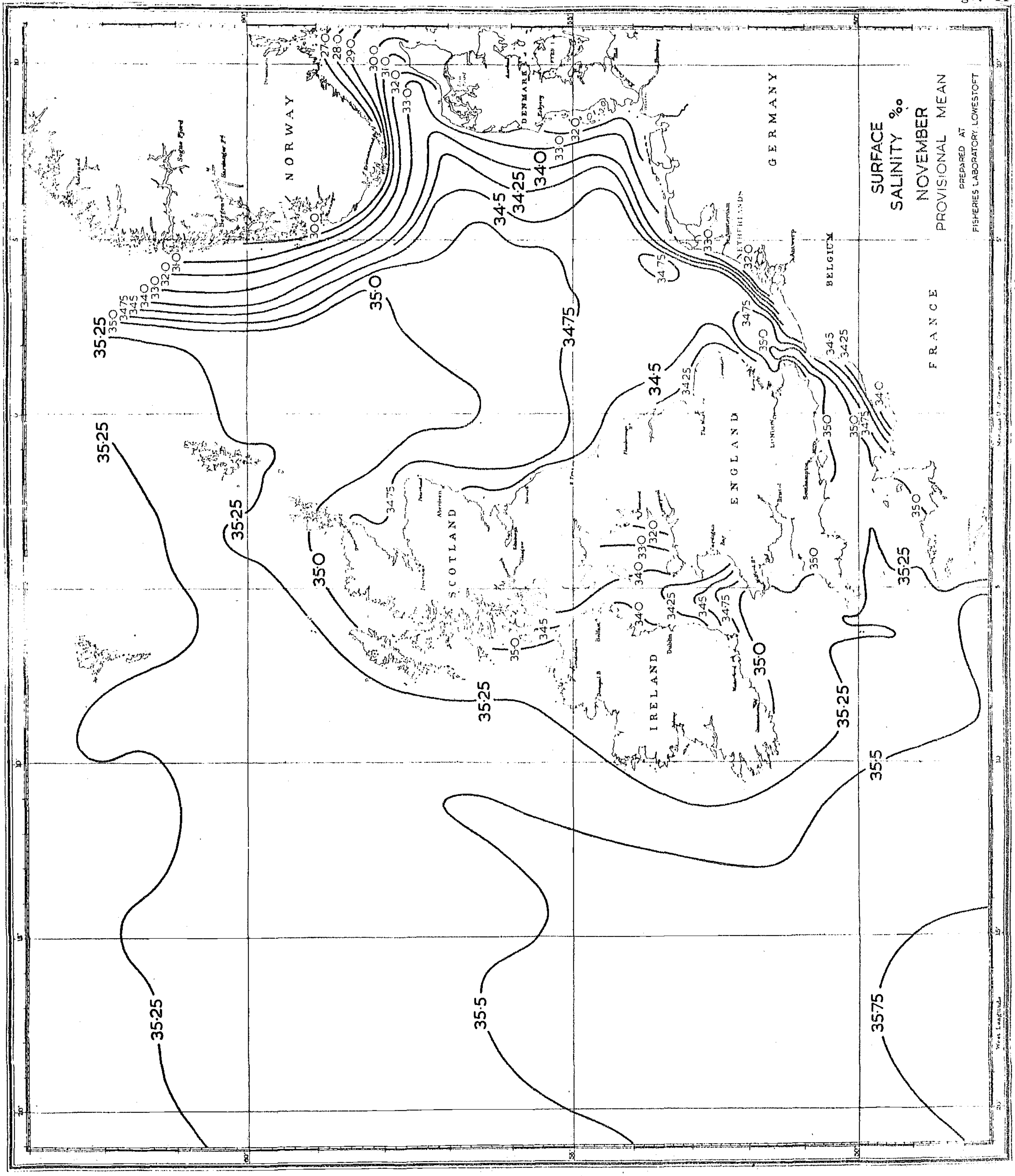
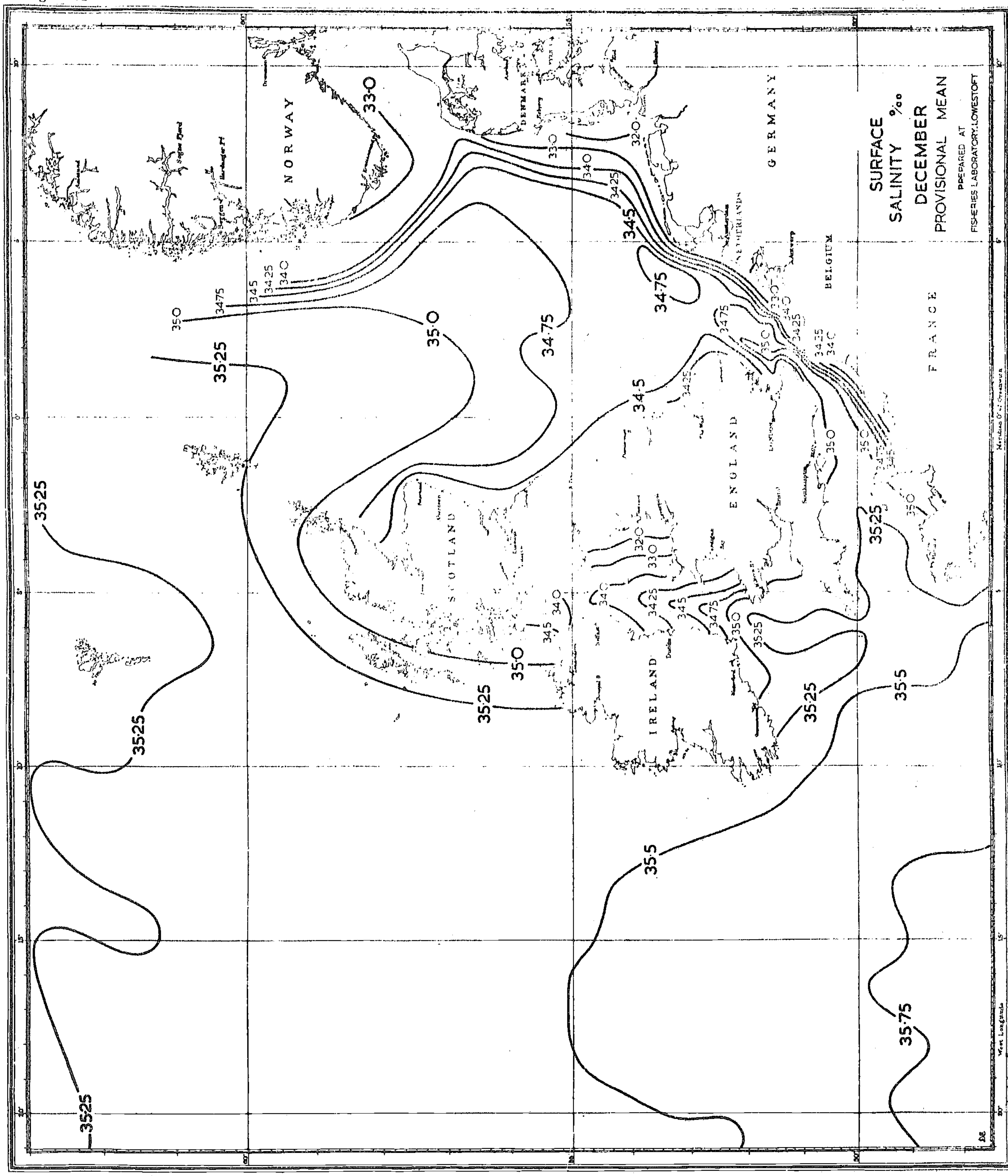

SURFACE
SALINITY ‰
NOVEMBER
PROVISIONAL MEAN
PREPARED AT
FISHERIES LABORATORY, LOWESTOFT
NORWAY
DENMARK
GERMANY
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
I.C.E.S. SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK

FIGURE 5.11


SURFACE
SALINITY ‰
DECEMBER
PROVISIONAL MEAN
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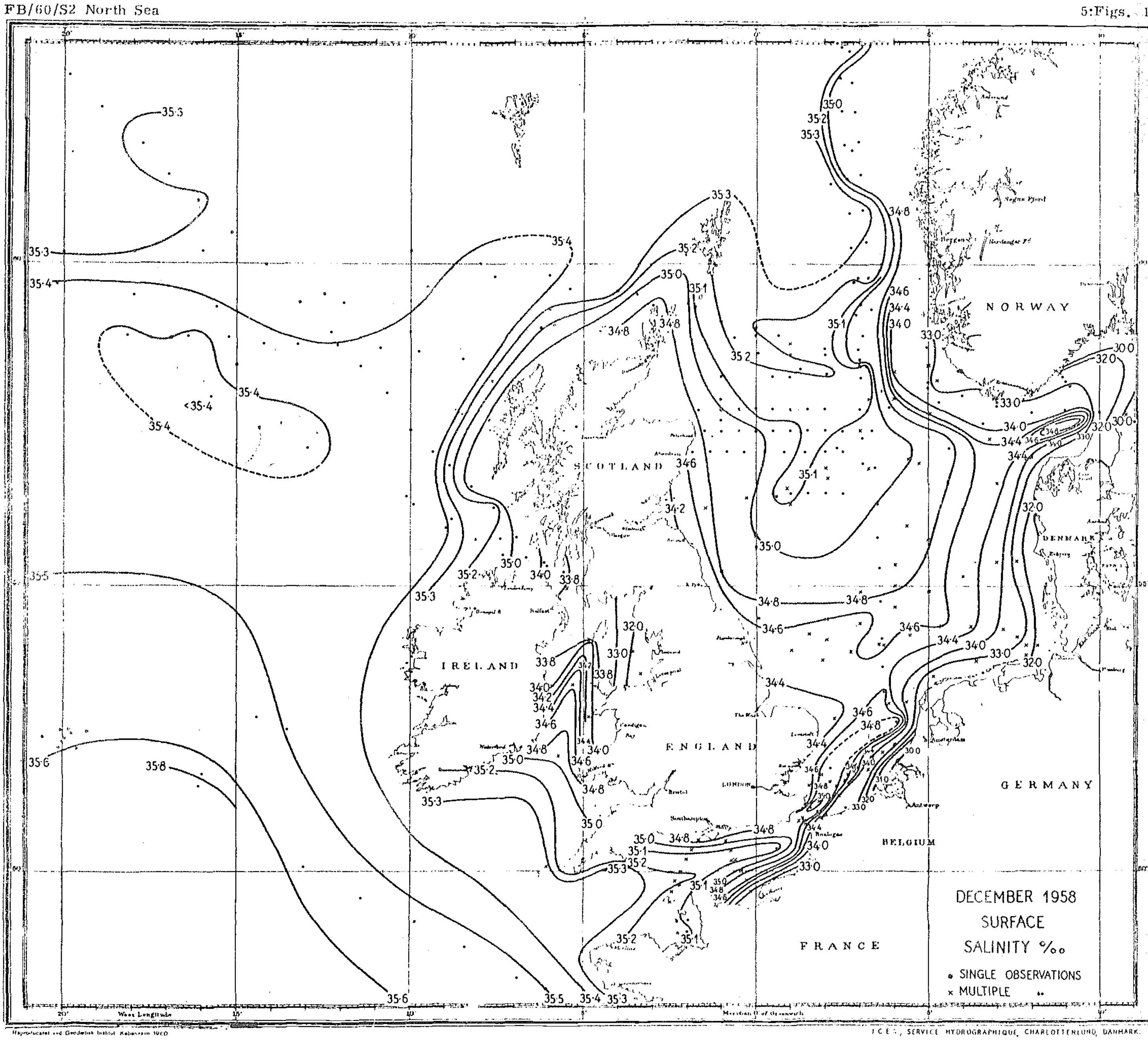
FISHERIES LABORATORY, LOWESTOFT
I.C.E.S. SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.
NORWAY
DENMARK
GERMANY
NETHERLANDS
BELGIUM
FRANCE
ENGLAND
SCOTLAND
IRELAND
33·0
32·0
34·0
34·25
34·5
34·75
35·0
35·25
35·5
35·75

FIGURE 5.12


DECEMBER 1958
SURFACE
SALINITY ‰
SINGLE OBSERVATIONS
MULTIPLE
NORWAY
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IRELAND
ENGLAND
DENMARK
GERMANY
BELGIUM
FRANCE
LONDON
I.C.E.S., SERVICE HYDROGRAPHIQUE, CHARLOTTENLUND, DANMARK.

FIGURE 5.13

TABLE 5.1

Mean values of the major constituents of the sea water at the lightship "West-Hinder" during 1951 to 1955 (after van Meel 1956)

Salinity ‰	34.19
Alkalinity HCl N ‰ cm^3	2.919
Specific Alkalinity	0.1539
Sulphates SO_4 mg ‰	2672.0
Ratio SO_4/Cl	0.1412
Ca mg ‰	452.3
Ratio Ca/Cl	0.02393
Mg mg ‰	1303.3
Ratio Mg/Cl	0.06895

TABLE 5.3

Amounts of trace elements reported from
North Sea and adjacent waters

(Note: Below each element is given a generally accepted representative value for sea water in general; designated ARV)

ARSENIC

Place of collection	ug/kg	ug-at/kg	Investigator
English Channel	30	.4	Barnes, 1932
" "	30	.4	Orton, 1924
Skagerrak (Gullmarfjord)	3	.04	I. and W. Noddack, 1939
ARV	3		

COBALT

Place of collection	ug/kg	ug-at/kg	Investigator
Skagerrak (Gullmarfjord)	.1	.0017	I. and W. Noddack, 1939
English Channel	.3	.005	Black and Mitchell, 1952
ARV	0.2		

COPPER

Place of collection	ug/kg	ug-at/kg	Investigator
English Channel	200	3.15	Orton, 1924
North Sea	64	.95	Ter-Meulen, 1931
English Channel	1.3-24	.02-.38	Atkins, 1953
Skagerrak (Gullmarfjord	4	.063	I. and W. Noddack, 1939
Baltic and North Sea	6-26	.095-.41	Meyer, 1938
Baltic	3-8	.032-.13	Buch, 1944
ARV	3		
Baltic	.7	.037	Forchhammer, 1850
Atlantic Ocean	1.19- 1.23	.0625- .0645	Thompson, Taylor, 1933
ARV	1.3		

GOLD

Place of collection	mg/t	Investigator
North Sea	6	Münster, 1891
Sea water (1500 spl)	.004	Haber, 1927
	.1	Glazunow, 1928
Atlantic Ocean	.1	Glaude, 1936
ARV	.004	

IODINE

Place of collection	ug/kg	ug-at/kg	Investigator
North Sea	18	.14	Heymann, 1925
" "	17	.13	Bleyer, 1927
" "	32	.25	Isenbruch, 1927
" "	11	.09	Matthes, Wallrabe, 1927
" "	45	.35	Reith, 1929
" "	20	.16	Closs, 1921
North Sea	45	.35	Reith, 1930
ARV	50		

IRON

Place of collection	ug/kg	ug-at/kg	Investigator
English Channel	20	.37	Orton, 1923
" "	6	.1	Harvey, 1925
" "	15	.27	Cooper, 1935
ARV	10		

LITHIUM

Place of collection	ug/kg	ug-at/kg	Investigator
North Sea	70	10.1	Goldschmidt, Berman, Hauptmann, Peters, 1933
" "	120	17.3	Strock, 1936
ARV	200		

MANGANESE

Place of collection	ug/kg	ug-at/kg	Investigator
Skagerrak (Gullmarfjord)	3.0	.055	I. and W. Noddack, 1939
English Channel	3000	55	Black and Mitchell, 1952
ARV	2		

MOLYBDENUM

Place of collection	ug/kg	ug-at/kg	Investigator
North Sea	.5	.005	Ernst, Hörmann, 1936
Skagerrak (Gullmarfjord)	.5	.005	I. and W. Noddack, 1939
English Channel	12		Black, Mitchell, 1952
ARV	10		

NICKEL

Place of collection	ug/kg	ug-at/kg	Investigator
North Sea	.12	.002	Ernst and Hörmann, 1936
Ardencaple Bay	1.5	.025	Black and Mitchell, 1952
ARV	1.5		

RADIUM

Place of collection	% x 10^{-14}	Investigator
North Sea	10	Satterly, 1911
Kattegat, Skagerrak	.87	Föyn, Karlik, Pettersson, Rona, 1939
ARV	30	

RUBIDIUM

Place of collection	mg/kg	mg-at/kg	Investigator
English Channel	.24	.0028	Burksep, Kovaleva, 1940
North Sea	.20	.0023	Goldschmidt, Berman, Hauptman, Peters, 1933
English Channel	.12	.0014	Smales, Salmon (unpubl.)
ARV	.12		

SILVER

Place of collection	mg/t	Investigator
North Sea	20	Münster, 1891
ARV	0.3	

STRONTIUM

Place of collection	mg/kg	mg-at/kg	Investigator
English Channel	13.5	.154	Desgrez, Meunier, 1921
Atlantic Ocean	13.3	.152	Webb, 1938
Atlantic Ocean	6.6	.093	Odum, 1951
ARV	8		

VANADIUM

Place of collection	ug/kg	ug-at/kg	Investigator
North Sea	.3	.006	Ernst, Hörmann, 1936
English Channel	2-7	.039-.137	Black, Mitchell, 1952
ARV	2		

ZINC

Place of collection	ug/kg	ug-at/kg	Investigator
English Channel	100	1.5	Orton, 1924
" "	5	.08	Atkins, 1936
Skagerrak (Gullmarfjord)	14	.21	I. and W. Noddack, 1939
English Channel	10- 20	.15- .31	Black and Mitchell, 1952
ARV	2		

6. FLORA OF THE NORTH SEA

6.1 Seaweeds

Considerable crops of seaweeds occur along the rocky coasts in the north, but along the southern sandy coasts very little seaweed grows. Although the tidal flats have spotty algal vegetation, the quantities are small and the typical zonation absent.

The species of seaweeds occuring in the North Sea can be divided into several groups, depending on their geographical distribution (see Table 6.1). The maximum depth of occurrence of sessile algae is determined by the turbidity conditions in specific localities during the growing season. (see Table 6.2). Although some quantitative surveys of seaweed resources have been made in some countries, no good summaries for the North Sea as a whole are available.

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6.2 Marine bacteria

There is extremely little data specifically for the North Sea available on marine bacteria.

6.3 Phytoplankton

The phytoplankton in the North Sea can be divided into certain communities by the occurrence of certain dominant species (see Table 6.3 and Figure 6.3). A more detailed community division is sometimes possible (see Figure 6.4), but in view of seasonal and year to year changes in the dominant species (see Table 6.4) this detailed division is impracticable.

The standing crop of phytoplankton shows considerable local, seasonal and year to year variation. Although a considerable amount of individual quantitative and qualitative data are available, no systematic working up of these data has been done. Tables 6.6 and 6.8 give some of the data available on the average standing crops of phytoplankton in the North Sea.

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6.4 Basic organic production

Many estimations of production of organic matter in the North Sea have been made, using various methods and approaches (see Table 6.7). There are also some data on seasonal variation of production available (Table 6.9), as well as experimental data on the influence of temperature on the rate of production (Table 6.10). The general knowledge on the factors determining the rate of production is at present sufficient for attempts to estimate the areal distribution of the basic organic production in the North Sea.

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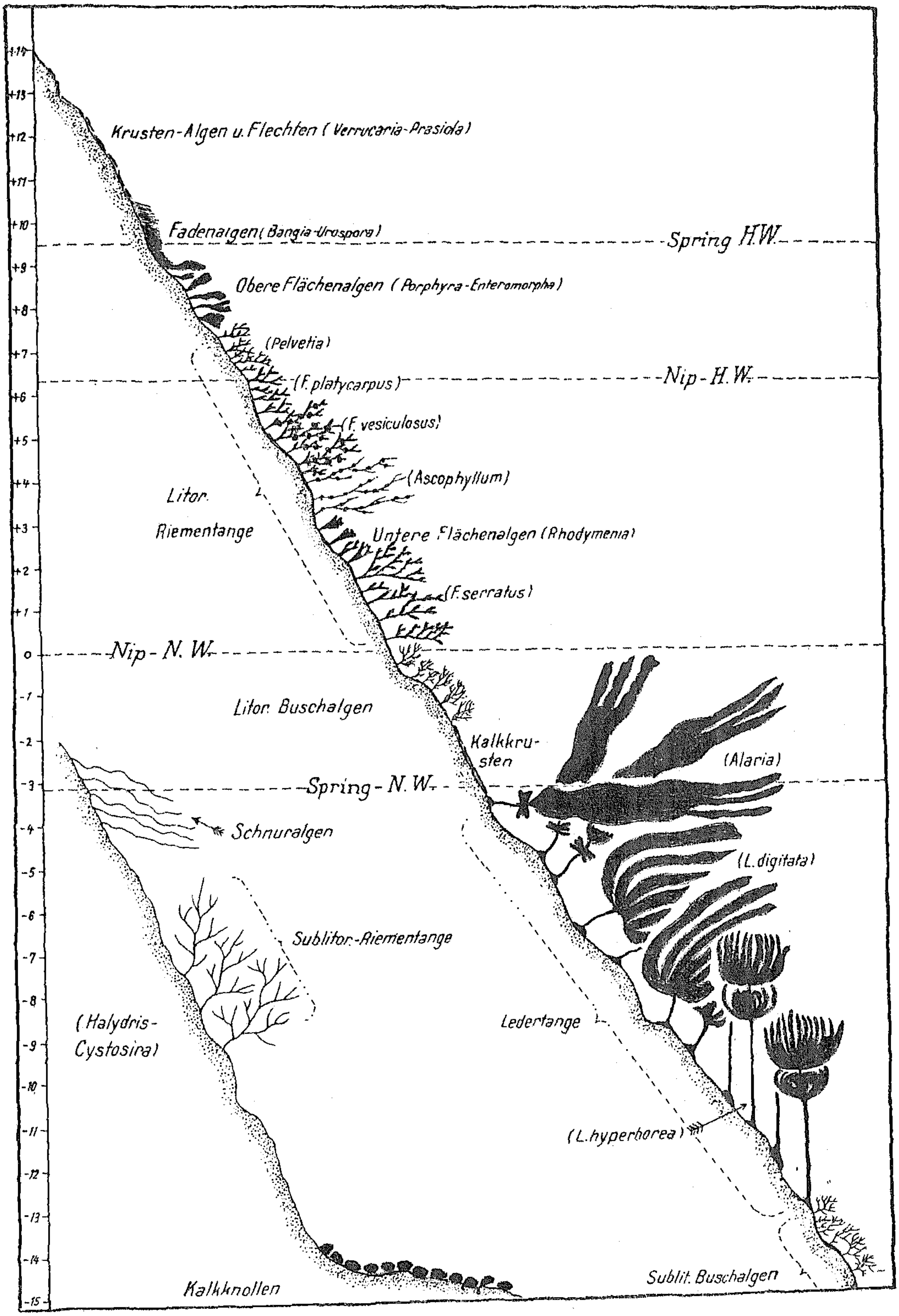

FIGURE 6.1

Schematic zonation of seaweeds along the coast of English Channel (after Nienburg)

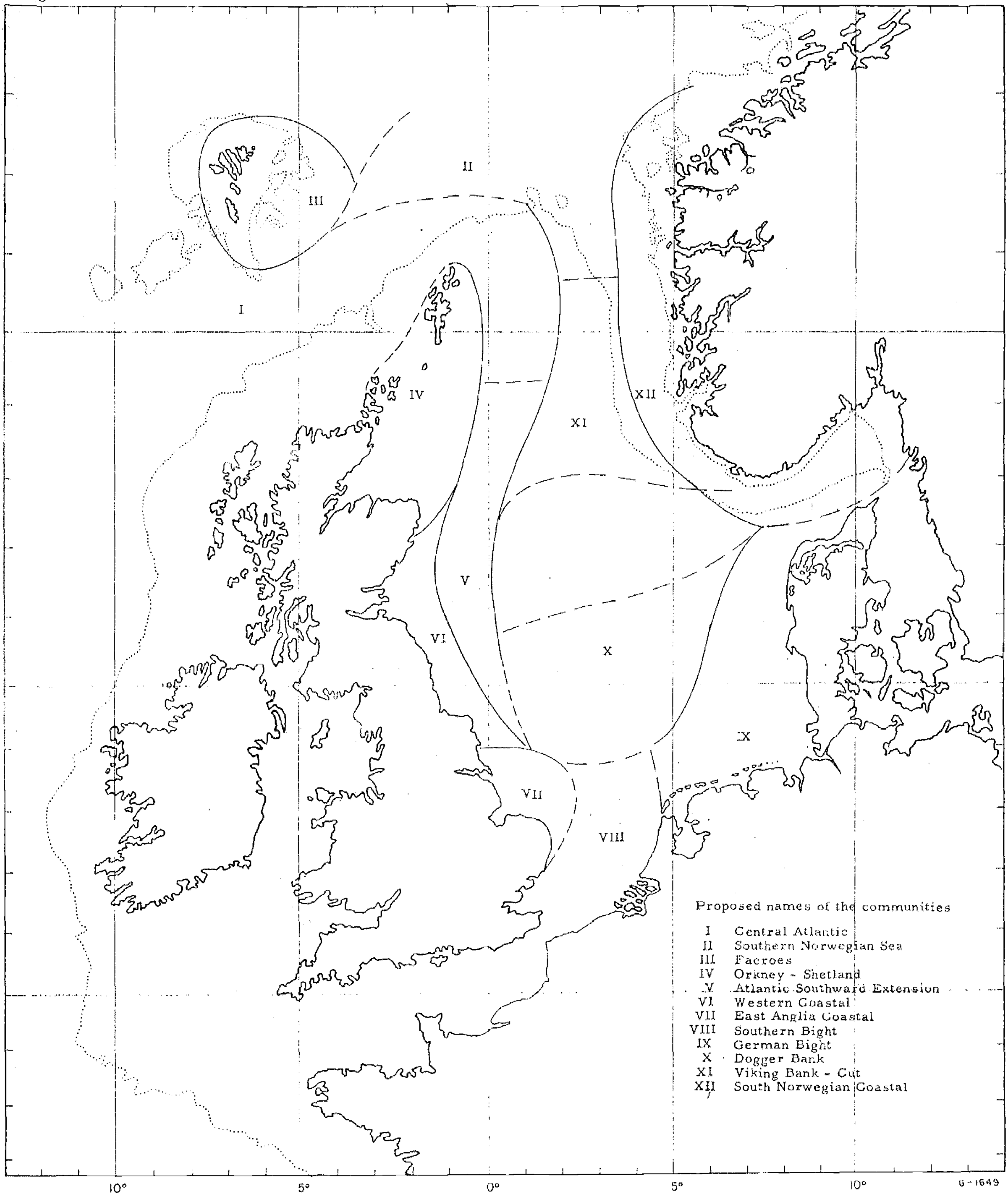

FIGURE 6.3 DISTRIBUTION OF CHARACTERISTIC PHYTOPLANKTON COMMUNITIES DURING SPRING

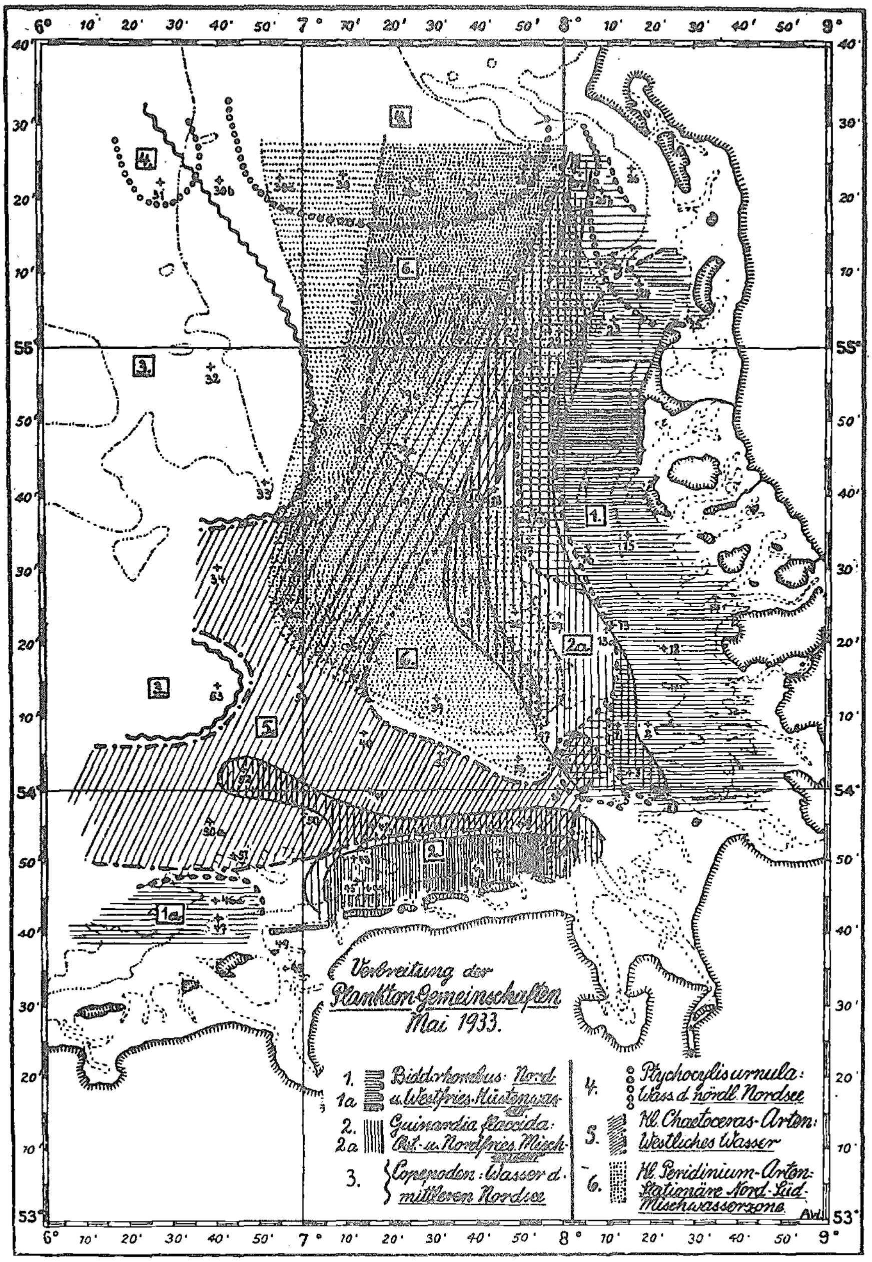

FIGURE 6.4

Distribution of plankton communities in the German Bight, May 1933 (after Wulff)

TABLE 6.1

Species in benthic vegetation occurring in the North Sea
(from Nienburg 1930, slightly modified)

1. Cosmopolitan species

Ulva lactuca, Enteromorpha compressa, Ceramium rubrum, Phyllitis fascia

2. Arctic - boreal species

Monostroma Grevillei, Ulothrix flacca, Urospora penicilliformis, Chaetomorpha melagonium, Lithoderma fatiscens, Myrionema globosum, Ectocarpus ovatus, Chaetopteris plumosa, Ralfsia clavata, Ectocarpus tomentosoides, Elachista fucicola, Punctaria plantaginea, Istmoplea sphaerophora, Stictyosiphon tortilis, Dictyosiphon foeniculaceus, Desmarestia viridis, D. aculeata, Litosiphon filiforme, Chordaria flagelliformis, Chorda tomentosa, Porphyra miniata, Phyllophora Brodiaei, Euthora cristata, Rhodymenia palmata, Delesseria sinuosa, Hildenbrandtia rosea, Odonthalia dentata, Rhodomela lycopodioides, Lithothamnion glaciale.

3. North European species (boreal)

Valonia ovalis, Ralfsia verrucosa, Ectocarpus tomentosus, E. dasycarpus, Sphacelaria radicans, S. cirrhosa, Cladostephus spongiosus, Dictyosiphon Chordaria, Castagnea virescens, Spermatochnus paradoxus, Laminaria saccharina, L. hyperborea, Alaria esculenta, Fucus platycarpus, Pelvetia canaliculata, Himanthalia lorea, Gigartina mamillosa, Phyllophora membranifolia, Cystoclonium purpurascens, Delesseria alata, D. sanguinea, Polysiphonia urceolata, P. violaca, P. artrorubescens, Rhodomela subfusca, Callithamnion roseum, Plumaria elegans, Ceramium Deslongchampsii Dumontia filiformis, Furcellaria fastigiata, Polyides rotundus, Petrocelis Henedyi, Lithothamnion Lenormandi, Corallina officinalis.

4. Subtropical - boreal species

Enteromorpha Linza, Chaetomorpha aerea, Bryopsis plumosa, Ascocylus orbicularis, Cladostephus verticillatus, Desmotrichum balticum, Asperococcus compressus, Leathesia difformis, Punctaria latifolia, Chordaria divaricata, Stilophora rhizodes, Saccorhiza bulbosa, Tilopteris Mertensii, Dictyota dichotoma, Cutleria multifida, Halidrys siliquosa, Porphyra leucosticta, Chondrus crispus, Plocamium coccineum, Nemalion multifidum, Gelidium corneum, Laurencia pinnatifida, Rhodophyllis bifida, Gracilaria confervoides, Nitophyllum punctatum, Brogniartella byssoides, Antithamnion cruciatum, Callithamnion corymbosum, Cruoria pellita, Lithothamnion Sonderi.

5. Subtropical species

Chaetomorpha crassa, Ectocarpus irregularis, Myriactis pulvinata, Cystosira ericoides, Colpomenia sinuosa, Scinaia furcellata, Naccaria Wigghii, Hypnea musciformis, Bostrychia scorpioides, Dasya elegans, Polysiphonia variegata, Griffithsia barbata, Lithophyllum lichenoides, Corallina squamata.

TABLE 6.2

Maximum depth of occurrence of sessile algae

(from Gessner 1955)

Locality	Depths in m.
Danish coast	38
Swedish W-coast	35
Faroe Islands	40 - 60
Oslo Fjord	45
Heligoland	15

TABLE 6.3

Characteristic and dominant species of (spring) phytoplankton communities in the North Sea

I. Central Atlantic Community

Coccolithus Huxley and *Exuviaella baltica*

II. Southern Norwegian Sea Community

Thalassiosira gravida and *Anthosphaera robusta*

III. Faeroes Community

Thalassiosira gravida, Sceletonema costatum, chaetoceros debilis and *Nitzschia delicatissima*

IV. Orkney-Shetland Community

Asterionella japonica, Chaetoceros debilis, C. decipiens, Thalassiosira gravida, Sceletonima costatum

V. Atlantic Southward Extension Community

Few diatoms, dominant of them *Chaetoceros* spp. Small populations of *dino flagellatis* dominant of them *Exuviaella baltica. Coccolithus Huxley* relatively abundant

VI. Western Coastal Community

Asterionella Chaetoceros, Nitschia and *Skeletonema* are leading genera

VII. East Anglia Coastal Community

Benthic diatoms and *Chaetocerus danicus, Asterionella* spp. *Biddulphia mobiliensis f. regia, Ptychocylis urnala*

VIII. Southern Bight Community

Large variety of diatoms and *dinoflagellates.* High number of bottom diatoms, e.g. *Melosira sulcata. Biddulphia sinensis* (in the Channel water) *Paralia sulcata, Coscinodiscus* spp. *Bellarochea malleus, Guinardia flaccida, Thalassiothrix nitzschioides, Ceratium fusus* and *C. furea*

IX. German Bight Community

Asterionella japonica, Chaetoceros debilis Phaecystis

X. Dogger Bank Community

Dinoflagellates characteristic; also *Rhizosolenia styliformis, Thalassiosira* and *Septocylindrieus*
During summer: *Ceratium longipes, C. macrocerus, C. tripos* and *C. bucophalum*

XI. Viking Bank - Cut Community

Mixed communities, *dinoflagellates* dominate in S. part

XII. South Norwegian Coastal Community

Extreme poverty of diatoms. Main components are *Gymnodinians*. *Ceratium* spp., *Exuviaella baltica, Peridinium trochoideum,* and *Coccolithus Huxley*

TABLE 6.4

Example of seasonal succession of dominant phytoplankton organisms in the northern North Sea (after Fraser, modified)

Season	Onshore		Offshore	
	Abundance	Dominant Species	Abundance	Dominant Species
February	During spring, bloom diatoms dominant	*Thalassiothrix nitzchioides* *Sceletonema costatum*		*Thalassiothrix nitzschioides* with *Coscinodiscus* and *Chactoceros* spp. in N.
March		*Sceletonema costatum* dominant		
April		In addition to *S. costatum* which has partly died down: *Thalassiosira gravida* in NW, *Chactoceros* near Shetland and *Rhizosolenia styliformis* in the Fair Isle area.	Diatoms dominant	*Rhizosolenia hebetata* off the Norwegian Coast, *Nitzschia seriata* in Central North Sea
May	*Dinoflagellates* become dominant	*Ceratium* spp.		*Rhizosolenia alata var. gracillima*, *Chaetoceros decipiens* and *C. convolutus*
June	*Dinoflagellates* form ca. 80 % of the phytoplankton	*Ceratium longipes*	*Dinoflagellates* dominant with some amount of diatoms	*Ceratium longipes* and *Peridinium* spp. with *Chaetocleros decipiens* in the N. *Ceratium tripos* in Central North Sea
July	Summer minimum. Diatoms very scarce, *dinoflagellates* less numerous		Summer minimum Diatoms scarce	
August	*Dinoflagellates* increase rapidly	*Ceratium fusus* and *C. longipes* near Shetland *Rhizosolenia alata* occurs	*Dinoflagellates* increase	*Ceratium tripos*

TABLE 6.4(contd)

Season	Onshore		Offshore	
	Abundance	Dominant Species	Abundance	Dominant Species
September	*Dinoflagellates* reach their peak	*Ceratium macroceros*, particularly E of Fair Isle	*Dinoflagellates* reach their peak diatoms increase	*Ceratium macroceros* and *Chaetoceros* spp.
October	Autumn bloom died down	*Coscinodiscus concinnus* and *Halosphaera*	As in coastal waters	
November		*Thalassiothrix nitzschoides*		*Rhizosolenia* spp. *Ceratium macroceros*

TABLE 6.6

Some data on the standing crop of phytoplankton

Place and Season	Standing Crop	Author
N. Sea and adjacent waters	460 mg dry organic matter/m^3	Cushing 1955
English Channel		
June	150 mg dry organic matter/m^2	)Atkins and
April	1,320 mg dry organic matter/m^2	)Jenkins 1953
North Sea		
Beginning April 1949	0.192 g C/m^3	)Cushing
End April 1949	0.063 g C/m^3	) 1955

TABLE 6.7

Estimations of basic organic production

Locality	Method	Season and other remarks	Amount	Unit*	Author
Romsdalsfjord	O_2 prod.	In 4 weeks in early summer	0.13–0.56	$gC/m^2/day$	) Gran, 1929
West coast of Norway	O_2 prod.	In 4 weeks in early summer	0.2	$gC/m^2/day$	)
Norwegian coast	O_2 Prod.	Short period	0.14	$gC/m^2/day$	Gran, 1927
Scottish coast	O_2 prod.	Short period	0.16	$gC/m^2/day$	Marshall and Orr, 1930
English Channel	Change in O_2		60	$gC/m^2/year$	Riley 1956
English Channel	Change in P		70	$gC/m^2/year$	(Atkins, 1923)
English Channel	P-consumption		84	gC/m^2year	(Atkins, 1923)
North Sea	P-consumption	Annual average	0.045 or 7.5	$mgP/cm^2/year$ $mg_2 org.subst./cm^2/year$	Kalle, 1942
North Sea	Changes in population	April 1949	0.073	$gC/m^3/day$	Cushing, 1955
North Sea	Changes in population	May, 1949	0.014	$gC/m^3/day$	Cushing, 1955

* 1 g. carbon = 42 g. phytoplankton biomass.

TABLE 6.7(contd.)

Locality	Method	Season and other remarks	Amount	Unit*	Author
Fladen Ground		Annual production	54 - 82	$gC/m^2/year$	Steele, 1956
Inshore water, North Sea			104 - 127		Steele, 1956
English Channel			55 - 91		Steele, 1956
NE Coast of England	C^{14}	Annual average	80	$gC/m^2/year$	Cushing, 1957
Kattegat	C^{14}	Gross annual production	61	$gC/m^2/year$	Steemann-Nielsen, 1957
Limfjord	C^{14}	Gross annual production	105	$gC/m^2/year$	Steemann-Nielsen, 1957
Seaweeds Scotland		Annual production of Laminaria	10	$kg/m^2 year$	Blinks, 1955

TABLE 6.8

Standing stock of organic carbon and its rate of production in the North Sea in spring in mg. C/m^3

(from Cushing, 1957, Production of Carbon in the Sea, Nature, 179(4565:876)

Period	Standing Stock	Daily Production	Production per day %
10-30 April 1949	44.1	16.7	38
23 Apr.-16 May 1949	15.8	3.8	22
8-15 April 1954	16.6	3.6	21.7
24-28 April 1954	37.5	10.7	28.7
4-14 May 1954	12.4	7.6	61.3
23-26 May 1954	16.0	13.2	82.5

$1 \ mm^3 = 0.086$ mg. C

TABLE 6.9

Production on Fladen Ground (gC/m^2)
(Steele 1956)

	Spring	Summer	Autumn	Total
1951	28.0	8.9	28.0	64.9
1952	30.4	22.4	29.5	82.3
1953	26.1	17.6	13.7	57.4

TABLE 6.10

Carbon production in the sea at the Smith's Knoll lightvessel
(after Wimpenny)

Water collected from the surface over the Eastern Deep water on 22.3.56 and illuminated at 5°, 10°, 15°C. at 16,000 lux for three hours

	Uptake of C in mg. per hours using ^{14}C
Experiments at 15°	1.25
Mean	0.807
	1.028
Experiments at 10°	0.803
Mean	0.697
	0.750
Experiments at 5°	0.350
Mean	0.327
	0.338
Standing crop of phytoplankton from counts as mg.C per m^3	6.12
% daily increase at 15°	168
% daily increase at 10°	122.5
% daily increase at 5°	55.2

7. FAUNA OF THE NORTH SEA

7.1 Zooplankton

The distribution of zooplankton is greatly influenced by current transport. There are species carried into the area from the north, through the English Channel and from the Skagerrak (see Table 7.2). In autumn oceanic plankton enters with the current from the north and maintains its character until the Moray Firth (Sagitta serratodentata, Chelophyes, Agalma, Galetta and Rhincalanus). In April, a rich population of Calanus usually develops and is maintained until July. There are certain species characteristic of different North Sea areas and water masses (Tables7.1 and 7.3 and Figure 7.1). Some species are especially sensitive to changing environmental conditions (see Figure 7.2). Inshore waters are usually poor in crustaceans but Meurobranchia is usually abundant there in the autumn.

The standing crop of zooplankton varies considerably from year to year, both in quantity and quality. (Figure 7.3 and Table 7.4). A considerable amount of information is available on the quantitative distribution (see Table 7.5) but no attempt has yet been made to summarize it on maps.

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7.2 Phytoplankton-zooplankton relationship

As mentioned earlier, the quantities of phyto- and zooplankton vary considerably from year to year and from locality to locality. In general there is a seasonally changing quantitative relation between these standing crops (see Table 7.6 and Figures 7.6 and 7.8), oontrolled by a predator-prey system. This relation is not however constant in detail because there are many additional influencing factors. (transport, patchiness and changes in environmental conditions)

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7.3 Benthos

The species composition of benthos communities and its biomass per unit area is much more stable than that of plankton and nekton. Although the benthos communities are well defined in North European waters, their distribution is not yet mapped in detail (see Figure 7.9 and Table 7.7). Data are available on the quantities of benthos in various localities, their seasonal and year to year variations and the content of fish food. The available quantitative data would allow rough mapping of the average quantitative distribution.

Very little data are available on the productivity of benthos. Some estimates show, e.g. that on the Dogger Bank 6 to 7 g fish food is produced per m^2 per year.

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7.4 Nekton

The fisheries problems will be summarized in another synopsis. The present one is conserned only with fish egg and larvae, the latter usually classified under nekton.

The catches of different commercial fish species in the North Sea are given in Table 7.15. The spawning areas of these species are known, some approximately, some in greater detail, but no summary mapping of these areas, with indication of spawning seasons, exists. Although there are some data available on the densities of eggs and larvae of various species on the spawning areas (see Table 7.16), again no detailed summary exists on the areal distribution of the eggs and larvae, although a considerable amount of detailed information has accumulated during the last 50 years.

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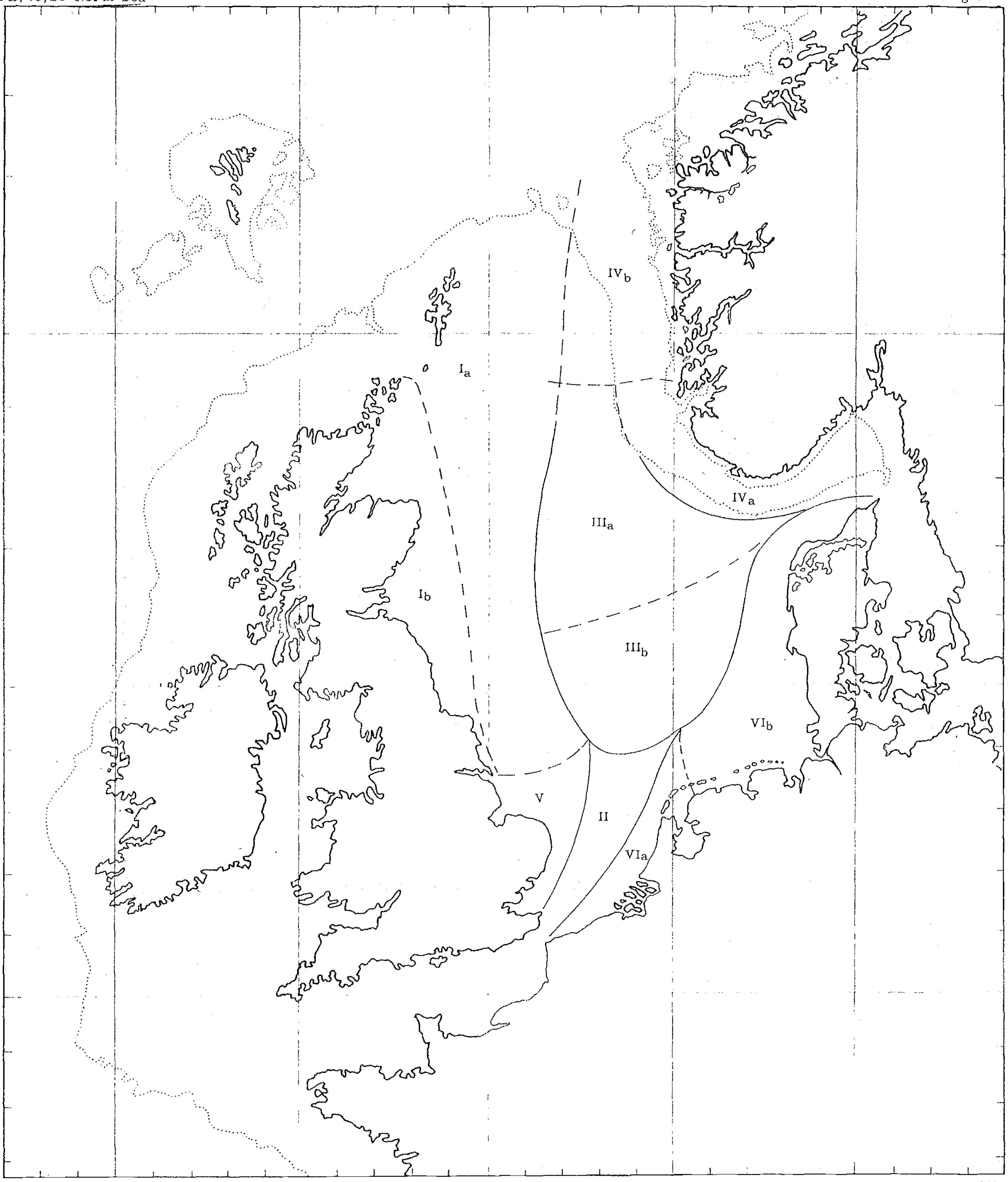


Figure 7.1 - BIOLOGICAL WATER MASSES OF THE NORTH SEA BY PLANKTONIC INDICATOR SPECIES

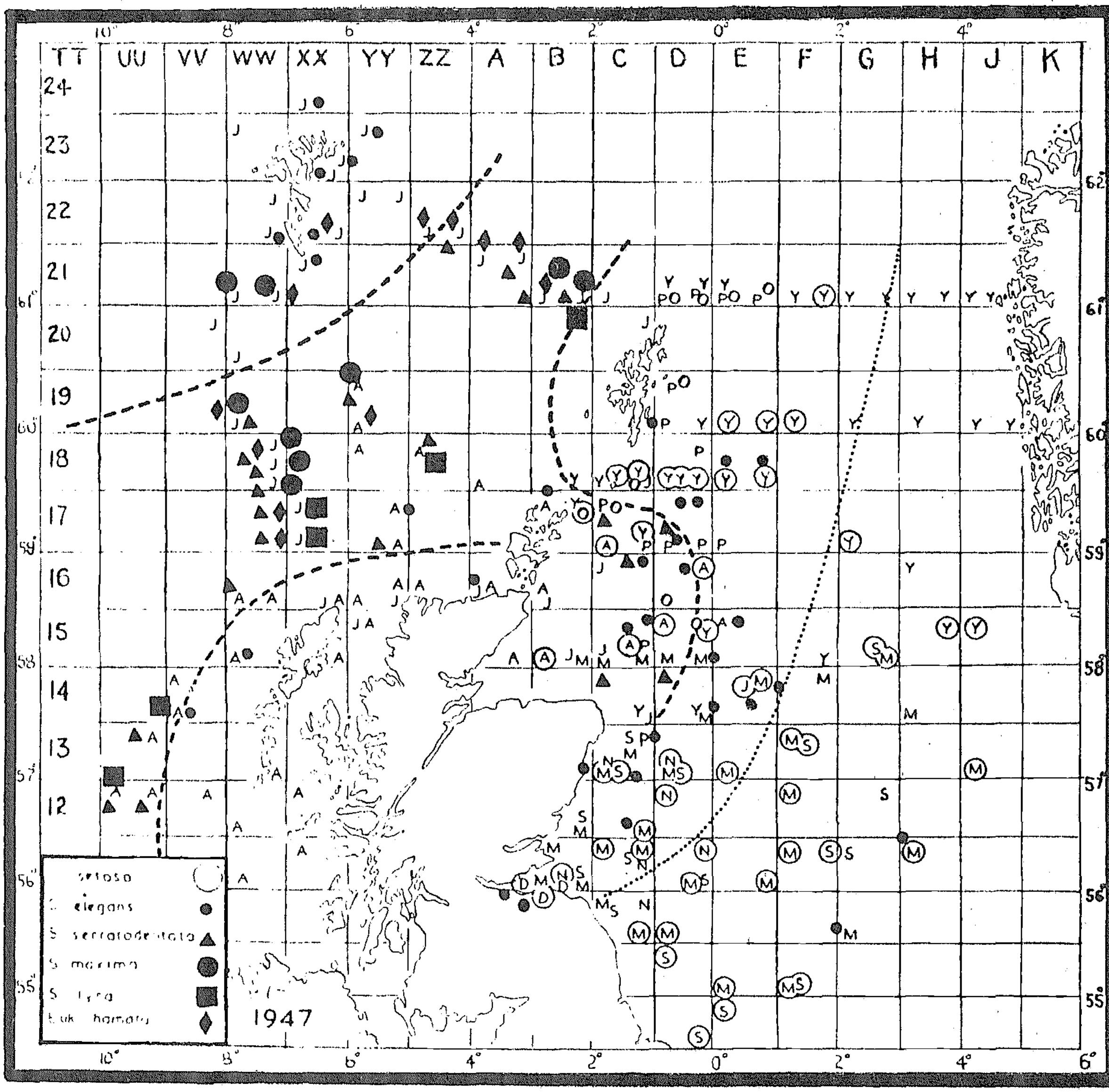


Figure 7.2 The distribution of Chaetognatha in 1947. In this chart, and in Figs. 4 and 5, the positions of the plankton stations are shown by a letter indicating the month of the year: P = April, M = May, J = June, Y = July, A = August, S = September, O = October, N = November, D = December. The positions are given only to the nearest sub-square and symbols representing the presence of organisms are placed conveniently near the appropriate station position. The dotted line indicates the hypothetical northerly limit of distributions of *Sagitta setosa* in years of normal Atlantic inflow into the northern North Sea. The distribution of one species—*S. serratodentata* in spring and summer is outlined by the broken line as an example of how the chart may be read.

(after Fraser)

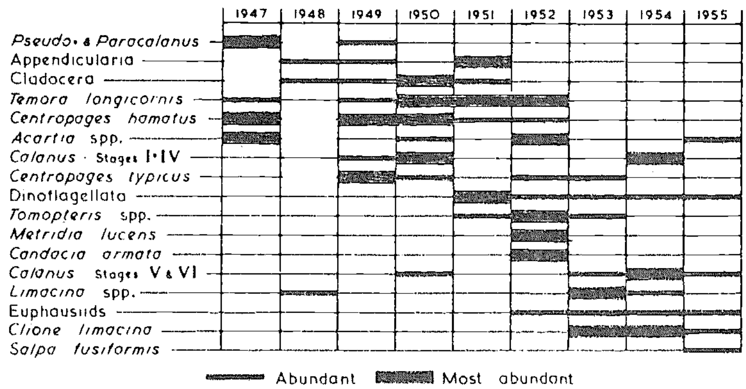


FIGURE 7.3

The relative seasonal abundance of the plankton of the Buchan fishing ground.
(after Glover)

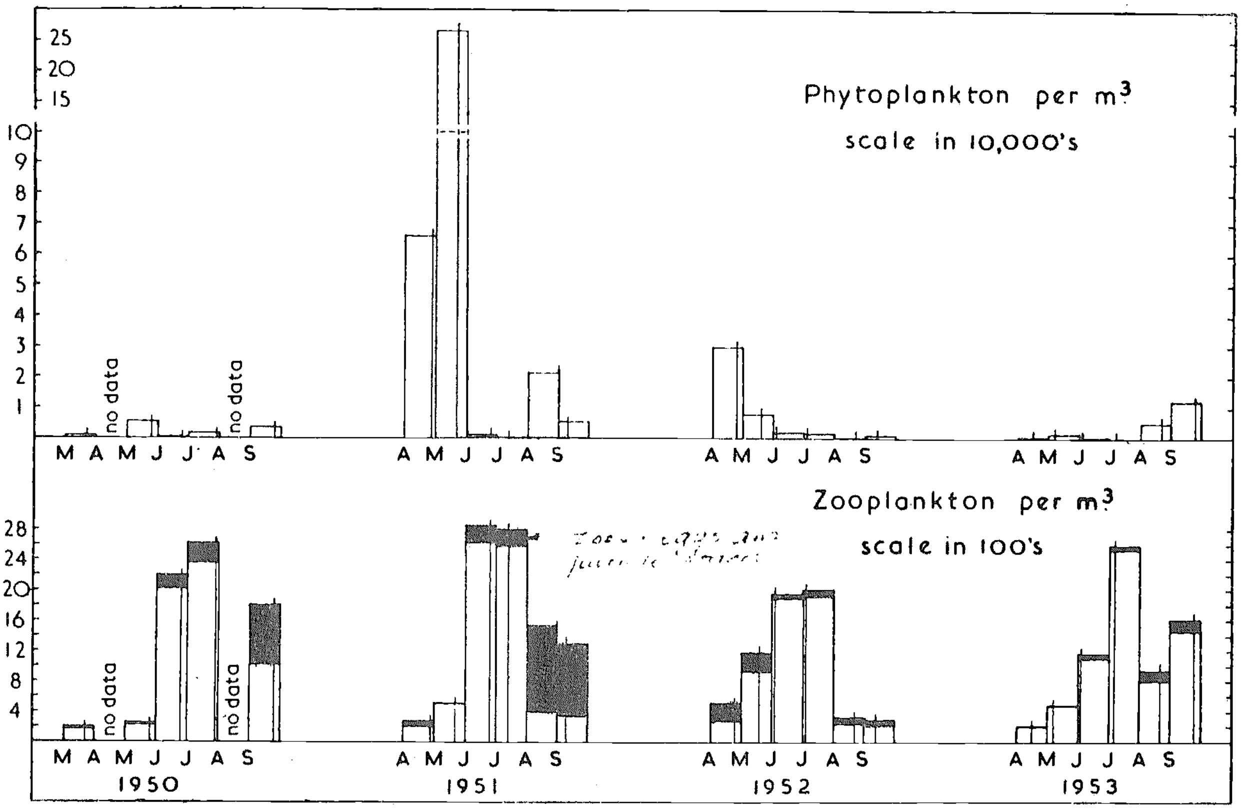


FIGURE 7.6

Histograms showing the mean monthly values of six stations between Flamborough Head and the Dogger Bank for phytoplankton and zooplankton (after Cattley)

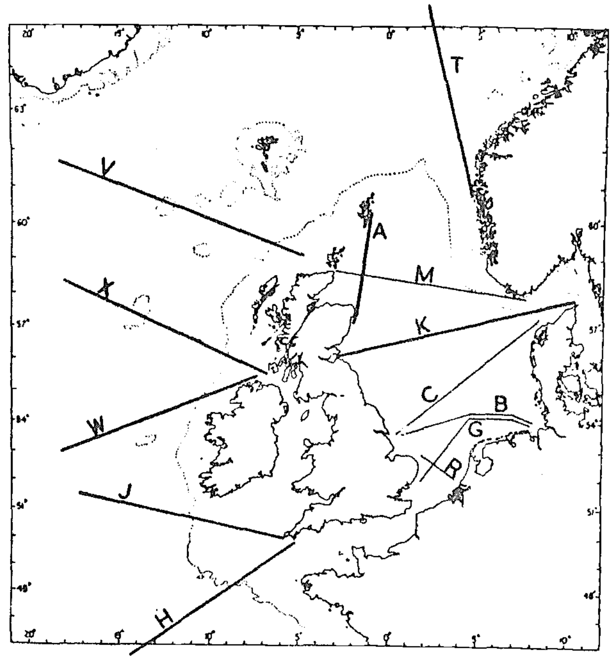
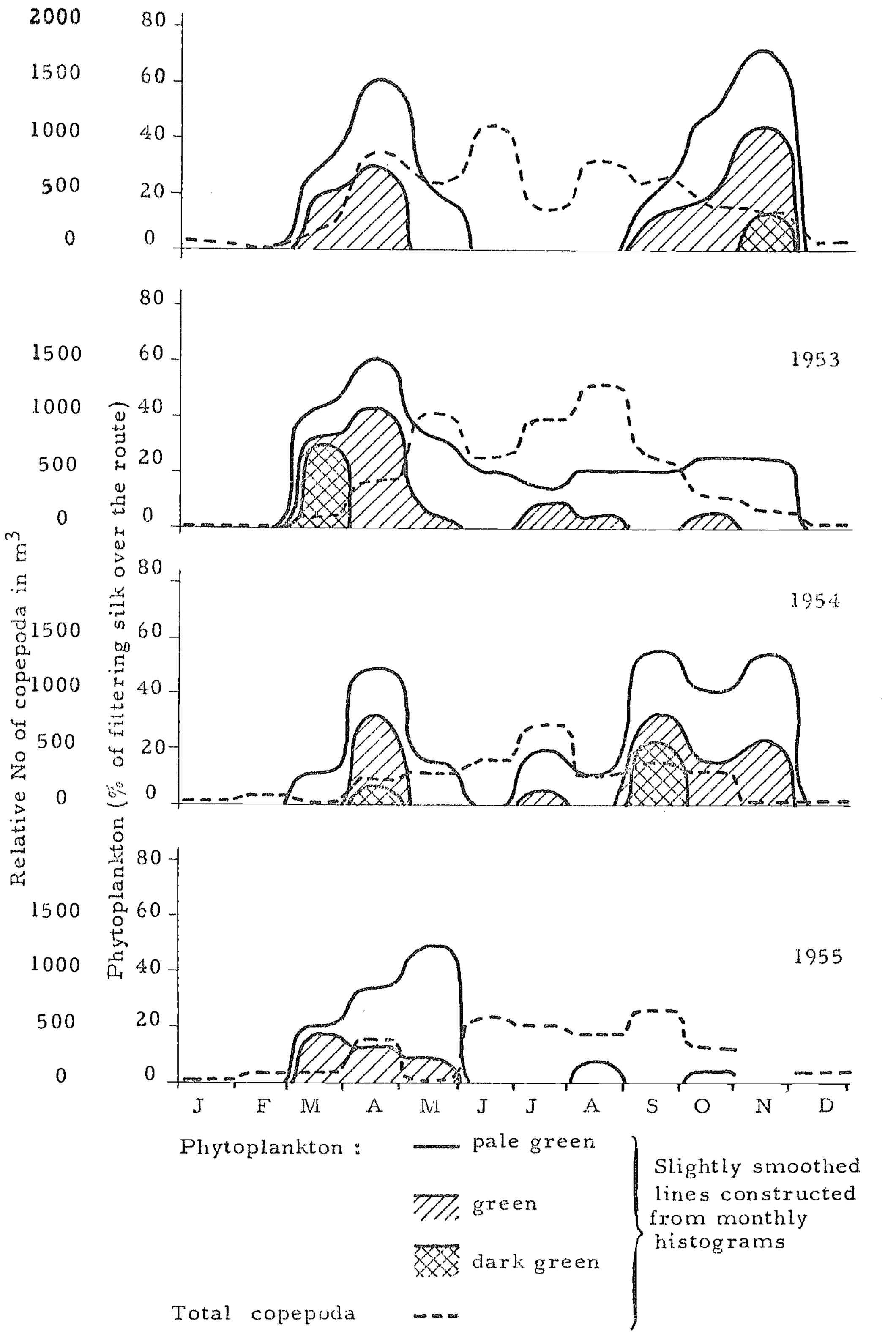


FIGURE 7.7

Routes along which the continuous plankton recorder was towed monthly during 1952 (after Rae)



ESTIMATED DENSITIES OF PHYTOPLANKTON AND RELATIVE NUMBERS OF TOTAL COPEPODA ALONG THE K LINE OF SCOTTISH PLANKTON RECORDER SURVEY 1952 - 55

FIGURE 7.8

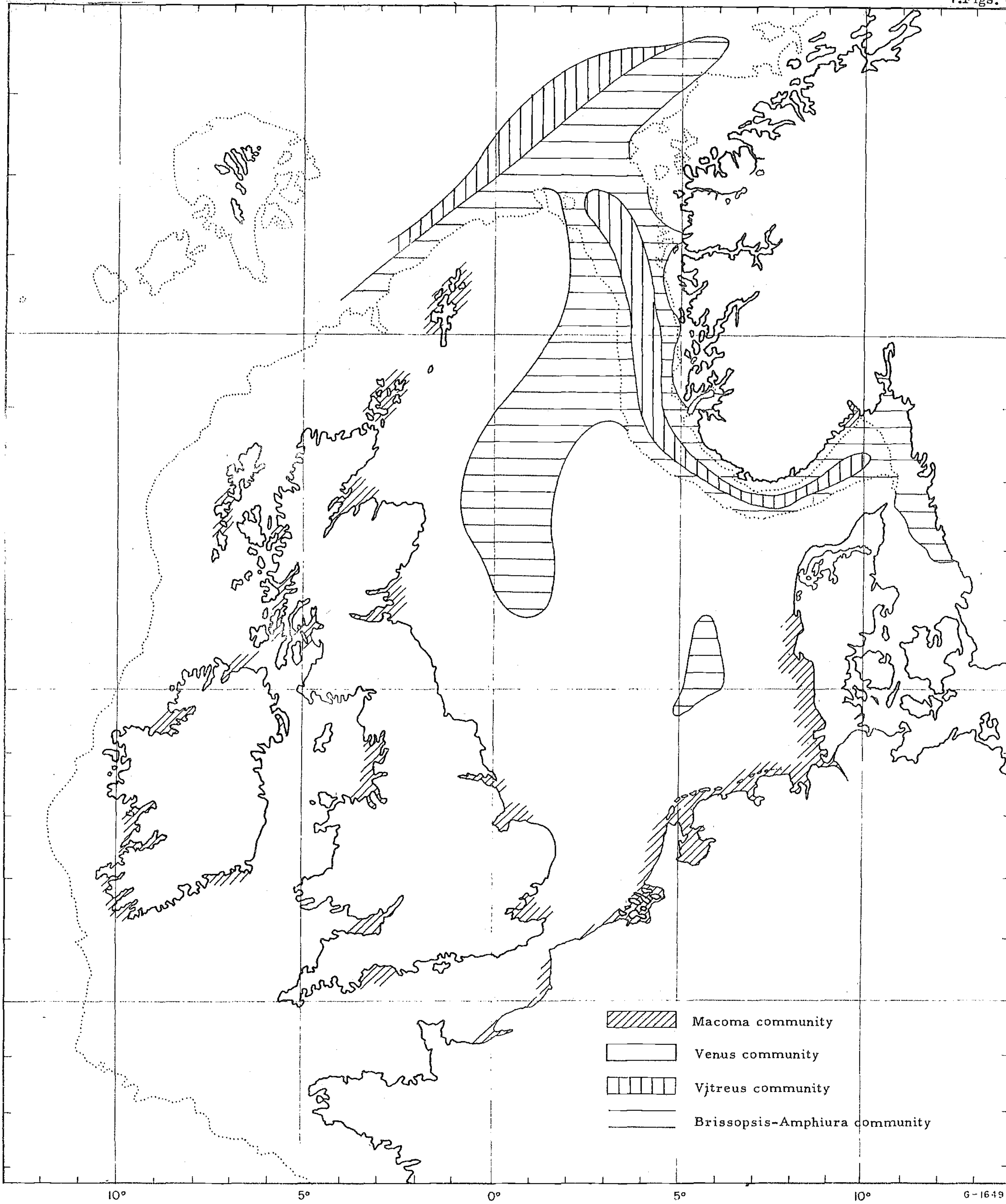


FIGURE 7.9 DISTRIBUTION OF BENTHIC COMMUNITIES (after Petersen)

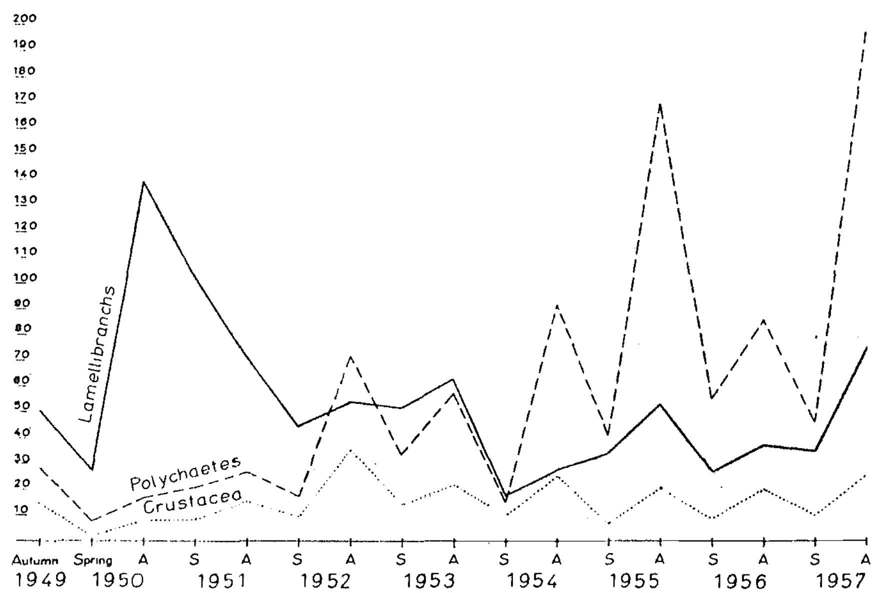


FIGURE 7.10

Variation of the numbers of various groups of benthic animals 0.1 m^{-2} in the German Bight 1949 to 1957 (after Ziegelmeier)

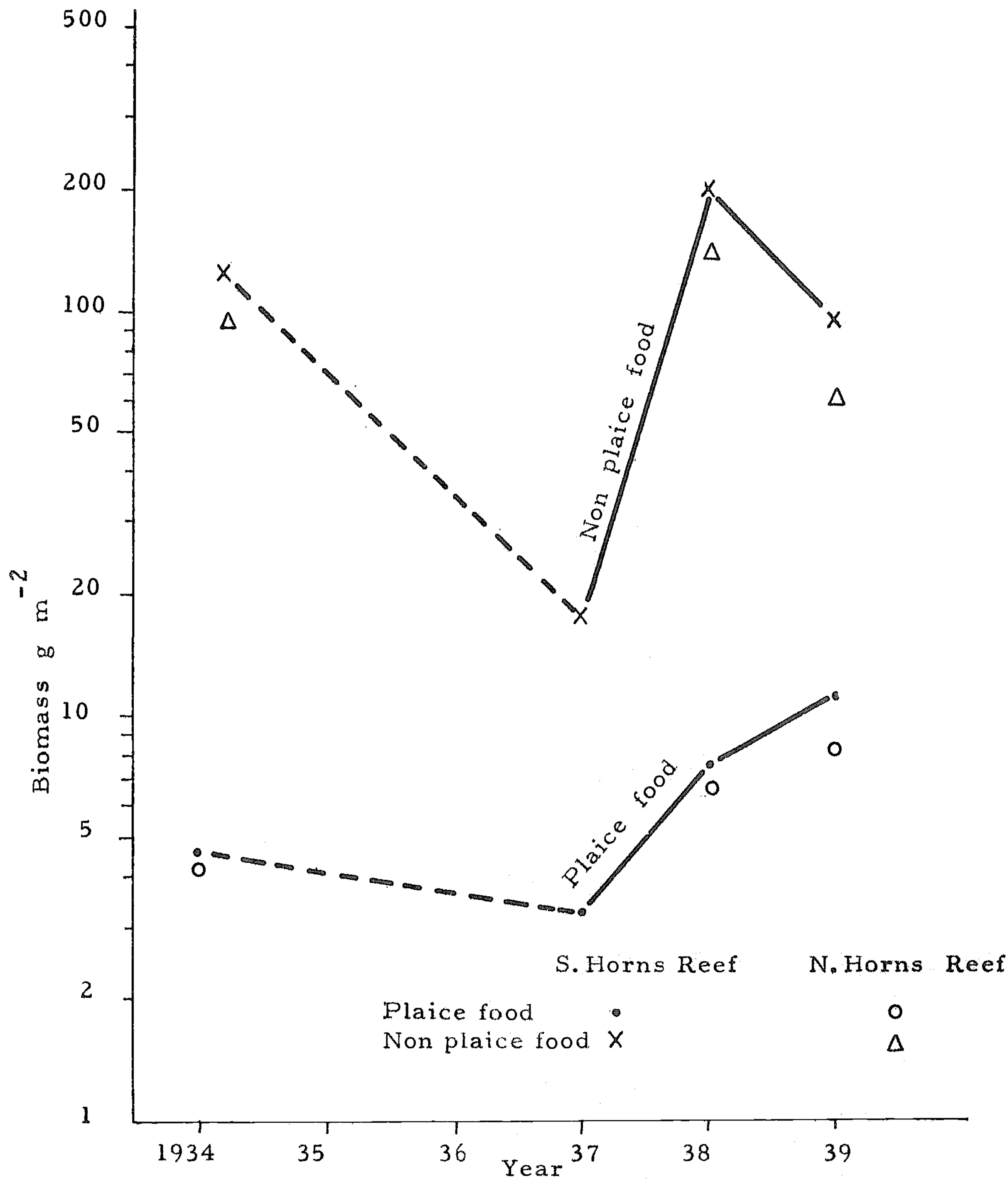


FIGURE 7.11 VARIATION OF BENTHOS BIOMASS IN HORNS REEF AREA (after Blegvad)

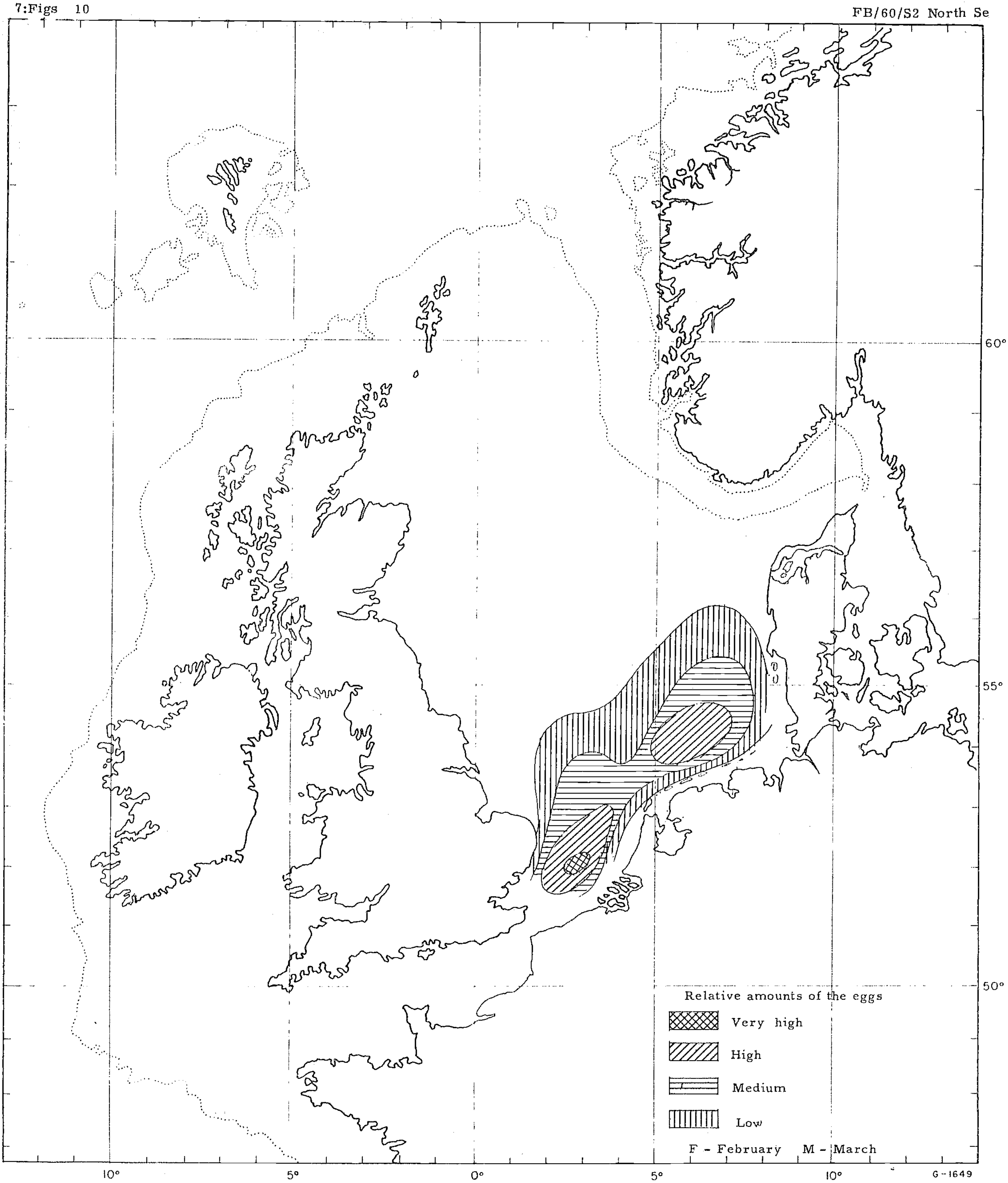


FIGURE 7.13 DISTRIBUTION OF PLAICE EGGS DURING FEBRUARY - MARCH (Incomplete)

TABLE 7.1

Zooplankton species characteristic for different North Sea Regions (Ostenfeld)

S - summer, A - autumn, W - winter, Sp. - spring

I. Flemish Sea

Very frequent: *Sagitta bipunctata*. Copepods: *Temora longicornis, Pseudocalanus elongatus, Acartia clausi, Centropages hamatus, Paracalanus parvus, Oithona nana, Calanus finmarchicus,* Copepods and copepod larvae (S). *Oikopleura,* frequent the copepod *Euterpe acutifrons* (S), *Pleurobrachia pileus* (Sp. and S). *Noctiluca miliaris* (S), Hydromeduse (S-A), not rare are: *Echinoderme* larvae (S), *Labidocera Wollastoni* (S); as frequent, are also mentioned:hemipelagic crustaceans: *Phtisica marina, Gastrosaccus, Paramysis spiritus*.

II. Southern North Sea

Frequent: *Oithona similis* (S), *Pseudocalanus elongatus, Oithona nana, Acartia clausi,* (S), *Tintinnopsis ventricosa* (A), *Noctiluca miliaris* (S), *Sagitta bipunctata* (S, A), as well as *Echinoderme* and *lamellibranch* larvae; not rare are: *Okopleura, Euterpe acutifrons* (A).

III. Northern North Sea

Very frequent: *Metridia lucens, Calanus finmarchicus,* frequent *Themisto abyssorum* (A), *Microsetella norvegica, Anomalocera patersoni* (S), *Temora longicornis* (S), *Pseudocalanus elongatus* (Sp./S), *Centropages typicus, Cyttarocylis denticulata, C. gigantea* (W), *Evadne nordmanni* (S), *Acartia clausi*, as well as Decapode and Schizopode larvae; not rare are the *Acanthometrides* (S), *Protocystis tridens* (S), and *Poden intermedius* (S).

IV. Skagerrak

Very frequent: *Pseudocalanus elongatus, Temora longicornis, Calanus finmarchicus, Sagitta elegans, Ecartia longiremis, Centropages hamatus, Oithona similis, Aglantha digitalis*.

TABLE 7.2

Zooplankton species, transported into the North Sea and indigenous species (after Remane 1940)

Warm water species entering through English Channel

Medusae: *Turritopsis polycirrha, T. nutricola, Gossea corynetes, Amphinema dinema, Clabberia halterata, Octorchis gegenbauri*

Gastropod larvae: *Lamellaria perspicua*

Tunicats: *Salpa democratica, Cyclosalpa bakeri, Doliolum nationalis, D. gegenbauri*

Siphonophores: *Muggiaea atlantica*

Warm water species entering North of Scotland

Medusae: *Cosmetira pilosella*

Tunicates: *Doliolum tritonis, Salpa fusiformis, Appendicularia sicula, Fritillaria venusta, Oikopleura parva, Salpa asymmetrica*

Gastropod: *Clio pyramidata*

Ostracod: *Conchoecia daphnoides*

Copepods: *Eucalanus elongatus, Rhincalanus nasutus*

Chaetognaths: *Sagitta serrata dentata, Tryphaena malmii*

Trachymedusae: *Solmaris corona*

Siphonophores: *Physophora hydrostatica, Cupulita sarsi, Arachnactis* larvae, etc.

Temperate water species entering Northern North Sea

Radiolarians: *Challengeron armatum, C. diodon, Choenicosphaera murrayana, Cladoscenium tricolpium, Clathrocyclas craspedota, Dictyophimus clevei, Echinomma trinacrium, Plagiacantha arachnoides, Protocystis tridens, P. xiphodon, Trochodiscus echinodiscus, T. helioides*

Tintinne: *Dictycysta elegans*

Ceriantharier larvae: *Arachnactis albida* and *A. Bournei*

Copepods: *Aetideus armatus, Candacia armata, C. gracilimna, C. norwegica, C. rotunda, Chiridius armatus, Metridia lucens, Oithona atlantica, O. similis, Pleuromamma robusta*

Amphipod: *Scina borealis*

TABLE 7.2 (contd.)

Indigenous species present in whole North Sea

Copepods: *Acartia Clausi, Anomalocera Patersoni, Centropages typicus, Euterpe acutifrons, Labidocera wollastonii, Microsetella norwegica, Sagitta bipunctata (elegans)*

TABLE 7.3

List of planktonic indicator species in the North Sea
(after Russell, modified)

I. North Atlantic Water

Ia. North Atlantic Water

Warm water forms:

Hydromedusae: siphonophores: *Physophora hydrostatica, Agalma elegans* and *Galeolaria truncata*

Chaetognatha: *Sagitta serratodentata*

Crustacea: copepods: *Rhincalanus nasutus* and several other species

Pteropoda: *Clio pyramidata*

Tunicata: various salps and doliolids

Temperate water forms:

Hydromedusae: siphonophores: *Dimophyes arctica*

Chaetognatha: *Sagitta maxima* and *Eukrohnia hamata*

Crustacea: copepods: *Calanus hyperboreus* and *Metridia longa*

Pteropoda: *Limacina heticina*

Ib. Mixed Scottish Coastal Water

Hydromedusae: *Neoturris pileata, Laodicea undulata, Malopsis ocellata, Cosmeira, Tima bairdi* and *Aglantha*

Chaetognatha: *Sagitta elegans*

Crustacea: amphipods: *Themisto* (*Calanus finmarchius* abundant)

Pteropoda: *Limacina retroversa*

II. Channel Water

Hydromedusae: *Turritopsis* and *Gossea corynetes*

Mollusca: *Lamellaria perspicua* larvae

TABLE 7.3 (Contd.)

III. Central North Sea Water

IIIa. North-Central

Chaetognata: *Sagitta setosa*

IIIb. South-Central

Hydromedusae: *Tima barrdi*, *Cosmetira*, *Aglantha*, and the siphonophore *Agalma elegans*

Chaetognatha: *Sagitta elegans elegans*

Crustacea: amphipods: euphasids: *Nyctiphanes couchi*, *Thysanoessa gregaria*, *Themisto abyssorum*

Pteropods: *Clione limacina* and *Limacina retroversa*

Echinoderms: *Luidia sarsi* larvae

Appendicularia: *Oikopleura labradoriensis*

IV. Skagerrak Water

Complex community with frequent occurrence of : *Pseudocalanus*, *Temora*, *Calanus*, *Acartia*, *Centropages*, *Oithona*, *Aglantha* and *Sagitta* spp.

V. English Coastal Water

Hydromedusae: *Turritopsis*

Chaetognatha: *Sagitta setosa*

VI. Continental Coastal Water

VIa. Flemish Coastal Water

Pelagic hydroid: *Clytia*

Medusa: *Sarsia tubulosa* (late winter and spring)

VIb. German Bight Water

Medusa: *Sarsia tubulosa*

TABLE 7.4

The Dry Weight of Hensen Egg-Net Plankton as mg. for m^3. (June, July, Sept.) (after Wimpenny)

	Stat. North of Flamborough Line (mean of 11-12 stations)	Flamborough Line (mean of 6 stations)
1947	55	66
1948	46	36
1949	44	47
1950	43	64
1951	43	53
1952	97	63
1953	65	81
1954	85	50

TABLE 7.5a

Standing crops of zooplankton biomass in the North Sea
(Mainly on the basis of Hensen net oatohes)

Looality	Season	mg/m^3	Author	Remarks
North Sea	Average	55	Wimpenny, 1953	Reoaloulated assuming 50 m depth
SW North Sea	Febr.-Maroh	152 - 397	Krey, 1953	

TABLE 7.5b

Average plankton biomass in the North Sea and adjaoent
waters aooording to the data oompiled by Bigelow and Sears (1939)
(Reoaloulated assuming 1 ml displaoement volume = 0.8 g biomass)

Looality	Season	Authority	Plankton biomass in mg/m^3
North Sea	June 1926	Savage 1931	460
	August 1926		400
	November 1926		480
		Jespersen 1923	10
English Channel	April 1925	Russell 1927	8
	May 1925		80
	June 1925		16
	July 1925		40
	August 1925		40
Skagerrak	February 1903	Cons.Perm.Intern. p. l'Explor. de la Mer (1904-1907)	32
	August 1903		40
	November 1903		112
	May 1904		72
	August 1904		40
	November 1904		128
	August 1906		16

TABLE 7.6

Quantitative relation between phytoplankton and zooplankton

Locality	Time	Biomass in mg/m^3		Phytoplankton / Zooplankton relation	Author
		Phyto-plankton	Zoo-plankton		
SW North Sea	February-March	27	241	0.1	Krey, 1953

Locality	Time	gC/m^2		Author and remarks
		Phyto-plankton	Zoo-plankton	
North Sea	Jan.	3.4	1.3	1.2 gCm^2 higher animals. Kalle, 1950
Fladen Ground	(Max.)	1.2	5	) Steel, 1956 (Phytoplankton recalculated)
Inshore waters North Sea	(Max.)	2.1	5	)
English Channel	(Max.)	2.5	5	)

TABLE 7.7

Composition of benthic communities
in the North Sea
(after Petersen)

1. The *Macoma baltica* community, with *Macoma baltica, Mya arenaria, Cardium edule, Arenicola marina* etc. as the most evenly distributed characteristic species.

2. The *Venus* communities with *Spatangidae* found mainly on sandy bottom
   a) *Echinocardium cordatum, Venus gallina, Tellina fabula, Mactra subtruncata,* in shallow water.

   b) *Spatangus purpureus, Echinocardium flavescens, Abra prismatica, Psammobia faeroensis, Mactra elliptica* etc., in deeper water.

   Cyprina islandica is frequently found as an attendant species in both a) and b). *Venus* communities which have not yet been subjected to valuation may doubtless be found in still deeper water, together with *Spatangus raschii* etc.

3. The *Brissopsis - Amphiura* community, on soft clay bottom with *Brissopsis lyrifera, Amphiura chiajei, Calocaris m'andrea, Nucula sulcata, Eumenia crassa* etc.

4. Communities from deeper water than the *Brissopsis,* presumably on soft clay bottom, with *Pecten vitreus, Abra longicallis,* and various other species as characteristic types or at least as important attendant species. Future investigations will doubtless reveal the necessity of further subdivision here, and possibly a revised classification *(Amphilepsis norwegica).*

TABLE 7.8

Frequent benthic animals and their importance as fish food in German Bight (after Ziegelmeier)

Polyohaetes:	- all important as fish food
Spiophanes bombyx	)) Most abundant
Pectinaria koreni	))
Lanice conchilega	)
Nephthys hombergi	) - On muddy bottom
Scoloplos armiger	)
Magelona papillicornis	- On sandy bottom
Scalibreme inflatum	- On muddy bottom in deep water
Crustacea:	
Amphipods:	
Urothoë poseidoni	) On sandy bottom
Bathyporeia guilliamsoniana	)
Ampelisca brevicornis	- On all bottoms
Cumaceans:	
Diastylis rathker	
" *bradyi*	
Iphinoë trispinosa	
Echinoderms:	
Echinocardium cordatum	)
Ophiura texturata	) All echinoderms are sensitive to cold winters
" *albida*	)
Amphiura filiformis	)
Lamellibranchs	
Angulus fabula	- Most important lamellibranch as food for plaice
Nucula nitida	
Montacuta bidentata	
Phaxas pellucidus	
Lunatica nitida	
Hydrobia alvae	
Abra nitida	- On muddy bottom
Abra alba	- On sandy bottom, further offshore

TABLE 7.9

Quantities of benthos and the amounts of plaice food in it in some localities in north European waters. (after Smidt, 1951)

Region	Benthos Community	Locality and its Characteristics	Number of individuals (av). m^2	Total weight (av) g/m^2	1st class plaice food Average g/m^2	1st class plaice food Max. g/m^2	Source
Danish Waddensea	Macoma	Waddens, Southern area, July-Aug. 1941	31,000	174	84	200	Smidt, 1951
		at Skallingen, Aug. 1942	63,000	497	249		
Ringkbing Fjord	Macoma	Tidal areas at the Tipper:					Sparck (unpubl).
		July-Aug. 1937	3,176	26.7	26.7		
		July 1938	3,190	42.4	42.4		
		June 1939	2,427	45.0	45.0		
Dybso Fjord	Macoma	Depth ca.0.1 - 10.9 m	844	55.2	55.2		Larsen (1936)
Cuxhaven	Macoma	America Harbour, depth 7 m	75,300	270	73		Hagmeier (1925)
Heligoland Bay	Macoma	Poor localities	59	6.9	5.4		Hagmeier (1925)
		Rich localities	358	30.8	18.2		

TABLE 7.9 (contd)

Region	Benthos Community	Locality and its Characteristics	Number of individuals (av). m^2	Total weight (av). g/m^2	1st class plaice food Average g/m^2	1st class plaice food Max. g/m^2	Source
Heligoland Bay	*Syndosmya*		700	105.4	76.0		Hagmeier (1925)
	Venus	Northeastern area	113	28.2	12.4		
		Southwestern area	273	25.1	4.8		
	Amphiura	Mixed with elements of					
		Venus-community	406	98.1	14.6		
		Syndosmya-community	1,770	232.8	33.9		
Limfjord	*Syndosmya*	Thisted Bredning (18 years invest.)			44.7	136.6	Blegvad (1928)
		Lovns Bredning (13 years invest.)			48.9	279.6	
		Sallingsuns (12 years invest.)			62.2	336.8	
Kattegat	*Venus*	Several years investigations in various localities	808	46.3	23.9	97.0	Blegvad (1930)
			368	26.8	10.7	16.8	
			344	71.0	18.2	88.7	
			121	100.6	8.8	9.1	
	Amphiura	Several years investigations in various localities	657	216.6	21.6	30.6	Blegvad (1930)
			309	219.5	10.1	13.8	
			277	138.6	22.0	30.5	
	Haploops	Two years investigations	1,458	54.9	34.4	54.9	Blegvad (1930)

TABLE 7.10

Standing crops of benthos biomass in the North Sea

Community and other remarks	g/m^2	Author
Venus gallina comm.		) Anon. 1934
Nucula nitida var.	30-130	)
Tellina fabula var.	5-10	)
Echinocardium cordatum var.	-500	)
Aonides var.	10	)
	346	Demel and Mulicki, 1954
	244	(Zernov, 1934), Moiseev, 1955
	260	Petersen, Jensen, 1911
Macoma comm.	7-31	) Hagmeier, 1925 (acc. Spärck 1935)
Syndosmya comm.	105	)
Venus comm.	25-28	)
Amphiura comm.	98-233	)

TABLE 7.11

Average number and biomass of benthic organisms in German Bight 1955-57 (after Ziegelmeier)

		1955		1956		1957	
		Spring	Aut.	Spring	Aut.	Spring	Aut.
Average numbers on 1/10 $m.^2$ at all stations	Lamellibranches	30.4	52.9	26.6	37.0	34.6	74.9
	Angelus	13.5	17.5	9.3	8.7	9.4	19.1
	Abra	0.4	5.3	0.6	8.0	1.7	4.1
	Polychaetes	40.8	168.5	54.9	85.3	45.5	195.7
	Crustacea	6.7	20.1	8.6	20.0	9.9	25.4
	Echinoderms	4.9	32.3	5.8	6.6	6.2	16.2
	of which *E. cordatum*	1.0	17.6	0.5	0.6	0.4	6.1
Average total stock on 1/10 $m.^2$ (biomass in $cm.^3$) *E. cordatum* excepted		3.2	5.0	2.7	4.6	4.8	8.1
Average stock on 1/10 $m.^2$ (biomass in $cm.^3$)	Lamellibranchs	1.9	1.6	1.3	1.7	2.2	3.2
	Polychaetes	1.1	2.5	1.1	2.0	2.1	4.1

TABLE 7.12

Average number of benthic animals per square metre in Moray Firth (after Stephen)

Organisms	Type of Bottom	Sand		Mud	
	Depth range	Under 20 fms.	Over 20 fms.	20-45 fms.	Kinnaird Deep
Echinoderms		10.5	14.6	35.6	109.7
Molluscs		33.4	25.6	52.1	25.0
Polychaets		10.2	22.0	47.1	61.8
Crustacea		8.5	16.5	16.4	15.5
Other forms		0.6	8.0	7.1	9.7

TABLE 7.13

Change in the composition of the bottom fauna of the Dogger Bank area (after Ursin)

	Number per square meter	
	Davis (Oct. 1922)	Ursin (May 1951)
Spisula subtruncata	272	5
Mactra corallina	11	1
Other species of bivalves	4	43
Polychaets	4	70
Echinoderms	4	28
Other groups	8	65
Total	303	212

TABLE 7.14

PLAICE FOOD IN KATTEGATT
(after Blegvad, 1930)

A I class plaice food	B II class plaice food	C No plaice food
All Lamellibranchia except those under II class and No plaice food	*Macoma calcarea* 2cm All species of the genera *Venus, Astarte, Lucina, Dosinia, Ledo, Corbula* and *Nucula* *Psammobia faerøensis* 2 cm *Mactra solida* 2 cm *Modiolaria nigra* 2 cm	*Pecten* sp. 2 cm *Cyprina islandica* 2 cm *Mya* sp. 3 cm
Natica all sp. *Bela turricola* *Lacuna*, all sp. *Rissoa*, all sp. *Philine*, all sp. *Acera bullata* *Cylichna cylindracea* *Nudibranchia* *Chaetoderma intidulum*	*Buccinum undatum* 0.5 g *Aporrhais pes pelecani* 0.5 g *Scalaria cinerareus* *Trochus festudinalis* *Chinton*, all sp.	*Buccinum undatum* 0.5 g *Nassa reticulata* *Nassa pygmaea* *Aporrhais pes pelecani* 0.5 g *Turritella terebra* *Dentalium entalis*
All worms with exception of those under B and C	*Aphrodite aculeata* *Phascolion strombi* *Amphiura chiajei* " *filiformis* *Ophiura* all sp. *Echinocardium cordatum* (Small 0 - Gr.) *Echinocyamus pusillus*	*Pomatoceros trigueter* All Echinoderms with exception of those mentioned in B
All Crustacea with exception of those under B and C	Small *Paguridae*	Big *Eupagurus bernh.* " *Carcinus maenas* " *Hyas* " *Nephrops novegicus*
Edwardsia chrysanthellum *Cerianthus danielsseni* *Amphioxus lanceolatus*	*Hydroidae*	*Actiniidae* with exception of those mentioned in A *Ascidiae* Foraminifera

TABLE 7.15

Catches of different species in the North Sea 1957

	mill.kgs.	%
Herring	1,047.8	57.6
Haddock	105.3	5.8
Cod	95.0	5.2
Whiting	84.3	4.6
Plaice	69.3	3.8
Mackerel	68.9	3.8
Saithe	51.8	2.9
Dogfish	26.4	1.5
Sprat	22.4	1.2
Ling	15.1	.8
Sole	11.7	.6
Skate and Ray	11.5	.6

Table 7.16

Density of fry on the spawning places of the south-eastern North Sea. (after Aurich 1954)

		Average	Maximum	
Cod	February 1936	35 - 56	116 - 176	eggs/m.^{2}
	March 1926, 1937			
	March 1953	75	192	eggs/m.^{2}
Plaice	February 1936	75	111 - 294	eggs/m.^{2}
		4	9	larvae/m.^{2}
	March 1926, 1935,	4 - 9	14 - 35	eggs/m.^{2}
	1937	4 - 11	15 - 51	larvae/m.^{2}
	March 1953	47	159	eggs/m.^{2}
		8	12	larvae/m.^{2}
Dab	February 1936		370 - 821	eggs/m.^{2}
	March 1926, 1935, 1937		300 - 1185	eggs/m.^{2}
	March 1953		300 - 765	eggs/m.^{2}