ON THE RESULTS OF NORTH SEA RESEARCH

HYDROGRAPHIC INVESTIGATIONS ON BOARD FRV *ANTON DOHRN* IN SUMMER 1959/60 AND WINTER 1962/63

by Dr. E. H. Rogalla
German Hydrographic Institute

Though the North Sea belongs to those waters where systematic fisheries biological and hydrographic investigations were first carried out, present knowledge of the large-scale distribution of different species of fish and their dependence upon hydrographic conditions is rather incomplete. It may be said that fisheries hydrography started in Europe with the foundation of the International Council for the Exploration of the Sea in 1902 and is based on the fact that propagation, growth, distribution, and mortality of fish depend to a great extent — though not exclusively — on the physical, chemical, and ecological systems.

When the large-scale distribution of fish is investigated by several research vessels, difficulties will arise when standardizing the results, as the vessels differ in their catching power. A satisfactory solution cannot be found. Thus, the German fisheries research circles tried to fulfil this task with only one vessel. FRV *Anton Dohrn* therefore undertook two pairs of research cruises. They were so planned that the distribution of fish and the hydrographic conditions during the same period of two successive

Investigations of the large-scale distribution of the species of fish in the North Sea on board FRV "Anton Dohrn"

1/ A survey of the observed hydrographic data

Current No.	No. of the cruise	length of the cruise from	to	Year	Nos. of the stations from	to	Hydrogr. stations	t°C observations	S ‰ determinations	σt computations	Bt recordings
1	37	22/6	24/7	1959	3286	3505	220	703	678	667	198
2	46	7/7	1/8	1960	786	966	181	679	656	648	169
3	58	8/1	3/2	1962	1	208	182	469	448	443	14
4	66	8/1	8/2	1963	1	243	243	592	588	580	14

2/ A survey of the evaluated hydrographic data

Current No.	No. of the cruise	length of the observations from	to	Year	track chart	surface charts t°C	S ‰	σt	bottom charts t°C	S ‰	σt	difference charts Δt°C	ΔS ‰	Δσt	Profiles North-South	West-East
1	37	23/6	23/7	1959	1	1	1	1	1	1	1	1	1	1	1	4
2	46	9/7	31/7	1960	1	1	1	1	1	1	1	1	1	1	1	1
3	58	8/1	2/2	1962	1	1	1	-	1	1	-	-	-	-	-	-
4	66	9/1	7/2	1963	1	1	1	-	1	1	-	-	-	-	-	-

years could be compared. A summary of the observations made during the research cruises, given in the form of a table, and the results derived will give an idea of the range of this operation.

In an article about hydrographic investigations in the North Sea, Summer 1959, contained in the May 1960 edition of the *Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung,* the author published some results of the horizontal distribution of the water masses near the bottom and the thermal layering. These results were derived from evaluation of the observational material of the 37th cruise of FRV *Anton Dohrn,* not finished at that time, and are of importance as a basis for fisheries biological investigations of the inter-relation between hydrographic conditions and the presence of fish. In February 1961 a short article was for the same reasons published in the *Annales Biologiques,* also describing some results of this research cruise. In May 1962 some results of the 46th research cruise of *Anton Dohrn* were published in the same journal, demonstrating the temperature and salinity distribution in the bottom water and the stratification in July 1960 (E. H. ROGALLA, 1960; 61; 62). The article issued in the *Informationen für die Fischwirtschaft* (D. SAHRHAGE & E. H. ROGALLA, 1960) examines the inter-relation between the presence of herring and the bottom water temperatures obtained during the two research cruises. E. GOEDECKE (1961) and I. HELA and T. LAEVASTU (1962) referred to the results of this short contribution. During a marine biological symposium D. SAHRHAGE (1963) reported at Bremerhaven on the large-scale distribution of the different species of fish in the North Sea, using the hydrographic charts. His contribution in the *Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung* (1964) gives a detailed description of these results and contains the temperature and salinity charts of the bottom water during the two research cruises.

This contribution is trying to give a clear idea of the hydrographic conditions in summer and winter, using for this purpose the charts of the temperature, salinity, and density distribution of the surface and bottom waters as well as the charts of the intensity distribution of the thermohaline layering. It further tries to illustrate the different forms of layering by vertical sections and to demonstrate the divergences in the different water bodies by comparison of the computed mean values with the long-term average.

As to the distribution and range of the fisheries hydrographic investigations, the station and track charts of the four research cruises given in plate 1 will be most informative. As the period of investigation had to be shortened in 1960, all stations to the North of 60° N and even the transverse profiles across the Norwegian Channel could not be repeated. Besides the investigations of the population dynamics, any information about the local and temporal variations in the spawning of commercial fish and its possible dependence upon the hydrographic conditions are of fundamental importance not only for science but also for practical fishermen. The pair of cruises carried out in January 1962/63 also covered the distribution and frequency of pelagic fish fry in the southern North Sea and the English Channel. They fit simultaneously into an international operation which started in January 1960. Great Britain, the Netherlands, and the Federal

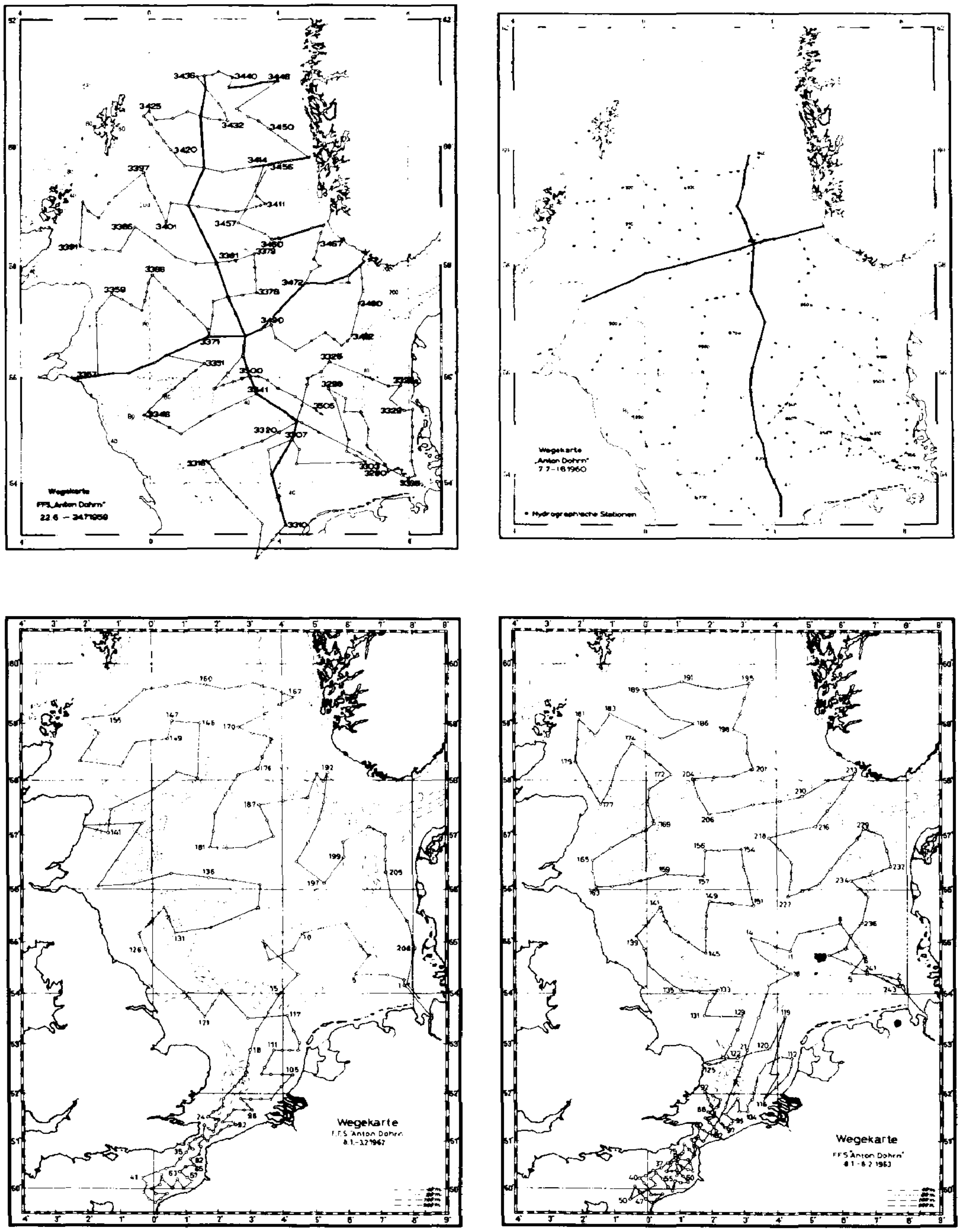


PLATE 1. — Station and track charts of the hydrographic research studies of FRV *Anton Dohrn* in the North Sea in Summer 1959/60 and Winter 1962/63.

Republic of Germany agreed upon a joint programme of research cruises to trace the destiny of herring spawn from their hatching in the spawning places in the English Channel and in the southern North Sea up to their arrival at the young fish grounds.

For the fisheries hydrographic investigations a quasi synoptic method of working was applied, giving an insight into the horizontal distribution of the water masses and their vertical structure despite the special problems arising in such a shallow tidal sea as the North Sea. A synoptic method of working in oceanography means a short-term spatial investigation of a sea area. Thus the thermal conditions are regarded as the heat contents of the water determined by the heat budget. The heat budget for its part is composed of the change of heat through radiation, evaporation, direct exchange of heat between the surface of the sea and the atmosphere, and the horizontal and vertical transport of heat by mixing processes and currents. As the change of all hydrographic factors is not only subject to strong annual variations but also to the weather conditions whereby the latter may seize the whole water column in near-coastal areas, only short-term observations may be processed into useful distribution charts and vertical sections. The plan of the research cruises of FRV *Anton Dohrn* was exclusively based upon fisheries biological points of view (D. SAHRHAGE, 1964). In view of the sometimes rather long and irregular distances between the stations, a subjective interpretation of the observations could therefore not completely be avoided. But the net of stations is large enough to make general comments on the hydrographic conditions during the periods given in the table. The positions were fixed according to the Decca system which, because of its high degree of accuracy, surpasses by far the accuracy of the track charts. The observations upon which the distribution charts, the profiles, and the computed mean values are based were made by surface and reversing thermometers. The water samples were taken by Nansen bottles. The bottom water samples were taken by a special bottle which closed 0.50 m above the bottom after having touched it. The reversing frame with the reversing thermometer was 1 m above the special bottle. The continuous vertical temperature recording was done down to the bottom water by a bathythermograph. The salinity of the water samples was determined at the laboratory of the German Hydrographic Institute, Hamburg, 1959/60 by chlorine titration and 1962/63 by a salinometer of the National Institute of Oceanography, Wormley, Great Britain (R. A. COX, 1958). The mean error of the temperatures measured by means of a surface thermometer amounts to ± 0.05 °C, the mean error of the reversing thermometer to ± 0.02° C. In the salinity determinations an accuracy of ± 0.02 and ± 0.005 $^0/_{00}$ is achieved. According to the international way of computation, the density distribution charts and the vertical sections of the density distribution are constructed from data computed as function of the temperature and salinity, with an accuracy of $\sigma_t = \pm\ 0.0001$.

All observational data have meanwhile been processed into punched cards and passed on to the *Bulletins Hydrographiques* of ICES, so that they are available to all interested persons. The geographic positions of the vertical sections are plotted on the station and track charts. The sections also contain, besides the marking used for classification purposes, the period in which the observations were made. The bottom profiles are constructed after the depth data taken from the North Sea fisheries chart No. 112 FC of the German Hydrographic Institute and consider the corrected soundings taken on the stations by a precision echograph. For some west-east profiles the depth scale is changed to 150 m. This change in the scale is indicated by a hatched line and makes it possible to show in one figure the strong horizontal and vertical differences in the temperature, salinity, and density distribution at depths up to 150 m and the relatively homogeneous conditions in the deeper regions of the Norwegian Channel.

The distribution of the water masses

The real North Sea covers an area of 575 000 square kilometres with a water volume of 54 000 cubic kilometres and a mean depth of 94 m (K. KALLE, 1949). It is connected in the North and West with the Atlantic Ocean, through the Skagerrak with the Baltic. These connections are the entries for the Atlantic and Baltic waters. The horizontal classification of the water masses in the North Sea is given by the cartographic representations of the salinity distribution, regularly published since 1902/14 in the *Bulletin Hydrographique* [2]. In June 1950 they were issued in a modified form by the Fisheries Laboratory, Lowestoft (J. R. LUMBY, 1950/52). Then the Service Hydrographique of ICES continued the work (J. SMED, 1952). The latest and most comprehensive representation of the monthly means of the temperature and salinity distribution at the surface is the Atlas of G. DIETRICH (1962) published on behalf of ICES. A great number of single investigations given in the papers of G. DIETRICH (1950) and T. LAEVASTU (1962; 63) demonstrate that the hydrographic conditions of the North Sea are marked by the presence of water masses of different origin. Their distribution is subject to strong variations. Each type of water has its own specific annual variations. These general facts form the basis of the knowledge that it is insufficient to start from mean conditions when studying the possible inter-relation between the different species of fish and the hydrographic conditions. According to the salinity distribution, a difference is made between Atlantic, Central, and Coastal water bodies. A further sub-division of these main water bodies (T. LAEVASTU, 1962; 63 and G. TOMCZAK and E. GOEDECKE, 1962) is made, but for fisheries biological purposes it is not always necessary. As the change of all hydrographic factors is not only due to strong annual variations but also to the weather conditions, whereby the latter may seize the whole water column in the North Sea, the distribution and expansion of the water masses are strongly influenced by the latter. A repeated synoptic survey of the hydrographic conditions in smaller parts of the North Sea had to be omitted for time reasons. Therefore, nothing can be said about the shift of the single water bodies within the period of investigation under the influence of distinct wind conditions. As is well known, the sea gets most of its energy from solar radiation and the thermal influence of the near-surface atmospheric layers. As a surface layer of 0 — 20 m is nearly always mixed by the turbulence of the wind-produced currents and waves, the influence of the respective weather conditions can best be seen from a representation of the temperature distribution in the surface water. June/July 1959 was one of the warmest, sunniest, and dryest months of the last decades [30; 31]. July 1960 was unusually rainy and its mean temperature was below the long-term average [32]. In the weather conditions of January 1962 the uninterrupted influx of Atlantic air-masses following quickly-moving depressions was prevailing. Short periods of sunshine and a considerable amount of precipitation were the consequence [33]. The cold November and December of 1962 were followed by a still colder January 1963. With a high pressure mainly in the area between Greenland and Iceland, sometimes also over Central Europe, the influx of polar air from North to East was predominant. The temperature deviations from the long-term mean amounted to more than 5 degrees. February 1963 was the fourth month of that winter with considerably negative temperature deviations [34]. The favourable weather conditions of the two summer cruises [4; 5; 6] permit one to call the distribution charts of plates 2 and 3 quasi synoptic. Wind forces of more than 7 Bft., able to bring about a rapid change in the hydrographic conditions, were however observed to 29 and 17 % during the two winter cruises. Thus G. GRÜNEWALD (*) elaborated a detailed analysis of the weather conditions prevailing over the area of investigation during the two winter cruises.

1. The weather conditions January 8 — February 3, 1962

A strong area of high pressure prevailing in the first days of January over the British Isles soon moved to the South and already on January 5 made room for a through west weather situation. In the North Sea the direction of the wind varied between NW and WSW. In the southern North Sea too, the wind temporarily reached 6 Bft. On January 8, the day of departure, a storm depression prevailed between Ireland and Iceland taking a NE course, the secondary disturbances of which crossed the North Sea on January 9 and 10. The winds in the German Bight and the southern North Sea, mainly blowing from SW, had a speed of 15-30 knots and only on January 10, at noon, diminished for a short time to 10 knots.

Another storm depression of 955 mb advancing to Scotland on January 11 only slowly shifted to the Baltic on January 12 and 13, while filling up. The velocities of the winds from SW to W varied on January 11 between 35 and 52 knots, on January 12 between 25 and 50 knots, and lessened to 25 knots from W on January 13 in the Dover area. A new Atlantic storm depression concentrated to 950 mb on January 15 to the West of Scotland and influenced the weather over the Channel and the south western North Sea until January 18, slowly moving to NE. The velocity of the wind mainly blowing from SW varied there between 20 and 40 knots. Until January 26 the North Sea was subjected to storm depressions advancing from the West and rapidly following each other, disregarding some short-term interruptions. On January 19, 21-22, and 24, the centres directly transversed the North Sea in a WE direction. Thus W winds of 40-45 knots rose in the western North Sea on January 19, SW

(*) I have to thank Dr. GRÜNEWALD, board meteorologist at the Deutscher Wetterdienst, Seewetteramt Hamburg, for his co-operation and the delivery of the results of his work for this publication.

winds of 35 knots on January 21, W winds of 50-55 knots on January 22, and SW winds of 25-30 knots on January 24. Due to the vicinity of the land, the height of the waves in the western North Sea did not surpass 1-3 m in this period and only increased on January 22 to 4-6 m. Under the influence of a storm depression moving to NE through the Denmark Strait, the wind in the northern North Sea increased to 40 knots, on January 25 the south wind, on January 26 the NW wind. An area of high pressure which advanced to the British Isles on January 26 and 27, bridged the North Sea to Scandinavia on January 28 and until the end of the month was pushed off to East Europe by new Atlantic depressions. In the northern North Sea the NW winds decreased to 30-20 knots on January 27. With NE winds of 5 knots on January 28, the weather was further calming. This lasted, however, for only a short time, as a S wind of more than 30 knots rose in the evening of the same day. On January 30, SSW winds of 40 knots were observed on board *Anton Dohrn* on the SE edge in the area of strong depressions; on January 31, 50-60 knots. In the rear of a line of perturbations which receded to Scandinavia the winds on February 1 and 2 shifted to NW-N in the eastern North Sea and decreased to 28-20 knots :

Table 1

Percentage frequency of velocity of winds and height of waves observed during the voyage on board of fishery research vessel "Anton Dohrn"

velocity of wind Bft.		0	1	2	3	4	5	6	7	8	9	10	11	12
height of waves m														
frequency	wind :	1	1	4	3	3	15	29	15	15	6	7	1	-
in %	waves :	10	41	30	5	4	3	3	2	2	-	-	-	-

The great frequency of lower waves is caused by the fact that the vessel was often sailing near the coast.

Characteristic weather periods in January 1962

1) January 6-10, 1962

The frequency of strong storm depressions in the area of the Irminger Sea and the Iceland region caused there an extended depression of 980 mb in the mean pressure distribution of these five days, while a wedge of high pressure extended from the Azores via Spain to South Europe. Over the North Sea and the English Channel perturbations moving ENE were prevailing.

2) January 11-14, 1962

The centres of the storm depressions developed this time farther south than in the preceding days. They moved via the North Sea to the East. The south European high pressure bridge was interrupted. Thus a depression of 970 mb appeared in the mean pressure distribution of this weather period to the South of the Faeroes, with a strong concentration of isobars over the Channel and the North Sea.

3) January 15-24, 1962

In this period the strongest storm depressions developed to the South of Iceland, which caused there a mean area of depression of 985 mb, while a mean SW current was prevailing over the Channel and the North Sea.

4) January 25-27, 1962

The centre of the North Atlantic depression moved towards the West into the region of Cape Farewell with a mean pressure of 980 mb, while an area of high pressure of 1 030 mb advanced from the Azores to Spain. NW winds of smaller forces prevailed over the Channel and the North Sea.

5) January 28-31, 1962

While the centre of the depression of an average of 980 mb remained in the region of south Greenland, an area of high pressure of an average of 1 035 mb formed over the North Sea. The northern North Sea was once again influenced by SW winds.

Table 2

Estimation of direction and force of medium ground wind in knots in virtue of weather charts of the Seewetteramt

Weather periods	Channel Eastern part	South-Western North Sea	German Bight	Middle North Sea Western part	Middle North Sea Eastern part	Northern North Sea Western part	Northern North Sea Eastern part
1/ 6.-10.1.62	SW 22	SW 15	SW 15	SW 22	SW 20	SW 20	SW 17
2/ 11.-14.1.62	WSW 27	WSW 29	SW 26	SW 25	SW 22	SW 20	SW 22
3/ 15.-24.1.62	SW 23	SW 22	SW 23	SW 22	SW 23	SW 17	SW 15
4/ 25.-27.1.62	WNW 13	WNW 10	W 8	W 8	W 6	WSW 10	SW 10
5/ 28.-31.1.62	light variable winds			SW 14	SW 10	SW 18	SW 25

Large-scale circulation in January 1962

In January 1962 an intensified zonal circulation prevailed in the European Atlantic region. The large area of depression of less than 990 mb between south Greenland and Iceland was opposed by high atmospheric pressure of 1 020 mb to the SW of the Azores. A trough of low pressure directed via the Norwegian Sea towards the Barentsz Sea pointed to the frequent migration of strong depression centres over the southern Norwegian Sea and Scandinavia to the Barentsz Sea, which resulted in an increase of the southern and western currents over the North Sea [7].

Deviation from the long-term mean

To the North of 50° northern latitude January had, on an average, negative anomalies. Near the Shetland Islands the mean pressure anomaly amounted to — 8.8 mb. The 5 mb isanomal crossed south Scotland and the German Bight. In the western part of the Channel the zero isanomal line took a course along the French coast and turned to SE to the East of Dieppe.

Table 3

Estimation of direction and force of medium anomaly winds at sea level in knots for January 1963

Channel Eastern part	South-Western North Sea	German Bight	Middle North Sea Western part	Middle North Sea Eastern part	Northern North Sea Western part	Northern North Sea Eastern part
W 8	WNW 15	W 3	W 6	W 3	WSW 9	SW 6

2. The weather conditions January 8 - February 8, 1963

An area of high pressure of 1 035 mb over south England and the Denmark Strait influenced with its wedge the British Isles and the North Sea at the beginning of the cruise, while an Atlantic storm depression of 985 mb formed to the West of the Bay of Biscay. Extensions of the perturbation reached France via the Bay of Biscay but were then turned to the northern Mediterranean. Winds from North to East between 10 and 20 knots were then registered during the first days in the southern North Sea. A secondary depression deepening to 995 mb and thus advancing from the Norwegian Sea via central Scandinavia to western Russia turned the wedge of high pressure to the West to Ireland, and caused the wind to increase on January 13 over the North Sea to 6-7 Bft. from North. The area of operation at that time covering the eastern part of the Channel was still influenced by the edge of the high pressure area where N and NW winds between 10 and 20 knots prevailed. On January 15, an anticyclone which had moved from the Bear Island region to the South increased over Scandinavia to 1 035 mb, and advancing farther to the South reached the anticyclone to the West of Ireland on January 16 via the North Sea. The east gradient, increasing in consequence in the Channel region, intensified still more as the depression, which had originally formed to the West of the Bay of Biscay, deepened again on January 17 off the Portuguese coast to 985 mb and made the extensions of the perturbation turn to the North in the direction of France. In the area of operation the E to NE wind increased on January 16 to 26 knots in the eastern part of the Channel, and on January 17 and 18 to 36 knots in the Flemish Bight. On January 19, the velocity of the wind in the south-western North Sea increased temporarily to more than 50 knots from the East and produced a wind sea with waves of 5 m in height hampering the work. The stormy east wind lessened noticeably only on January 21, as the Norwegian Sea anticyclone increasing to 1 045 mb over the North Sea moved towards south England so that the south-western North Sea came under the influence of its centre. On the north flank of this anticyclone depressions were again forming on January 23 over Iceland in the direction of the Norwegian Sea so that the velocities of the wind varied in the western part of the central North Sea between

15 and 20 knots from the West until January 25. On January 26, the wind freshened to a stormy north wind of 35 knots between a secondary depression of 1 010 mb moving via south Scandinavia and the Baltic to Russia and the anticyclone, which increased again to 1 045 mb over Ireland. The resulting wind sea of 5 m again hampered the research work.

The western North Sea was on January 27 and 28 influenced by secondary effects of the British anticyclone with NW winds between 10 and 15 knots. A line of perturbation turning to SE from the Norwegian Sea transversed the area of operation off north Scotland on January 29 and caused the wind to increase in the evening to more than 30 knots from the North. The strong northern current prevailed in the northern North Sea until January 31 and again produced a wind sea of 5 m which temporarily interrupted the work.

On the south flank of a high pressure bridge spanning from the Irminger Sea to Scandinavia the wind decreased on February 1 to 15 knots, turning East, and on February 2 to slightly shifting winds within the bridge. Under the influence of a flat North Sea depression the wind again freshened to 24 knots from the North on February 3. An extension of the storm depression of 975 mb, which on February 4 became stationary to the West of Ireland, turned NE over south England/north France and on February 6 caused strong gusty winds of 30 and 40 knots from the SE over the southern North Sea so that the cruise had a stormy end.

Table 1

Percentage frequency of velocity of winds and height of waves observed during the voyage on board of fishery research vessel "Anton Dohrn"

velocity of wind height of waves		Bft m	0	1	2	3	4	5	6	7	8	9	10	11	12
frequency	wind :		0	2	3	13	18	27	9	11	13	3	1	-	-
in %	waves :		6	46	16	10	13	9	-	-	-	-	-	-	-

Characteristic weather periods in the period under review

1) January 7-13, 1963

The large stationary anticyclone in the area Denmark Strait — Iceland — coast of north Scotland, with a wedge via the North Sea to eastern Europe, was predominant. The secondary perturbations of the east Atlantic depression turning N via the Bay of Biscay and France intensified the easterly current in the southern North Sea and the Channel. On the east flank of the anticyclone secondary perturbations of the North Scandinavian depression moving S to SE mainly influenced the northern and eastern North Sea.

2) January 14-17, 1963

The high pressure bridge spanning from the east Atlantic anticyclone via the northern North Sea to the cell of high pressure intensifying over

Scandinavia determined this weather period. The depressions pushed off to eastern Europe intensified the gradient on the SE flank of the anticyclone over the Baltic and the southern North Sea.

3) January 18-21, 1963

A strong anticyclone extending from east Greenland to the Balkans, with a nuclear pressure of 1 035 mb over the Norwegian Sea and south Scandinavia, determined the mean pressure distribution. A depression of 1 000 mb on the Portuguese coast, with extensions to the western Mediterranean, caused a strong SE current over the south-western North Sea and the Channel.

4) January 22-28, 1963

During this period the whole area was under the influence of the anticyclone of 1 040 mb over the Channel. Over the North Sea NW current components were predominant.

5) January 29-31, 1963

The Channel high had moved into the sea area to the South of Iceland, keeping the same pressure of 1 040 mb, and formed a bridge to the anticyclone of 1 030 mb over Russia. In the North Sea the N current was predominant; in the Channel the NE current.

6) February 1-3, 1963

The anticyclone of 1 040 mb to the South of the Irminger Sea was only loosely connected via Scandinavia with the anticyclone of 1 030 mb over Siberia. Over the North Sea and the Channel an east current prevailed.

7) February 4-6, 1963

A depression of 990 mb off the coast of west Ireland caused a south current over the Channel and a SE current over the North Sea, whereas between this depression and the anticyclone over east Greenland strong NE winds were blowing from the Norwegian Sea via Iceland to the central North Atlantic.

Table 2
Estimation of direction and force of medium ground wind in knots in virtue of drafted middle charts of weather periods :

Weather periods	Channel Eastern part	South-Western North Sea	German Bight	Middle North Sea Western part	Middle North Sea Eastern part	Northern North Sea Western part	Northern North Sea Eastern part
1/ 7.-13.1.63	E 15	ENE 12	NE 7	NE 9	NNE 7	N 8	NNW 12
2/ 14.-17.1.63	E 2	NNW 12	NNW 15	NNE 12	NE 22	NNE 1	light variable
3/ 18.-21.1.63	ESE 22	ESE 18	E 12	SE 14	E 12	SE 13	E 10
4/ 22.-28.1.63	ESE 13	NNW 8	NW 12	NNW 10	NW 13	WNW 13	NW 16
5/ 29.-31.1.63	NE 13	NE 9	NE 5	NE 6	NE 3	N 6	N 3
6/ 1.- 3.2.63	NE 13	NE 13	NE 14	NE 14	NE 16	NE 10	NE 7
7/ 4.- 6.2.63	SSW 13	SSW 5	light variable	S 7	light variable	SE 8	E 7

Large-scale circulation in January 1963

The uninterrupted forming of strong high pressure areas to the North of 50° N blocked the normal west circulation in the European Atlantic region in January 1963. In the mean air pressure distribution of the month, a large high reaching from Iceland to the British Isles and the North Sea, with its centre of 1 030 mb to the South of the Faeroes, was opposed by a depression of 1 010 mb to the North of the Azores with a trough of 1 015 mb in the direction of the Mediterranean. The mean pressure distribution showed the course of the Atlantic cyclones far in the South and their rise off the Portuguese coast, single secondary perturbations moving to the Mediterranean. Over Europe, the southern North Sea, and the Channel, the eastern current component prevailed; over the other parts of the North Sea the NE current component [8].

Deviation from the long-term mean

In the January mean the northern Atlantic, the Norwegian Sea, Greenland, and most of Europe were under the influence of positive pressure anomalies. At the coast of south Ireland the mean pressure anomaly amounted to + 28.5 mb. It was opposed by a weak negative anomaly in the Barentsz Sea and an anomaly centre of — 15.0 mb to the East of the Azores, with an extension of — 6 mb in the Mediterranean.

Table 3

Estimation of direction and force of medium anomaly winds at sea level in knots for January 1963

Channel Eastern part	South Western North Sea	German Bight	Middle North Sea Western part	Middle North Sea Eastern part	Northern North Sea Western part	Northern North Sea Eastern part
E 22	ENE 18	NE 15	NE 15	NE 12	NE 12	NE 11

As to the distribution of the water masses, there is little to add to the charts of plates 2-5. They represent the hydrographic conditions observed. The strong horizontal stratification of the water masses are clearly shown in the expansion processes. According to the properties the water masses had during single periods of observation, their distribution can be described as follows :

1) The distribution of the water masses, June 23 - July 23, 1959 (Plate 2)

The salinity distribution charts

Atlantic water bodies

In an eastern and western branch, Atlantic north water of more than 35 ‰ salinity advances to the North Sea between the Orkney Islands and

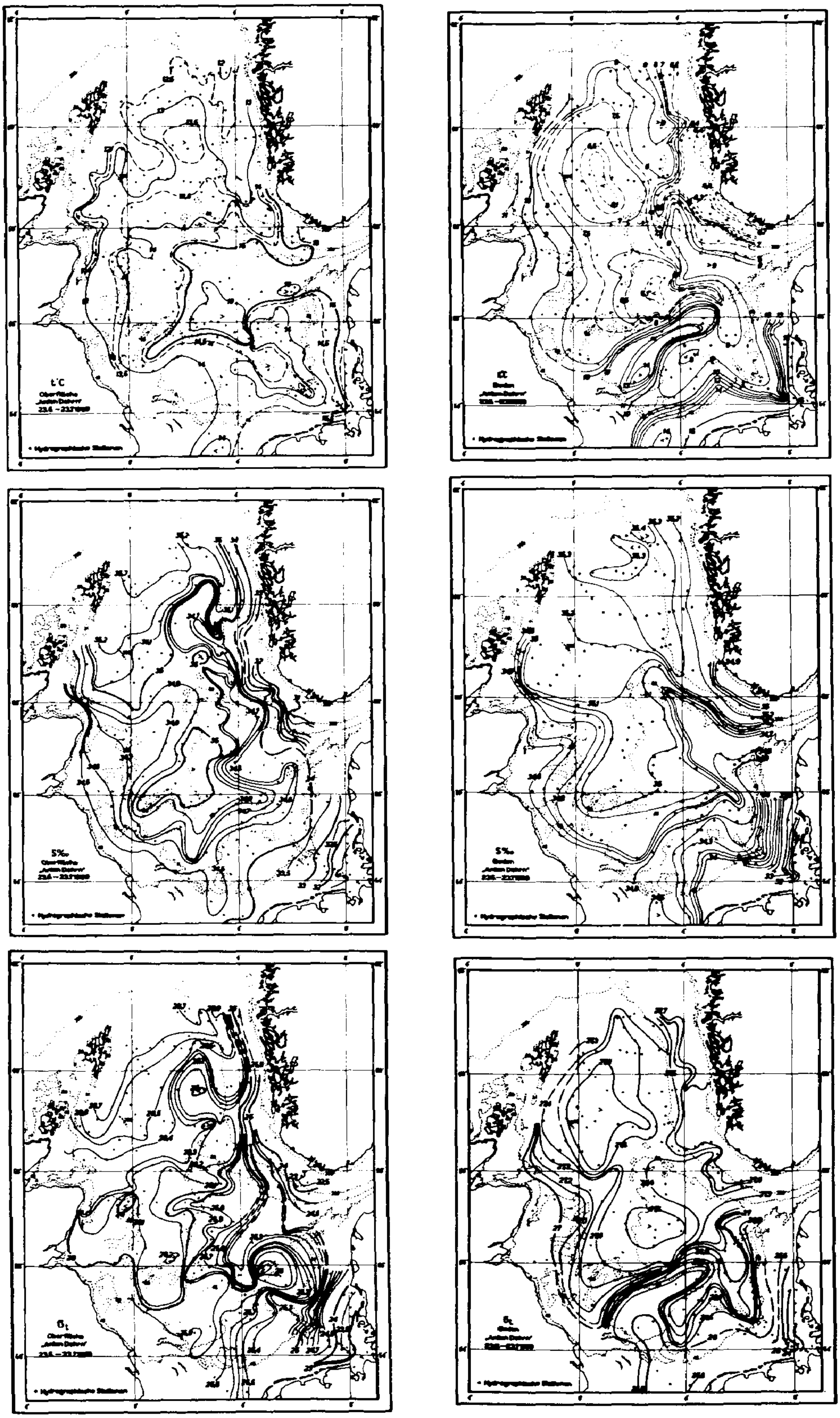


PLATE 2. — Temperature, salinity and density distribution in the North Sea at the surface and the bottom according to observations of FRV *Anton Dohrn* June 23 - July 23, 1959.

the Norwegian coast, assuming the shape of a tongue. At the surface an extensive body of residual water situated in the central part of the central North Sea and a small water body at 59° N and 2°30′ E have been severed from the western tongue. Near the bottom the western branch to the East of the 0 meridian stretches South down to 55°40′ N. It is severed at 3° E, above 58° N, from the eastern branch by North Sea water moving NW.

Central water bodies

North Sea water consisting of different water masses and forming a mixed water body of a salinity between 34 and 35 $^0/_{00}$ lies at the surface and on the bottom, the expansion varying. On the bottom it almost reaches the Scottish coast.

Coastal water bodies

a) English coastal water off the Scottish/north English coast of a salinity less than 34.5 $^0/_{00}$, a thin band parallel to the coast, only at the surface.

b) Continental coastal water off the continental coast at the surface and on the bottom between 53 and 56° N, of a salinity less than 34 $^0/_{00}$.

c) Coastal water off the Norwegian coast to the West of the Skagerrak, only at the surface, salinity less than 34 $^0/_{00}$. It is composed of Baltic water and water from the Norwegian continent. Precipitation and the inflow of fresh water caused a surplus in the eastwards increasing surface layer of the Baltic water masses which steadily moves in an outward direction until it flows as Baltic Outflow into the North Sea.

The temperature distribution charts

The range of the surface temperature variations comprises more than 4 degrees. The course of the 14.5-16.5° isotherms parallel to the continental coasts and the course of the 12° and 13° isotherms off the Scottish/north English coast are a reliable observational fact appearing again in the isohalines and the isodenses. No reliable reference can, however, be found in other surface charts for the strong tongue-shaped deviation of the 15° isotherm from the south Norwegian and Danish coasts to SW up to 0°30′ E at 55°10′ N. The two residual water bodies with temperatures of more than 16° must therefore be autochthonous. The difference of 3° in the temperature of the English coastal water off the Scottish/English coast compared with the coastal water off the south Norwegian coast can be explained by the different effects of the tidal stream turbulence. According to G. Dietrich (1954), it locally reaches velocities of more than 100 cm/sec at springs off the Scottish/English coast, and can mix the whole water column in view of the low water depth. Off the Norwegian coast the maximum velocities of the tidal streams are less than 20 cm/sec. The variation range of the bottom temperatures covers almost 10 degrees. The temperature representation of the bottom water indicates considerable horizontal differences of temperature in the Dogger Bank region, off the continental coast, and on the west flank of the Norwegian Channel. In the central part of the northern North Sea and in the central North Sea we have two cold water bodies surrounded by the 7° isotherm with temperatures of less than 6.1° in their centres. To the SE of the Dogger Bank we have another body of cold bottom water with temperatures of less than 8 degrees.

PLATE 3. — Temperature, salinity and density distribution in the North Sea at the surface and the bottom according to observations of FRV *Anton Dohrn* July 9-31, 1960.

Density distribution charts

While the density distribution at the surface depends to a great extent on the salinity, the density of the bottom water below the thermocline is determined by the temperature distribution.

2) THE DISTRIBUTION OF THE WATER MASSES, JULY 9-31, 1960 (Plate 3)

The salinity distribution charts

Atlantic water bodies

a) At the surface the western branch of the Atlantic north water and a body of residual water separated from it can be traced in the central part of the central North Sea. Near the bottom the Atlantic north water in the western part of the central North Sea almost reaches the northern edge of the Dogger Bank.
b) English Channel water of about 35 $^{0}/_{00}$ salinity covers the colder North Sea water to the West of the Isle of Texel.

Central water bodies

At the surface and on the bottom, North Sea water has different expansions between the Atlantic and the coastal water bodies.
a) English coastal water at the surface and on the bottom off the coast of north England.
b) Continental coastal water at the surface to the North of 54° N up to Hanstholm, and on the bottom from the Isle of Texel in the South to the Lim-Fjord in the North.
c) Coastal water off the south Norwegian coast.

The temperature distribution charts

The variation range of the surface temperatures covers more than 2.5°, the bottom temperature variation range more than 9 degrees. The course of the 15° isotherm in the surface water considerably deviates from the course parallel to the coast only in the eastern and western parts of the central North Sea in circa 3° E. The bottom temperature chart shows considerable horizontal differences of temperature, particularly in the Dogger Bank region. To the north of the Dogger Bank, a zone of cold bottom water with temperatures of less than 6.5 degrees extends to the Ling Bank.

The density distribution charts

At the surface the density distribution is again determined to a great extent by the salinity; on the bottom by the temperature.

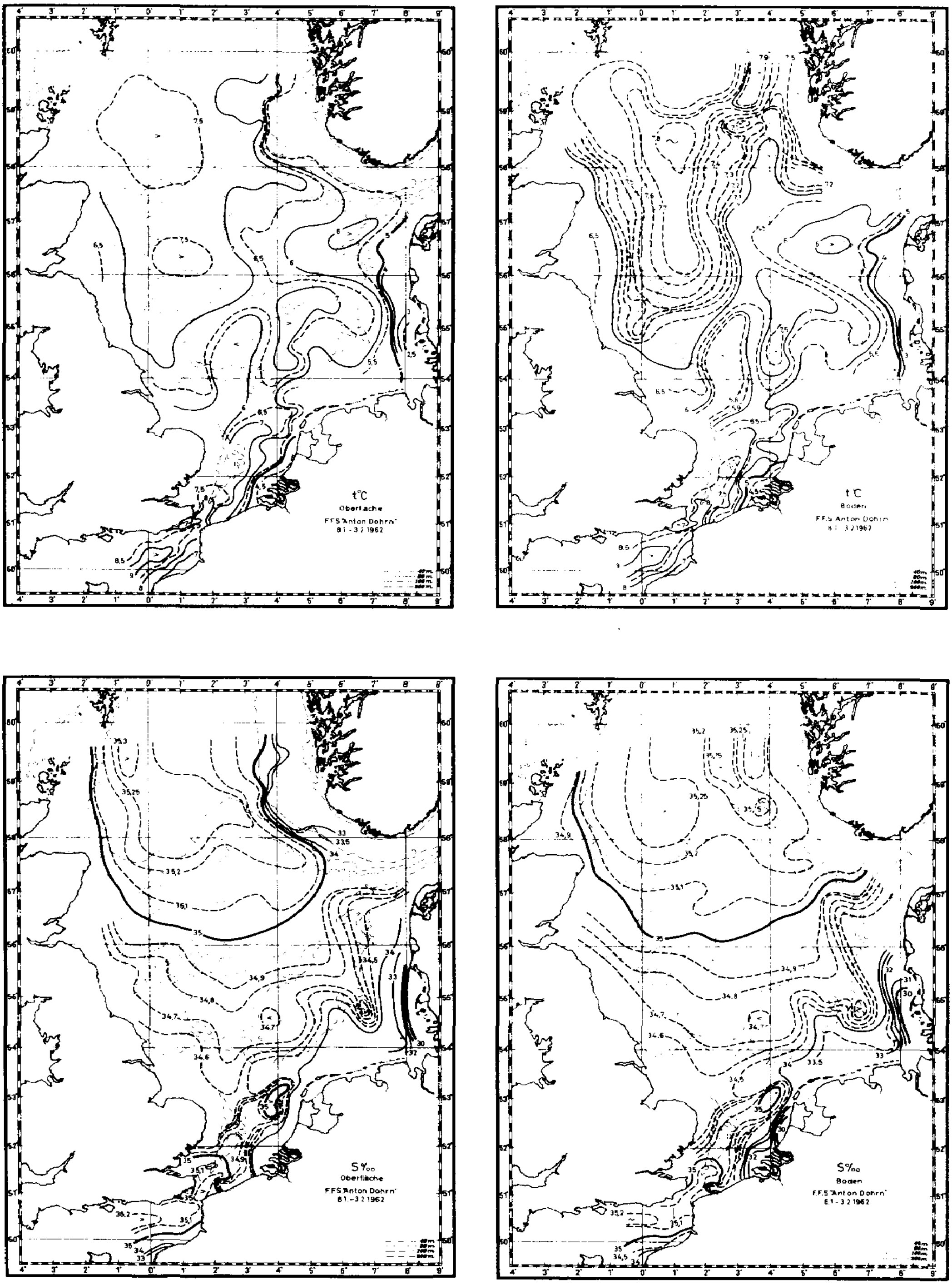


PLATE 4. — Temperature and salinity distribution in the North Sea at the surface and the bottom according to observations of FRV *Anton Dohrn* January 8 - February 3, 1962.

3) THE DISTRIBUTION OF THE WATER MASSES, JANUARY 8 - FEBRUARY 3, 1962 (Plate 4)

The salinity distribution charts

Atlantic water bodies

a) Atlantic north water advances in an extensive tongue at the surface and on the bottom to circa 56° N in the North Sea. Considerable deviations in the expansion of this water mass at the surface and on the bottom appear only in the eastern part of the northern North Sea where Atlantic north water, North Sea water, and Baltic water are very close to each other.

b) English Channel water moves in a continuous line through the Strait of Dover into the southern North Sea. In the latitude of the Isle of Texel lies a body of residual water. There are only slight deviations in the expansion of the Channel water between surface and bottom water.

Central water bodies

North Sea water with locally almost equal salinities from the surface down to the bottom between the Atlantic and the coastal water bodies.

Coastal water bodies

a) Continental coastal water between 49°30′ N and 56° N. Off the Dutch coast and the west coast of Schleswig-Holstein the salinity decreases to less than 30 $^0/_{00}$ due to the inflow of fresh water from the rivers Rhine, Meuse, and Elbe.

b) Coastal water at the surface off the Norwegian coast to the North of 58° N.

The temperature distribution charts

The range of the surface temperature variations covers 6.5° and decreases for the bottom water by circa 0.5°. The Baltic water has temperatures of less than 5.5° near the west flank. The Atlantic water body is more than 2.5° warmer on the bottom of the Norwegian Channel. The winter convection, going down to the bottom in most parts of the North Sea, is here limited to the surface layer while the water masses below the thermocline are excluded from the exchange with the surface.

4) THE DISTRIBUTION OF THE WATER MASSES, JANUARY 9 - FEBRUARY 7, 1963 (Plate 5)

The salinity distribution charts

Atlantic water bodies

a) To the East of the 0 meridian, Atlantic north water advances over latitude 56° to the South. Strong deviations in the expansion of the bottom water were observed only in the NE part of the North Sea. A small body of residual water appeared in circa 55° N and 6° E.

b) English Channel water is pushed off to the English Channel coast by French continental coastal water already to the South of the Strait of

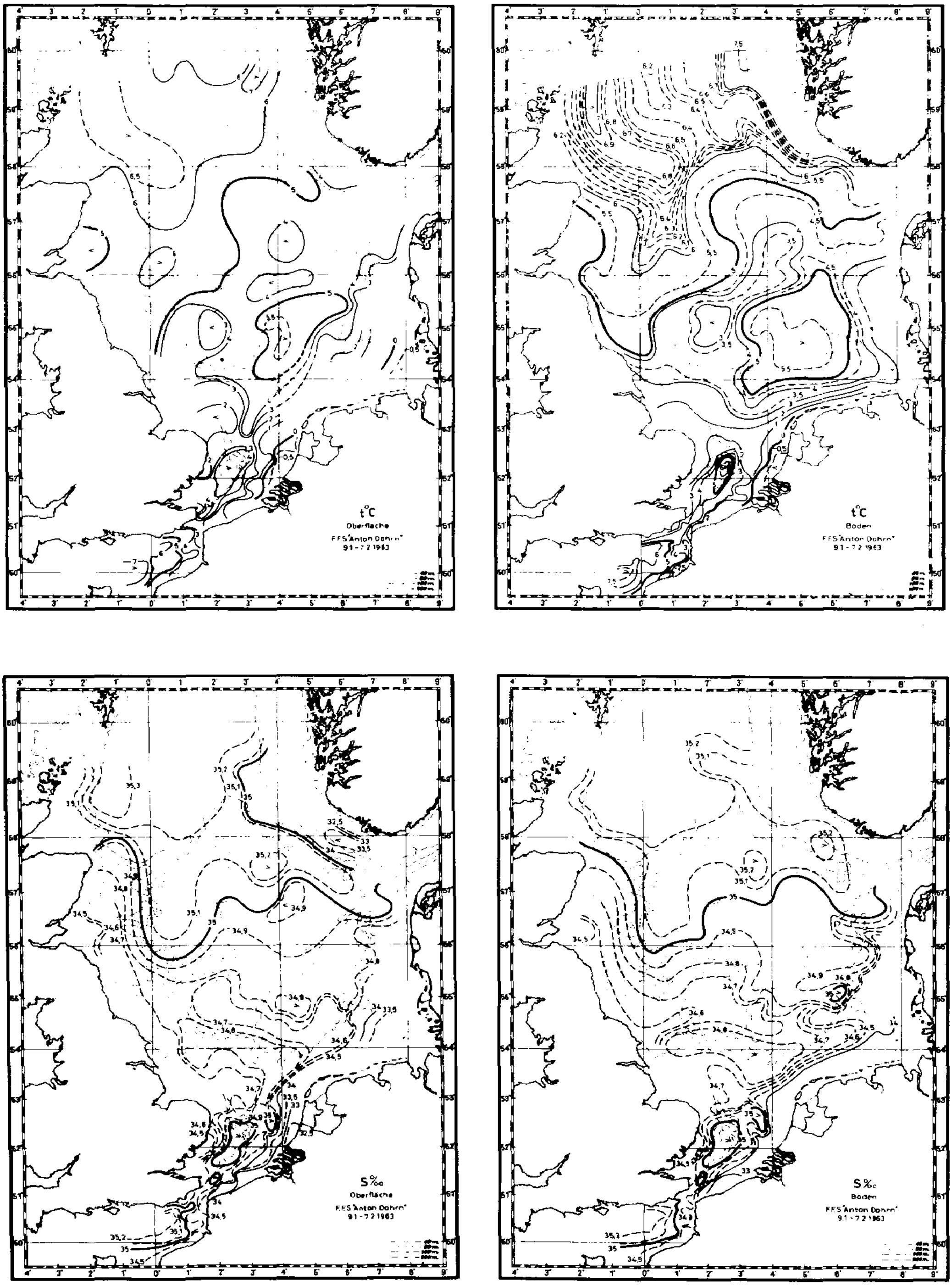


PLATE 5. — Temperature and salinity distribution in the North Sea at the surface and the bottom according to observations of FRV *Anton Dohrn* January 9 - February 7, 1963.

Dover. In the North Sea it dissolves in three residual water bodies of different expansion at the surface and on the bottom.

Central water bodies

North Sea water between the Atlantic and the coastal water bodies.

Coastal water bodies

a) English coastal water from the surface down to the bottom off the Firth of Forth.

b) Continental coastal water at the surface off the Dutch and north Frisian coasts and on the bottom off the Dutch/east Frisian coast and the north Frisian coast.

c) Coastal water at the surface off the south Norwegian coast.

The temperature distribution charts

The near surface temperature variations between the continental coastal water bodies and the Atlantic water masses range from — 0.5° to more than 7° C. The temperature charts clearly state the influence of the extremely cold winter 1962/63 which was among the first in the series of coldest winters. The frozen surface water bottles forced us to use reversing thermometers for measurements at a depth of 5 m. In the bottom water the variation range of the temperature distribution is 0.5° larger than at the surface. The Baltic Outflow to the South of 58° N transported water with temperatures of less than 4°. The Atlantic water near the bottom was more than 3° warmer in this region. Measurements of comparison near Heligoland demonstrated that the temperatures of one month decreased by circa 2.9° in the German Bight under the influence of the weather conditions and that the temperature charts of the 66th cruise can no longer be called quasi synoptic. The observed deviations of the salinity amounted near Heligoland to more than 1.0 ‰.

As regards the areas of cold bottom water (Plates 2 and 3) marked by the 7.5° isotherm, it is winter water remaining every year in the North Sea under the thermocline over spring and summer until late autumn. But the position of the bodies of cold bottom water varies a little due to the currents. Their temperatures differ from year to year depending on the preceding winter. The fisheries biologists are of the opinion that it is proved that the location of herring shoals is determined by the position of these cold water bodies, whereby temperatures of less than 6.5° C seem to have a great influence on the concentration of herring shoals (G. DIETRICH, D. SAHRHAGE and K. SCHUBERT, 1959). Should this prove true to the full extent, it would be important news for fishermen who could observe the relative bottom water temperatures when the beginning of the spawn migration is predicted half a year in advance. In late autumn the thermocline dissolves in most parts of the North Sea and the influence of the meteorological conditions reaches down to the bottom (Plates 4 and 5). Only in the region of the Baltic Outflow the density gradient remains so strong that the winterly vertical convection has its end at depths of 20-50 m.

In view of the complicated hydrographic conditions, it would consume much time with little prospect of success to construct a true chart of the currents of water masses in the North Sea. As the salinity distribution is only to a small extent determined by climatic influences but to a great extent by currents, the course of the isohalines in the salinity distribution charts of plates 2-5 may give a reliable insight into the current conditions. A comparison of the charts of periods comparable with each other shows considerable differences in the expansion of the water bodies. The temperature charts indicate that this factor is much more subject to the exchange with the atmosphere than is salinity.

The mean hydrographic conditions (Index chart and Tables 1+2)

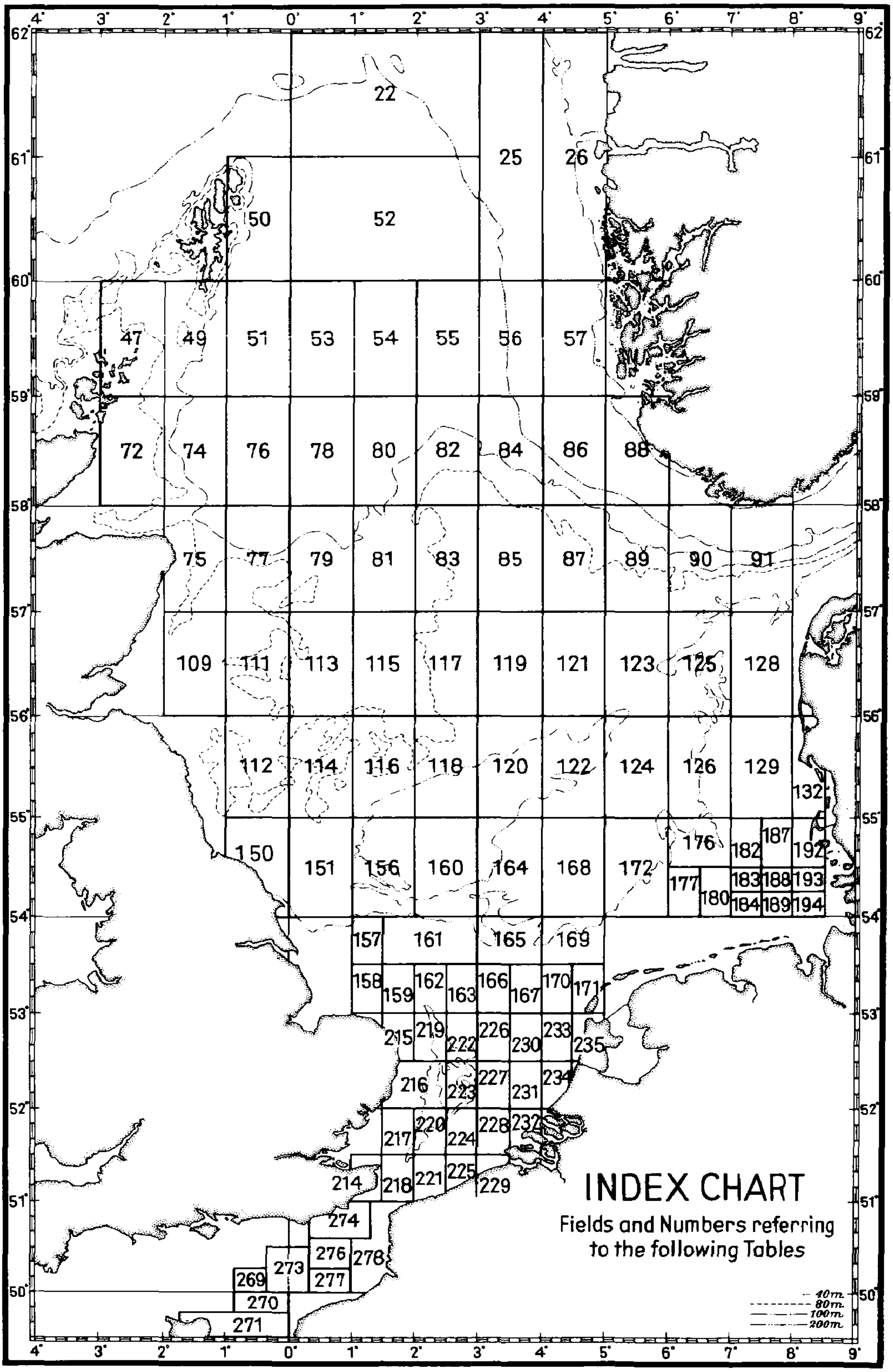
As the hydrographic data are, unfortunately, rather irregularly spread over the fields given in the index chart, they have little to say as mean values. A comparison of the computed mean values with the long-term mean of the surface values of 1905-54 (G. Dietrich, 1962) and with the mean bottom water temperatures of 1902-54 (G. Tomczak and E. Goedecke, 1962) (*), as well as a comparison of the mean values of the comparable periods, is the object of the two tables.

From 1910 to 1940 a considerable heating up affected large sections of the northern hemisphere. The results of this heating — a shift to the North of fish appearances and catching grounds — can still be observed. This effect was caused by large-scale variations of the pressure and wind conditions in the atmosphere. Thus the frequency of the blocking areas of high pressure between Iceland and Finland causing, as you know, the severe winter of 1962/63 has varied during the last 80 years in a cycle of 20 years (H. Flohn, 1963). In the North Sea the investigation of the commercial fish problem has become an urgent scientific need with considerable economic consequences. It is now believed that the mean effect of the weather situations is the main reason for the unsteadiness, the frequent migration, and the instability of herring shoals. The present climatic fluctuation is marked by an intensified meridional air circulation over the North Atlantic and is followed by a more marked activity of cyclones over the North Sea. The effects are said to result in a stronger inflow of alien Atlantic water into the North Sea. The mean hydrographic conditions in the Atlantic water bodies of some selected fields were subjected to a quantitative analysis :

1) Field No. 78 in the western branch of the North Atlantic water showed mean increases of the surface and bottom water temperatures ranging between + 0.21 and + 0.83° in July 1959/60 and decreases to + 0.04 - + 0.16° C in January 1962. The salinity values were up to — 0.03 ‰ below the long-term mean. In January 1963 the negative temperature anomaly amounted to — 0.92° at the surface and — 0.73° on the bottom. The surface salinity surpassed the 50 years' mean by 0.06 ‰.

2) In July 1960 and January 1962, Field No. 56 in the eastern branch of the North Atlantic water had mean temperature anomalies of + 0.97 and + 0.04° in the surface water. The mean negative anomaly of July 1959 was — 0.55°. In the bottom water the anomalies of July 1959/60 and

(*) I have to thank Drs. G. Tomczak and E. Goedecke, GHI, Hamburg, for placing at my disposal their still-unpublished mean values of the bottom water temperatures.


INDEX CHART
Fields and Numbers referring to the following Tables
40m
80m
100m
200m

Hydrographic Investigations in the North Sea
in July 1959/60
Means of the Surface Temperature and Salinity

Field No.	Means July	Means Cruise I	Δt°C I - July	Means Cruise II	Δt°C II - July	Means July	Means Cruise I	S‰ I - July	Means Cruise II	S‰ II - July
22	13.06	12.59	-0.48	-	-	34.87	35.28	+0.41	-	-
25	12.61	12.35	-0.26	-	-	33.16	34.91	+1.75	-	-
26	13.27	12.78	-0.49	-	-	30.57	34.90	+4.33	-	-
50	11.88	12.38	+0.50	-	-	35.29	35.33	+0.04	-	-
52	12.55	12.75	+0.20	-	-	34.97	35.26	+0.29	-	-
47	11.45	11.40	-0.05	13.06	+1.61	35.00	34.80	-0.20	34.77	-0.23
49	11.51	11.68	+0.17	13.34	+1.83	35.20	35.18	-0.02	35.13	-0.07
51	12.48	13.03	+0.55	13.58	+1.10	35.18	35.20	+0.02	35.17	-0.01
53	12.96	12.88	-0.08	13.83	+0.87	35.07	35.13	+0.06	35.08	+0.01
54	12.83	13.14	+0.31	13.95	+1.12	34.65	34.99	+0.34	35.10	+0.45
55	13.44	13.78	+0.34	14.24	+0.80	33.64	34.65	+1.01	34.40	+0.76
56	13.57	13.02	-0.55	14.54	+0.97	32.43	34.73	+2.30	34.23	+1.80
57	13.85	12.92	-0.93	-	-	31.02	33.73	+2.71	-	-
72	11.86	11.77	-0.09	12.80	+0.94	34.83	34.67	-0.16	34.67	-0.16
74	12.24	12.26	+0.02	13.39	+1.15	35.02	34.92	-0.10	34.82	-0.20
76	12.93	13.14	+0.21	13.76	+0.83	35.09	35.08	-0.01	35.06	-0.03
78	13.15	13.12	-0.03	13.84	+0.69	34.97	35.04	+0.07	34.63	-0.34
80	13.72	13.54	-0.18	14.06	+0.34	34.92	34.92	0.00	34.91	-0.01
82	13.40	13.34	-0.06	14.12	+0.72	34.49	34.96	+0.47	34.23	-0.26
84	13.96	13.60	-0.06	14.25	+0.39	33.12	34.87	+1.75	34.05	+0.93
86	13.89	13.02	-0.87	14.77	+0.88	31.21	32.96	+1.75	32.90	+1.69
88	14.30	14.52	+0.22	14.80	+0.50	30.62	31.83	+1.21	32.82	+2.20
75	12.04	12.08	+0.04	13.02	+0.98	34.77	34.68	-0.09	34.66	-0.11
77	13.11	13.79	+0.68	13.38	+0.27	34.95	34.77	-0.18	34.74	-0.19
79	13.71	13.95	+0.24	13.64	-0.07	34.93	34.86	-0.07	34.95	+0.02
81	13.60	14.70	+1.10	13.30	-0.30	34.92	34.90	-0.02	35.05	+0.13
83	13.71	15.46	+1.75	13.35	-0.36	34.76	34.92	+0.16	34.99	+0.23
85	13.59	14.71	+1.12	13.71	+0.12	34.21	34.91	+0.70	34.07	-0.14
87	13.95	14.67	+0.72	15.62	+1.67	33.60	34.66	+1.06	33.47	-0.13
89	14.51	14.71	+0.20	15.35	+0.84	32.86	32.81	-0.05	33.30	+0.44
90	14.75	15.73	+0.98	15.56	+0.81	31.13	31.26	+0.13	33.31	+2.18
91	14.91	-	-	15.97	+1.06	30.44	-	-	34.27	+3.83
109	12.70	13.15	+0.45	12.96	+0.26	34.64	34.52	-0.12	34.61	-0.03
111	13.35	13.65	+0.30	13.37	+0.02	34.86	34.64	-0.22	34.76	-0.10
113	13.73	14.04	+0.31	14.34	+0.61	34.92	34.84	-0.08	34.89	-0.03
115	13.76	14.24	+0.48	13.80	+0.04	34.90	34.99	+0.09	35.02	+0.12
117	13.95	16.16	+2.21	13.21	-0.74	34.87	35.01	+0.14	35.02	+0.15
119	14.04	15.95	+1.91	13.46	-0.58	34.76	34.87	+0.11	34.74	-0.02
121	14.33	15.68	+1.35	13.12	-1.21	34.55	34.35	-0.20	34.84	+0.29
123	14.29	15.10	+0.81	14.61	+0.32	34.29	34.38	+0.09	34.55	+0.26
125	14.84	16.31	+1.47	14.12	-0.72	33.95	34.40	+0.45	34.21	+0.26
128	15.15	-	-	16.24	+1.09	33.66	-	-	34.14	+0.48
112	13.71	15.11	+1.40	13.72	+0.01	34.65	34.77	+0.12	34.59	-0.06
114	14.01	14.37	+0.36	14.36	+0.35	34.76	34.90	+0.14	34.79	+0.03
116	14.07	14.75	+0.68	13.99	-0.08	34.89	34.92	+0.03	34.81	-0.08
118	14.23	16.03	+1.80	-	-	34.93	35.02	+0.09	-	-
120	14.27	15.74	+1.47	14.00	-0.27	34.83	34.84	+0.01	34.76	-0.07
122	14.70	14.58	-0.12	13.88	-0.82	34.75	34.64	-0.11	34.61	-0.14
124	15.03	14.43	-0.60	12.90	-2.13	34.70	34.50	-0.20	34.60	-0.10
126	15.08	14.07	-1.01	12.86	-2.22	34.37	34.04	-0.33	34.45	+0.08
129	15.40	14.84	-0.56	14.50	-0.90	32.92	33.08	+0.16	33.42	+0.50
132	17.41	15.83	-1.58	15.61	-1.80	31.35	32.18	+0.83	32.88	+1.53
150	13.39	-	-	15.77	+2.36	34.33	-	-	34.46	+0.13
151	13.49	14.09	+0.60	13.51	+0.02	34.49	34.67	+0.18	34.60	+0.11
156	13.86	13.93	+0.07	13.23	-0.63	34.69	34.55	-0.14	34.69	0.00
160	14.66	13.87	-0.79	15.04	+0.36	34.79	34.61	-0.18	34.80	+0.01
164	14.86	14.12	-0.74	13.62	-1.24	34.71	34.38	-0.33	34.65	-0.06
168	14.97	14.07	-0.90	13.26	-1.71	34.55	34.10	-0.45	34.58	+0.03
172	15.20	14.87	-0.33	13.80	-1.40	34.52	34.35	-0.17	34.56	+0.04
176	14.63	14.02	-0.61	13.25	-1.38	33.87	33.52	-0.35	34.03	+0.16
177	15.63	13.80	-1.83	13.32	-2.31	34.02	33.42	-0.60	34.37	+0.35
180	16.64	14.54	-2.10	13.60	-3.04	33.85	33.28	-0.57	33.74	-0.11
182	15.70	-	-	-	-	33.13	-	-	-	-
183	15.47	13.95	-1.52	14.20	-1.27	33.34	32.70	-0.64	33.01	-0.33
184	15.76	14.22	-1.54	-	-	33.54	32.55	-0.99	32.60	-0.94
187	16.60	-	-	-	-	30.97	-	-	-	-
188	16.53	14.66	-1.87	14.36	-2.17	31.74	31.66	-0.08	32.48	+0.74
189	16.19	14.59	-1.60	14.51	-1.68	31.72	31.50	-0.22	32.11	+0.39
192	17.22	15.95	-1.27	15.62	-1.60	31.41	31.50	+0.09	32.39	+0.96
193	17.24	15.97	-1.27	15.51	-1.73	31.41	31.22	-0.19	32.36	+0.95
194	17.53	15.37	-2.16	14.38	-3.15	29.32	31.29	+1.97	31.41	+2.09
157	13.15	-	-	12.95	-0.20	34.54	-	-	34.69	+0.15
161	13.47	14.15	+0.68	15.06	+1.59	34.73	34.53	-0.20	34.68	-0.05
162	14.24	-	-	14.32	+0.08	34.54	-	-	34.68	+0.14
163	14.54	-	-	15.00	+0.46	34.49	-	-	34.49	0.00
165	14.55	-	-	13.93	-0.62	34.59	-	-	34.50	-0.09
166	14.27	13.87	-0.40	14.75	+0.48	34.37	34.36	-0.01	34.39	+0.02
167	14.85	-	-	-	-	34.72	-	-	-	-
169	15.25	-	-	14.49	-0.76	34.39	-	-	34.48	+0.09
170	15.00	14.98	-0.02	15.26	+0.26	34.51	34.42	-0.09	35.08	+0.57
226	14.43	14.40	-0.03	-	-	34.55	34.90	+0.35	-	-
227	14.72	14.40	-0.32	-	-	34.33	34.90	+0.57	-	-
230	15.07	14.58	-0.49	15.06	-0.01	34.33	34.77	+0.44	35.10	+0.77

Hydrographic Investigations in the North Sea
in July 1959/60
Means of the Bottom Temperatures

Field No.	Means July	Means Cruise I	Δt°C I - July	Means Cruise II	Δt°C II - July	Δt°C I - II
22	7.8	8.73	+0.93	-	-	-
25	7.2	7.66	+0.46	-	-	-
26	6.5	7.17	+0.67	-	-	-
50	8.8	9.89	+1.09	-	-	-
52	7.5	8.25	+0.75	-	-	-
47	10.3	11.10	+0.80	11.07	+0.77	+0.03
49	9.2	7.86	-1.34	8.57	-0.63	-0.71
51	7.2	6.84	-0.36	6.90	-0.30	-0.06
53	6.7	6.63	-0.07	6.70	0.00	-0.07
54	6.8	6.74	-0.06	6.89	+0.09	-0.15
55	7.3	8.20	+0.90	8.04	+0.74	+0.16
56	7.3	8.40	+1.10	8.33	+1.03	+0.07
57	6.3	6.42	+0.12	-	-	-
72	10.0	10.79	+0.79	10.32	+0.32	+0.47
74	8.4	10.00	+1.60	9.67	+1.27	+0.33
76	7.2	7.83	+0.63	7.58	+0.38	+0.25
78	6.7	6.62	-0.08	6.66	-0.04	-0.04
80	6.7	7.01	+0.31	6.67	-0.03	+0.34
82	6.6	7.12	+0.52	7.26	+0.66	-0.14
84	6.8	7.45	+0.65	7.32	+0.52	+0.13
86	6.4	6.70	+0.30	6.49	+0.09	+0.21
88	6.5	6.27	-0.23	6.44	-0.06	-0.17
75	9.5	10.08	+0.58	9.86	+0.36	+0.22
77	8.4	8.59	+0.19	8.38	-0.02	+0.21
79	7.6	7.50	-0.10	7.11	-0.49	+0.39
81	6.8	6.92	+0.12	6.53	-0.27	+0.39
83	6.6	7.18	+0.58	6.76	+0.16	+0.42
85	6.7	7.30	+0.60	7.32	+0.62	-0.02
87	6.7	7.41	+0.71	7.18	+0.48	+0.23
89	6.9	7.35	+0.45	7.43	+0.53	-0.08
90	6.4	6.73	+0.33	6.89	+0.49	-0.16
91	7.0	-	-	11.88	+4.88	-
109	9.2	8.70	-0.50	10.08	+0.88	-1.38
111	7.9	8.13	+0.23	8.62	+0.72	-0.49
113	7.2	7.60	+0.40	7.32	+0.12	+0.28
115	6.6	6.92	+0.32	6.70	+0.10	+0.22
117	6.4	6.16	-0.24	6.80	+0.40	-0.64
119	6.4	6.45	+0.05	6.80	+0.40	-0.35
121	6.8	7.06	+0.26	6.38	-0.42	+0.68
123	7.7	8.86	+1.16	9.42	+1.72	-0.56
125	9.2	9.23	+0.03	10.66	+1.46	-1.43
128	11.1	-	-	12.72	+1.62	-
112	7.4	7.68	+0.28	7.56	+0.16	+0.12
114	7.2	7.60	+0.40	7.64	+0.44	-0.04
116	8.1	8.60	+0.50	8.84	+0.74	-0.24
118	9.1	7.09	-2.01	-	-	-
120	9.8	10.91	+1.11	9.92	+0.12	+0.99
122	8.8	10.01	+1.21	9.87	+1.07	+0.14
124	8.3	8.07	-0.23	9.06	+0.76	-0.99
126	10.5	8.20	-2.30	11.74	+1.24	-3.54
129	13.8	13.44	-0.36	14.15	+0.35	-0.71
132	15.8	15.96	+0.16	15.52	-0.28	+0.44
150	9.4	-	-	8.39	-1.01	-
151	9.3	8.31	-0.99	9.52	+0.22	-1.21
156	12.1	11.57	-0.53	12.04	-0.06	-0.47
160	12.7	12.81	+0.11	13.26	+0.56	-0.45
164	10.5	8.48	-2.02	10.60	+0.10	-2.12
168	10.8	9.05	-1.75	10.68	-0.12	-1.63
172	11.8	9.60	-2.20	12.85	+1.05	-3.25
176	11.4	8.87	-2.53	12.51	+1.11	-3.64
177	12.4	10.53	-1.87	13.19	+0.79	-2.66
180	13.7	9.52	-4.18	13.22	-0.48	-3.70
182	11.8	-	-	-	-	-
183	13.4	9.54	-3.86	13.92	+0.52	-4.38
184	13.4	10.66	-2.74	13.79	+0.39	-3.13
187	14.3	-	-	-	-	-
188	14.4	11.79	-2.65	14.06	-0.34	-2.27
189	14.4	11.87	-2.53	14.09	-0.31	-2.22
192	16.7	15.89	-0.81	15.62	-1.08	+0.27
193	16.0	15.92	-0.08	15.60	-0.40	+0.32
194	16.0	14.52	-1.48	14.27	-1.73	+0.25
157	12.4	-	-	12.88	+0.48	-
161	13.1	14.03	+0.93	14.80	+1.70	-0.77
162	14.1	-	-	14.30	+0.20	-
163	13.5	-	-	14.92	+1.42	-
165	12.6	-	-	13.78	+1.18	-
166	14.1	13.88	-0.22	14.89	+0.79	-1.01
167	14.2	-	-	-	-	-
169	13.8	-	-	14.53	+0.73	-
170	15.0	14.98	-0.02	14.96	-0.04	+0.02
226	15.4	14.01	-1.39	-	-	-
227	15.4	14.01	-1.39	-	-	-
230	15.4	14.44	-0.96	14.88	-0.52	-0.44

Hydrographic Investigations in the North Sea
in July 1959/60
Means of the Surface Temperature and Salinity

Field No.	Cruise No. I	Cruise No. II	Δt°C I-II	Cruise No. I	Cruise No. II	S‰ I-II
22	12.58	-	-	35.28	-	-
25	12.35	-	-	34.91	-	-
26	12.78	-	-	34.90	-	-
50	12.38	-	-	35.33	-	-
52	12.75	-	-	35.26	-	-
47	11.40	13.06	-1.66	34.80	34.77	+0.03
49	11.68	13.34	-1.66	35.18	35.13	+0.05
51	13.03	13.58	-0.55	35.20	35.17	+0.03
53	12.88	13.83	-0.95	35.13	35.08	+0.05
54	13.14	13.95	-0.81	34.99	35.10	-0.11
55	13.78	14.24	-0.46	34.65	34.40	+0.25
56	13.02	14.54	-1.52	34.73	34.23	+0.50
57	12.92	-	-	33.73	-	-
72	11.77	12.80	-1.03	34.67	34.67	0.00
74	12.26	13.39	-1.13	34.92	34.82	+0.10
76	13.14	13.76	-0.62	35.08	35.06	+0.02
78	13.12	13.84	-0.72	35.04	34.63	+0.41
80	13.54	14.06	-0.52	34.92	34.91	+0.01
82	13.34	14.12	-0.78	34.96	34.23	+0.73
84	13.80	14.25	-0.45	34.87	34.05	+0.82
86	13.02	14.77	-1.75	32.96	32.90	+0.06
88	14.52	14.80	-0.28	31.83	32.82	-0.99
75	12.08	13.02	-0.94	34.68	34.66	+0.02
77	13.79	13.38	+0.41	34.77	34.74	+0.03
79	13.95	13.64	+0.31	34.86	34.95	-0.09
81	14.70	13.30	+1.40	34.90	35.05	-0.15
83	15.46	13.35	+2.11	34.92	34.99	-0.07
85	14.71	13.71	+1.00	34.91	34.07	+0.84
87	14.67	15.62	-0.95	34.66	33.47	+1.19
89	14.71	15.35	-0.64	32.81	33.30	-0.49
90	15.73	15.56	+0.17	31.26	33.31	-2.05
91	-	15.97	-	-	34.27	-
109	13.15	12.96	+0.19	34.52	34.61	-0.09
111	13.65	13.37	+0.28	34.64	34.76	-0.12
113	14.04	14.34	-0.30	34.84	34.89	-0.05
115	14.24	13.80	+0.44	34.99	35.02	-0.03
117	16.16	13.21	+2.95	35.01	35.02	-0.01
119	15.95	13.46	+2.49	34.87	34.74	+0.13
121	15.68	13.12	+2.56	34.35	34.84	-0.49
123	15.10	14.61	+0.49	34.38	34.55	-0.17
125	16.31	14.12	+2.19	34.40	34.21	+0.19
128	-	16.24	-	-	34.14	-
112	15.11	13.72	+1.39	34.77	34.59	+0.18
114	14.37	14.36	+0.01	34.90	34.79	+0.11
116	14.75	13.99	+0.76	34.92	34.81	+0.11
118	16.03	-	-	35.02	-	-
120	15.74	14.00	+1.74	34.84	34.76	+0.08
122	14.58	13.88	+0.70	34.64	34.61	+0.03
124	14.43	12.90	+1.53	34.50	34.60	-0.10
126	14.07	12.86	+1.21	34.04	34.45	-0.41
129	14.84	14.50	+0.34	33.08	33.42	-0.34
132	15.83	15.61	+0.22	32.18	32.88	-0.70
150	-	15.77	-	-	34.46	-
151	14.09	13.51	+0.58	34.67	34.60	+0.07
156	13.93	13.23	+0.70	34.55	34.69	-0.14
160	13.87	15.04	-1.17	34.61	34.80	-0.19
164	14.12	13.62	+0.50	34.38	34.65	-0.27
168	14.07	13.26	+0.81	34.10	34.58	-0.48
172	14.87	13.80	+1.07	34.35	34.56	-0.21
176	14.02	13.25	+0.77	33.52	34.03	-0.51
177	13.80	13.32	+0.48	33.42	34.37	-0.95
180	14.54	13.60	+0.94	33.28	33.74	-0.46
182	-	-	-	-	-	-
183	13.95	14.20	-0.25	32.70	33.01	-0.31
184	14.22	-	-	32.55	32.60	-0.05
187	-	-	-	-	-	-
188	14.66	14.36	+0.30	31.66	32.48	-0.82
189	14.59	14.51	+0.08	31.50	32.11	-0.61
192	15.95	15.62	+0.33	31.50	32.39	-0.89
193	15.97	15.51	+0.46	31.22	32.36	-1.14
194	15.37	14.38	+0.99	31.29	31.41	-0.12
157	-	12.95	-	-	34.69	-
161	14.15	15.06	-0.91	34.53	34.68	-0.15
162	-	14.32	-	-	34.68	-
163	-	15.00	-	-	34.49	-
165	-	13.93	-	-	34.50	-
166	13.87	14.75	-0.88	34.36	34.39	-0.03
167	-	-	-	-	-	-
169	-	14.49	-	-	34.48	-
170	14.98	15.26	-0.28	34.42	35.08	-0.66
226	14.40	-	-	34.90	-	-
227	14.40	-	-	34.90	-	-
230	14.58	15.06	-0.48	34.77	35.10	-0.33

Hydrographic Investigations in the North Sea
in January 1962/63
Means of the Surface Temperatures and Salinity.

Field No.	Means January	Means Cruise III	Δt°C III - January	Means Cruise IV	Δt°C IV - January	Means January	Means Cruise III	S‰ III - January	Means Cruise IV	S‰ IV - January
47	7.69	7.30	-0.39	6.50	-1.19	35.08	34.88	-0.20	35.09	+0.01
49	7.36	7.50	+0.14	6.65	-0.71	35.19	35.24	+0.05	35.31	+0.12
51	7.33	7.60	+0.27	6.12	-1.21	35.25	35.30	+0.05	35.26	+0.01
53	7.40	7.38	-0.02	6.03	-1.37	35.29	35.25	-0.04	35.26	-0.03
54	7.17	7.37	+0.20	6.16	-1.01	35.24	35.25	+0.01	35.28	+0.04
55	7.13	7.08	-0.05	6.00	-1.13	35.22	35.12	-0.10	35.07	-0.15
56	7.08	7.12	+0.04	7.01	-0.07	34.66	34.60	-0.06	35.17	+0.51
57	6.13	5.88	-0.25	-	-	32.42	33.05	+0.63	-	-
72	7.09	7.20	+0.11	6.25	-0.84	34.83	34.90	+0.07	35.10	+0.27
74	7.38	7.50	+0.12	6.82	-0.56	35.07	35.18	+0.11	35.31	+0.24
76	7.47	7.51	+0.04	6.55	-0.92	35.21	35.21	0.00	35.27	+0.06
78	7.11	7.74	+0.63	6.53	-0.58	35.23	35.29	+0.06	35.25	+0.02
80	7.44	7.60	+0.16	6.33	-1.11	35.21	35.27	+0.06	35.22	+0.01
82	7.26	7.18	-0.08	5.94	-1.32	35.04	35.20	+0.16	35.14	+0.10
84	6.63	6.72	+0.09	6.07	-0.56	34.84	34.64	-0.20	34.99	+0.15
86	6.23	-	-	-	-	33.61	-	-	-	-
88	5.41	5.50	+0.09	3.56	-1.85	32.66	33.52	+0.86	33.02	+0.36
75	6.75	7.02	+0.27	5.98	-0.77	34.62	35.00	+0.38	34.91	+0.29
77	7.48	7.30	-0.18	5.85	-1.63	35.09	35.11	+0.02	35.03	-0.06
79	6.56	7.60	+1.04	6.32	-0.24	35.08	35.26	+0.18	35.13	+0.05
81	7.56	7.38	-0.18	5.62	-1.94	35.10	35.15	+0.05	35.11	+0.01
83	7.11	7.20	+0.09	4.81	-2.30	35.06	35.18	+0.12	35.06	0.00
85	6.65	6.78	+0.13	4.71	-1.94	35.03	35.17	+0.14	35.24	+0.21
87	6.05	6.95	+0.90	4.87	-1.18	34.92	35.21	+0.29	35.06	+0.14
89	6.03	6.20	+0.17	4.33	-1.70	34.52	34.67	+0.15	34.55	+0.03
90	5.94	5.70	-0.24	4.40	-1.54	34.36	34.97	+0.61	34.27	-0.09
91	5.46	6.00	+0.54	4.68	-0.78	33.24	34.72	+1.48	34.98	+1.74
109	6.75	6.40	-0.35	5.17	-1.58	34.69	34.62	-0.07	34.65	-0.04
111	7.29	7.10	-0.19	5.68	-1.61	34.97	34.93	-0.04	34.92	-0.05
113	7.49	7.55	+0.06	6.14	-1.35	35.04	34.99	-0.05	35.09	+0.05
115	7.24	7.52	+0.28	5.82	-1.42	34.99	35.06	+0.07	35.02	+0.03
117	6.81	7.05	+0.24	4.93	-1.88	34.98	35.08	+0.10	34.96	-0.02
119	6.42	6.67	+0.25	4.50	-1.92	34.92	35.07	+0.15	34.96	+0.04
121	6.13	5.98	-0.15	3.52	-2.61	34.89	35.05	+0.16	34.90	+0.01
123	6.23	5.88	-0.35	4.63	-1.60	34.86	34.78	-0.08	34.91	+0.05
125	5.91	-	-	4.40	-1.51	34.68	-	-	34.91	+0.23
128	5.39	5.39	0.00	4.69	-0.70	34.58	34.51	-0.07	34.97	+0.39
112	7.08	7.10	+0.02	5.21	-1.87	34.77	34.72	-0.05	34.70	-0.07
114	7.06	7.31	+0.25	4.95	-2.11	34.87	34.78	-0.09	34.82	-0.05
116	6.82	7.00	+0.18	3.81	-3.01	34.97	34.86	-0.11	34.73	-0.24
118	6.36	-	-	4.57	-1.79	34.92	-	-	34.84	-0.08
120	6.04	6.40	+0.36	4.30	-1.74	34.90	34.85	-0.05	34.85	-0.05
122	6.11	7.20	+1.09	4.04	-2.07	34.79	34.71	-0.08	34.90	+0.11
124	6.14	6.92	+0.78	5.18	-0.96	34.81	34.75	-0.06	34.84	+0.03
126	5.91	-	-	3.17	-2.74	34.67	-	-	34.91	+0.24
129	5.05	3.82	-1.23	-	-	34.10	32.78	-1.32	-	-
150	6.53	7.20	+0.67	5.03	-1.50	34.57	34.66	+0.09	34.70	+0.13
151	6.42	6.88	+0.46	4.01	-2.41	34.65	34.60	-0.05	34.73	+0.08
156	6.35	6.70	+0.35	3.51	-2.84	34.74	34.54	-0.20	34.76	+0.02
160	6.08	5.90	-0.18	4.03	-2.05	34.74	34.70	-0.04	34.82	+0.08
164	6.11	6.40	+0.29	5.26	-0.85	34.69	34.68	-0.01	34.81	+0.12
168	6.29	7.32	+1.03	5.47	-0.82	34.61	34.74	+0.13	34.76	+0.15
172	6.06	-	-	2.38	-3.68	34.70	-	-	34.40	-0.30
176	5.46	6.58	+1.12	3.82	-1.64	34.31	34.74	+0.43	34.58	+0.27
177	6.38	6.20	-0.18	4.61	-1.77	34.51	33.58	-0.93	34.66	+0.15
180	6.08	-	-	2.70	-3.38	34.12	-	-	34.13	+0.01
182	5.94	-	-	-	-	34.13	-	-	-	-
183	5.44	5.40	-0.04	2.13	-3.31	33.85	33.98	+0.13	33.84	-0.01
184	7.31	-	-	-	-	34.22	-	-	-	-
187	3.91	-	-	-	-	31.25	-	-	-	-
188	6.18	5.05	-1.13	2.71	-3.47	33.90	33.33	-0.57	33.76	-0.14
189	5.11	5.18	+0.07	1.83	-3.28	32.96	33.44	+0.48	33.58	+0.62
192	-	2.40	-	-	-	-	29.39	-	-	-
157	6.88	6.41	-0.47	-	-	34.67	34.56	-0.11	-	-
158	6.05	-	-	-	-	34.46	-	-	-	-
159	5.94	-	-	-	-	34.65	-	-	-	-
161	7.21	6.23	-0.98	2.70	-4.51	34.65	34.59	-0.06	34.76	+0.11
162	6.29	-	-	-	-	34.59	-	-	-	-
163	6.34	-	-	2.86	-3.48	34.60	-	-	34.68	+0.08
165	6.05	6.45	+0.40	4.06	-1.99	34.81	34.48	-0.33	34.80	-0.01
166	6.50	6.15	-0.35	-	-	34.80	34.40	-0.40	-	-
167	6.80	-	-	-	-	34.85	-	-	-	-
169	6.15	5.70	-0.45	3.21	-2.94	34.47	34.38	-0.09	34.86	+0.39
170	6.93	6.60	-0.33	-	-	34.82	35.00	+0.18	-	-
171	5.76	5.10	-0.66	-	-	33.25	31.86	-1.39	-	-
215	5.70	-	-	2.11	-3.59	34.16	-	-	34.75	+0.59
216	7.71	-	-	1.24	-6.47	34.87	-	-	34.38	-0.49
219	6.04	-	-	2.61	-3.43	34.42	-	-	34.78	+0.32
222	6.82	-	-	2.06	-4.76	34.85	-	-	34.61	-0.24
223	7.87	7.52	-0.35	4.36	-3.51	35.00	34.89	-0.11	35.13	+0.13
226	7.30	7.00	-0.30	2.89	-4.41	34.94	34.83	-0.11	34.82	-0.12
227	6.90	6.30	-0.60	1.62	-5.28	34.87	34.75	-0.12	34.79	-0.08
230	6.56	6.47	-0.09	0.76	-5.80	34.79	34.95	+0.16	34.67	-0.12
231	4.95	5.35	+0.40	-0.09	-5.04	32.19	33.64	+1.45	34.09	+0.45
233	6.10	6.10	0.00	-0.16	-6.26	34.18	34.23	+0.05	33.07	-1.11
234	5.10	5.07	-0.03	-0.69	-5.79	28.02	32.07	+4.05	33.17	+5.15
235	5.59	5.20	-0.39	-	-	31.68	32.76	+1.08	-	-
214	7.89	6.60	-1.29	2.91	-4.98	34.80	34.99	+0.19	34.82	+0.02
217	6.96	7.80	+0.84	3.70	-3.26	34.89	35.09	+0.20	34.91	+0.02
218	7.02	8.01	+0.99	3.25	-3.77	34.81	35.10	+0.29	34.59	-0.22
220	7.54	7.53	-0.01	3.98	-3.56	34.89	35.05	+0.16	34.95	+0.06
221	6.84	7.37	+0.53	1.83	-5.01	34.55	34.95	+0.40	33.67	-0.88
224	7.40	7.02	-0.38	3.33	-4.07	34.72	34.86	+0.14	34.76	+0.04
225	5.27	6.90	+1.63	0.46	-4.81	33.81	34.93	+1.12	32.36	-1.45
228	5.12	5.38	+0.26	0.92	-4.20	33.34	33.91	+0.57	34.24	+0.90
229	4.70	-	-	-	-	31.86	-	-	-	-
232	5.41	4.10	-1.31	-0.19	-5.60	32.54	31.22	-1.32	33.74	+1.20
269	9.48	-	-	7.40	-2.08	35.12	-	-	35.20	+0.08
273	8.85	8.91	+0.06	6.34	-2.51	35.15	35.03	-0.12	35.19	+0.04
274	8.98	8.36	-0.62	4.28	-4.70	35.07	35.09	+0.02	34.92	-0.15
276	9.37	8.87	-0.50	5.48	-3.89	35.12	35.16	+0.04	35.15	+0.03
277	8.83	7.67	-1.16	5.06	-3.77	34.62	34.73	+0.11	35.12	+0.50
278	8.14	7.92	-0.22	3.34	-4.80	34.77	35.03	+0.26	34.65	-0.12
270	8.71	8.47	-0.24	6.79	-1.92	34.78	34.65	-0.13	35.02	+0.24
271	7.58	7.55	-0.03	4.90	-2.68	33.35	33.63	+0.28	34.58	+1.23

Hydrographic Investigations in the North Sea
in January 1962/63
Means of the Bottom Temperatures

Field No.	Means January	Means Cruise III	Δt°C III - January	Means Cruise IV	Δt°C IV - January	Δt°C III-IV
47	8.3	7.50	-0.80	6.60	-1.70	0.90
49	7.7	7.54	-0.16	6.80	-0.90	0.74
51	7.0	7.70	+0.70	6.32	-0.68	1.38
53	7.1	7.44	+0.34	6.26	-0.84	1.18
54	6.9	7.42	+0.52	6.51	-0.39	0.89
55	6.7	7.16	+0.46	6.74	+0.04	0.42
56	7.5	7.78	+0.28	7.28	-0.22	0.50
57	7.3	7.18	-0.12	-	-	-
72	7.4	7.15	-0.25	6.38	-1.02	0.77
74	7.6	7.70	+0.10	7.04	-0.56	0.66
76	7.4	7.56	+0.16	6.67	-0.73	0.89
78	7.1	7.79	+0.69	6.64	-0.46	1.15
80	7.0	7.68	+0.68	6.35	-0.65	1.33
82	6.6	7.22	+0.62	6.09	-0.51	1.13
84	7.3	7.18	-0.12	6.28	-1.02	0.90
86	6.9	-	-	-	-	-
88	7.0	7.36	+0.36	6.61	-0.39	0.75
75	7.0	7.07	+0.07	6.27	-0.73	0.80
77	7.4	7.40	0.00	5.90	-1.50	1.50
79	7.3	7.62	+0.32	6.36	-0.94	1.26
81	7.2	7.47	+0.27	5.67	-1.53	1.80
83	6.9	7.42	+0.52	4.86	-2.04	2.56
85	6.9	7.00	+0.10	4.82	-2.08	2.18
87	6.8	7.10	+0.30	4.89	-1.91	2.21
89	7.2	7.00	-0.20	5.36	-1.84	1.64
90	7.5	5.75	-1.75	5.34	-2.16	0.41
91	6.6	6.02	-0.58	4.56	-2.04	1.46
109	6.9	6.40	-0.50	5.18	-1.72	1.22
111	7.1	7.10	0.00	5.76	-1.34	1.34
113	7.4	7.64	+0.24	6.08	-1.32	1.56
115	7.1	7.62	+0.52	5.85	-1.25	1.77
117	6.5	7.15	+0.65	5.03	-1.47	2.12
119	6.3	6.79	+0.49	4.66	-1.64	2.13
121	6.3	6.02	-0.28	3.58	-2.72	2.44
123	6.1	5.91	-0.19	4.61	-1.49	1.30
125	6.1	-	-	4.51	-	-
128	5.7	5.44	-0.26	4.54	-1.16	0.90
112	7.2	7.24	+0.04	5.40	-1.80	1.84
114	7.2	7.33	+0.13	5.16	-2.04	2.17
116	7.0	7.14	+0.14	3.69	-3.31	3.45
118	6.6	-	-	4.48	-	-
120	6.5	6.46	-0.04	4.33	-2.17	2.13
122	6.4	7.18	+0.78	4.07	-2.33	3.11
124	6.3	7.00	+0.70	5.32	-0.98	1.68
126	5.9	-	-	3.07	-2.83	-
129	4.8	4.26	-0.54	-	-	-
150	7.3	7.30	0.00	5.26	-2.04	2.04
151	7.0	6.92	-0.08	3.95	-3.05	2.97
156	6.6	6.80	+0.20	3.43	-3.17	3.37
160	6.8	5.74	-1.06	3.82	-2.98	1.92
164	6.9	6.45	-0.45	5.32	-1.58	1.13
168	6.5	7.40	+0.90	5.47	-1.03	1.93
172	6.8	-	-	2.36	-	-
176	6.0	6.66	+0.66	3.94	-2.06	2.72
177	6.7	6.23	-0.47	5.35	-1.35	0.88
180	6.3	-	-	2.74	-3.56	-
182	5.3	-	-	-	-	-
183	5.1	5.44	+0.34	0.07	-5.03	5.37
184	5.1	-	-	-	-	-
187	4.3	-	-	-	-	-
188	4.9	5.29	+0.39	3.12	-1.78	2.17
189	4.9	5.30	+0.40	2.30	-2.60	3.00
192	3.1	2.56	-0.54	-	-	-
157	7.3	6.42	-0.88	-	-	-
158	5.5	-	-	-	-	-
159	5.6	-	-	-	-	-
161	6.8	6.28	-0.52	2.60	-4.20	3.68
162	5.3	-	-	-	-	-
163	6.3	-	-	2.91	-3.39	-
165	7.6	6.49	-1.11	4.05	-3.55	2.44
166	6.7	6.19	-0.51	-	-	-
167	6.9	-	-	-	-	-
169	6.4	5.74	-0.66	3.52	-2.88	2.22
170	6.7	6.78	+0.08	-	-	-
171	6.0	5.34	-0.66	-	-	-
215	6.5	-	-	1.36	-5.14	-
216	7.0	-	-	1.98	-5.02	-
219	7.5	-	-	2.57	-4.93	-
222	7.5	-	-	2.01	-5.49	-
223	7.5	7.65	+0.15	5.84	-1.66	1.81
226	6.8	6.94	+0.14	3.09	-3.71	3.85
227	6.8	6.48	-0.32	2.02	-4.78	4.46
230	6.8	6.40	-0.40	1.20	-5.60	5.20
231	6.8	5.33	-1.47	0.49	-6.31	4.84
233	5.9	6.07	+0.17	0.14	-5.76	5.93
234	5.9	5.47	-0.43	-0.04	-5.94	5.51
235	5.9	5.37	-0.53	-	-	-
214	7.9	6.92	-0.98	3.15	-4.75	3.77
217	7.9	8.08	+0.18	4.04	-3.86	4.04
218	7.9	8.09	+0.19	3.50	-4.40	4.59
220	7.5	7.66	+0.16	4.41	-3.09	3.25
221	7.5	7.37	-0.13	2.40	-5.10	4.97
224	7.5	7.04	-0.46	3.58	-3.92	3.46
225	7.5	6.84	-0.66	1.11	-6.39	5.73
228	6.5	5.34	-1.16	2.11	-4.39	3.23
229	6.5	-	-	-	-	-
232	6.5	4.46	-2.04	-0.04	-6.54	4.50
269	-	-	-	7.76	-	-
273	-	9.01	-	6.60	-	2.41
274	8.5	8.38	-0.12	4.45	-4.05	3.93
276	-	8.76	-	5.72	-	3.04
277	-	7.75	-	5.23	-	2.52
278	8.5	7.83	-0.67	3.56	-4.94	4.27
270	-	8.45	-	6.91	-	1.54
271	-	7.51	-	5.08	-	2.43

Hydrographic Investigations in the North Sea
in January 1962/63
Means of the Surface Temperatures and Salinity.

Field No.	Cruise No. III	Cruise No. IV	Δt°C III-IV	Cruise No. III	Cruise No. IV	S‰ III-IV
47	7.30	6.50	0.80	34.88	35.09	-0.21
49	7.50	6.65	0.85	35.24	35.31	-0.07
51	7.60	6.12	1.48	35.30	35.26	+0.04
53	7.38	6.03	1.35	35.25	35.26	-0.01
54	7.37	6.16	1.21	35.25	35.28	-0.03
55	7.08	6.00	1.08	35.12	35.07	+0.05
56	7.12	7.01	0.11	34.60	35.17	-0.57
57	5.88	-	-	33.05	-	-
72	7.20	6.25	0.95	34.90	35.10	-0.20
74	7.50	6.82	0.68	35.18	35.31	-0.13
76	7.51	6.55	0.96	35.21	35.27	-0.06
78	7.74	6.53	1.21	35.29	35.25	+0.04
80	7.60	6.33	1.27	35.27	35.22	+0.05
82	7.18	5.94	1.24	35.20	35.14	+0.06
84	6.72	6.07	0.65	34.64	34.99	-0.35
86	-	-	-	-	-	-
88	5.50	3.56	1.94	33.52	33.02	+0.50
75	7.02	5.98	1.04	35.00	34.91	+0.09
77	7.30	5.85	1.45	35.11	35.03	+0.08
79	7.60	6.32	1.28	35.26	35.13	+0.13
81	7.38	5.62	1.76	35.15	35.11	+0.04
83	7.20	4.81	2.39	35.18	35.06	+0.12
85	6.78	4.71	2.07	35.17	35.24	-0.07
87	6.95	4.87	2.08	35.21	35.06	+0.15
89	6.20	4.33	1.87	34.67	34.55	+0.12
90	5.70	4.40	1.30	34.97	34.27	+0.70
91	6.00	4.68	1.32	34.72	34.98	-0.26
109	6.40	5.17	1.23	34.62	34.65	-0.03
111	7.10	5.68	1.42	34.93	34.92	+0.01
113	7.55	6.14	1.41	34.99	35.09	-0.10
115	7.52	5.82	1.70	35.06	35.02	+0.04
117	7.05	4.93	2.12	35.08	34.96	+0.12
119	6.67	4.50	2.17	35.07	34.96	+0.11
121	5.98	3.52	2.46	35.05	34.90	+0.15
123	5.88	4.63	1.25	34.78	34.91	-0.13
125	-	4.40	-	-	34.91	-
128	5.39	4.69	0.70	34.51	34.97	-0.46
112	7.10	5.21	1.89	34.72	34.70	+0.02
114	7.31	4.95	2.36	34.78	34.82	-0.04
116	7.00	3.81	3.19	34.86	34.73	+0.13
118	-	4.57	-	-	34.84	-
120	6.40	4.30	2.10	34.85	34.85	0.00
122	7.20	4.04	3.16	34.71	34.90	-0.19
124	6.92	5.18	1.74	34.75	34.84	-0.09
126	-	3.17	-	-	34.91	-
129	3.82	-	-	32.78	-	-
150	7.20	5.03	2.17	34.66	34.70	-0.04
151	6.88	4.01	2.87	34.60	34.73	-0.13
156	6.70	3.51	3.19	34.54	34.76	-0.22
160	5.90	4.03	1.87	34.70	34.82	-0.12
164	6.40	5.26	1.14	34.68	34.81	-0.13
168	7.32	5.47	1.85	34.74	34.76	-0.02
172	-	2.38	-	-	34.40	-
176	6.58	3.82	2.76	34.74	34.58	+0.16
177	6.20	4.61	1.59	33.58	34.66	-1.08
180	-	2.70	-	-	34.13	-
182	-	-	-	-	-	-
183	5.40	2.13	3.27	33.98	33.84	+0.14
184	-	-	-	-	-	-
187	-	-	-	-	-	-
188	5.05	2.71	2.34	33.33	33.76	-0.43
189	5.18	1.83	3.35	33.44	33.58	-0.14
192	2.40	-	-	29.39	-	-
157	6.41	-	-	34.56	-	-
158	-	-	-	-	-	-
159	-	-	-	-	-	-
161	6.23	2.70	3.53	34.59	34.76	-0.17
162	-	-	-	-	-	-
163	-	2.86	-	-	34.68	-
165	6.45	4.06	2.39	34.48	34.80	-0.32
166	6.15	-	-	34.40	-	-
167	-	-	-	-	-	-
169	5.70	3.21	2.49	34.38	34.86	-0.48
170	6.60	-	-	35.00	-	-
171	5.10	-	-	31.86	-	-
215	-	2.11	-	-	34.75	-
216	-	1.24	-	-	34.38	-
219	-	2.61	-	-	34.78	-
222	-	2.06	-	-	34.61	-
223	7.52	4.36	3.16	34.89	35.13	-0.24
226	7.00	2.89	4.11	34.83	34.82	+0.01
227	6.30	1.62	4.68	34.75	34.79	-0.04
230	6.47	0.76	5.71	34.95	34.67	+0.28
231	5.35	-0.09	5.44	33.64	34.09	-0.45
233	6.10	-0.16	6.26	34.23	33.07	+1.16
234	5.07	-0.69	5.76	32.07	33.17	-1.10
235	5.20	-	-	32.76	-	-
214	6.60	2.91	3.69	34.99	34.82	+0.17
217	7.80	3.70	4.10	35.09	34.91	+0.18
218	8.01	3.25	4.76	35.10	34.59	+0.51
220	7.53	3.98	3.55	35.05	34.95	+0.10
221	7.37	1.83	5.54	34.95	33.67	+1.28
224	7.02	3.33	3.69	34.86	34.76	+0.10
225	6.90	0.46	6.44	34.93	32.36	+2.57
228	5.38	0.92	4.44	33.91	34.24	-0.33
229	-	-	-	-	-	-
232	4.10	-0.19	4.29	31.22	33.74	-2.52
269	-	7.40	-	-	35.20	-
273	8.91	6.34	2.57	35.03	35.19	-0.16
274	8.36	4.28	4.08	35.09	34.92	+0.17
276	8.87	5.48	3.39	35.16	35.15	+0.01
277	7.67	5.06	2.61	34.73	35.12	-0.39
278	7.92	3.34	4.58	35.03	34.65	+0.38
270	8.47	6.79	1.68	34.65	35.02	-0.37
271	7.55	4.90	2.65	33.63	34.58	-0.95

January 1962 were positive and amounted to + 1.10 - + 0.28° C. In January 1963 they deviated by — 0.07 and — 0.22. The mean salinity deviated in the two summer months by + 2.30 and + 1.80 ‰, and was in January 1962 — 0.06 ‰ below and, in 1963, 0.51 ‰ above the long-term surface mean.

3) In January 1962/63 Field No. 276 in the English Channel water had negative temperature anomalies of — 0.50 and — 3.89°. The mean increase in salinity amounted to + 0.03 and + 0.04 ‰.

As we do not have an almost equal distribution of the observational data over the months, it is difficult to explain the different anomalies. Characteristic anomalies as in the distribution charts of plates 2-5 are strongly obliterated, especially in the North Sea, by averaging by means of one-degree fields. The counter-directed variations of the temperature and the salinity in the water bodies point to different effects of the atmospheric circulation. For fisheries biological purposes the mean values are of little importance.

The stratification of the water masses

As already stated, the convection in most parts of the North Sea as a consequence of winter cooling goes down to the bottom. Therefore, the water masses have locally the same temperature, salinity, and density from the surface down to the bottom in winter and spring. The only exception is the north-eastern North Sea, where Baltic water of a low salinity advectively superposes North Sea water of a high salinity and where, below the discontinuity layer, not the mixing effect of the tidal stream but vertical circulation and advection determine the mixing of all properties of sea water. As the research cruises of *Anton Dohrn* in January 1962/63 only partly covered the western flank of this region and as the winter homogeneity of the North Sea is a proved observational fact, plates 6-7 represent only the summerly thermohaline layering. It is certain that the heating starting in spring develops in the cycle of a day and is primarily limited to a thin surface layer (K. KALLE, 1953). The daily heat inflow leads to the forming of a summer thermocline at a depth of 0-50 m. It is a normal phenomenon in the higher latitudes and separates the homogeneous surface layer from the homogeneous or only slightly stratified bottom layer. The results of G. DIETRICH's (1954) investigation of the influence of the tidal stream turbulence on the hydrographic structure of the North Sea are confirmed by the values compiled in plates 6-9. A weak effect of the tidal stream turbulence resulting from weak tidal streams or great depths can only partly make the lower section homogeneous. Surface layer, thermocline, and the upper stratified part of the bottom layer remain unchanged. The tidal stream turbulence increasing, the whole bottom layer will first become homogeneous, then the thermocline will shrink until the heterogeneous layer near the bottom and the heterogeneous layer near the surface will overlap so that no thermocline can form. The N-S profiles of plates 6 and 8 nearly correspond to the longitudinal axis of the North Sea. The N-S profile of 1959 is based on observational data gathered between June 27 and July 23 and gives an insight into the structure of the North Atlantic water and the North Sea water. The N-S profile of 1960 is constructed after the hydrographic data obtained between July 13 and 29 and cuts North Atlantic water, North Sea water, and English Channel water in the southern North Sea. The W-E profiles of the plates 6-8 are almost at right angles with the longitudinal profiles and give an insight into the distribution of the North Sea, the North Atlantic, and the Baltic waters over the Norwegian Channel. As mentioned above, the track charts of the 37th and 46th research cruises give the exact position of all seven vertical profiles (plate 1). We have an insignificant salinity layering in the North Sea. Therefore, the density layering is almost exclusively determined by the temperature layering. The profiles are based on measurements performed with reversing thermometers on Nansen bottles. To fix the depth of the thermocline, the curves of the temperature distribution recorded by a bathythermograph were used. As the confining effect on the tidal stream turbulence is caused by the density gradient, it is recommended to take the density distribution when interpreting the profiles. In the case of the bottom layer, the following regional differences can be observed in the N-S profiles :

1) In the northern North Sea the lower heterogeneous layer is restricted to the near-bottom water in view of the weak tidal streams. The layer conditions to the North of stations Nos. 3382/59 and 950/60 have an oceanic character. The thermoclines are situated at depths of circa 18 m and are almost 25 m thick.

2) The central North Sea has smaller depths and higher velocities of the tidal streams. Up to stations Nos. 3500/59 and 865/60 the bottom layers are homogeneous. The thermoclines are noticeably thinner.

3) With smaller depths or stronger tidal streams to the North and South of the Dogger Bank up to stations Nos. 3307/59 and 820/60, the thermocline reduces to a single one covering only a few metres.

4) To the South of stations Nos. 3307/59 and 820/60 the tidal streams gain such high velocities that the heterogeneous layer near the bottom and the heterogeneous layer near the surface overlap. Therefore, the whole southern North Sea is homogeneous even in summer.

As in the longitudinal profiles in the North Sea, the effects of tidal stream turbulence can also be traced in the latitudinal profiles (July 7-22, 1959, and July 25-30, 1960) of plates 6-8, from the Scottish to the south Norwegian coast. On the Scottish side of the North Sea we have a very strong heterogeneous bottom layer. Complete homogeneity, i.e. identity between surface and bottom layer, could not be proved, either in 1959 or in 1960. To the East of stations Nos. 3472/59 and 950/60, the distribution of the hydrographic factors beneath the thermocline pointed to vertical circulation and advection. The latitudinal profiles of plate 7 across the Norwegian Channel give an insight into the water exchange of this region. The course of the isolines indicates that the strongest inflow in the eastern branch of the North Atlantic water, with salinities of more than 35 $^0/_{00}$, is bound to the western flank of the Norwegian Channel. The difference in the layering between areas with a weak and a strong tidal stream mixing effect (G. DIETRICH, 1950) is especially clearly stated in the latitudinal profiles between Scotland and Norway. On the Norwegian side the thermocline reaches as far as the Continental Shelf, on the Scottish side its dissolution begins off the coast. Due to the vertical mixing, the bottom water temperatures increase, while at the same time the surface temper-

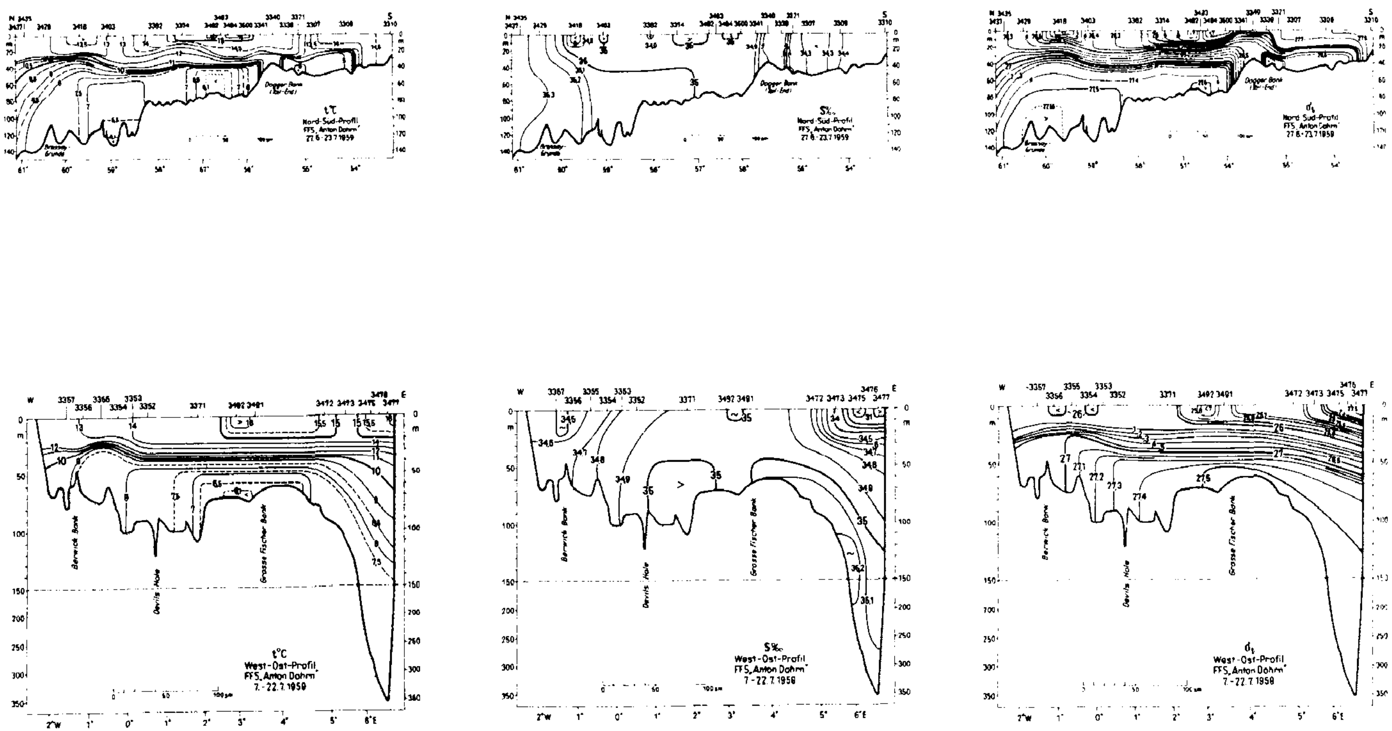
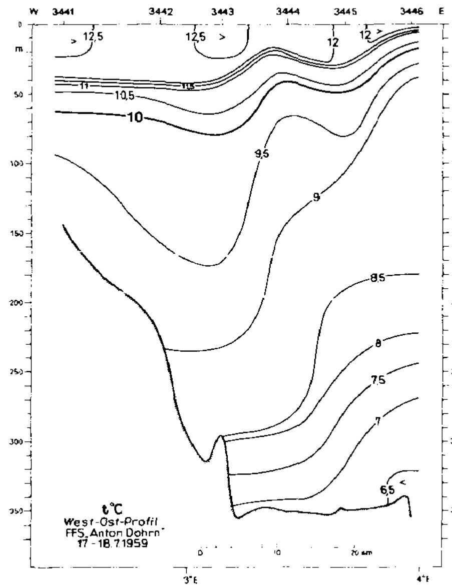
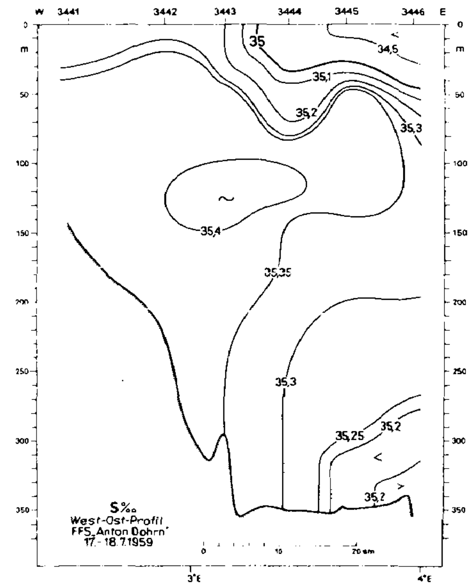
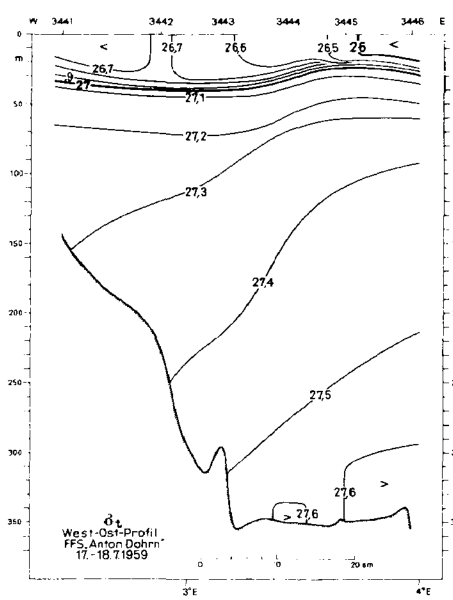
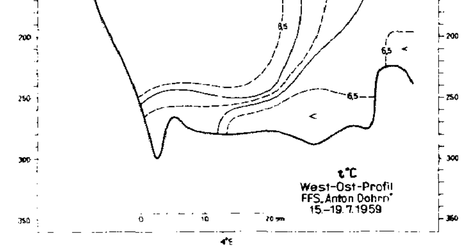


PLATE 6. — Temperature, salinity and density distribution on a longitudinal and a transverse profile across the North Sea in Summer 1959.


W 3441 3442 3443 3444 3445 3446 E
t°C
West-Ost-Profil
FFS „Anton Dohrn"
17.-18.7.1959
3°E
4°E


W 3441 3442 3443 3444 3445 3446 E
S‰
West-Ost-Profil
FFS „Anton Dohrn"
17.-18.7.1959
3°E
4°E


W 3441 3442 3443 3444 3445 3446 E
σt
West-Ost-Profil
FFS „Anton Dohrn"
17.-18.7.1959
3°E
4°E


W 3415 3414 3456 3455 3454 3453 3452 E
t°C
West-Ost-Profil
FFS „Anton Dohrn"
15.-19.7.1959
4°E

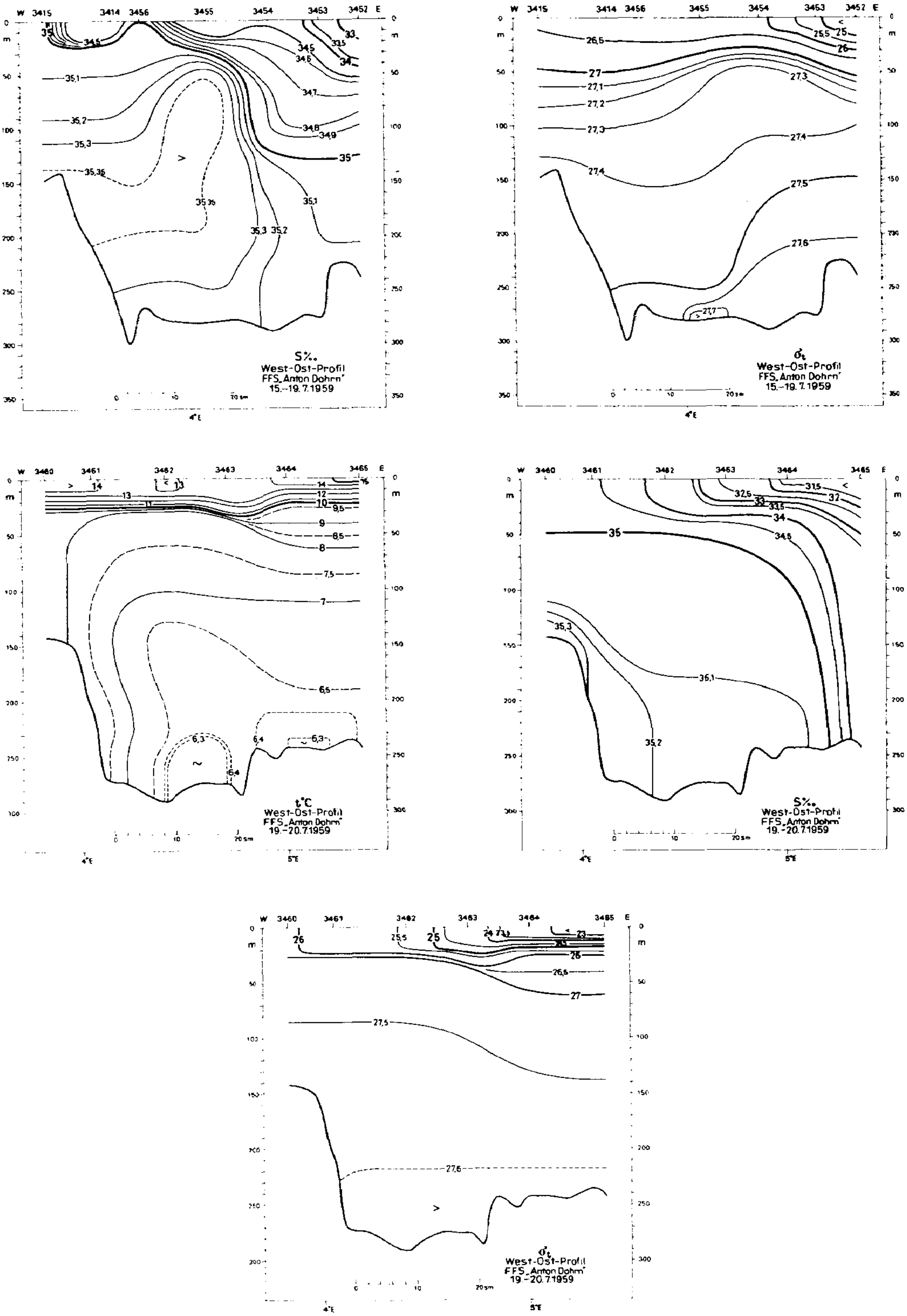


PLATE 7. — Temperature, salinity and density distribution on three cross-sections across the Norwegian Channel in Summer 1959.

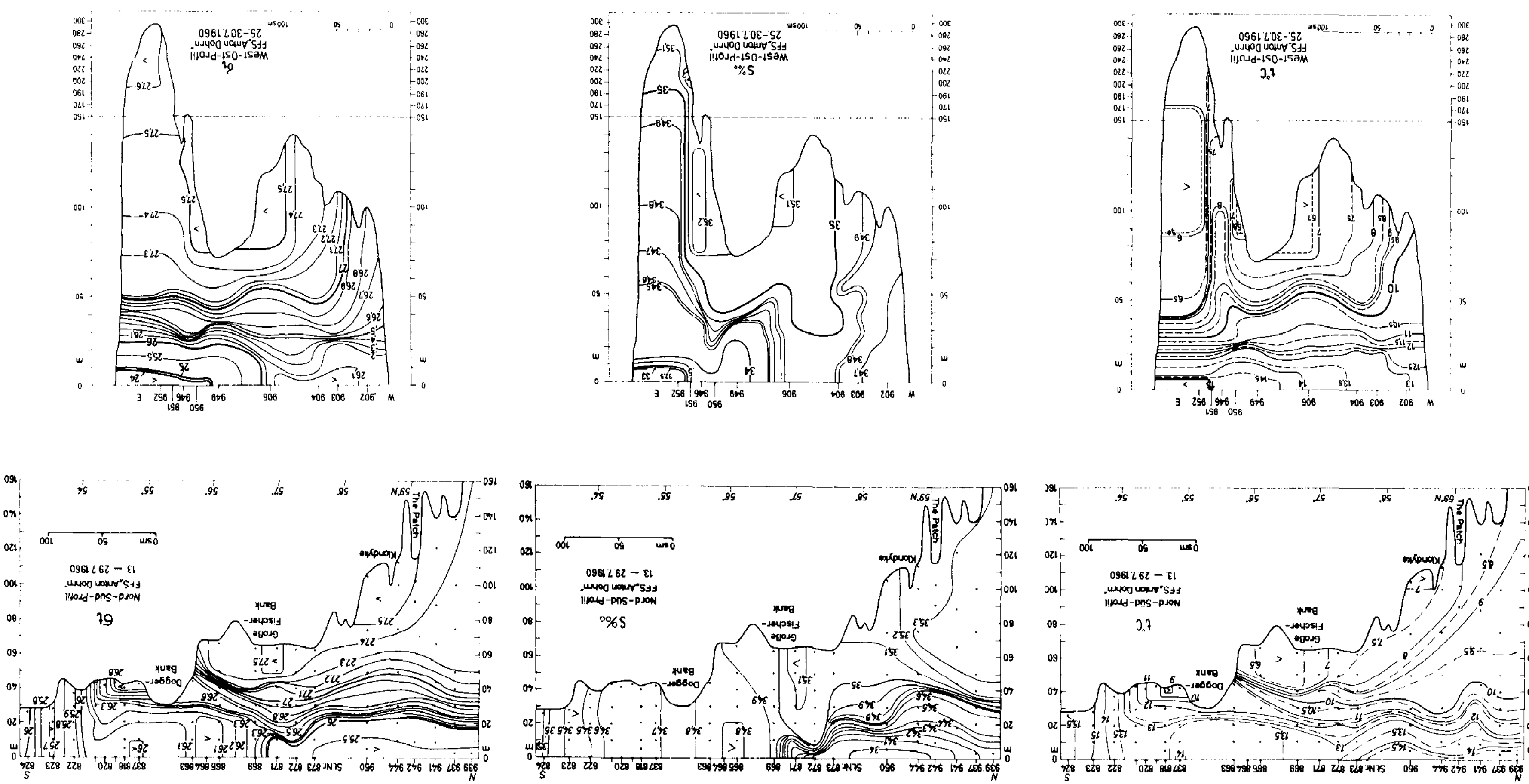


PLATE 8. — Temperature, salinity and density distribution on a longitudinal and a transverse profile across the North Sea in Summer 1960.

PLATE 9. — Intensity distribution in the discontinuity layer because of difference between surface and bottom water in the North Sea in Summer 1959/60.

atures decrease. On the Norwegian side, with a negligible mixing effect of tidal stream turbulence, we have at the same time higher surface temperatures and lower bottom temperatures. The table gives a summary of the temperature, salinity, and density values and the intensity of the layering off the Scottish and Norwegian coasts in July 1959/60 :

The hydrographic stratification off the Scottish and Norwegian Coast in July 1959/60

No	Cruise No.	Station No.	Date	t°C Surface	t°C Bottom	S ‰ Surface	S ‰ Bottom	σt Surface	σt Bottom	Δ t°C Surface minus Bottom	Δ S ‰ Bottom minus Surface	Δ σt Bottom minus Surface
1	37	3357	7.7.1959	12,94	9,02	34,50	34,68	26,03	26,87	3,92	0,18	0,84
2	46	902	25.7.1960	13,02	9,86	34,66	34,77	26,14	26,80	3,16	0,11	0,76
3	37	3475	20.7.1959	15,88	5,93	30,78	35,12	22,55	27,67	9,95	4,34	5,12
4	46	952	30.7.1960	15,36	6,21	32,28	35,12	23,83	27,63	9,15	2,84	3,80

These summer differences are the usual symptoms of the annual variations and can also be seen from the long-term mean values. They are given in the atlases of monthly temperature charts of G. Böhnecke and G. Dietrich (1951), and G. Dietrich (1962), as well as in the monthly charts of North Sea temperatures of G. Tomczak and E. Goedecke (1962). When the heat received in spring and summer at the surface penetrates to the bottom — reaching different depths in the different areas depending on the respective tidal stream turbulence — this means that the intermediate water returns this heat to the surface in autumn through convection. The areas with the lowest surface temperatures in summer are the warmest in late autumn and winter. The charts of plate 9 give a summary of the regional distribution of stratified and unstratified water masses and demonstrate the different intensity of the thermocline. The intensity of the thermocline means the total fall of the temperatures or the increase in the salinity and density from the lower to the upper limit. In the North Sea the difference between the surface and the bottom water values is a very reliable criterion for the intensity of the layering. A comparison of the difference charts of June 23 - July 23, 1959, and July 9-31, 1960, demonstrates considerable regional differences in the expansion of stratified and unstratified water masses. The intensity of the thermocline in July 1959 was more than 10° to the North of the Dogger Bank. In July 1960 differences only a little over 7.5° were measured in that part of the northern North Sea lying above the cold bottom water. A stable salinity layering had formed in 1959 over the Norwegian Channel to the East of 4° E. The difference chart of the salinity in July 1960 shows the strong westward shift of the Baltic Outflow which gives this region, called haline throughout the year by G. Dietrich (1950) and T. Laevastu (1963), its special hydrographic position. In the rest of the North Sea the intensity of the salinity discontinuity layer is negligible due to the insignificant salinity layering. Due to the higher water temperatures, we had a more intense density discontinuity layer in July 1959 than in 1960. In view of the long periods of sunshine in June/July 1959, even the water masses of the German Bight and the continental coastal water off the north Frisian/Danish coast were stratified where it has to be considered (E. Goedecke, 1952) that this near-coastal region has a special position within the whole North Sea, with regard to the seasonal appearance of the thermohaline layering.

The fisheries hydrographic investigations performed on behalf of and with the funds of the Deutsche Wissenschaftliche Kommission für Meeresforschung cover the different distribution of the water masses in the North Sea in four nearly-similar periods of time. It is represented in the charts of the temperature, salinity, and density at the surface and on the bottom. The mean variations are given in tables. The different forming of the thermocline can be seen from the longitudinal profiles and the intensity charts. Due to the great number of plankton organisms contained therein, pelagic fish can be found there, a factor of special importance for fishermen. With regard to the literature referred to under " references ", a mathematical treatment was regarded unnecessary. In view of the variety of factors influencing the inorganic environment of fish and the distribution of food, it can hardly be expected that the stronger inflow of Atlantic water into the North Sea not covered by this paper will be the explanation of the various fluctuations in the fish stocks.

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