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RRS Charles Darwin Cruise P11/12/86 - 30 April - 15 May, 1986

Scientific Report

1. Personnel:

P M Holligan	MBA, Plymouth	(Principal Scientist)
C Brownlee	" "	
C Gill	" "	
R N Head	" "	
J W Wood	" "	
G T Mardell	" "	(1-7 May)
A G Davies	" "	(30 April - 7 May)
J Sleep	" "	(7-15 May)
S M Turner	UEA, Norwich	
I Thompson	" "	(30 April - 7 May)
D Shooter	" "	(7-12 May)
D Purdie	Southampton Univ.	(30 April - 12 May)
D Crawford	" "	
S Bradshaw	Bristol Univ.	
C Lancelot	Brussels Univ.	
S Mathot	" "	
M Veldhuis	Gröningen Univ.	
T Ietswaart	" "	(7-15 May)
G W Miller	RVS, Barry	
R Griffiths	" "	
M Davies	" "	

2. Itinerary:

30 April	Departed Falmouth
1 May	Rendezvous with RV Squilla off Guernsey
7 May	Harwich (water, personnel exchange)
12 May	Yarmouth (personnel disembarked)
15 May	Arrived Falmouth

The cruise track and station positions are shown in Figs. 1-3.

3. Scientific programme:

As outlined in the original proposals and programmes the main objectives of the cruise were:

(a) Sampling and analysis of biogenic sulphur compounds in the sea and marine atmosphere at the time of Phaeocystis blooms in the southern North Sea (contract financed by the CEC)

(b) Related hydrographic observations (temperature, salinity, chlorophyll, inorganic nutrients etc.), and measurements of primary production using ^{14}C and O_2 methods

(c) Biochemical studies on Phaeocystis blooms - partitioning of organic carbon and nitrogen in dissolved and particulate phases, mucous production, and phosphorus assimilation

(d) Secondary production (copepods) and geochemical (water column and sediments) studies in waters affected by Phaeocystis

After locating dense Phaeocystis populations, mainly off the Dutch coast, these were all successfully achieved. No time was lost due either to bad weather, or to equipment failures.

4. Results

(a) Hydrography. Observations at hydrographic stations are summarised in Tables 1 and 2. Throughout the cruise temperature, salinity, chlorophyll fluorescence, light transmission (Sea Tech 660 nm) and inorganic nutrients (NO_3, NO_2, NH_4, Si) were measured continuously using the ship's non-toxic pump supply (intake depth 4.5 m). The CTD vertical profiles included measurements from fluorescence and oxygen sensors. Bottle samples were taken for salinity, oxygen and nutrient (including PO_4) determinations. Some 500 fluorimetric measurements of chlorophyll and phaeopigments were made during the cruise, and a number of parallel samples were stored for laboratory fluorometer and spectrophotometer analyses.

The water column was well mixed except in the region of station 9 ($\Delta T \sim 2°C$) and in some coastal areas where slight surface-to-bottom salinity differences were observed (ΔS up to 0.85°/oo at Sta. 8). Temperatures was generally in the range 7.0 to 8.5°C with weak horizontal gradients.

Chlorophyll concentrations were relatively low in the southern part of the North Sea (< 5 mg m^{-3}) and high in the eastern part (locally > 50 mg m^{-3}). As expected, dissolved nitrate and phosphate generally showed an inverse pattern of distribution compared to phytoplankton biomass, although in the fresher waters close to the coasts of Holland and Germany substantial quantities of nitrate (up to $\sim$ 10 µM) but not phosphate were still present. Extensive supersaturation of oxygen was observed in the chlorophyll-rich areas.

Phaeocystis and diatoms were the dominant phytoplankton, the former mainly within the Rhine outflow (stas. 14, 17 etc.) and off the north Dutch coast (sta. 7 etc.), and the latter off Belgium (sta. 4 etc.) and in the German Bight (st. 8). Within the Phaeocystis areas, an attempt to monitor diel changes in hydrographic properties was attempted by following a parachute drogue (stas. 18-28), and comparisons were made of physiological properties under conditions of depletion (stas. 14, 16, 30) and non-depletion (stas. 17, 31) of nitrate. Preliminary analyses of Lugols samples indicate that the highest chlorophyll concentrations for Phaeocystis correspond to cell densities of $\sim$70,000 ml^{-1}.

(b) Sulphur measurements. Organic sulphur compounds in sea water were measured using a cryogenic purge and trap extraction technique by FPD gas chromatrography. Data for dimethyl sulphide (DMS), its precursor dimethyl sulphoniopropionate (DMSP) and minor sulphur gases were obtained from over 400 samples representing a range of hydrographic and biological conditions. DMS-sulphur concentrations in surface waters ranged from about 20 to >1000 ng l^{-1}.

Sampling was concentrated within areas of high Phaeocystis densities, with compatible chlorophyll, nutrient and cell count samples to investigate factors affecting the distribution of DMS. The possibility of a diel cycle in DMS production was tested at the drogue station (see Fig. 3) over a period of 36h. Water samples were also incubated on deck to measure rates of DMS production.

The data (together with that from earlier cruises) will be used to calculate the annual flux of volatile organic sulphur to the atmosphere for the North Sea.

Other related work included the collection and preservation of water samples for laboratory bacteriological studies, and two experiments to test the effects of sunlight irradiation on organic sulphur compounds in sea water.

Atmospheric particulate samples were also collected with a high volume pump, sampling continuously over 12h periods from the start of the cruise until 11 May (when the pump failed). The filters were frozen for laboratory analyses of the oxidation products of DMS (methane sulphonic acid, dimethyl sulphoxide etc). On 14 May the filters were assayed for radioactivity with a geiger counter and showed two well-defined maxima corresponding to fall out events from the Chernobyl reactor (Fig. 4).

(c) Primary production (also see section d). Measurements of $^{14}CO_2$ assimilation were carried out with populations consisting mainly of diatom species (Stas. 1-6, 8, 12, 15, 29, 32) or Phaeocystis (other stations - see Table 2) as follows:

i) Photosynthesis/irradiance (P/1) relationships in light gradient incubators - 15 stations.

ii) Long term uptake in light and dark to follow incorporation of label into cell (particulate), mucous and soluble organic fractions, together with parallel ^{32}P uptake measurements - Stas. 10, 14.

iii) Short term time course for uptake into particulate fraction - Stas. 8, 21.

iv) Effects of nutrient levels and nutrient additions on P/1 relationships - Stas. 16, 17, 30, 31.

v) Comparison of ^{14}C uptake and O_2 evolution - Stas. 4, 6, 8, 10, 12, 14, 16, 17.

Photosynthesis and respiration rates were also determined by measuring changes in dissolved oxygen concentrations using an automated Winkler titration procedure. Samples were incubated in glass bottles in deck and laboratory incubators at various light intensities, and included parallel incubations with ^{14}C samples (see above) to measure photosynthesis by both methods. High ambient oxygen saturation levels (up to 160%, Table 2) indicated high in situ photosynthetic activity.

At the drogue station (Fig. 3) measurements of dissolved O_2 were made at four depths over a 36h period, every 3h during daylight and 4-6h at night. Preliminary results suggest that primary production rates can be estimated from observed diel changes which in turn, can be compared to in vitro derived rates.

(d) Biochemical studies on phytoplankton

(i) Carbon and nitrogen assimilation: Two types of experiment were carried out. The first, at stations where diatoms were dominant (Stas. 1, 2, 3, 6), consisted of measuring ^{14}C uptake rates and incorporation into specific products over periods up to 4h at 6 light levels. The second, with one diatom sample (Sta. 4) and five Phaeocystis samples (Stas. 10,

14, 17, 27, 30), included ^{14}C and ^{15}N assimilation measurements from sunrise to sunset and then sunset to sunrise (i.e. at total of 24h). Also measurements were made of the synthesis and breakdown of mucous, and of bacterial activity. Samples were collected for determination of chlorophyll and total organic carbon, and for cell counts by epifluorescence.

(ii) Phosphorus metabolism: Measurements of ^{32}P assimilation (Stas. 1-6, 8, 10, 14, 16, 17, 27) and alkaline phosphatase activity (APA) (at the above stations, and for other water samples obtained during the cruise) were made for comparison with earlier laboratory studies on Phaeocystis. APA is only induced or derepressed at very low soluble reactive phosphate concentrations. High APA, comparable to that measured in cultures, was detected for all Phaeocystis samples except those directly influenced by the nutrients from the Rhine. In agreement with earlier results, the high NO_3/PO_4 ratios (Table 2) and high APA confirm that phytoplankton in the Southern Bight can be severely phosphorus limited, with the algae relying on residual organic-bound phosphorus.

(e) Zooplankton. Vertical hauls were made with 500 µm nets for zooplankton at most stations (see Table 1), and the chlorophyll contents of copepods' guts were compared from different water types using fluorescence analysis. Zooplankton were relatively scarce within dense Phaeocystis populations.

Temora longicornis were kept in filtered seawater overnight, and their feeding and swimming activity was recorded with the impedance system on board ship. Copepods remained active for up to 24 hr in bloom concentrations of Phaeocystis - there was no appendage clogging by mucous from colonies. Temora responded immediately to the introduction of cells, and activity was higher with individual cells compared to colonies. However, fluorescence measurements of copepods' gut contents 30 min after feeding had commenced, showed that copepods fed colonies of Phaeocystis assimilated chlorophyll more rapidly than those fed individual cells.

(f) Geochemistry. The following samples were collected for lipid analyses by GC and GC-MS techniques.

i) Plankton samples (total 19). Collected from the non-toxic supply, 5-10 l filtered on GFC filters, stored in 50/50 CH_2Cl_2/MeOH.

ii) Sediment samples (total 17). Collected with a Day grab, 0 to 10 cm in depth. At three stations surface and sub-surface layers were separated, corresponding to apparent oxic and anoxic horizons. About 250 ml of each stored in deep freeze.

iii) Faecal pellet/gut samples. Animals collected with the Agassiz trawl and Day grab were washed and placed in glass aquaria with filtered sea water. Faecal pellets were extracted on GFC filters at frequent intervals and stored in 50/50 CH_2Cl_2/MeOH. For some larger organisms gut contents were dissected out and stored in the same way.

5. Working up of results

Preliminary analyses of the hydrographic and experimental data will be completed within the next 3-6 months. It is proposed to hold a meeting in Plymouth in late 1986 to discuss and exchange information about the main results of the cruise. Individual scientists will be responsible for writing up their own work, but it is planned that a general account of the observations on Phaeocystis will be prepared in early 1987. A report for the CEC contract must be submitted by late 1986.

6. Scientific equipment and ship operations

The MBA 347 data interface performed well on its first use for a cruise. The following modifications are recommended - the interface should be wired directly from the instruments and not via the chart recorders, the fluorometer signal should be averaged before logging, and further work on the software for data plotting is required.

The condition of the Linseis Chart recorders is very poor, and they should not be taken to sea again in their present state. The light meters all require calibration, and cannot be properly interfaced without suitable data on their output characteristics.

No problems were experienced with equipment supplied by RVS Barry, apart from occasional minor difficulties with the CTD system. Support from the RVS staff both for equipment maintenance and ship operations was excellent. The general purpose container facility was invaluable for the work with radioisotopes - the scientific programme could not have been completed without this.

The non-toxic sea water supply gave insufficient water for all the scientific instruments and incubators. This was due, in part, to back pressure due to the plumbing systems added on deck. As far as possible full bore piping should be used to feed the main outputs.

7. Conclusions

This was a successful cruise, with the scientific work benefiting from the full cooperation of the ships' officers and crew. The main scientific objectives of the cruise were fully met.

P.M. Holligan
MBA, Plymouth
3 June, 1986

TABLE 1. Hydrographic Station Details

Station No	Date	Time (GMT)	Lat.	Long.	Water depth (m)	Secchi depth (m)	K (m^{-1})	Sampling*
1	1/5	1010-1355	49°40'N	02°29'W	62	-	0.18	C,W,G,Z
2	2/5	0430-0845	50°01'N	00°02'E	42	10	0.20	C,W,G,Z,A
3		1110-1250	49°49'N	00°14'E	27	7	0.31	C,W,G,Z
4	3/5	0550-0840	51°29'N	02°50'E	27	-	0.38	C,W,G,Z,A
5		1523-1545	52°03'N	02°35'E	42	-	-	W
6	4/5	0515-0730	53°05'N	04°33'E	27	3	0.60	W,G,Z,A
7		1445-1545	53°34'N	05°41'E	24	4	0.53	C,W,G
8	5/5	0430-0730	54°10'N	08°18'E	15.5	2.75	0.83	C,W,G,Z,A
9		2100-2150	54°30'N	05°46'E	42	-	-	C,G,A
10	6/5	0400-0710	53°34'N	05°42'E	26	2.5	0.91	C,W,Z,A
11		1550-1640	53°01'N	03°28'E	30	7.5	-	C,G,A
12	7/5	0500-0645	52°15'N	02°00'E	32	3.5	0.41	C,W,G,Z,A
14		2150-2250	52°11'N	03°41'E	27	-	-	W
15	8/5	0800-0900	51°26'N	02°48'E	20	-	0.44	C,W,Z
16	9/5	0400-0430	52°12'N	03°41'E	21	3.5	-	W
17		0600-0830	52°12'N	04°02'E	21	2	0.91	C,W,G,Z,A
18		2000	53°33'N	05°38'E	22.5	-	-	C
19		2300	53°33'N	05°45'E	23	-	-	C
20	10/5	0400	53°34'N	05°38'E	23.5	-	-	C
21		0740	53°34'N	05°46'E	24	-	-	C,W
22		1000	53°34'N	05°52'E	22	2.75	-	C,G
23		1345	53°36'N	05°53'E	24	-	-	C
24		1615	53°36'N	05°50'E	22	2.5	-	C
25		1900	53°36'N	05°49'E	22	-	-	C
26		2300	53°37'N	06°01'E	24	-	-	C
27	11/5	0500-0700	53°38'N	05°56'E	22	2	1.32	C,W,G,Z
28		1445-1510	53°33'N	05°38'E	20	2.5	-	C
29	12/5	1420-1540	52°42'N	02°25'E	49	4.5	-	C,W,G,Z,A
30	13/5	0500-0700	52°12'N	03°42'E	27	3.5	0.45	C,W,G
31		0850-0930	52°13'N	04°08'E	18	2	0.87	C,W
32		1757-1805	51°29'N	02°50'E	27	-	-	C,W

*C = CTD profile, W = 30 l water bottle, G = Day grab, Z = Vertical zooplankton haul, A = Agassiz net

TABLE 2. Hydrographic measurements for experimental water samples
(Collection depth = 5m)

Station No.	Temp °C	Sal °/oo	Chlorophyll mg m^{-3}*	Phaeopig.	Oxygen % sat.	NO_3	NO_2	NH_4 µM	NH_4†	Si	PO_4†
1	8.26	35.31	0.72	0.51	117	4.7	-	-	∿0	-	0.20
2	7.60	35.07	0.74	0.38	108	11.9	-	-	∿0	-	0.59
3	7.91	33.49	6.91	0.41	-	18.3	-	-	0.2	-	0.67
4	7.81	34.09	10.71	1.00	122	0.8	0.32	1.3	∿0	0.25	0.03
5	7.17	35.04	1.86	0.37	-	4.0	0.07	1.0	-	0.20	0.24
6	7.88	30.58	31.48	1.83	-	8.8	0.64	0.6	0.1	0.19	0.09
7	7.61	31.83	16.23	2.63	-	5.4	0.21	0.7	0.7	0.38	0.04
8	8.40	27.14?	19.45	5.92	139	8.7	2.31	1.2	0.7	0.25	0.04
10	7.49	31.63	30.65	2.73	160	5.3	0.18	1.7	1.0	0.83	0.09
12	7.49	34.67	2.32	0.35	111	11.4	0.04	0.1	0.1	0.83	0.54
14	7.01	33.73	23.07	1.55	-	0.6	0.04	0.2	-	0.25	0.02
15	8.65	34.23	16.48	3.88	132	0.3	<0.02	<0.1	-	0.20	0.04
16	7.17	34.05	24.47	2.88	-	0.2	0.04	0.2	0.5	0.89	0.02
17	7.50	32.33	40.25	4.13	157	9.3	0.11	0.1	0.3	1.02	0.03
21	8.25	31.93	27.11	5.07	153	8.0	-	0.4	0.8	0.25	0.03
27	8.60	31.48	59.33	9.44	146	5.0	-	-	0.6	-	0.07
29	6.82	33.98	1.08	0.33	-	16.5	0.06	0.2	-	2.86	-
30	7.87	34.37	9.68	2.12	-	0.6	0.03	-	0.1	0.72	0.02
31	8.65	32.20	39.80	5.00	-	7.3	0.06	0.3	0.3	1.27	0.07
32	9.00	34.51	3.11	0.56	-	0.4	<0.02	0.3	-	0.70	-

*These values are still provisional. Calibration factors need to be checked, and comparisons made with stored samples.

†Manual methods

MIAS 3172

FIG. 1

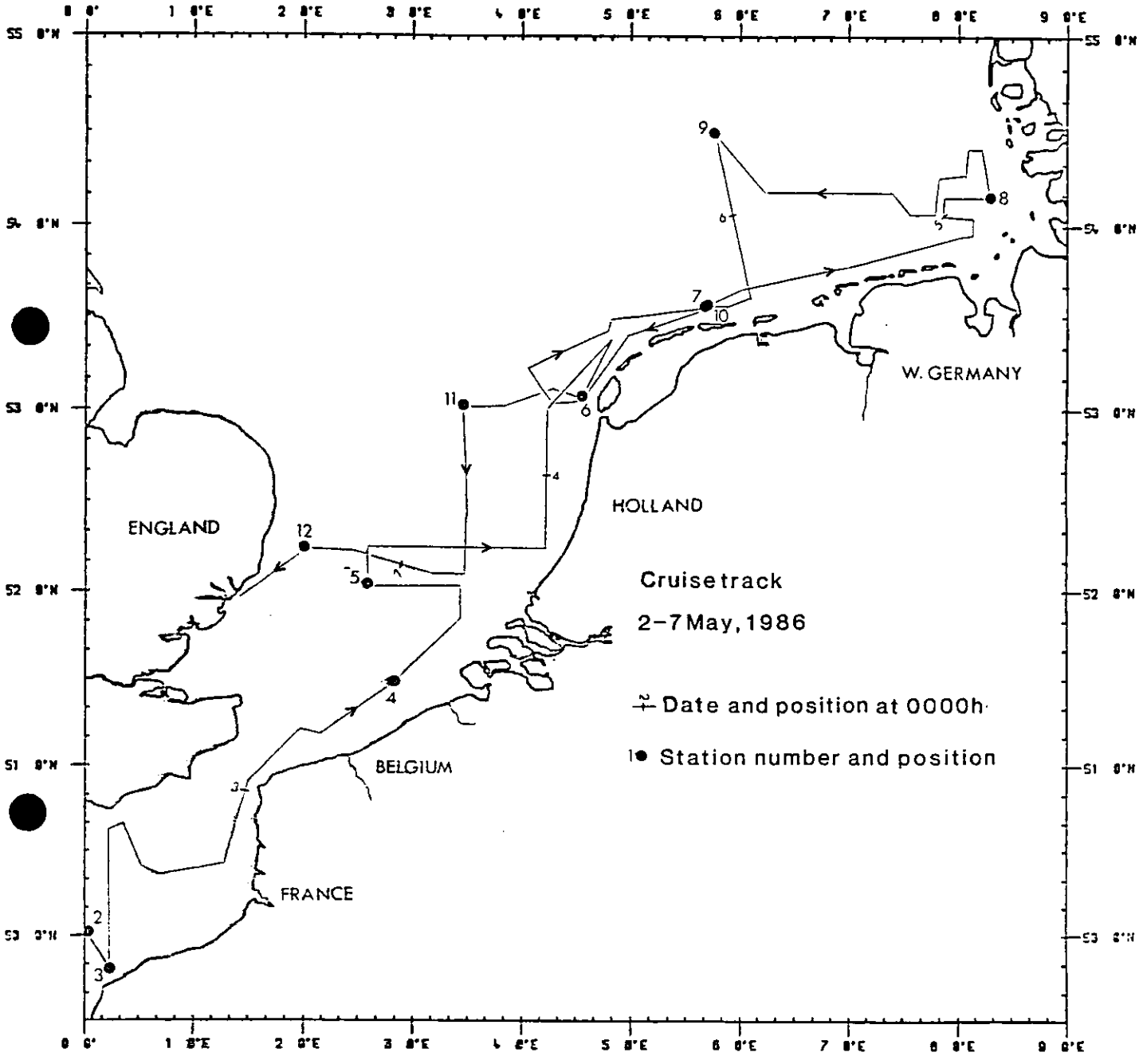

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FIG. 2

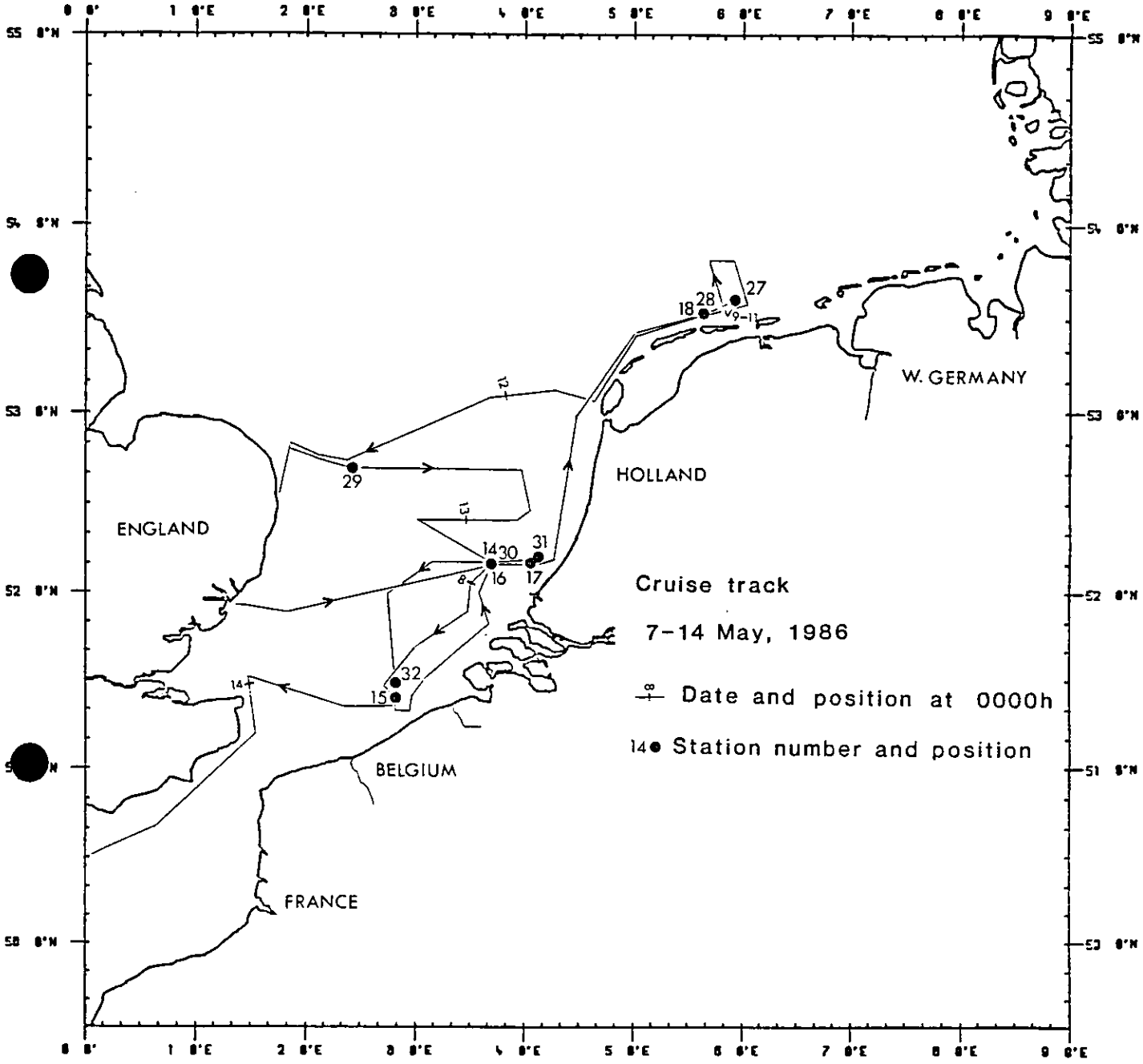

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FIG. 3

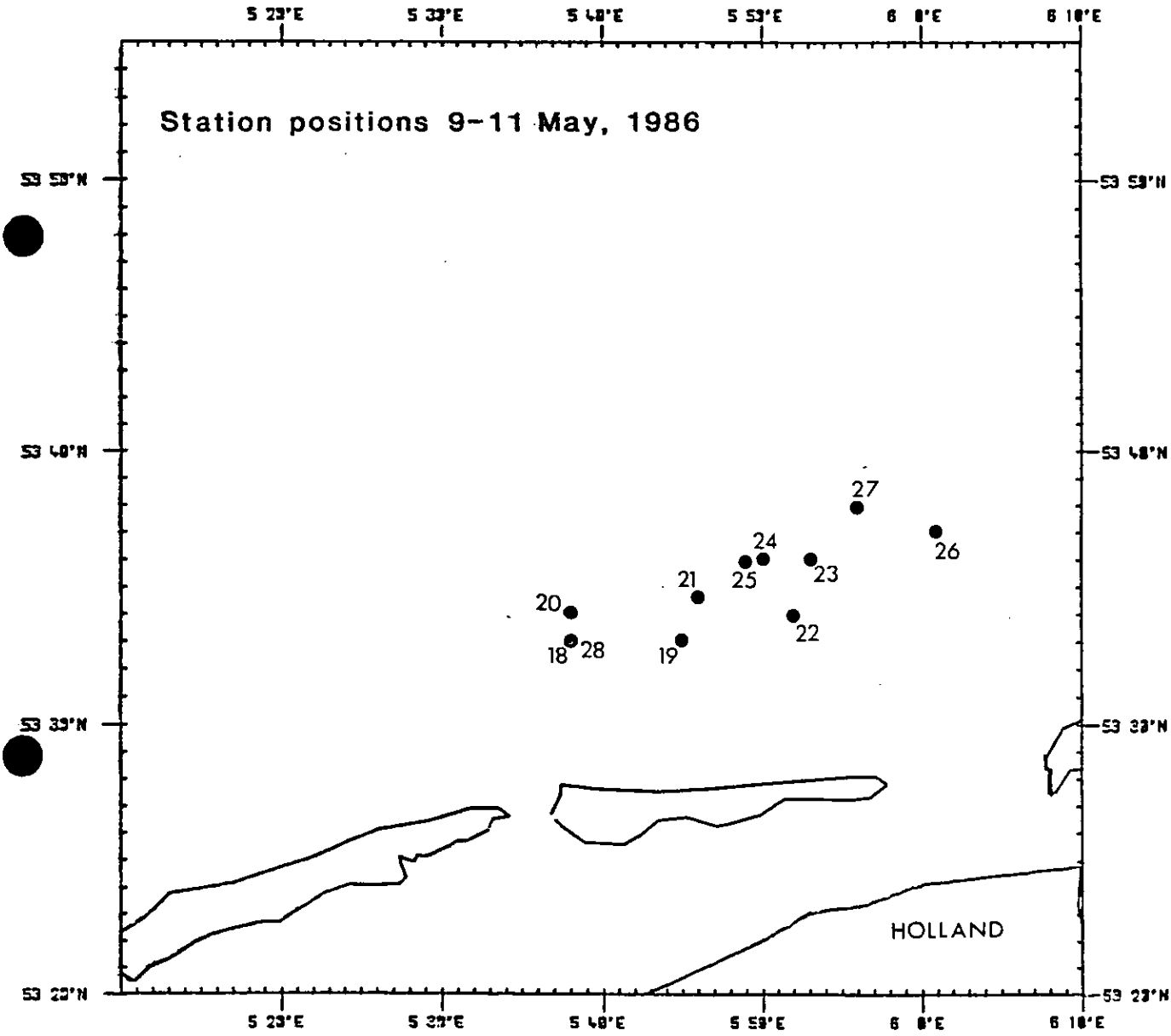
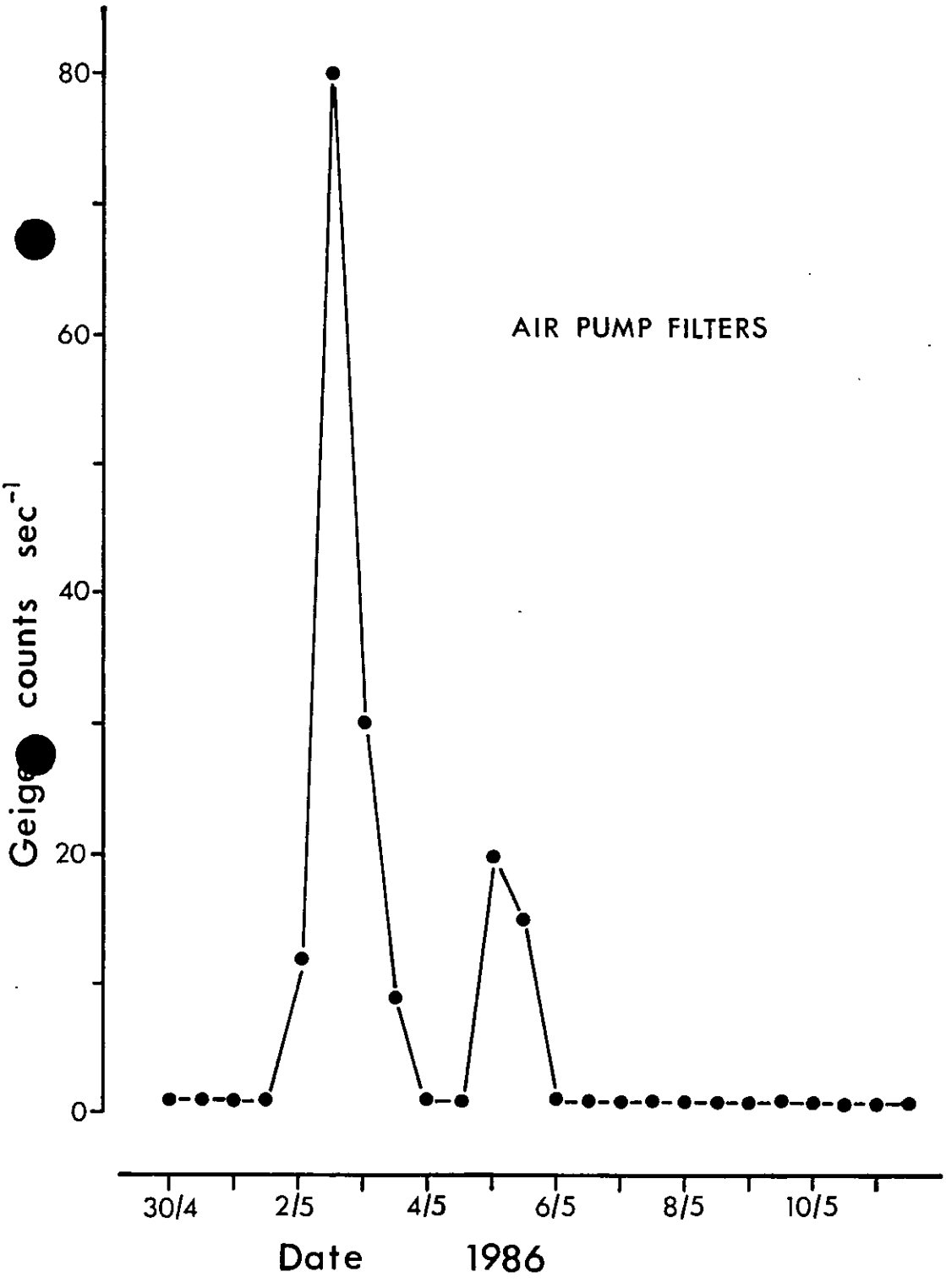

Station positions 9-11 May, 1986
5 23'E
5 33'E
5 48'E
5 53'E
6 8'E
6 18'E
53 53'N
53 48'N
53 33'N
53 28'N
20
18
28
19
21
25
24
27
23
22
26
HOLLAND

FIG. 4


80
60
40
20
0
Geiger counts sec^{-1}
AIR PUMP FILTERS
30/4
2/5
4/5
6/5
8/5
10/5
Date 1986