I.O.S.

RRS FREDERICK RUSSELL

CRUISE 12/85

21 - 30 NOVEMBER 1985

GEOCHEMICAL STUDIES IN THE ENGLISH CHANNEL

CRUISE REPORT NO. 177

1986

INSTITUTE OF
OCEANOGRAPHIC
SCIENCES

NATURAL ENVIRONMENT RESEARCH COUNCIL

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

WORMLEY

RRS FREDERICK RUSSELL
Cruise 12/85
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Geochemical studies in the English Channel

Principal Scientist

D.J. Hydes

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M.A. Harding	Master
N.A.C. Jonas	Chief Officer
P. Oldfield	Second Officer
I. McGill	Chief Engineer
N. Wilson-de Roze	Second Engineer
A. Greenhorn	Third Engineer
D. Wiseman	Chief Petty Officer

SCIENTIFIC PERSONNEL

D.J. Hydes	IOS, Wormley	Principal Scientist
J. Taylor	IOS, Wormley	
P.J. Statham	University of Southampton	Oceanography
A.D. Tappin	University of Southampton	Oceanography
A.G. Howard	University of Southampton	Chemistry
C.M.G. van den Berg	University of Liverpool	Oceanography
P. Newton	University of Liverpool	
M. Nimmo	University of Liverpool	

ACKNOWLEDGEMENTS

The willing help, co-operation and advice of the Master, Officers and Crew of RRS *Frederick Russell* are gratefully acknowledged, as is the help of RVB Barry in fitting out the ship. Everyone played their part to make FR 12/85 a very successful cruise.

ITINERARY

Depart Falmouth, U.K.	21 November 1985
Port Call: St. Peter Port, Guernsey, for water	26 November 1985
Arrive Falmouth, U.K.	30 November 1985

OBJECTIVES

This was the first of a three-cruise programme. These cruises are aimed at determining the concentrations of biogeochemically active metals which are potential pollutants in coastal waters. The three cruises (November 1985, April 1986, August 1986) will allow assessment to be made of how metal concentrations vary in relation to the biological and other processes which create the well-documented annual cycle in nutrient element concentrations in coastal waters. On each cruise a grid of 48 stations will be worked across the English Channel from 0°00' to 5°30'W. Three areas of work will be conducted on these cruises.

1. Collection and shipboard analysis of samples to determine the hydrography of the water being sampled - temperature, salinity and micronutrients.
2. Collection of samples for trace metal and metalloid analysis by established methods.
3. Development of electrochemical methods which will allow trace metal determinations to be made on board ship.

In addition on this cruise, atmospheric particle sampling was carried out.

NARRATIVE

On November 18th a small hydraulic winch for use with a "clean" Kevlar hydrographic line had been welded to the deck on the port side just aft of the trawl winch. Scientific fitting-out of the laboratory and sampling equipment commenced on November 19th, RRS *Frederick Russell* alongside at Falmouth. The GOFLO bottle rack was mounted opposite the NIO bottles in the hydro-lab. Samples were filtered directly from the bottles mounted on the rack, using pressure filtration. The pressure was supplied from nitrogen gas bottles which are conveniently mounted behind the hydro-winches outside the hydro-lab. In the main lab. the clean bench was set up, along with the thermosalinograph, aluminium determination fluorimeter and the salinometer. The electrochemical apparatus was set up in the fume laboratory. The autoanalyser was set up in the scientific plot. All the setting-up progressed smoothly.

Three problems were encountered. First, the electrical supply on the Frederick Russell contains variable amounts of noise depending on what gear is in operation. This degraded the quality of the autoanalyser signal but the system was still operable. Smoothing boxes will be used on this apparatus on future cruises. The second problem was with the pump for the air sampler. This required 415V three-phase supply whereas the three-phase supply on the Frederick Russell is 3809V (French Standard). This blew a fuse on the pump. This problem was solved by fitting a higher amperage-rated fuse, after which the pump ran successfully for the duration of the cruise. The third problem was that, due to a misunderstanding, the IOS-GOFLO bottles had been left in Wormley. Fortunately, these were rapidly found (many thanks are due to Helen Sutherland and Roger Wilson) and despatched to the ship.

We left the quay at Falmouth at 0940 on November 21st to lie off to wait for the arrival of the GOFLO bottles, which were on board at 1130. We then got underway to Station A1 in Mounts Bay. Work at Station A1 commenced at 1450. Procedure was to work NIO bottles on the normal steel hydro-wire followed by the GOFLO bottles on the Kevlar line. The Kevlar line was run through a sheaf hung on the end of the Hiab crane arm. The winch gave good control of the line speed and the sheaf position could be controlled conveniently by the Hiab crane. Line-out measurement was by counting marks on the line which were at five and ten metre intervals. Because of the unknown durability of Kevlar line used in this manner and the considerable cost of GOFLO bottles, no more than two bottles were attached to the Kevlar line at any one time. After station D04, the bottom 50 m were cut from the Kevlar line and inspected. Some fraying of the outer polyester casing was visible where bottles had been clamped to the line. The inner Kevlar fibres appeared to be intact at such points. Peter Statham will arrange breaking-strain gauge testing of the line on its return to Southampton.

Between Stations A1 and A2, testing of the Liverpool underway sampling fish started. This was lowered into the water at the fish position, starboard side aft. A line was run from the fish to a peristaltic pump in the lab. Tests of the two Liverpool fish were unsuccessful as they were too light to stay submerged. Track A was completed at 1239 on November 22nd. The average time for bottle handling at each station was 58 minutes and, due to calm weather, we were able to make 10 knots between stations. Track B was started at Station B8 at 1728 on November 22nd and completed at 1044 on November 23rd. En route from Track B to Track C, the influence of the Tamar was looked for on a track from 50°17'N, 4°31'W to 50°11'N, 03°48'W. This track was run at 8 knots with sampling from the non-toxic seawater supply. Track C was started at C1 at 1713 on November 23rd. Between stations C2 and C6, the ship's speed was reduced to 5 knots so that sample processing could catch up with sample collection. Track C was completed at 1400 on November 24th.

The weather freshened between the nights of 23/24. When the speed was put back to 10 knots (C6), the gear needed to be lashed down. At 1500 the Master informed me that, due to the worsening weather, he intended to run into the lee of the Cherbourg peninsula to seek shelter from the forecast easterly gale. At 2100 the weather had improved sufficiently for us to set course for the start of Track D at D10, which was commenced at 0130 on November 25th. Track D was completed at 0054 on November 26th. We then sailed to St. Peter Port on Guernsey to take on fresh water; docked 0900, sailed 1500. At 1913 Track E was commenced at Station E5. The snap shackles bought in St. Peter Port improved the handling of the safety line on the GOFLO bottles when fitting and removing them from the Kevlar line. Track E was completed at 0506 on November 27th. Track F was commenced at Station F1 at 0811. At 1130, en route between Stations F2 and F3, we were informed by RVB that the French authorities had forbidden us to work within their 12-mile zone. This meant that we had to terminate Track F at Station F5. This was completed at 1740. Two extra stations were added to the programme, G1 and G2, at 00°W outside the French 12-mile zone in the hope of finding the fresh water signal from the River Seine that we had hoped to sample at Stations F6 and F7. Station G1 was completed at 2141.

We then headed across the Channel at 8 knots to arrive at the eastern end of the Solent Nab Tower at 0719 on November 28th. We proceeded through the Solent to an Anchor Station off Yarmouth Pier. We remained at anchor for one tidal cycle until 2400. GOFLO bottle samples were taken each hour. Continuous monitoring of the water provided by the non-toxic supply was undertaken. At 0747 on November 29th we rounded Start Point en route from a second Anchor Station in Plymouth Sound. Between Start Point and the Plymouth Breakwater, the ship's speed was varied to test its effect on the precision of the electrochemical determinations. We anchored in Plymouth Sound at 1122 and sampled the Tamar output until 2200. At 0536 on November 30th a detailed reoccupation of Station A3 was commenced. Sampling was completed at 0917 and a course set for Falmouth. We were alongside at 1415 and disassembly of the scientific gear commenced. The last analyses were made at 0900 on December 1st and the scientific party left the ship at 1300.

HYDROGRAPHIC SAMPLING

At each station a string of up to six NIO bottles was deployed from the midships winch and A-frame on a 6 mm steel hydrowire. The bottles were each fitted with a reversing thermometer. The thermometers were checked before the GOFLO bottles were deployed to see if any structure was present in the water column. The bottles were subsampled for salinity (250 ml glass medicine bottle), nutrients (30 ml acrylic vial) and aluminium (300 ml linear polyethylene bottle). The filled salinity bottles were allowed to equilibriate with the laboratory temperature and then measured on a Plessey portable salinometer; the conductivities were recorded and converted to salinities on shore. Nutrient samples were stored in the refrigerator until run on the autoanalyser.

Throughout the cruise the surface water temperature and salinity were monitored using a thermosalinograph connected to the ship's non-toxic supply, flushing at 400 gallons an hour. The thermosalinograph temperature and salinity were recorded at each station. The trace showed (a) a well-defined front between Stations C8 and C9, (b) complex structure between stations D7 to D5, and (c) sharp gradients between D2 and D1 and along Track E.

A. Howard D. Hydes M. Nimmo
P. Statham A. Tappin J. Taylor

NUTRIENT ANALYSIS

The nutrients were determined using a Chemlab continuous-flow automatic analyser system coupled to a data reduction system based on a Commodore Pet microcomputer. Nitrate, phosphate and silicate were determined on each sample collected using standard methods described in IOS Report No. 177. Overall, the system worked well and was able to keep up with the rate of sample collection. A few minor problems arose:

1. The electrical supply on the Frederick Russell contains some noise which is amplified by the computer interface amplifier on the data reduction system.
2. For determinations covering Stations A1 to A9 and B8 to B4 the phosphate

peak was noisy. This noise had the form expected from poor matching of sample and water salinities. A sodium chloride solution 35% was used as the wash. The reported peak height is an average figure read from the chart recorder output.

3. Blockage of the nitrate column occurred due to an area of high reactivity developing near the start of the column. This broke up the copper cadmium granules to a size which packed down and blocked the column.
4. On two occasions, pump tubes collapsed and stopped pumping. This is an unusual occurrence. All the pump tubes were new at the start of the cruise.

J. Taylor D. Hydes

ALUMINIUM

Subsamples for aluminium determinations were taken from each of the NIO bottle samples taken and, at two sites, samples were taken from the GOFLO bottles for comparison. Samples were stored unfiltered and unacidified in linear polyethylene bottles. Samples were processed between one hour and seven days after collection; the majority of samples were processed within one day of collection. Remeasurements of samples during the cruise showed concentrations of determinable aluminium in these samples to be stable. Aluminium was determined using the fluorescent dye, lumogallion, and a Perkin Elmer LS2 fluorimeter.

D. Hydes

ATMOSPHERIC SAMPLING

Major objectives were to test the operation of the six-stage cascade impactor (CI) system built at Liverpool University Department of Oceanography (LUDO) and to use this equipment to obtain size-fractionated samples of marine and/or continental aerosols. On deployment, the cascade impactor was clamped in a circa 1 m length of 75 mm internal diameter stainless steel tube which was attached to the jack-staff so that the impactor was positioned immediately in front of the bow rail. The centrifugal pump and coupled three-phase motor was located in the forward paint locker and was connected to the CI by flexible 75 mm hosing. The tubing passed through the deck via the vent for the forepeak store. Flow rates through the CI were monitored using a manometric technique and other relevant parameters, e.g. wind direction and speed, were logged.

Atmospheric sampling could only be undertaken when (1) winds were approaching the ship from between circa 45 degrees port and starboard of the heading (to prevent contamination from the ship), (2) there was no precipitation, (3) there was no spray breaking over the bow of the ship, and (4) there was adequate wind velocity. These conditions were met on two occasions during the cruise and the corresponding sampling times were 7 hours 31 minutes and 6 hours 43 minutes. These relatively short sampling times resulted in only small loadings on the collection substrates, with the vast majority of the sampled material located on the last impactor stage (particle diameters of circa 0.52 μm) and on the back-up filter (< 0.5 μm).

These samples will be analysed at LUDO for a range of trace elements and the data processed to provide information on the contamination potential of the system and the atmospheric loading and sources of the trace elements determined. In the light of the experience gained, modifications will be made to the CI system as regards materials used and mode of deployment before future use is made of the equipment on other cruises.

The assistance of RVS with the installation of the CI system is gratefully acknowledged.

P.J. Statham

DISSOLVED TRACE METALS (Cd, Mn, Co, Cu, Ni, Pb, Zn, Fe)

This is the first of three planned cruises (the remainder are planned for Spring and Summer 1986) which have been designed to provide information on the biogeochemical cycling of a series of trace metals in a coastal zone of the British Isles. Measurements of dissolved metals by other participating groups (LUDO, SUC; see below) will complement and extend the range of elements determined. This first cruise will give data on the base-line concentrations of dissolved trace metals in the vertically and horizontally well-mixed water mass, typical of winter English Channel conditions, and against which possible influences of spring and summer phytoplankton growth and stratification on trace metal concentrations and distributions may be compared and contrasted. This latter data will stem from the remaining cruises inn 1986. Additionally, the sampling strategy will allow for any benthic inputs of dissolved trace metals to be recognised.

Within an area of the English Channel bounded by 50°36'-48°25'N, 05°23'-0°00'W, a total of 48 stations on seven N-S transects were occupied. Additional samples were taken at a single anchor station in the Solent (50°42-43'N, 1°27-28'W) over a single tidal cycle. A total of 132 samples was collected for subsequent trace metal analysis during the cruise.

Trace metal samples were obtained using a 'clean' system. This consisted of 2.5-litre Teflon-coated GOFLO bottles deployed from a separate winch on the aft deck which had been wrapped with plastic sheeting and wound with 6 mm Kevlar line (polycarbonate core, Dacron sheath). The Kevlar line was led over the ship's side via an all-plastic sheave fitted to the navigation deck crane and was weighted with a polyester-coated lead hydroweight. The use of this system was considered necessary to prevent adventitious contamination of the seawater samples. Up to four GOFLO bottles per station were deployed, with no more than two bottles on the line at any one time.

The GOFLO bottles were sub-sampled on board for nutrients (PO_4, NO_3, SiO_4) and chlorophyll. Samples of particulates for chlorophyll analysis were collected by vacuum filtration on Whatman GF/F filters and stored frozen until land-based laboratory fluorometric and high-performance liquid chromatographic analysis. To obtain samples for dissolved trace metal analysis, each GOFLO was pressurised to 10 psi (using filtered nitrogen) and the seawater was filtered through an in-line acid-cleaned 0.4 µm Nuclepore membrane into an acid-cleaned polyethylene bottle. These samples were acidified (1-ml sub-boiling concentrated HNO_3 per litre of seawater) to a pH of approximately two and stored at room temperature. At all times during filtering and storage the polyethylene bottles were kept in re-sealable polyethylene bags. Membranes used for filtration were retained and stored frozen. All membrane handling and acidification steps were carried out in a laminar-flow, clean-air hood.

At the shore laboratory, a series of trace metals (Cd, Mn, Co, Cu, Ni, Pb and possibly Zn and Fe) will be determined in the seawater samples using chelation followed by solvent extraction as a pre-concentration and separation step prior to measurements of the metal concentrates by graphite furnace atomic absorption spectrophotometry. Correlations between metal concentrations and other parameters (salinity, nutrients, chlorophyll) will be identified in order to gain insights into the biogeochemical cycling of these metals in the coastal environment.

Analysis of the particulates for trace metals using a sequential leaching technique will also be carried out, if time permits, in order to assist in the interpretation of metal cycling.

A. Tappin P. Statham A. Howard

METALLOIDS ELEMENT

To investigate the distribution and chemical forms of dissolved metalloids in the western section of the English Channel; paying particular attention to the effects of land-derived material and seasonal variability in both spatial distribution and speciation.

Forty-five stations were occupied on a grid covering the English Channel from 5°30'W to 0°00'. At each station, between two and four Teflon-coated 2.5-litre GOFLO bottles were deployed from the ship using a Kevlar line to ensure metal-free sampling conditions. These were then pressure-filtered, under nitrogen, through 0.4 µm Nuclepore filters. These samples (<u>ca</u> 130 ml) were frozen for arsenic speciation analysis on return to the laboratory. Samples of unfiltered water were also collected for the identification of phytoplankton and for bacterial counting. At each station the temperature and salinity structure of the water column was monitored by deploying up to six NIO water bottles fitted with reversing thermometers.

In view of the particularly high metalloid load carried into the Channel by the river Tamar, and continuing studies of that system being carried out at Southampton, the coastal region around the Tamar estuary was studied in greater detail. A string of stations along the Devon/Cornwall coast were sampled between Transects B and C. These samples will be analysed for arsenic and antimony species. Later in the cruise, samples were taken while approaching Plymouth Sound. A station was then occupied in the Sound for a period of 13 hours, during which time samples were taken to assess the tidal variation of metalloid discharge into the Channel. In all, a further 40 samples were collected in this region.

This cruise was the first of a series planned to study the chemical form and distribution of nutrients, metals and metalloids in the English Channel. Cruise 12/85 was expected to provide baseline conditions of a well-mixed water column having little biological activity. Measurements made during the cruise confirmed these expectations and it is intended that further measurements will be made during the spring and summer of 1986 to study the system under conditions of high biological activity and stratification of the water column.

A. Howard P. Statham A. Tappin

SHIPBOARD ELECTROCHEMICAL METAL DETERMINATIONS

Purposes of the cruise were testing of the metal monitor and collection of water samples for metal speciation studies.

Water samples were collected using 2.5-litre GOFLO bottles (from IOS) at three locations and two depths (5 m and 40 m). These samples were filtered and stored frozen. Speciation of nickel, copper and zinc will be determined later in Liverpool.

The metal monitor was tested during the cruise. From measurements in water collected using GOFLOs and in the non-toxic water supply it was found that nickel could be determined relatively easily. This metal was then determined in two-minute intervals while on station during a tidal cycle in the Solent, during the crossing back to Plymouth, in the Plymouth Sound during a tidal cycle and during the cruise back to Falmouth. The data obtained are equivalent to a few hundred discrete samples.

Tests with a simple peristaltic pumping system were largely unsuccessful but water from the non-toxic water supply appeared to be suitable for nickel analysis, as checked against bottle samples.

C.M.G. van den Berg P.M. Newton M. Nimmo

BRIEF DESCRIPTION OF HYDROGRAPHIC, NUTRIENT AND ALUMINIUM DATA

Table 1 lists the station positions, time of arrival at the station and the water depth. Results for salinity, temperature, silicon, phosphate, nitrate and aluminium for each sample are listed in Table 2. In Table 3, averaged results for each station for salinity, aluminium, silicon, phosphate and nitrate are listed. The results from Table 3 were investigated by linear regression analysis to find out how much inter-relationship there was between the variables measured. The results of this analysis are presented in Table 4. Corresponding plots are presented in Figures 1 to 7. In Figures 8 to 12, the geographical distribution of the data from Table 3 is presented. As would be expected at this time of year, the water was well mixed vertically.

Salinity

The salinity pattern clearly shows high-salinity ocean water pushed well up the Channel. This cruise was preceded by a period of westerly gales.

Silicon

Of the variables measured, silicon correlates most closely with salinity. This indicates that the strongest input to Channel waters is from river sources rather than from a sediment source.

Aluminium

Also correlates well with salinity. The lack of an impact from a sedimentary source is consistent with aluminium and silicon being taken up into the hard parts of shell material and so being slow to return to solution. In Table 5, the measurements made in July 1984 are compared to those found on this cruise. Aluminium clearly appears to be depleted in Channel waters during the summer.

Phosphate and Nitrate

Phosphate and nitrate correlate less well with salinity than do silicon and aluminium, but they do correlate together. This is consistent with their uptake into the soft parts of organisms which decay rapidly in sediments. The ratio of N to P of 13 is close to the Redfield ratio of 16 for marine organic material and is consistent with some reduction of nitrate before release from the sediment.

TABLES

Frederick Russell Cruise 12/85

TABLE 1 - Station Positions

STATION Number	POSITION Latitude N	Longitude W	Date	Time GMT	Depth m
Track A					
1	50°00'	05°31'	21/11	14.42	50
2	49°48'	05°30'	21/11	17.30	83
3	49°36'	05°30'	21/11	20.22	94
4	49°24'	05°30'	21/11	23.10	103
5	49°13'	05°29'	22/11	01.27	110
6	49°00'	05°30'	22/11	03.42	110
7	48°51'	05°25'	22/11	05.49	106
8	48°30'	05°30'	22/11	10.00	100
9	48°25'	05°29'	22/11	11.34	113
Track B					
1	50°10'	04°30'	23/11	10.44	61
2	49°59'	04°31'	23/11	08.22	73
3	49°47'	04°31'	23/11	06.06	80
4	49°35'	04°32'	23/11	03.06	86
5	49°25'	04°30'	23/11	00.48	92
6	49°13'	04°30'	22/11	22.21	92
7	49°01'	04°31'	22/11	20.00	96
8	48°49'	04°30'	22/11	17.55	95
Track C					
1	50°16'	03°30'	23/11	17.13	55
2	50°06'	03°30'	23/11	20.01	63
3	49°56'	03°30'	23/11	22.47	67
4	49°45'	03°31'	24/11	01.27	70
5	49°36'	03°30'	24/11	04.06	76
6	49°26'	03°30'	24/11	07.08	72
7	49°16'	03°30'	24/11	09.27	73
8	49°05'	03°30'	24/11	12.00	72
9	48°56'	03°28'	24/11	13.45	70
Track D					
1	50°29'	02°31'	26/11	00.09	36
2	50°18'	02°29'	25/11	22.00	44
3	50°08'	02°23'	25/11	19.33	60
4	49°58'	02°22'	25/11	17.21	64
5	49°46'	02°30'	25/11	14.14	78
6	49°34'	02°28'	25/11	11.31	54
7	49°22'	02°30'	25/11	08.52	55
8	49°13'	02°30'	25/11	06.30	54
9	48°59'	02°30'	25/11	04.00	46
10	48°50'	02°30'	25/11	01.52	40

TABLE 1 - continued (2)

STATION Number	POSITION Latitude N	Longitude W	Date	Time GMT	Depth m
Track E					
1	50°35'	01°30'	27/11	04.28	24
2	50°23'	01°30'	27/11	02.20	36
3	50°11'	01°30'	26/11	23.40	78
4	49°59'	01°30'	26/11	21.39	62
5	49°47'	01°30'	26/11	19.11	64
Track F					
1	50°36'	00°30'	27/11	08.11	35
2	50°24'	00°30'	27/11	10.18	50
3	50°12'	00°30'	27/11	12.10	48
4	50°00'	00°30'	27/11	14.28	50
5	49°49'	00°30'	27/11	16.29	37
Track G					
1	49°56'	00°00'	27/11	21.15	42
2	50°06'	00°00'	27/11	19.36	43
Track A					
3A	49°36.2'	05°29.6'	30/11	07.10	95
3B	49°34.7'	05°29.4'	30/11	05.36	97
3C	49°36.3'	05°27.3'	30/11	08.22	95

Frederick Russell Cruise 12/85

TABLE 2 - Hydrographic Results

STATION and TS Reading	NIO Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	GOFLO Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
A1	0	35.134	12.06	2.9	0.33	5.2	25.6	5	3.1	0.33	4.2	
S 35.24	10	35.131	12.06	2.9		4.6	31.5	40	3.2		4.3	
T 12.18	20	35.129	12.06	3.0		5.1	29.2					
	30	35.125	12.05	3.0		4.6	61.2^c					
	40	35.123	12.05	3.0		4.3	27.4					
A2	0	35.220	12.45	2.3	0.29	4.2	14.7	5	2.3	0.29	4.0	
S 35.28	10	35.218	12.48	2.3		4.5	18.3	40	2.2		3.9	
T 12.55	20	35.215	12.48	2.3		4.1	19.3					
	35	35.213	12.50	2.3		4.4	16.2					
	50	35.217	12.50	2.2		4.4	36.1^c					
	70	35.213	-	2.3		3.8	12.9					
A3	0	35.236	12.47	2.2	0.38	5.8	15.6	5	2.1	0.38	5.2	
S 35.29	10	35.234	12.47	2.1		5.4	19.0	40	2.1		5.1	
T 12.50	25	35.234	12.47	2.1		5.4	15.5					
	40	35.233	12.47	2.1		4.7	16.8					
	60	35.235	12.47	2.2		5.1	16.6					
	80	35.234	12.47	2.2		5.4	16.0					
A4	0	35.260	12.43	2.2	0.41	5.3	13.5	5	2.2	0.41	5.5	
S 35.32	10	35.257	12.42	2.2		5.7	15.8	40	2.2		5.4	
T 12.40	25	35.255	12.45	2.2		5.2	16.1					
	45	35.253	12.45	2.2		5.0	16.2					
	65	35.254	12.45	2.2		5.1	22.6					
	85	35.254	12.45	2.2		5.2	15.1					

c = not used to calculate mean aluminium concentration

TABLE 2 - continued (2)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
A5	0	35.283	12.40	2.3	0.41	5.7	11.8	5	2.2	0.41	5.1	
S 35.32	10	35.282	12.40	2.2		5.2	16.9	40	2.2		5.0	
T 12.38	25	35.281	12.40	2.2		5.6	15.3					
	45	35.281	12.40	2.3		5.6	16.3					
	65	35.281	12.40	2.2		5.4	21.7					
	85	35.282	12.40	2.2		5.1	15.6					
A6	0	35.299	12.24	2.4	0.42	5.3	15.0	5	2.4	0.42	5.1	
S 35.34	10	35.297	12.25	2.4		4.8	18.4	40	2.4		5.2	
T 12.33	30	35.302	12.25	2.3		4.8	14.9					
	50	35.299	12.27	2.3		4.6	11.9					
	70	35.304	12.25	2.3		4.7	14.3					
	90	35.301	12.25	2.4		4.6	18.5					
A7	0	35.322	12.25	2.3	0.40	4.5	11.0	5	2.4	0.40	4.8	
S 35.36	10	35.323	12.28	2.3		4.5	21.2	40	2.3		5.0	
T 12.38	30	35.321	12.28	2.3		4.4	12.7					
	50	35.318	12.28	2.4		4.5	17.4					
	70	35.318	12.30	2.3		4.7	17.4					
	90	35.318	12.30	2.3		4.5	16.2					
A8	0	35.340	12.50	2.4	0.40	4.8	12.3	5	2.4	0.40	5.0	
S 35.41	10	35.341	12.50	2.4		4.5	19.3	40	2.4		5.0	
T 12.60	30	35.344	12.51	2.4		4.3	11.9					
	50	35.345	12.55	2.4		4.6	18.9					
	70	35.345	12.53	2.4		4.2	11.5					
	90	35.347	12.53	2.4		4.2	20.6					

TABLE 2 - continued (3)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
A9	0	35.352	12.59	2.5	0.40	5.3	10.2	5	2.6	0.40	5.5	
S 35.41	10	35.356	12.60	2.5		5.4	14.1	40	2.6		5.9	
T 12.67	30	35.356	12.60	2.5		5.0	9.4					
	50	35.355	12.61	2.5		4.5	14.2					
	75	35.354	12.61	2.5		4.6	14.6					
	100	35.356	12.60	2.5		4.5	18.0					
B1	0	35.123	12.54	2.5	0.27	2.9	19.4	5	2.5	0.27	3.1	
S 35.22	10	35.122	12.55	2.5	0.26	2.9	23.2	20	2.5	0.29	3.3	
T 12.65	20	35.122	12.54	2.5	0.27	3.0	-	40	2.5	0.27	3.1	
	35	35.123	12.56	2.5	0.26	3.0	23.2					
	50	35.124	12.54	2.5	0.27	2.8						
B2	0	35.154	12.60	2.4	0.28	2.2	16.5	5	2.4	0.27	3.2	
S 35.24	10	35.154	12.62	2.4	0.28	3.1	18.3	20	2.4	0.27	3.4	
T 12.70	20	-	12.62	2.4	0.27	3.3	9.0	40	2.4	0.27	3.5	
	30	35.153	12.66	2.4	0.27	3.1	18.2	60	2.4	0.27	3.1	
	40	35.154	12.65	2.4	0.27	3.1	21.6					
	60	35.154	-	2.4	0.26	3.1	19.3					
B3	0	35.204	12.51	2.7	0.29	3.8	18.2	5	2.7	0.30	4.1	
S 35.24	10	35.203	12.54	2.7	0.29	3.9	15.1	20	2.8	0.32	4.0	
T 12.60	20	35.204	12.52	2.7	0.29	3.8	20.3	40	2.7	0.30	3.9	
	35	35.206	12.55	2.7	0.29	3.6	14.5	70	2.7	0.29	4.1	
	50	35.204	12.55	2.7	0.33	3.8	16.7					
	70	35.204	12.52	2.7	0.29	3.7	14.2					

TABLE 2 - continued (4)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
B4	0	-	12.67	2.4	0.33	4.4	14.8	5	2.4	0.33	3.9	
S 35.30	10	35.232	12.69	2.4		4.4	12.8	20	2.4		4.4	
T 12.77	20	35.232	12.69	2.4		4.0	13.9	40	2.4		4.4	
	35	35.232	12.70	2.4		4.1	15.2					
	50	35.234	12.71	2.3		4.1	14.6					
	70	35.232	12.14	2.3		4.2	12.6					
B5	0	35.291	12.81	2.6	0.37	4.4	20.7	5	2.7	0.37	4.3	
S 35.33	10	35.282	12.84	2.6		3.9	24.3	20	2.6		4.9	
T 12.93	25	35.281	12.82	2.6		4.1	35.4c	40	2.6		5.2	
	40	35.279	12.86	2.6		4.8	14.8					
	55	35.275	12.85	2.6		5.2	21.2					
	70	35.278	12.85	2.7		4.8	13.9					
B6	0	35.274	12.73	2.4	0.37	5.2	15.6	5	2.3	0.37	5.1	
S 35.45	10	35.272	12.77	2.4		4.8	14.6	20	2.3		5.3	
T 12.85	20	35.271	12.70	2.4		4.8	18.8	40	2.4		5.2	
	40	35.272	12.78	2.4		4.6	15.7					
	60	35.270	12.78	2.4		4.2	23.2					
	85	35.270	12.78	2.4		4.3	21.9					
B7	0	35.279	12.70	2.5	0.39	3.9	15.6	5	2.4	0.39	3.9	
S 35.38	10	35.281	12.72	2.5		3.3	17.9	20	2.4		3.5	
T 12.83	25	35.278	12.72	2.5		4.1	18.6	40	2.5		4.4	
	45	35.279	12.75	2.5		4.4	16.4	85	2.5		4.1	
	65	35.281	12.73	2.6		4.5	23.3					
	85	35.280	12.72	2.5		4.8	14.2					

c = not used to calculate mean aluminium concentration

TABLE 2 - continued (5)

STATION and TS Reading	NIO							GOFLO				
	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
B8	0	35.323	12.85	2.7	0.36	4.2	16.3	5	2.7	0.36	4.2	
S 34.39	10	35.322	12.87	2.6		4.3	14.7	20	2.7		4.0	
T 12.95	25	35.322	12.87	2.7		4.3	15.9	40	2.7		4.0	
	45	35.322	12.89	2.7		4.2	16.4	85	2.7		4.1	
	65	35.321	12.89	2.7		4.2	18.5					
	85	35.319	12.88	2.6		4.0	18.4					
C1	0	34.973	11.82	3.3	0.28	3.3	26.1	5	3.3	0.31	3.2	
S 35.02	10	34.964	11.82	3.3	0.26	3.3	28.1	40	3.4	0.32	5.0	
T 11.90	20	34.961	11.80	3.3	0.29	3.4	26.3					
	35	34.960	11.80	3.4	0.31	3.1	26.7					
	45	34.958	11.80	3.3	0.30	3.2	28.0					
C2	0	34.958	12.30	3.7	0.31	4.2	26.9	5	3.7	0.32	4.0	30.0
S 35.03	10	34.956	12.30	3.7	0.28	3.6	28.8	40	3.7	0.29	4.6	30.4
T 12.35	20	34.956	12.30	3.7	0.28	3.7	27.4					
	30	34.958	12.30	3.7	0.27	3.7	28.3					
	40	34.960	12.30	3.7	0.28	3.6	29.2					
	50	34.957	12.29	3.7	0.27	3.7	27.4					
C3	0	35.096	12.65	2.5	0.26	4.1	22.8	5	2.5	0.26	4.1	21.1
S 35.17	10	35.095	12.69	2.5	0.25	2.9	22.1	40	2.5	0.26	4.1	22.4
T 12.72	20	35.096	12.69	2.5	0.26	3.0	20.5					
	30	35.095	12.72	2.5	0.26	3.3	21.0					
	45	35.096	12.77	2.5	0.26	3.2	21.8					
	55	35.094	12.70	2.5	0.27	3.1	21.4					

TABLE 2 - continued (6)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
C4	0	35.183	12.88	3.3	0.30	3.8	21.2	5	3.3	0.31	3.4	
S 35.26	10	35.180	12.91	3.3	0.30	3.7	22.5	40	3.3	0.31	3.7	
T 12.90	20	35.181	12.90	3.3	0.28	3.7	19.8					
	30	35.185	12.91	3.2	0.30	-	16.3					
	40	35.180	12.92	3.3	0.30	-	21.7					
	50	35.180	12.91	3.2	0.31	-	21.0					
C5	0	35.160	13.10	3.6	0.33	5.3	26.8	5	3.6	0.35	4.8	
S 35.23	10	35.155	13.12	3.5	0.34	5.5	25.6	40	3.6	0.34	5.4	
T 13.20	20	35.162	13.12	3.5	0.34	5.4	26.0					
	30	35.154	13.13	3.5	0.33	5.2	25.7					
	45	35.153	13.14	3.5	0.34	5.2	24.0					
	60	35.152	13.12	3.5	0.35	5.1	26.1					
C6	0	35.097	-	3.5	0.37	5.6	33.8	5	3.5	0.37	5.6	
S 35.20	10	35.096	13.18	3.5	0.35	5.5	29.0	40	3.5	0.35	5.5	
T 13.28	20	35.097	13.18	3.5	0.35	5.5	28.6					
	30	35.097	13.18	3.5	0.36	5.4	30.3					
	45	35.097	13.18	3.5	0.35	5.8	28.6					
	60	35.099	13.19	3.5	0.36	5.4	29.5					
C7	0	35.042	12.14	3.6	0.38	5.8	31.9	5	3.6	0.37	5.5	
S 35.14	10	35.050	13.35	3.6	0.37	5.8	30.6	40	3.5	0.37	5.9	
T 13.70	20	35.049	13.36	3.6	0.37	5.8	30.9					
	35	35.049	13.40	3.5	0.37	6.2	23.8					
	45	35.056	13.36	3.5	0.36	5.9	31.1					
	60	35.060	13.34	3.5	0.36	6.0	30.5					

TABLE 2 - continued (7)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
C8	0	35.026	13.18	3.7	0.38	6.1	35.5	5	3.7	0.35	6.1	
S 35.12	10	35.026	13.19	3.7	0.48	6.7	34.3	40	3.7	0.37	6.0	
T 13.60	20	35.026	13.19	3.7	0.38	6.3	31.5					
	30	35.029	13.26	3.7	0.42	6.7	34.6					
	45	35.039	13.20	3.7	0.38	5.8	33.4					
	60	35.041	13.20	3.7	0.38	6.2	34.2					
C9	0	35.031	12.72	4.3	0.43	6.8	39.5	5	4.3	0.42	6.5	
S 35.04	10	34.963	12.73	4.3	0.43	7.0	39.2	40	4.4	0.44	6.8	
T 12.80	20	34.962	12.73	4.3	0.43	6.9	37.8					
	30	34.961	12.75	4.4	0.43	7.1	35.3					
	40	34.961	12.73	4.4	0.43	6.9	39.5					
D1	0	34.911	10.70	4.8	0.37	3.9	27.2	5	4.7	0.38	4.1	
S 34.98	5	34.913	10.72	4.7	0.37	4.1	27.2	20	4.8	0.39	4.3	
T 11.58	15	34.913	10.70	4.8	0.35	4.1	26.8					
	25	34.912	10.71	4.8	0.35	3.7	26.7					
D2	0	34.940	11.98	4.0	0.40	6.4	29.2	5	3.9	0.45	6.3	
S 35.01	5	34.940	12.00	4.0	0.38	6.0	29.8	15	3.9	0.42	5.9	
T 12.10	10	34.940	12.00	4.0	0.38	5.9	30.4	30	4.0	0.42	5.9	
	20	34.940	12.00	3.9	0.39	5.7	29.3					
	35	34.938	12.00	3.9	0.39	5.4	28.5					
D3	0	35.030	12.50	3.2	0.42	6.9	29.4	5	3.2	0.41	6.7	
S 35.12	10	35.024	12.50	3.2	0.41	6.9	31.2	20	3.1	0.41	6.6	
T 12.60	20	35.021	12.50	3.2	0.40	6.9	29.6	40	3.2	0.42	6.3	
	30	35.023	12.51	3.1	0.40	6.5	30.5					
	40	35.022	12.50	3.1	0.40	6.8	33.8					
	50	35.019	12.50	3.1	0.40	6.8	32.4					

TABLE 2 - continued (8)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
D4	0	35.121	-	3.5	0.40	5.8	30.4	5	3.4	0.40	6.0	
S 35.12	10	35.118	-	3.3	0.39	5.7	32.1	20	3.3	0.42	6.6	
T 12.87	20	35.113	-	3.3	0.39	6.4	30.2	40	3.3	0.40	6.4	
	30	35.114	-	3.3	0.40	6.0	30.9					
	40	35.033	-	3.4	0.41	6.2	32.2					
	50	35.114	-	3.3	0.39	5.5	31.3					
D5	0	35.168	13.01	2.9	0.31	4.8	25.3	5	3.0	0.30	4.7	
S 35.17	10	35.170	13.03	2.9	0.30	5.2	25.9	20	3.0	0.31	4.5	
T 13.12	20	35.170	13.02	2.9	0.29	4.8	25.0	40	3.0	0.31	4.3	
	35	35.168	13.04	2.9	0.29	4.4	24.6					
	50	35.168	13.02	2.9	0.32	4.5	25.2					
	65	35.167	13.02	2.9	0.30	4.7	24.7					
D6	0	35.096	12.23	3.6	0.38	6.8	35.1	5	3.6	0.42	7.2	
S 35.12	10	35.100	12.22	3.5	0.38	6.9	36.2	20	3.5	0.40	6.5	
T 12.30	20	35.097	12.22	3.6	0.37	6.1	34.6	40	3.6	0.42	6.6	
	30	35.096	12.21	3.6	0.37	6.2	35.5					
	45	35.096	-	3.6	0.37	6.2	36.2					
D7	0	35.116	12.58	3.4	0.38	6.1	33.2	5	3.4	0.33	6.3	
S 35.12	10	35.117	12.60	3.3	0.37	6.6	33.4	20	3.4	0.39	6.4	
T 12.70	20	35.119	12.60	3.4	0.38	5.9	32.7	40	3.4	0.39	6.2	
	30	35.111	12.60	3.4	0.40	6.1	32.6					
	45	35.113	12.60	3.4	0.38	6.5	31.8					

TABLE 2 - continued (9)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
D8	0	35.047	12.80	3.6	0.39	5.8	34.8	5	3.6	0.38	6.0	
S 35.07	10	35.051	12.82	3.6	0.39	5.7	35.0	20	3.6	0.41	5.9	
T 12.95	20	35.048	12.81	3.6	0.37	6.0	34.3	40	3.6	0.46	6.0	
	30	35.051	12.82	3.6	0.38	5.9	34.3					
	40	35.051	12.82	3.6	0.37	5.8	36.0					
	45	35.052	12.80	3.6	0.38	5.8	34.3					
D9	0	35.072	12.57	3.7	0.38	5.8	34.6	5	3.7	0.38	6.5	
S 35.06	10	35.073	12.58	3.7	0.38	6.0	34.1	20	3.7	0.39	5.8	
T 12.65	20	35.073	12.60	3.7	0.38	6.3	34.4	35	3.7	0.38	6.0	
	30	35.073	12.60	3.7	0.37	6.4	36.7					
	35	35.069	12.60	3.6	0.38	6.1	34.9					
D10	0	35.056	11.99	4.1	0.45	7.1	38.8	5	4.1	0.44	7.1	
S 35.08	5	35.056	11.97	4.1	0.42	6.9	38.1	20	4.1	0.41	7.4	
T 12.08	10	35.056	11.98	4.1	0.43	7.0	37.7	35	4.1	0.41	7.2	
	20	35.056	12.00	4.1	0.43	7.0	38.1					
	30	35.057	11.99	4.0	0.42	7.2	37.9					
E1[a]	0	34.801	9.58	4.6	0.56	7.0	74.2	5	4.7	0.56	6.7	
S 34.89	5	34.803	9.60	4.6	0.56	7.0	68.4					
T 9.65	15	34.804	9.60	4.6	0.58	6.5	59.9					
E2	0	34.873	9.90	3.6	0.40	6.1	46.1	5	3.6	0.48	4.6	
S 34.95	5	34.873	9.91	3.7	0.47	5.6	44.8					
T 9.95	15	34.874	9.90	3.7	0.49	6.4	49.2					
	25	34.871	9.93	3.7	0.50	5.7	48.3					

a = high suspended load dredge boats discharging or collecting sand ½-mile upstream

TABLE 2 - continued (10)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
E3	0	35.271	12.33	3.1	0.39	7.4	32.6	5	3.1	0.40	7.5	
S 35.05	10	34.974	12.34	3.1	0.40	7.2	32.1					
T 12.43	20	34.973	12.33	3.1	0.39	6.9	31.4					
	30	34.973	12.36	3.1	0.39	6.9	31.6					
	45	34.973	12.33	3.0	0.41	6.7	31.1					
	60	34.973	12.36	3.0	0.40	7.1	32.5					
E4	0	34.928	12.70	3.6	0.45	7.5	34.3	5	3.6	0.48	7.5	
S 35.00	10	34.927	12.72	3.5	0.46	6.9	35.8					
T 12.84	20	34.926	12.71	3.5	0.45	7.1	34.3					
	30	34.788	12.75	3.5	0.44	7.5	33.3					
	40	34.926	12.73	3.5	0.45	7.1	34.6					
	50	34.927	12.73	3.6	0.45	6.7	34.4					
E5	0	34.560	12.00	5.5	0.78	8.7	33.1	5	5.3	0.78	8.4	
S 34.64[b]	10	34.564	12.05	5.4	0.77	9.3	34.5					
T 12.40	20	34.531	11.95	5.7	0.80	9.2	32.8					
	30	34.534	11.94	5.7	0.77	9.5	32.6					
	40	34.534	11.92	5.6	0.79	9.3	37.7					
	50	34.525	11.90	5.7	0.78	9.3	37.1					
F1	0	34.930	11.40	3.6	0.36	5.1	33.2	5	3.6	0.39	5.3	
S 34.98	5	34.929	11.40	3.6	0.35	4.7	35.2					
T 11.49	15	34.934	11.40	3.5	0.34	5.2	34.7					
	25	34.931	11.42	3.6	0.34	5.0	36.1					

b = noisy trace on thermosalinograph

TABLE 2 - continued (11)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
F2	0	34.928	11.74	3.6	0.41	7.0	37.7	5	3.6	0.48	6.8	
S 34.98	10	34.928	11.76	3.5	0.41	6.2	34.2	20	3.5	0.38	6.0	
T 11.83	20	34.927	11.75	3.5	0.43	6.1	35.5	40	3.6	0.43	7.0	
	30	34.927	11.77	3.6	0.45	6.7	35.0					
	40	34.926	11.76	3.5	0.41	6.3	37.4					
F3	0	34.944	11.88	3.4	0.44	6.9	35.7	5	3.5	0.48	6.9	
S 35.00	5	34.944	11.89	3.5	0.44	7.1	36.3	20	3.5	0.47	8.1	
T 11.95	15	34.943	11.88	3.4	0.44	6.8	35.3	40	3.4	0.46	7.4	
	25	34.945	11.90	3.4	0.44	7.6	34.2					
	35	34.944	11.89	3.4	0.45	7.2	35.0					
F4	0	34.858	12.22	3.9	0.57	7.3	36.6	5	3.9	0.51	7.4	
S 34.94	10	34.862	12.22	3.9	0.51	7.8	36.4	20	3.9	0.52	7.8	
T 12.34	20	34.872	12.29	3.8	0.50	7.6	34.9	40	3.8	0.50	7.8	
	30	34.880	12.31	3.8	0.51	8.0	35.9					
	40	34.873	12.30	3.8	0.51	7.4	35.9					
F5	0	34.718	11.54	4.9	0.60	8.0	38.1	5	4.9	0.59	7.0	
S 34.79	10	34.724	11.54	4.9	0.59	7.6	37.4	20	4.9	0.60	6.8	
T 11.65	20	34.722	11.56	4.9	0.60	8.1	39.6					
	25	34.724	11.57	4.9	0.59	8.3	40.2					
G1	0	34.887	11.48	4.4	0.49	5.9	35.1	5	4.3	0.50	7.3	
S 34.93	10	34.887	11.49	4.3	0.50	7.0	35.0	20	4.4	0.49	6.9	
T 11.68	20	34.888	11.48	4.3	0.49	8.2	34.8					
	30	34.889	11.49	4.3	0.49	7.7	35.3					

TABLE 2 - continued (12)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
G2	0	34.791	11.50	5.0	0.55	8.3	37.1	5	5.0	0.55	6.7	
S 34.83	10	34.789	11.51	4.9	0.55	7.9	35.4	20	5.0	0.57	8.0	
T 11.60	20	34.791	11.50	5.0	0.55	8.3	35.6					
	30	34.790	11.52	5.0	0.55	8.2	37.4					
A3A	0	35.234	-	2.5	0.45	5.4	16.6	5	2.6	0.45	5.2	
S 35.34	5	35.233	-	2.5	0.45	5.2	17.3	40	2.5	0.46	5.9	
T 12.70	10	35.232	-	2.4	0.44	5.5	16.3					
	20	35.232	-	2.4	0.41	5.2	16.6					
	30	35.233	-	2.4	0.43	5.4	17.9					
	40	35.236	-	2.4	0.40	5.0	16.0					
	50	35.230	12.10	2.4	0.40	5.4	16.7					
	60	35.230	12.09	2.4	0.43	5.2	17.0					
	70	35.230	12.09	2.4	0.40	5.1	17.0					
	80	35.230	12.10	2.4	0.41	5.0	16.6					
A3B	0	35.340	12.11	2.4	0.43	4.9	16.0					
S 35.34	5	35.239	12.10	2.4	0.42	5.1	16.7					
T 12.75	10	35.241	12.11	2.4	0.42	5.2	16.7					
	20	35.242	12.13	2.4	0.40	5.2	17.4					
	30	35.240	12.10	2.4	0.42	5.2	17.3					
	40	35.242	12.10	2.4	0.39	5.4	16.5					
	50	35.241	12.11	2.4	0.44	5.2	16.3					
	60	35.241	12.14	2.4	0.40	5.1	16.1					
	70	35.241	12.10	2.4	0.39	5.6	17.7					
	80	35.242	12.12	2.4	0.39	5.3	18.3					

TABLE 2 - continued (13)

	NIO							GOFLO				
STATION and TS Reading	Sample Depth m	Salinity	Temp. °C	Silicon µM	Phosphate µM	Nitrate µM	Al nM	Sample Depth m	Silicon µM	Phosphate µM	Nitrate µM	Al nM
A3C S 35.34 T 12.70	0	35.232	12.10	2.4	0.37	5.0	16.4					
	5	35.232	12.10	2.4	0.39	5.1	17.5					
	10	35.232	12.10	2.4	0.38	5.1	16.6					
	20	35.234	12.10	2.4	0.38	5.2	16.7					
	30	35.233	12.09	2.4	0.36	5.0	17.7					
	40	35.232	12.10	2.4	0.39	5.1	16.7					
	50	35.230	12.10	2.4	0.36	5.0	17.0					
	60	35.228	12.11	2.4	0.38	5.0	17.4					
	70	35.230	12.10	2.4	0.35	4.8	17.6					
	80	35.235	12.10	2.4	0.40	5.6	16.8					

Frederick Russell Cruise 12/85

TABLE 3 - Averaged Results for Each Station

STATION Number	Salinity	Al nM	Silicon µM	Phosphate µM	Nitrate µM
Track A					
1	35.13	28.4	3.0	0.33	4.8
2	35.22	16.3	2.3	0.29	4.2
3	35.23	16.6	2.1	0.38	5.3
4	35.26	16.6	2.2	0.41	5.3
5	35.28	16.3	2.2	0.41	5.4
6	35.30	15.5	2.4	0.42	4.8
7	35.32	16.0	2.3	0.40	4.5
8	35.34	15.8	2.4	0.40	4.9
9	35.36	13.4	2.5	0.40	4.9
Track B					
1	35.12	16.7	2.5	0.27	2.9
2	35.15	17.7	2.4	0.27	3.0
3	35.20	18.3	2.7	0.29	3.8
4	35.23	18.3	2.4	0.33	4.2
5	35.28	14.0	2.6	0.37	4.5
6	35.27	16.5	2.4	0.37	4.7
7	35.28	17.2	2.5	0.39	4.2
8	35.32	21.9	2.7	0.36	4.2
Track C					
1	34.96	27.0	3.3	0.30	3.3
2	34.96	28.0	3.7	0.28	3.8
3	35.10	21.6	2.5	0.26	3.3
4	35.18	20.4	3.3	0.30	3.7
5	35.15	25.7	3.6	0.34	5.3
6	35.10	30.0	3.5	0.36	5.5
7	35.05	29.8	3.6	0.37	5.9
8	35.03	33.9	3.7	0.38	6.3
9	34.96	38.4	4.4	0.43	6.9
Track D					
1	34.91	27.0	4.8	0.36	4.0
2	34.94	29.4	4.0	0.39	5.9
3	35.02	31.2	3.2	0.40	6.8
4	35.11	31.2	3.3	0.40	5.6
5	35.17	20.9	2.9	0.30	4.7
6	35.10	35.5	3.6	0.37	6.4
7	35.12	32.7	3.4	0.38	6.2
8	35.05	34.8	3.6	0.38	5.8
9	35.07	34.9	3.7	0.38	6.1
10	35.06	38.1	4.1	0.43	7.0

TABLE 3 - continued (2)

STATION Number	Salinity	Al nM	Silicon µM	Phosphate µM	Nitrate µM
Track E					
1	34.80	67.2	4.6	0.56	6.8
2	34.87	47.1	3.7	0.49	5.9
3	34.97	31.9	3.1	0.39	7.0
4	34.93	34.5	3.5	0.45	7.1
5	34.53	34.6	5.6	0.78	9.2
Track F					
1	34.93	34.8	3.6	0.35	5.0
2	34.93	36.0	3.5	0.41	6.5
3	34.94	35.3	3.4	0.44	7.1
4	34.86	35.9	3.8	0.51	7.6
5	34.72	38.8	4.9	0.60	8.0
Track G					
1	34.89	35.1	4.3	0.49	7.2
2	34.79	36.4	5.0	0.55	8.2
Track A					
3A	35.23	16.8	2.4	0.42	5.2
3B	35.24	16.9	2.4	0.41	5.3
3C	35.23	17.0	2.4	0.38	5.1

TABLE 4 - Linear regression analysis of variables listed in Table 3

Variables	Correlation Coefficient	Regression Line
S% - Si	-0.8935	[Si] = 153 - 4.27 [S%]
PO_4 - NO_3	0.8383	[NO_3] = 0.35 + 12.99 [PO_4]
S% - Al	-0.7883	[Al] = 1646 - 46.13 [S%]
Al - Si	0.7389	[Si] = 1.5 + 0.063 [Al]
Si - NO_3	0.6738	
Al - NO_3	0.6531	
Si - PO_4	0.6199	
S% - PO_4	-0.6162	[PO_4 = 11.4 - 0.31 [S%]
Al - PO_4	0.5119	
S% - NO_3	-0.5043	[NO_3] = 105 - 2.84 [S%]

	Predicted River Inputs μM	Tamar[a] μM	Great Ouse μM
Al	1.6	0.6 - 0.7	
Si	153	25 - 31	165 - 180
PO_4	11.4	3.0	
NO_3	105	71 - 107	

a = R. Howland, personal communication

TABLE 5 - Comparison of Aluminium concentrations observed in the Channel during July 1984 and those predicted by the equation in Table 4

Meteor 69/1 Station No.	Salinity	Al Predicted	Al Observed
54	35.13	25.5	9.6
55	35.17	23.6	10.0
56	35.22	21.3	6.2
57	35.06	28.7	6.2
58	34.95	33.8	6.7
59	34.92	35.1	11.0
60	34.82	39.8	16.6
61	34.33	62.4	17.8
62	34.19	68.8	10.6
63	34.37	60.5	20.4
64	33.01	123.2	37.9

FIGURES

Regression line plots

1. Silicon versus Salinity.
2. Phosphate versus Nitrate.
3. Aluminium versus Salinity.
4. Aluminium versus Silicon.
5. Phosphate versus Silicon.
6. Phosphate versus Salinity.
7. Nitrate versus Salinity.

Contoured geographical distributions

8. Salinity.
9. Aluminium.
10. Silicon.
11. Phosphate.
12. Nitrate.

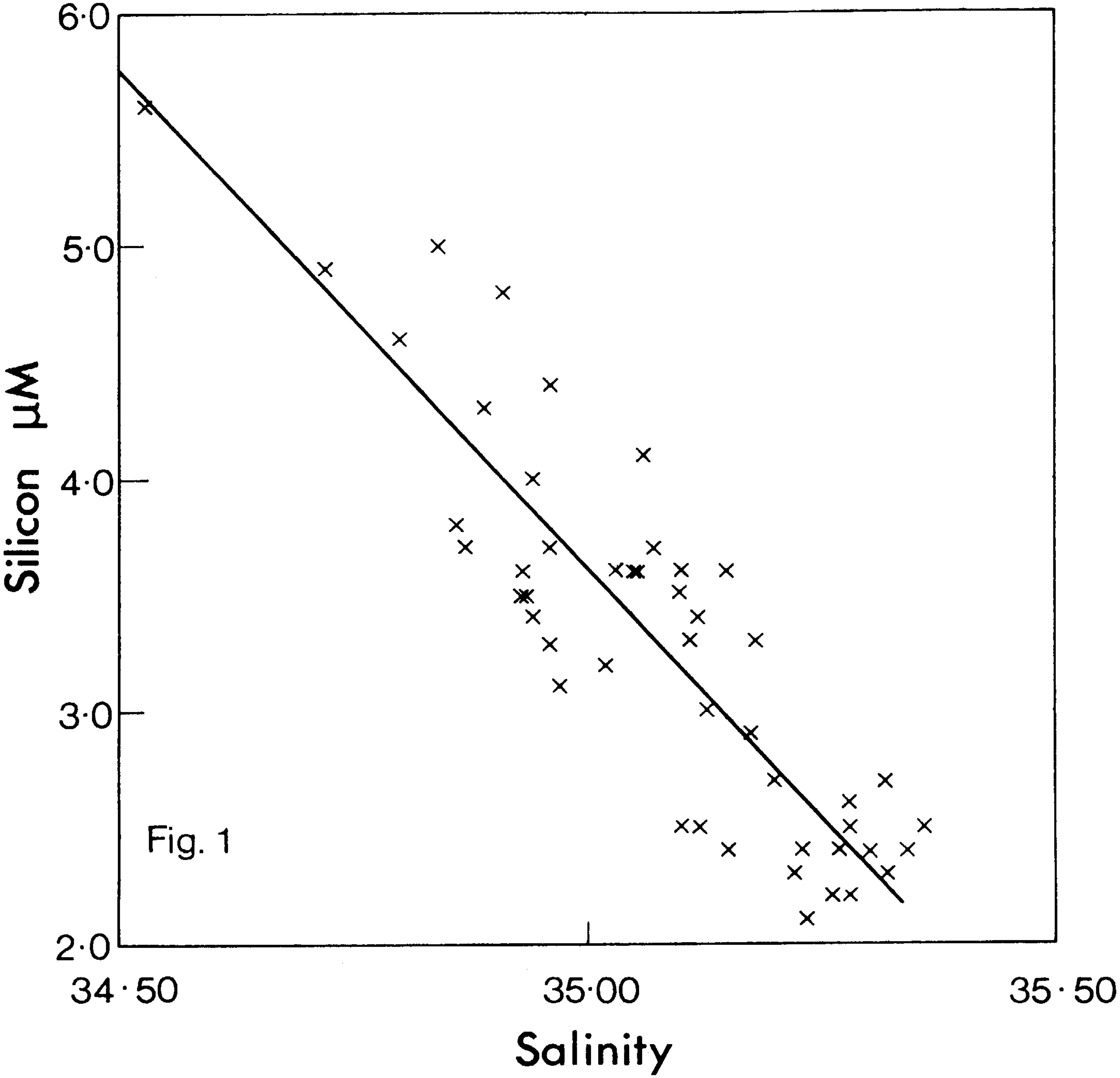


Fig. 1

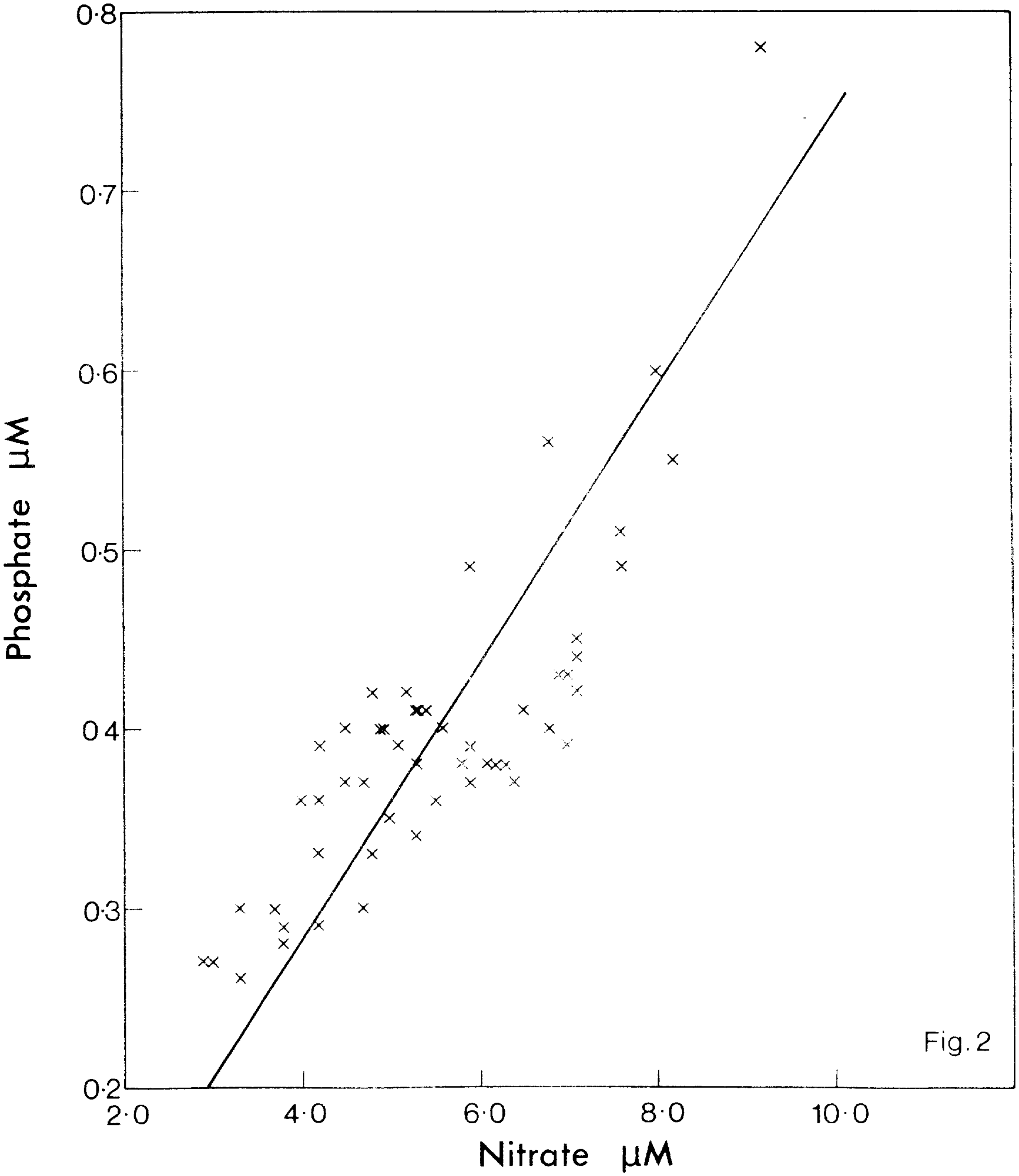
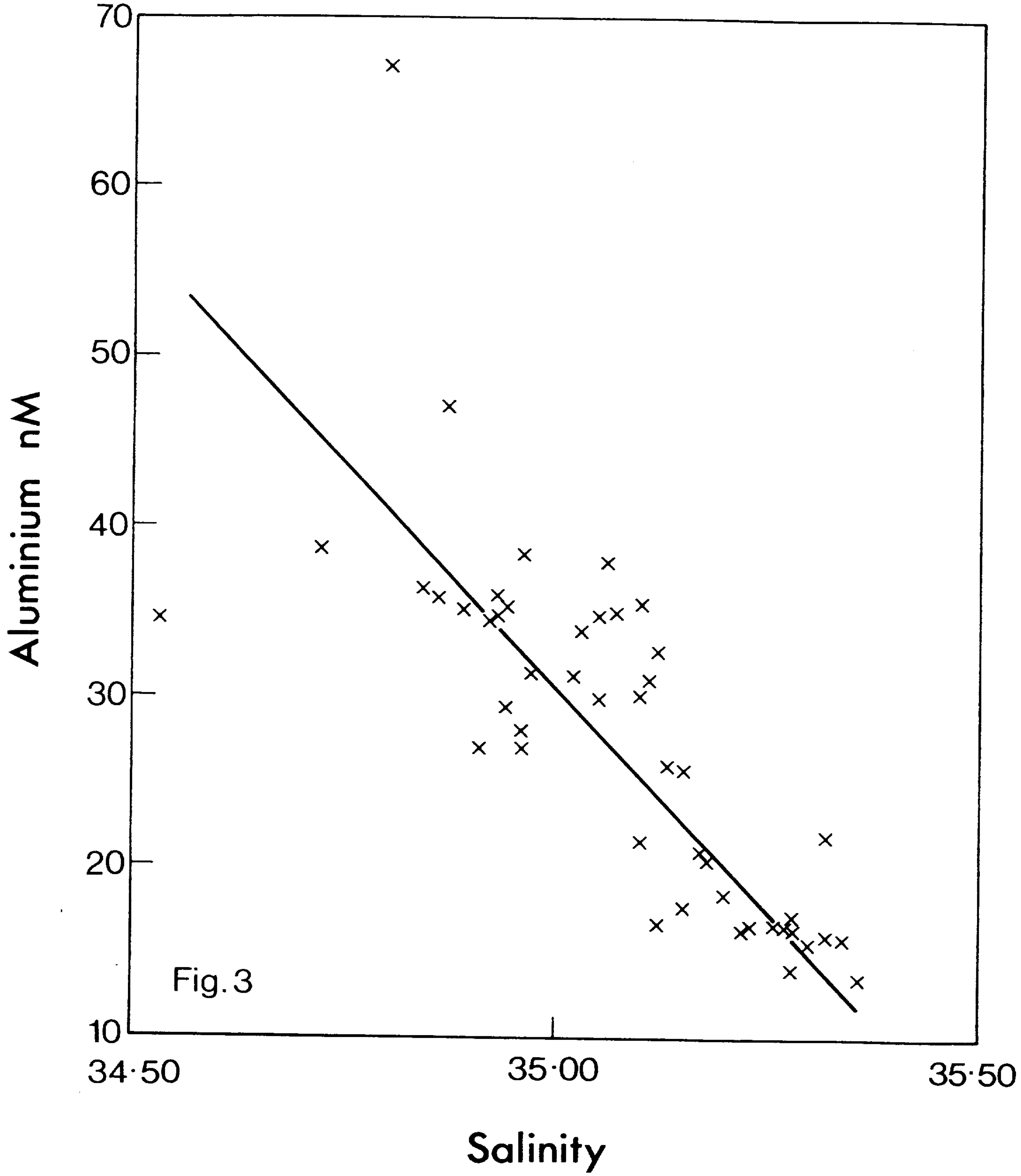


Fig. 2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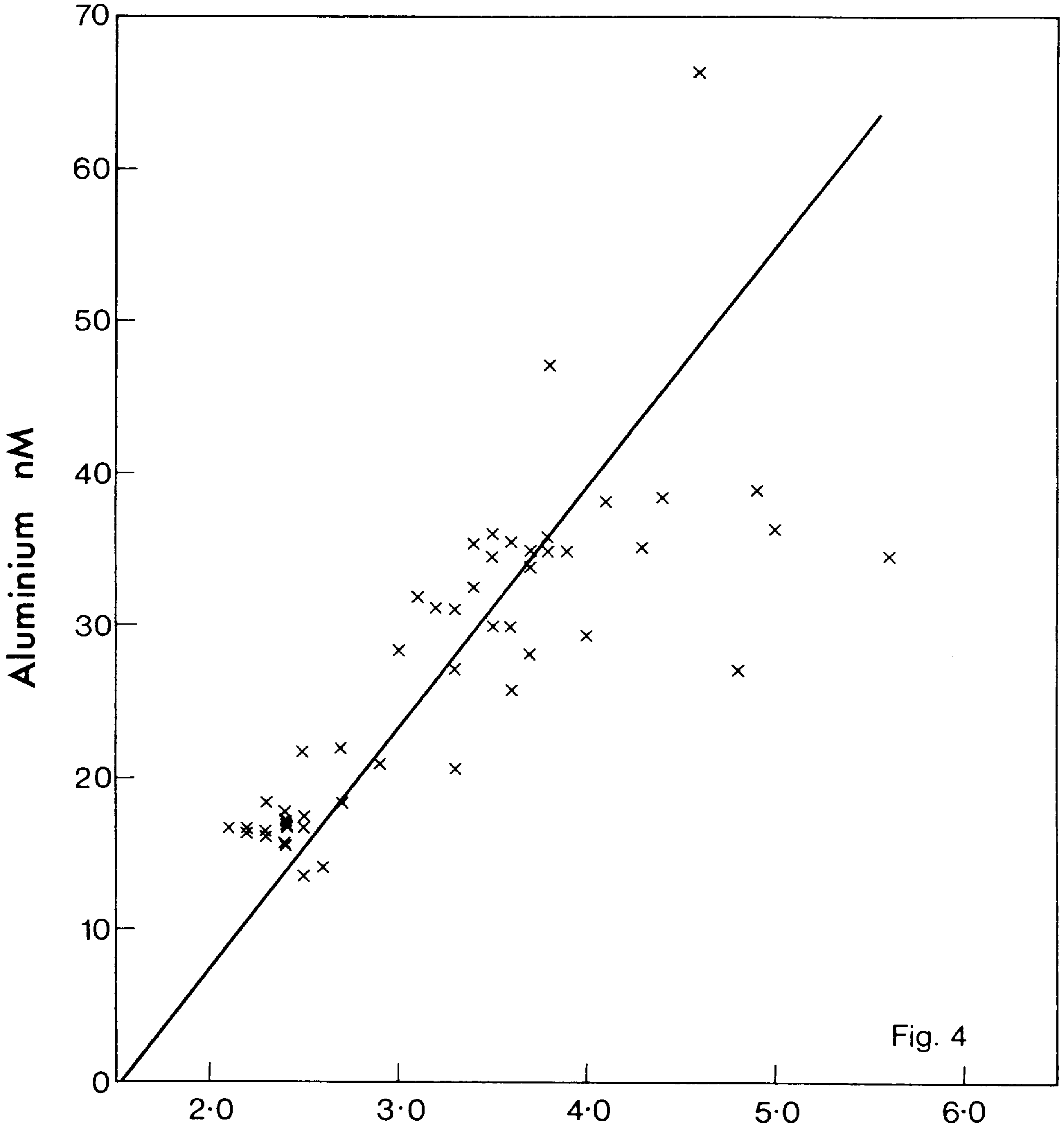
60
50
40
30
20
10
Aluminium nM
34·50
35·00
35·50
Salinity
Fig. 3


Aluminium nM
70
60
50
40
30
20
10
0
2·0
3·0
4·0
5·0
6·0
Silicon µM
Fig. 4

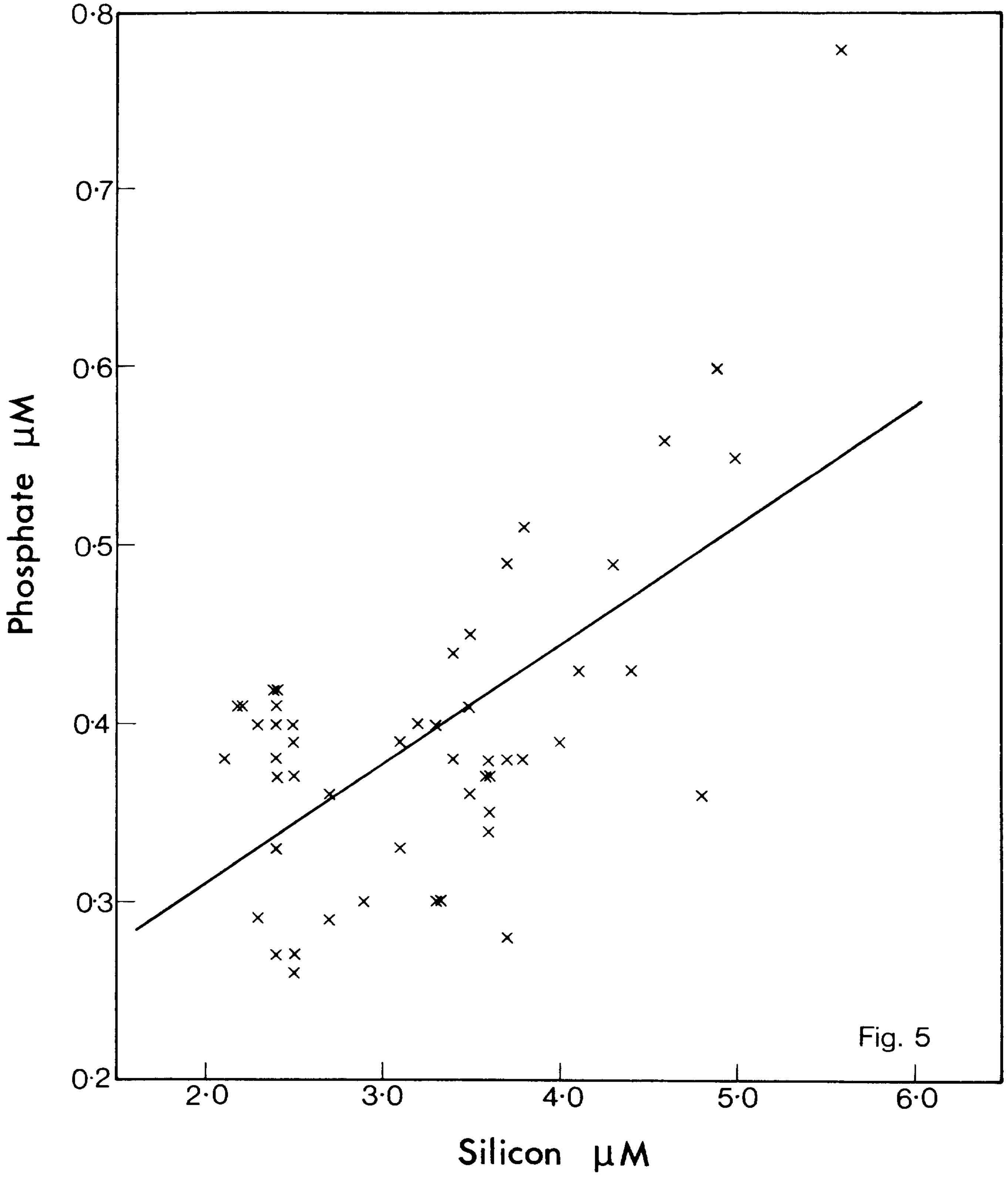


Fig. 5

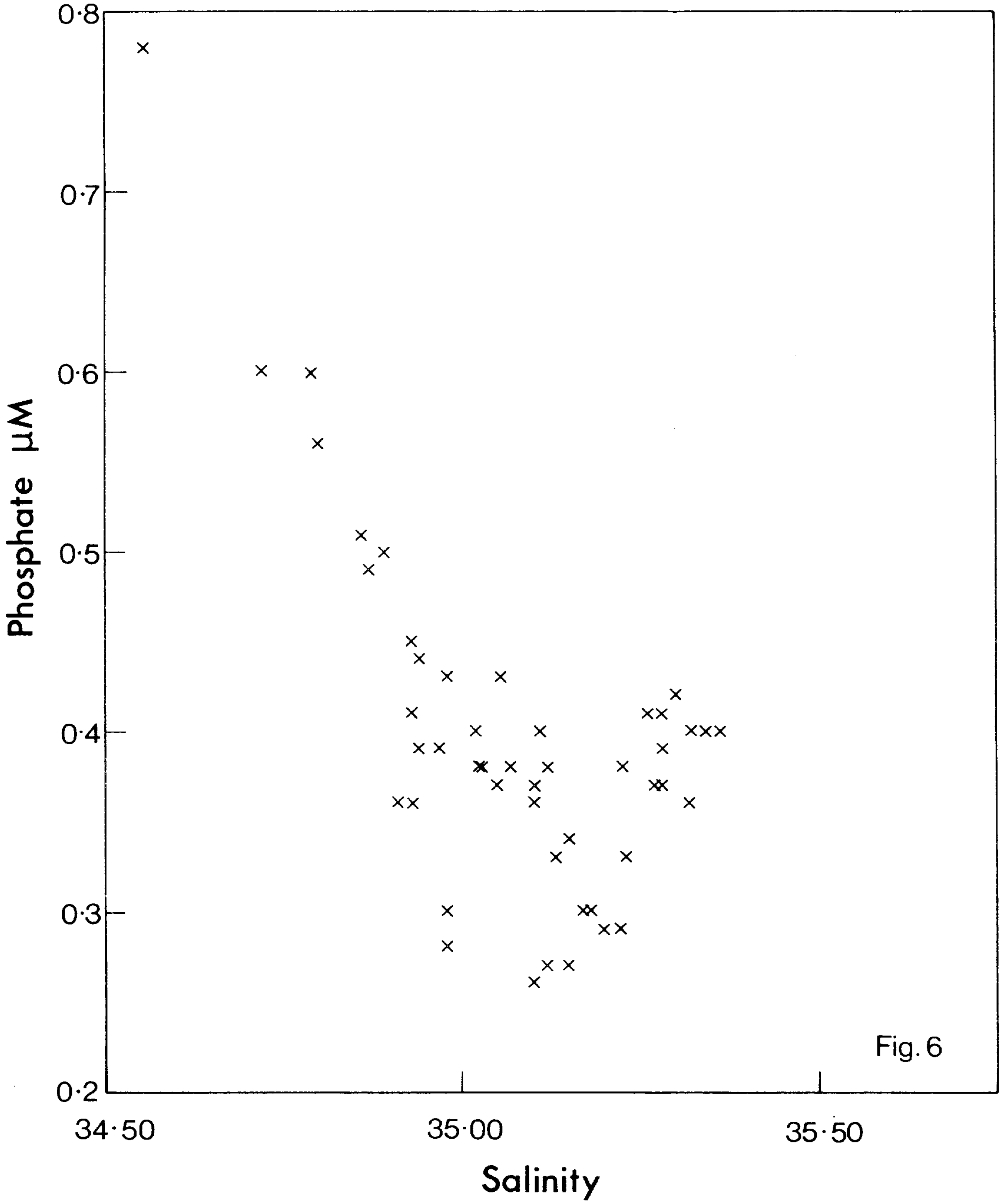


Fig. 6

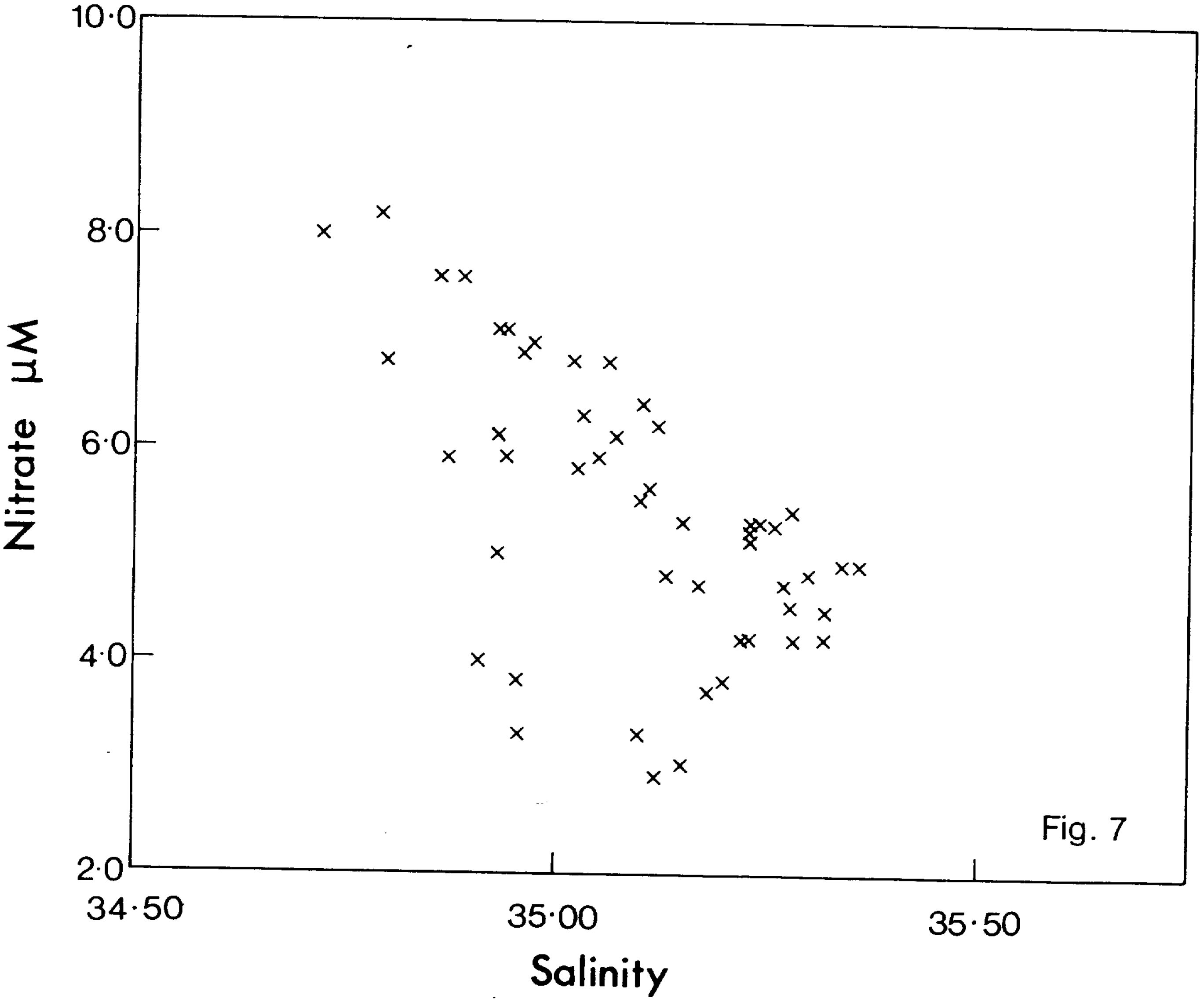
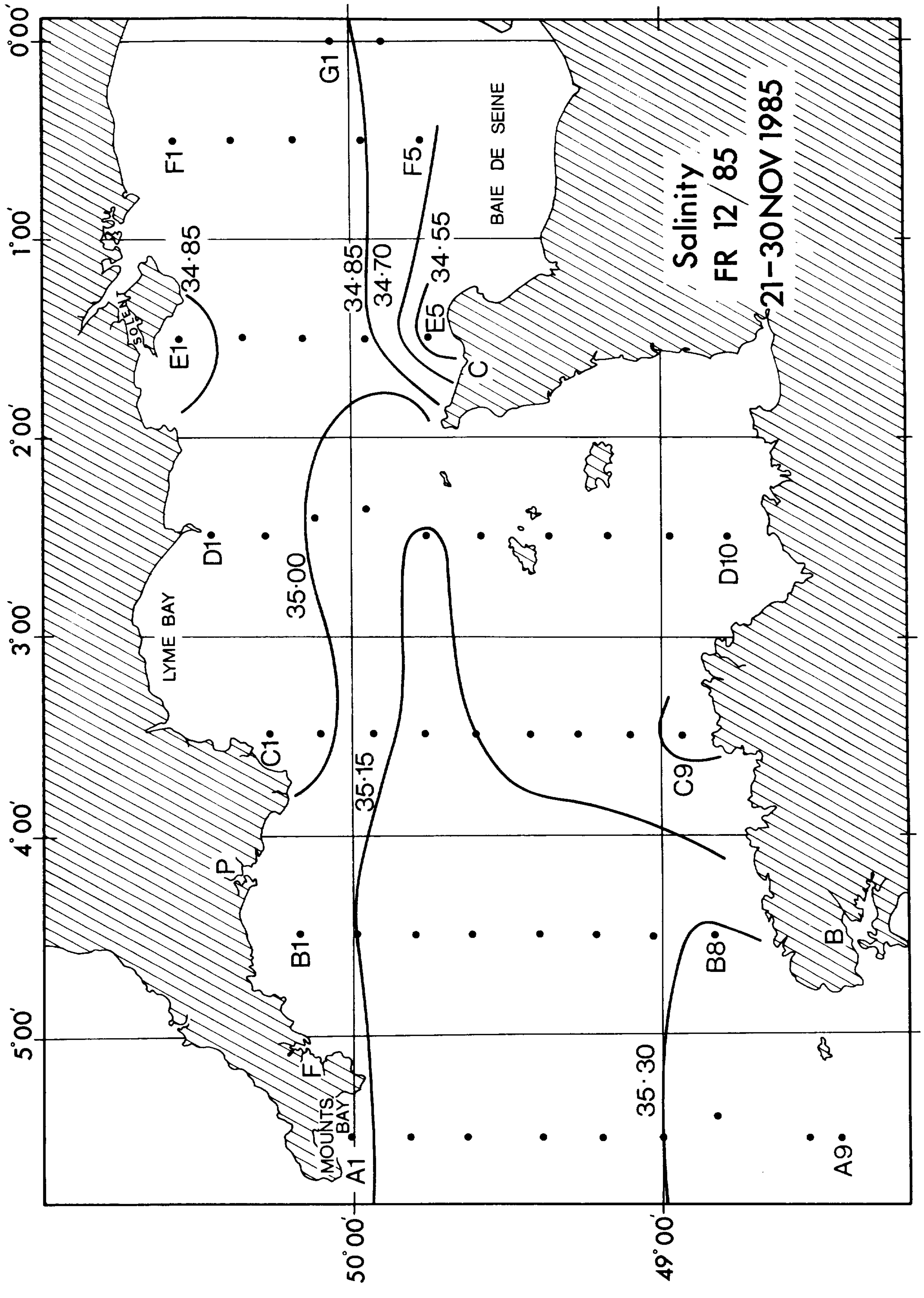


Fig. 7


Salinity
FR 12/85
21-30 NOV 1985
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1°00'
2°00'
3°00'
4°00'
5°00'
50°00'
49°00'
34·85
34·85
34·70
34·55
35·00
35·15
35·30
BAIE DE SEINE
LYME BAY
SOLENT
MOUNTS BAY
A1
A9
B1
B8
C1
C9
D1
D10
E1
E5
F1
F5
G1
P
F
C
B

Fig. 8

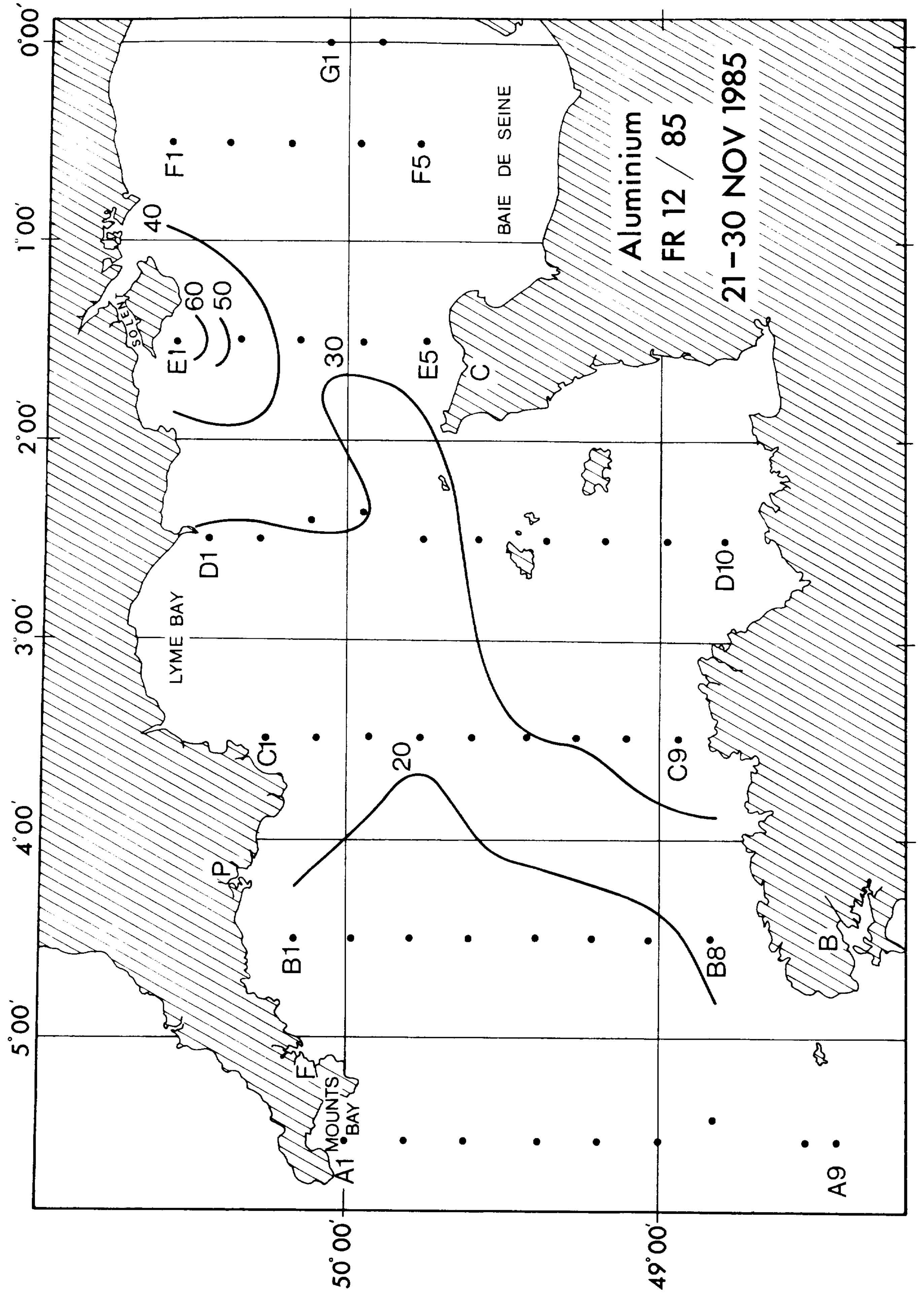
Aluminium
FR 12 / 85
21–30 NOV 1985
0°00'
1°00'
2°00'
3°00'
4°00'
5°00'
50°00'
49°00'
BAIE DE SEINE
LYME BAY
SOLENT
MOUNTS BAY
A1
A9
B1
B8
C1
C9
D1
D10
E1
E5
F1
F5
G1
20
30
40
50
60
P
F
C
B

Fig. 9

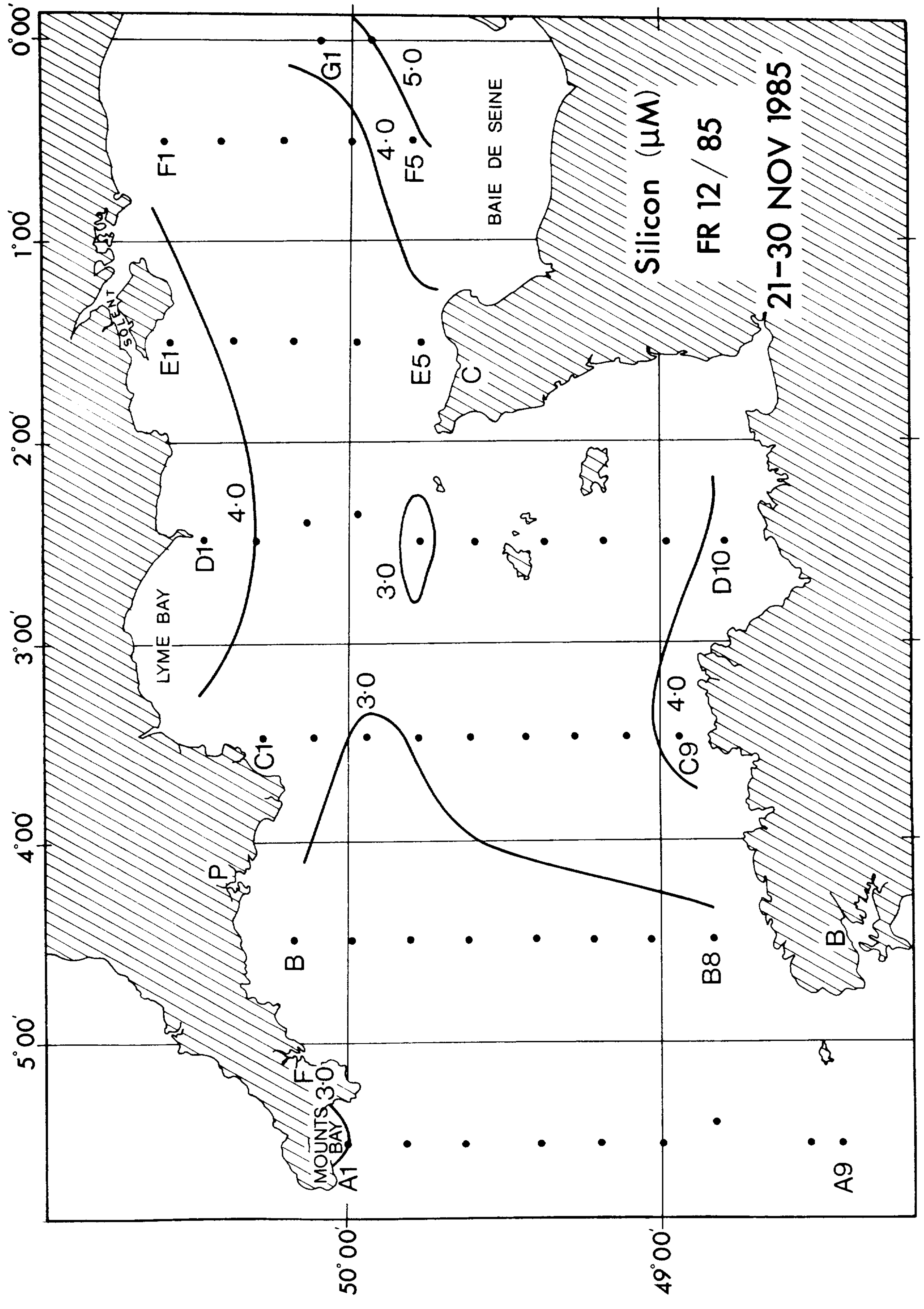
Silicon (µM)
FR 12/85
21–30 NOV 1985
0°00'
1°00'
2°00'
3°00'
4°00'
5°00'
50°00'
49°00'
BAIE DE SEINE
SOLENT
LYME BAY
MOUNTS BAY
A1
A9
B
B8
C1
C9
D1
D10
E1
E5
F1
F5
G1
C
P
F
B
3·0
3·0
3·0
4·0
4·0
4·0
4·0
5·0

Fig. 10

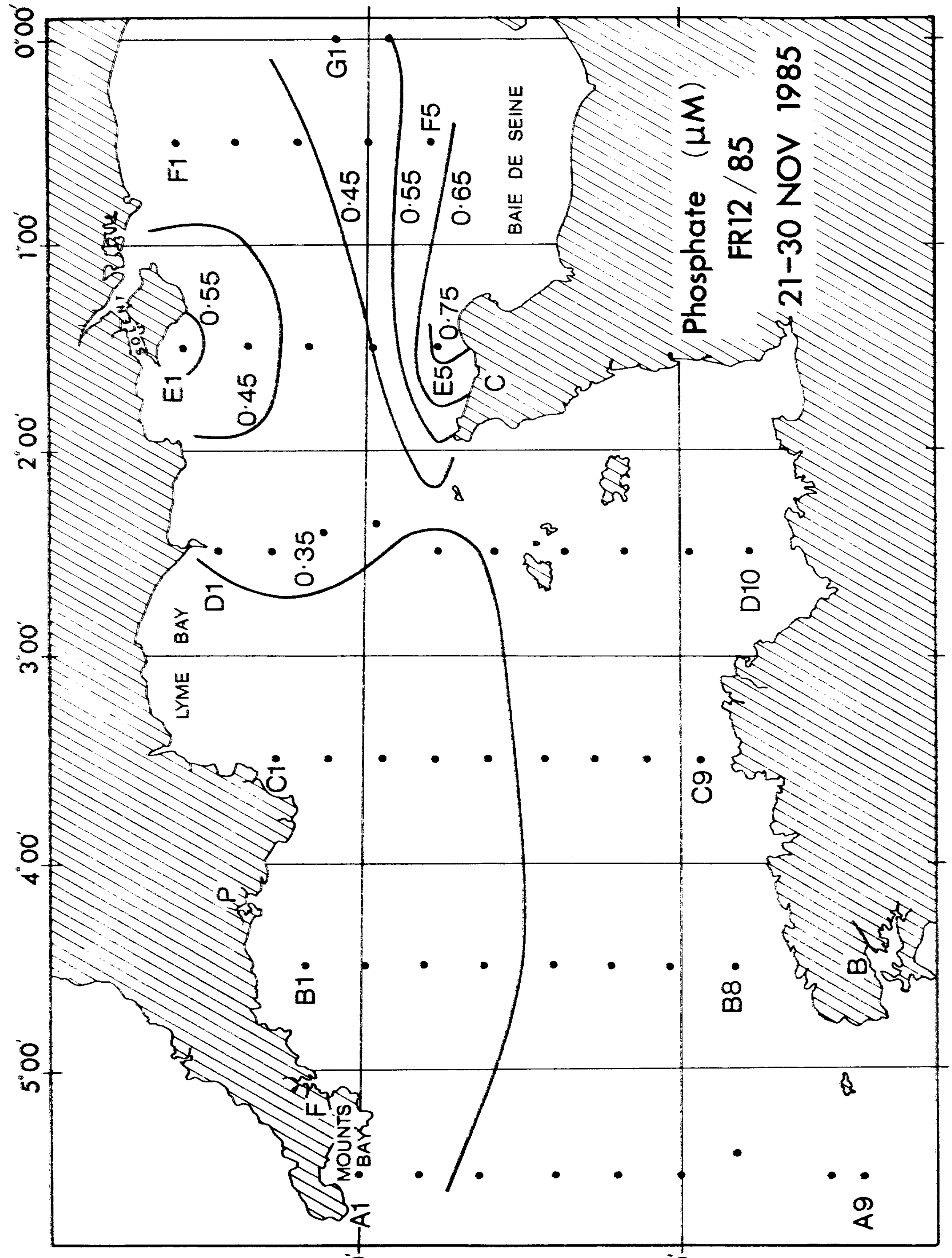
Phosphate (µM)
FR12/85
21–30 NOV 1985

Fig. 11

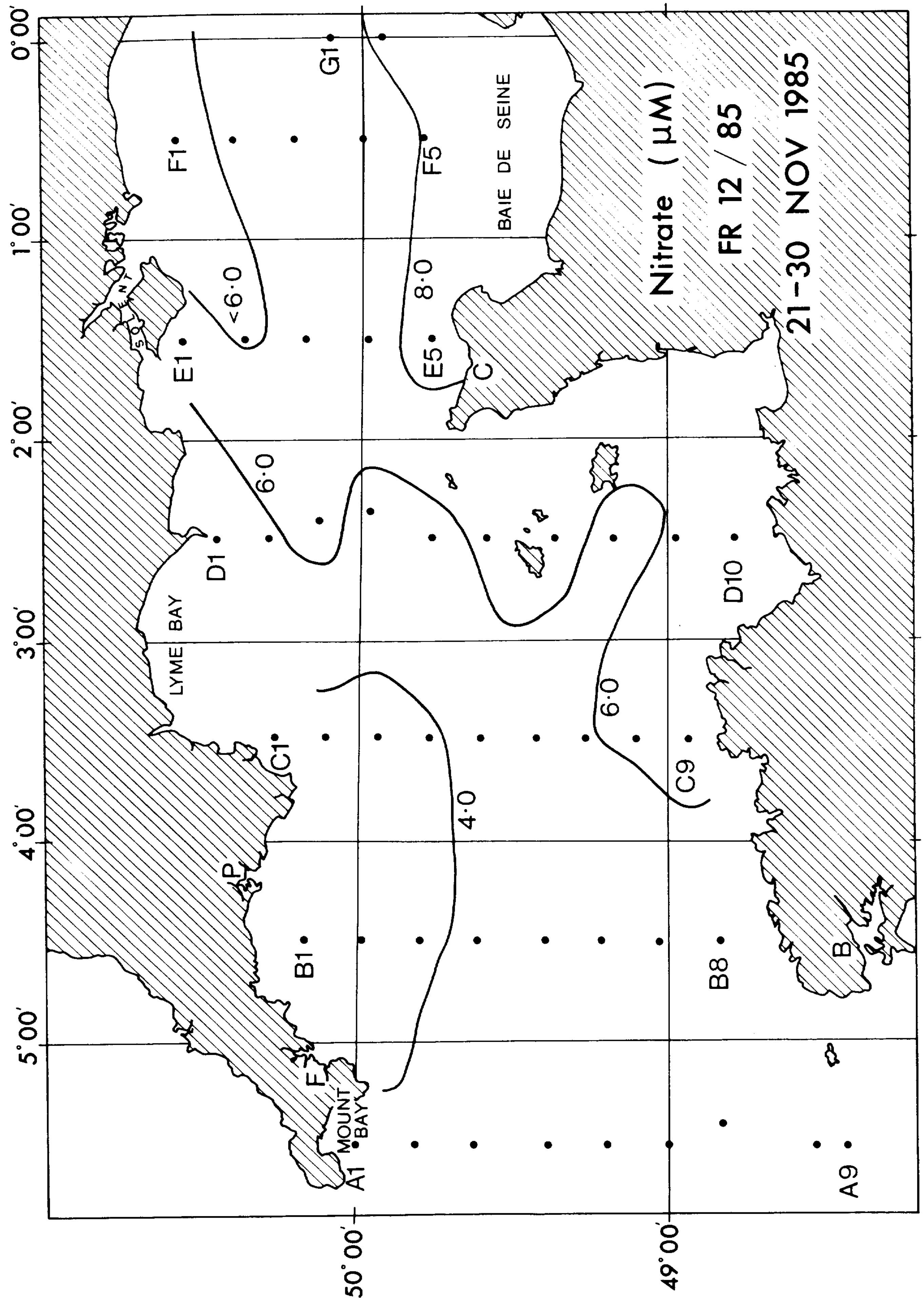
Nitrate (μM)
FR 12 / 85
21-30 NOV 1985
0°00'
1°00'
2°00'
3°00'
4°00'
5°00'
50°00'
49°00'
BAIE DE SEINE
LYME BAY
MOUNT BAY
<6·0
6·0
8·0
4·0
A1
A9
B1
B8
C1
C9
D1
D10
E1
E5
F1
F5
G1
B
C
F
P
S
O
L
E
N
T

Fig. 12