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Firth of Lorne Study : Report No. 2

Hydrography, nutrients and chlorophyll in the Firth of Lorne
and its associated sea lochs, 3rd - 19th February 1982

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S.M.B.A. Internal Report No. 87

Introduction

This report presents nutrient, chlorophyll and hydrographic data from the Firth of Lorne and associated sea lochs obtained on trips of R.V. Calanus between 3rd and 19th February 1982. This work forms an integral part of a long-term study of the Firth of Lorne (Grantham, 1983) aimed at the detection and investigation of long-term changes in the physical and chemical characteristics of the water, and the biological consequences of these changes.

The report contains a full set of data obtained during the survey, but, only a brief discussion of the results, since a detailed interpretation can only be carried out on several years data.

The survey was organised and conducted by K. Jones, who will present the detailed cruise report and his own interpretation of the hydrographic and chlorophyll results in a separate Internal Report (Jones, 1983). I am grateful to him for his help.

Methods

Temperature and Salinity.

Temperature and salinity were measured with a Braystoke STM 500 T/S probe. Details of the operation and calibration of this instrument are given in Jones (1983).

Nutrients.

Water samples were taken from standard depths or from depths

chosen on the basis of water column density distribution (Jones, 1983), using N.I.O. bottles. Samples were filtered through GF/C filter papers and the filtrate stored frozen in polythene bottles. Analyses for nitrate and silicate were carried out on a Technicon Autoanalyzer (Grantham, 1982) using methods of Folkard (1978) for nitrate and Grasshoff (1969) for silicate.

Chlorophyll a

The particulate matter remaining on each GF/C filter was used for a measurement of chlorophyll a. The extraction in 90% acetone was carried out immediately as described in Grantham (1983). The extract was subsequently measured fluorimetrically on a Turner Model 10 fluorometer using the method of Tett and Wallis (1978).

Results

Table 1 briefly summarises station details. Fuller details are given in Jones (1983). Station positions are shown in figure 1. A full set of tabulated data is given in the Appendix.

Discussion

Hydrography

The longitudinal sections of temperature (fig. 2) and salinity (fig. 3) from station FL1 off Colonsay at the mouth of the Firth of Lorne, to the head of Loch Eil illustrate the

fjordic nature of the system. Each of the major sills restricts the inflow of deeper saline water to its adjacent basin upstream. As a result salinities decrease successively from basin to basin landwards. This effect can be clearly seen in the T/S diagrams of Jones (1983).

The seawards moving brackish surface layer was more pronounced in upper Loch Linnhe and Loch Eil but persisted as far down as station LM1 in the Lynn of Morven. It is likely that the greater part of this surface water will flow seawards through the Sound of Mull rather than south through the channel connecting with the Firth of Lorne because the Sound of Mull is the deeper and less restricted route. The southerly channel is shallow (~ 30 m) and uneven with tidal races and overfalls, hence any surface water passing through will be subject to considerable mixing with the deeper water. As a result the T/S profile for station 700 off the mouth of Loch Spelve showed no evidence of a brackish surface layer.

The lower Firth of Lorne from Seil seawards has an irregular bottom with several potential sills rising to 50 m or less. However a deeper channel (> 100 m) southeast of the Garvellachs may provide a route for deeper water. The topography of the lower Firth of Lorne is therefore more like that of an estuary. The hydrographic results were consistent with estuarine behaviour, showing a "salt-wedge" condition between stations FL1 and FL4 (fig. 3).

Nutrients.

Nutrient samples were not collected at every station visited during the survey and therefore there is insufficient data with which to draw full sections of the whole system. Instead truncated sections are shown for nitrate (fig. 4) and silicate (fig. 5) with individual profiles for stations LY1 and FL1.

At the time of the survey (early February) nutrient values would be expected to have reached their winter maxima.

Nitrate.

Throughout the system nitrate varied between 5.29 and 7.68 $\mu\text{g-at}/\ell$, the lowest values being found at station LL1 in upper Loch Linnhe at a depth of 50 m. This may represent a semi-isolated pocket of older water. Above this depth nitrate values may have resulted from the mixing down of higher nutrient surface water from Loch Eil, while the deeper water of high nitrate content may have originated from lower Loch Linnhe at the depth of the sill at Corran Narrows. Alternatively the higher nitrate values in the deep water may be the result of regeneration in the sediments.

In Loch Eil at both stations E70 and E24 nitrate increased with depth reaching 7.68 $\mu\text{g-at}/\ell$ at 60 m at E70. This is somewhat higher than values found at E70 in February 1976 (6.09 $\mu\text{g-at}/\ell$ at 55 m), but this difference may not be significant since much higher values (8.35 $\mu\text{g-at}/\ell$ at 40 m) were found at station E2 in January 1976 only some 0.7 km from E70.

The nitrate variation with depth appeared to be related to salinity but a detailed investigation will be needed to establish this relationship. Regeneration may also be responsible for the higher nitrate values in the deep water.

In contrast, at both stations LY1 and FL1 nitrate tended to decrease with depth. The higher surface values at LY1 may reflect the outflow of high nitrate surface water from Loch Etive. At the time of this survey nitrate values of $7.32 \mu\text{g-at}/\ell$ were found at 5 m at station E6 in the lower basin of Loch Etive.

Nitrate values at LY1 were somewhat lower than those found in 1976 (Grantham, 1981).

Silicate.

On this survey silicate values ranged between 4.77 and $10.68 \mu\text{g-at}/\ell$, the highest values being found in Loch Eil, the lowest at station FL1 off Colonsay. There appeared to be a marked relationship between low salinity surface water and high silicate. This was apparent at stations LL1, LY1 and FL1 (fig. 5). At FL1 the lower silicate values occurred in the deeper water (80 m) which corresponds with the high salinity part of the salt wedge.

As with nitrate, silicate showed a minimum at 50 m at station LL1. This may indicate a pocket of older water or it may point to the inflow at an intermediate level of a tongue of low silicate water from lower Loch Linnhe.

In general silicate showed a far greater variation with depth and between stations than nitrate and may therefore prove to be a more sensitive indicator of external changes and processes within water masses than nitrate. However the regeneration processes of the two nutrients are likely to differ in their rates and reactive pathways, and this difference may be important in identifying areas where regeneration occurs.

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Table 1 : Station List

Station FL1

Off Colonsay, lat. $56^{\circ}11'N$, long. $6^{\circ}4'.5W$, depth 80 m.

Station FL4

Firth of Lorne, lat. $56^{\circ}14'6N$, long. $6^{\circ}W$, depth 95 m.

Station 700

Off Loch Spelve, lat. $56^{\circ}14'.6N$, long. $5^{\circ}59'.7W$, depth 125 m.

Station LY1

Lynn of Lorne, lat. $56^{\circ}28'.9N$, long. $5^{\circ}30'.1W$, depth 43 m.

Station C3

Loch Creran, lat. $56^{\circ}31'N$, long. $5^{\circ}22'.4W$, depth 45 m.

Station C5

Loch Creran, lat. $56^{\circ}32'.1N$, long. $5^{\circ}19'.4W$, depth 20 m.

Station CU

Upper Loch Creran, lat. $56^{\circ}32'.9N$, long. $5^{\circ}16'.1W$, depth 30 m.

Station LM1

Lynn of Morven, lat. $56^{\circ}29'.6N$, long. $5^{\circ}38'.4W$, depth 200 m.

Station LL3

Loch Linnhe, lat. $56^{\circ}40'.8N$, long. $5^{\circ}17'.8W$, depth 70 m.

Station LL1

Upper Loch Linnhe, lat. $56^{\circ}45'.3N$, long. $5^{\circ}12'.5W$, depth 150 m.

Station 53

Upper Loch Linnhe, lat. $56^{\circ}47'.3N$, long. $5^{\circ}9'.9W$, depth 110 m.

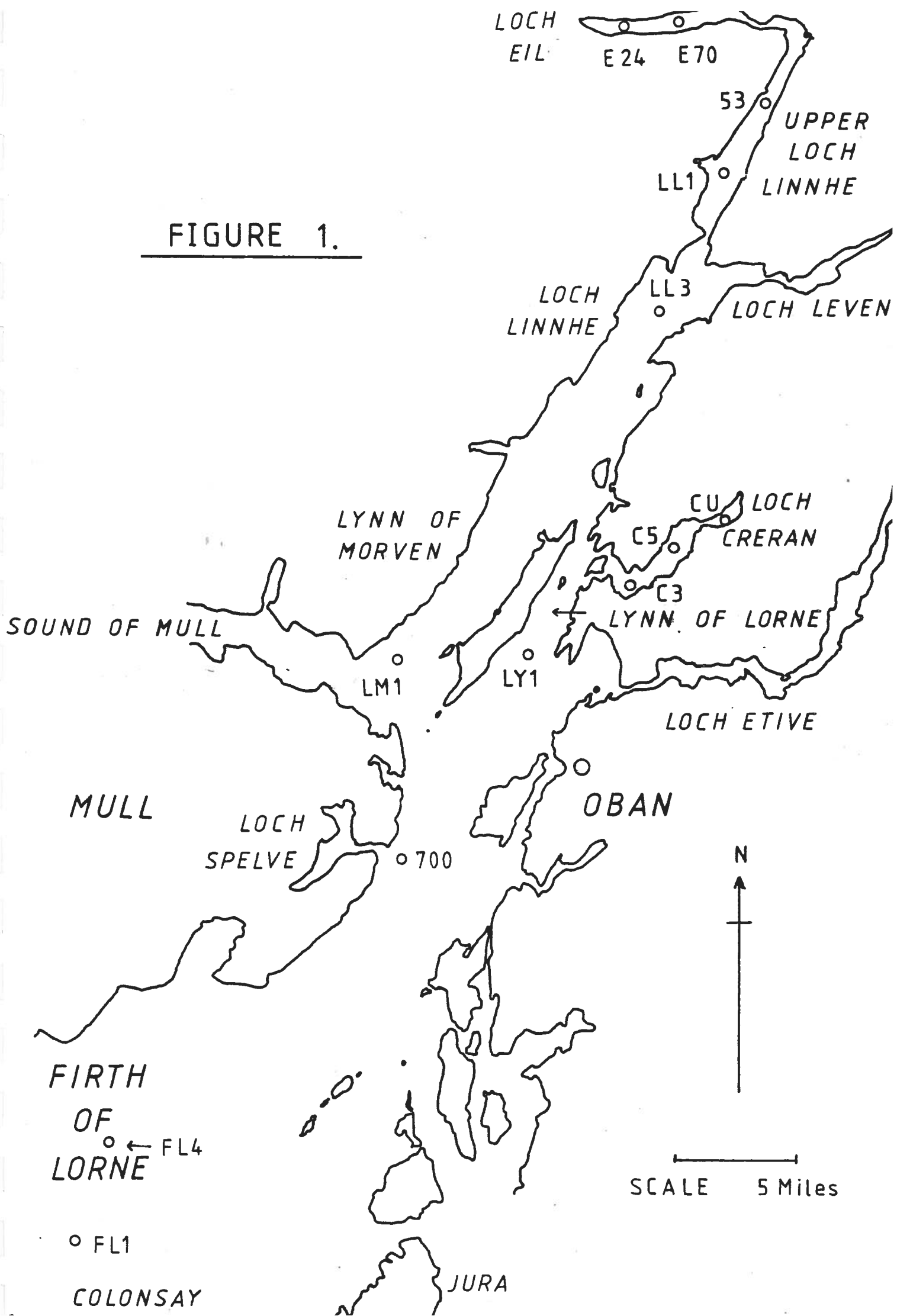
Station E70

Loch Eil, lat. $56^{\circ}51'.1N$, long. $5^{\circ}12'.6W$, depth 65 m.

Station E24

Loch Eil, lat. $56^{\circ}51'N$, long. $5^{\circ}16'.9W$, depth 40 m.

FIGURE 1.



TEMPERATURE °C

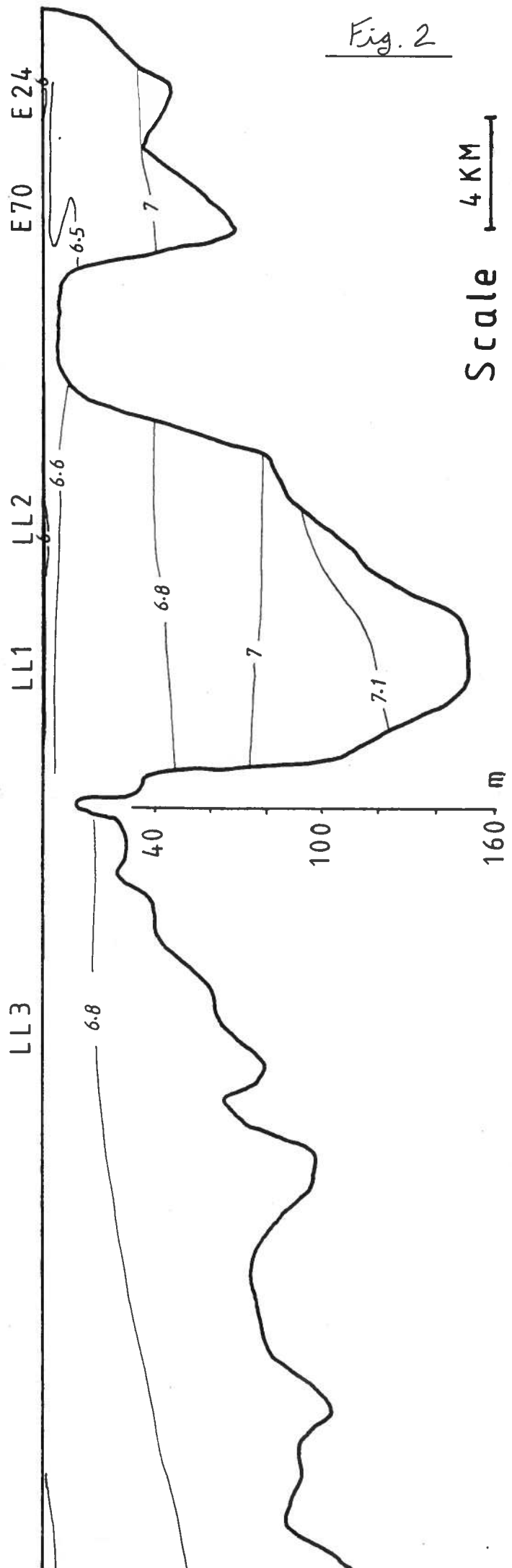


Fig. 2

Scale 4 KM

4 FEB →
19 FEB →

FL4

700

LM1

6.6

6.7

6.71

6.7

6.6

6.7

6.8

6.8

6.8

6.8

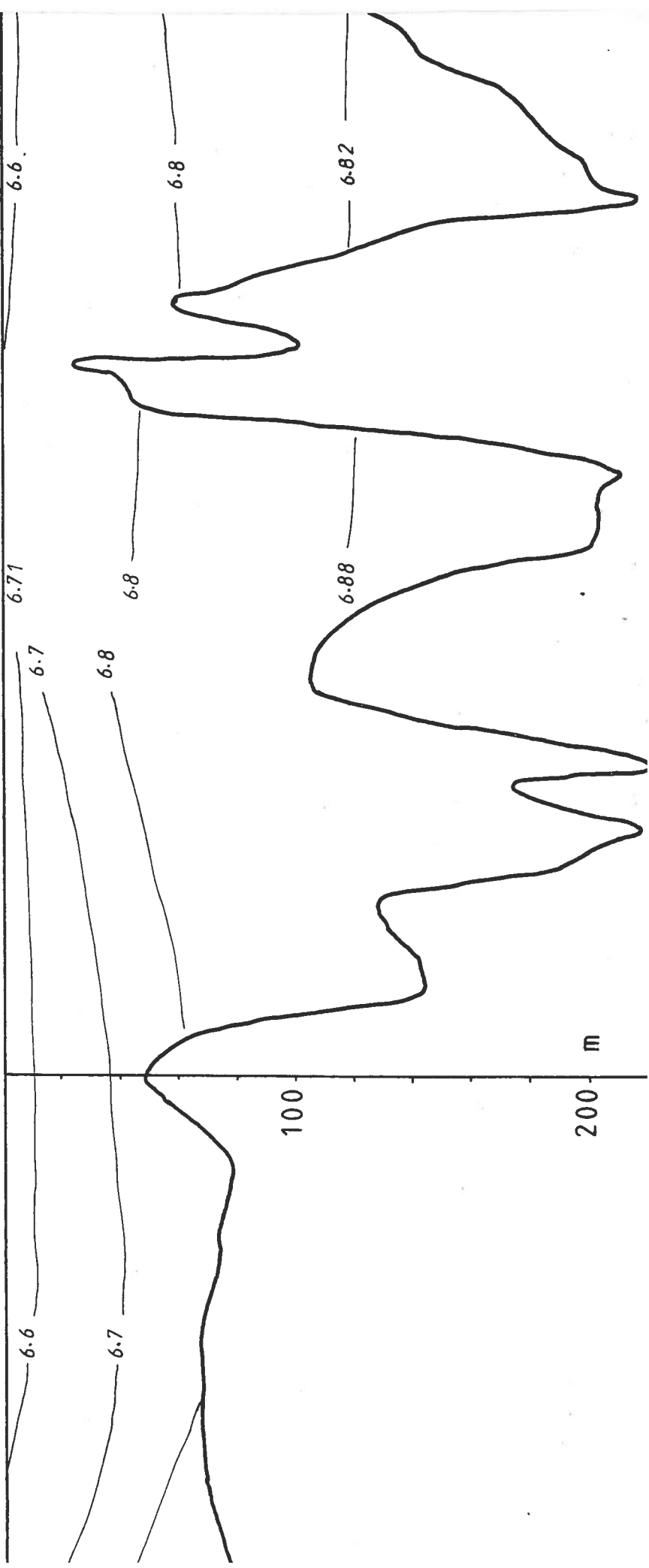
100

6.88

6.82

m

200



SALINITY ‰

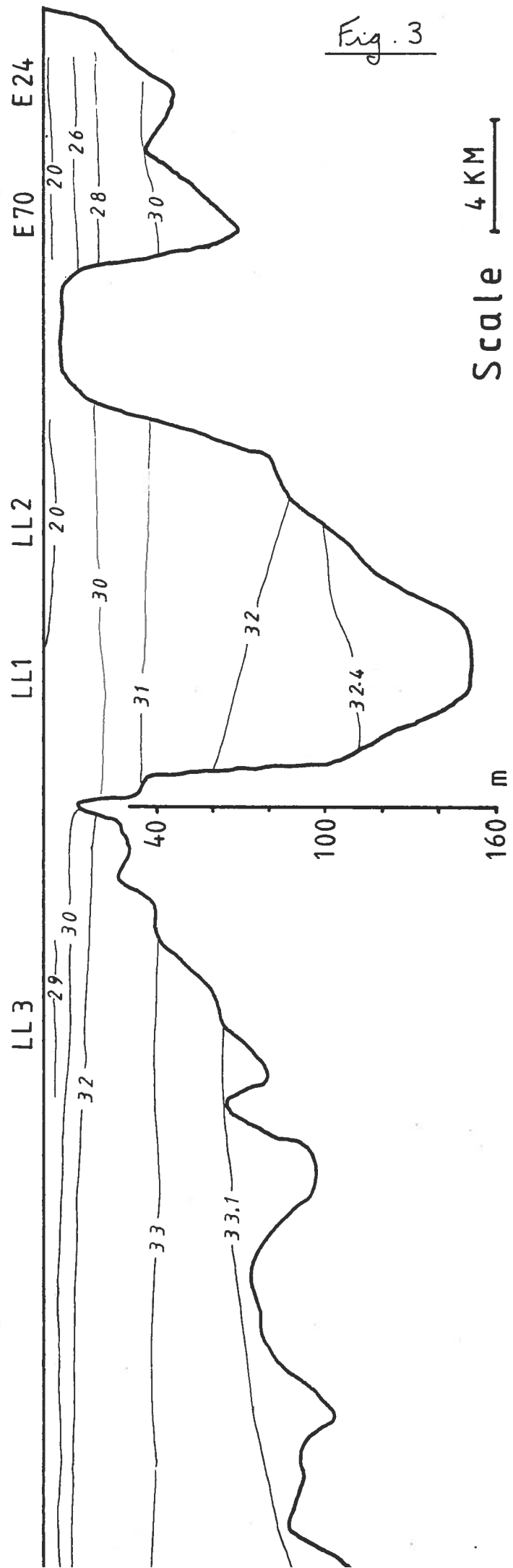
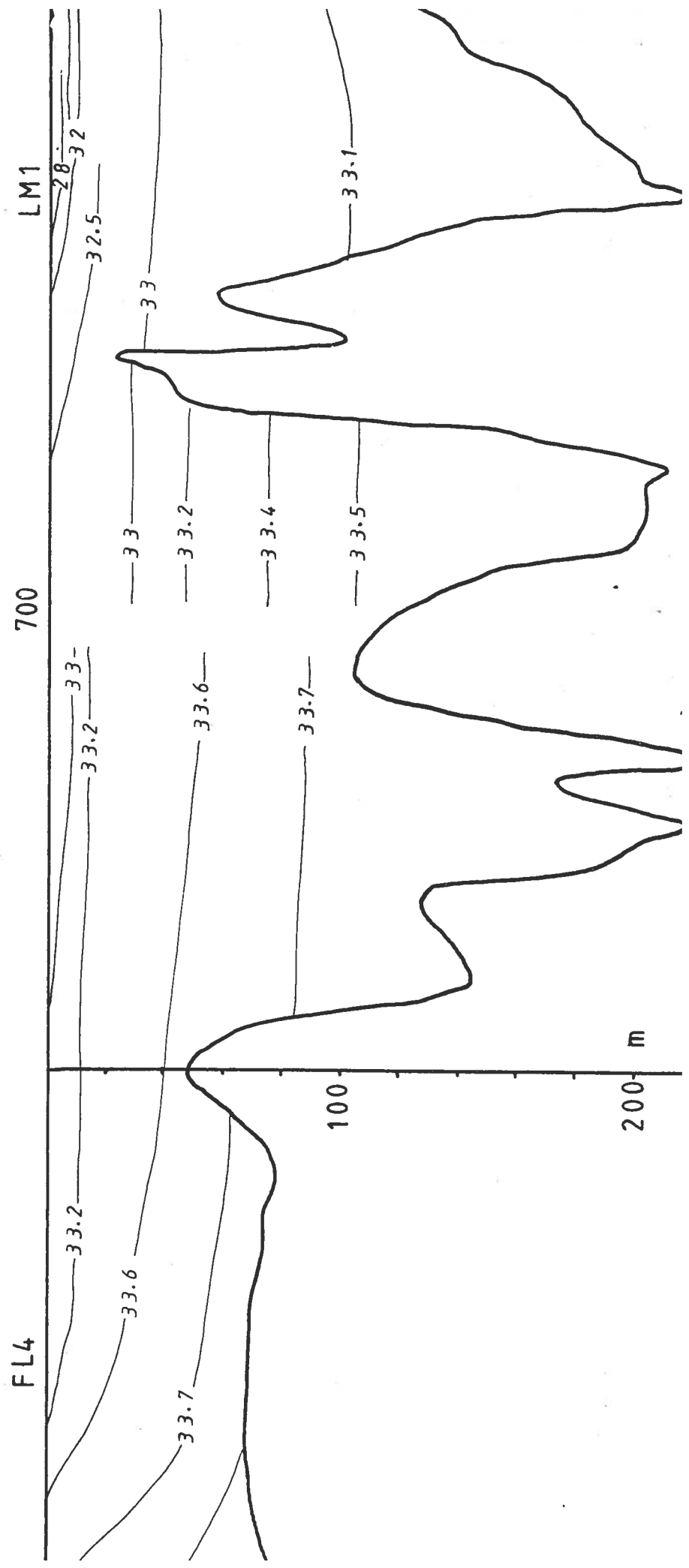


Fig. 3

Scale 4 KM

4 FEB ↓
19 FEB ↓



NITRATE (+ NITRITE)

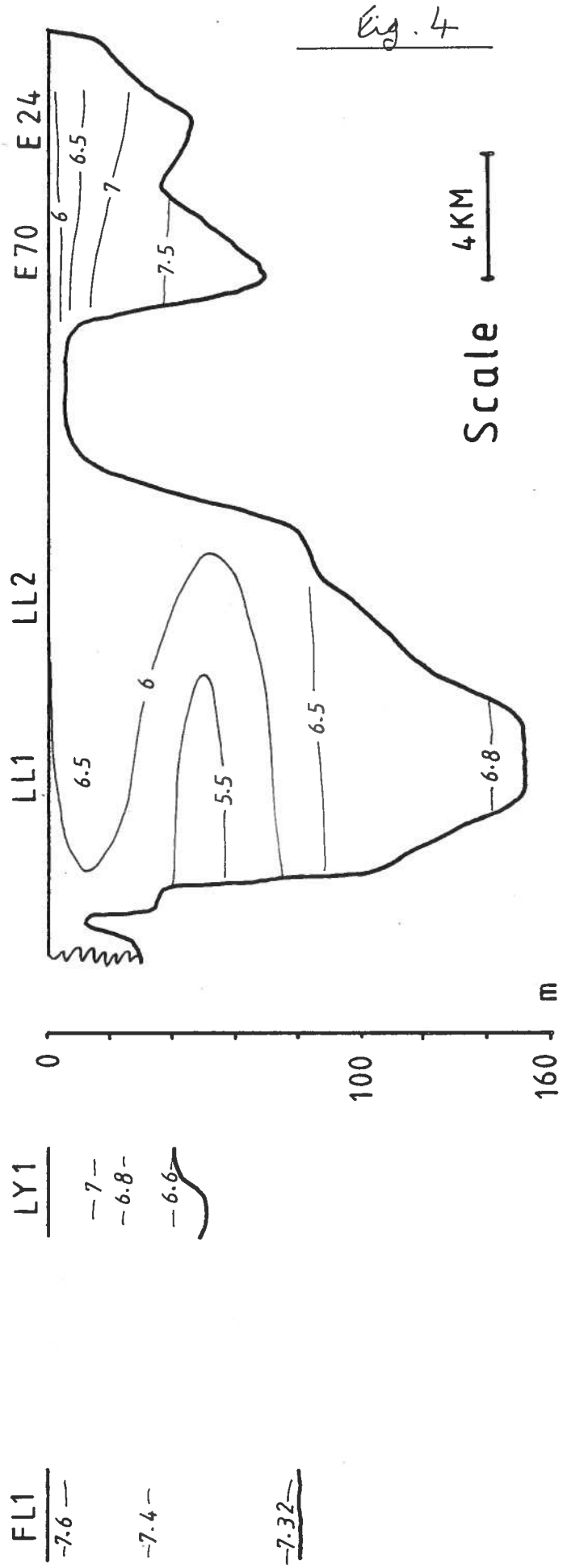
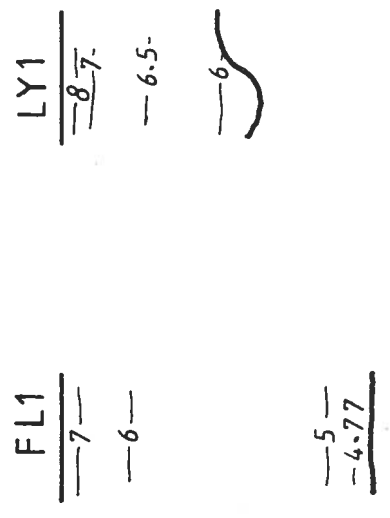
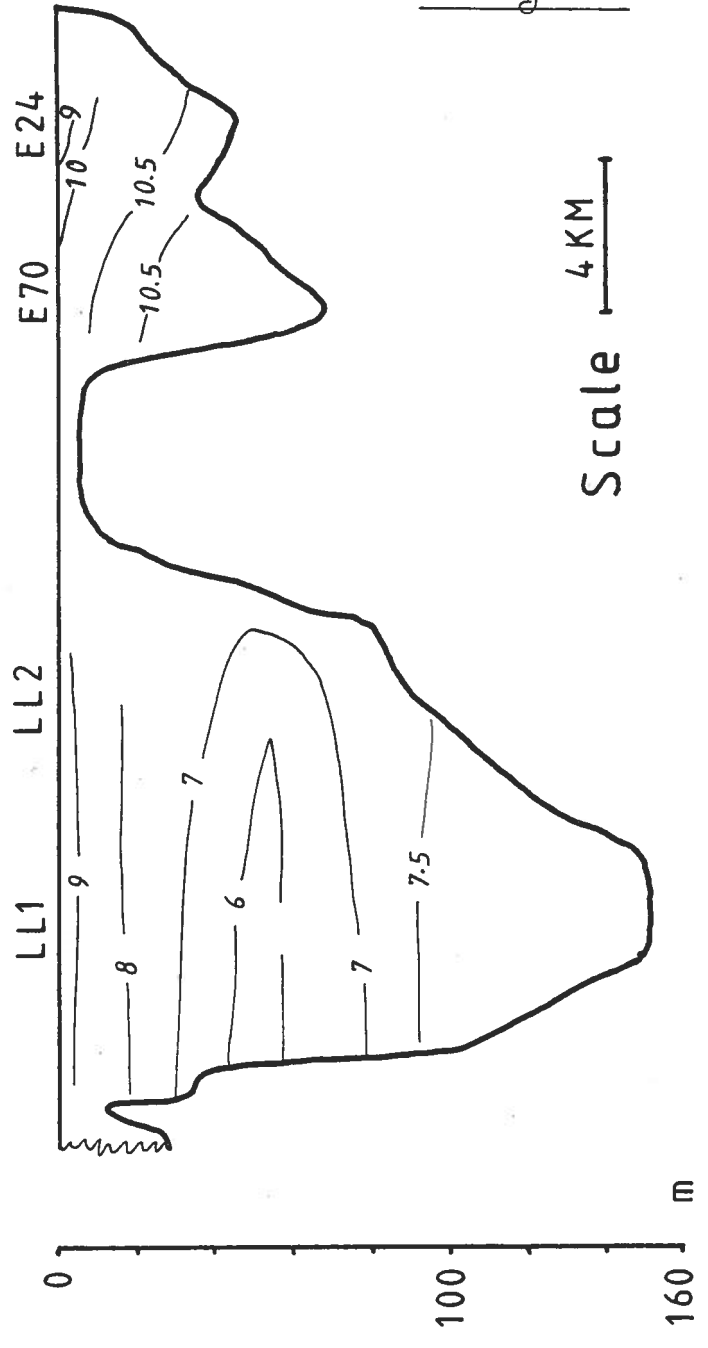


Fig. 4

Scale 4 KM

Fig. 5

SILICATE



APPENDIX

Data are arranged in spatial order, starting with the station at the head of Loch Eil (E24) and ending with the station at the entrance to the Firth of Lorne (FL1). It must be noted that this differs from the chronological order. One station (700) was visited twice during the survey period.

Units

The units used throughout the report are as follows:-

Depth	- metres	m
Temperature	- degrees Celcius	°C
Salinity	- parts per thousand	‰
Dissolved Inorganic Nitrogen	- microgram-atoms per litre	µg-at/l
Silicate	- microgram-atoms per litre	µg-at/l
Chlorophyll <u>a</u>	- milligrams per cubic metre	mg/m ³
Phaeopigment	- milligrams per cubic metre	mg/m ³
Acid Ratio	- ratio (dimensionless)	

Station E24 (Loch Eil) 5 FEBRUARY 1982. 09.00 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	5.9	15.7					
1 m	6.2	18.8					
2 m	6.6	21.1	6.01	9.29	0.06	0.11	1.33
3 m	6.7	22.2					
4 m	6.7	22.5					
5 m	6.7	23.0					
6 m	6.7	23.8					
8 m	6.7	24.9					
10 m	6.7	25.7	6.44	10.10	0.06	0.08	1.43
12 m	6.7	26.2					
14 m	6.7	26.8					
16 m	6.6	27.2					
18 m	6.6	27.8					
20 m	6.7	28.3					
25 m	6.9	29.3					
30 m	6.9	29.7	7.26	10.44	0.06	0.14	1.30
35 m	7.0	30.0					
40 m	7.0	30.1					

Station E70 (Loch Eil) 5 FEBRUARY 1982. 10.10 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.3	16.8					
1 m	6.4	17.7					
2 m	6.4	18.3	5.60	10.18	0.09	0.11	1.44
3 m	6.5	21.0					
4 m	6.5	21.4					
5 m	6.4	22.4					
6 m	6.4	23.7					
8 m	6.5	25.0					
10 m	6.6	25.7	6.87	10.68	0.05	0.08	1.38
12 m	6.5	26.1					
14 m	6.6	26.6					
16 m	6.6	27.3					
18 m	6.6	27.6					
20 m	6.7	28.2					
25 m	6.8	29.0					
30 m	6.9	29.6					
35 m	6.9	29.8					
40 m	7.0	30.0	7.56	10.19	0.04	0.08	1.34
45 m	7.0	30.2					
50 m	7.1	30.3					
55 m	7.1	30.4			0.04*	0.09*	1.30*
60 m	7.1	30.4	7.68	10.11			
2-10 m Mix.			6.34	9.62			

Station 53 (Upper Loch Linnhe) 4 FEBRUARY 1982. 16.20 G.M.T.

Depth	Temperature	Salinity
0 m	5.5	13.6
1 m	5.6	16.5
2 m	6.2	21.4
3 m	6.3	22.4
4 m	6.6	25.0
6 m	6.7	27.2
8 m	6.7	28.7
10 m	6.7	29.0
12 m	6.7	29.1
14 m	6.7	29.6
16 m	6.7	29.7
18 m	6.7	30.0
20 m	6.7	30.2
25 m	6.7	30.6
30 m	6.8	30.8
40 m	6.8	31.1
50 m	6.8	31.3
60 m	6.9	31.4
70 m	6.9	31.6
80 m	7.0	31.9
90 m	7.1	32.3
95 m	7.1	32.4
100 m	7.1	32.4
105 m	7.1	-

Station LL1 (Upper Loch Linnhe) 5 FEBRUARY 1982. 14.00 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.4	20.8					
1 m	6.5	21.8					
2 m	6.5	22.8	6.01	9.10	0.14	0.05	1.72
4 m	6.6	25.2					
6 m	6.6	26.3					
8 m	6.7	27.6					
10 m	6.8	28.4	6.48	8.52	0.06	0.08	1.43
12 m	6.6	28.7					
15 m	6.7	29.3					
20 m	6.7	29.9					
25 m	6.7	30.3					
30 m	6.8	30.7					
40 m	6.8	31.2					
50 m	6.8	31.5	5.29	5.64	0.06	0.06	1.47
60 m	6.8	31.6					
70 m	7.0	32.0					
80 m	7.0	32.2					
90 m	7.1	32.3					
100 m	7.1	32.3	6.90	7.88	0.04	0.06	1.37
110 m	7.1	32.4					
120 m	7.1	32.4					
140 m	-	-	6.79	7.72	0.04	0.08	1.34
2-10 m Mix.			6.74	9.80			

Station LL3 (Loch Linnhe) 5 FEBRUARY 1982. 16.25 G.M.T.

Depth	Temperature	Salinity
0 m	6.8	27.3
1 m	6.8	27.7
2 m	6.8	27.9
3 m	6.8	28.3
4 m	6.8	29.0
5 m	6.8	29.2
6 m	6.8	30.1
8 m	6.8	30.7
10 m	6.8	31.2
12 m	6.8	31.7
15 m	6.8	32.0
20 m	6.8	32.7
25 m	6.8	32.8
30 m	6.8	32.9
40 m	6.8	33.0
50 m	6.9	33.1
60 m	6.9	33.1
65 m	6.9	33.1

Station LM1 (Lynn of Morven) 4 FEBRUARY 1982. 13.10 G.M.T.

Depth	Temperature	Salinity
0 m	6.4	27.7
1 m	6.4	27.7
2 m	6.4	27.8
3 m	6.4	27.9
4 m	6.4	28.2
5 m	6.7	31.0
6 m	6.8	31.6
7 m	6.7	32.1
8 m	6.7	32.1
10 m	6.7	32.3
12 m	6.7	32.3
15 m	6.7	32.5
20 m	6.7	32.6
25 m	6.7	32.7
30 m	6.8	32.9
35 m	6.8	33.0
40 m	6.8	33.0
50 m	6.8	33.0
60 m	6.8	33.0
70 m	6.8	33.0
80 m	6.8	33.1
90 m	6.8	33.1
100 m	6.8	33.1
110 m	6.8	33.1
120 m	6.8	33.2

Station CU (Loch Creran) 3 FEBRUARY 1982. 13.00 G.M.T.

Depth	Temperature	Salinity	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.2	26.5	0.15	0.08	1.65
1 m	6.2	26.5			
2 m	6.2	26.5	0.26	0.09	1.75
3 m	6.3	26.6			
4 m	6.4	28.0	0.14	0.08	1.63
5 m	6.4	28.3			
6 m	6.4	28.6			
7 m	6.4	28.8			
8 m	6.3	29.1	0.10	0.06	1.64
9 m	6.3	29.1			
10 m	6.3	29.4			
12 m	5.8	30.4			
14 m	5.7	31.3	0.08	0.07	1.52
16 m	5.6	31.7			
18 m	5.5	32.1			
20 m	5.5	32.2			
22 m	5.5	32.3			
24 m	5.5	32.3			
26 m	5.5	32.3			
28 m	5.5	32.3			
30 m	5.5	32.3	0.03	0.09	1.27

Station C5 (Loch Creran) 3 FEBRUARY 1982. 14.10 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	5.9	24.2			0.18	0.10	1.64
1 m	6.1	25.9					
2 m	6.6	28.1	6.66	8.87	0.23	0.15	1.61
3 m	6.6	28.6					
4 m	6.6	29.1			0.18	0.09	1.67
5 m	6.6	29.5					
6 m	6.6	29.5			0.07	0.08	1.48
7 m	6.6	29.7					
8 m	6.6	30.1					
9 m	6.6	30.2					
10 m	6.6	30.2	6.52	7.72	0.06	0.08	1.41
12 m	6.6	30.5			0.06	0.09	1.40
14 m	6.6	30.8					
16 m	6.6	31.0	6.35	7.39	0.05	0.09	1.36
18 m	6.5	31.6					
20 m	6.5	31.7					
2-10 m Mix.			7.02	8.57			

Station C3 (Loch Creran) 3 FEBRUARY 1982. 11.00 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.1	27.3					
1 m	6.1	27.4					
2 m	6.1	27.4	6.69	9.09	0.20	0.12	1.61
3 m	6.1	27.5					
4 m	6.1	27.7					
5 m	6.2	28.0					
6 m	6.4	29.3					
7 m	6.5	29.6					
8 m	6.5	29.8					
9 m	6.5	30.2					
10 m	6.6	30.5	6.74	7.83	0.07	0.08	1.47
12 m	6.6	30.8					
14 m	6.6	30.9					
16 m	6.6	30.9					
18 m	6.5	31.3					
20 m	6.5	31.5					
25 m	6.4	31.7					
30 m	6.4	31.8					
35 m	6.4	31.9					
40 m	6.4	32.0	6.61	8.30	0.04	0.10	1.32
2-10 m Mix.			6.71	8.42			

Station LY1 (Lynn of Lorne) 3 FEBRUARY 1982. 16.00 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.2	27.9					
1 m	6.2	28.0					
2 m	6.3	29.5	7.14	8.51	0.14	0.09	1.61
3 m	6.6	31.5					
4 m	6.6	31.7					
5 m	6.6	32.0					
6 m	6.7	32.0					
7 m	6.7	32.3					
8 m	6.8	32.7					
9 m	6.8	32.8					
10 m	6.8	32.8	7.08	6.80	0.15	0.06	1.72
12 m	6.8	32.9					
14 m	6.8	32.9					
16 m	6.8	33.0					
18 m	6.8	33.0					
20 m	6.8	33.1					
25 m	6.8	33.1					
30 m	6.8	33.1					
35 m	6.8	33.1					
40 m	6.8	33.1	6.60	6.09	0.07	0.07	1.51
2-10 m Mix.			7.33	7.22			

Station 700 (Mouth of Loch Spelve) 4 FEBRUARY 1982. 11.30 G.M.T.

Depth	Temperature	Salinity	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.7	32.6			
2 m	6.7	32.6	0.10	0.07	1.59
4 m	6.7	32.6			
6 m	6.7	32.6			
8 m	6.7	32.6			
10 m	6.7	32.6	0.10	0.07	1.60
12 m	6.7	32.6			
15 m	6.7	32.6			
20 m	6.7	32.7			
25 m	6.8	32.9			
30 m	6.8	33.0			
35 m	6.8	33.1			
40 m	6.8	33.1			
45 m	6.8	33.2			
50 m	6.8	33.3	0.10	0.07	1.57
55 m	6.8	33.3			
60 m	6.8	33.3			
70 m	6.8	33.4			
80 m	6.8	33.4			
90 m	6.8	33.4			
100 m	6.9	33.5			
110 m	6.9	33.5			
120 m	6.9	33.5	0.11	0.08	1.56

Station 700 (Mouth of Loch Spelve) 19 FEBRUARY 1982. 16.00 G.M.T.

Depth	Temperature	Salinity	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.4	32.6			
2 m	6.5	32.6	0.17	0.03	1.86
4 m	6.5	32.6			
6 m	6.6	33.0			
8 m	6.7	33.1			
10 m	6.7	33.1	0.12	0.04	1.75
12 m	6.7	33.2			
15 m	6.7	33.3			
20 m	6.8	33.4			
25 m	6.8	33.4			
30 m	6.8	33.5			
40 m	6.8	33.5			
50 m	6.8	33.5	0.13	0.04	1.75
60 m	6.8	33.6			
70 m	6.8	33.7			
80 m	6.9	33.7			
90 m	6.9	33.7			
100 m	6.9	33.7			
110 m	6.9	33.7			
120 m	6.9	33.7	0.15	0.05	1.75

Station FL4 (Firth of Lorne) 19 FEBRUARY 1982. 14.00 G.M.T.

Depth	Temperature	Salinity
0 m	6.5	33.1
2 m	6.5	33.1
4 m	6.5	33.2
6 m	6.6	33.2
8 m	6.6	33.4
10 m	6.6	33.4
12 m	6.6	33.4
14 m	6.6	33.5
16 m	6.6	33.5
18 m	6.6	33.5
20 m	6.7	33.5
30 m	6.7	33.6
40 m	6.7	33.7
50 m	6.7	33.7
60 m	6.7	33.7
70 m	6.7	33.7
80 m	6.7	33.7
90 m	6.7	33.7

Station FL1 (off Colonsay) 19 FEBRUARY 1982. 12.10 G.M.T.

Depth	Temperature	Salinity	D.I.N.	Silicate	Chlorophyll	Phaeopigment	Acid Ratio
0 m	6.7	33.8					
2 m	6.7	33.8	7.60	6.97	0.30	0.06	1.83
4 m	6.7	33.8					
6 m	6.7	33.8					
8 m	6.7	33.8					
10 m	6.7	33.8	7.57	6.13	0.27	0.05	1.84
12 m	6.7	33.8					
14 m	6.7	33.8					
16 m	6.7	33.8					
18 m	6.7	33.8					
20 m	6.7	33.8					
25 m	6.7	33.8					
30 m	6.8	33.8					
35 m	7.0	34.0					
40 m	7.0	34.0					
50 m	6.9	34.1	7.29	5.59	0.27	0.07	1.80
70 m	7.0	34.1					
80 m	7.2	34.3	7.32	4.77	0.24	0.07	1.77
2-10 m Mix.			7.57	6.35			