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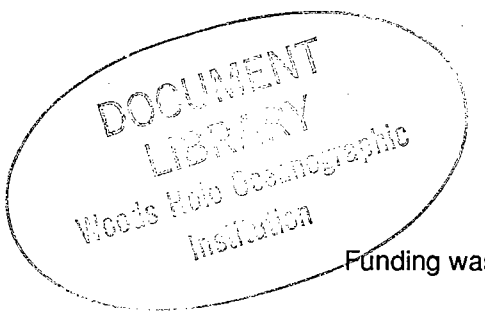
CTD Observations on the North Brazil Shelf During A Multidisciplinary Amazon Shelf SEDiment Study (AMASSEDS) February – March 1990

by

Richard Limeburner and Robert C. Beardsley



May 1991

Technical Report

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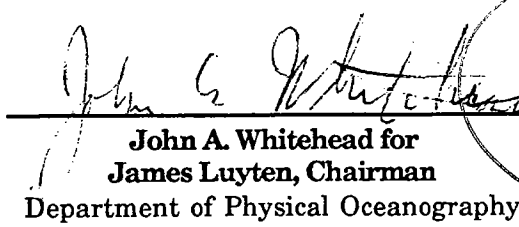
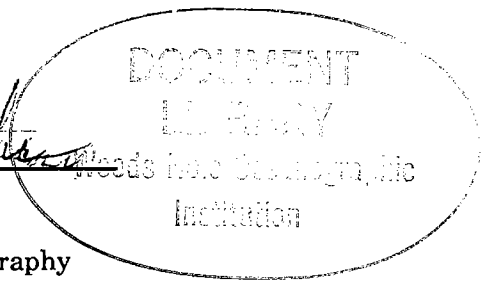


John A. Whitehead for
James Luyten, Chairman
Department of Physical Oceanography



CTD Observations on the North Brazil Shelf During A Multidisciplinary Amazon Shelf SEDiment Study (AMASSEDS) February–March 1990

Abstract

Hydrographic (CTD) and acoustic Doppler current profiler (ADCP) observations were made on the North Brazil shelf adjacent to the mouth of the Amazon River during R/V *Iselin* cruise I9002 February 10—March 29, 1990 as part of A Multidisciplinary Amazon Shelf SEDiment Study (AMASSEDS). These observations were obtained during a small-scale survey on Leg 1 in support of mooring deployment operations, during a large-scale survey on Leg 3 in support of geological and geochemical sampling, during a frontal zone survey on Leg 4 consisting of 12 and 24 hourly CTD casts at anchored stations, and during a bottom tripod recovery on Leg 5. The maximum sampling depth at each station was within two meters of the bottom.

The primary objectives of the AMASSEDS hydrographic measurement program were (a) to observe and characterize the temperature, salinity, density, oxygen, fluorescence and light transmission fields and their spatial variability on the north Brazilian shelf directly influenced by the Amazon River discharge, (b) to resolve the seaward extent and vertical structure of the surface plume of low salinity Amazon River water during different stages of river discharge, (c) to describe the spatial structure of the turbidity and associated suspended sediment distributions across the shelf, (d) to characterize the properties of the Amazon shelf water beneath the surface plume and their seasonal variability, and (e) to describe the landward penetration of the North Brazil Current with respect to water properties and shelf currents. This report represents a summary in graphic and tabular form of the hydrographic observations made during the second AMASSEDS cruise (I9002) on the R/V *Iselin*.

Table of Contents

1. Introduction

A Multidisciplinary Amazon Shelf SEDiment Study (AMASSEDS) is a multi-institutional international program to investigate physical, geological, geochemical and biological processes within the Amazon dispersal system. The primary objective of AMASSEDS is to understand the sedimentary processes on the continental shelf near the mouth of the Amazon River. Previous studies of the Amazon shelf and similar environments suggest that the enormous suspended sediment load carried over the inner shelf in the local water column strongly influences other factors such as seabed morphology and biological productivity, and leads to creation of a subaqueous delta. The physical oceanographic component of AMASSEDS is directed toward understanding circulation and boundary layer processes on the Amazon shelf. The primary objectives are (a) to measure and characterize the flow and mixing processes in the low salinity frontal zone, (b) to estimate the contributions to bottom stress from subtidal motions, tidal flow, and surface waves, and (c) to quantify the cross-shelf advective and dispersive transport mechanisms. The physical oceanographic field work includes: short-term (February – May, 1990) moored measurements of wind, current, temperature, conductivity, and surface waves to determine tidal and low-frequency variability in the shelf flow field, density stratification, and surface and bottom stresses; a series of four large-scale hydrographic surveys to map the distributions of temperature, salinity, and turbidity during different stages of river discharge; and short-term high resolution measurements of the small-scale circulation and mixing processes in the frontal zone. Satellite imagery of the sea surface is being collected to describe the synoptic distribution of suspended sediment. Finally, two satellite-tracked drifting buoys are being deployed on each of the four hydrographic surveys. The first survey was completed in August, 1989 during falling river discharge (Limeburner and Beardsley, 1989); the second survey was completed in March, 1990 during rising river discharge; the third survey was completed in June, 1990 during maximum river discharge, and the fourth and last cruise is planned for November, 1991 during low river discharge These measurements include hydrographic and current profiling with a CTD and either a 150 or 600 kHz acoustic Doppler current profiler (ADCP) respectively.

We present here in graphic and tabular form a preliminary analysis of the CTD observations made on the North Brazil shelf on board the R/V *Iselin* during cruise I9002 February 10 – March 29, 1990. A total of 241 CTD stations was made on I9002, and the following station summary is intended to provide a brief description of the sequence of CTD sampling during the cruise. Vertical and horizontal sections of water properties obtained from the individual transects and large-scale CTD surveys are shown in Section 7. Listings of the CTD observations at standard depths for all stations are given in Section 8.

Individual CTD casts were initially labelled consecutively for all legs of cruise I9002. In this report CTD cast names are given as consecutive numbers for each leg.

CTD STATION LISTING SUMMARY

Leg 1 — February 10–11, 1990

- Stations 1–15. Cross-shelf section made during the initial AMASSEDS mooring deployment operations.

Leg 3 — February 28–March 7, 1990

- Stations 1–54. Large-scale survey of the North Brazil shelf consisting of 7 cross-shelf transects to map the initial fields of temperature, salinity, sigma-t, oxygen, fluorescence, and light transmission.
- Stations 57–59. Short cross-shelf transect at the mouth of the Amazon River.

Leg 4 — March 9–21, 1990

- Stations 1–45. Frontal zone study of the Amazon River plume consisting of hourly casts at seven time series anchor stations, and other various CTD stations.
  - Station 5 — Anchor Station 1
  - Station 15 – Anchor Station 2
  - Station 18 – Anchor Station 3
  - Station 20 – Anchor Station 4
  - Station 28 – Anchor Station 5
  - Station 44 – Anchor Station 6
  - Station 45 – Anchor Station 7

Leg 5 — March 23–30, 1990

- Station 241. Single station made during Geoprobe search.

The following table cross references the consecutive CTD station names for each leg of cruise I9002 used in this report and the archived consecutive CTD casts for all legs on I9002.

Leg	I9002 Station Number	Consecutive CTD Cast	Work Area
1	1–15	1–15	Open shelf section
3	1–54	16–69	Large-scale survey
3	57–59	70–72	River mouth section
4	1–4	73–77	To river mouth
4	5.01–5.19	78–94	Anchor station 1
4	6–14	95–101	To open shelf
4	15.01–15.27	102–127	Anchor station 2
4	16–17	128–129	To anchor station 3
4	18.01–18.24	130–136	Anchor station 3
4	20.01–20.26	137–161	Anchor station 4
4	21–27	162–168	Small-scale survey
4	28.01–28.26	169–194	Anchor station 5
4	29–43	195–210	Small-scale survey
4	44.01–44.17	211–227	Anchor station 6
4	45.01–45.13	228–240	Anchor station 7
5	241	241	River mouth

2. Instrumentation and Calibration

A Neil Brown Instrument Systems (NBIS) model MKIII CTD fish was used as the primary profiling instrument during R/V *Iselin* cruise I9002. The instrument provided continuous sampling of pressure, temperature, conductivity, fluorescence and light transmission. Salinity, density, and suspended sediment concentration were subsequently derived from the measured variables. The instrument package consisted of the MKIII CTD underwater unit mounted one meter below a General Oceanics rosette sampler with 12 five-liter Niskin bottles. A Sea Tech 5 cm pathlength transmissometer and a Sea Tech fluorometer were mounted near the CTD fish. The fast response thermistor on the CTD fish was disabled and the instrument sampled at a rate of 16 Hz. Lowering speeds were approximately 36 m/min to match the response times of the temperature and conductivity sensors (Giles and McDougall, 1986). The pressure sensor had a full range of 1600 db.

The CTD underwater unit was part of the R/V *Iselin*'s scientific equipment. A water sample for conductivity calibration was normally collected at each station on the upcast at a depth where the vertical stratification and suspended sediment concentration were minimal. The calibration samples were then processed onboard during the cruise using a Guildline AutoSal salinometer to determine salinity. The individual salinities were converted to *in situ* conductivity and compared to the conductivity output of the instrument. A least-squares fit of the difference between the 45 bottle and instrument conductivity calibration samples collected on Legs 1 and 3 gives

$$\mathrm{C(CTD)} - \mathrm{C(Bottle)} \;=\; 0.00029 * \mathrm{X} \;+\; 0.0085,$$

where X is the station number which varied from 1 to 72, and the sum of the squares of the residuals is 0.0605 mmho^2. This means that the CTD conductivity sensor drift and offset were small during the cruise and that the rms difference between the corrected CTD and bottle conductivity values was ± 0.037 mmho. No conductivity calibration samples were collected on Leg 4 and Leg 5, and the following calibration from Leg 3 was applied to the Leg 4 and Leg 5 conductivity data,

$$\mathrm{C(Corrected)} \;=\; \mathrm{C(CTD)} - \;0.029.$$

Suspended sediment samples were also normally collected at each station during the cruise to calibrate the light transmission sensor. The individual suspended sediment concentrations were compared to the transmissometer output (Figure 1). For suspended sediment concentrations less than about 109 mg/l (corresponding to a light transmission of 7.8% and higher) a least-squares exponential fit of the suspended sediment concentration data to the light transmission output (in percent transmission) gives

$$\text{Sediment Concentration (mg/l)} \;=\; 147.2e^{-0.0379*\ \text{Light (\%)}}.$$

The rms of the residuals (i.e., the difference between the fitted curve and measured sediment concentration based on the 63 calibration samples) was $\pm$ 9.5 mg/l .

Concentrations greater than 109 mg/l exhibited a different calibration with the observed light transmission, probably due to larger particle size at high sediment concentrations. For light transmission less than about 7.8% a least-squares exponential fit of the

suspended sediment concentration data to the light transmission output gives

$$\text{Sediment Concentration (mg/l)} = 577.7e^{-0.2129* \text{ Light (\%)}}.$$

The rms of the residuals for the 4 calibration samples in this concentration range is ± 31.6 mg/l. Light transmission values of 0% were recorded and given a maximum sediment concentration of 577.7 mg/l.

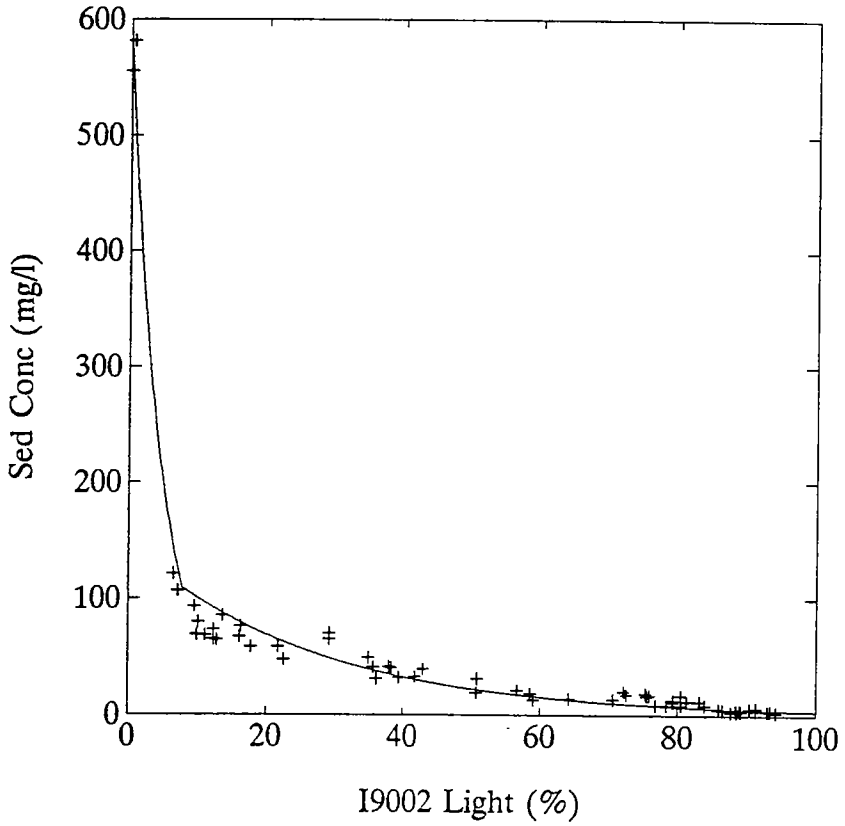


Figure 1. Observed relationship between light transmission (in percent transmission) and suspended sediment concentration (in mg/l). Samples are shown as crosses; the resulting (solid) calibration curve is used to predict suspended sediment concentration from light transmission measurements.

The Sea Tech fluorometer data are presented as a percent of full scale. Frequent data drop out were observed with the oxygen sensor, and no attempt was made to correct these data gaps.

3. Data Processing

The CTD data were recorded at sea with a PC-based data acquisition system written by Howard Saklad of the Institute of Marine Science, University of Alaska. The program acquires the raw CTD data at 16 Hz, displays the data in real time, computes postcast data averages, and prints lists of data at each station. Normally, only the down profile is processed at sea. During post cruise data processing, the conductivity calibration was first applied to the raw data. Then an exponential recursive filter (Middleton and Foster, 1980) was applied to pressure and conductivity to match the amplitude and phase of the platinum temperature sensor. The filter has the form

$$c'(t) = w_0 c'(t - dt) + (1 - w_0)c(t),$$

where $c'(t)$ is the filtered conductivity at time t, $c'(t - dt)$ is the previous filtered conductivity, and $c(t)$ is the original unfiltered conductivity at time t. The filter weight is given by

$$w_0 = e^{-dt/tlag},$$

where $dt = .063$ sec is the sampling period, and $tlag = .235$ sec is the time lag of the platinum temperature sensor. A uniform pressure series of 1 db interval was then created from the filtered data, after spurious data observations (spikes) had been replaced with interpolated data. Salinity was calculated according to Lewis (1980) and a value of 42.914 was used to convert to conductivity ratio (Culkin and Smith, 1980).

4. Data Presentation

The edited hydrographic data collected on cruise I9002 are shown in the form of vertical sections, T/S correlations and horizontal sections in Section 7, and vertical profiles and tabular lists at graduated depths are given in Section 8.

5. Acknowledgments

R/V *Iselin* cruise I9002 was supported by NSF Grant OCE88-12917. R. Beardsley, R. Limeburner, W. Geyer, and G. Kineke were Chief Scientists on Leg 1, Leg 3, Leg 4, and Leg 5, respectively. The work was a cooperative effort by H. Astwood, I. Carvalho, B. Genna, R. Gorski, J. Ivo, S. Hardin, H. Kelly, K. McCoy, H. Morgan, T. Milligan, R. Pope, I. Soares, H. Vital, and C. Vilela. Their assistance is greatly appreciated. Finally, the helpfulness of the marine technicians C. Crosby and M. Aparicio, and the officers and crew of the R/V *Iselin* contributed significantly to the success of the cruise.

6. References

Culkin, F. and N. D. Smith, 1980. Determination of the concentration of potassium chloride having the same electrical conductivity, at 15°C and infinite frequency, as standard seawater of salinity 35.000 ppm (chlorinity 19.37394 ppm). *IEEE Journal of Ocean Engineering*, **OE-5**, 22–23.

Giles, A. B. and T. J. McDougall, 1986. Two methods for the reduction of salinity spiking of CTDs. *Deep-Sea Research*, **33**(9), 1253–1274.

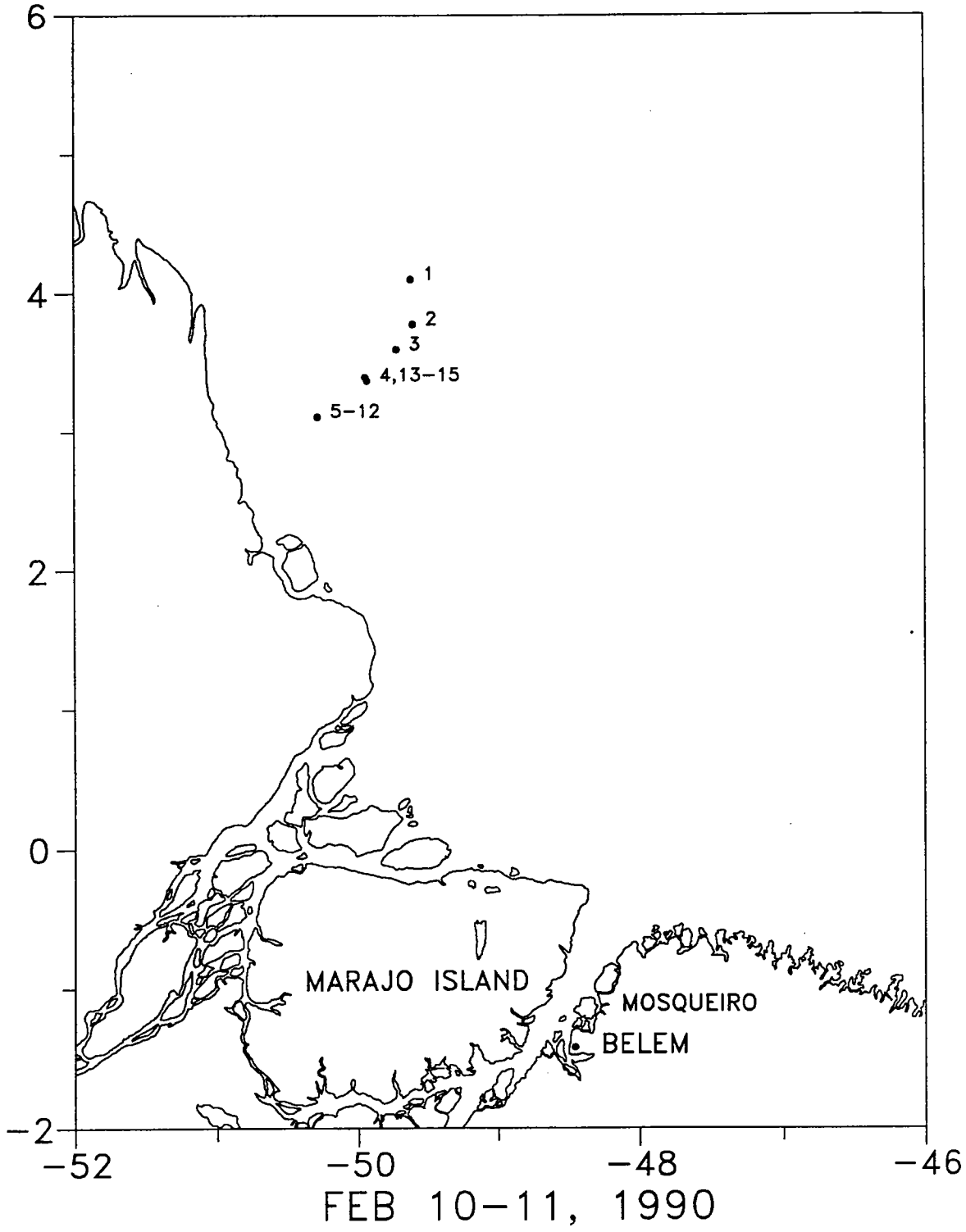
Lewis, L. L., 1980. The Practical Salinity Scale 1978 and its antecedents. *IEEE Journal of Ocean Engineering*, **OE-5**, 3–8.

Limeburner, R. and R. C. Beardsley, 1989. CTD observations off northern Brazil during A Multidisciplinary Amazon Shelf SEDiment Study, AMASSEDS, August 1989. *Woods Hole Oceanographic Institution Technical Report* WHOI-89-53, 134 pp.

Middleton, J. H. and T. D. Foster, 1980. Fine structure measurements in a temperature compensated halocline. *Journal of Geophysical Research*, **85**(C2), 1107–1122.

7. Graphic Description of CTD Data

A. Leg 1 – Section F — February 10–11, 1990
Stations 1 to 15


6
4
2
0
−2
−52
−50
−48
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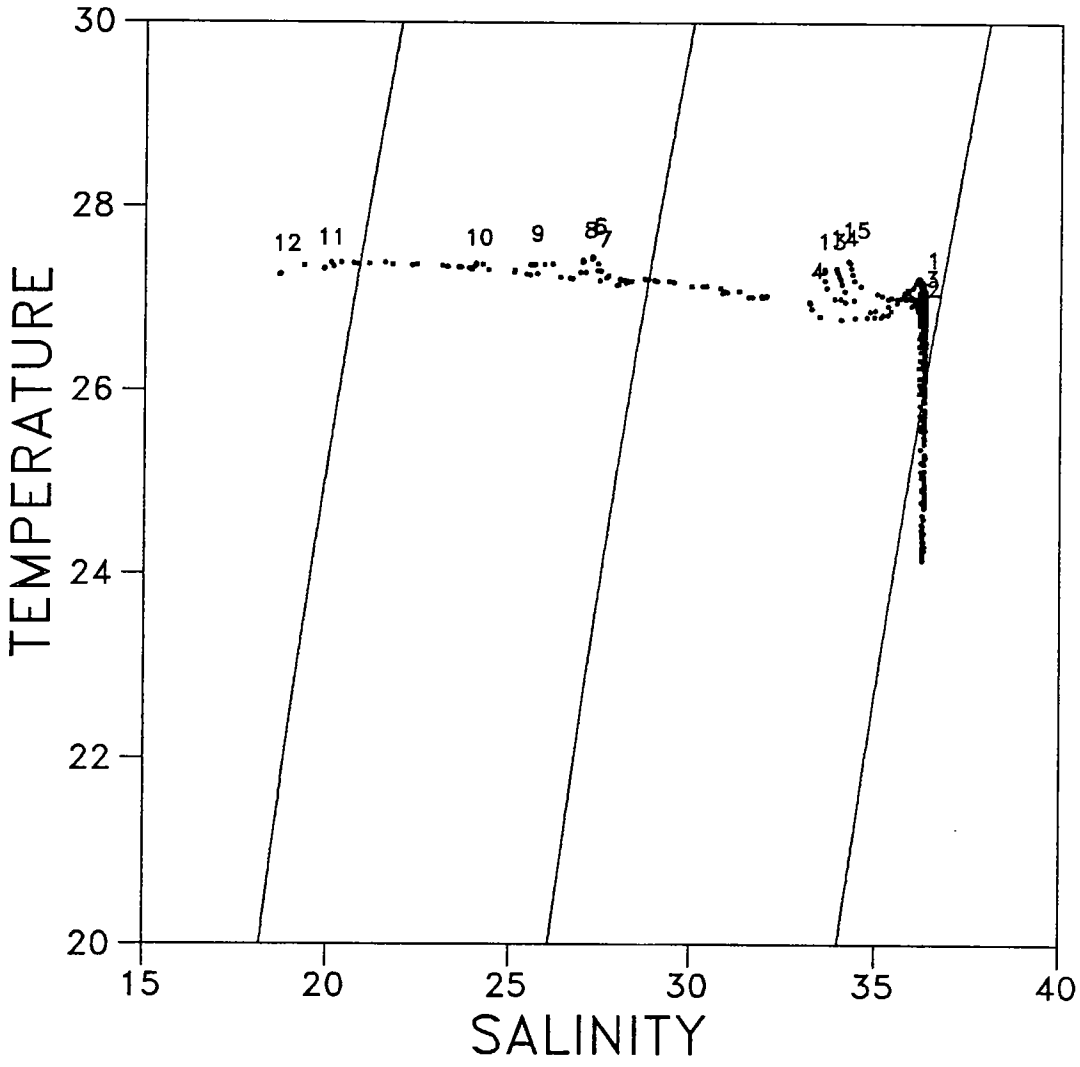
1
2
3
4,13−15
5−12
MARAJO ISLAND
MOSQUEIRO
BELEM
FEB 10−11, 1990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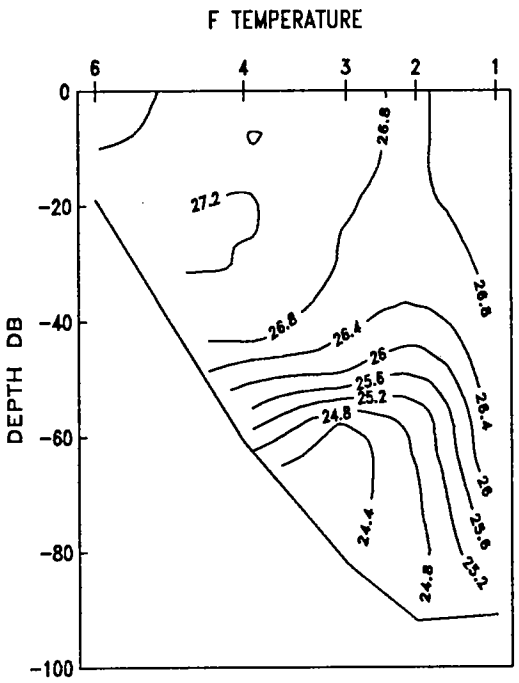
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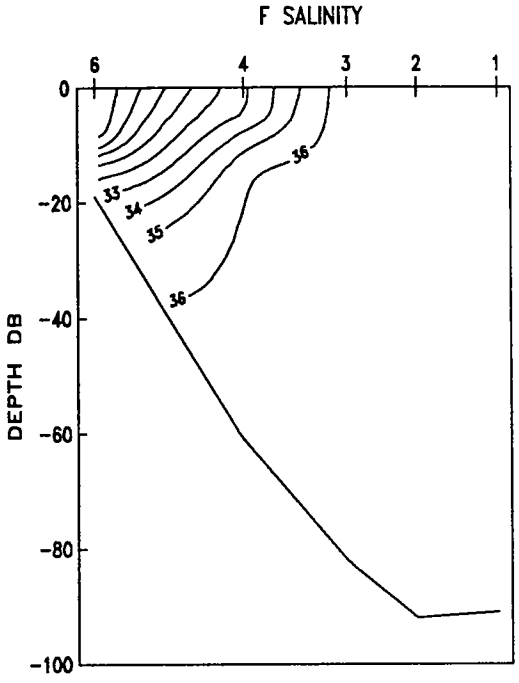
25.2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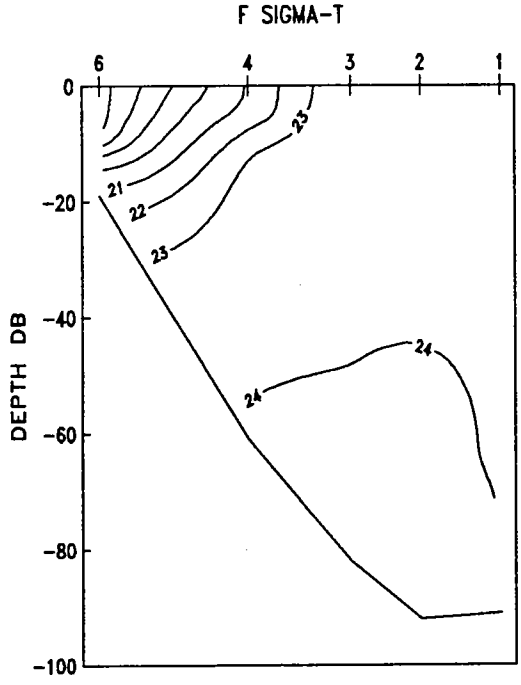
36
36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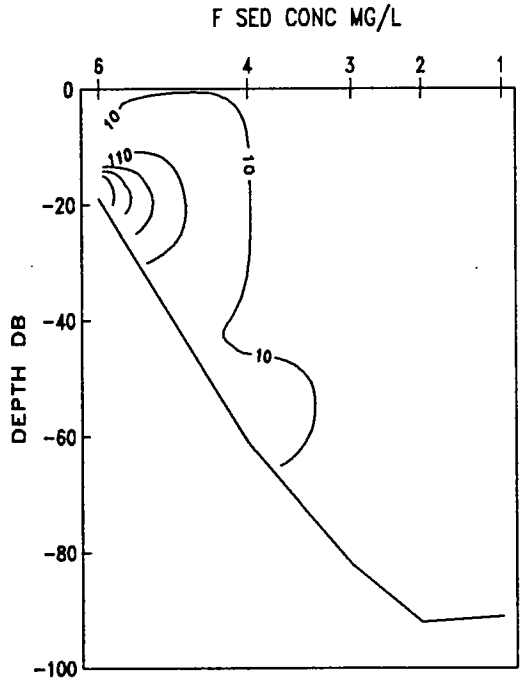
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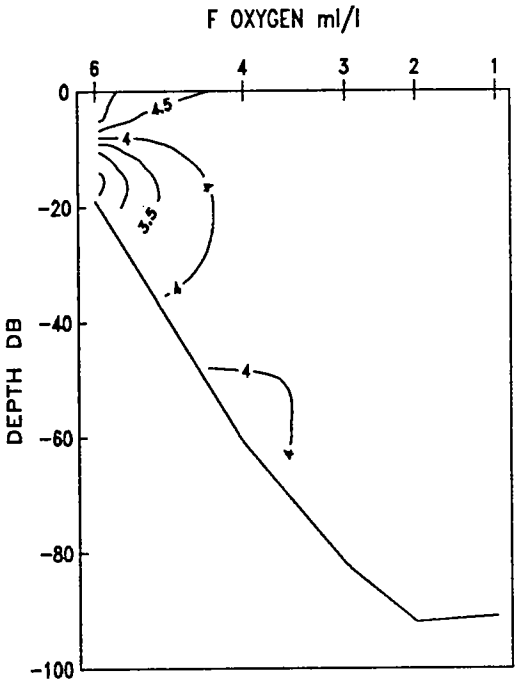
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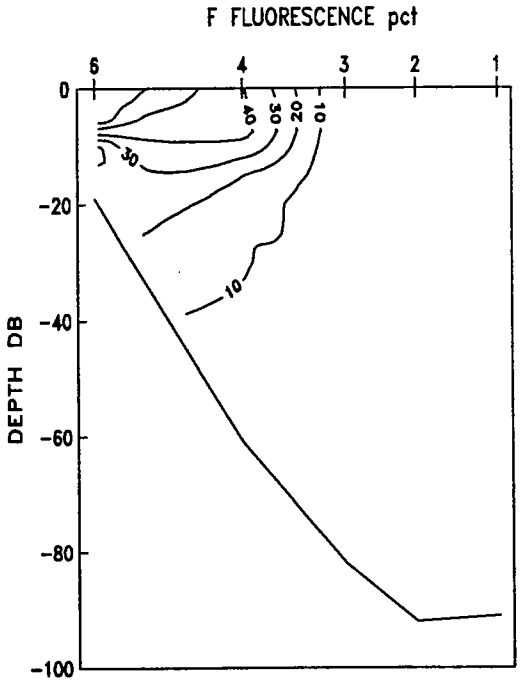
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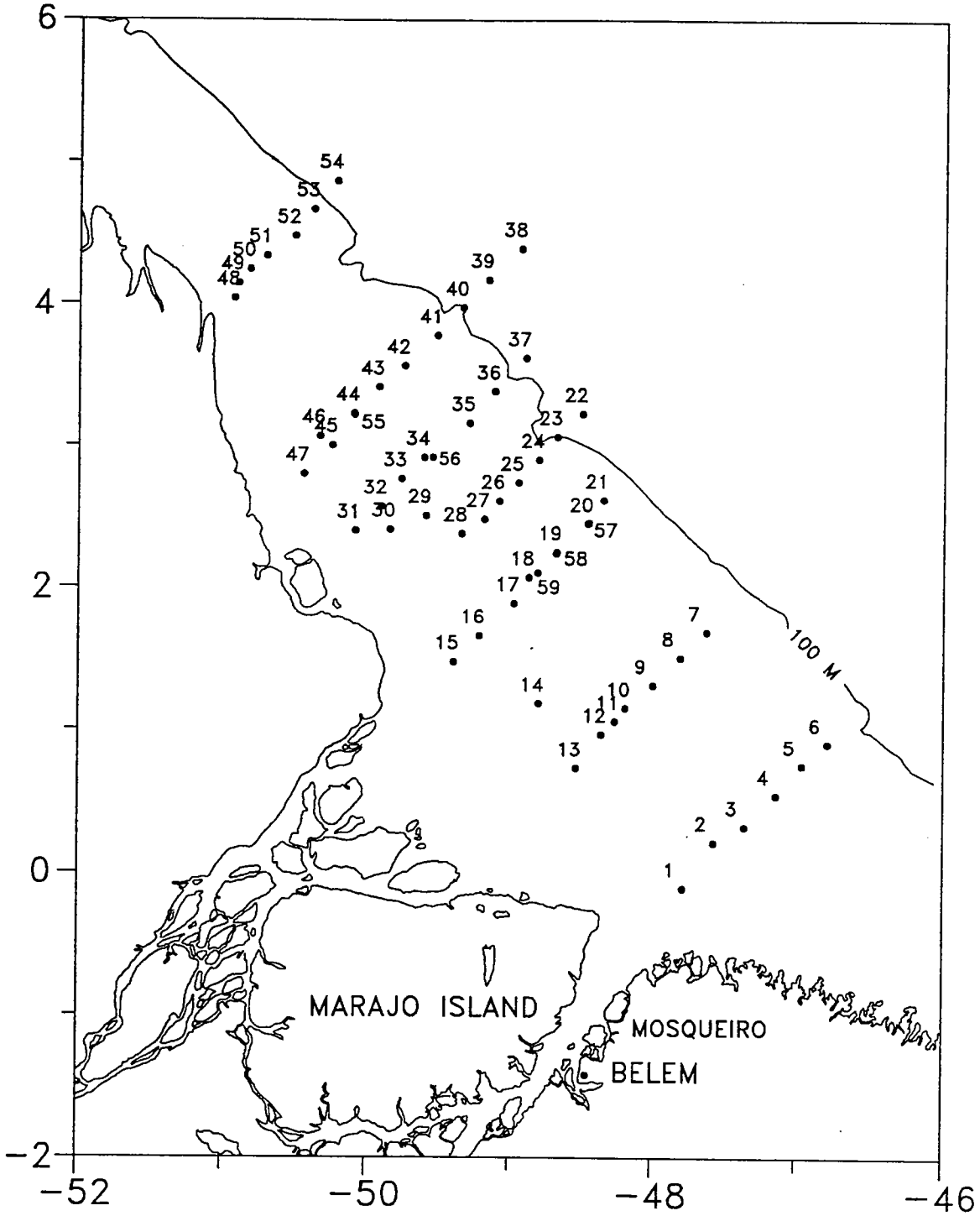
B. Leg 3 – Large-Scale Survey — February 28–March 7, 1990
Stations 1 to 54



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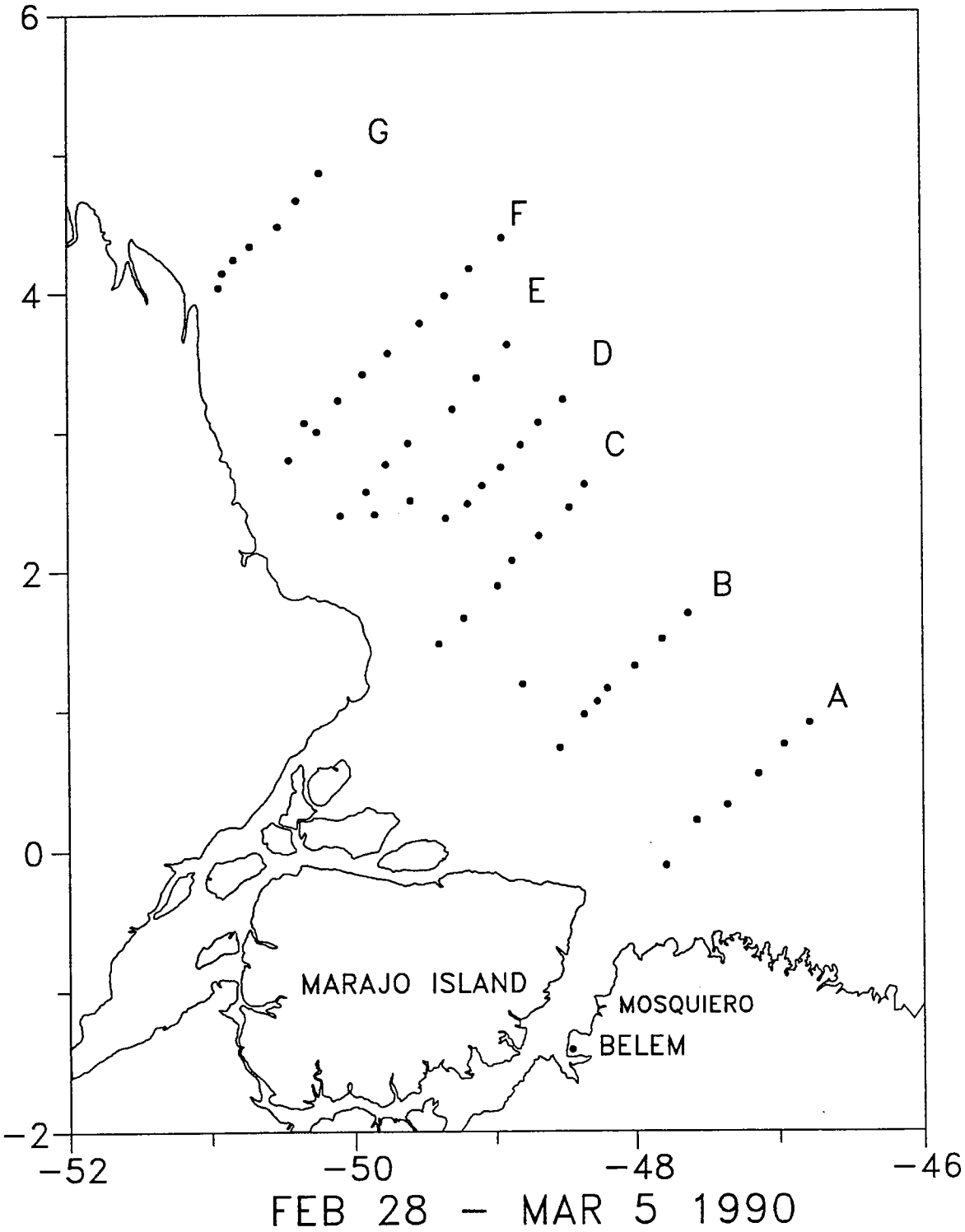
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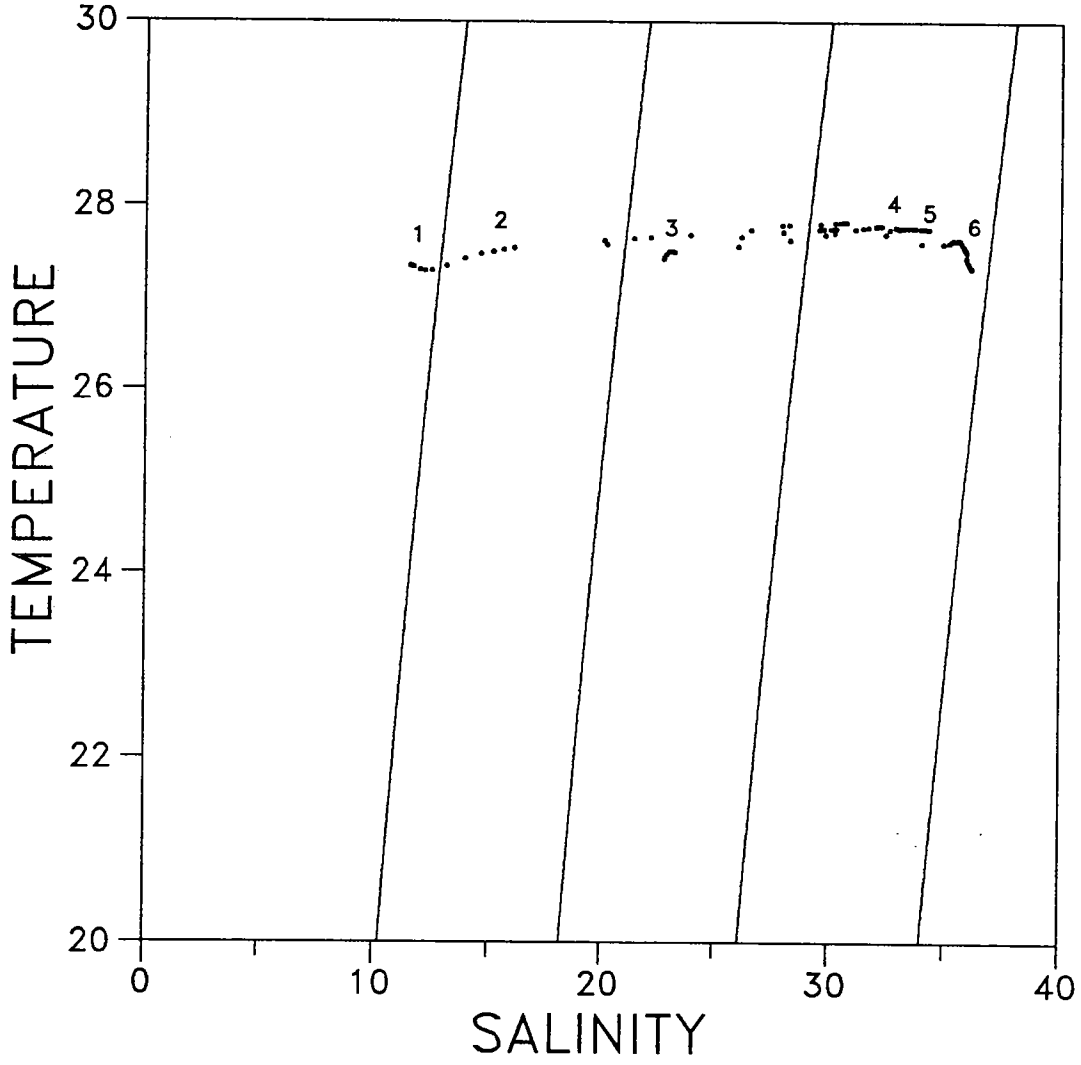
MOSQUIERO
BELEM
FEB 28 − MAR 5 1990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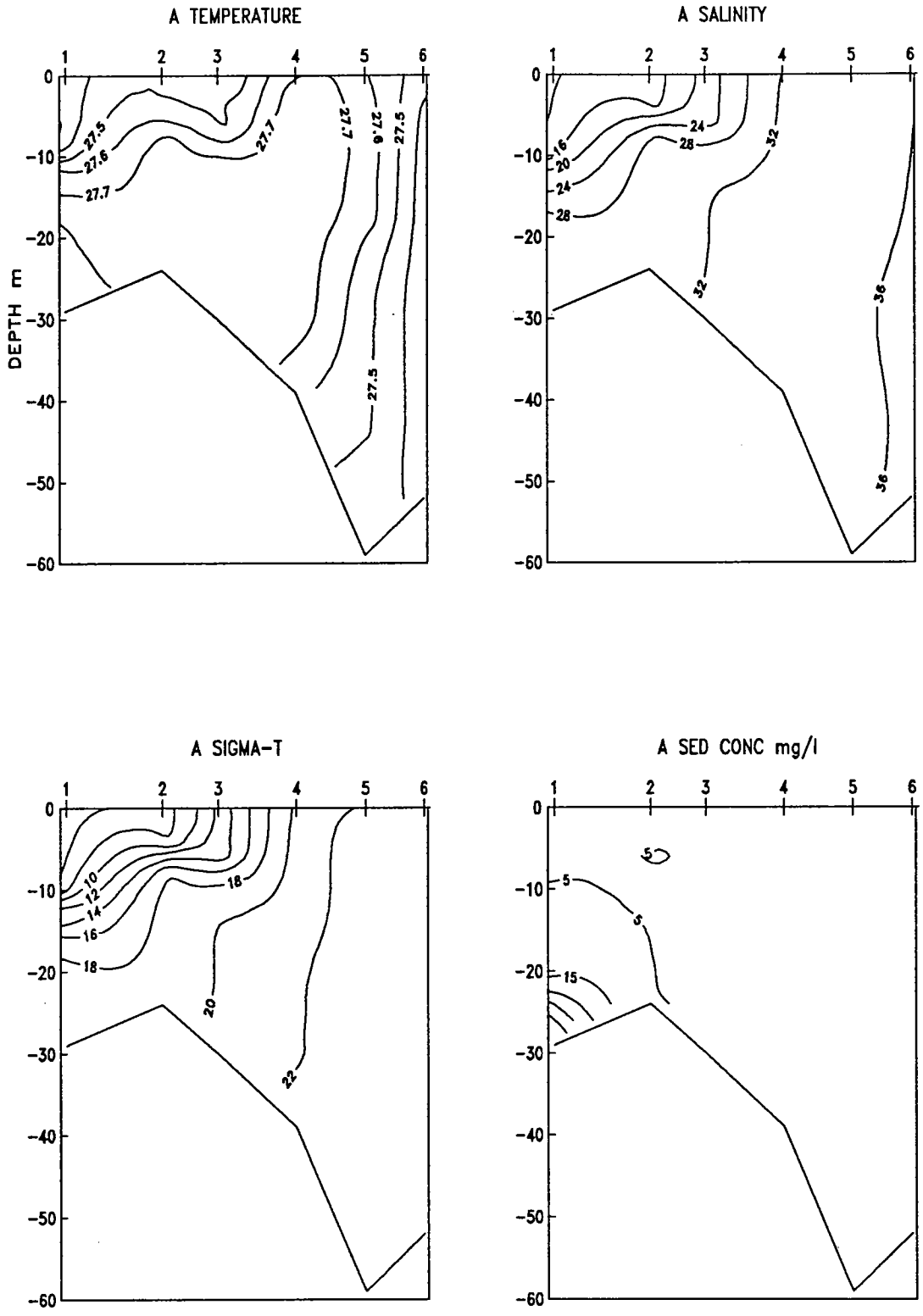
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A SIGMA-T
A SED CONC mg/l
DEPTH m
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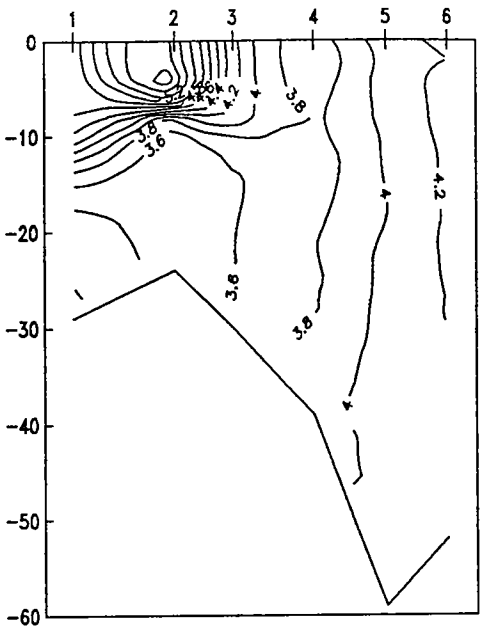
15

A OXYGEN ML/L



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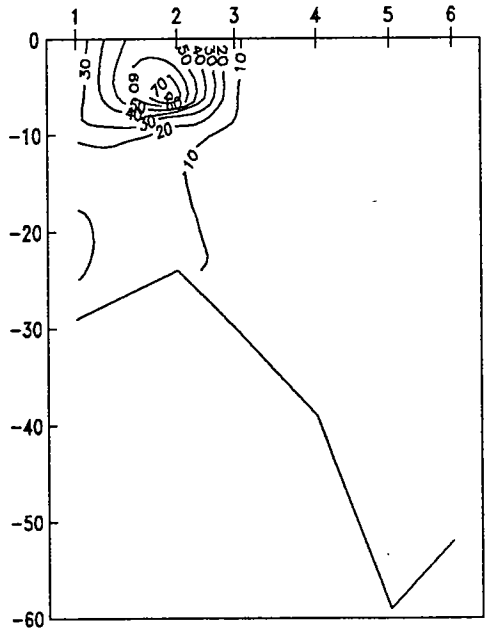

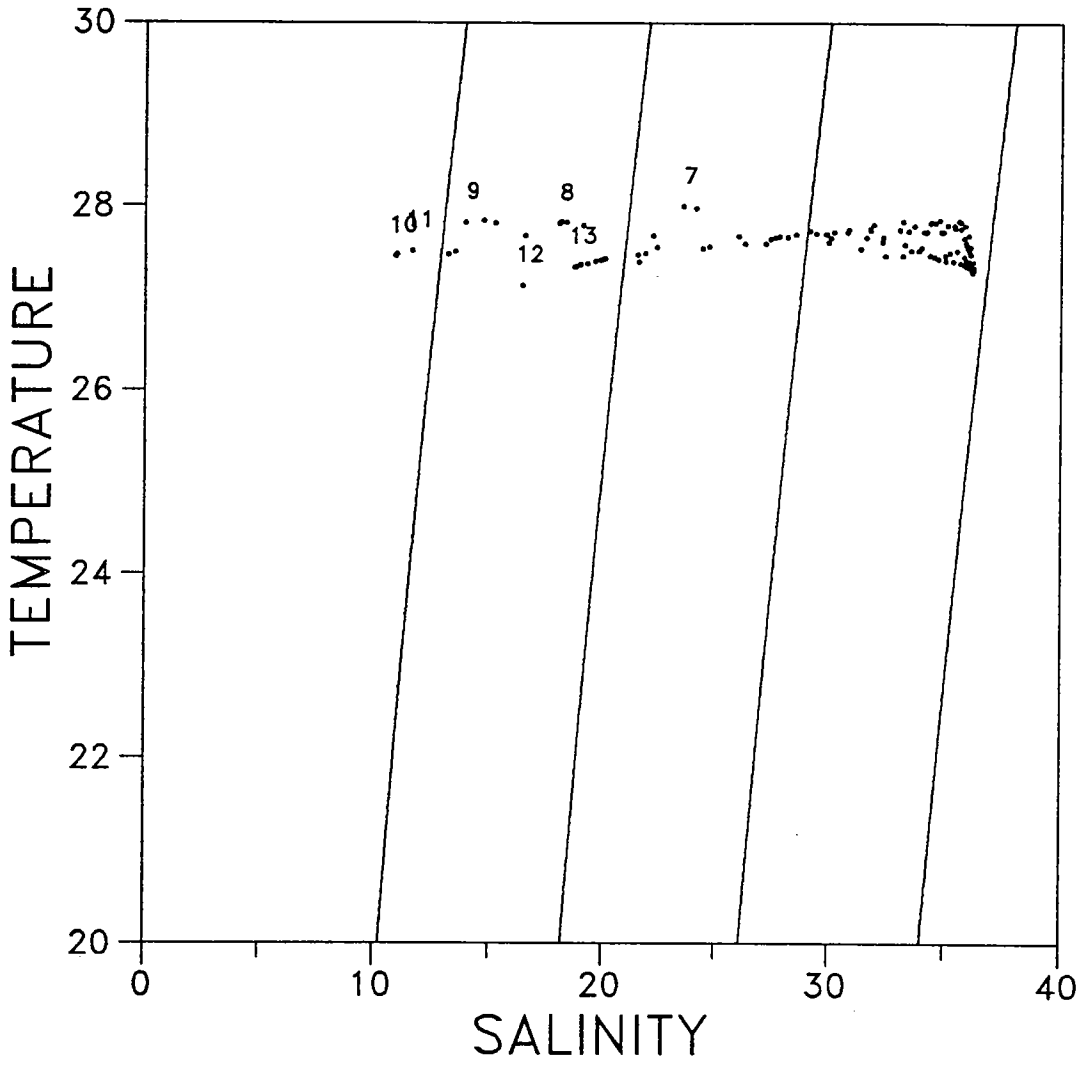
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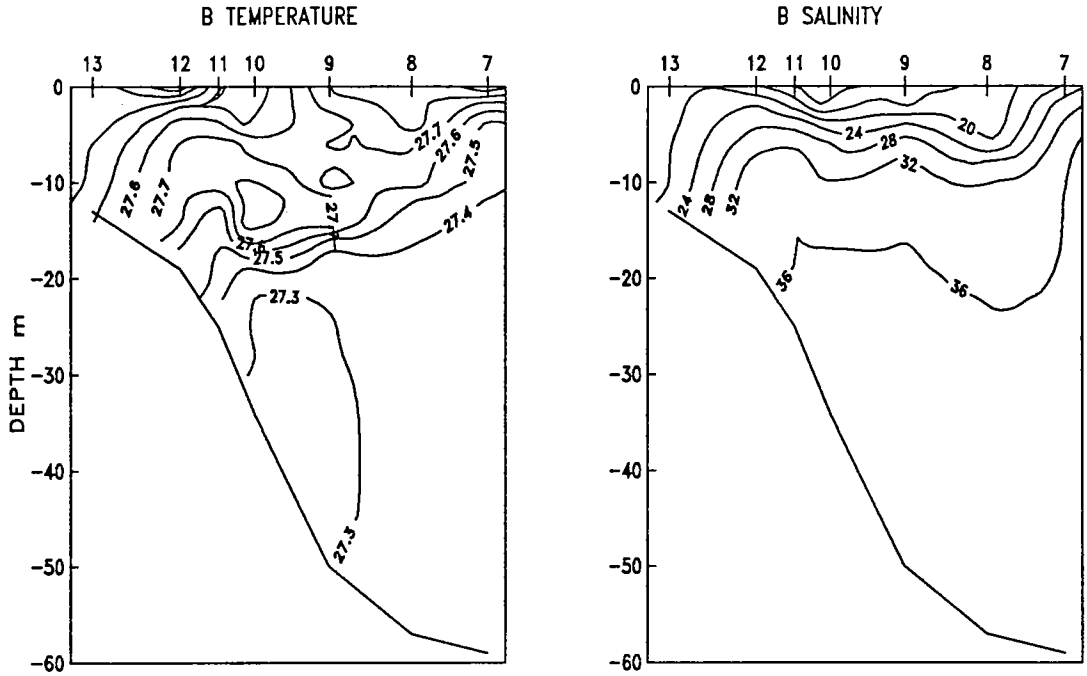
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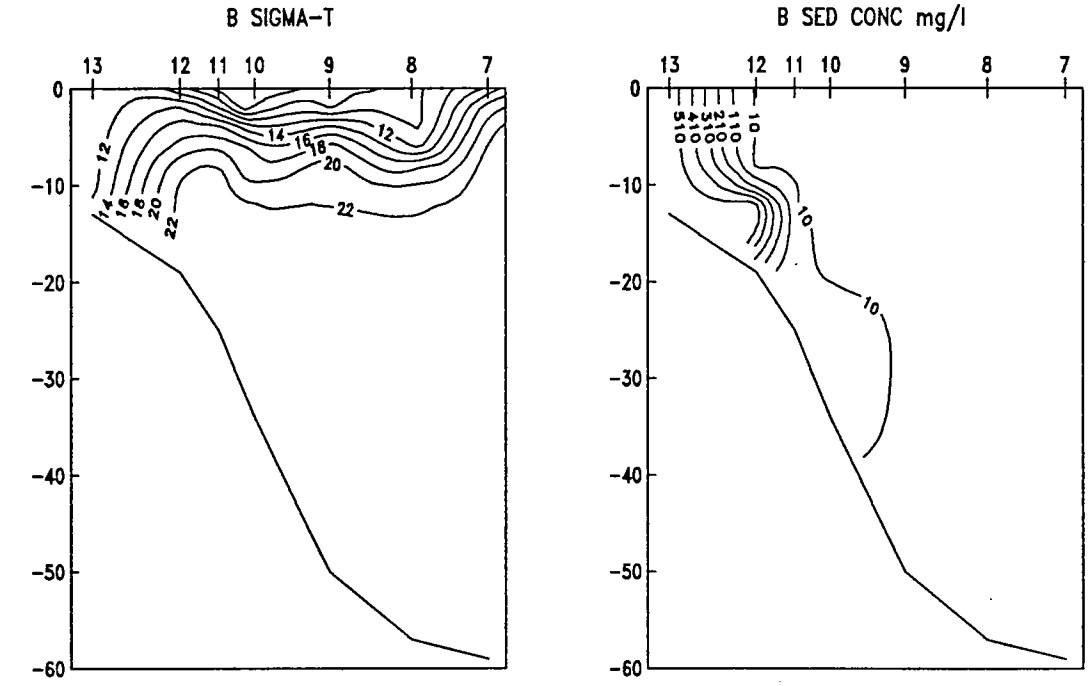
24 28 32 36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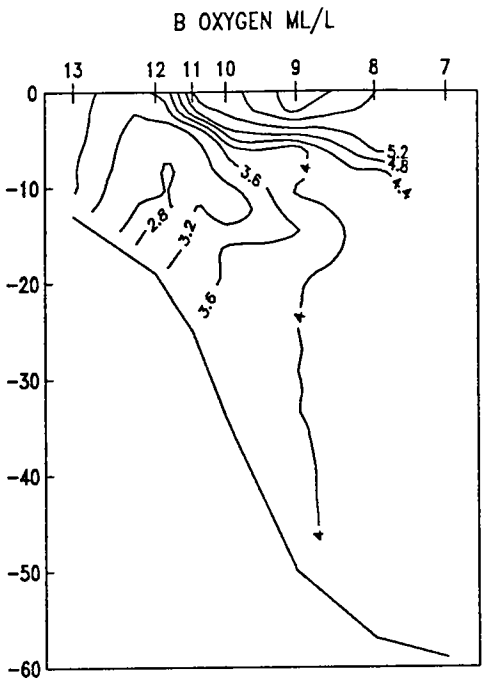
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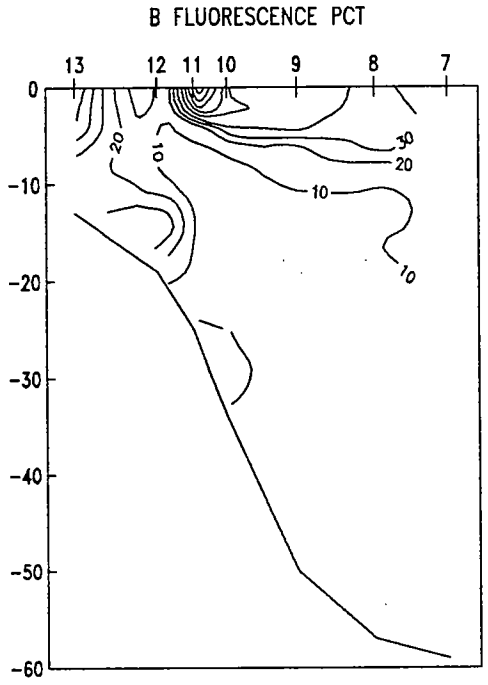
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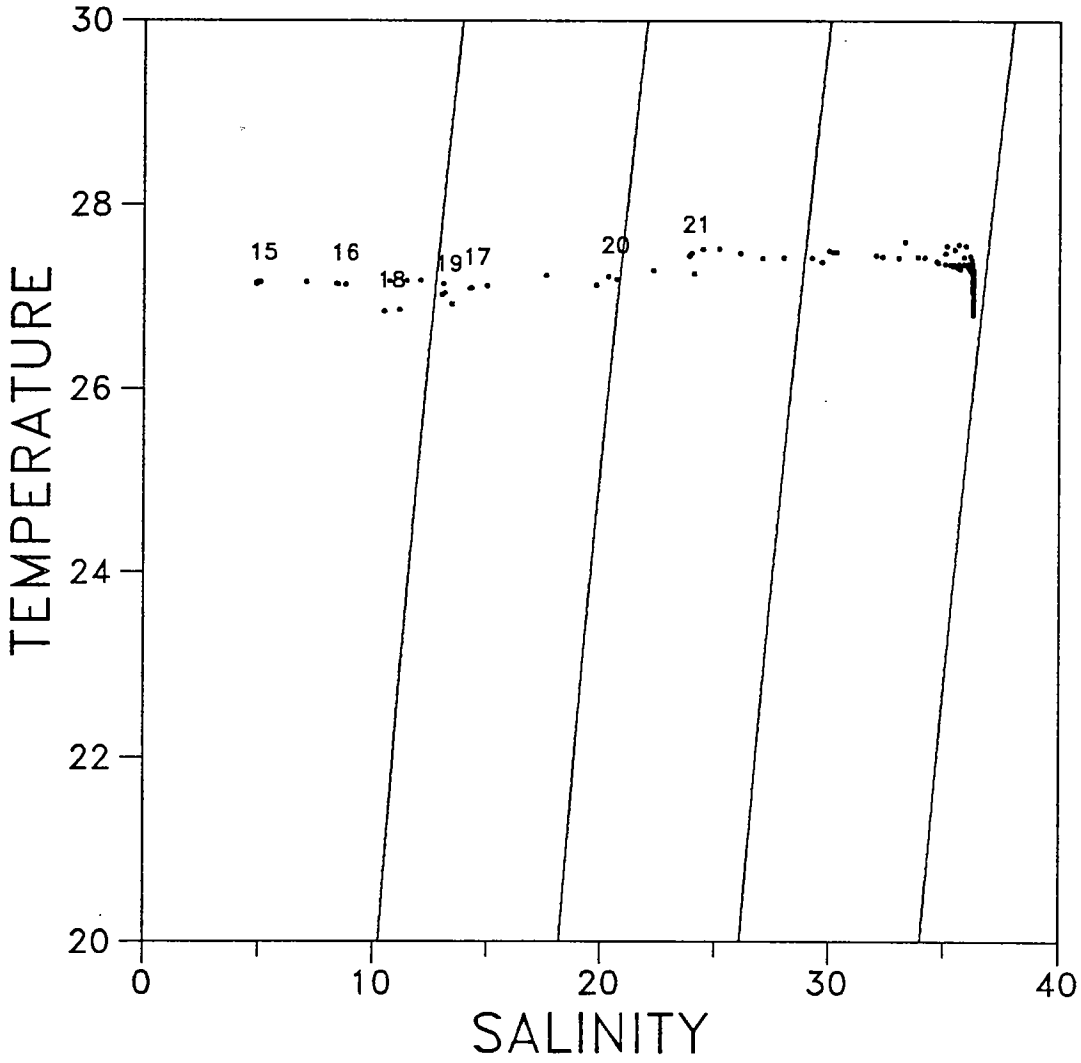
30
28
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24
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20
TEMPERATURE
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10
20
30
40
SALINITY
15
16
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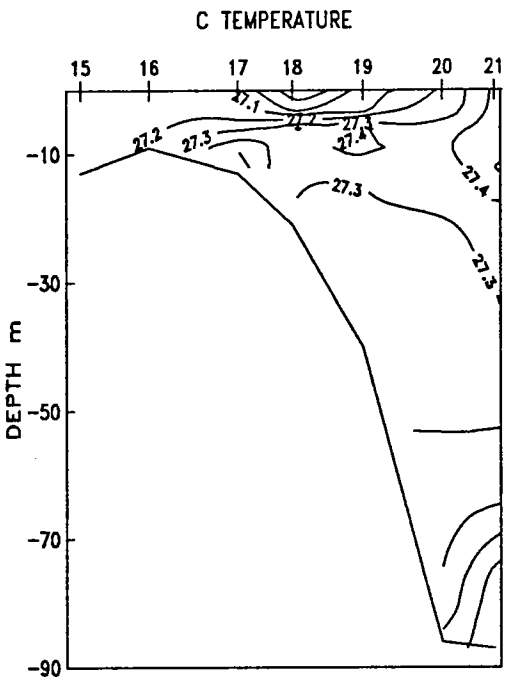
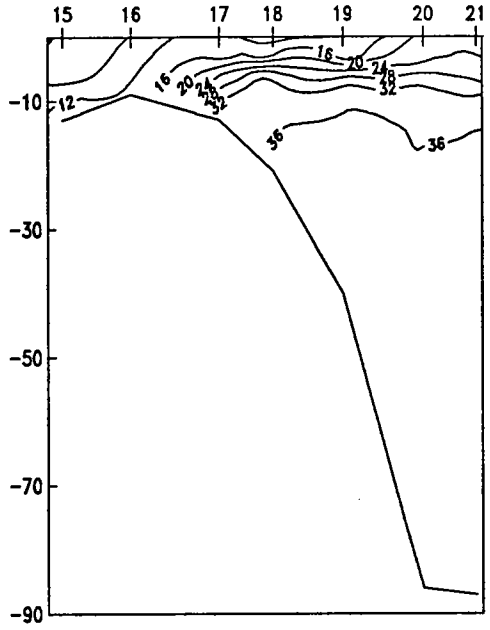
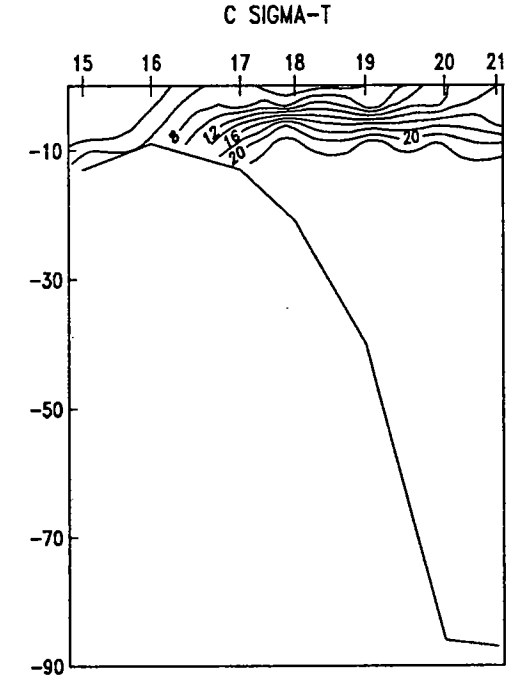
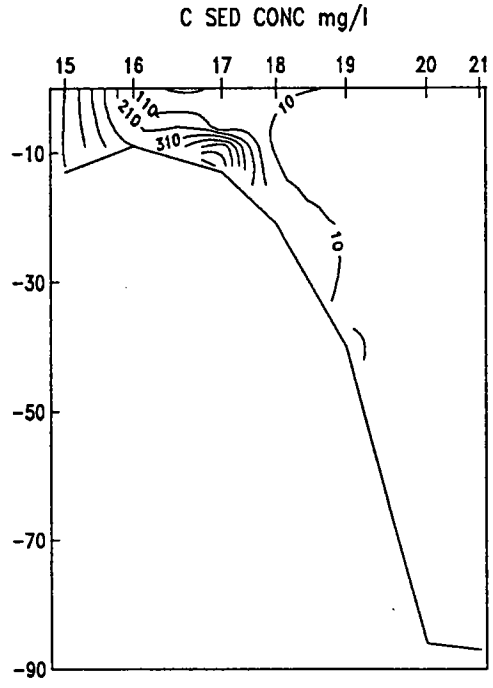
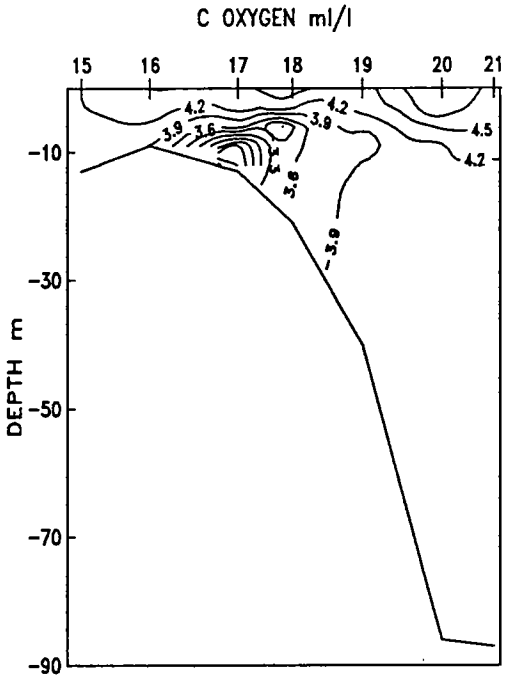
19
17
20
21

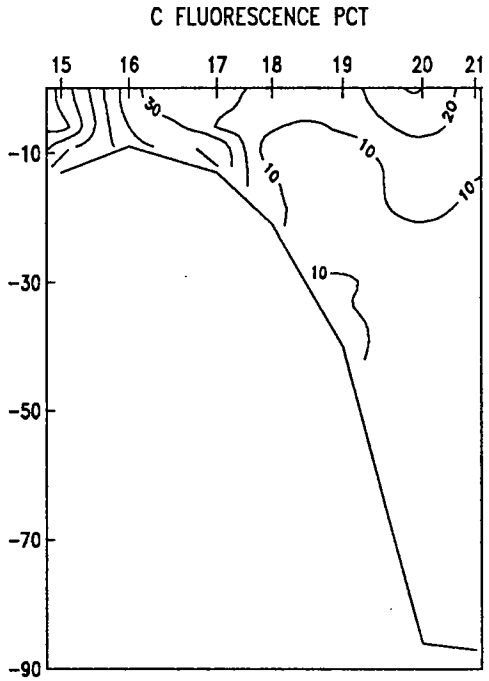

C TEMPERATURE
DEPTH m
15 16 17 18 19 20 21
-10 -30 -50 -70 -90
27.1 27.2 27.3 27.4


C SALINITY
15 16 17 18 19 20 21
-10 -30 -50 -70 -90
12 16 20 24 28 32 36


C SIGMA-T
15 16 17 18 19 20 21
-10 -30 -50 -70 -90
8 12 16 20


C SED CONC mg/l
15 16 17 18 19 20 21
-10 -30 -50 -70 -90
110 210 310 10


C OXYGEN ml/l
15
16
17
18
19
20
21
-10
-30
-50
-70
-90
DEPTH m
4.2
4.2
3.9
3.6
3.9
4.5
4.2
3.6
3.9


C FLUORESCENCE PCT
15
16
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18
19
20
21
-10
-30
-50
-70
-90
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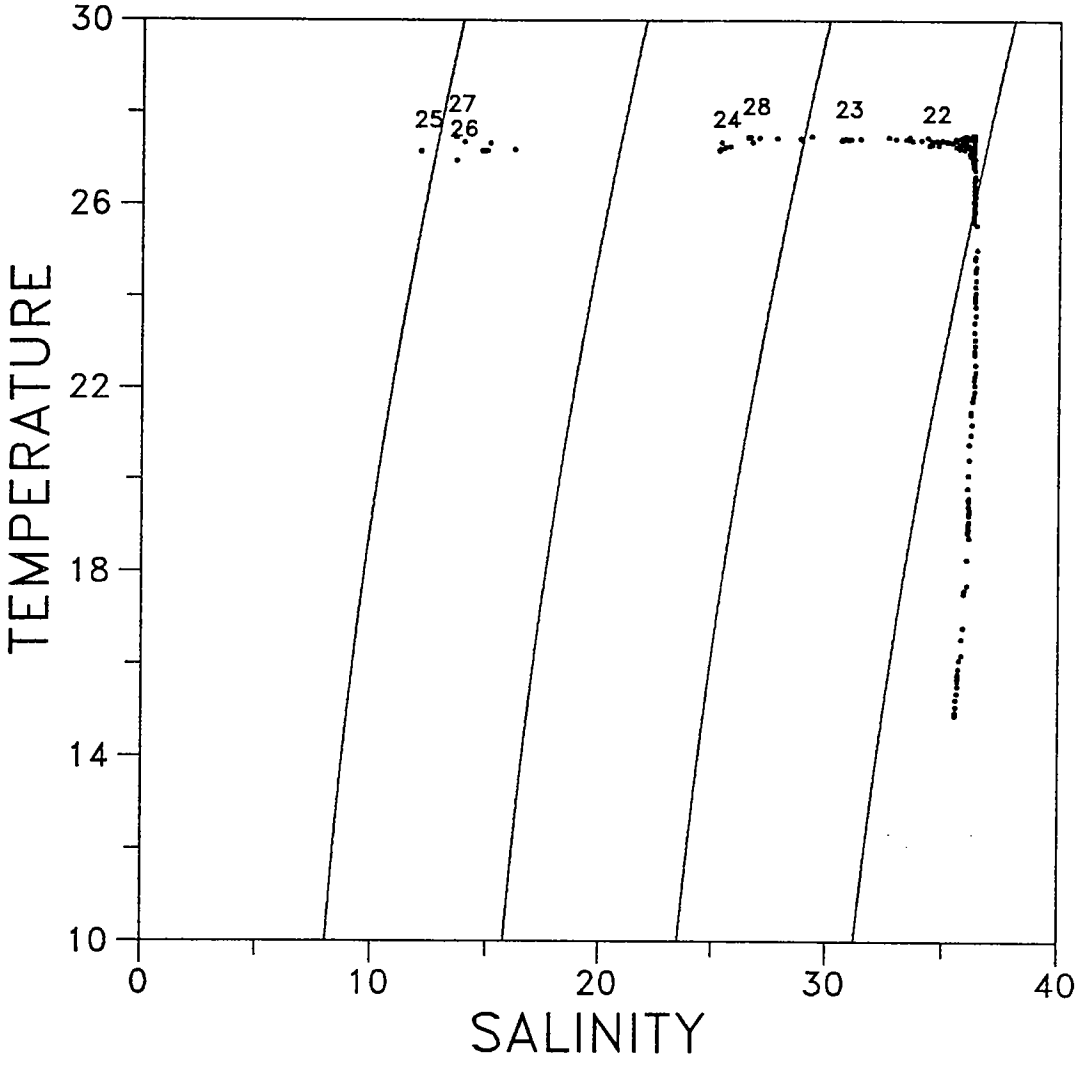
10
10


30
26
22
18
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10
TEMPERATURE
0
10
20
30
40
SALINITY
25
27
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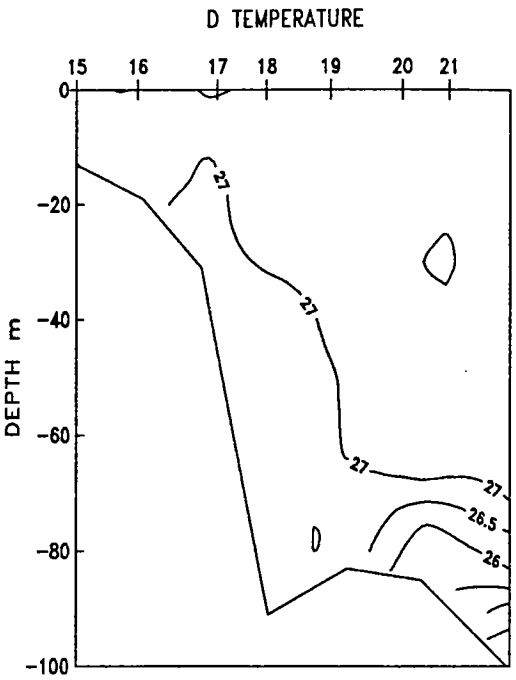
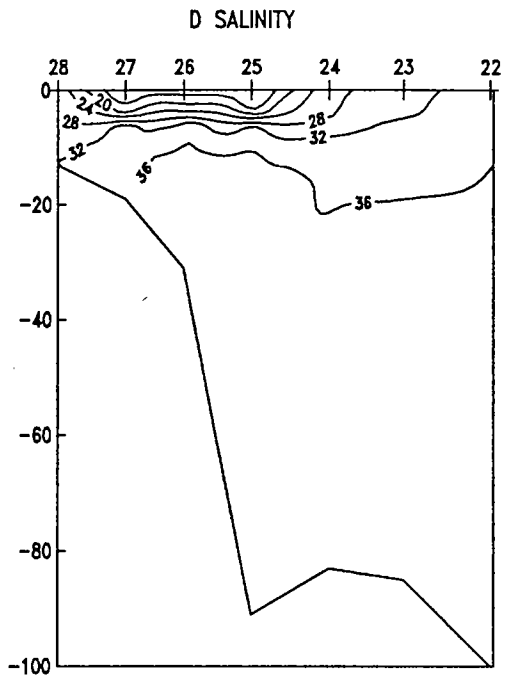
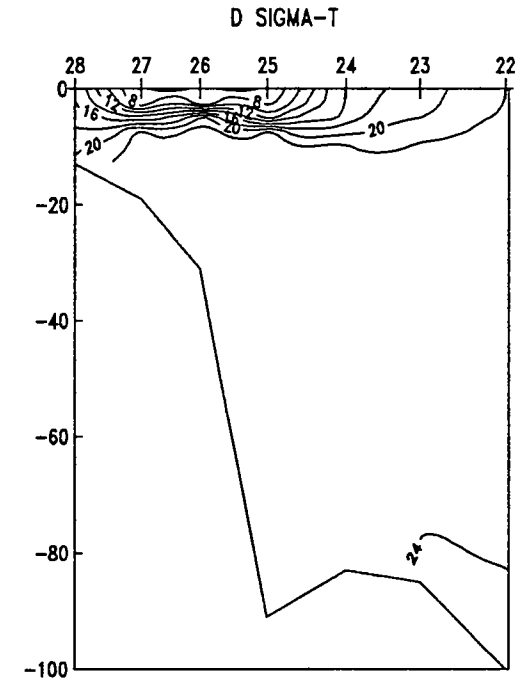
24
28
23
22


D TEMPERATURE
15 16 17 18 19 20 21
0
-20
-40
-60
-80
-100
DEPTH m
27
27
27
27
26.5
26
D


D SALINITY
28 27 26 25 24 23 22
0
-20
-40
-60
-80
-100
24
28
32
32
28
36
36


D SIGMA-T
28 27 26 25 24 23 22
0
-20
-40
-60
-80
-100
16
20
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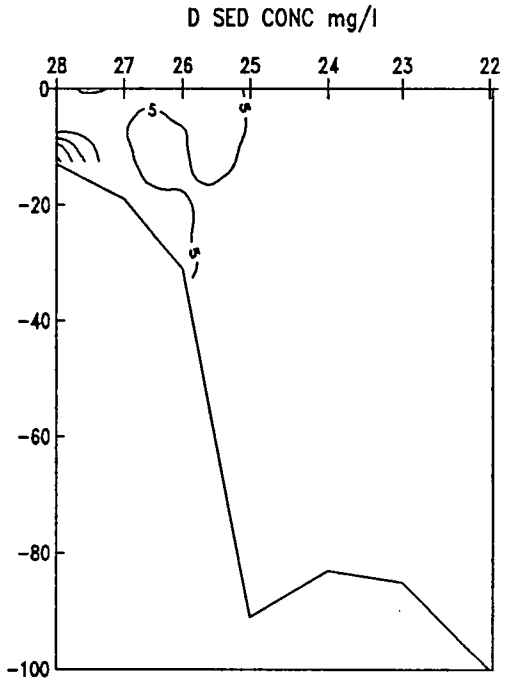
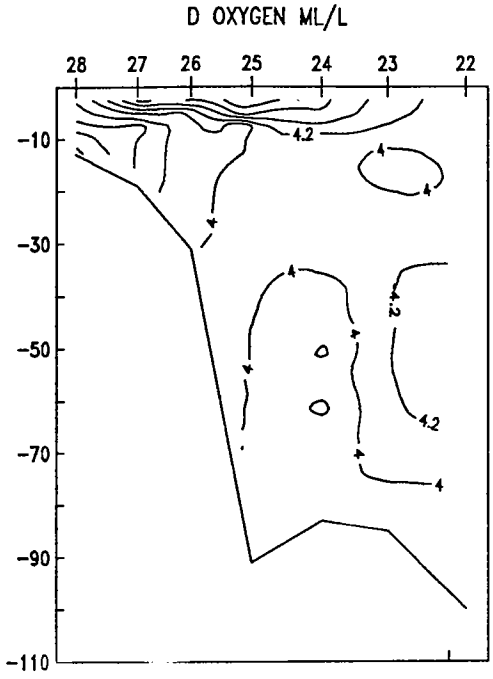
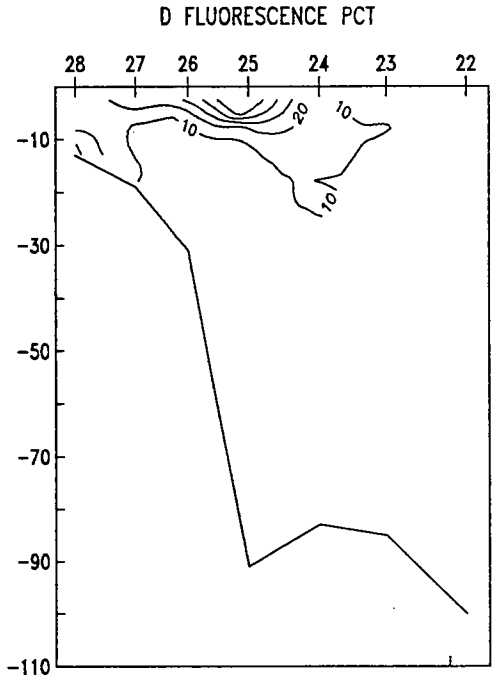
20
24


D SED CONC mg/l
28 27 26 25 24 23 22
0
-20
-40
-60
-80
-100
5
5
5


D OXYGEN ML/L
28
27
26
25
24
23
22
-10
-30
-50
-70
-90
-110
4.2
4
4.2
4
4
4
4
4
4.2
4


D FLUORESCENCE PCT
28
27
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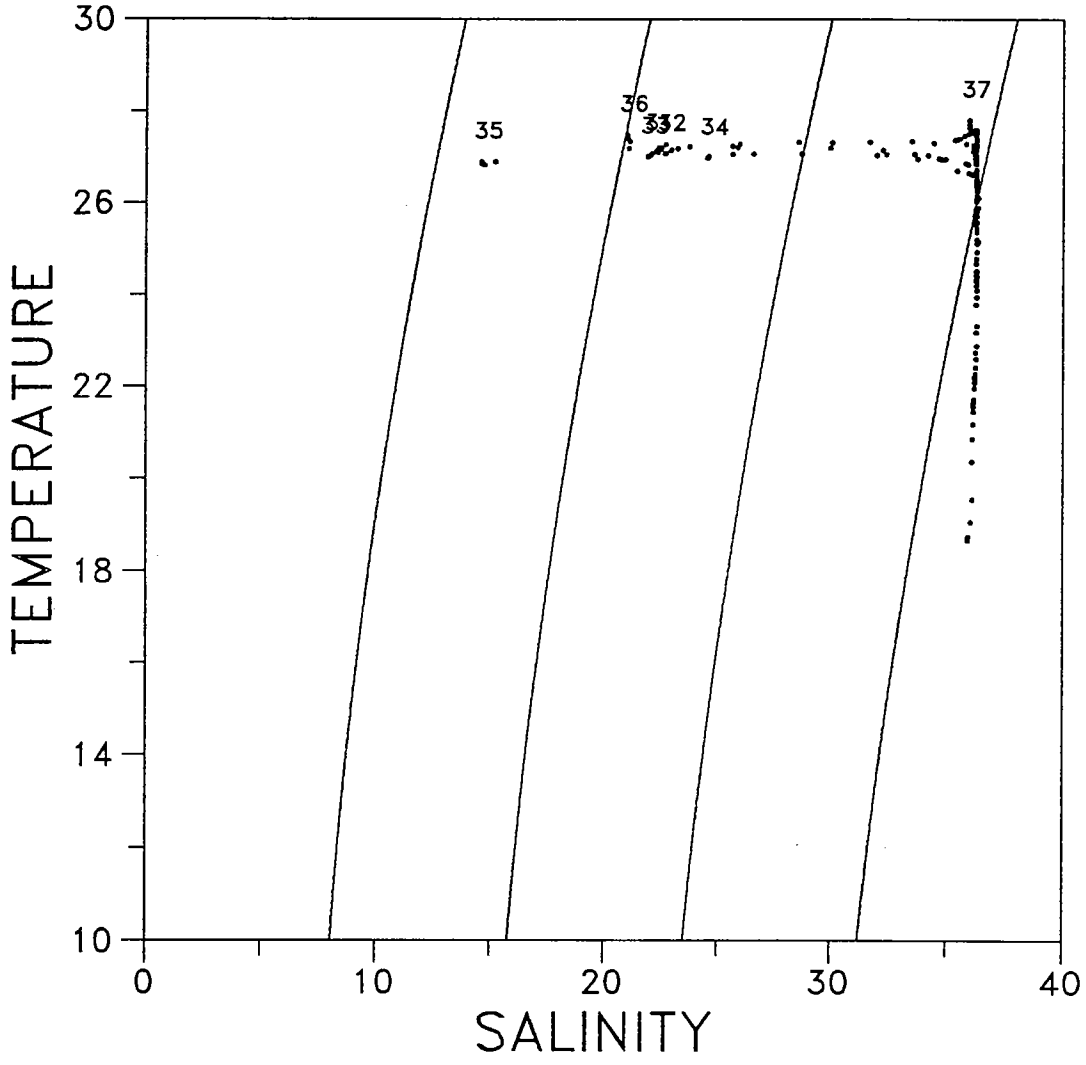
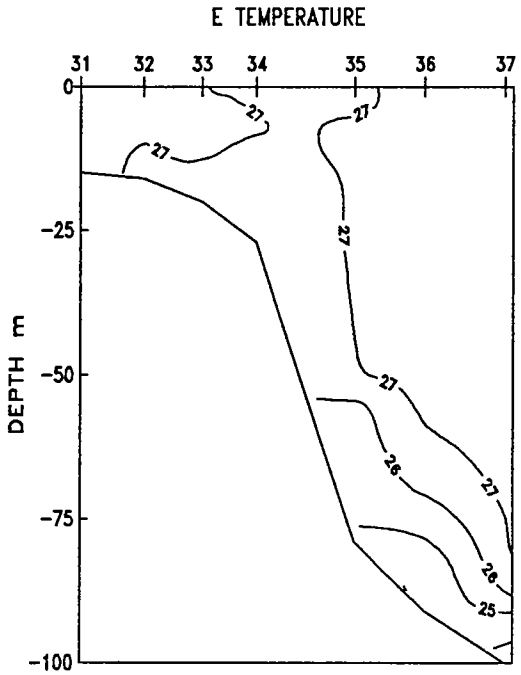
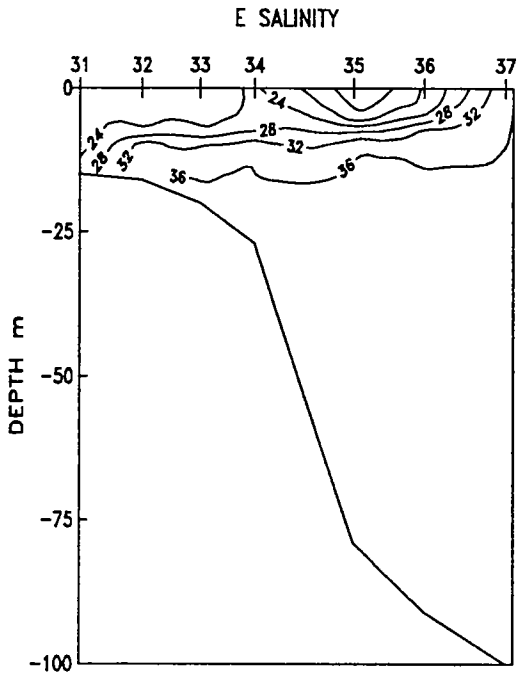
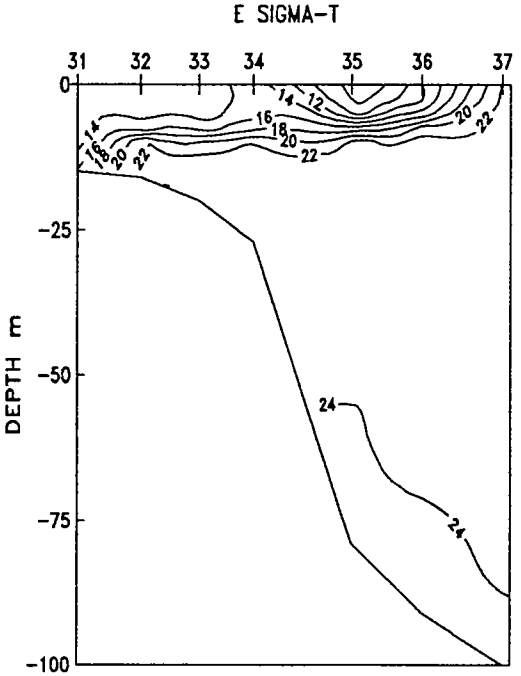
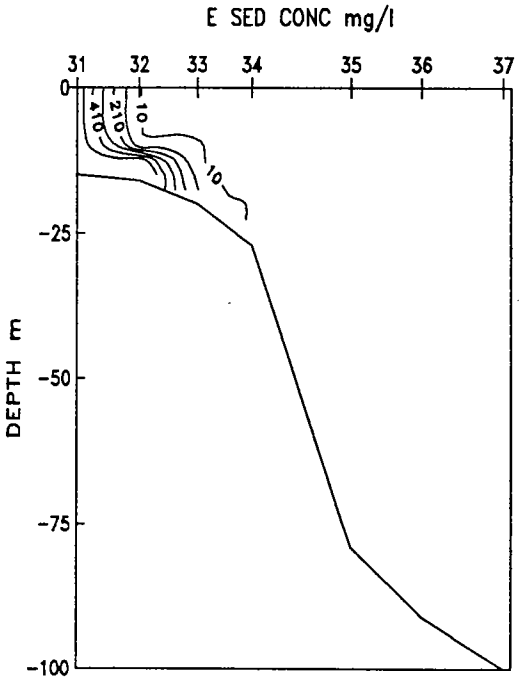
25
24
23
22
-10
-30
-50
-70
-90
-110
10
20
10
10
10

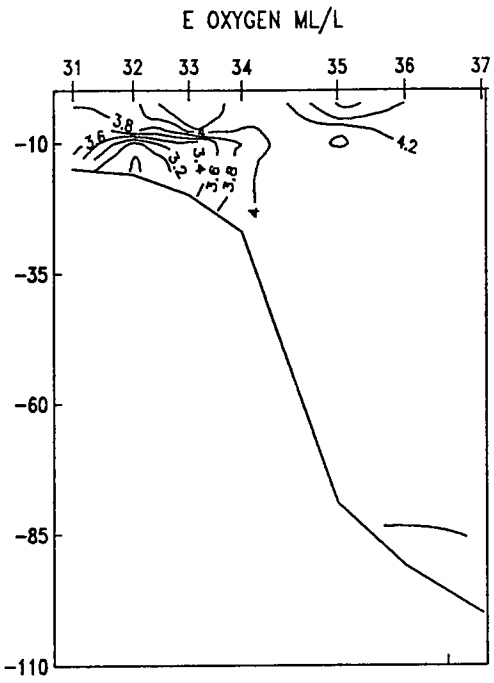

30
26
22
18
14
10
TEMPERATURE
0
10
20
30
40
SALINITY
35
36
33
32
34
37

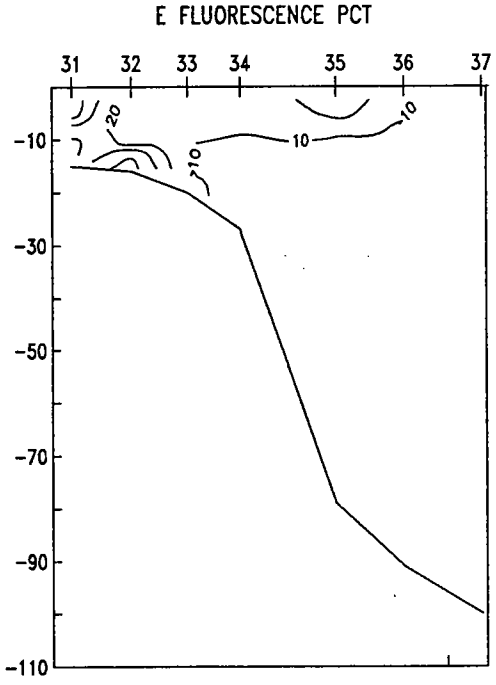

E TEMPERATURE
31 32 33 34 35 36 37
0
-25
-50
-75
-100
DEPTH m
27
26
25

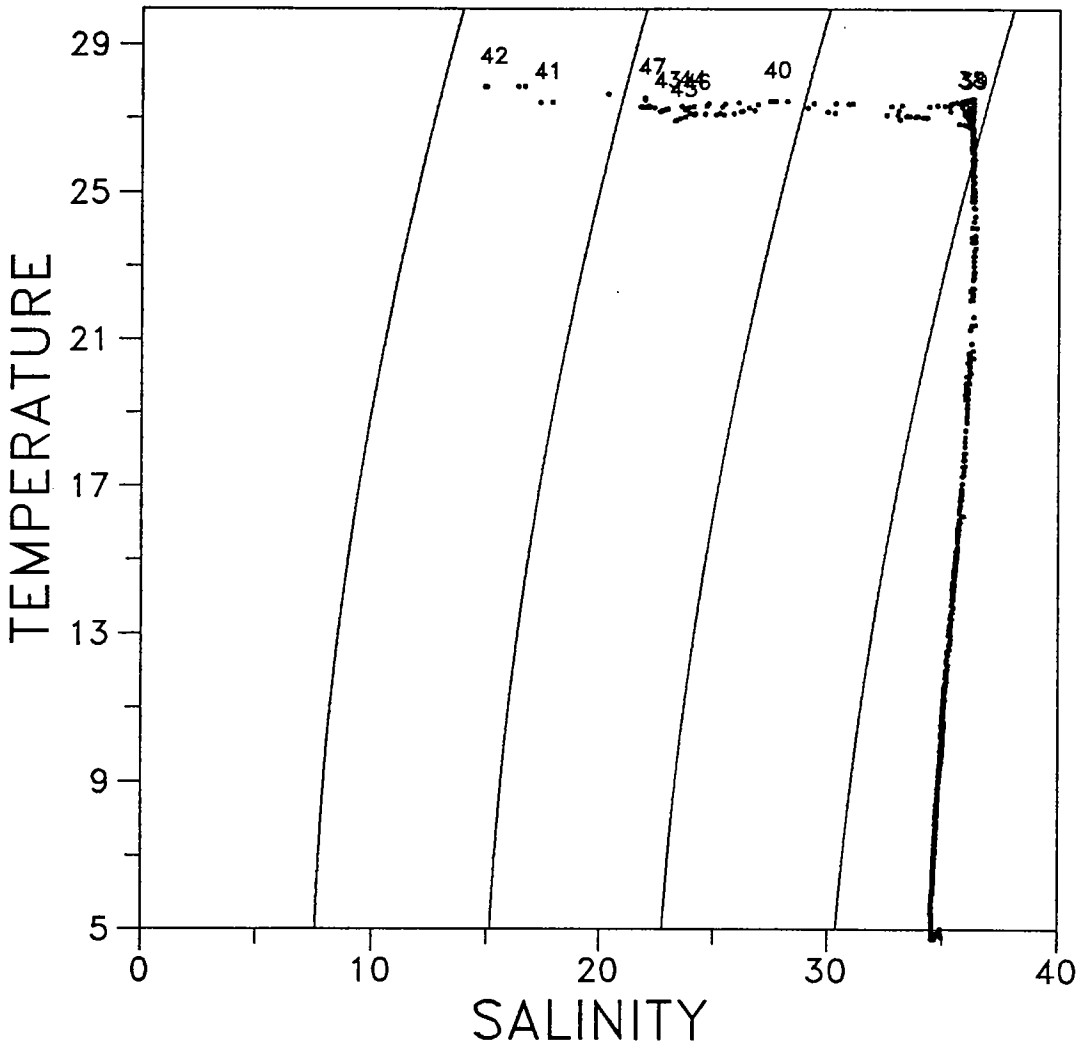

E SALINITY
31 32 33 34 35 36 37
0
-25
-50
-75
-100
DEPTH m
24
28
32
36


E SIGMA-T
31 32 33 34 35 36 37
0
-25
-50
-75
-100
DEPTH m
14
16
18
20
22
24


E SED CONC mg/l
31 32 33 34 35 36 37
0
-25
-50
-75
-100
DEPTH m
10


E OXYGEN ML/L
31
32
33
34
35
36
37
-10
-35
-60
-85
-110
3.8
3.6
3.4
3.2
3.6
3.8
4
4.2


E FLUORESCENCE PCT
31
32
33
34
35
36
37
-10
-30
-50
-70
-90
-110
20
10
10
10


TEMPERATURE
29
25
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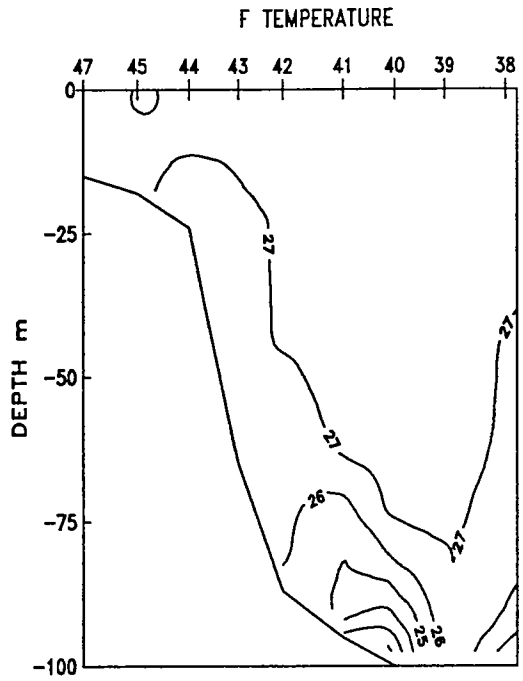
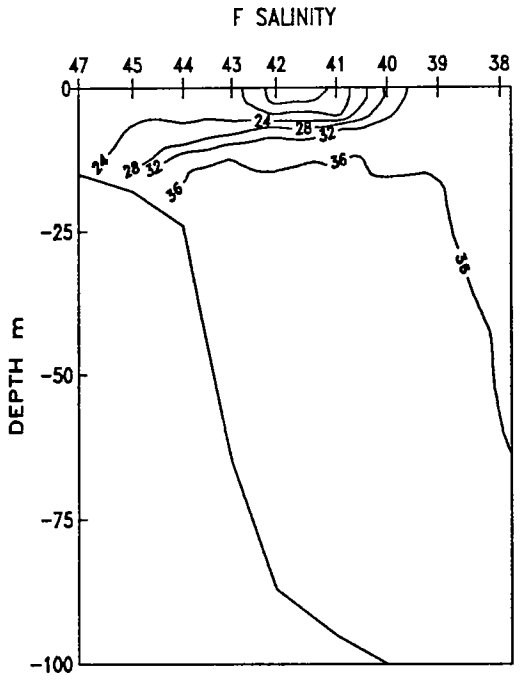
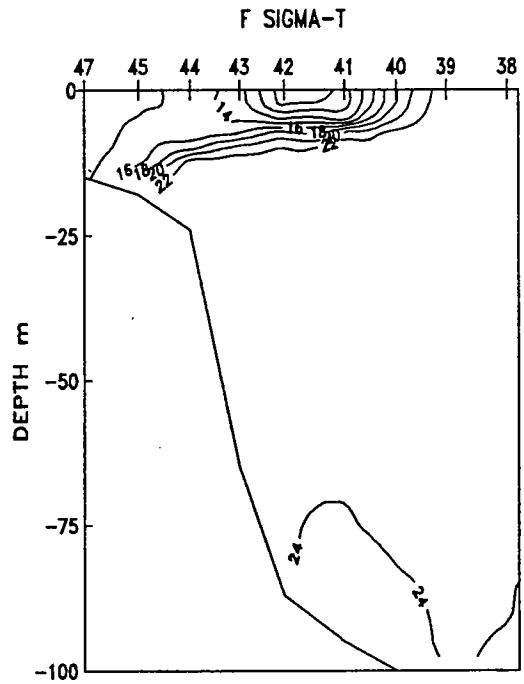
13
9
5
0
10
20
30
40
SALINITY
42
41
47
40
38


F TEMPERATURE
47 45 44 43 42 41 40 39 38
0
-25
-50
-75
-100
DEPTH m
27
27
27
26
25
26
27


F SALINITY
47 45 44 43 42 41 40 39 38
0
-25
-50
-75
-100
DEPTH m
24
28
32
24
28
32
36
36
36


F SIGMA-T
47 45 44 43 42 41 40 39 38
0
-25
-50
-75
-100
DEPTH m
14
16
18
20
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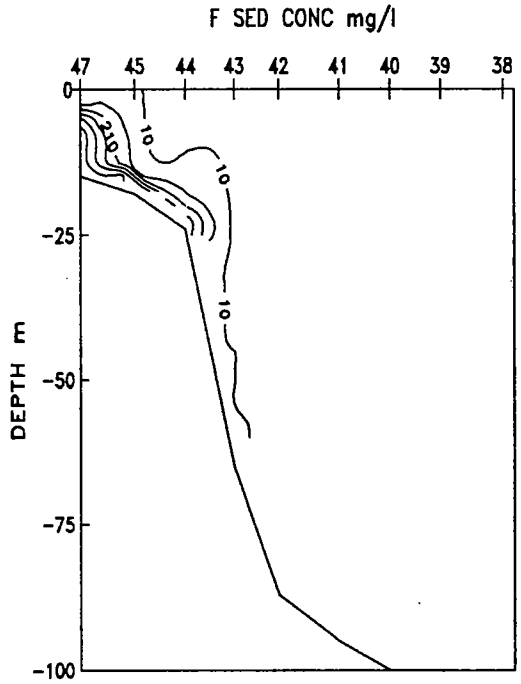
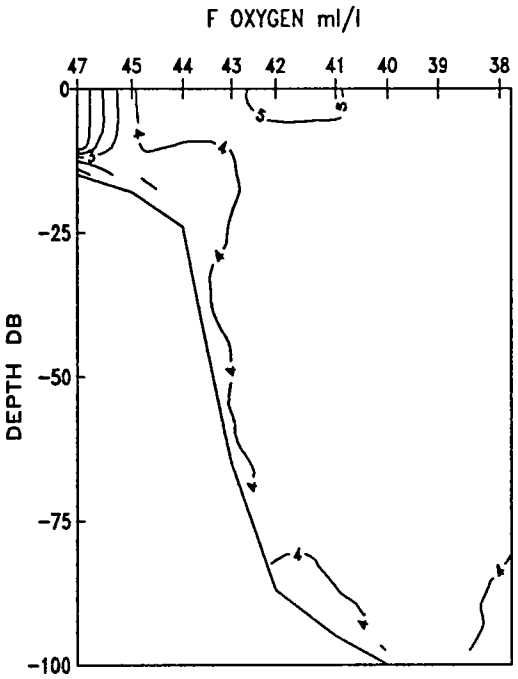
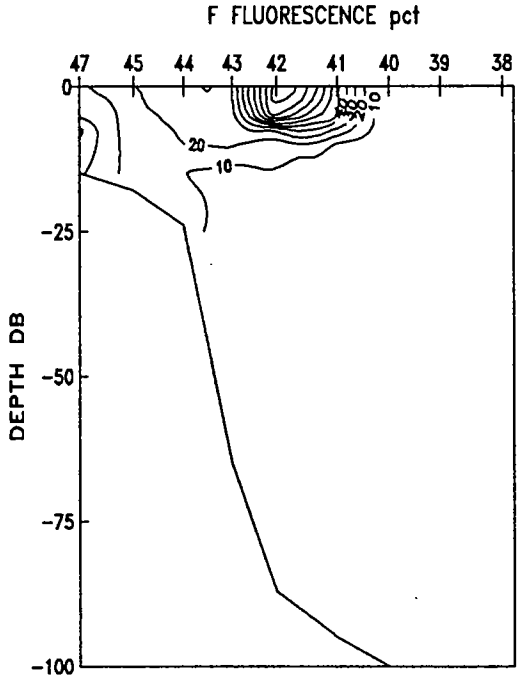
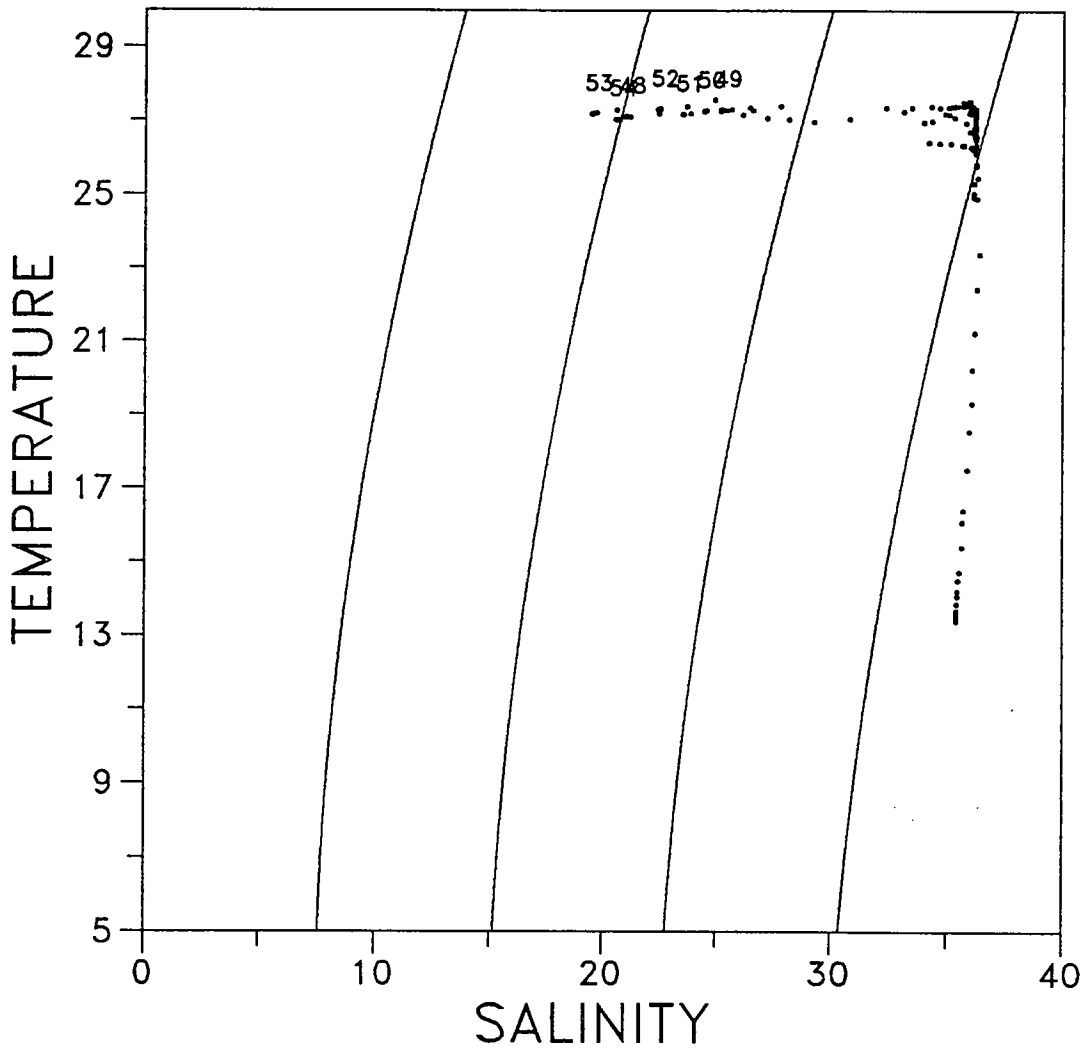
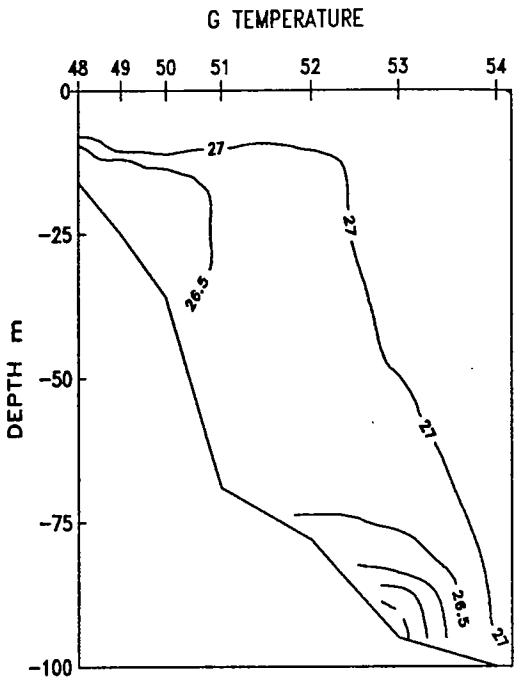
16
18
20
22
24
24

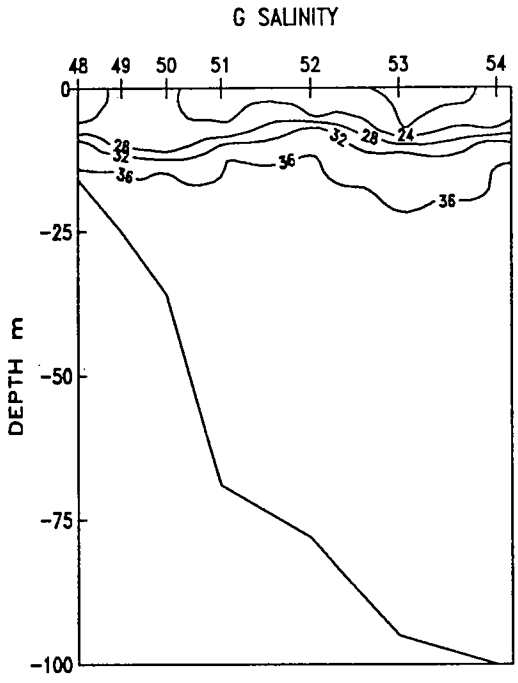

F SED CONC mg/l
47 45 44 43 42 41 40 39 38
0
-25
-50
-75
-100
DEPTH m
10
10
10
10


F OXYGEN ml/l
47
45
44
43
42
41
40
39
38
0
-25
-50
-75
-100
DEPTH DB
5
4


F FLUORESCENCE pct
47
45
44
43
42
41
40
39
38
0
-25
-50
-75
-100
DEPTH DB
20
10


TEMPERATURE
29
25
21
17
13
9
5
0
10
20
30
40
SALINITY


G TEMPERATURE
48 49 50 51 52 53 54
0
-25
-50
-75
-100
DEPTH m
27
27
26.5
27
26.5
27


G SALINITY
48 49 50 51 52 53 54
0
-25
-50
-75
-100
DEPTH m
28
32
36
32
28
24
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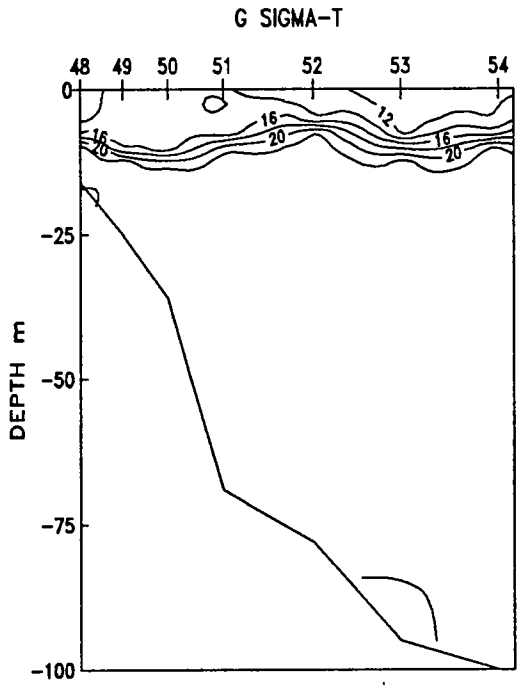
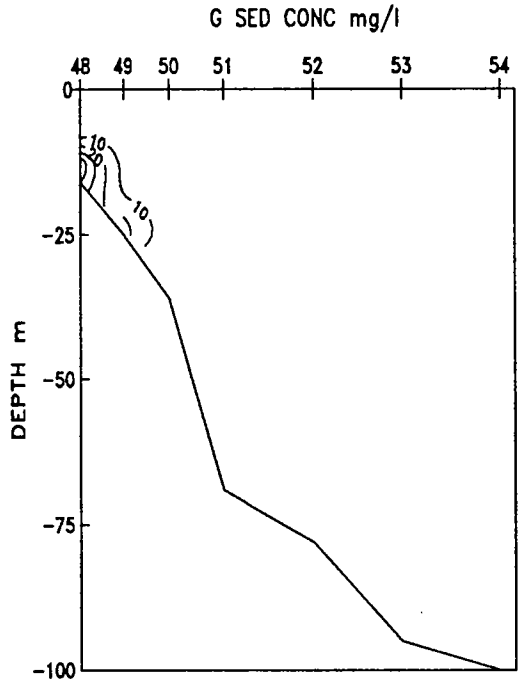
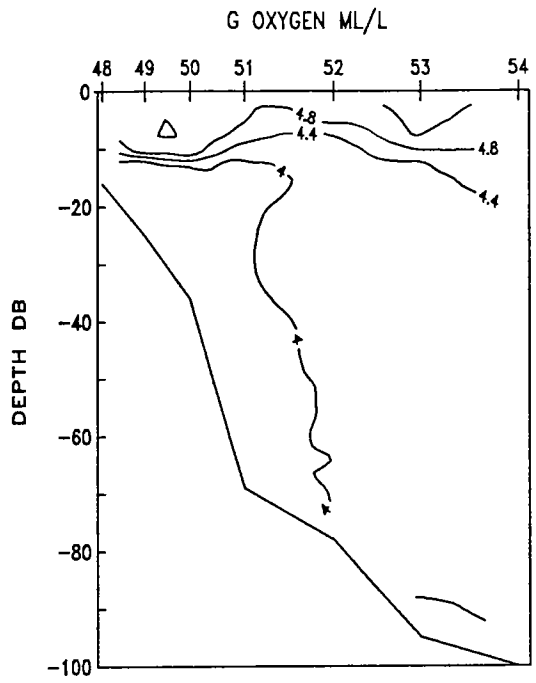
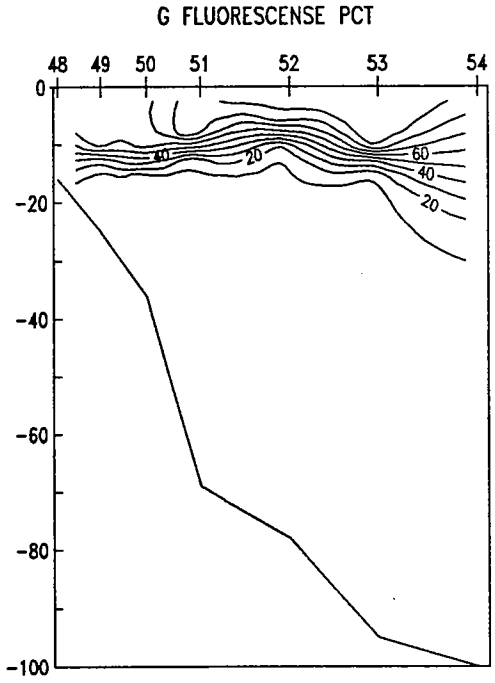
36


G SIGMA-T
48 49 50 51 52 53 54
0
-25
-50
-75
-100
DEPTH m
16
20
12
16
20
16
20


G SED CONC mg/l
48 49 50 51 52 53 54
0
-25
-50
-75
-100
DEPTH m
10
10
10


G OXYGEN ML/L
48 49 50 51 52 53 54
0
-20
-40
-60
-80
-100
DEPTH DB
4.8
4.4
4.8
4.4
4
4
4


G FLUORESCENSE PCT
48 49 50 51 52 53 54
0
-20
-40
-60
-80
-100
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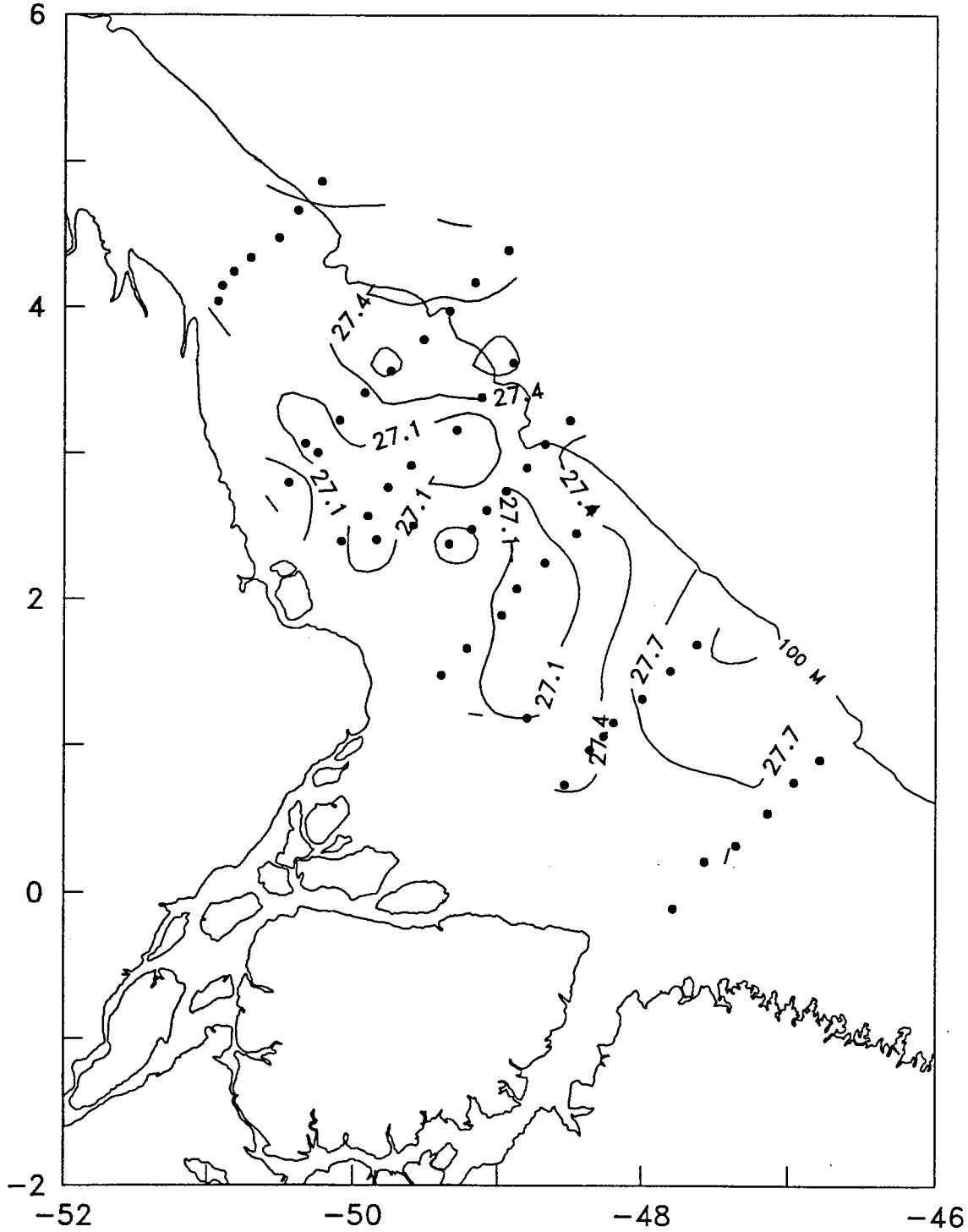
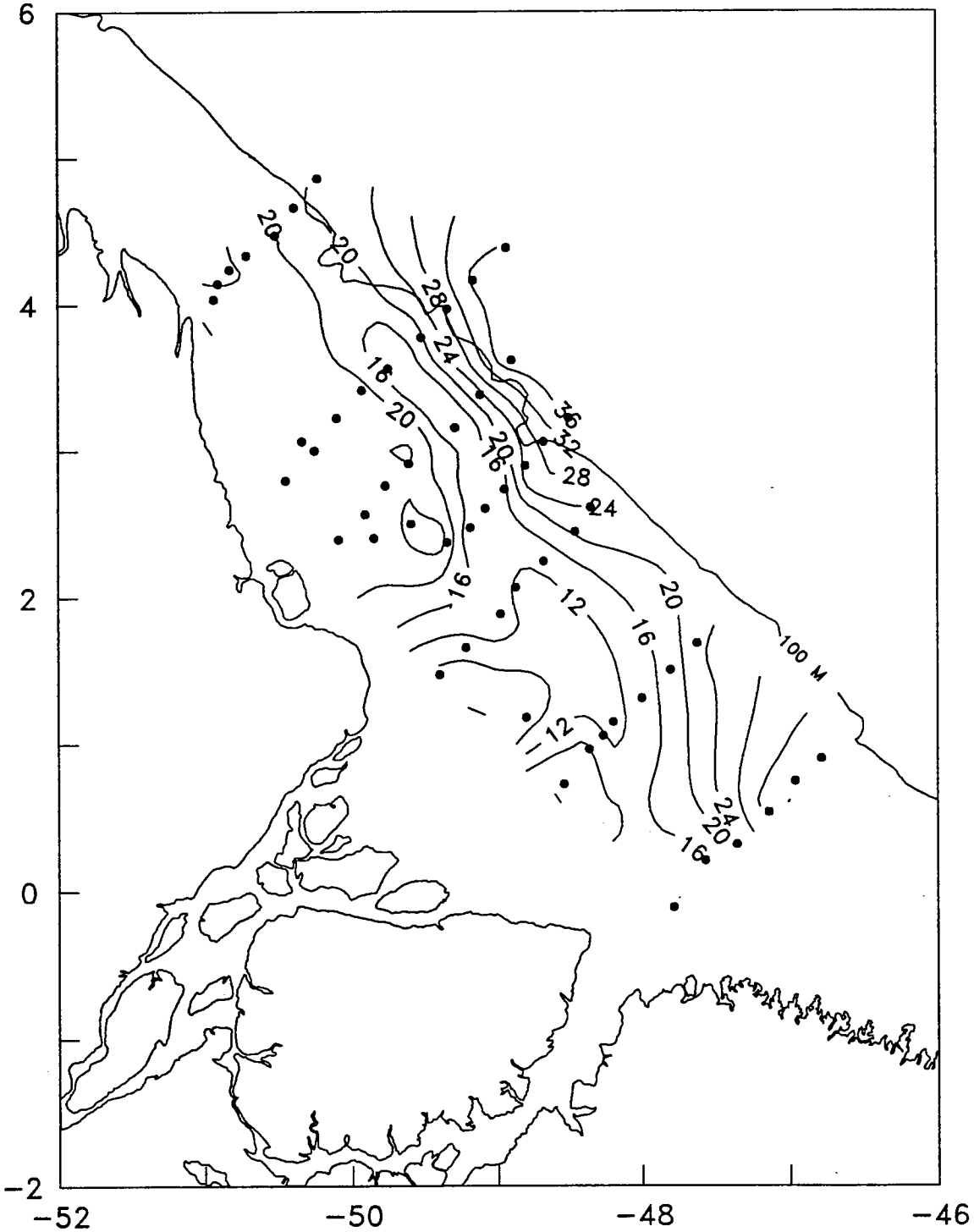
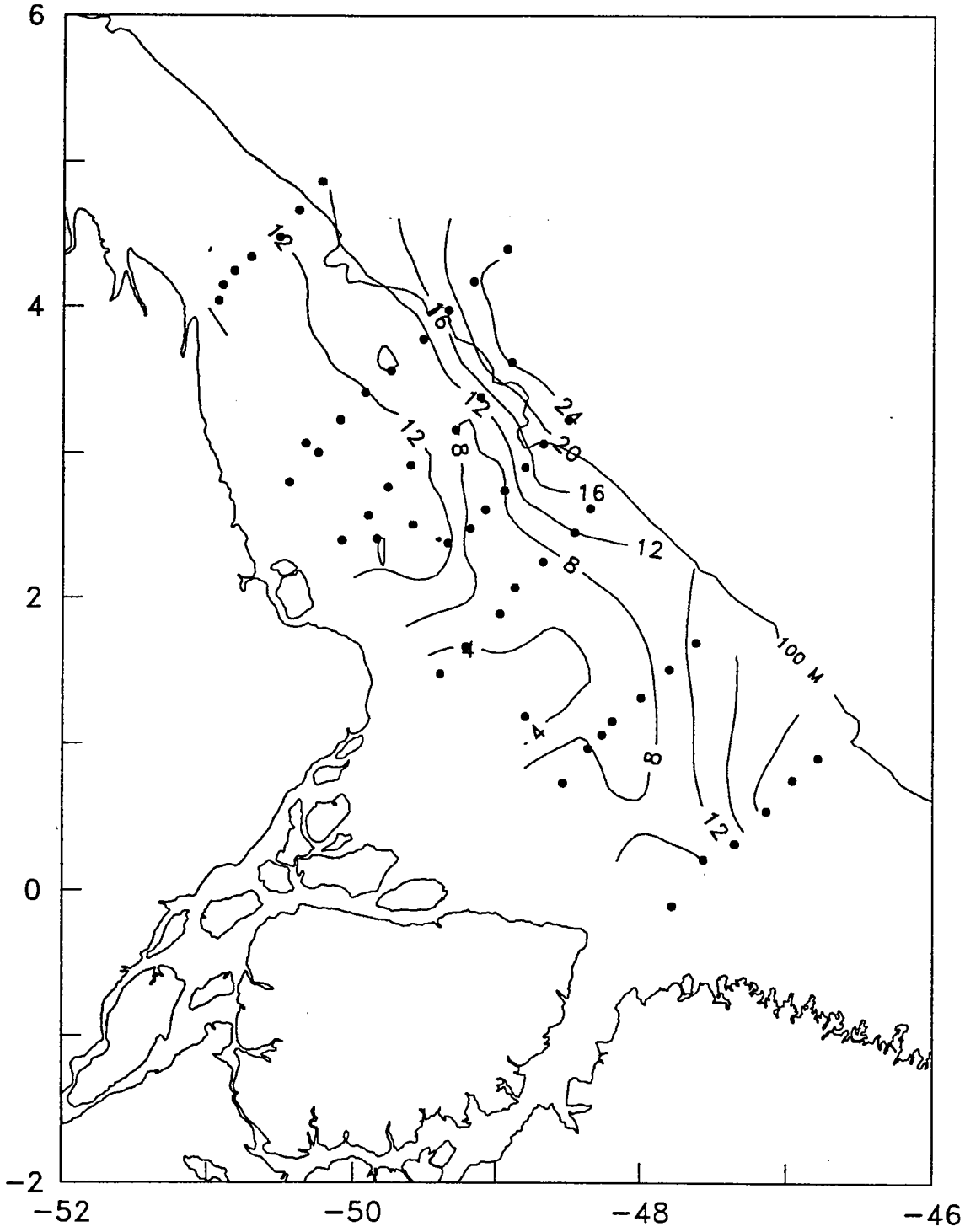
40
20
60
40
20



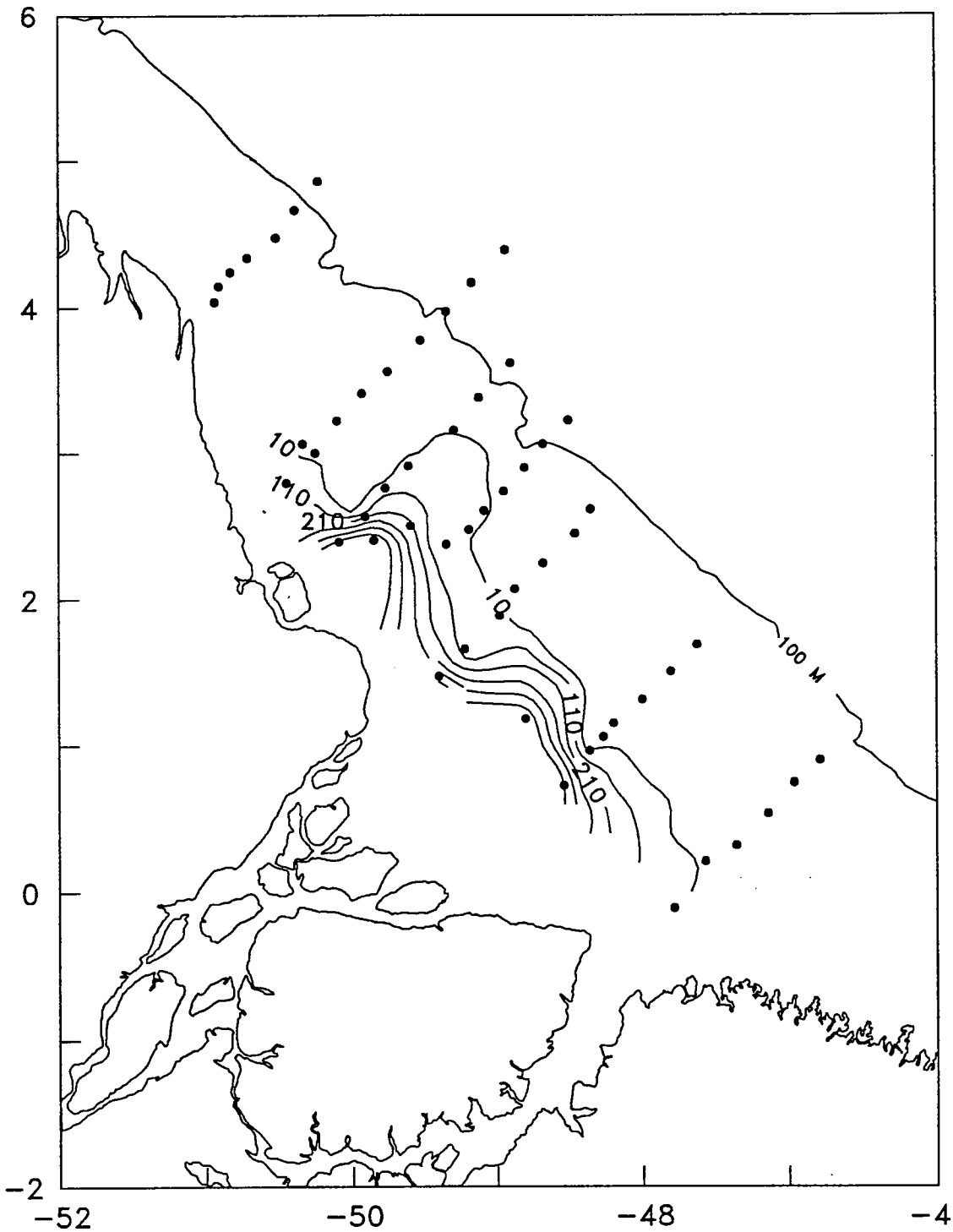
SURFACE TEMP FEB 27 – MAR 7, 1990



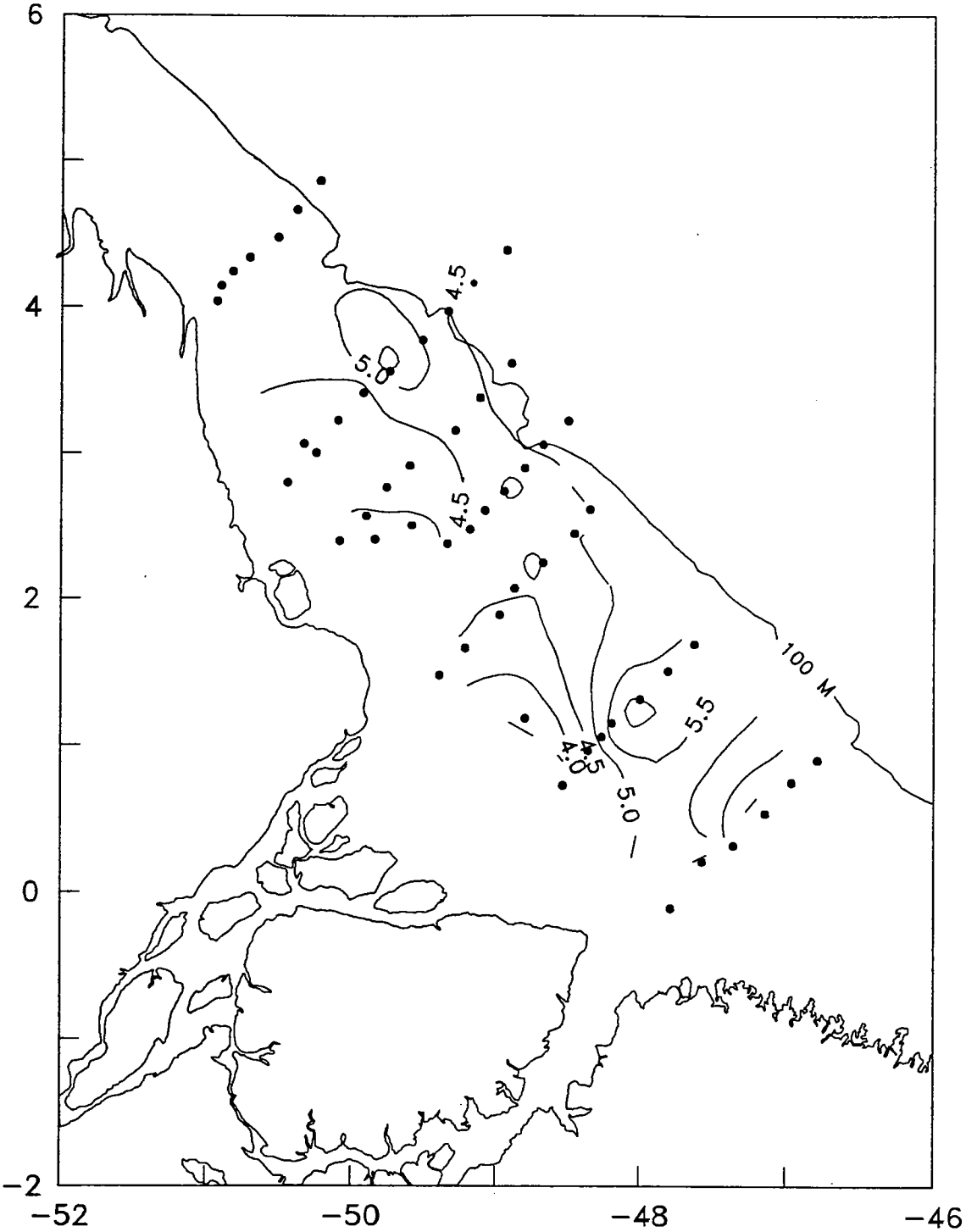
SURFACE SALINITY FEB 28 – MAR 7, 1990



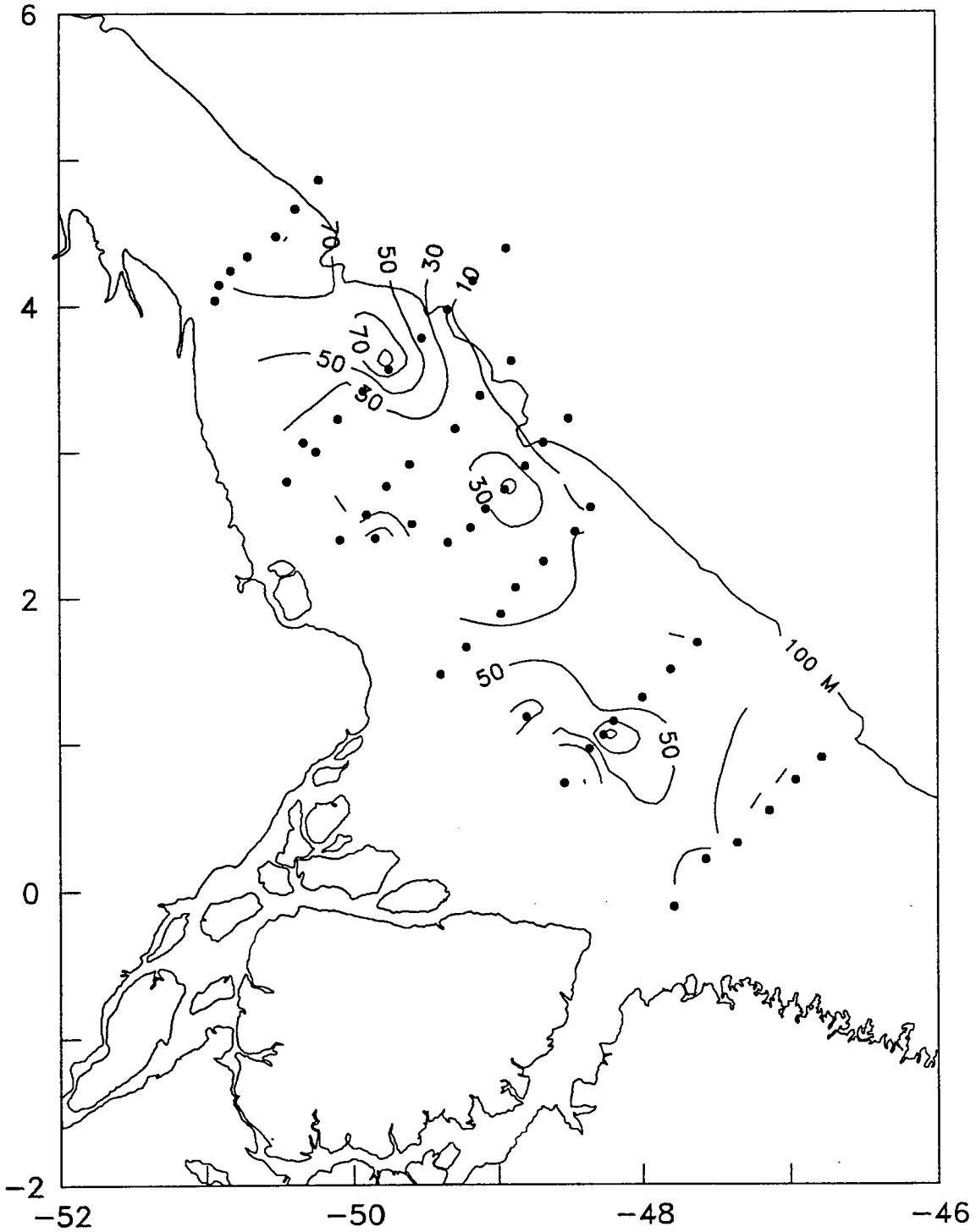
SURFACE SIGMA−T FEB 28 − MAR 7, 1990



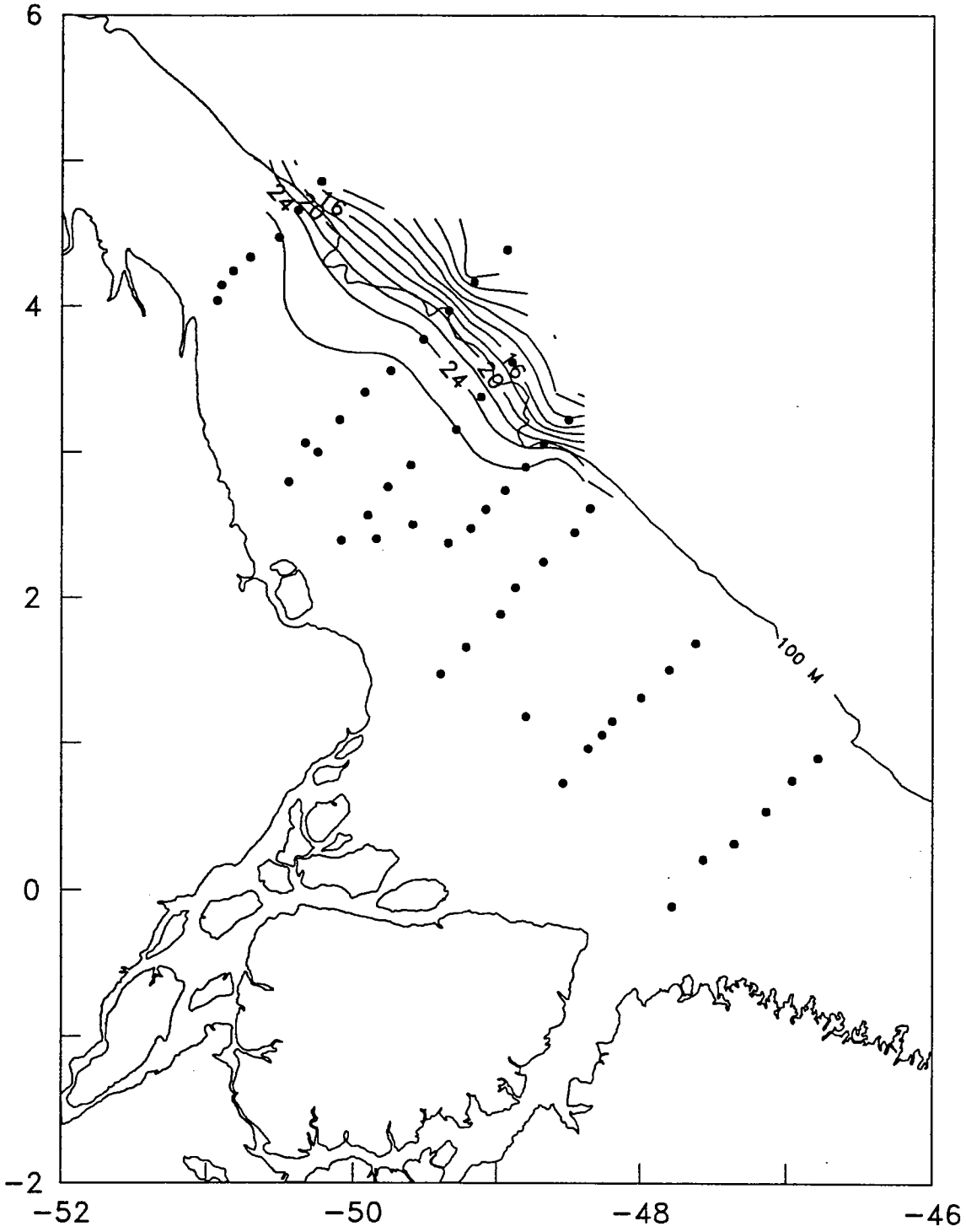
SURFACE SED CONC mg/l FEB 28 – MAR 7, 1990



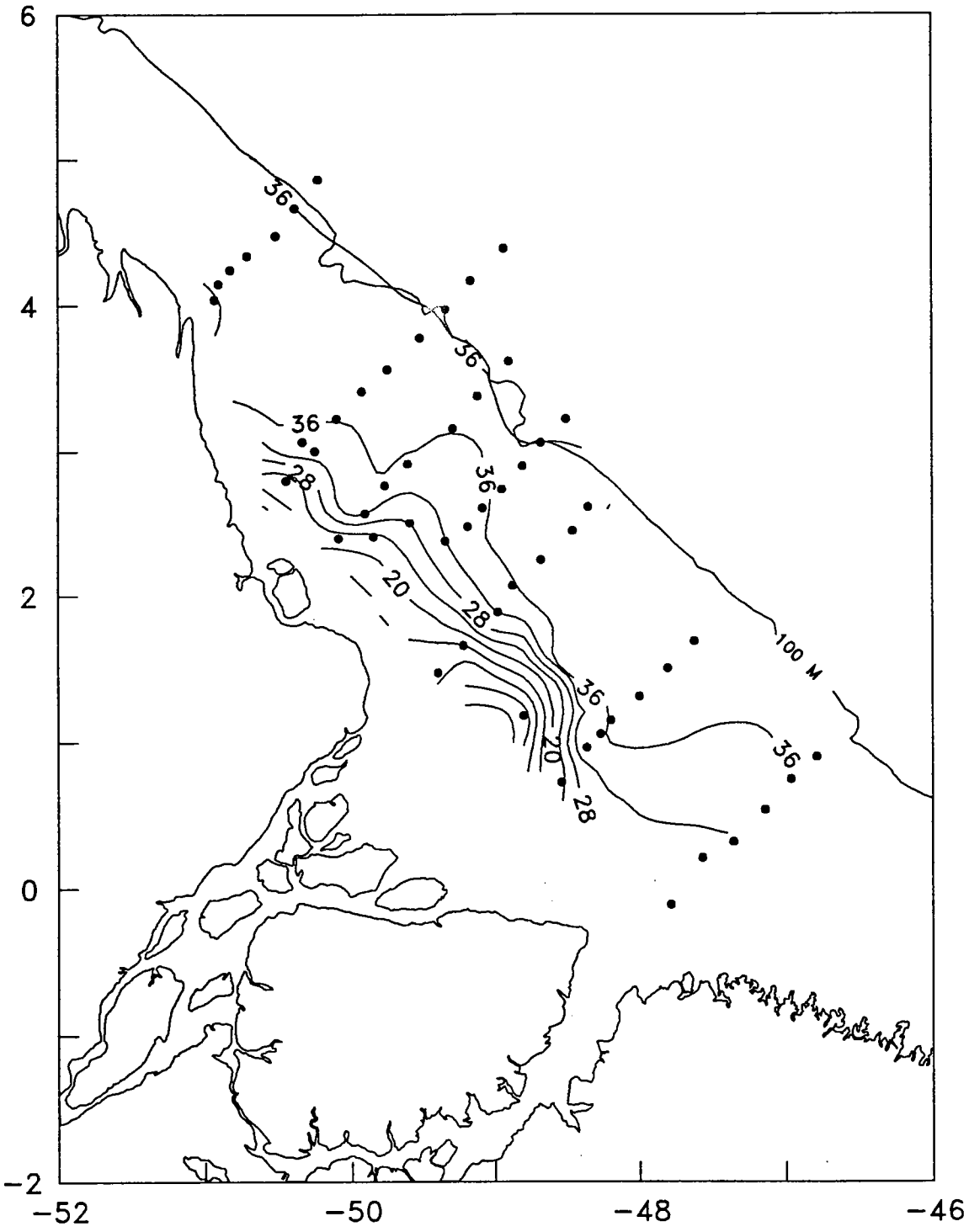
SURFACE OXYGEN FEB 28 – MAR 7, 1990



SURFACE FLUORESCENCE PCT FEB 28 – MAR 7, 1990



BOTTOM TEMPERATURE FEB 28 – MAR 7, 1990



BOTTOM SALINITY FEB 28 – MAR 7, 1990