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# Woods Hole Oceanographic Institution

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by

Richard Limeburner and Robert C. Beardsley

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## Technical Report

Funding was provided by the National Science Foundation through Grant No: OCE 88-12917.

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**Approved for Distribution:**

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

CTD Observations on the North Brazil Shelf During
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**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 I9004 May 23–June 13, 1990 as part of A Multidisciplinary Amazon Shelf SEDiment Study (AMASSEDS). These observations were obtained during a large-scale survey on Leg 3 in support of geological and geochemical sampling, and during a frontal zone survey on Leg 4 consisting of 12 and 24 hourly CTD casts at anchored stations. 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 third AMASSEDS cruise (I9004) 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 (Limeburner and Beardsley, 1991) 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 I9004 May 23–June 13, 1990. A total of 260 CTD stations was made on I9004, 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 I9004. In this report CTD cast names are given as consecutive numbers for each leg.

## CTD STATION LISTING SUMMARY

### Leg 3 — May 23–30, 1990

- Stations 1–57. 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, optical backscattering and light transmission.
- Stations 58–64. Cross-shelf transect at the mouth of the Amazon River.

### Leg 4 — June 1–13, 1990

- Stations 1–55. 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 18 – Anchor Station 2
  - Station 19 – Anchor Station 3
  - Station 20 – Anchor Station 4
  - Station 21 – Anchor Station 2a
  - Station 42 – Anchor Station 5
  - Station 54 – Anchor Station 6
  - Station 55 – Anchor Station 7

The following table cross references the consecutive CTD station names for each leg of cruise I9004 used in this report and the archived consecutive CTD station names for all legs on I9004.

| Leg | I9004 Station Number | Consecutive CTD Cast | Work Area |
|---|---|---|---|
| 3 | 1–57 | 1–57 | Large-scale survey |
| 3 | 58–64 | 58–64 | River mouth section |
| 4 | 1–4 | 65–68 | To river mouth |
| 4 | 5.01–5.26 | 69–94 | Anchor station 1 |
| 4 | 6–17 | 95–107 | To open shelf |
| 4 | 18.01–18.14 | 108–121 | Anchor station 2 |
| 4 | 19.01–19.27 | 122–149 | Anchor station 3 |
| 4 | 20.01–20.26 | 150–177 | Anchor station 4 |
| 4 | 21.01–21.09 | 178–187 | Anchor station 2a |
| 4 | 22–41 | 188–205 | Small-scale survey |
| 4 | 42.01–42.18 | 206–223 | Anchor station 5 |
| 4 | 43–53 | 224–234 | Small-scale survey |
| 4 | 54.01–54.13 | 235–248 | Anchor station 6 |
| 4 | 55.01–55.13 | 249–260 | Anchor station 7 |

## 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 I9004. The instrument provided continuous sampling of pressure, temperature, conductivity, fluorescence, light transmission and optical backscatter. 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. On some stations the fluorometer was replaced with an optical backscatter sensor to observe suspended sediment concentrations above the light transmissometer limit of 0.5 gm/l. 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. Water samples were 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 30 bottle and instrument conductivity calibration samples collected on Leg 3 gives

$$\mathrm{C(Bottle)} - \mathrm{C(CTD)} = -0.00021 * \mathrm{X} - 0.0703,$$

where $X$ is the station number which varied from 1 to 64, and the sum of the squares of the residuals is 0.0027 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 $\pm 0.010$ mmho. No conductivity calibration samples were collected on Leg 4, and the following calibration from Leg 3 was applied to the Leg 4 conductivity data,

$$\mathrm{C(Corrected)} = \mathrm{C(CTD)} - 0.083.$$

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 124 mg/l (corresponding to a light transmission of 6.0% and higher), a least-squares exponential fit of the suspended sediment concentration data to the light transmission output (in percent transmission) gives

$$\text{Sediment Concentration (mg/l)} = 159.5\, e^{-0.0428 *\ \text{Light (\%)}}.$$

The rms of the residuals (i.e., the difference between the fitted curve and measured sediment concentration based on the 65 calibration samples) was $\pm$ 12.1 mg/l .

Concentrations greater than 124 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 6.0%, a least-squares exponential fit of the suspended sediment concentration data to the light transmission output gives

$$\text{Sediment Concentration (mg/l)} = 545.5\ e^{-0.2492 * \text{Light (\%)}}.$$

The rms of the residuals for the 3 calibration samples in this concentration range is ± 16.0 mg/l. Light transmission values of 0% were recorded and given a maximum sediment concentration of 545.5 mg/l.

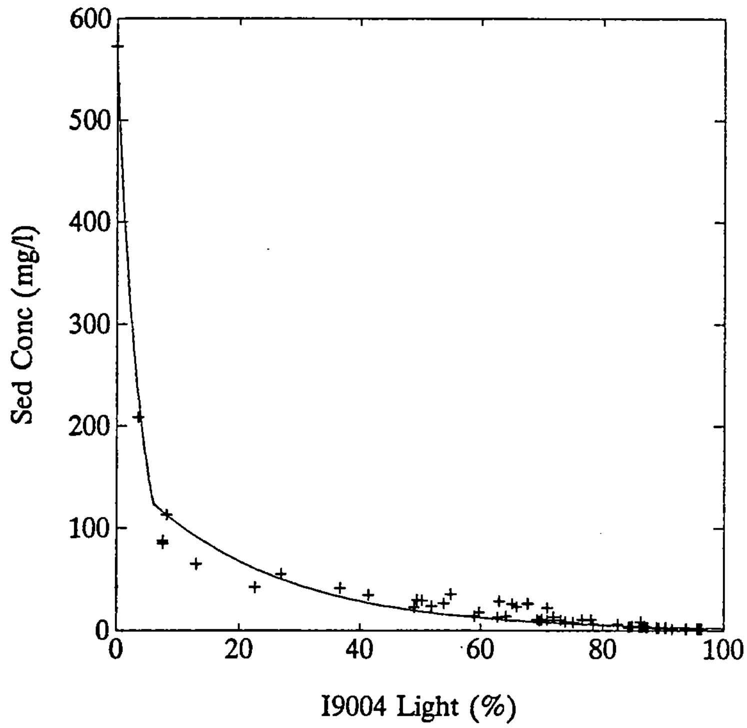



Figure 1. Observed relationship between light transmission (in percent transmission) and suspended sediment concentration (in mg/l). Samples are shown as crosses; the resulting (solid) calibration curve is used to predict suspended sediment concentration from light transmission measurements.

At stations 14–17 on Leg 3 and stations 1–4, 6–17, 22–41, and 42.18–54.11 on Leg 4, an Optical Backscatter Sensor (OBS) replaced the fluorescence sensor. The OBS is capable of estimating suspended sediment concentrations greater than 0.5 g/l. The OBS sensor was calibrated against 126 suspended sediment samples from bottles (see Figure 2), and a least squares fit gives

$$\text{OBS (volts)} = C_1 X^2 + C_2 X + C_3,$$

where X is sediment concentration in grams, $C_1$ is $-0.0326$, $C_2 = 0.699$, and $C_3 = 0.0091$. The rms of the residuals is $\pm$ 0.226 g/l. To covert OBS output in volts to sediment concentration in g/l, we used

$$\text{Sediment Concentration (g/l)} = \frac{-C_2 + \sqrt{{C_2}^2 - 4C_1(C_3 - \text{OBS})}}{2C_1}.$$

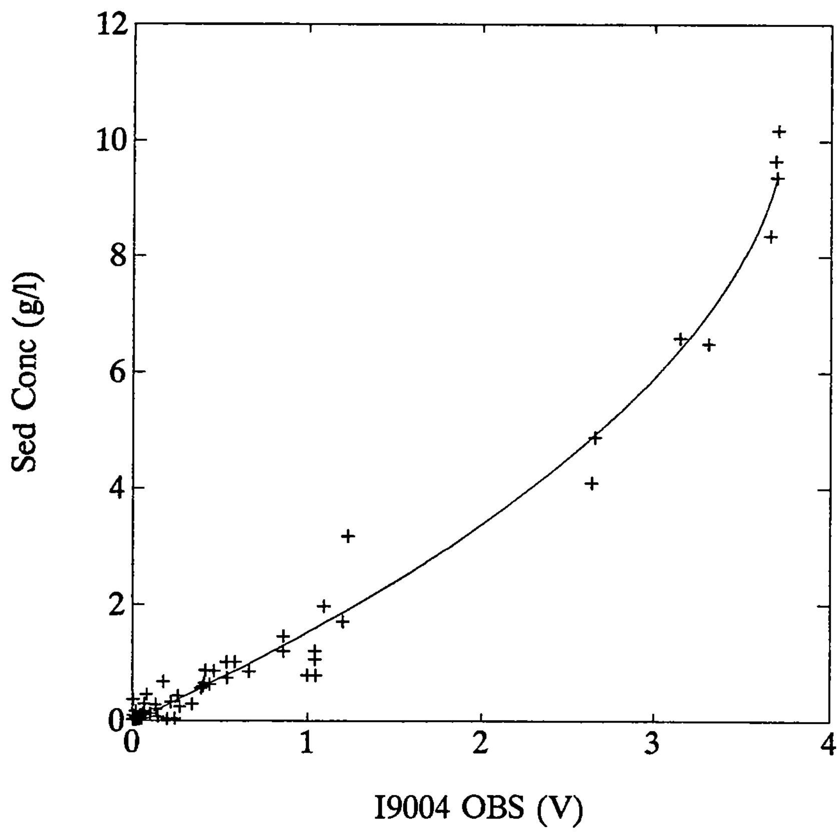



Figure 2. Observed relationship between OBS (in volts) and suspended sediment concentration (in g/l). Samples are shown as crosses and the resulting (solid) calibration curve is used to predict suspended sediment concentration from OBS measurements.

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 hydrographic data collected on cruise I9004 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 I9004 was supported by NSF Grant OCE88-12917. D. Demaster and W. Geyer were the Chief Scientists on Leg 3 and Leg 4, respectively. The work was a cooperative effort by H. Astwood, T. Bolmer, J. Candela, N. Carneiro, M. El-Robrini, A. Fernandes, H. Ferreira, S. Hardin, V. Hatje, H. Kelly, G. Kineke, E. Lindahl, T. Milligan, H. Morgan, R. Pope, N. Ramalho, C. Reis, J. Rich, L. Ruffeil, H. Seltmann, W. Showers, D. Smoak, I. Soares, and H. Vital. Their assistance is greatly appreciated. G. Kineke provided the suspended sediment data and fitted curve for the OBS sensor calibration. Finally, the helpfulness of the marine technicians C. Maxwell, and R. Hadden 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.

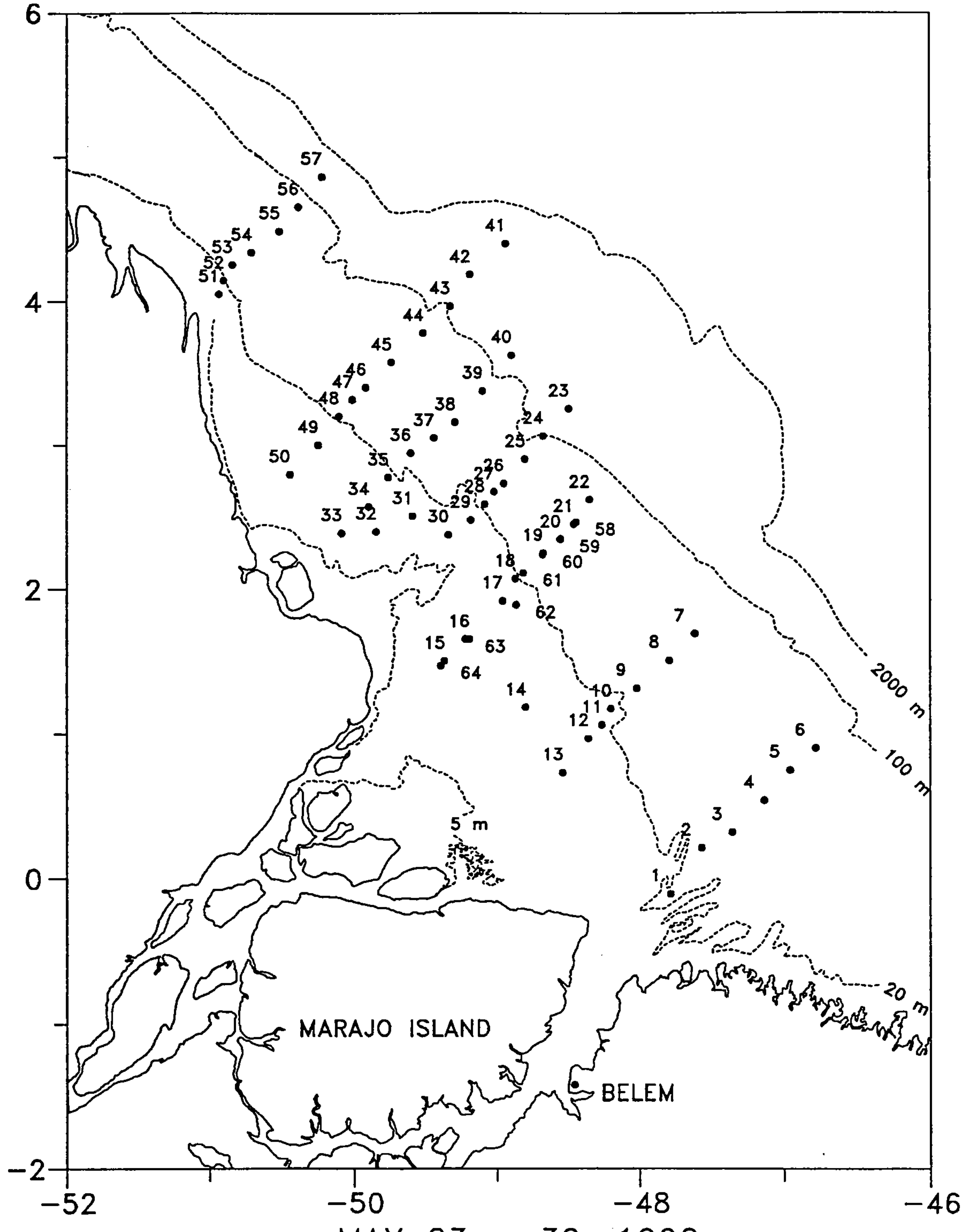
Limeburner, R. and R. C. Beardsley, 1989. CTD observations off northern Brazil during A Multidisciplinary Amazon Shelf SEDiment Study, AMASSEDS, August 1989. *Woods Hole Oceanographic Institution Technical Report* WHOI-89-53, 134 pp.

Limeburner, R. and R. C. Beardsley, 1991. CTD observations off northern Brazil during A Multidisciplinary Amazon Shelf SEDiment Study, AMASSEDS, February–March 1990. *Woods Hole Oceanographic Institution Technical Report*, in press.

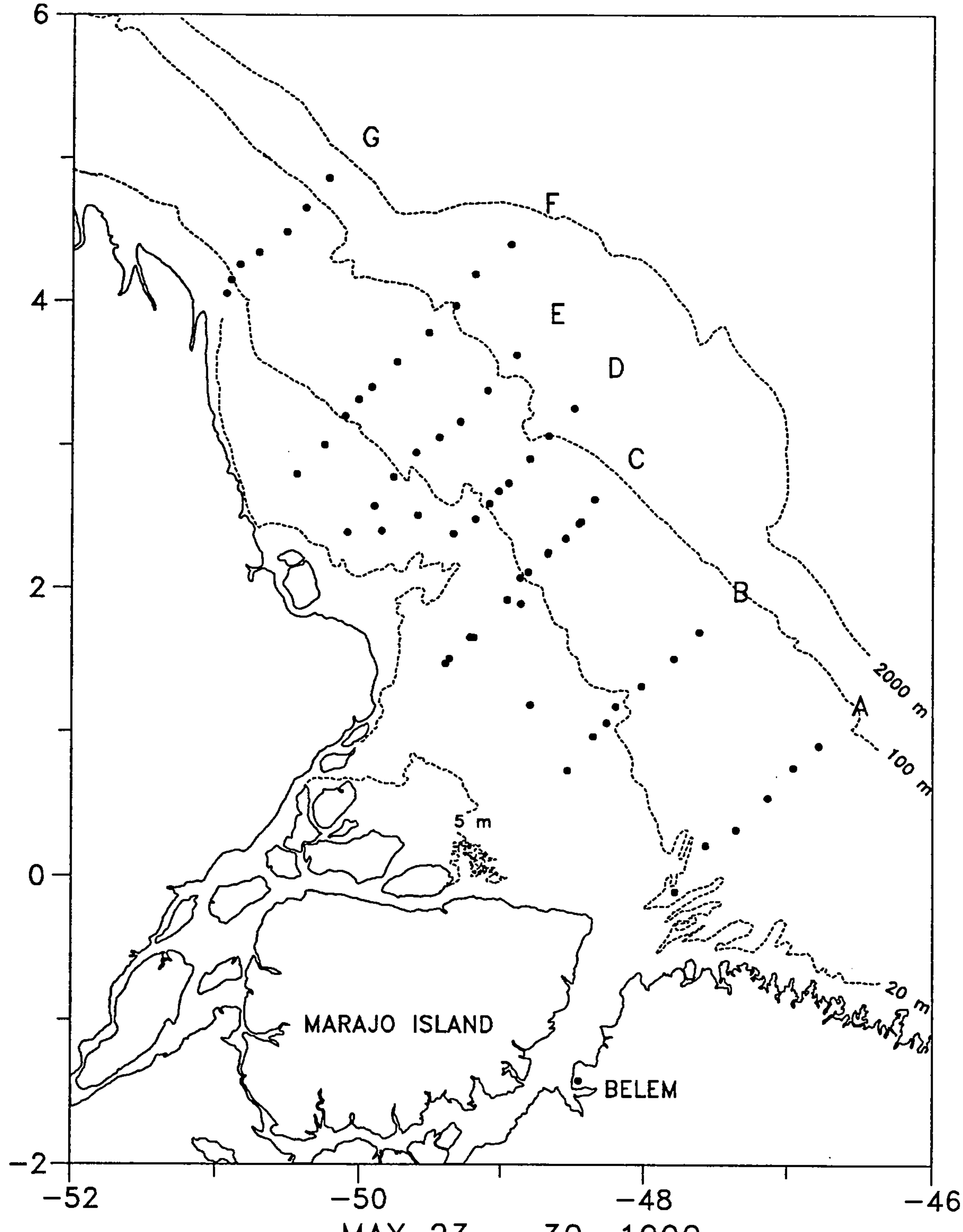
Middleton, J. H., and T. D. Foster, 1980. Fine structure measurements in a temperature compensated halocline. *Journal of Geophysical Research*, **85**(C2), 1107–1122.

## 7. Graphic Description of CTD Data

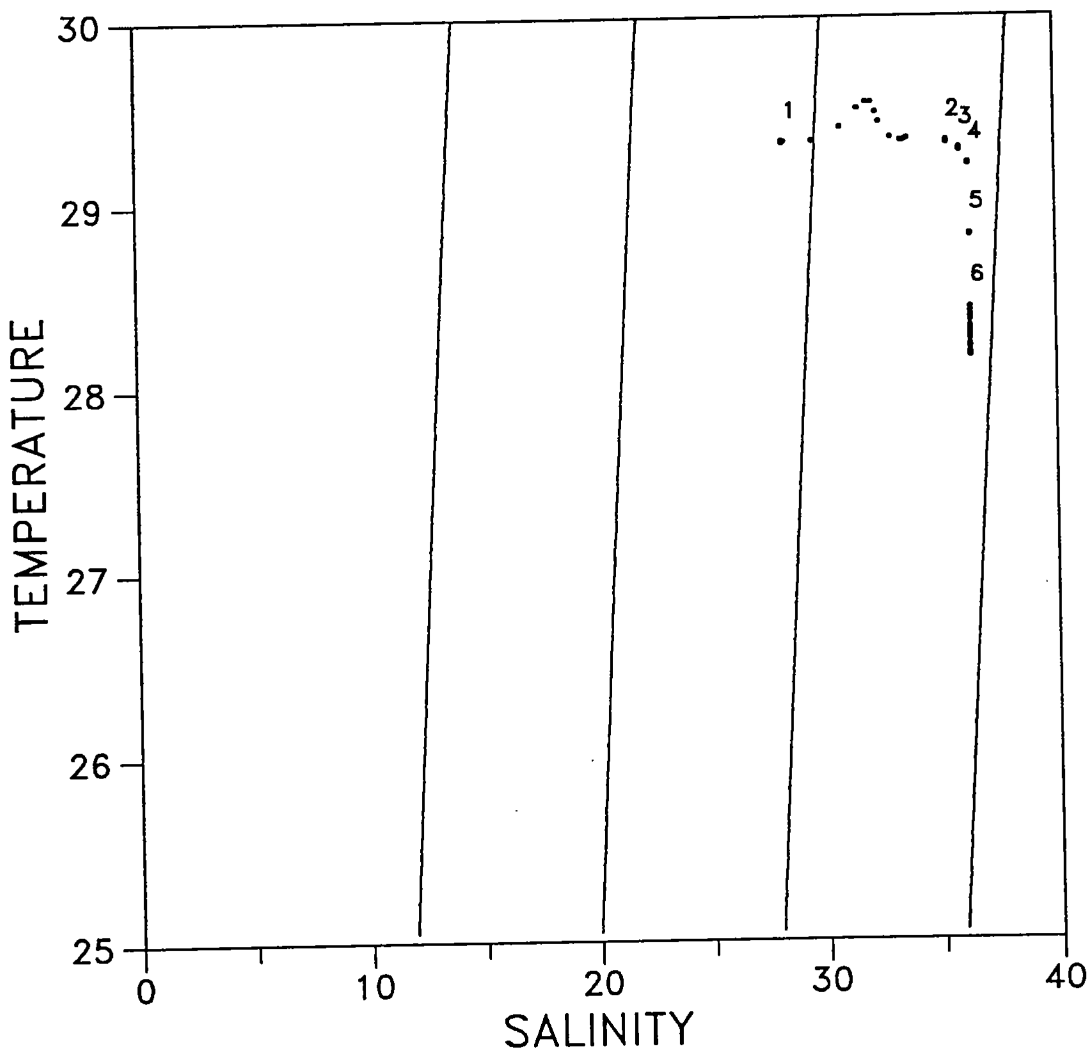
### A. Leg 3 – Large-Scale Survey — May 23–30, 1990
### Stations 1 to 57




MAY 23 – 30, 1990




MAY 23 - 30, 1990


30
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25
TEMPERATURE
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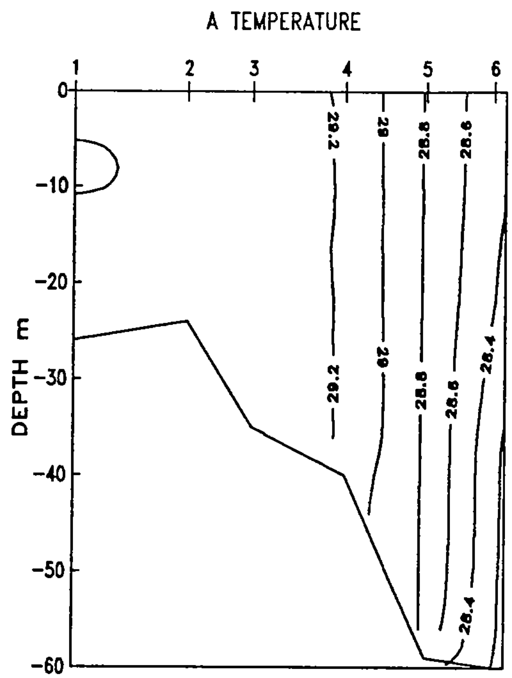
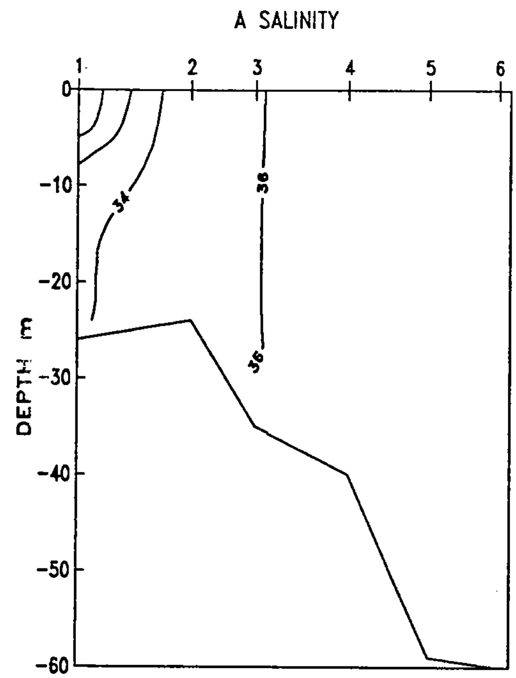
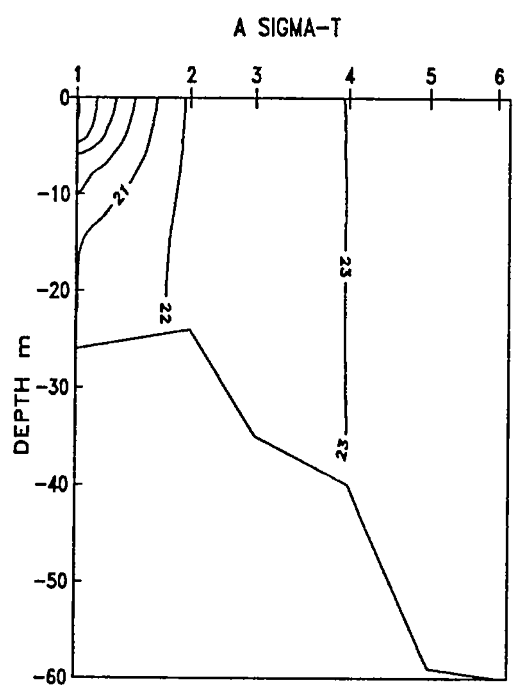
40
SALINITY


A TEMPERATURE
DEPTH m
29.2
29
28.8
28.6
28.4


A SALINITY
DEPTH m
34
36


A SIGMA-T
DEPTH m
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22
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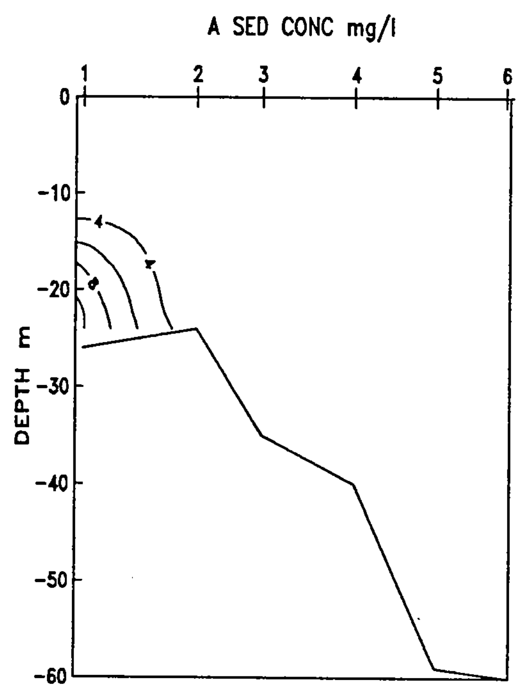
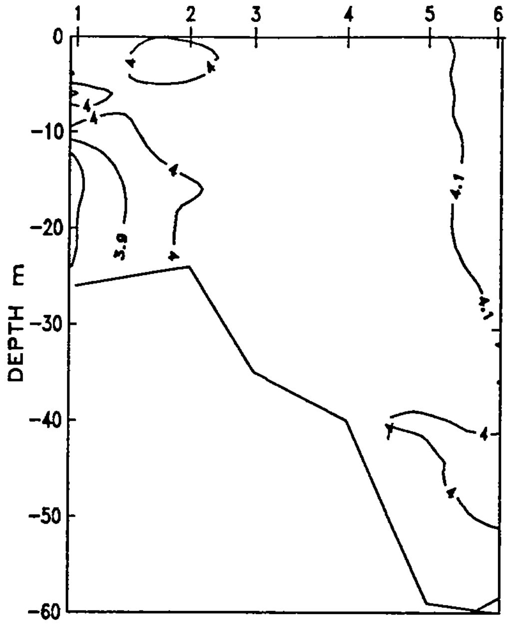
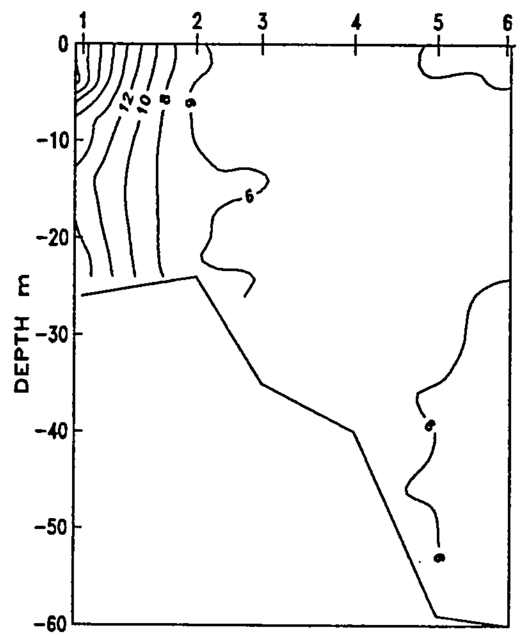
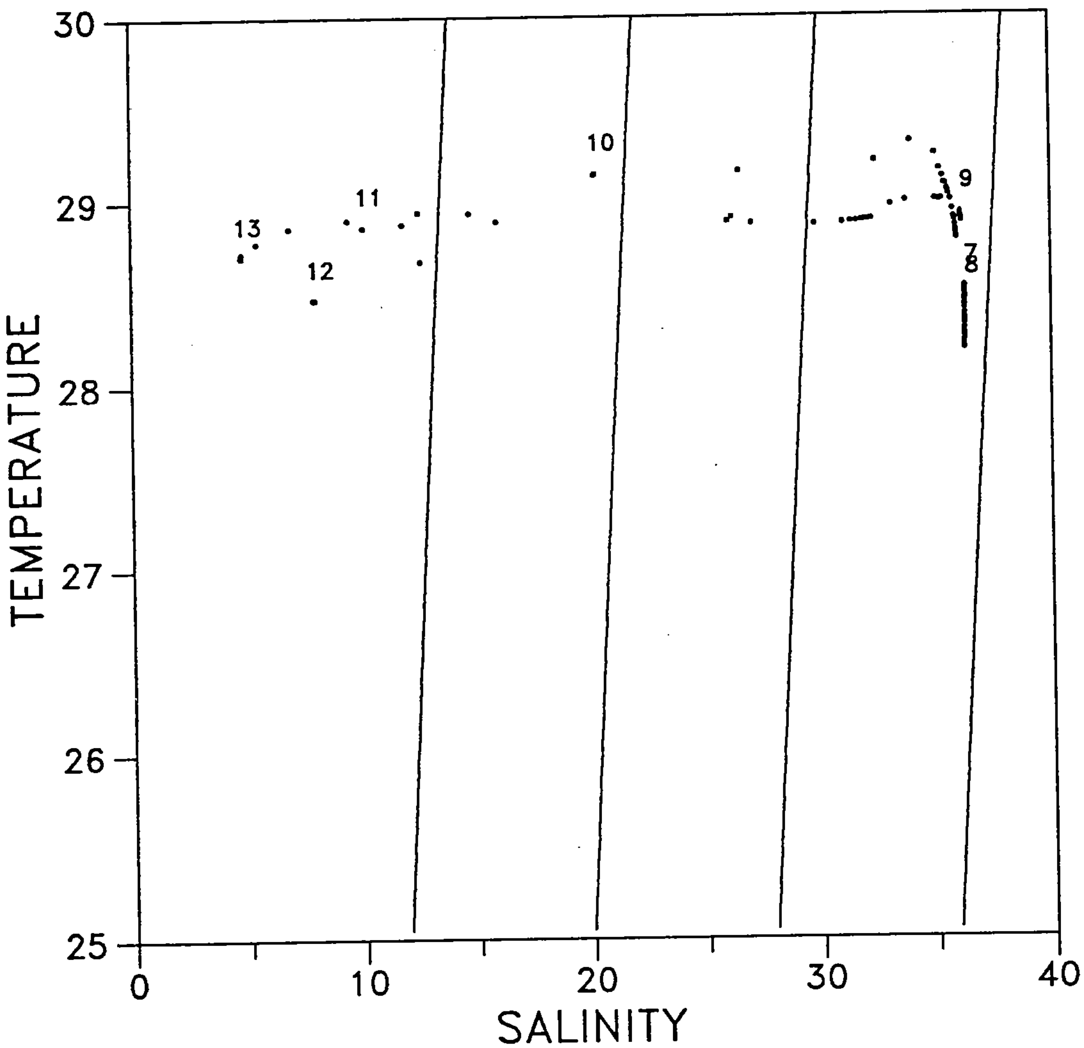

A SED CONC mg/l
DEPTH m
4
6

A OXYGEN ml/l




A FLUORESCENCE pct





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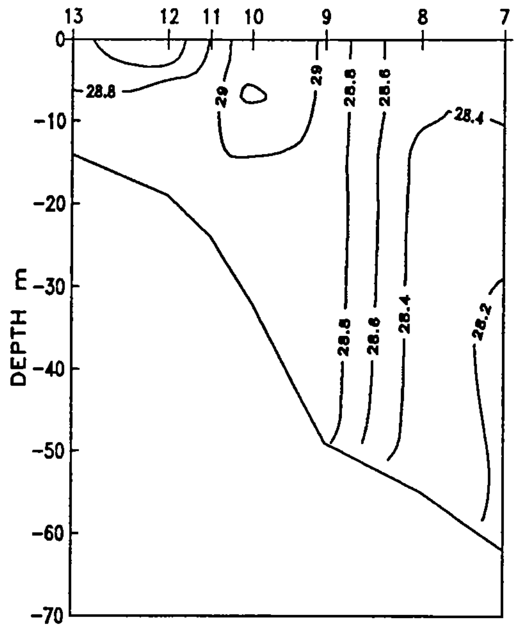
B TEMPERATURE

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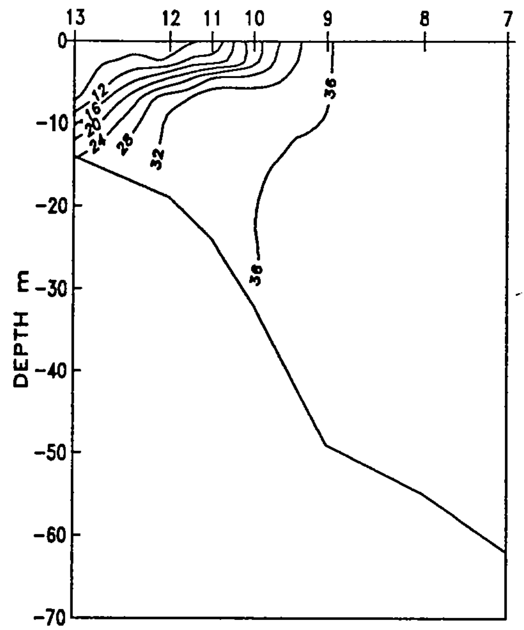


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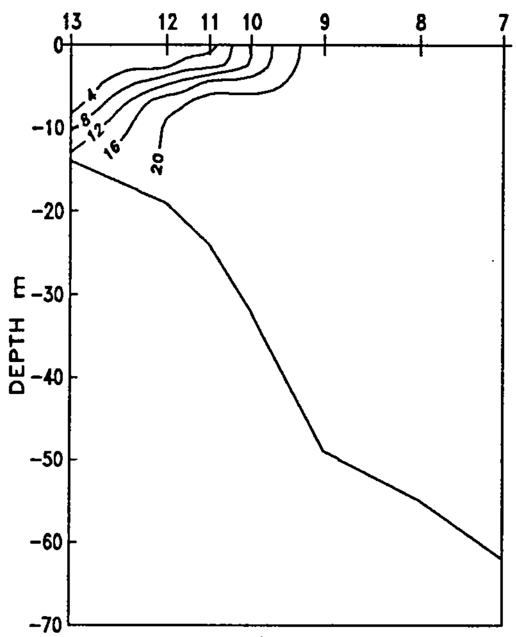
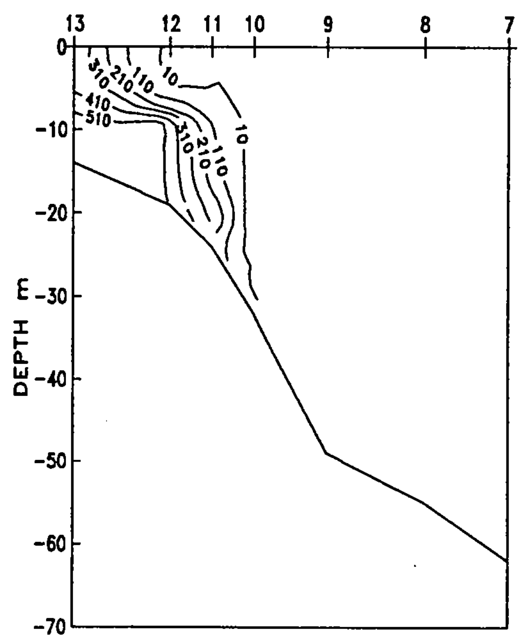
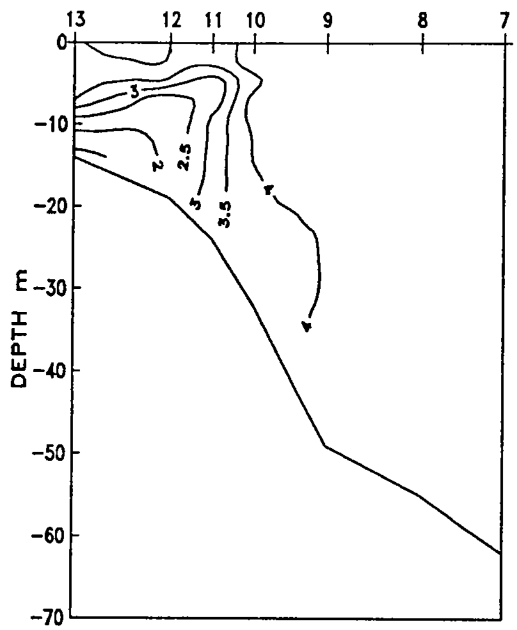



B SED CONC mg/l



B OXYGEN ml/l

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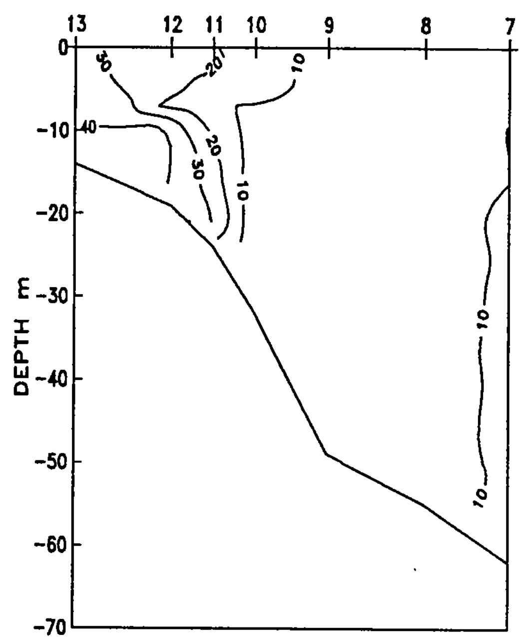

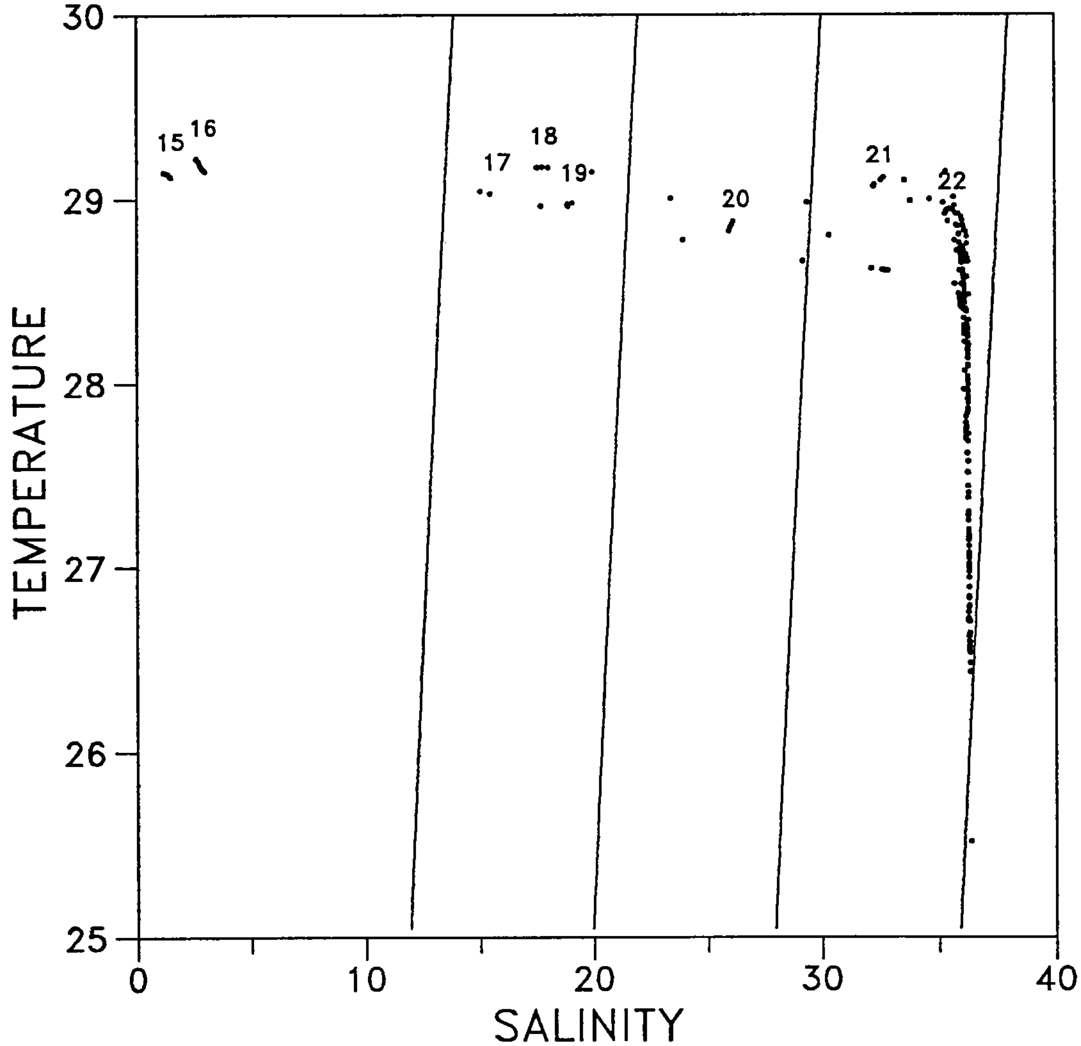
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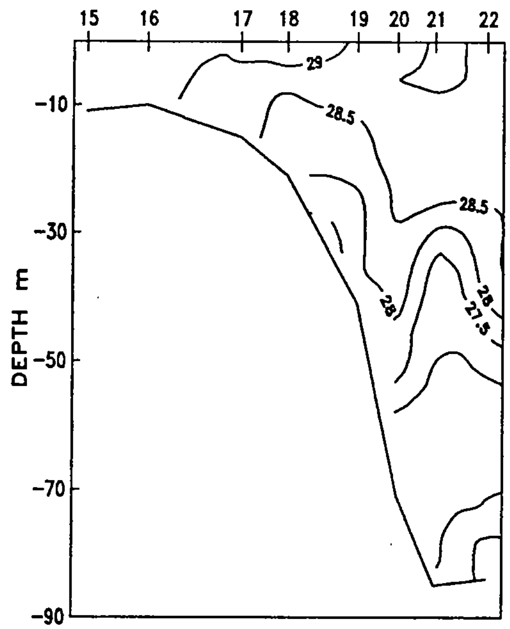


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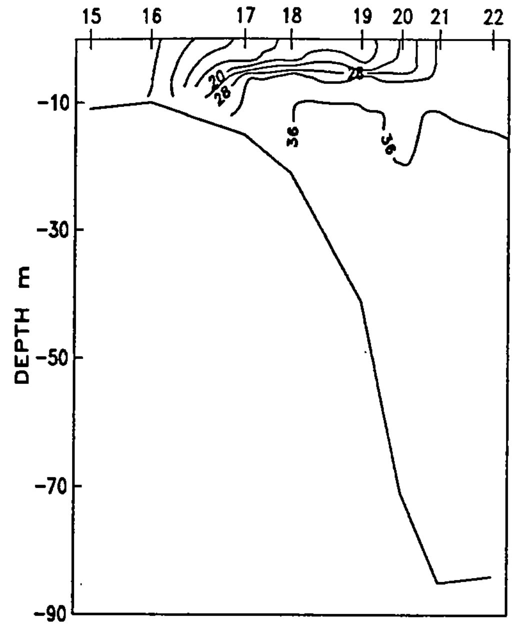


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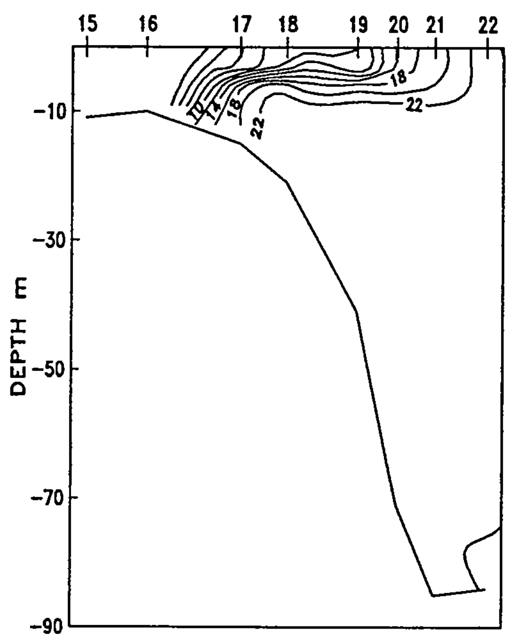


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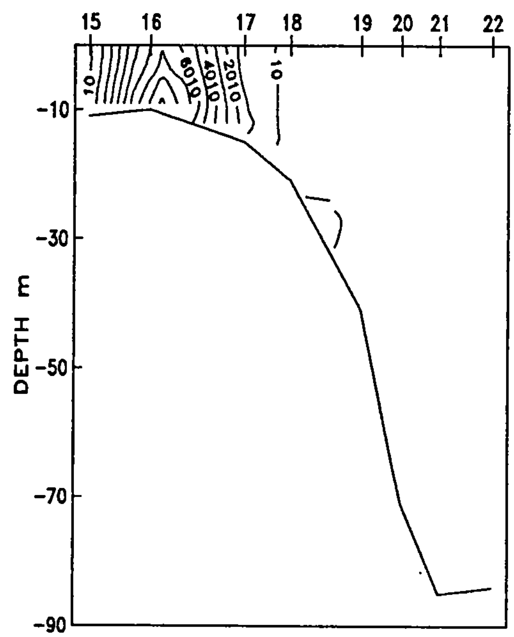
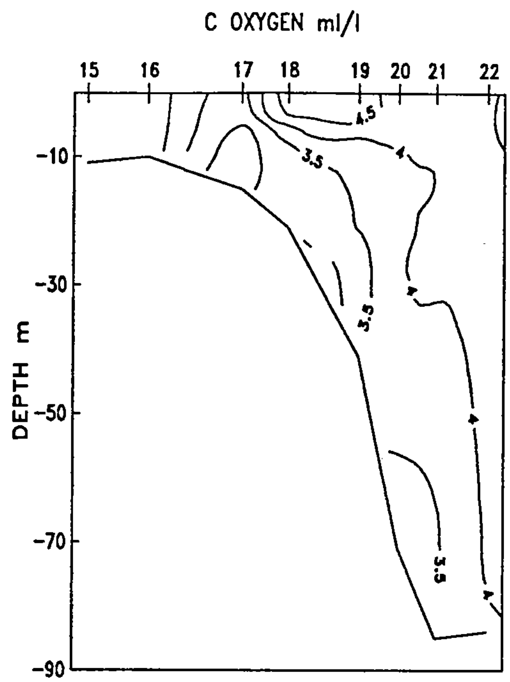



C SED CONC mg/l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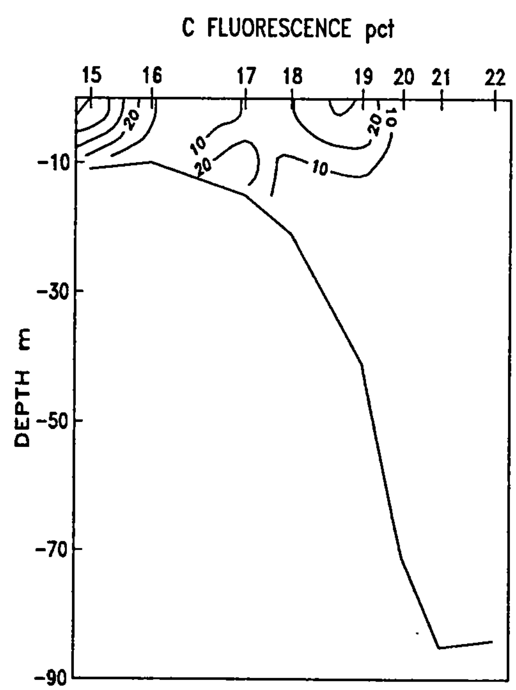
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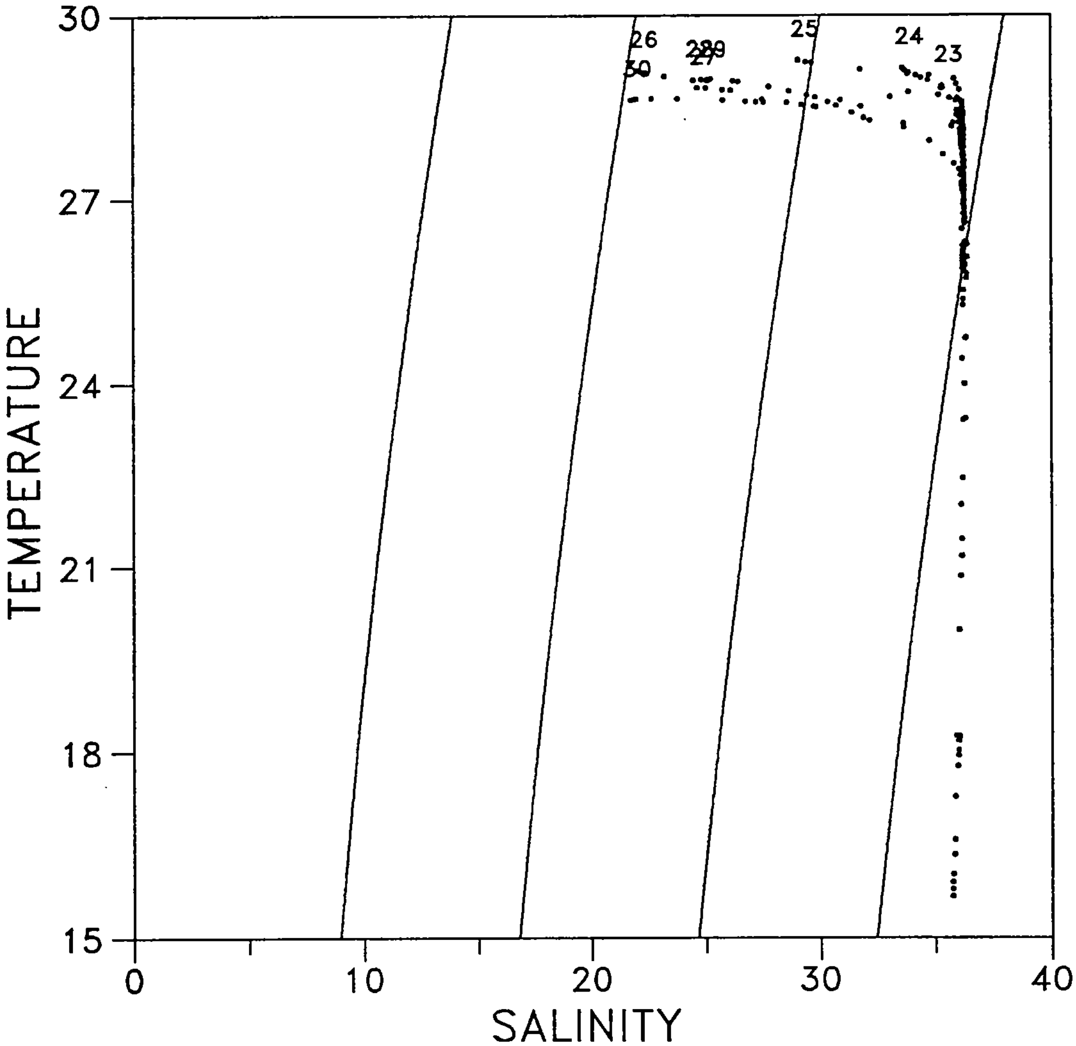

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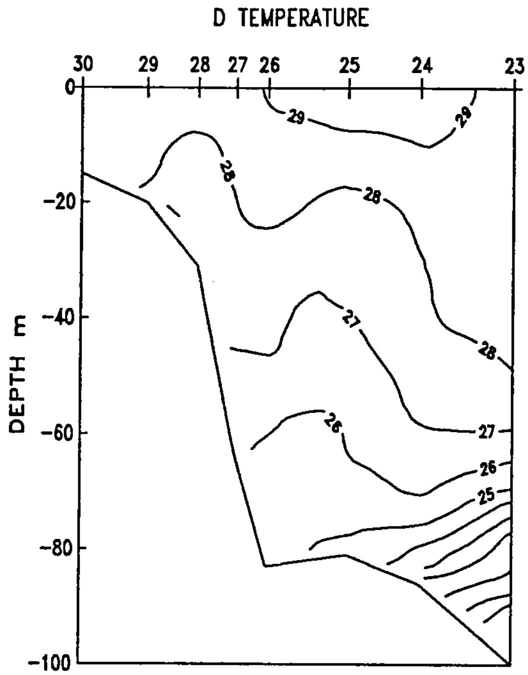
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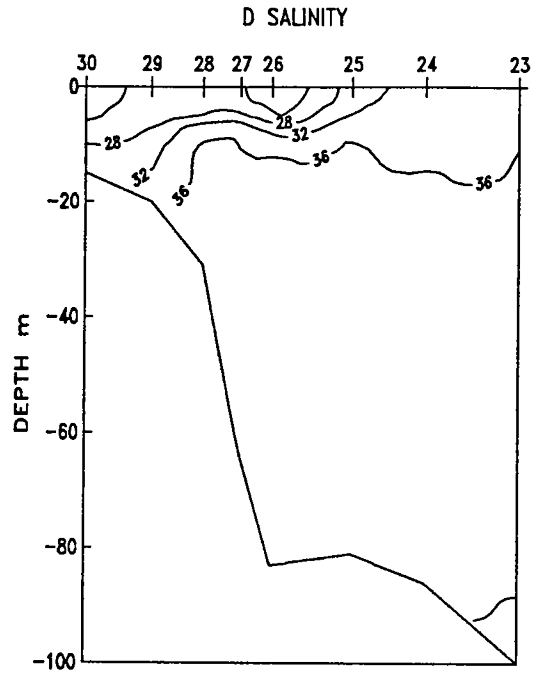
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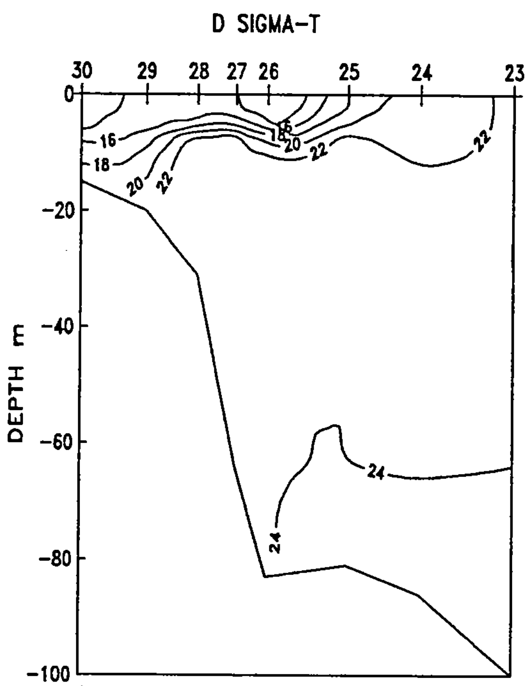
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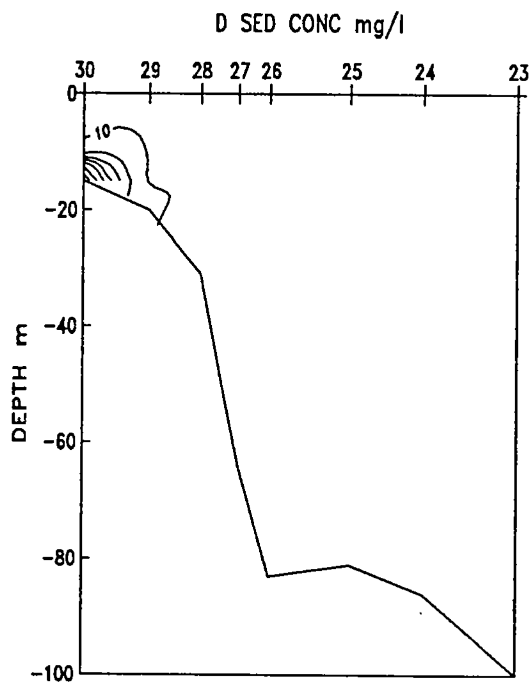
D SED CONC mg/l
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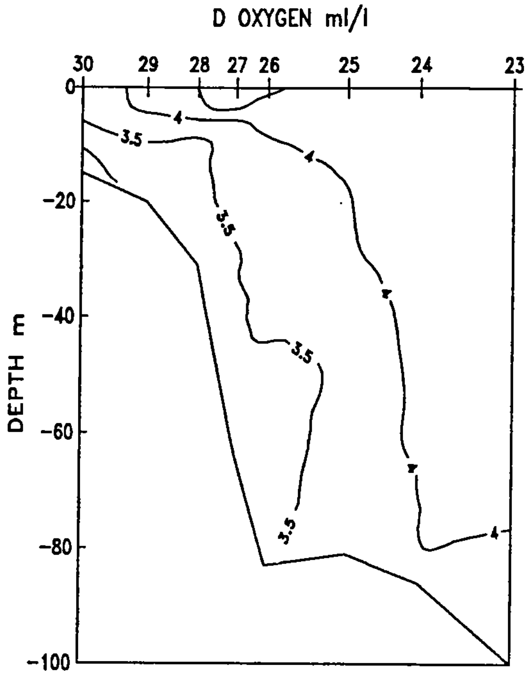
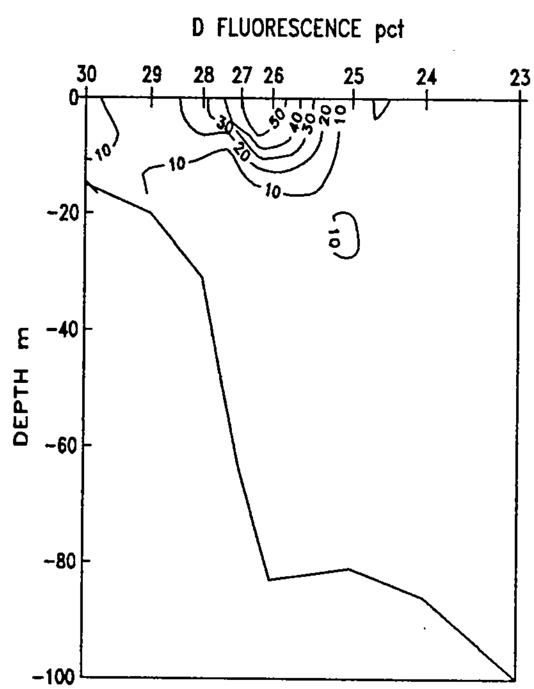
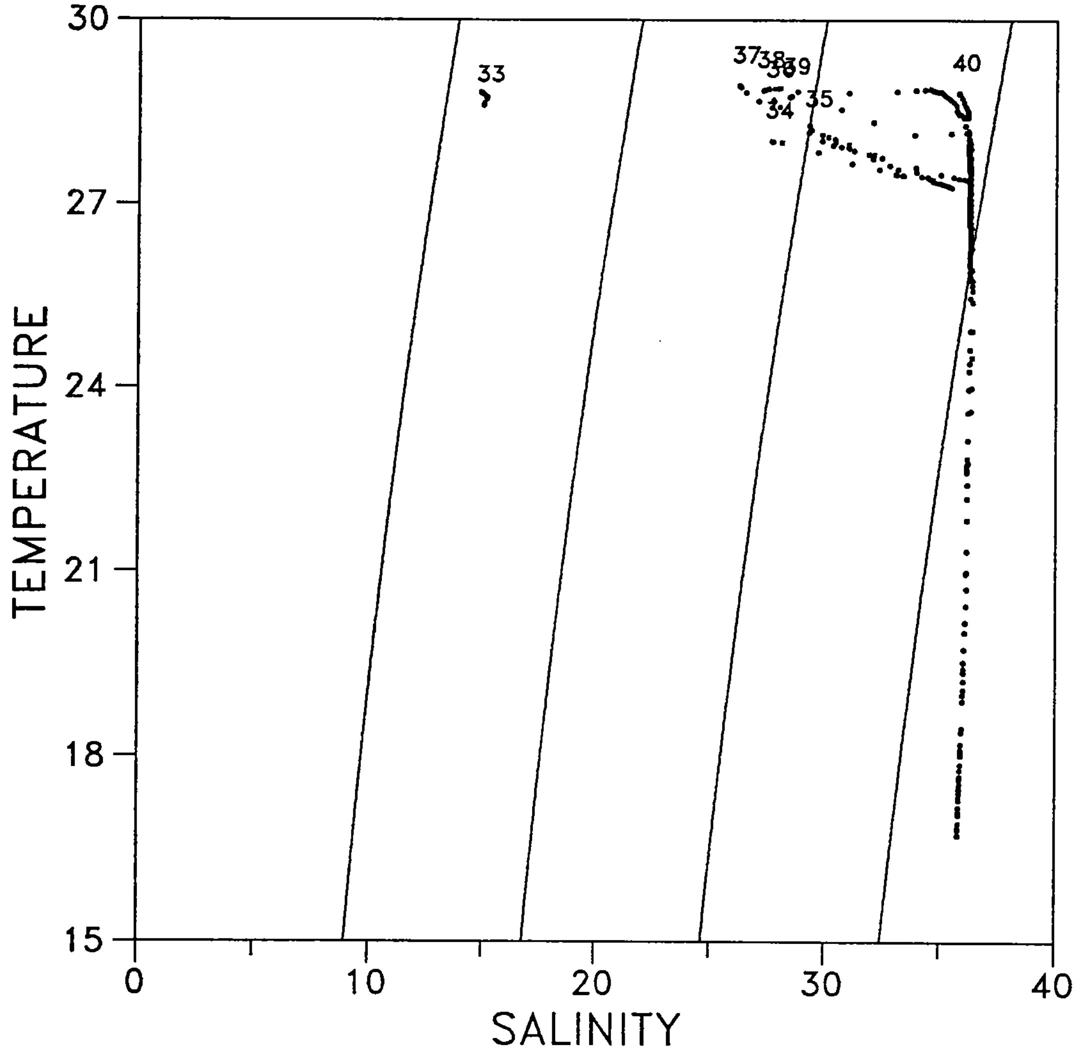
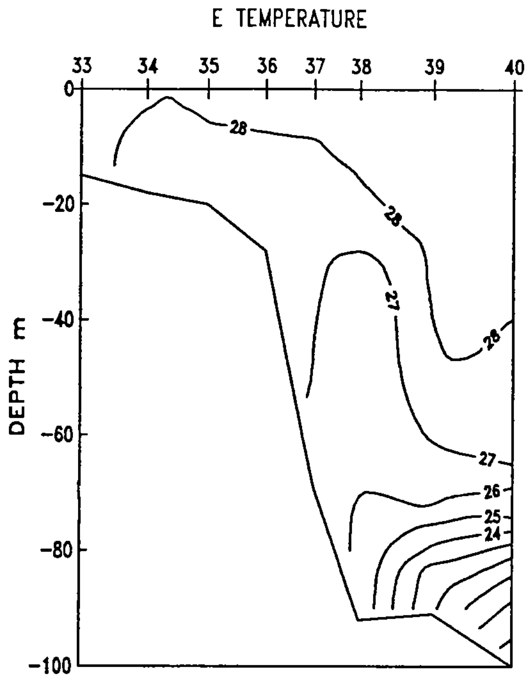
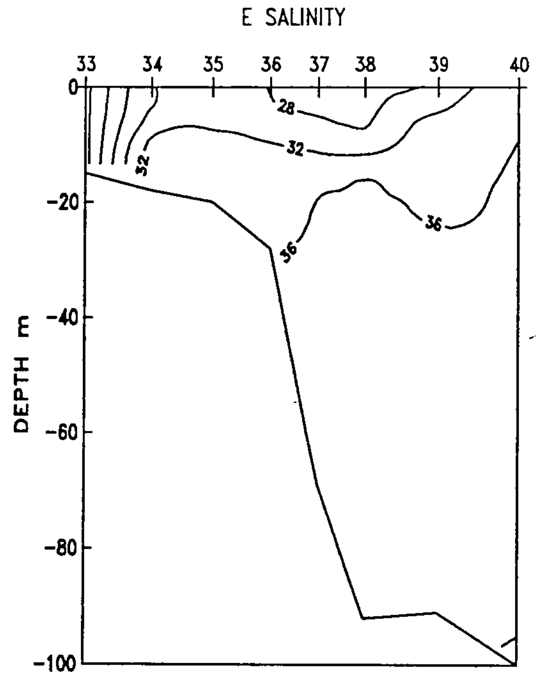
DEPTH m
10


D OXYGEN ml/l
30
29
28
27
26
25
24
23
0
-20
-40
-60
-80
-100
DEPTH m
4
3.5


D FLUORESCENCE pct
30
29
28
27
26
25
24
23
0
-20
-40
-60
-80
-100
DEPTH m
10
20
30
40
50


30
27
24
21
18
15
0
10
20
30
40
SALINITY
TEMPERATURE
33
37
38
36
39
35
34
40


E TEMPERATURE
33 34 35 36 37 38 39 40
0
-20
-40
-60
-80
-100
DEPTH m
28
28
27
28
27
26
25
24


E SALINITY
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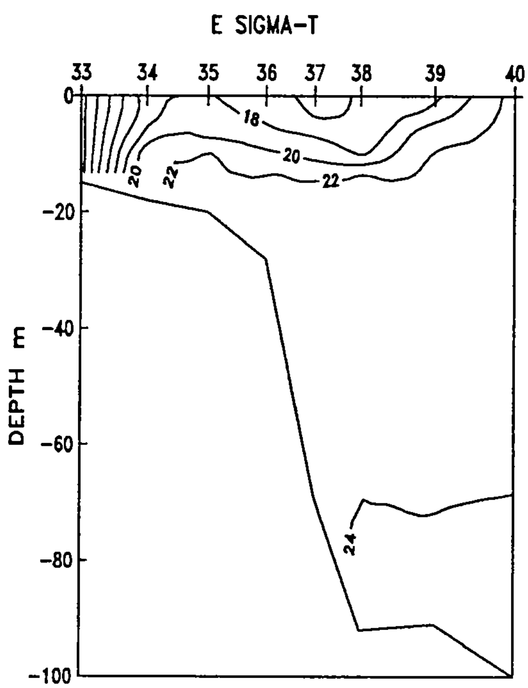
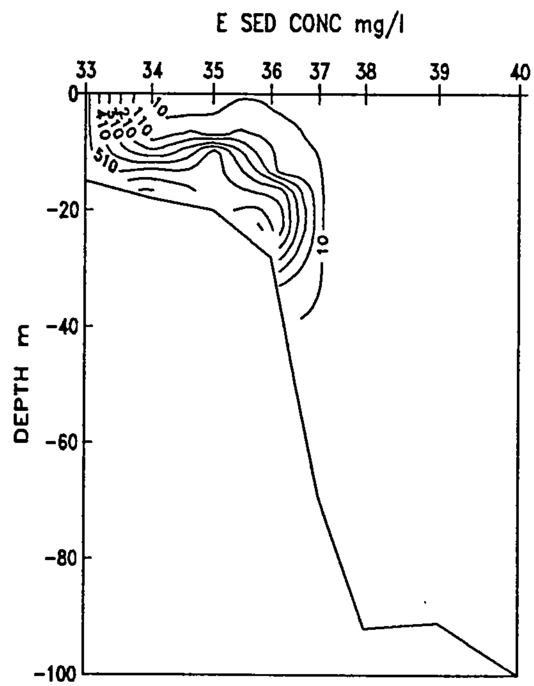
0
-20
-40
-60
-80
-100
DEPTH m
28
32
32
36
36


E SIGMA-T
33 34 35 36 37 38 39 40
0
-20
-40
-60
-80
-100
DEPTH m
18
20
20
22
22
24


E SED CONC mg/l
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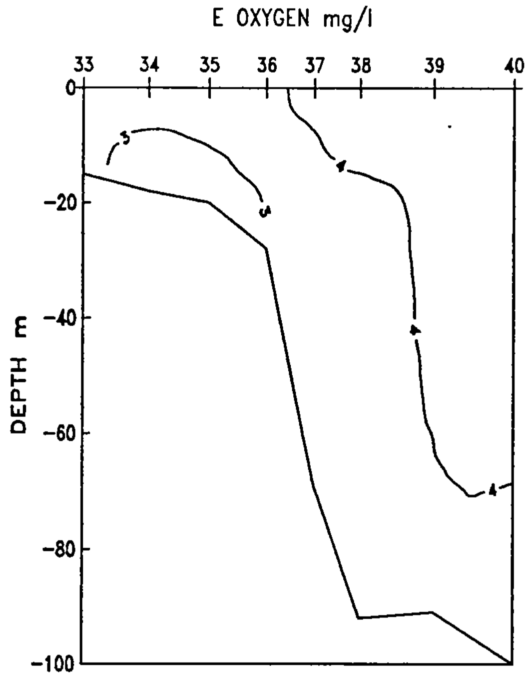
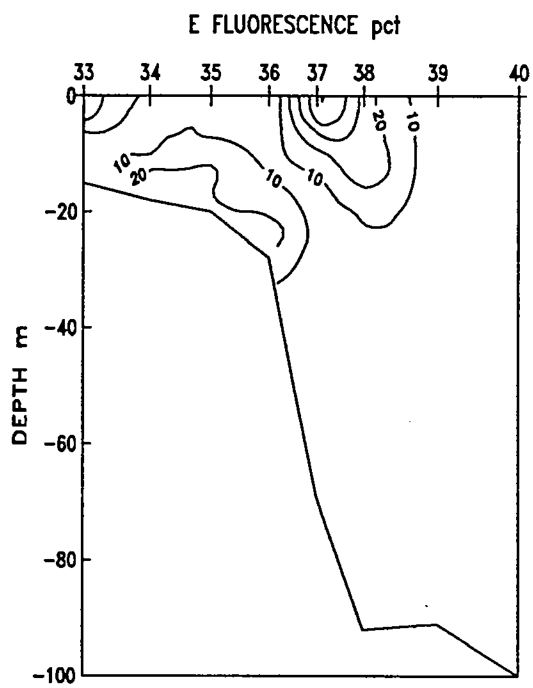
0
-20
-40
-60
-80
-100
DEPTH m
10
510
10


E OXYGEN mg/l
33
34
35
36
37
38
39
40
0
-20
-40
-60
-80
-100
DEPTH m
3
3
4
4
4


E FLUORESCENCE pct
33
34
35
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40
0
-20
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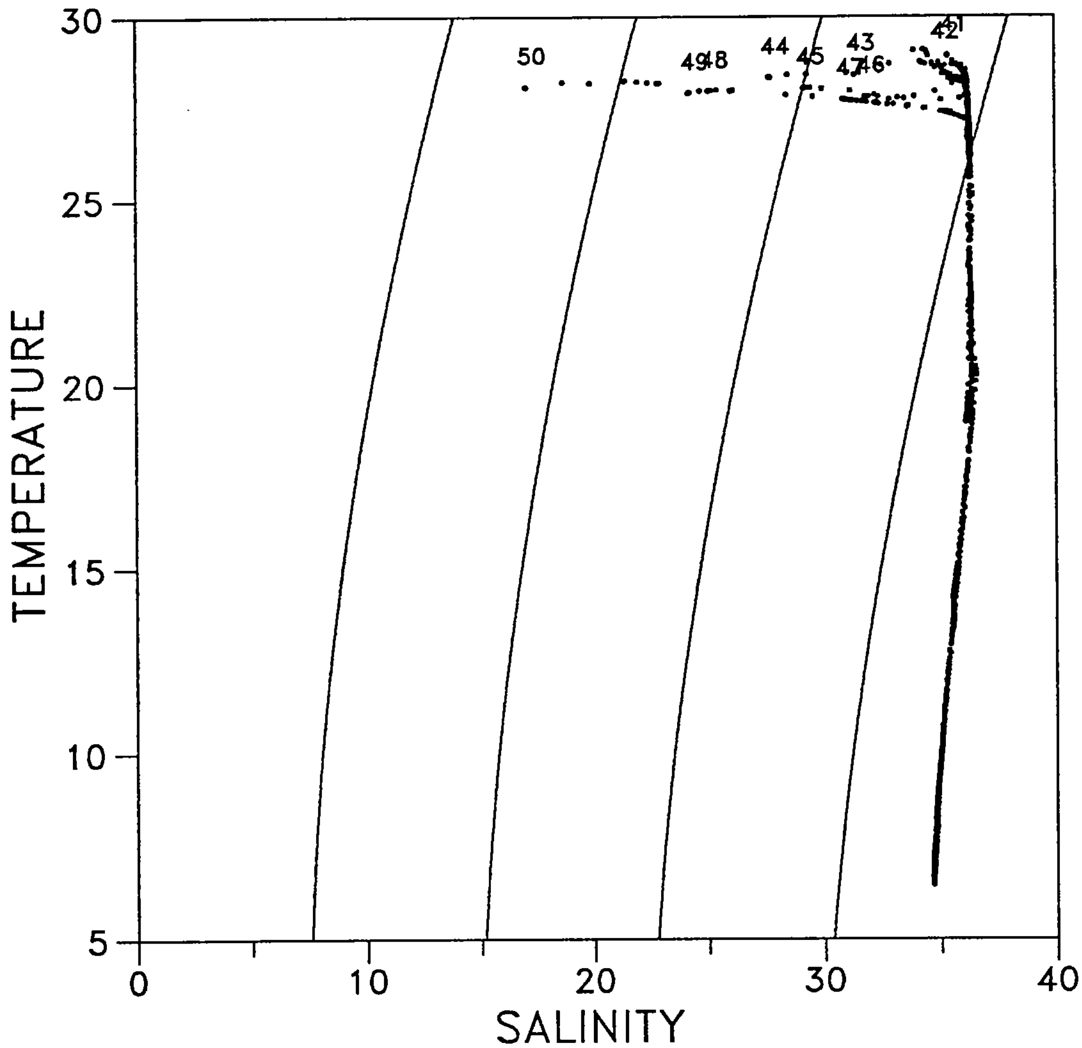
-60
-80
-100
DEPTH m
10
20
10
10
20
10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25
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5
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20
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40
SALINITY
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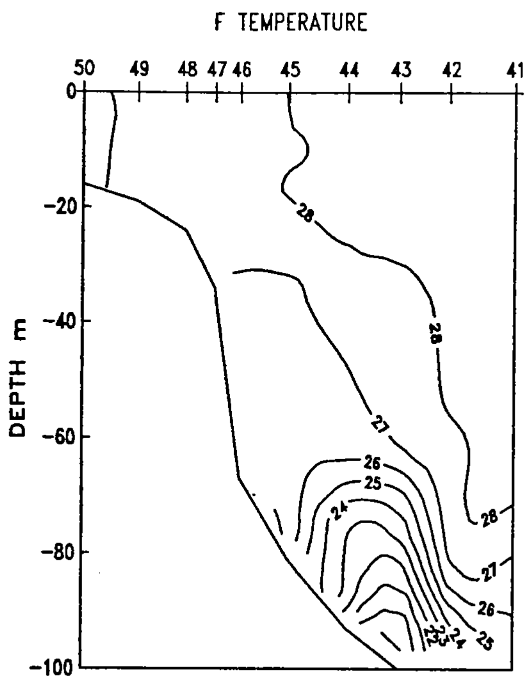
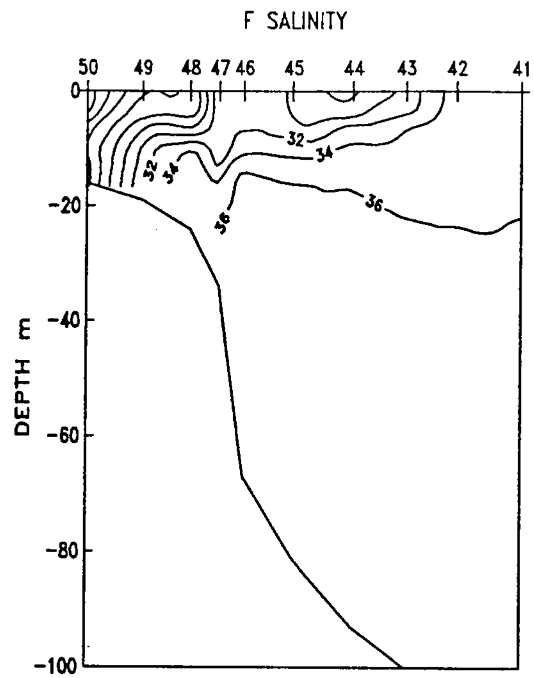
42


F TEMPERATURE
50 49 48 47 46 45 44 43 42 41
0
-20
-40
-60
-80
-100
DEPTH m
28
27
26
25
24
23
22


F SALINITY
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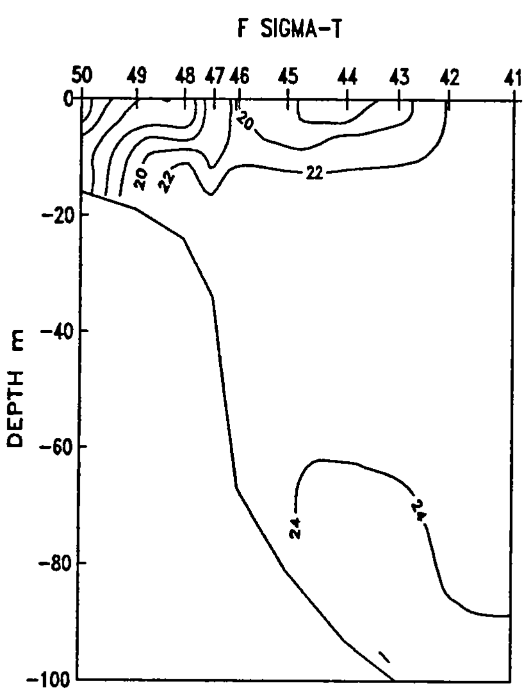
0
-20
-40
-60
-80
-100
DEPTH m
32
34
36


F SIGMA-T
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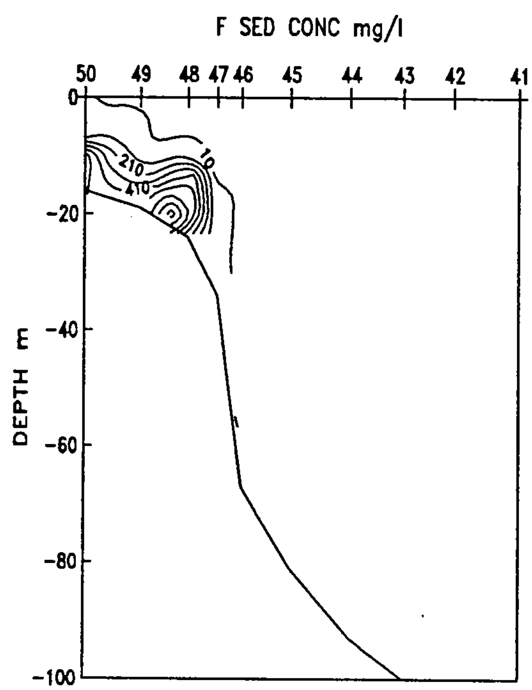
0
-20
-40
-60
-80
-100
DEPTH m
20
22
24


F SED CONC mg/l
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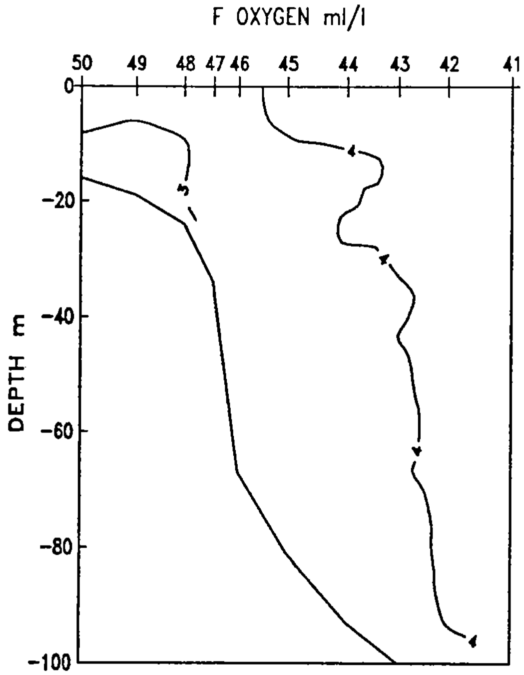
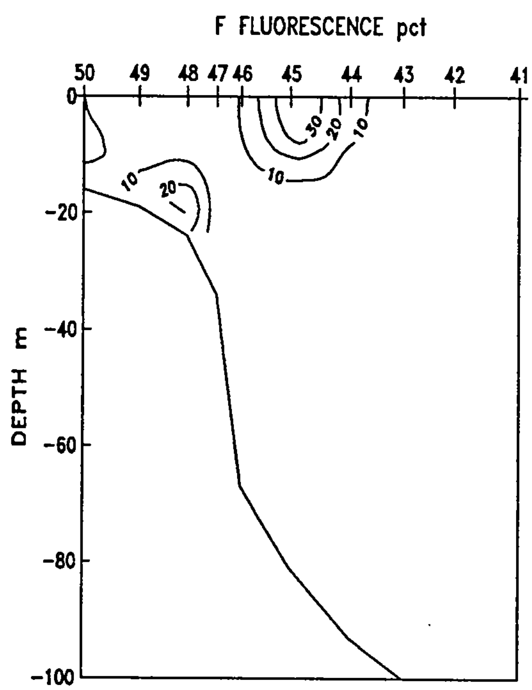
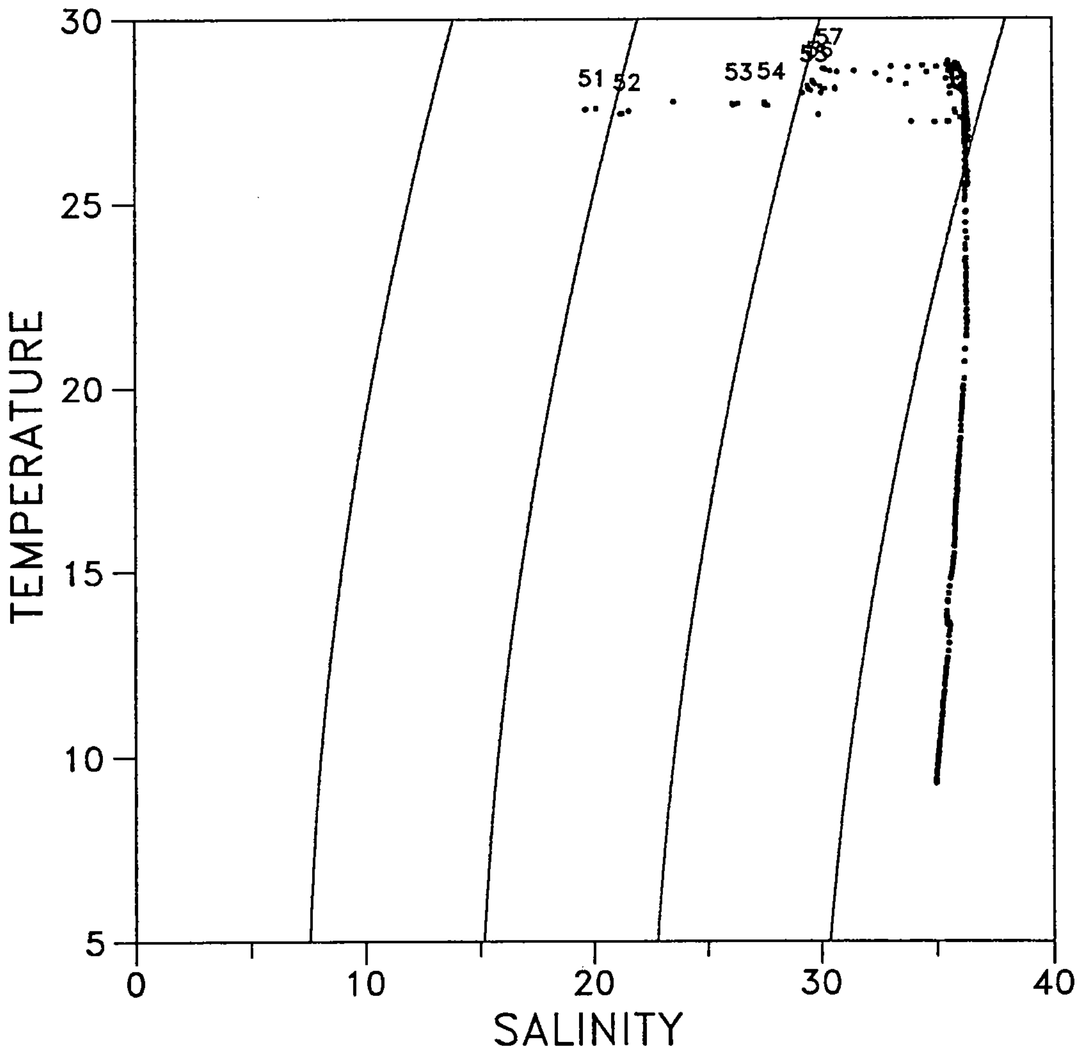
0
-20
-40
-60
-80
-100
DEPTH m
10
210
410


F OXYGEN ml/l
50
49
48
47
46
45
44
43
42
41
0
-20
-40
-60
-80
-100
DEPTH m
3
4


F FLUORESCENCE pct
50
49
48
47
46
45
44
43
42
41
0
-20
-40
-60
-80
-100
DEPTH m
10
20
30


30
25
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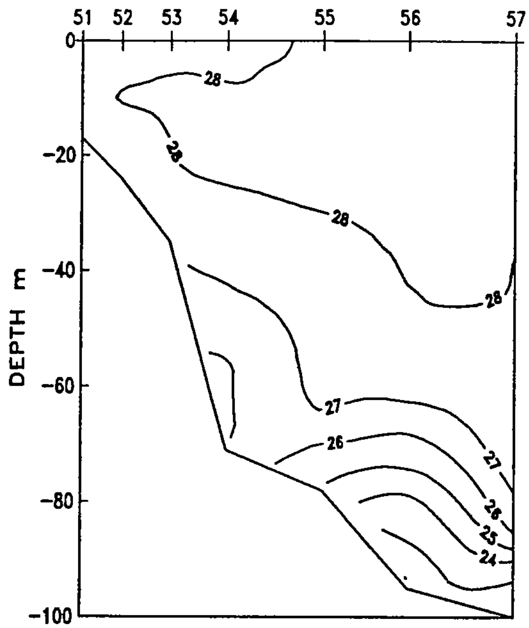
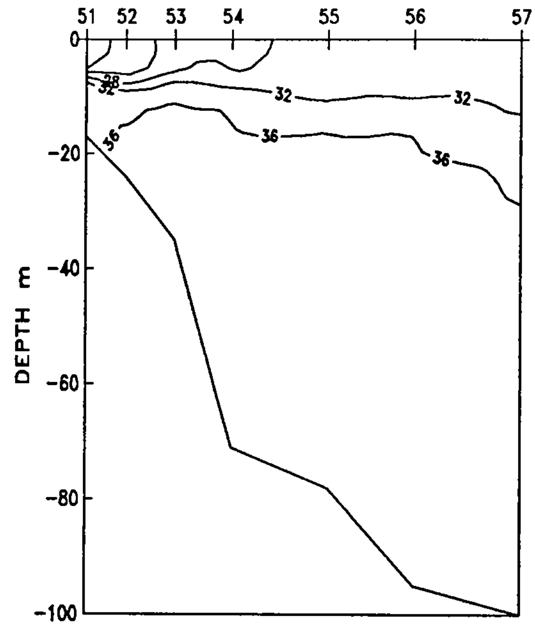
15
10
5
TEMPERATURE
0
10
20
30
40
SALINITY
51
52
53
54
57

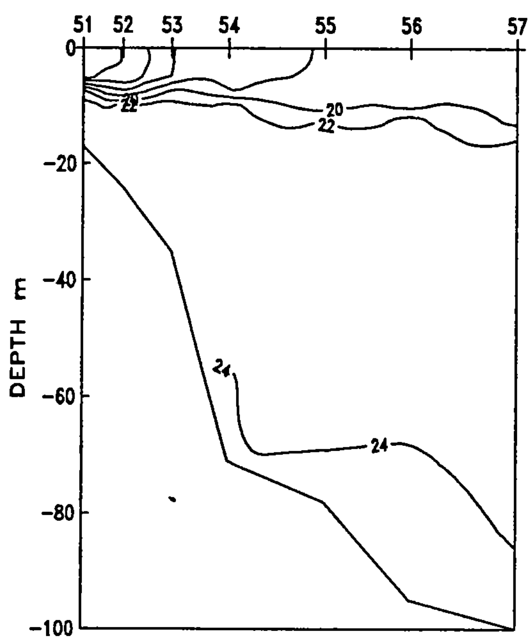
G TEMPERATURE



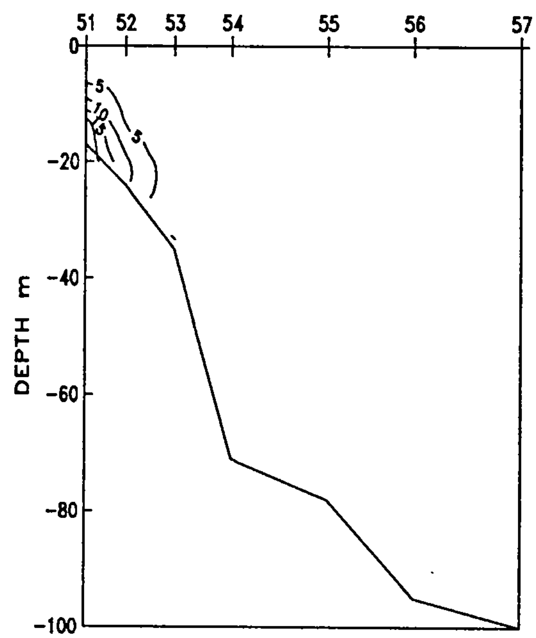

G SALINITY



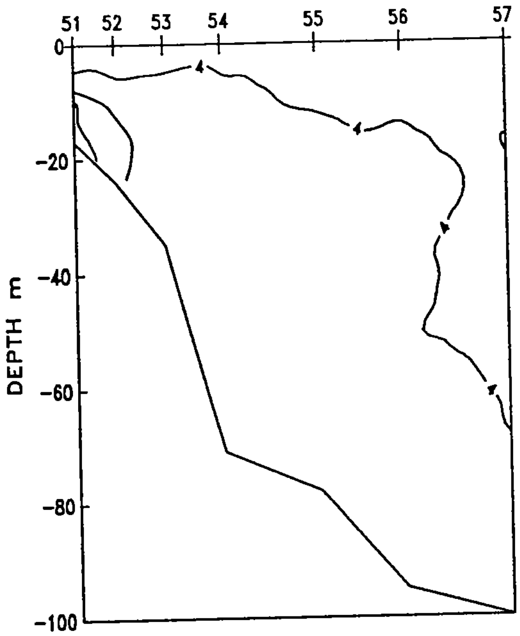

G SIGMA-T



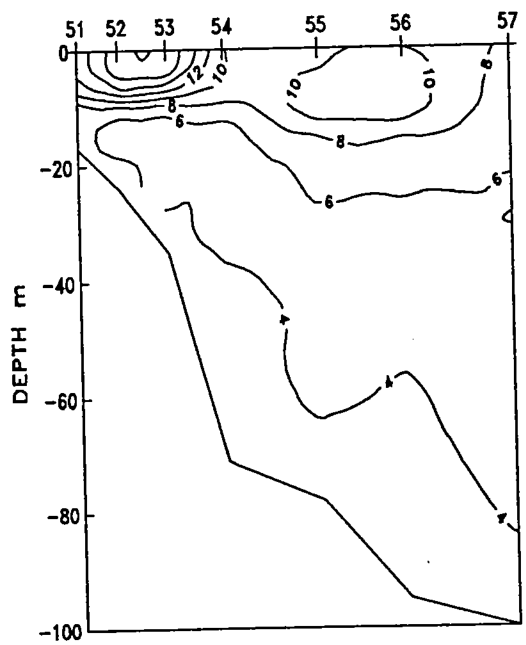

G SED CONC mg/l

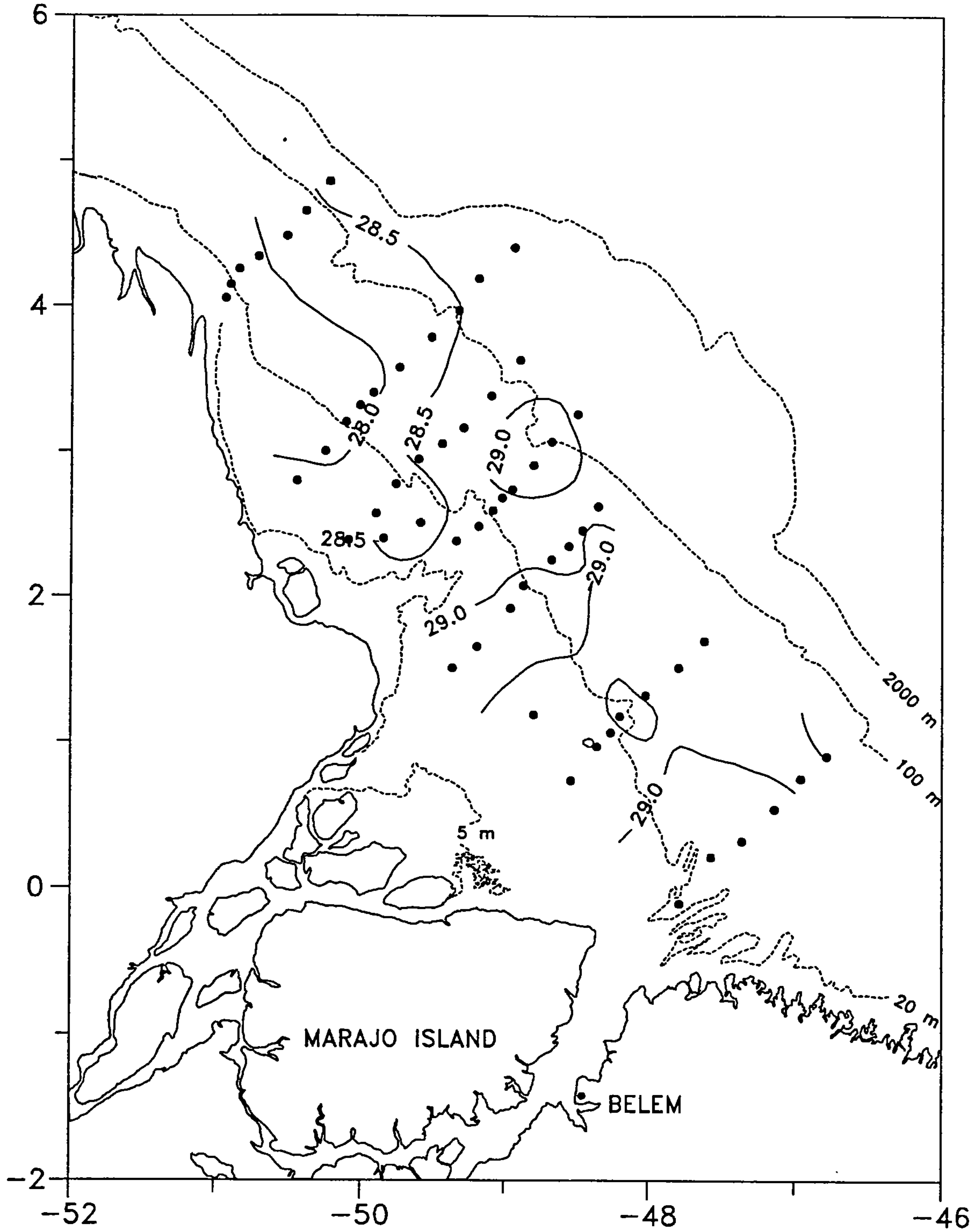


G OXYGEN ml/l

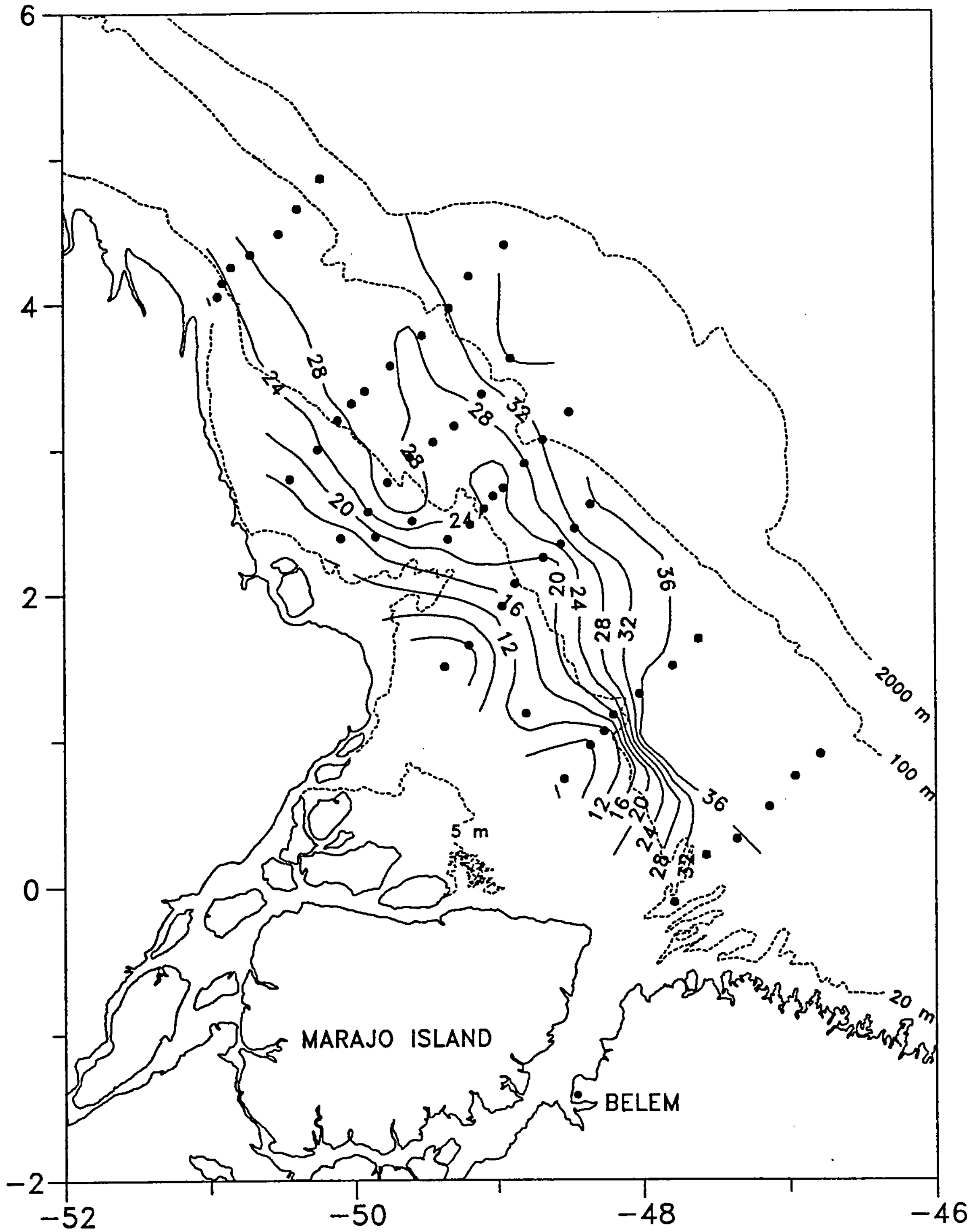



G FLUORESCENCE pct

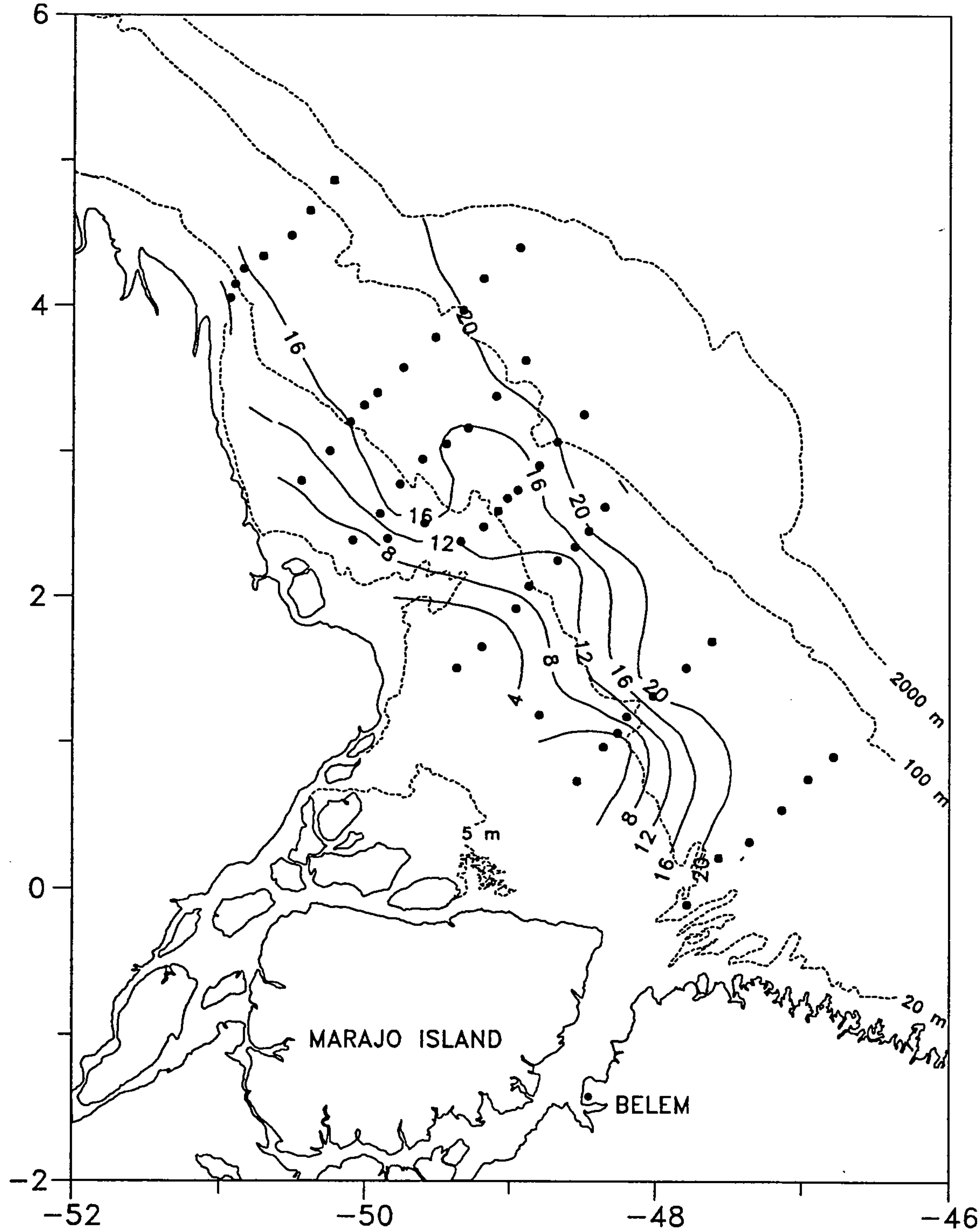




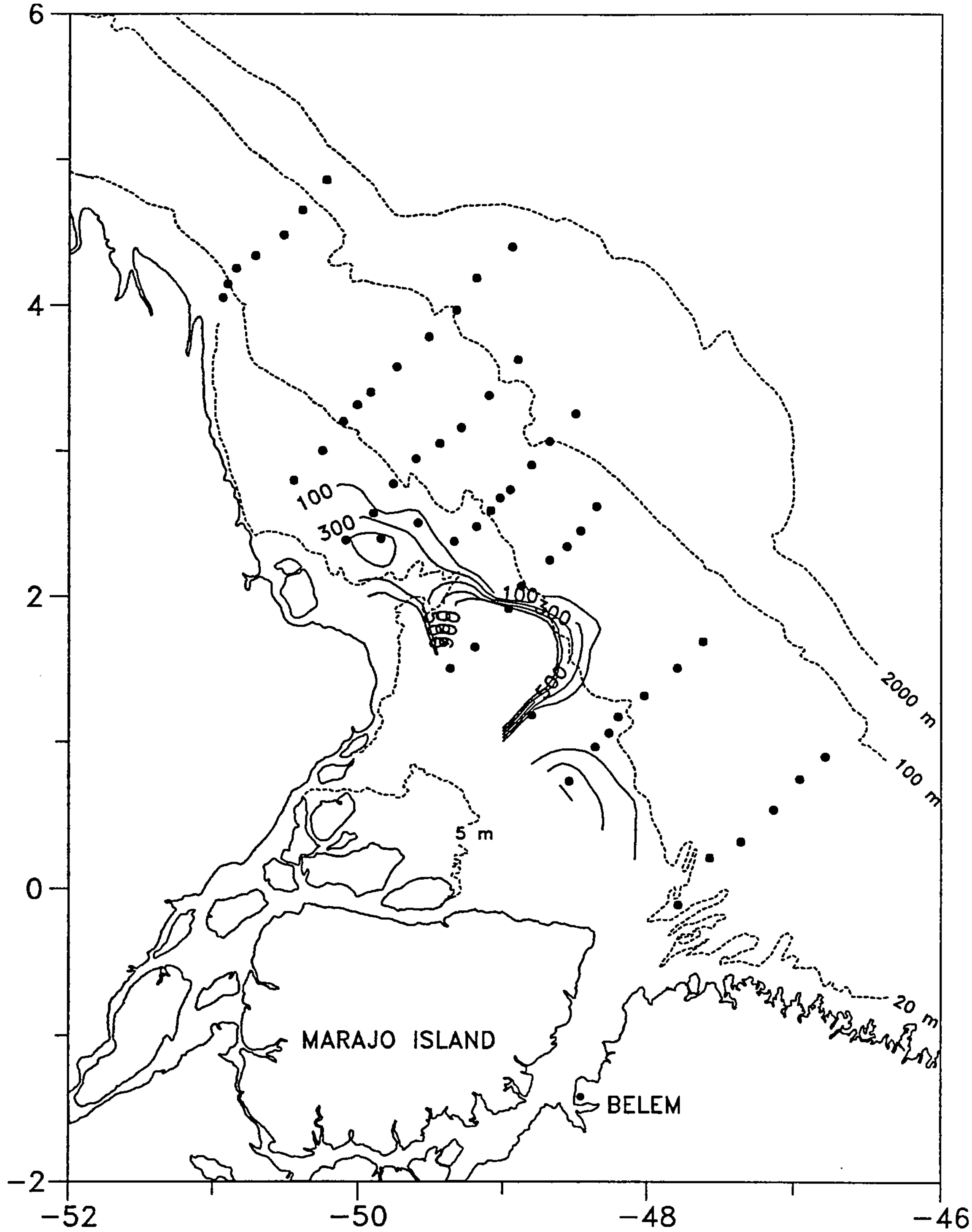
SURFACE TEMPERATURE MAY 23−30, 1990



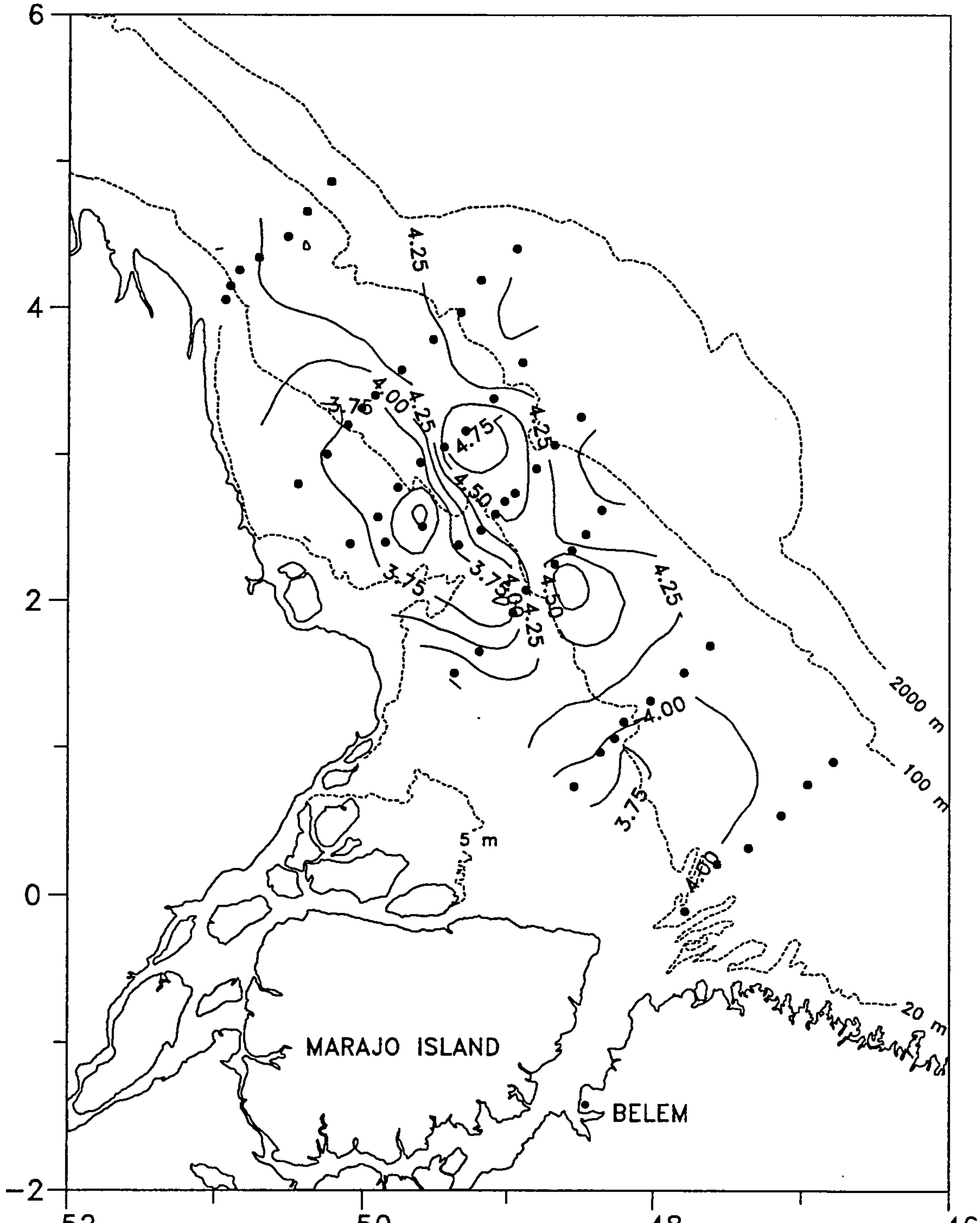

SURFACE SALINITY MAY 23–30, 1990



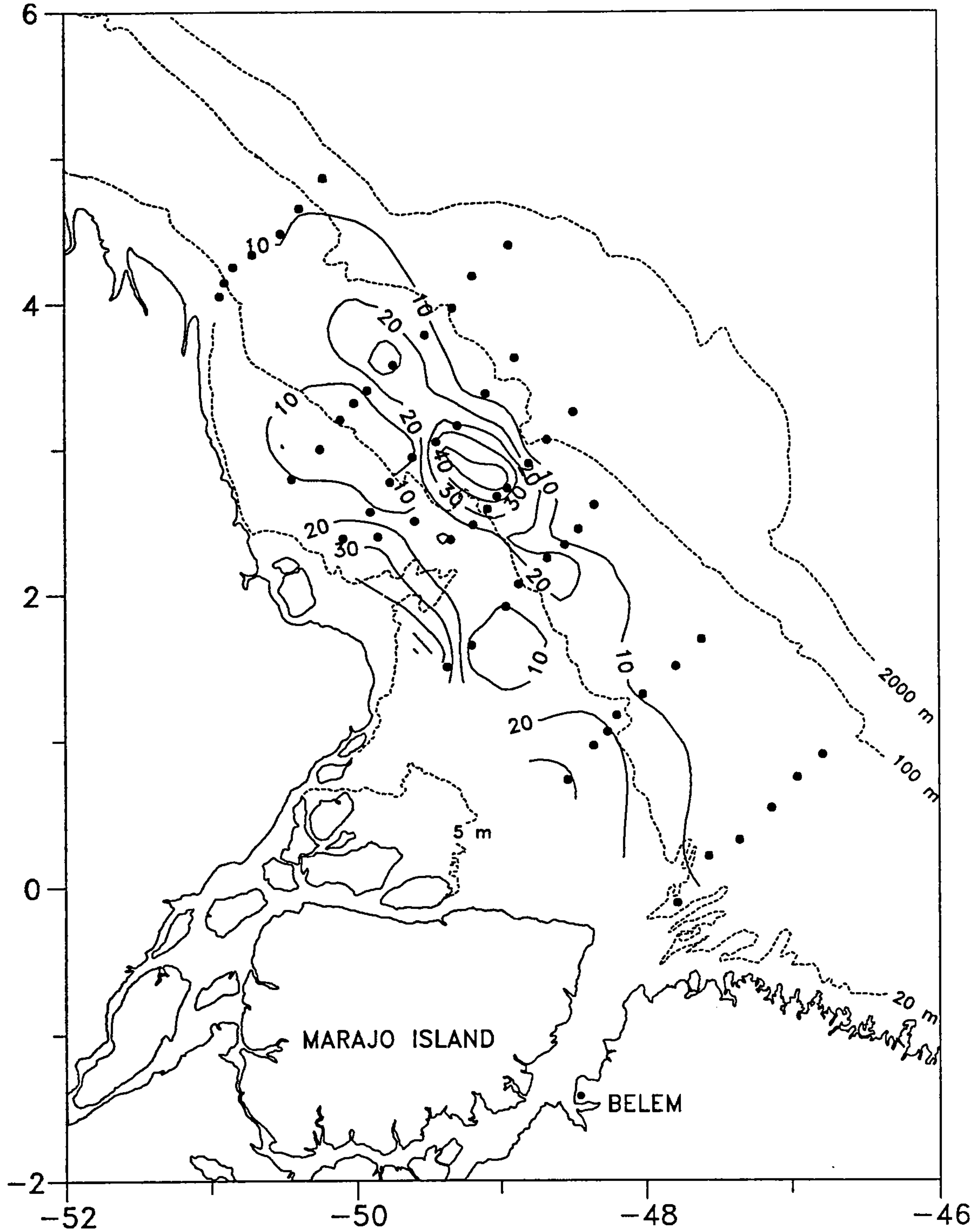

SURFACE SIGMA-T MAY 23-30, 1990



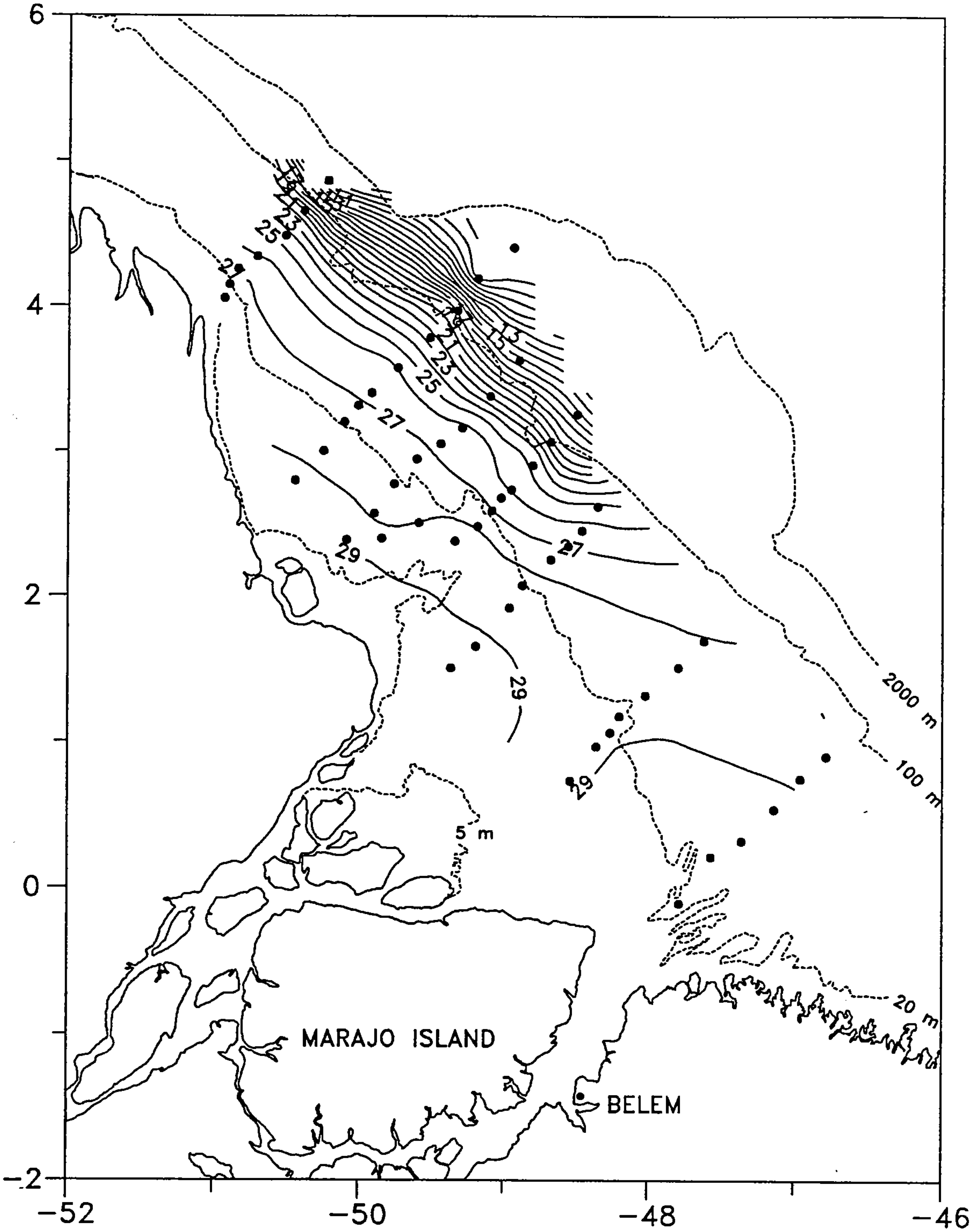

SURFACE SEDIMENT mg/l MAY 23–30, 1990



SURFACE OXYGEN ml/l MAY 23−30, 1990




SURFACE FLUORESCENCE MAY 23-30, 1990




BOTTOM TEMPERATURE MAY 23-30, 1990