SOME CHEMICAL ASPECTS OF THE MARINE ENVIRONMENT OFF THE AMAZON AND PARÁ RIVERS, BRAZIL

(Received 3/20/1971)

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SYNOPSIS

This paper describes the salinity, temperature, dissolved oxygen and inorganic phosphate distributions for the Brazil northern coast, with special reference to the marine environment off the Amazon and Pará rivers.

The change in direction of the coast with the consequent change in the axis of the Guiana Current together with the large amount of suspended matter contributed by river waters, create peculiar conditions on the continental shelf. These conditions are also influenced by the wind and rain system. Out from the continental shelf Tropical Atlantic oceanic conditions are prevalent.

In contrast to the very low fertility of the Guiana Current the coastal waters, directly influenced by the rivers, show a supersaturation of dissolved oxygen. The nutrients absorbed by suspended matter are partly liberated when the rivers mix with the oceanic water. However, the low light penetration restricts the oxygen production to only few meters.

INTRODUCTION

The oceanographic cruise "EQUALANT I", aboard the Brazilian Navy Destroyer CT. "Bertioga", comprised two series of observations made during the periods 20-28th February 1963 (series A) and 15-30th March (series B). The two series differ in that series A consists of principally deep water stations, and series B of stations on the continental shelf. The cruises were part of an oceanographic research program under the "International Cooperative Investigations of the Tropical Atlantic" (ICITA). The Oceanographic Institute of the University of São Paulo was responsible for the area between 0^o - 10^oN Latitude and 042^o - 052^oW Longitude (Fig. 1).

Publ. no. 309 do Inst. Ocean. da USP

The first investigations on the distribution of dissolved oxygen in the Atlantic Ocean waters, appear in Wattenberg (1938) and Seiwell (1937). However, the oceanographic data on the Tropical Atlantic is scarce, especially in areas close to the northern coast of Brazil, and is even more scarce for areas around the estuaries of the Amazon and Pará rivers. Some expeditions, "Meteor" (1925-27), "Dana" (1921-22), "Crawford" (1957-58) and "M. Lomonozov" (1963) give limited information on chemical distributions whereas the work of the "Almirante Saldanha", (1958) and "Toko-Maru" (1957) give more detailed information in the vicinity of the

Amazon and Pará rivers.

The oceanographic conditions of the area concerning the continental shelf are strongly influenced by the presence of a large water mass from the rivers Amazon and Pará, and beyond the limit of the continental shelf influenced by a complex diversity of surface and deeper currents.

The present paper gives the results of the EQUALANT I (Ct. "Bertioga") cruise(series B) specifically for dissolved oxygen and inorganic phosphate and in more detail for the stations influenced by the rivers Amazon and Pará.The station list and oceanographic data were prepared by the National Oceanographic Data Center (1964) and published by ICITA.

The Winkler method has been used for determinations of dissolved oxygen and the results refer to the absolute values of oxygen as well as to the relative saturation values i.e. as a percentage of total saturation for a known chlorinity and temperature, following Truesdale & Gameson (1957).

The determination of inorganic phosphate was obtained by the molybdate method using a electrophotometer ELKO II; the chlorinity was measured by the Knudsen method and the hydrogen concentration was measured by a Metrohm potentiometer.

HORIZONTAL DISTRIBUTION

SURFACE

SALINITY - Considering the isohaline 35°/oo as the outer limit of the influence of the fresh water from the Amazon and Pará rivers (Figs. 2 and 3), it is observed that the penetration of these waters over the continental shelf extends northeasternly almost reaching the edge of the continental shelf. Thereafter they flow, NW, parallel to the coast (Fig. 2).

From the diagram the mixing process and its displacement towards the northeast may be followed. Surface isohalines show clearly that the water from the rivers is contained by the Guiana Current and follows the general direction of that current (i.e. NW). The curve of the northern coast-line forces the fresh-water from the rivers Amazon and Pará to run closer to the coast as far as Cape Orange, where it is reinforced by the outflow from the Oyapoque river, which determines the conditions recorded at station 14, in front of Cayenne. To the east of the Pará river mouth it is observed that 35°/oo surface isohaline lies inshore on the continental shelf.

However, in the vicinity of the Pará river it swings away from the coast approaching the outerlimit of the continental shelf. The southern limit of the 35°/oo isohaline seems to be near 1°S, as determined by Murano (1963).

A wedge of highly saline surface water (36,4°/oo) is seen entering from the east, isolating a mass of less saline water (35,7°/oo) off shore. A similar distribution has been recorded by the "Toko-Maru" (Murano, 1963) at the same period of the year. During an extremely dry period the "Almirante Saldanha" (Silva, 1958-59) recorded a different salinity distribution with high surface salinity values throughout the area.

TEMPERATURE - The region under consideration may be broadly subdivided by the 27°C surface isotherm (Fig. 3a) into two distinct parts; a northern one, with temperature lower than 27°C and a southern part with temperature above 27°C.

It is worth noticing in the temperature distribution (Fig. 3a) that the water from the rivers Amazon and Pará presents temperature values (27° - 27.5°C) lower than those of the water mass common to the northeastern coast of Brazil (>27.5°C).

OXYGEN - The dissolved oxygen (Fig. 3b) ranges from 5.23 ml/l to 3.44 ml/l, the highest surface values are recorded as isolines near the coast, with a maximum value of 5.23 ml/l, at 01°N and 048°W, in waters with 15°/oo salinity and 27.4°C temperature. It may be observed that the values of dissolved oxygen decrease as the water from the rivers mixes out into the ocean.

Although significant distributions of dissolved oxygen are recorded at the mouths of the Amazon and Pará rivers with values ranging from 4.7 to 5.2 ml/l, greater insight is obtained from distributions of the relative values of dissolved oxygen. Figure 3d shows three very significant characteristics: 1) a narrow belt bordering the coast of over saturated water (110%) associated with the coastal drift of river to the west; 2) a 100% isoline, parallel to the coast beginning at the Amazon river mouth which seems to stem from a high productivity associated with outflow of river water; 3) a water with low relative content (90%-100%) from the northeastern coast of Brazil,which extends over a greater part of the north region under consideration.

The surface distribution of salinity, temperature and dissolved oxygen show the same general features.

PHOSPHATE - The inorganic phosphate distribution (Fig. 3c) shows an average value of 0.40µgat PO_4-P/1 with a maximum value of 0.69µgat PO_4-P/1 at 4^oN-45^oW.

High concentration of inorganic phosphate (0.60µgat PO_4-P/1) are also recorded near Salinópolis at the river mouth with associated low dissolved oxygen concentrations (92%).

In summary it is worth mentioning that stations 23 and 24(series B), near Salinópolis, have distinctly oceanic characteristics in all aspects, compared to the corresponding stations 1, 2, 3 (series A), taken one month earlier.

10 m LAYER

SALINITY - The $35^o/oo$ isohaline at 10 m (Fig. 4) is found in very near the coast; the lesser valued isohaline are thus restricted to within the river mouths with correspondingly higher salinities than those at the surface.

A fact worth-noticing is the presence of a low salinity water mass ($28.9^o/oo$) at station 4 in a region where salinity values range between $34^o/oo$ and $35^o/oo$. This is most probably due to a depression of the halocline in the centre of a vortex created in the wake of a shallow bank (15 m)situated in the river mouth.

TEMPERATURE - A distribution similar to that of the surface may be found for the temperature (Fig. 4a). At stations south of the Equator, temperature values are slightly higher than those at the surface, with a 28.13^oC, near Salinópolis (c.f. maximum surface temperature 27.79^oC).

As before the 27^oC isotherm may be regarded as dividing the region into two temperature regimes. However, with the exception of station 4 (27.3^oC), coastal stations show temperatures greater than 27.5^oC.

OXYGEN - Maximum value of dissolved oxygen is 4.3 ml (c.f. 5.2 ml/1 for the surface),except at station 4 (Fig. 4b) . The values of relative oxygen are everywhere less than 100% even near the river mouth (Fig. 4d), and near Salinópolis drops as low as 34%. From it is clear that high productivity is restricted the first 10 m.

PHOSPHATE - The inorganic phosphate distribution (Fig. 4c) shows some interesting points. Station 24,near Salinópolis,presents a maximum of 0.87µgat PO_4-P/1, an exceptional value for coastal waters which is in accordance with the lowest value of dissolved oxygen (1.55 ml/1), and with the high temperature (28.13^oC). If nitrite values are considered they show a completely uniform distribution at all depths with the unique exception of station 24, which presents a maximum value (1.20µgat NO_2-N/1).The probable explanation for this anomalous values lies in the fact that a stationary eddy forms to the east of the Pará river mouth due to the changes in the outflow. The centre of the eddy stagnates, killing off the biomass produced the month before under favorable conditions. Decomposition consumes the oxygen and causes the liberation of phosphorus and nitrogen compounds to the water.

20 m LAYER

SALINITY - The $35^o/oo$ isohaline (Fig. 5)is restricted to the three stations near the Pará river mouth, and oceanic water predominates in the remaining part of the region. At station 14, near Cayenne, water presenting characteristics of the 50 m layer appears from 20 m down.

TEMPERATURE - A small region of warm water (28.6^oC) is found near the coast, at Salinópolis (Fig. 5a). From the north an intrusion of colder waters temperature below 27^oC, is recorded. At station 14, also the minimum temperature for the layer was encountered, 26.01^oC. The isotherm 27^oC follows the same pattern of the shallower layers except for station 14.

OXYGEN - Near Salinópolis, a minimum of dissolved oxygen was recorded (1.79 ml/1), while at Cayenne (Fig. 5b), still near the coast, the maximum values for dissolved oxygen (4.6 ml/1) were recorded,associated with water from the deeper layers. The relative values (Fig. 5d) of oxygen show the penetration of two tongues lower than 90%

from SE and N.

PHOSPHATE - Inorganic phosphate distribution (Fig. 5c) maintains the same characteristics as those of the shallower layers.

30 m LAYER

SALINITY - Salinity values in this layer (Fig. 6) are almost all about 36°/oo; a restricted zone of low salinity is recorded, (below 35°/oo), around the Pará river mouth. Using the value 35°/oo the limit of the influence of fresh water, the last trace of its presence is recorded in this layer.

TEMPERATURE - The warm water mass coming from the SE (Fig. 6a) with a maximum temperature of 28.01°C at 0°N and 47°W is still present.

The 27°C isotherm still divides the area into two parts. The anomalous station near Cayenne show a temperature of 25.9° C, the minimum for that layer.

OXYGEN - Two facts may be pointed out in the distribution of dissolved oxygen (Figs. 6b and 6d): 1) the presence of waters with high dissolved oxygen values near Cayenne; 2) waters with low dissolved oxygen values, coming from the northeast.

PHOSPHATE - Inorganic phosphate maintains the same characteristics, however an exceptional value 0.85µgat PO_4-P/l is noted for station 5 (Fig. 6c).

50 m LAYER

SALINITY - The fresh water from the rivers is no longer present (Fig. 7).

TEMPERATURE - Temperatures (Fig. 7a) above 27°C are still recorded as the result of the presence of water from the northeast coast. In the station near Cayenne the presence of deeper water upwelling is more marked due to the 23.9°C isotherm (c. f. 27°C).

OXYGEN - The distribution of dissolved oxygen (Fig. 7b and 7d) in that layer is not significant. In general, all values are around 4.00 ml/l, except for stations near the 50 m isobath.

PHOSPHATE - For the inorganic phosphate (Fig. 7c) the isolines near the 50 m isobath and following it, are of special interest since a relatively high concentration of inorganic phosphate to be expected due to the proximity to the bottom. However, for the greater part values under 0.5µgat- PO_4-P/l were found.

VERTICAL DISTRIBUTION

Four sections perpendicular to and one parallel to the coast were chosen for vertical distribution (Fig. 1).

In section 1, (Fig. 8) the 35°/oo isohaline reaches the station 22, about 100 nm off the coast, extending from the surface to the bottom, delineating in a very marked fashion the seaward penetration of fresh water. The 30°/oo isohaline extends almost 50 nm off shore, but never exceeds 10 m depth.

From the surface to 50 meters depth, temperature (Fig. 9) over 26.8°C are recorded increasing to over 27.5°C towards the coast. Special reference should be made to the coastal station (no. 24) with a high dissolved oxygen content (Fig. 10) in surface waters of low salinity 21°/oo and high temperature 27.7°C. Below 5 m until the bottom salinity and temperature increase (31°/oo and 28°C) and a high inorganic phosphate (Fig. 11) is recorded.

Section II (Fig. 12), fronting the Amazon and Pará rivers, shows the 35°/oo isohaline reaching about 150 nm off shore, and attaining a maximum depth of 20 m. A core of warm water (Fig. 13) is readily identified as extending to 30 m. Below this core we find a high value of inorganic phosphate (0.80µgat PO_4-P/l) (Fig.15). It is concluded that this maximum is caused by liberation of phosphate from the sediment, yet at the same time, the utilization of this phosphate by phytoplankton is impeded by the very small quantities of light penetrating the water column below 20 m. Nevertheless a distinct rise in the oxygen content of the usually oxygen-poor Guiana Current is noted (Fig.14).

In section III, the 35°/oo isoline, (Fig. 16) approaches the coast and is not recorded below 15 m. The 150 m layer shows salinities above 36°/oo throughout. Temperatures above 27°C (Fig. 17) indicate the presence of the Guiana Current at stations near the coast (12 and 13). Station 13, nearest to the coast, shows a high dissolved oxygen content, (Fig. 18) for all depths, indicating an average value of relative oxygen above saturation. For the same station, the inorganic phosphates are in a relatively high concentration which originates from the sediments in the river-ocean mixing zone (Fig. 19).

In section IV, the 35°/oo isoline is confined to the surface layer (Fig.20) reaching about 80 nm off the coast. There is evidence that the Guiana Current begins to swing away from the coast allowing subsurface waters to dominate in the stations nearer the coast (Fig. 21). The oxygen profile (Fig. 22) of the coastal stations show 2 maximums dissolved oxygen associated with two different water masses: a surface one, restricted to a 5 m layer, in low salinity waters and the other at 40 m in oceanic water. Inorganic phosphates were reduced in the surface layer due to intense consumption (Fig. 23).

In section V, parallel to the coast, the outflow of the fresh water from the Pará and Amazon rivers (Fig. 24) is more intense at the mouth of the latter (station 3), and therefore salinity values are not higher than 12°/oo. This is due not only to the fresh water volume, but also to the direction of the Guiana Current in relation to the coastline. The whole section reveals the presence of a wedge shaped mass of fresh water, with a sharp interface of penetration into the Guiana Current at the river mouth. The wedge gradually looses its intensity in a long tail of mixing.

The distribution observed can be explained by the superposition of 3 wedges which relate to the outflow of three main rivers the Pará, Amazon and Oyapoque.

Dissolved oxygen concentration (Fig.26) is directly influenced by the waters from the Amazon and Pará rivers. From 5 ml/l at the surface, and in only 10 m, the profile, shows a sharp drop of 3.8 ml/l (station 2), or from a relative concentration of 103% to 85%, due to mixing with oxygen-poor surface waters of the northeast coast.

At stations 13 and 14, the isotherms show a strong presence of cooler waters; the isotherm 26°C, never found at depths above 50 m, are recorded at 20 m, at station 14, (Fig. 25). Upwelling waters, relatively rich in inorganic phosphate content,give relative oxygen values above saturation for all the superficial layer (Fig. 27).

WATER MASSES SYSTEMS AND CURRENTS

Beyond the continental shelf, far from the influence of fresh water from Amazon and Pará rivers, characteristic salinity maximums over 36.5°/oo were recorded between 75-125 m depth, just within the thermocline (Newmann & Pierson, 1966). Minimum salinity values around 34.5°/oo, are recorded at 400-900 m depth (5.2-5.5°C). Thereafter, salinity values increase up to a maximum of 35°/oo at a depth varying between 1,000 and 1,500 m, (3.5 - 4.0°C) whereafter they decrease again. The TS relationship for the region free from the influence of the rivers, as well as, the vertical distribution of temperature and salinities at each station, are not presented herein since they agree with those of Sverdrup *et al.*,(1942).

Silva (1958-1959) in his paper emphasizes that he found in the north the same South Atlantic ocean structure mentioned in Sverdrup's "The Oceans". Silva characterizes the minimum salinity layer (34.5°/oo) from the minimum salinity value found in the southeastern coast of Brazil; the intermediate waters of the north Atlantic is recorded in a layer of 1,000 to 1,500 m and also with the maximum salinity value higher than in the east coast and, as the author emphasizes, probably with a reinforcement of waters from the Mediterranean.

Murano (1963) discusses the distribution of the water system peculiar to the whole region under observation, and mentions in his paper the following 4 systems:

a - the south Equatorial Current (Guiana Current), displacing NW, beyond the continental shelf, with a surface salinity of about 35.5°/oo - 36°/oo;

b - a Coastal Current, also displacing NW, on continental shelf, with salinity below 20.0°/oo, originating in the Amazon river;

c - waters from Amazon and Pará rivers running initially eastwardly, with salinity lower than 20.0°/oo and;

d - a Northern Coastal Water, with low salinity (15-20°/oo), as mentioned by Murano, seems to be part of the waters from Amazon and Pará rivers. The details are unknown.

Some of these points are raised by Luedemann (1967) in her paper on the release of drifting bottles, during the cruises A and B. Her results clearly show the behaviour of the bottles in the same area (stations 1-A and 24-B). The bottles released in March drifted southeasterly. This dependence on the local season, shows that the waters from Pará river flow eastward and confirms the formation of a stationary eddy at Salinópolis at these times of the year.

At other periods, however, little may be ascertained in relation to details, since the region under influence of the Amazon and Pará rivers is probably very much related to the wind variations, to the supply of fresh water and to the northern coastline which is characterized by strong concavity at the rivers mouth.

NUTRIENTS AND OXYGEN

According to Gessner (1962), the Amazon river waters are extremely poor in soluble phosphate. However, Gessner carried out a series of experiments and verified that sediment in permanent contact with the rivers waters supplies phosphate to the water. Thus, the phosphate consumed by photosynthetic activities is constantly replaced by sediments.

According to Moore (*cit. in* Armstrong, 1965, p. 333) the amount of phosphorus absorbed by the sediment in an estuary is about 10^5 times the concentration recorded for the subjacent water. Carritt & Goodgal (*cit. in* Armstrong, 1965, p. 333) showed that the sediment phosphatus uptake is reversible and that the description is favored by an increase in pH. The Amazon river carries a large amount of sediment in suspension which supply phosphorus when it reaches the estuary. The phosphatus discharged in the Amazon estuary is, however, promptly consumed at the first 5 m, where the turbidity is reduced permitting light penetration. A photometric depth transmission was taken in cruise B at the following stations: 3, 7, 11, 15, 18, 22 (Teixeira & Tundisi, 1967).

It is worth mentioning the relative values of primary productiviy found by Teixeira & Tundisi (*op. cit.*) for the surface. Taking a 100% value corresponding to 0.86 gC/m^2/day for station 3, which is under direct influence of fresh water, the other 5 oceanic stations studied would show relative values under 30%. The stations near the coast, 3 and 22, showed the highest primary production, a fact specially important at station 3 in front of the Amazon river mouth. The light penetration at station 3 did not reach deeper than 10 m (total extinction), while the dissolved oxygen did not reach saturation, a fact also found at station 22. Gessner (*op. cit.*) states that decisive changes in the dissolved oxygen concentration are recorded at the river mouth caused by reduction of water speed, bringing about sedimentation. The precipitation of sediments would allow greater light penetration and thereby stimulating phyto - plankton development.

The values of consumed oxygen or its apparent utilization were evaluated by means of the actual oxygen content and the values of the oxygen solubility in the sample in equilibrium with the atmosphere at 760 nm of Hg, regarding salinity and temperature (Richards & Corwin, 1956), for the stations 1-A, 24-B; 2-A and 23-B, we find the average values of : 0.71 ml/l, 2.27 ml/l, 0.68 ml/l and 0.78 ml/l. A great increase of consumed oxygen may be seen in the correlationed stations 1-A and 24-B. At stations 2-A and 23-B a small increase was recorded. In general, the same conditions were recorded throughout the column at stations 2-A and 23-B, for 32 days. The difference observed does not indicate an intense change in oxygen content. For stations 1-A and 24-B, with 32 day interval, the water column showed an average increase of 1.56 ml/l for apparent oxygen utilization. However, the surface of station 1-A was saturated with oxygen (105%). The surface values compared of stations 1-A and 24-B show an increase of 0.49 ml/l.

Therefore, the great change found in the apparent utilization of oxygen, refers only to the station nearest to the coast, and particularly within the top 5 m. Since the salinity and temperature conditions remained the same for both stations (1-A and 24-B) it may be assumed that the variation recorded at the surface is not physical altering the partial pressure of the oxygen in liquid phase.

On the other hand, nitrogen combined in its inorganic forms (nitrite, nitrate, ammonia) seems to be supplied by the water of the Amazon and Pará rivers, since the water mass carried by the South Equatorial Current is practically exhausted in inorganic nitrogen. During the Equalant I, some determinations of nitrite were made (Ct. "Bertioga", "M. Lomonosov", "Zvezda" and "Olonets"). Otherwise no determinations were made for others forms of nitrogen. The area covered by "M. Lomonosov", "Zvezda" and "Olonets" expeditions (NODC, 1964) was 004°W - 020°W and 12°S - 09°S, and the nitrite data indicate extremely low values not only in the subsurface but also in the deeper layers, besides a regular structure of dissolved oxygen content. Thus the inorganic nitrogen should be supplied by the water rivers.

SUMMARY

1 - The penetration of the fresh waters from Amazon and Pará rivers over the continental shelf extends northeasternly almost reaching the edge of the continental shelf. Thereafter, they are contained by the Guiana Current and follow the NW direction of that Current.

2 - The temperature of the less saline waters (<35°/oo) is 27°C - 27.5°C lower than the water mass from the northeastern coast of Brazil (>27.5°C).

3 - The highest dissolved oxygen values (5.23 ml/l) are found near the coast, in waters with 15°/oo salinity and 27.4°C temperature, and in the first 5 m. The values of dissolved oxygen decrease as the water from the rivers mixes into the ocean.

4 - The river water carries a larger amount of sediment in a position to supply phosphorus when it reaches the estuary. The phosphate discharged in the estuary is promptly consumed within the top 5 m. This is due to a reduction of turbidity promoted by sediment settling permiting deeper light penetration.

ACKNOWLEDGEMENTS

The author wishes to acknowledge Mr. Norman J. Rock for his critical reading and kind revision.

RESUMO

1 - A penetração da água doce dos rios Amazonas e Pará, extende-se na direção NE atingindo a borda da plataforma continental, onde são retidas pela corrente da Guiana tomando a direção dessa corrente, isto é, NW.

2 - A temperatura das águas menos salinas (<35°/oo) está entre 27°C - 27,5°C, inferior à temperatura da massa d'água originária da costa nordeste do Brasil (>27,5°C).

3 - Os altos valôres de oxigênio dissolvido (5,23 ml/l) são encontrados próximos à costa em águas com 15°/oo de salinidade e 27,4°C de temperatura, nos primeiros 5 m. Os valôres de oxigênio dissolvido decrescem na medida em que as águas dos rios se misturam com as águas oceânicas.

4 - A água dos rios Amazonas e Pará transportam grandes quantidades de matéria em suspensão pronta a fornecer fósforo ao atingir o estuário. Pela sedimentação e consequente redução de turbidês, o fosfato liberado é prontamente consumido.

5 - Além da plataforma continental e fora da influência dos rios as condições prevalecentes são as mesmas para o Atlântico Equatorial.

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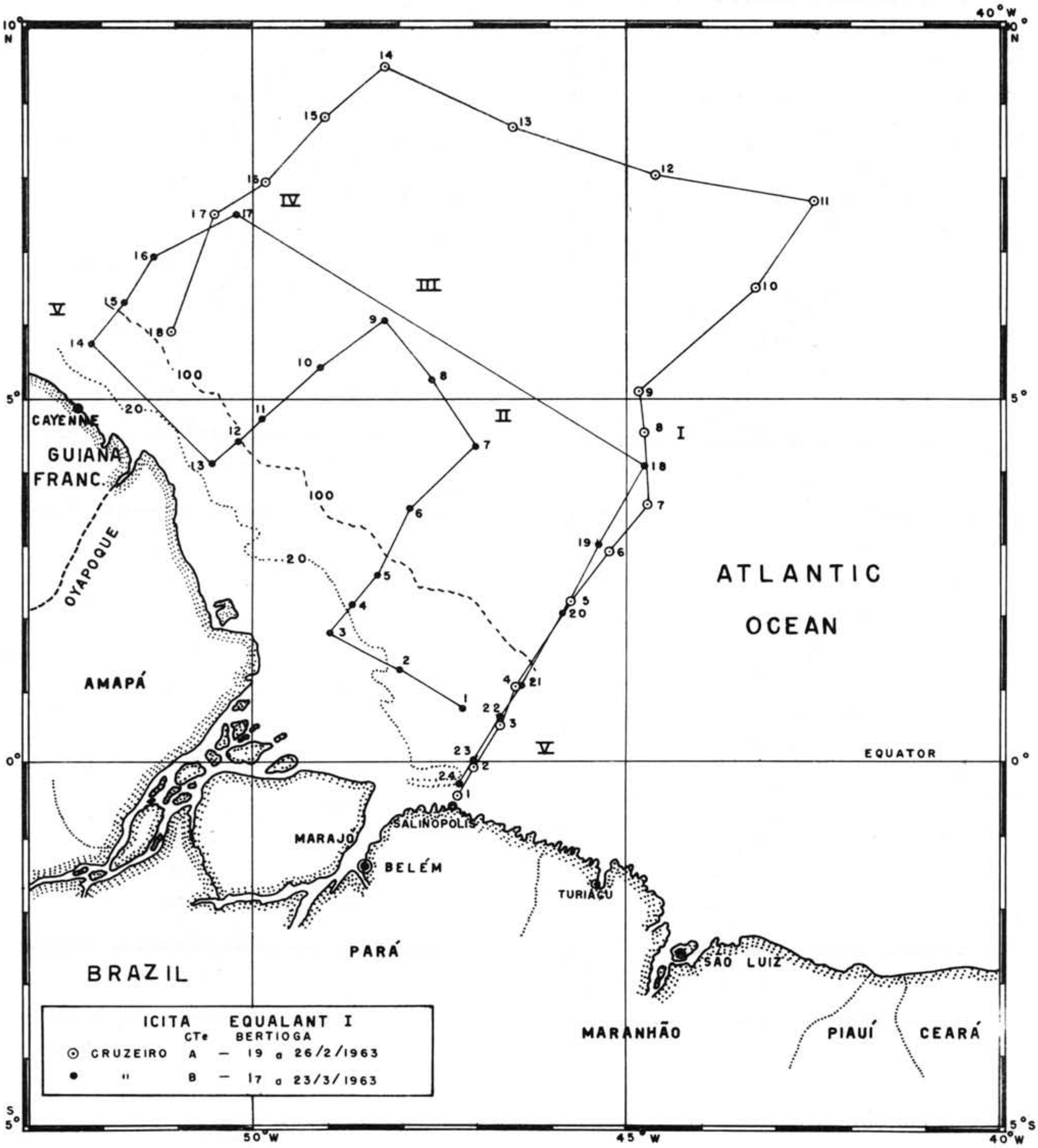


FIG. 1 - Stations occupied during EQUALANT I, February-March, 1963. Cruise A (open circles) and cruise B (dots). Roman numbers indicate vertical sections discussed in text.

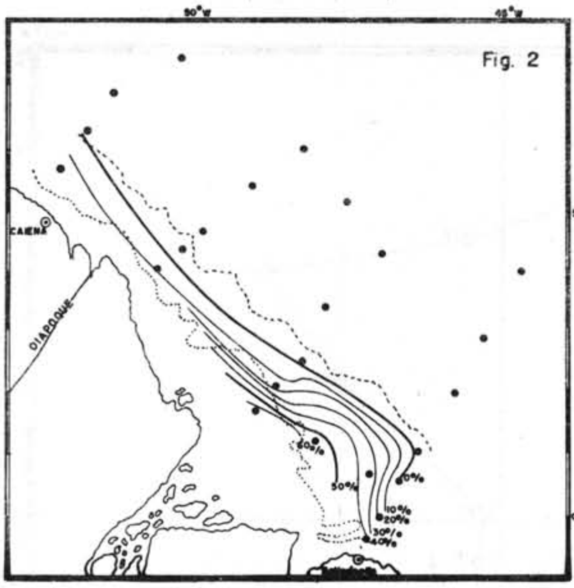


FIG. 2 - Surface Amazon and Pará rivers fresh water percentual values.

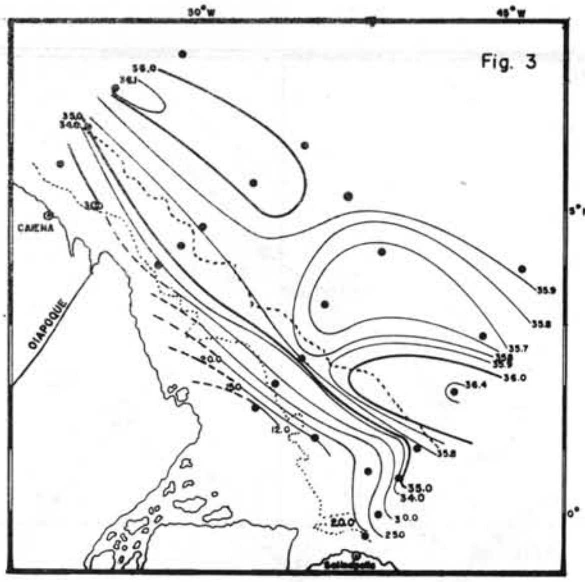


FIG. 3 - Surface salinities (°/oo).

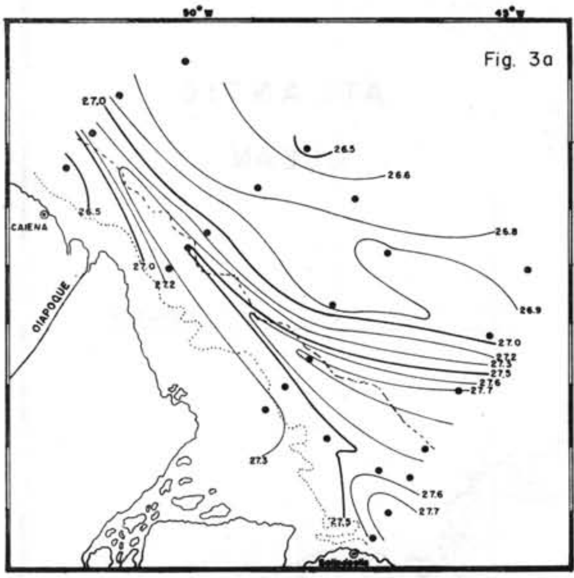


FIG. 3a - Surface temperatures (°C)

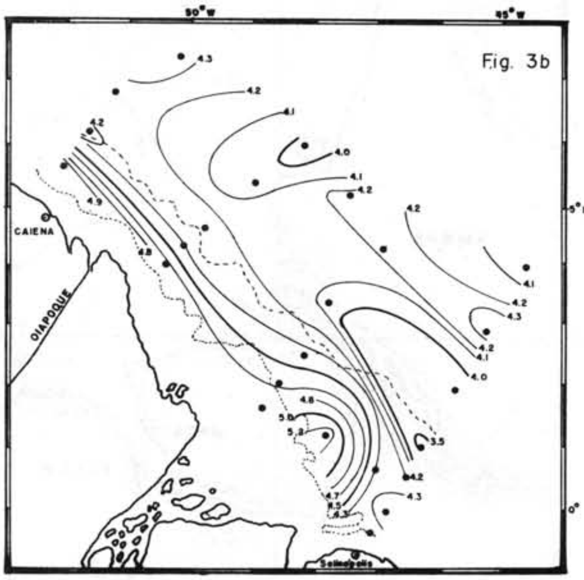


FIG. 3b - Surface dissolved oxygen (ml/l)

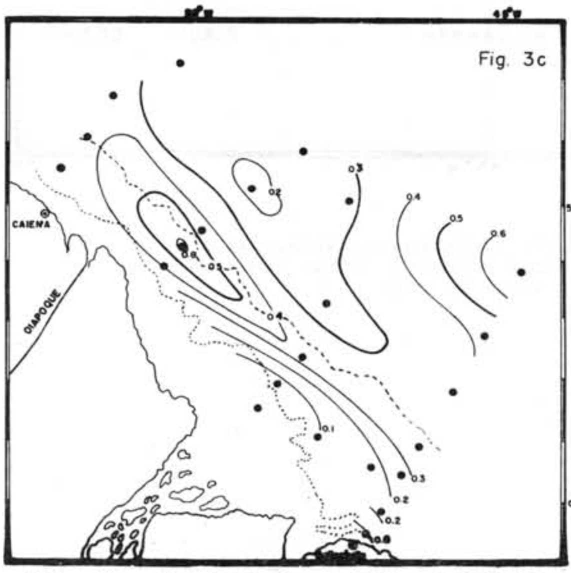


FIG. 3c - Surface inorganic phosphate (μgat PO_4-P/l).

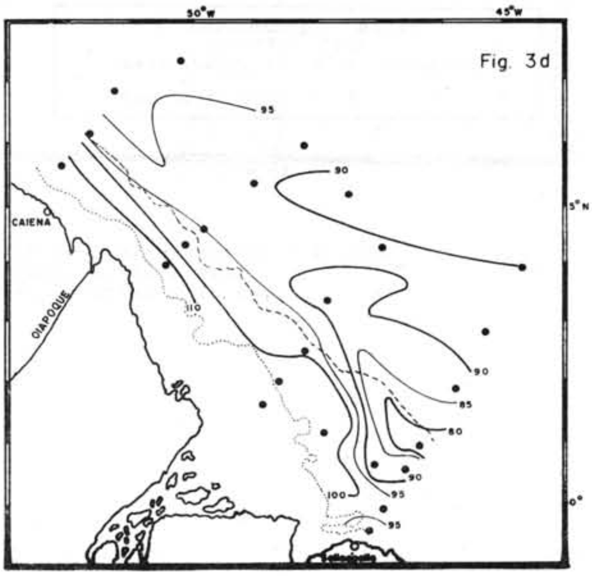
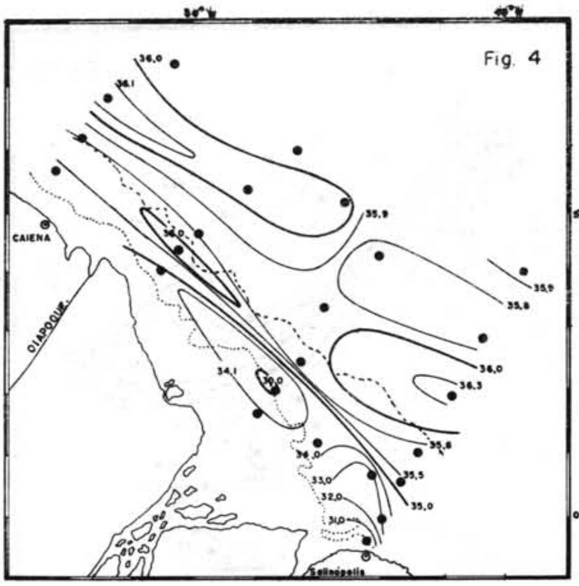
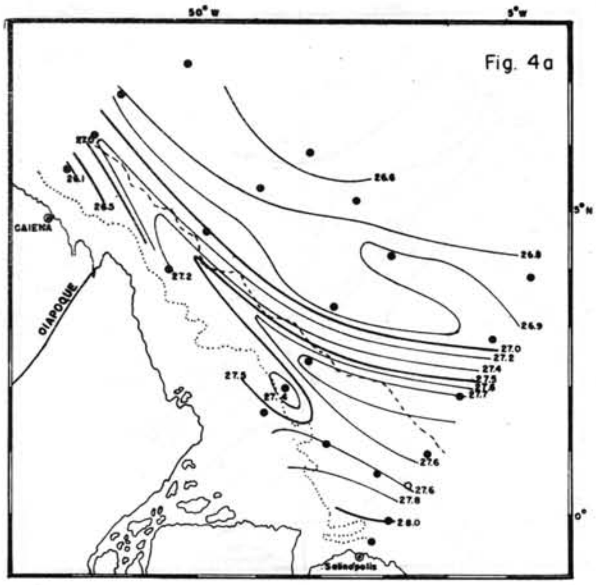
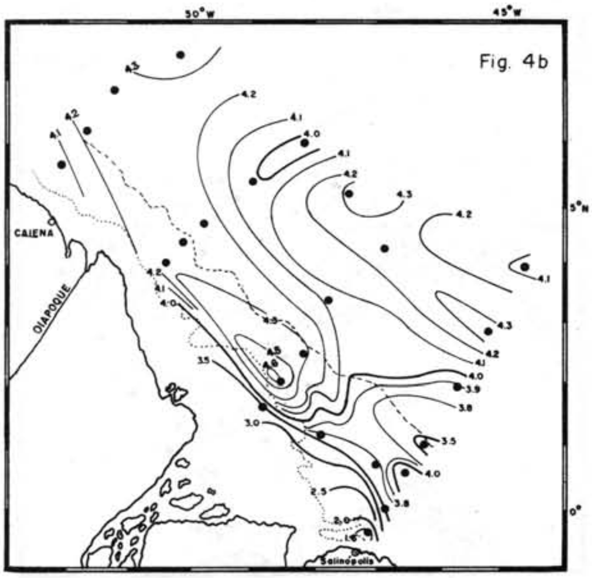
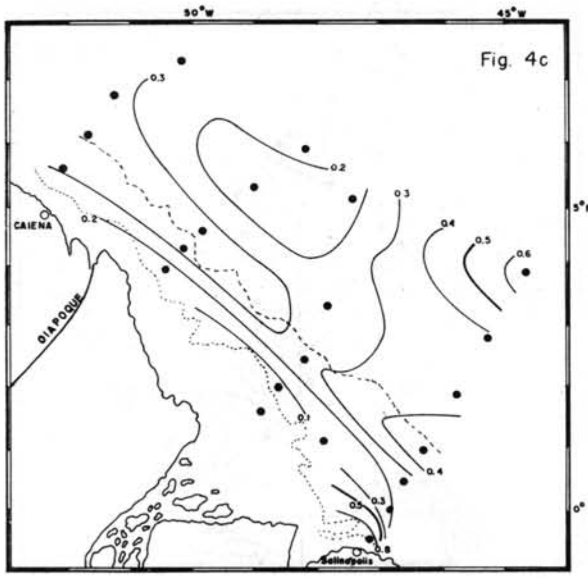


FIG. 3d - Surface relative oxygen (%)









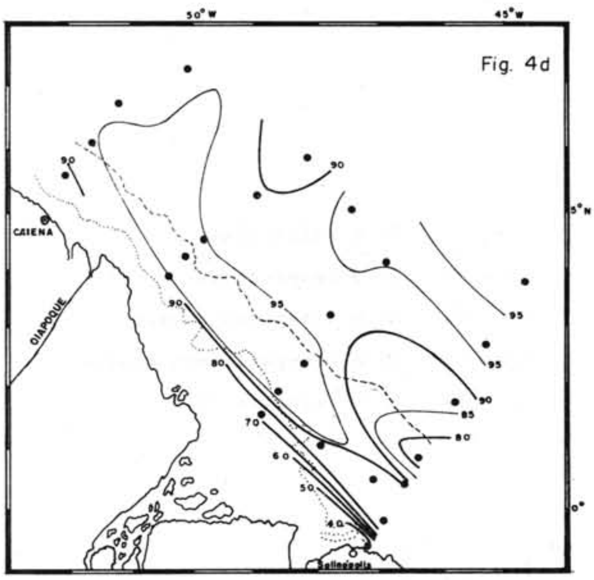


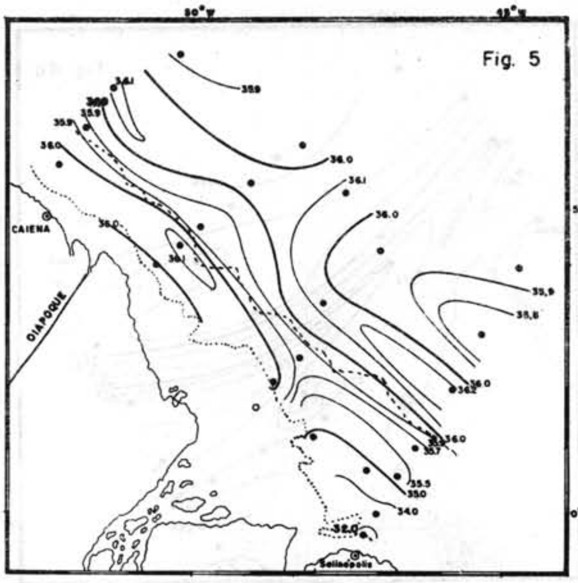
FIG. 4 - 10 m salinities

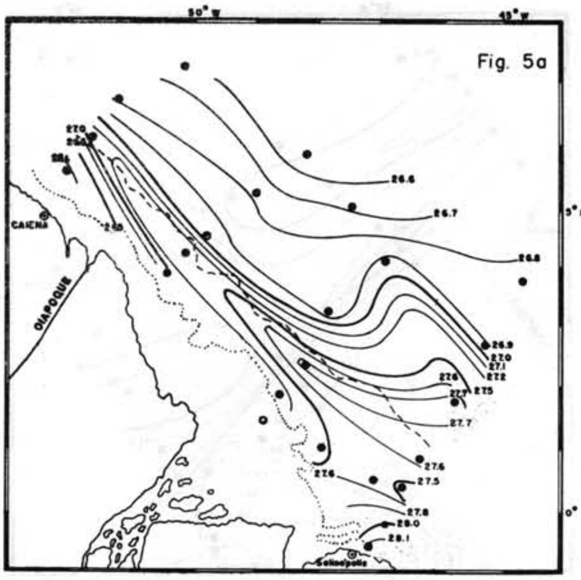
FIG. 4a - 10 m temperatures

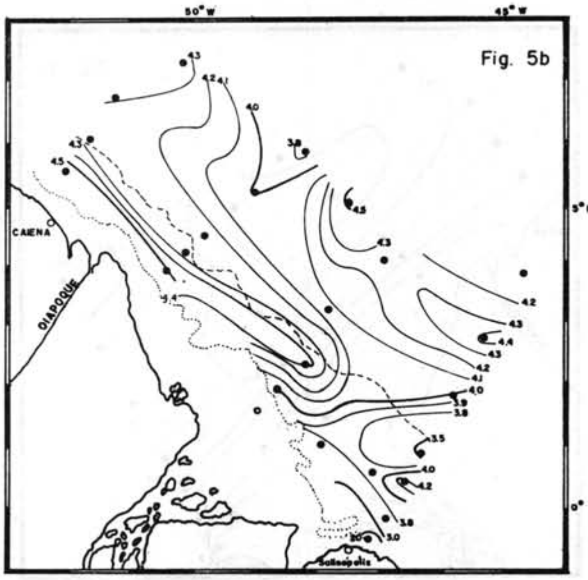
FIG. 4b - 10 m dissolved oxygen

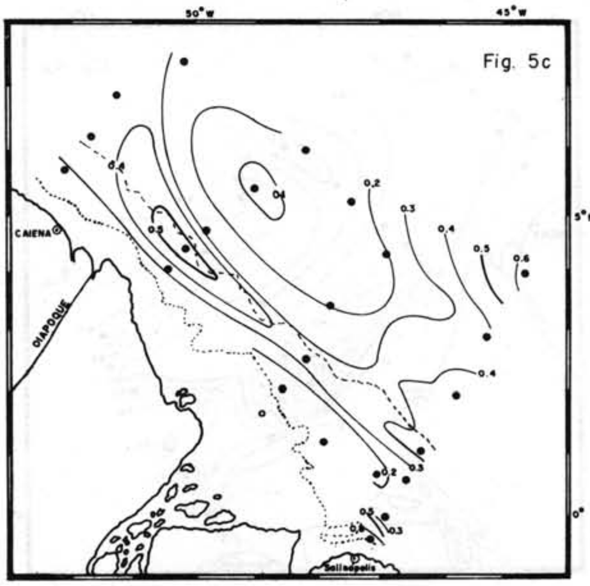
FIG. 4c - 10 m inorganic phosphate

FIG. 4d - 10 m relative oxygen









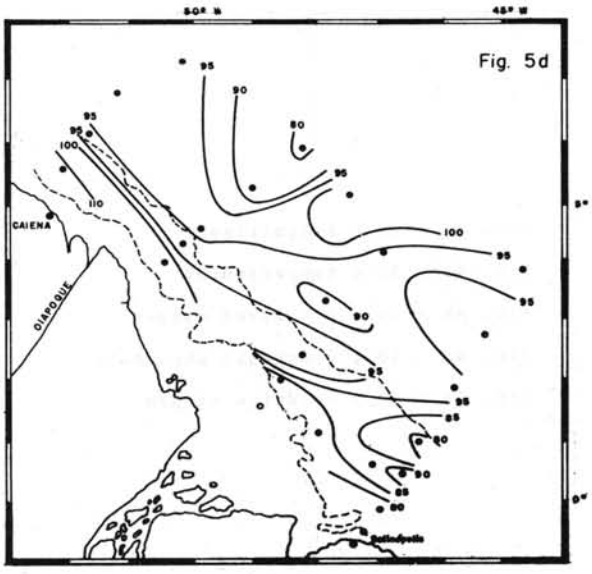


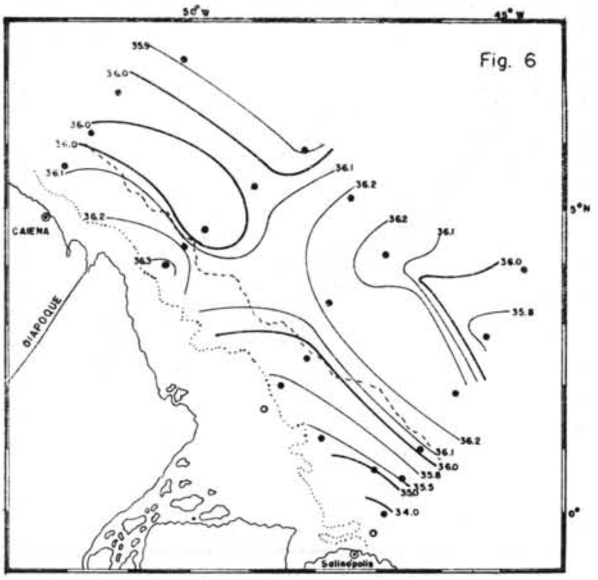
FIG. 5 - 20 m salinities

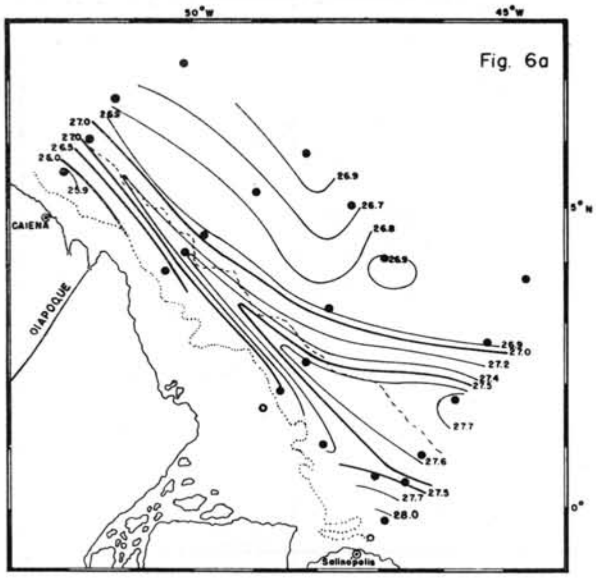
FIG. 5a - 20 m temperatures

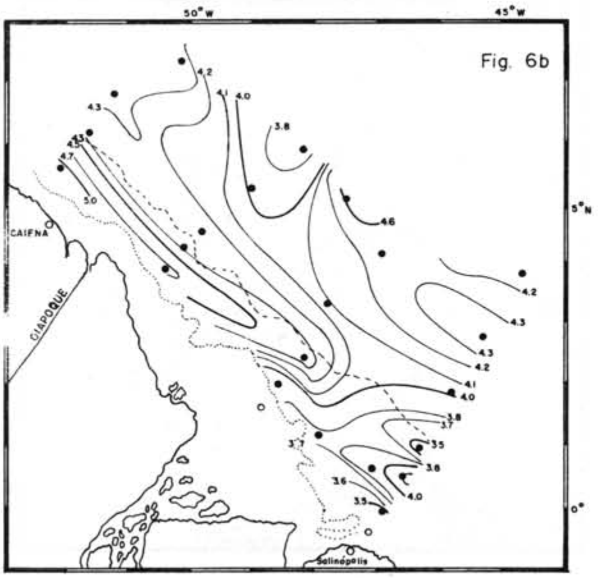
FIG. 5b - 20 m dissolved oxygen

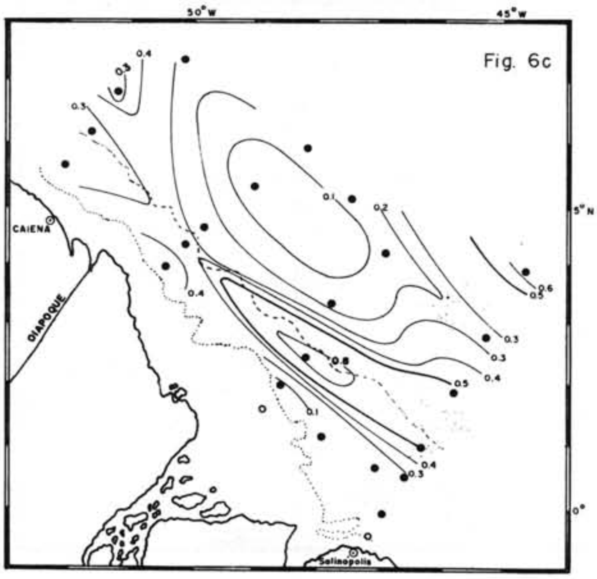
FIG. 5c - 20 m inorganic phosphates

FIG. 5d - 20 m relative oxygen









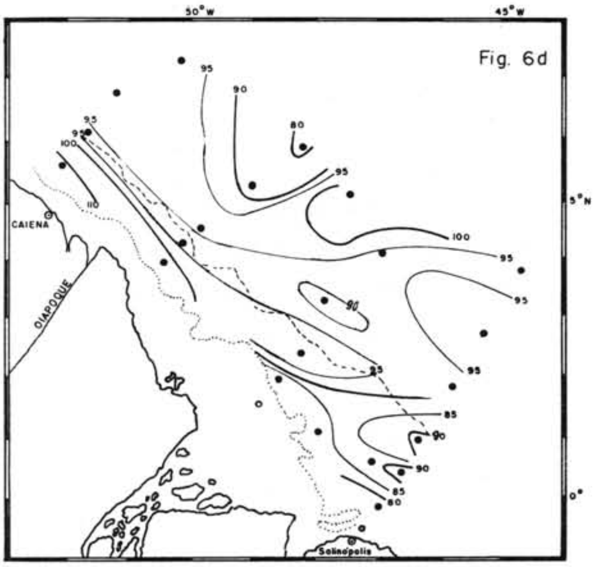


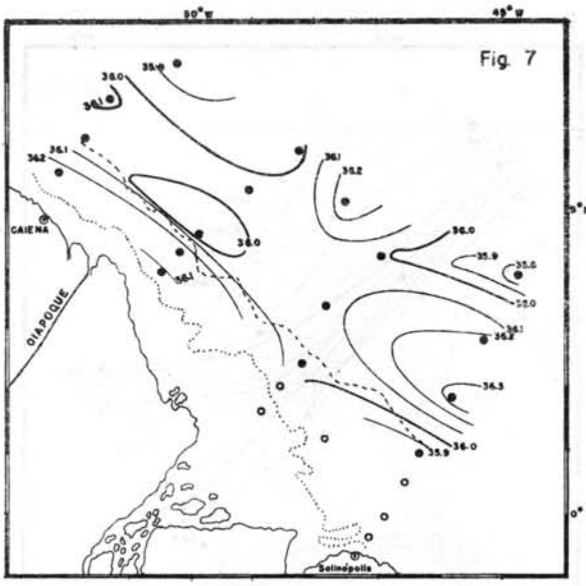
FIG. 6 - 30 m salinities

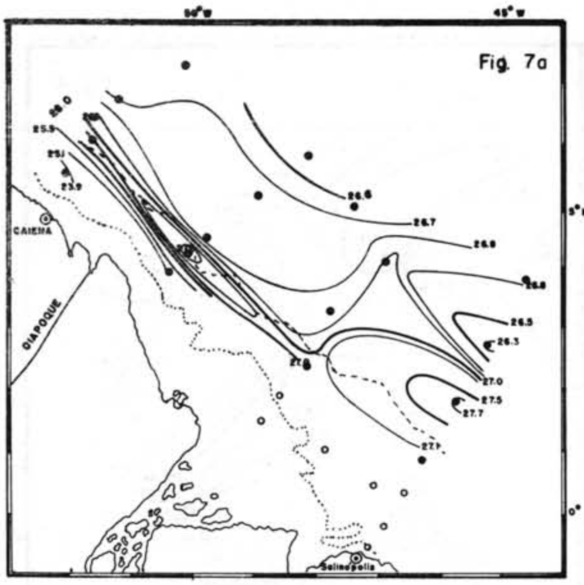
FIG. 6a - 30 m temperatures

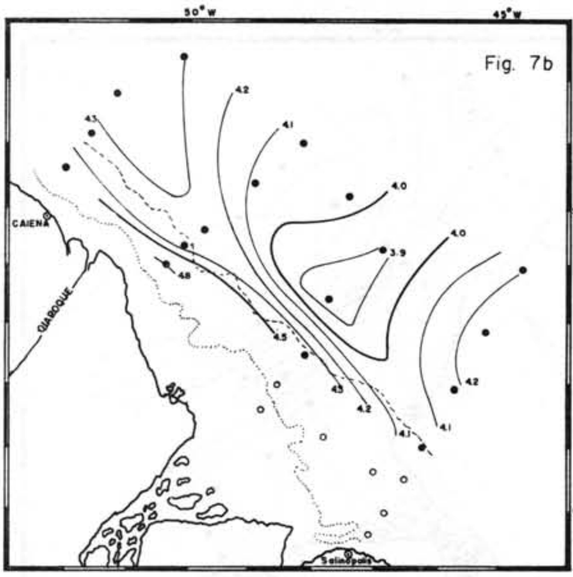
FIG. 6b - 30 m dissolved oxygen

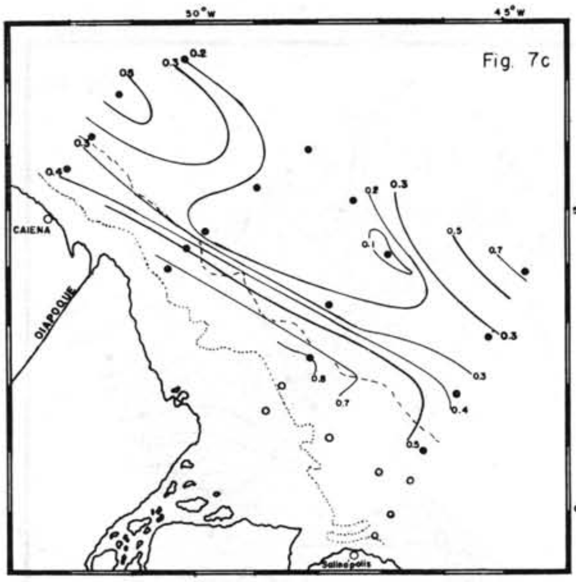
FIG. 6c - 30 m inorganic phosphate

FIG. 6d - 30 m relative oxygen









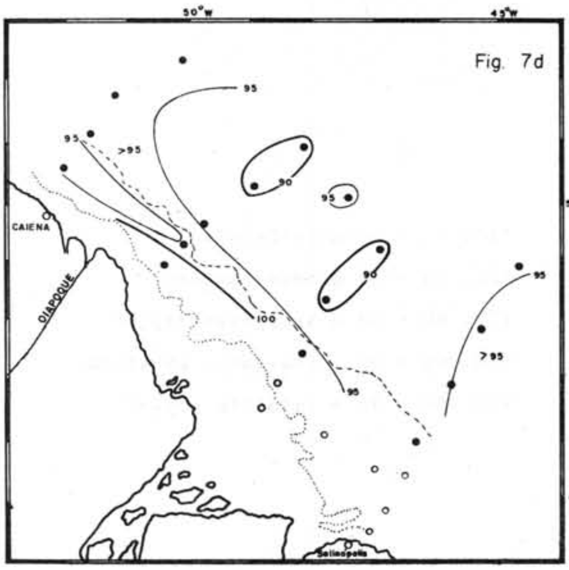


FIG. 7 - 50 m salinities

FIG. 7a - 50 m temperatures

FIG. 7b - 50 m dissolved oxygen

FIG. 7c - 50 m inorganic phosphate

FIG. 7d - 50 m relative oxygen

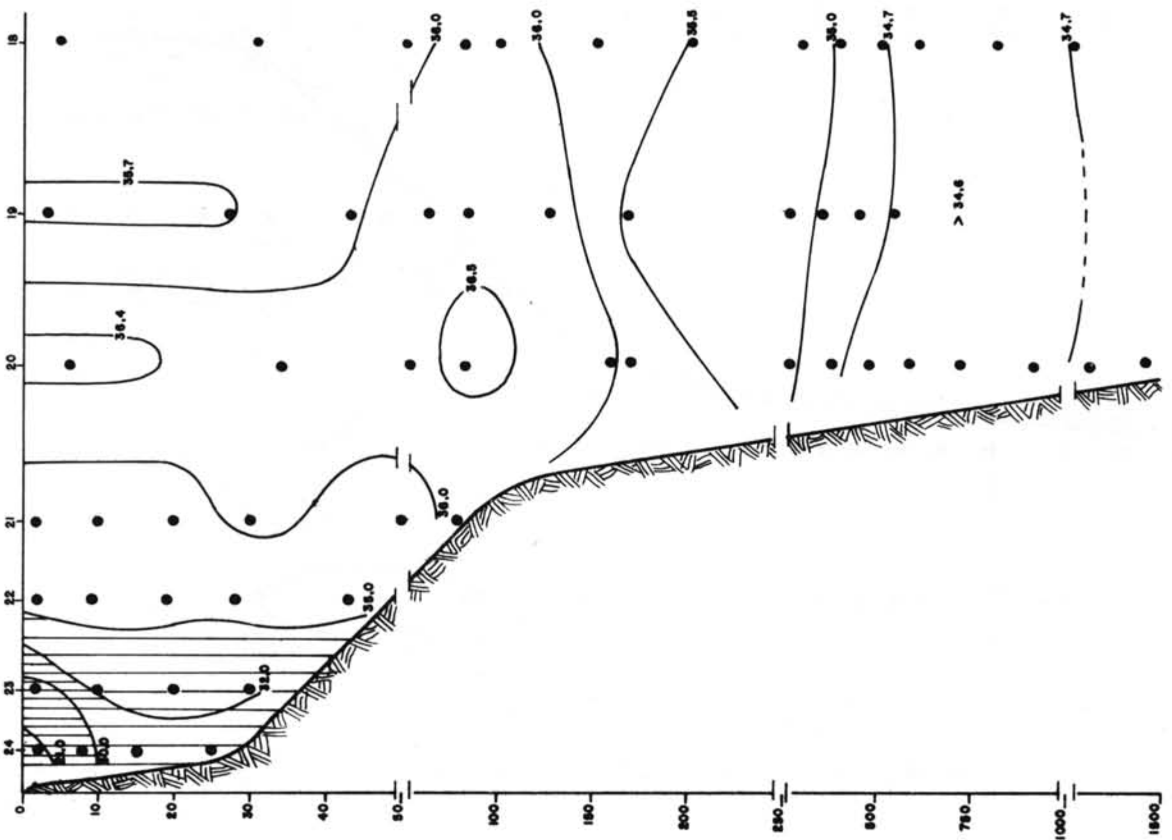


FIG. 8 - Section I. Salinities (°/oo).
Sampling positions indicate by dots.

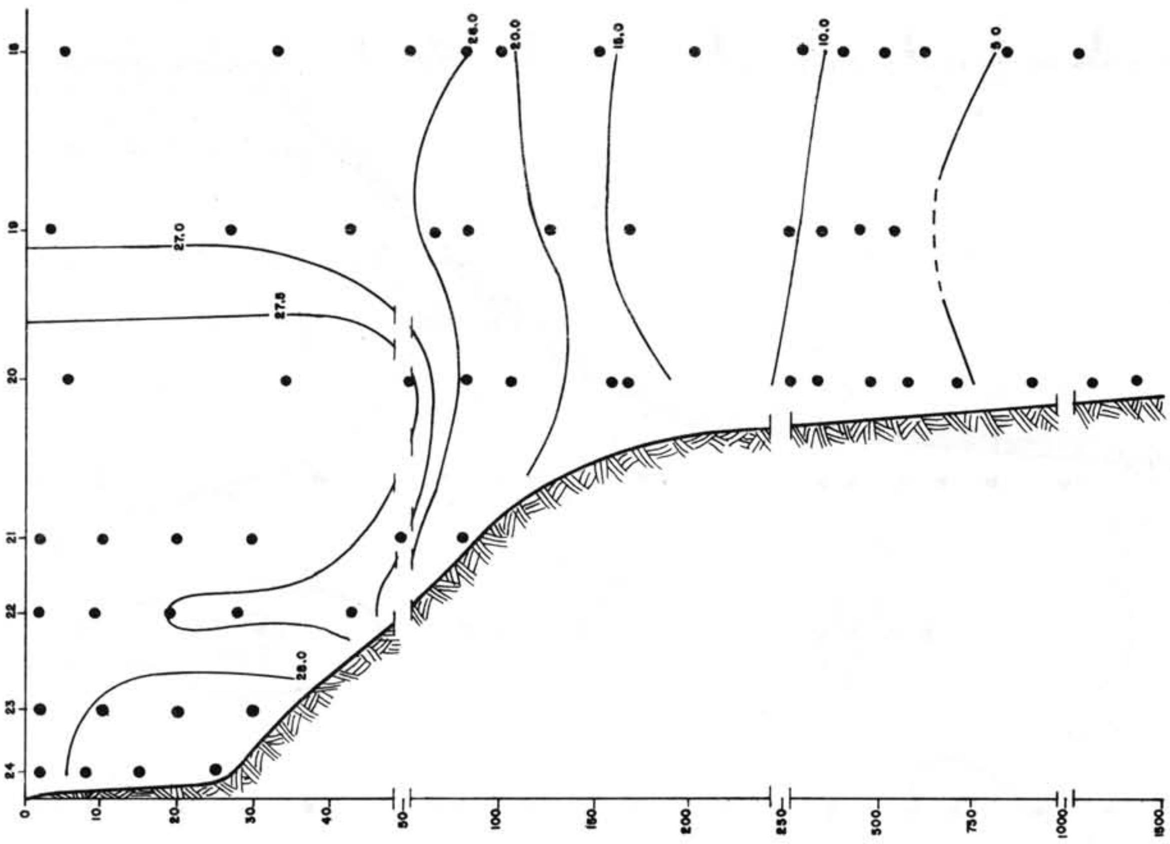


FIG. 9 - Section I. Temperatures (°C).

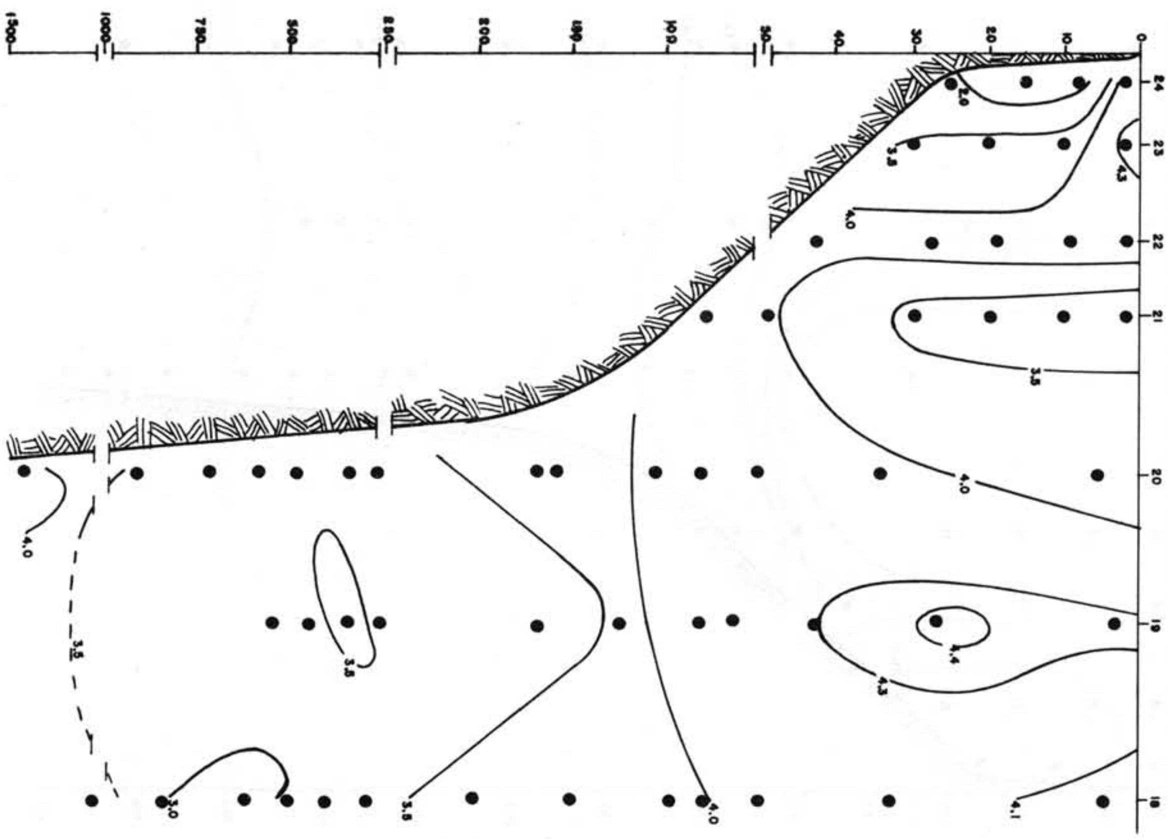


FIG. 10 - Section I. Dissolved oxygen (ml/l).

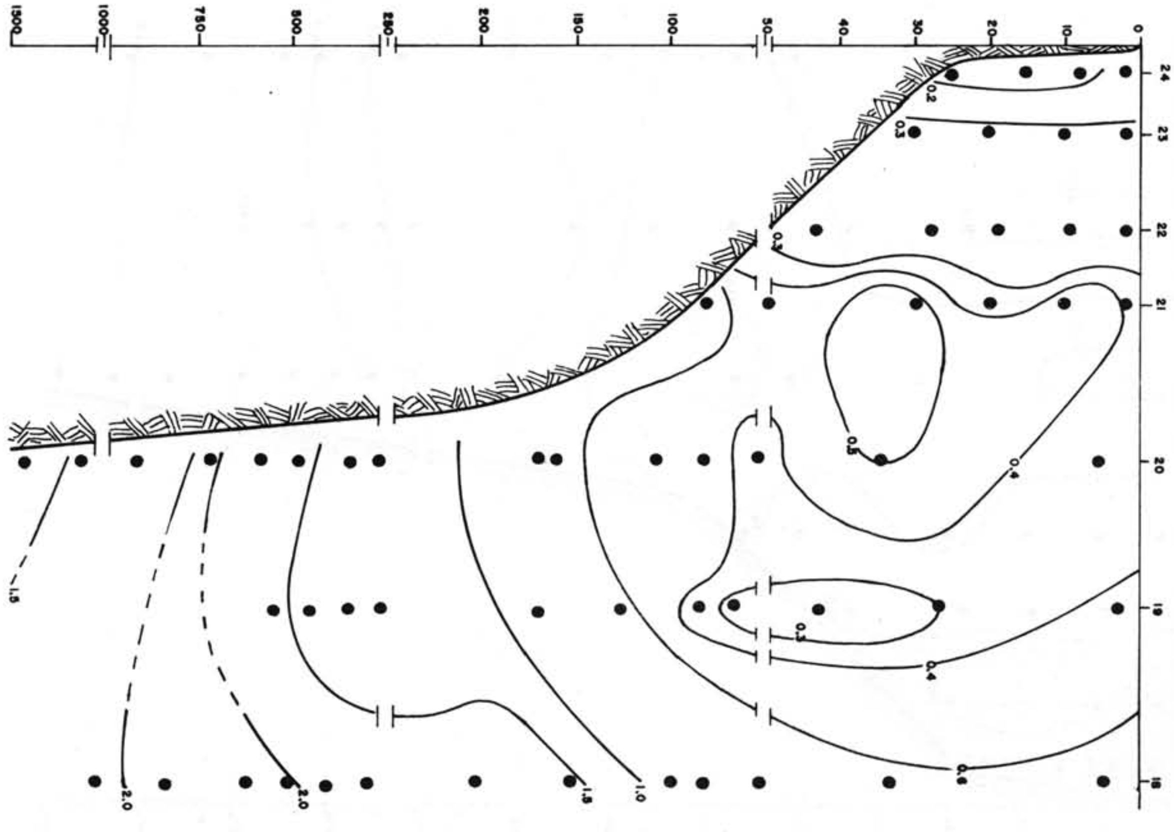


FIG. 11 - Section I. Inorganic phosphate (µgat PO_4-P/l).

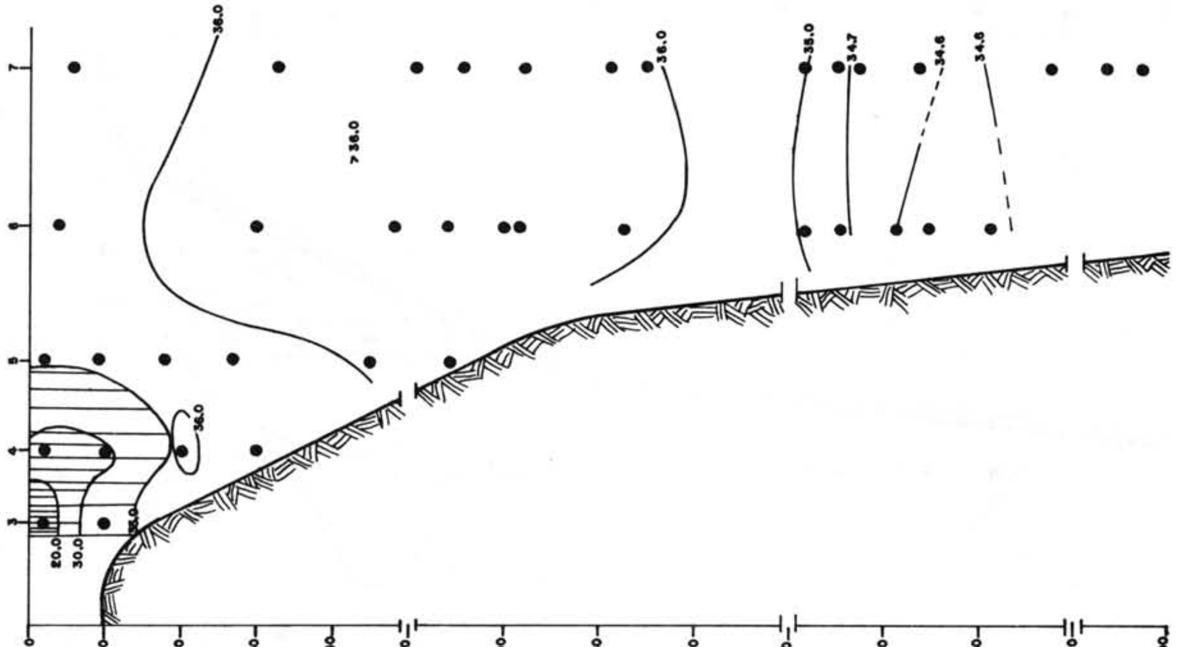


FIG. 12 - Section II. Salinities (°/oo).

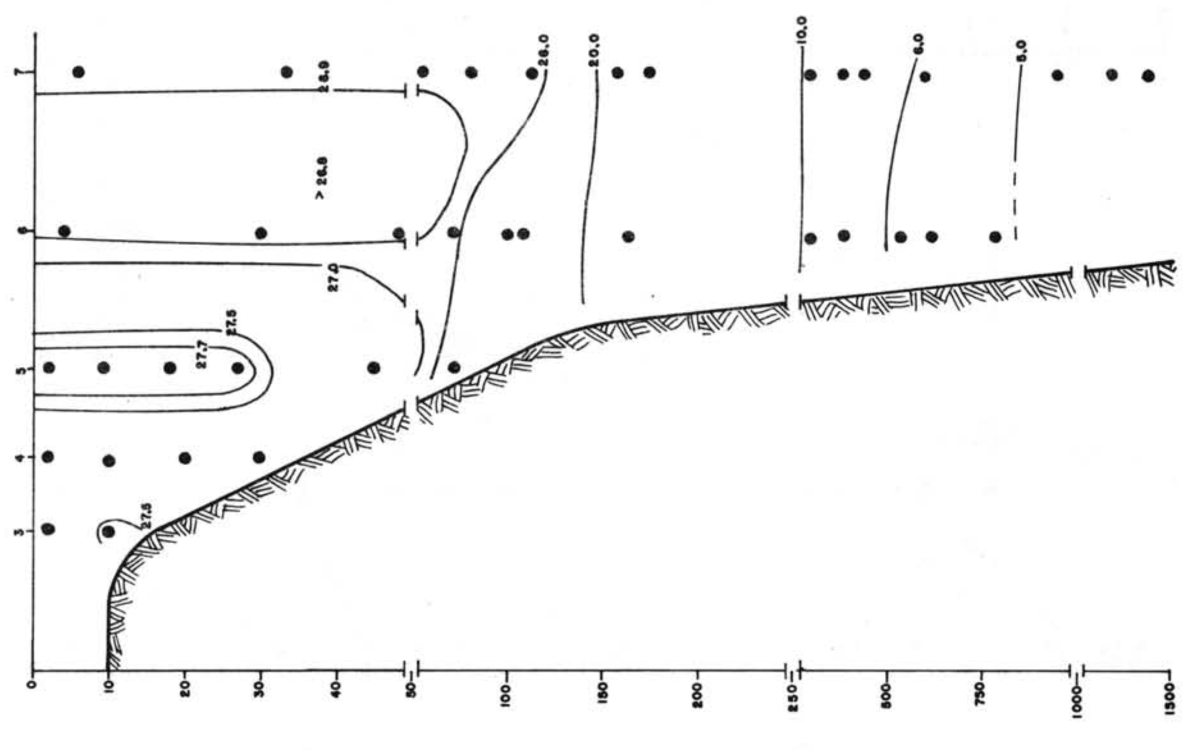


FIG. 13 - Section II. Temperatures (°C).

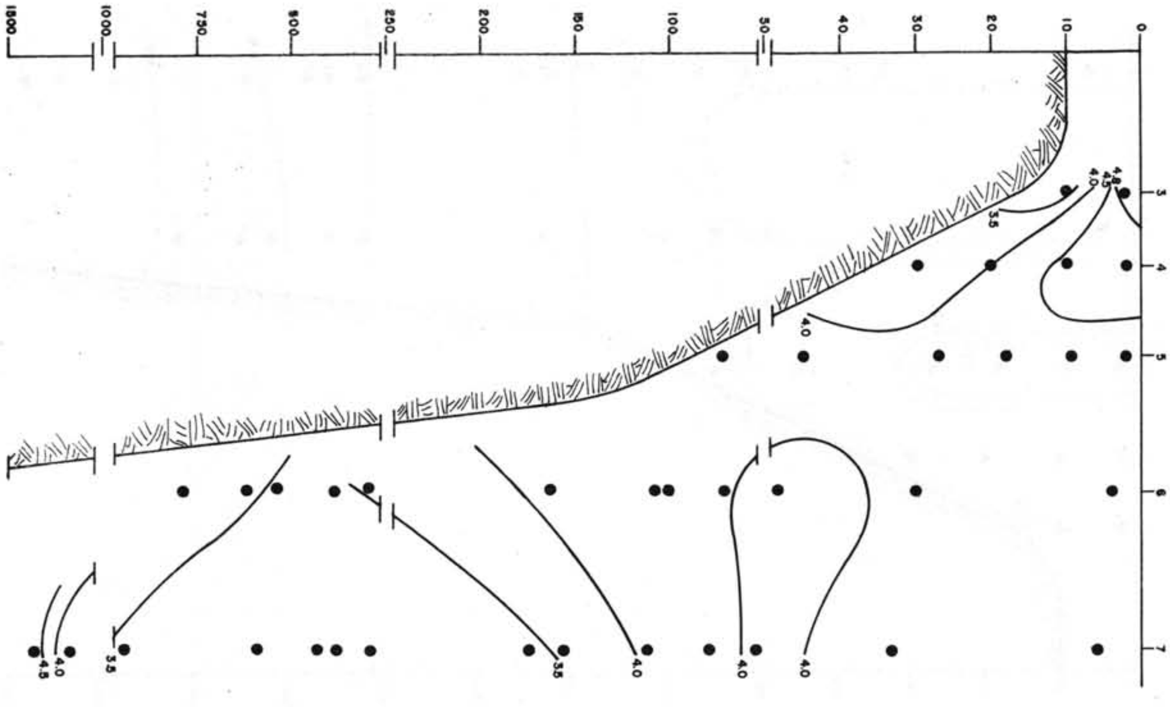


FIG. 14 - Section II. Dissolved oxygen (ml/l).

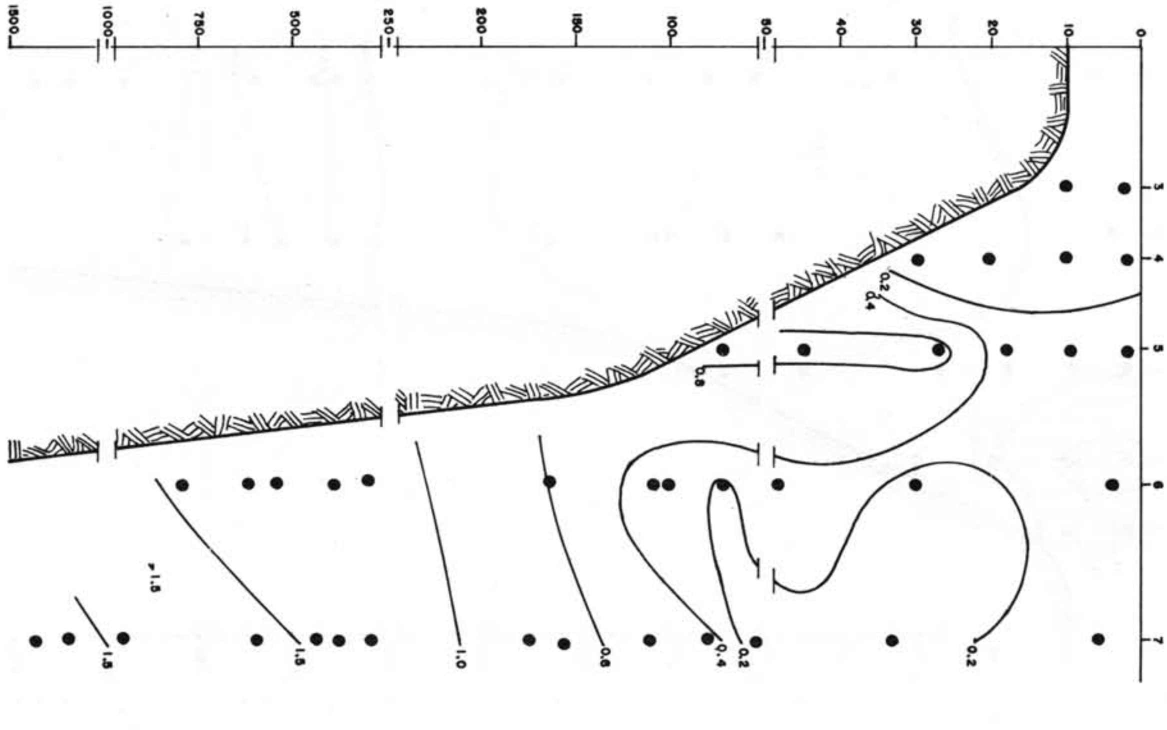


FIG. 15 - Section II. Inorganic phosphate (μgat PO_4-P/l).

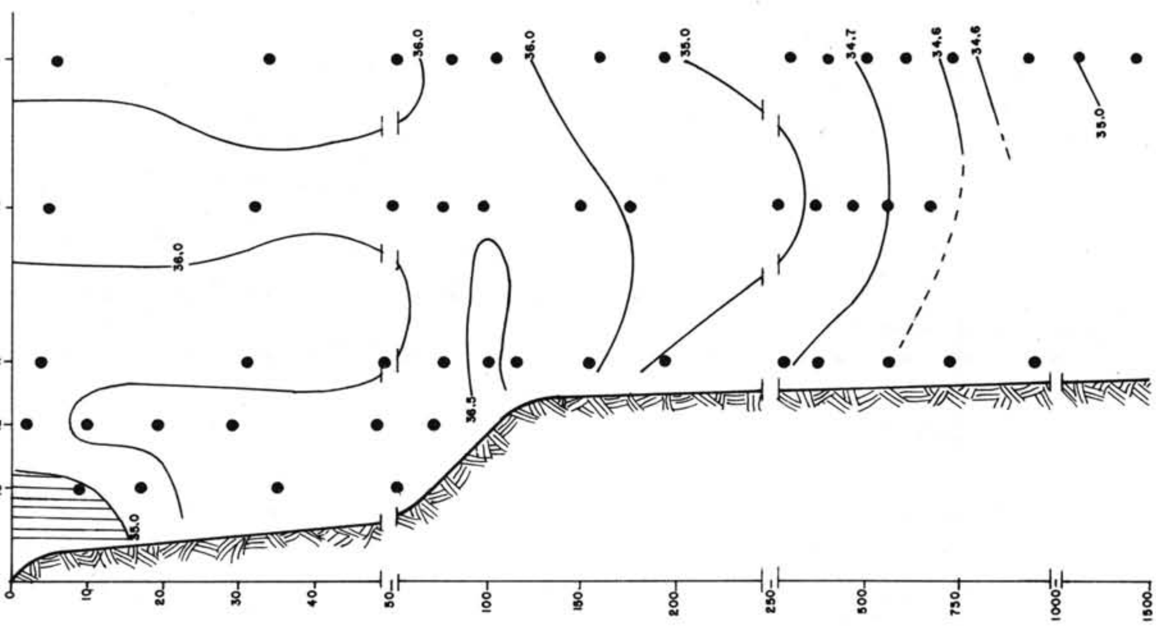


FIG. 16 - Section III. Salinities (°/oo).

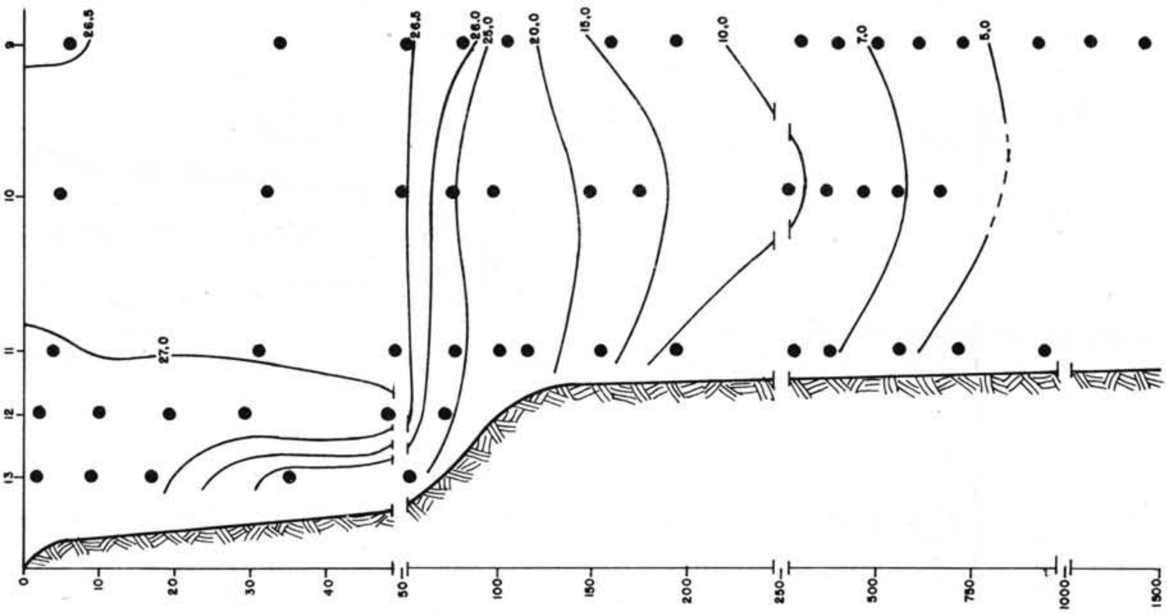


FIG. 17 - Section III. Temperatures (°C).

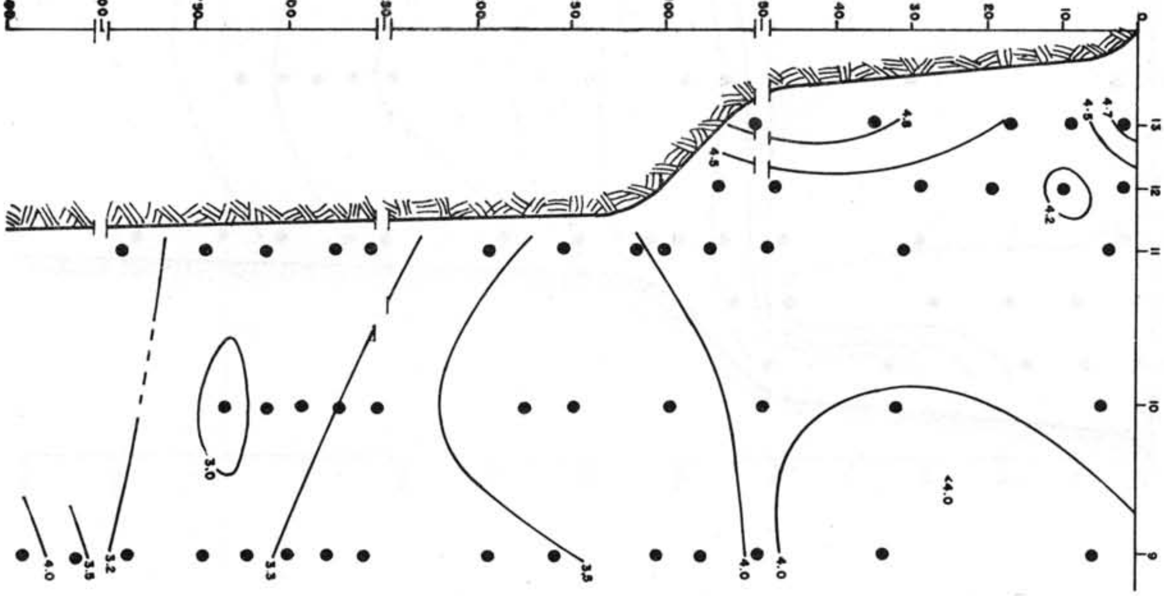


FIG. 18 - Section III. Dissolved oxygen (ml/l).

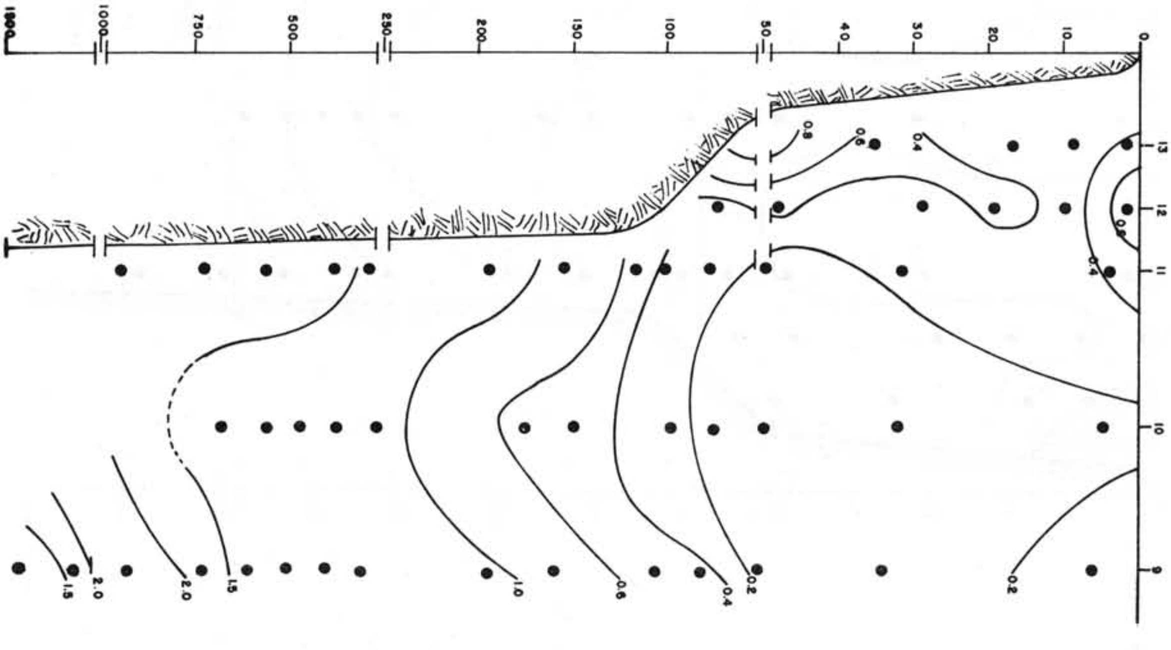


FIG. 19 - Section III. Inorganic phosphate (μgat PO_4-P/l).

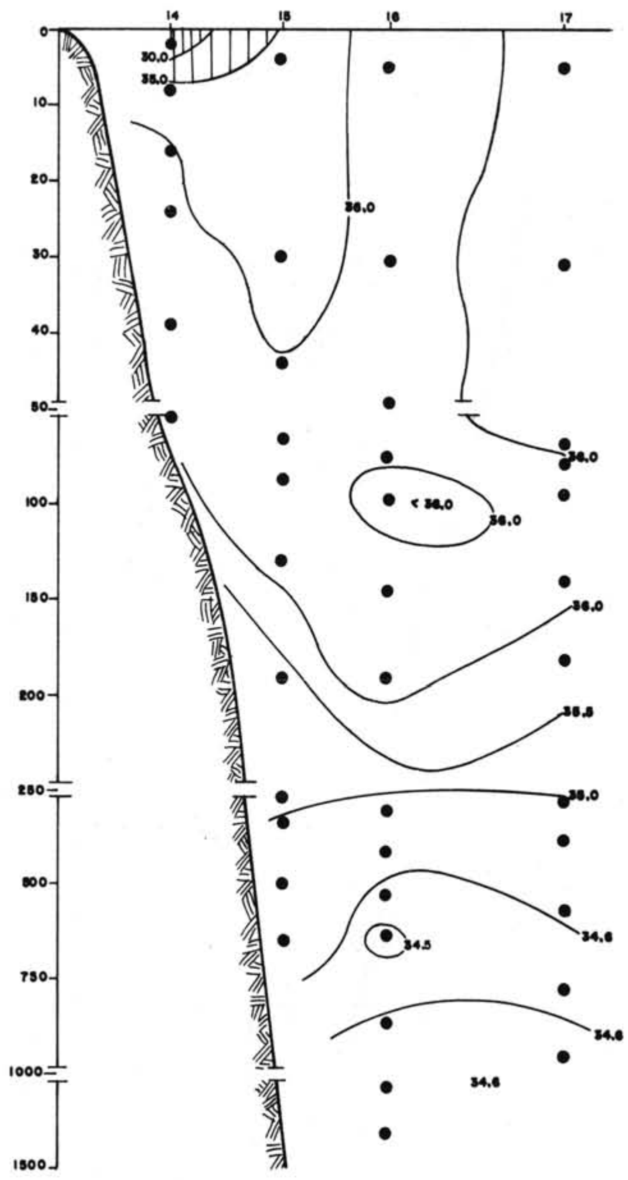


FIG. 20 - Section IV. Salinities ($^{o}/oo$).

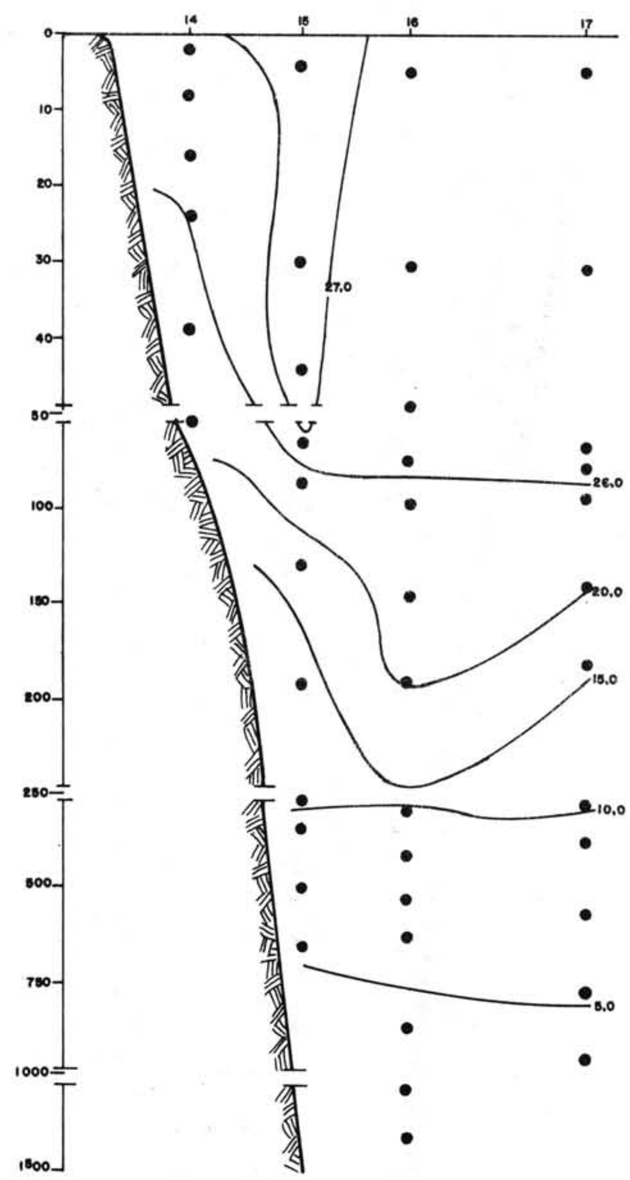


FIG. 21 - Section IV. Temperatures (^{o}C).

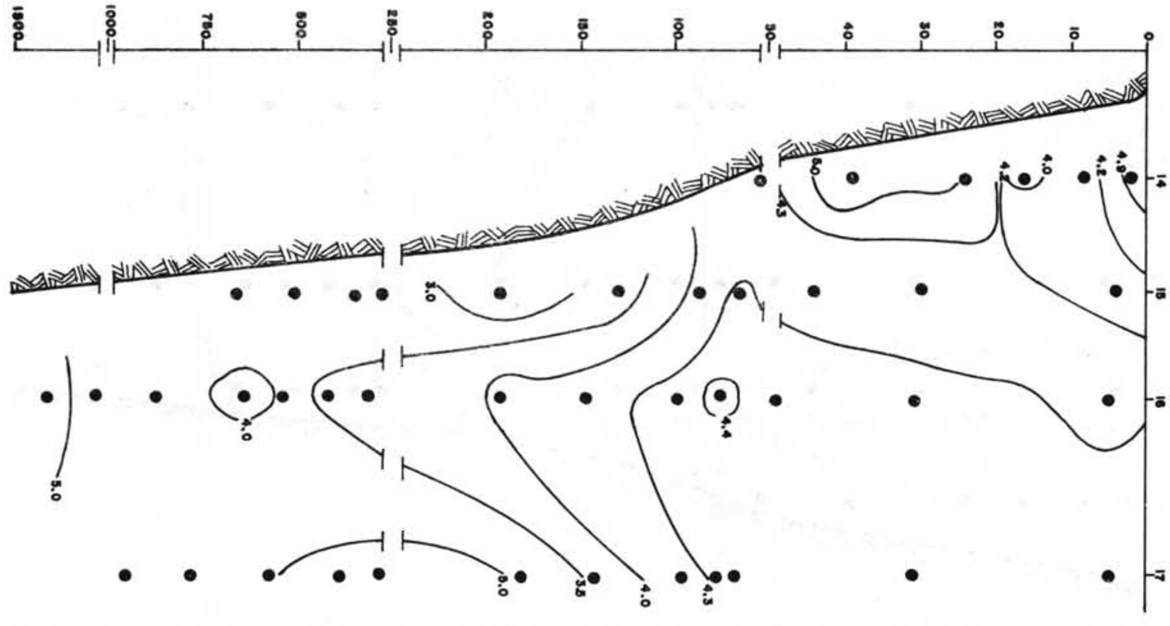


FIG. 22 - Section IV. **Dissolved oxygen (ml/l).**

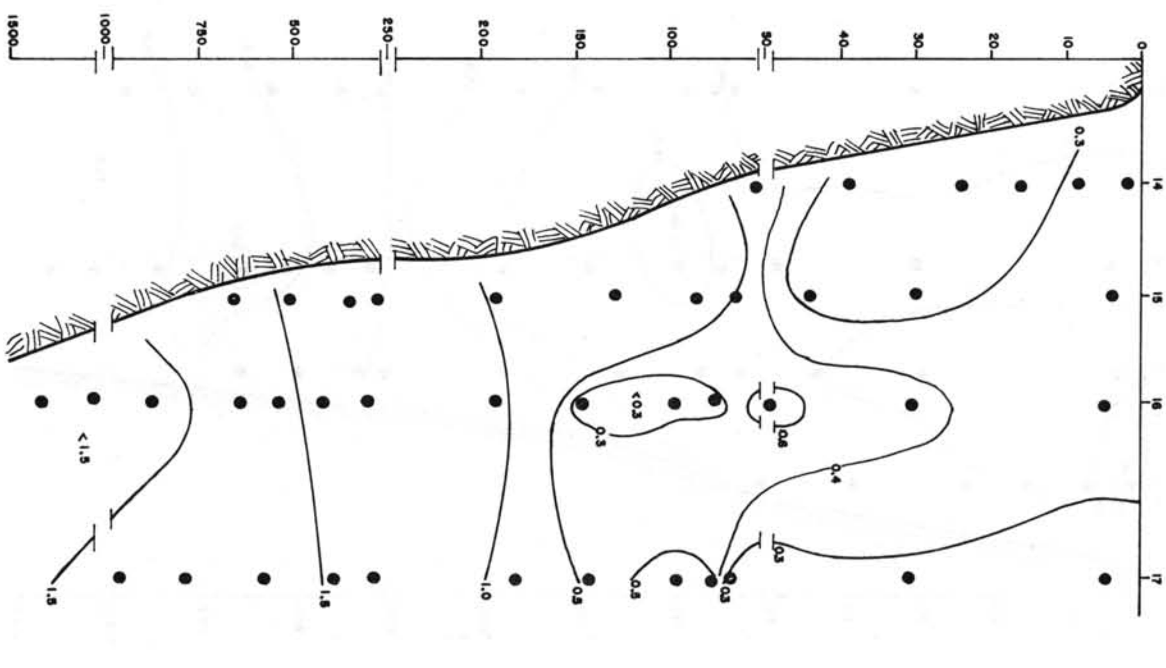


FIG. 23 - Section IV. Inorganic phosphate (μgat PO_4-P/l).

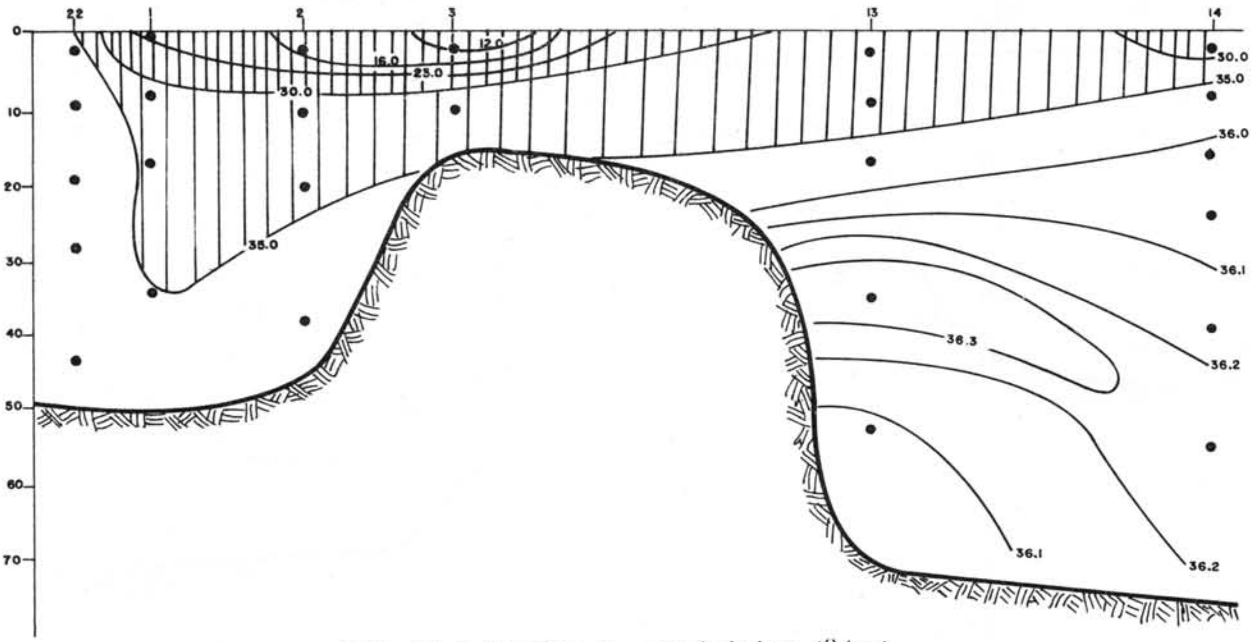


FIG. 24 - Section V. Salinities (°/oo).

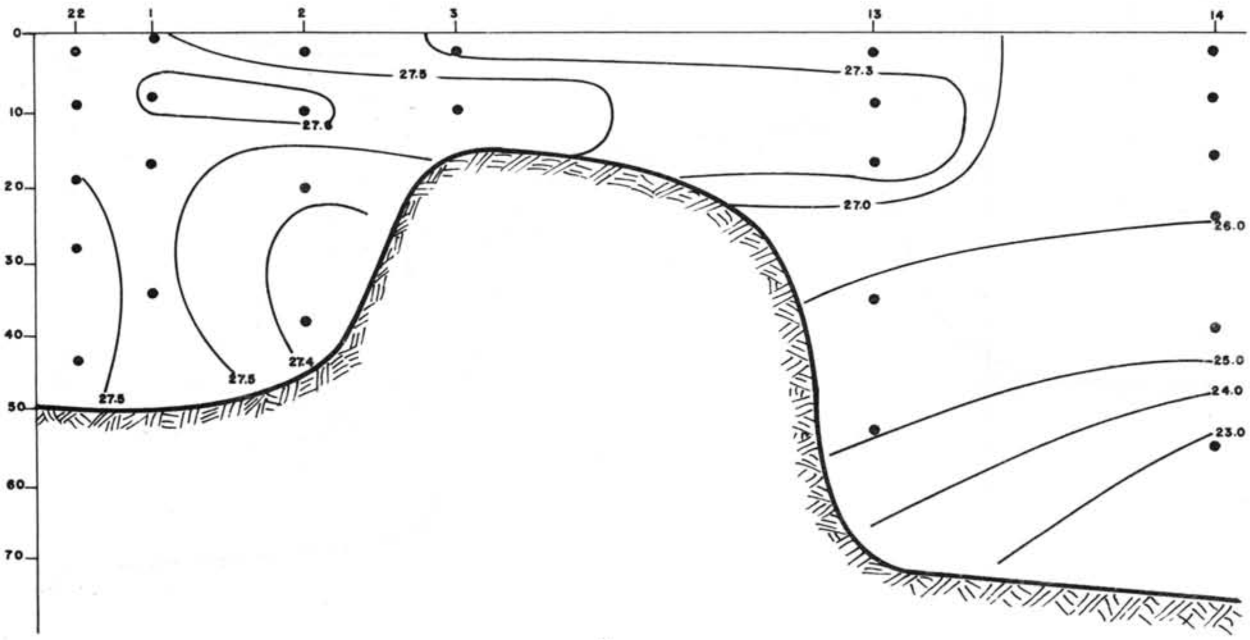


FIG. 25 - Section V. Temperatures (°C).

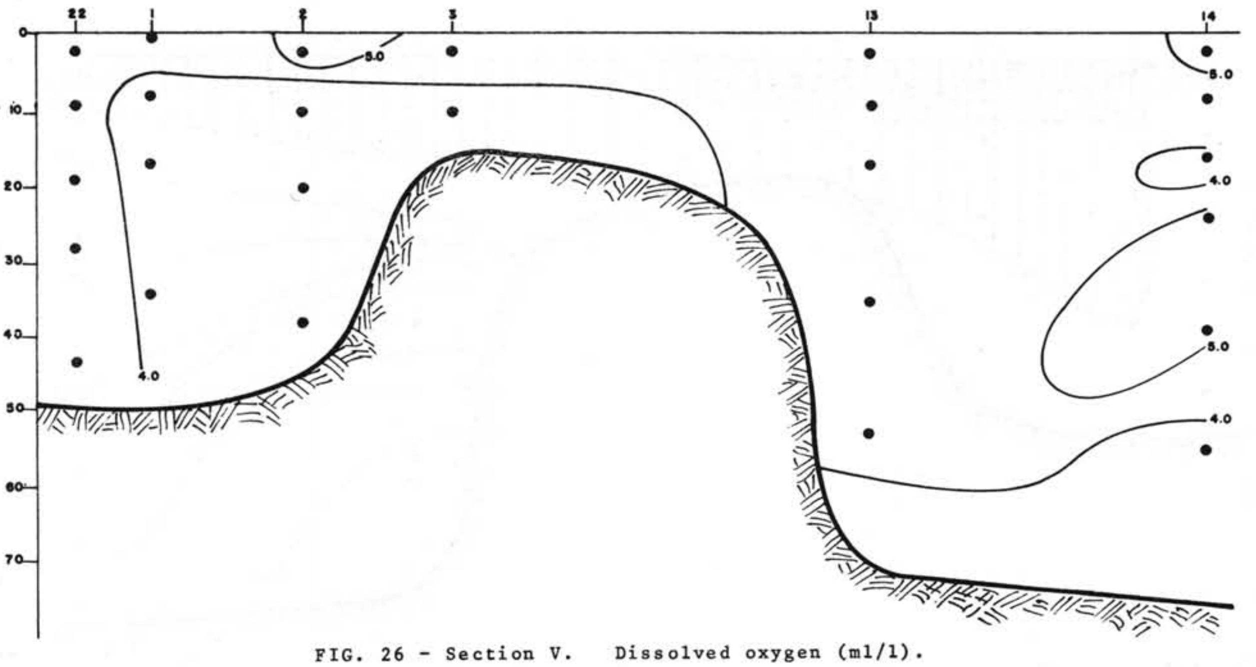


FIG. 26 - Section V. Dissolved oxygen (ml/l).

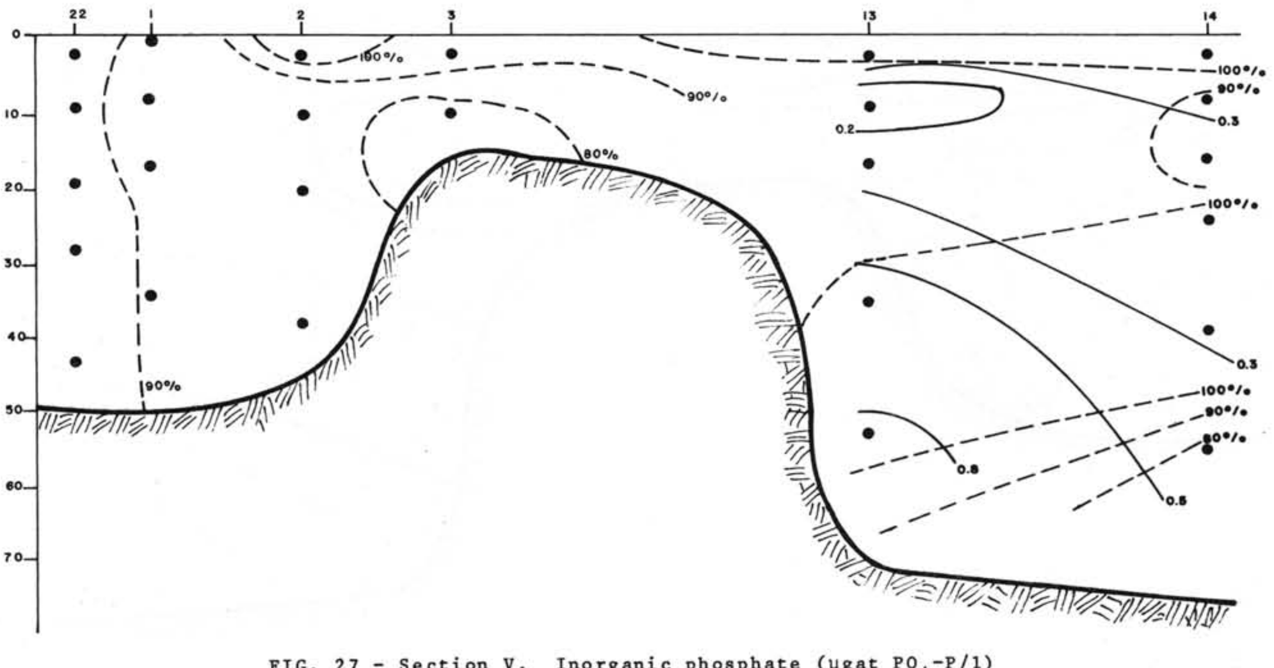


FIG. 27 - Section V. Inorganic phosphate (μgat PO_4-P/l) and relative oxygen (%).