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STATE OF RIO DE JANEIRO
THE FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON RECUPERATION OF THE GUANABARA BAY ECOSYSTEM

VOLUME 4
SUPPORTING REPORT Ⅱ

Ⅳ. Pollution Level and Pollution Mechanism in Guanabara Bay
Ⅴ. Numerical Pollution Simulation on Guanabara Bay

MARCH 1994

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THE STUDY ON RECUPERATION OF THE GUANABARA BAY ECOSYSTEM

VOLUME 4
SUPPORTING REPORT II

IV. Pollution Level and Pollution Mechanism in Guanabara Bay
V. Numerical Pollution Simulation on Guanabara Bay

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国際協力事業団
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PART IV

POLLUTION LEVEL AND POLLUTION MECHANISM IN GUANABARA BAY

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ABBREVIATIONS

BOD	:	Biochemical Oxygen Demand
C	:	Carbon
Cd	:	Cadmium
Chl-a	:	Chlorophyll-a
CN	:	Cyanide
COD(Cr)	:	Chemical Oxygen Demand by Potassium Dichromate Method
COD(Mn)	:	Chemical Oxygen Demand by Potassium Permanganate Method
Cr^{6+}	:	Sexivalent chromium
DBOD	:	Dissolved Biochemical Oxygen Demand
DCOD	:	Dissolved Chemical Oxygen Demand
DDT	:	Dichlorodiphenyltrichloroethane
DIN	:	Dissolved Inorganic Nitrogen
DIP	:	Dissolved Inorganic Phosphorus
DO	:	Dissolved Oxygen
EC	:	Electric Conductivity
Fe	:	Iron
H_2S	:	Hydrogen Sulfide
IL	:	Ignition Loss
MPN	:	Most Probable Number
NH_4-N	:	Ammonium Nitrogen
Ni	:	Nickel
NO_2-N	:	Nitrite Nitrogen
NO_3-N	:	Nitrate Nitrogen
Pb	:	Lead
PCB	:	Polychlorinates Biphenyl

pH	:	Potential of Hydrogen
PO_4-P	:	Phosphate Phosphorus
POP	:	Particulate Organic Phosphorus
PON	:	Particulate Organic Nitrogen
SS	:	Suspended Solids
TDP	:	Total Dissolved Phosphorus
T-Hg	:	Total Mercury
TKN	:	Total Kjeldahl Nitrogen
TOP	:	Total Organic Phosphorus
TON	:	Total Organic Nitrogen
TN	:	Total Nitrogen
TP	:	Total Phosphorus
V.S.	:	Volatile Solids

CHAPTER 1

DISTRIBUTION OF ENVIRONMENTAL FACTORS IN THE BAY

CHAPTER 1

DISTRIBUTION OF ENVIRONMENTAL FACTORS IN THE BAY

1.1 Survey on Physical Environmental Factors

Physical environmental factors: temperature, salinity and electric conductivity were measured on the occasions of the preliminary surveys 1 and 2, the first, the second and the third simultaneous surveys, and during measurements near the mouth of the Bay.

Water density *in situ*, expressed by Sigam-t, was calculated by using the obtained temperature and salinity values at the same stations.

Dissolved oxygen was also measured at the same time.

1.1.1 Simultaneous Surveys

The methods and the details of the simultaneous surveys are as mentioned in Chapter II.

In this Chapter, the physical characteristics are referred to using mainly the results from the simultaneous surveys, for the preliminary surveys took several days, and some surveys for preliminary survey-2 were conducted under bad weather conditions.

The survey period of one year was divided into two seasons ; dry season - April to September, 1992 ; wet season - October, 1992 to March, 1993

1.1.2 Preliminary Surveys

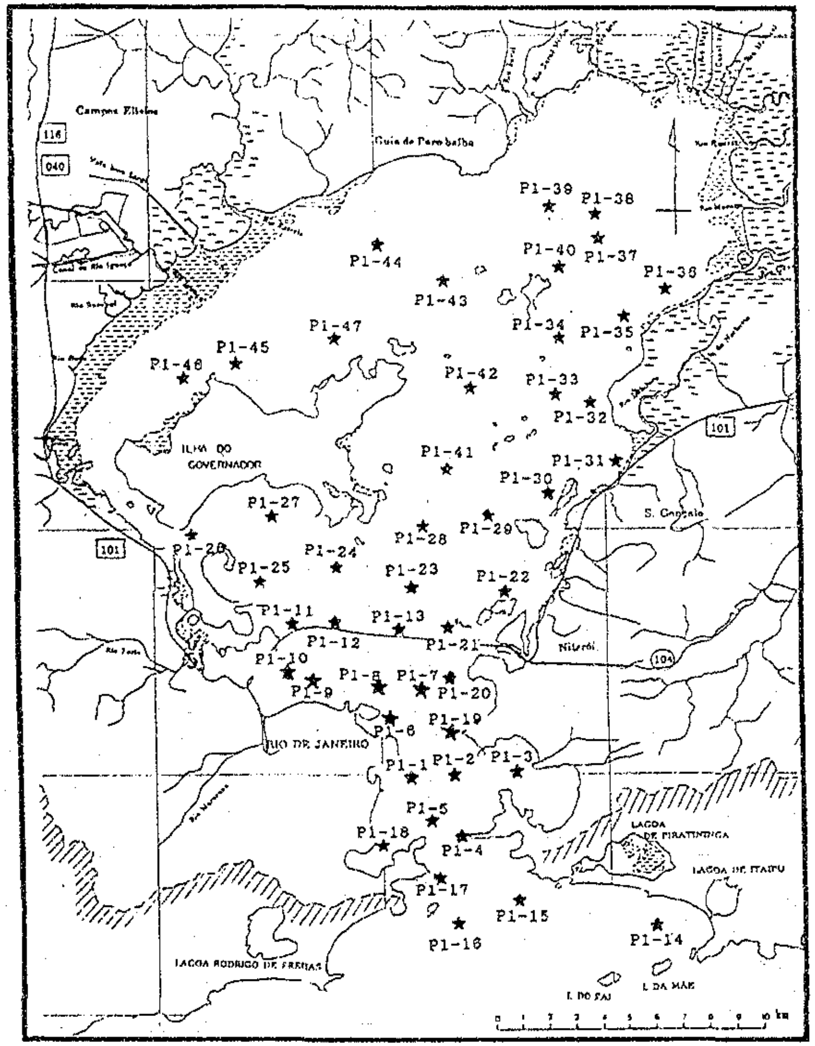
Prior to the first and the third simultaneous surveys, the preliminary surveys were performed on 47 and 34 stations, respectively (Fig.1.1-1).

These stations covered almost the whole Bay area in order to obtain the horizontal and vertical distributions of the basic physical characteristics.

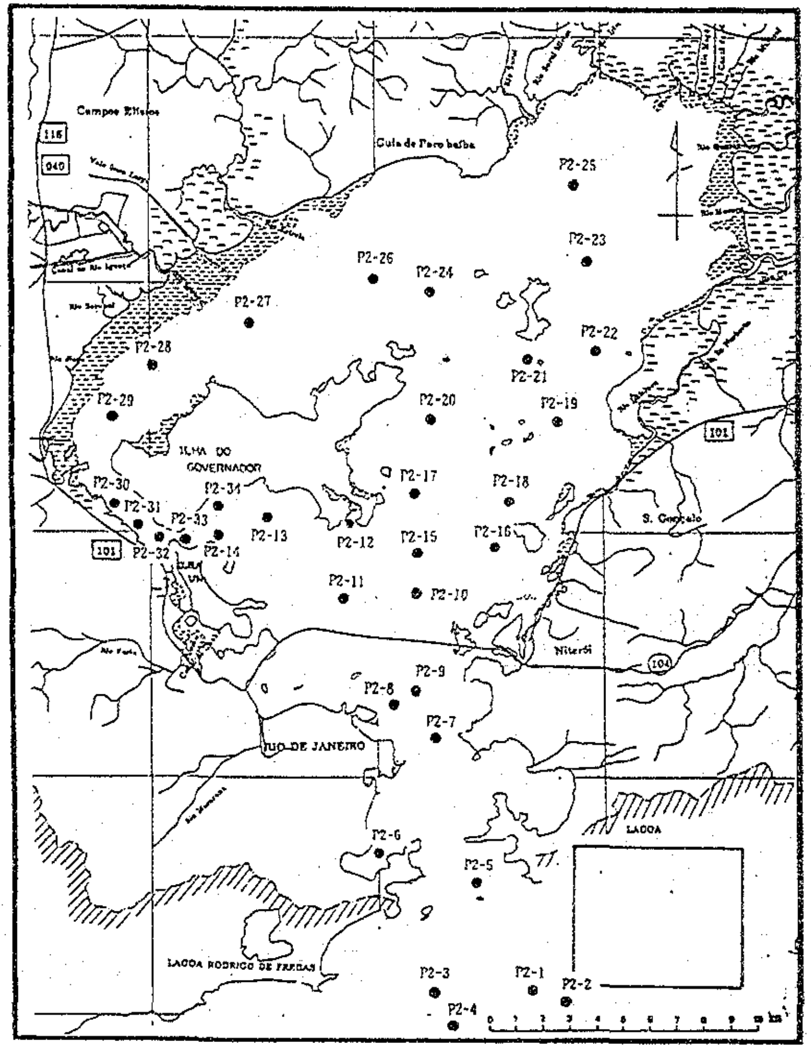
The results were expected to help in the execution of each simultaneous survey.

Preliminary survey-1:	April 23, 24, 25, and May 1, 1992
Preliminary survey-2:	October 17 - 20, 1992

The equipment for measurement were the same as those used in the



Preliminary Survey-1



Preliminary Survey-2

Fig. 1.1-1 Measurement Stations for Preliminary Survey simultaneous surveys.

1.1.3 Measurement of the Physical Characteristics near the Mouth of the Bay

As the mouth of the Bay is very narrow, different physical characteristics from other areas, such as mixing or turnover of water is expected to be present around the area.

Measurement was done on May 17 and November 11, 1992, respectively (Fig. 1.1-2).

1.2 Horizontal and Vertical Distributions of Salinity

1.2.1 Horizontal Distribution

Surface salinity is widely distributed in the Bay in both seasons, and decreases generally from the outer area toward the inner Bay area (Tables APP 1.2-1 - 6).

In the dry season, surface salinity tends to be low at the western side of the inner Bay; around 26 ‰ (Fig. 1.2-1(1)).

Contrarily, remarkably lower salinity values were obtained in the wet season on the northeastern side of the Bay, particularly in low tide (13.1 ‰ at St. 16 at high tide; 8.7 ‰ at St. 15 in low tide) (Fig. 1.2-1(2)).

Prior to the survey there were significant differences between the mean salinity values for the dry season (mean at each station) and the mean values for the wet season at the surface and the bottom.

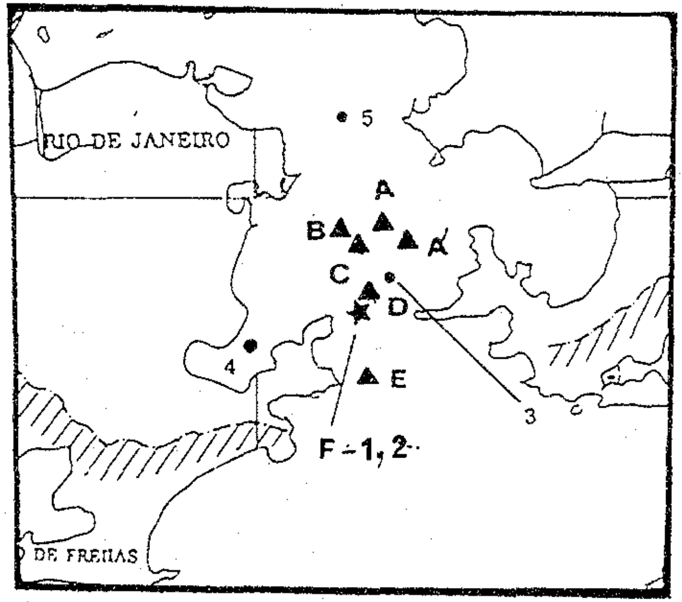
Salinity values, nevertheless, near the mouth and the outer part of the Bay in both seasons were obtained similarly at around 33 to 34 ‰.

Reflecting river discharge condition, salinity in the low tide was generally lower than in the high tide for two seasons, although the difference was not significant.

1.2.2 Vertical Distribution

Salinity increased downward and tended to greatly increase in the inner Bay than in the outer Bay. However, it only slightly increased downward near the mouth of the Bay, reflecting offshore water salinity (Fig. 1.2-2).

The seasonal difference was considerable. Dry season surface levels were often greater than levels recorded at the bottom during the wet season.



A – E : Measurement-1
F-1, 2 : Measurement-2
3, 4, 5 : simultaneous survey stations

Fig. 1.1-2 Measurement Stations near the Mouth of the Bay

Unit(‰)

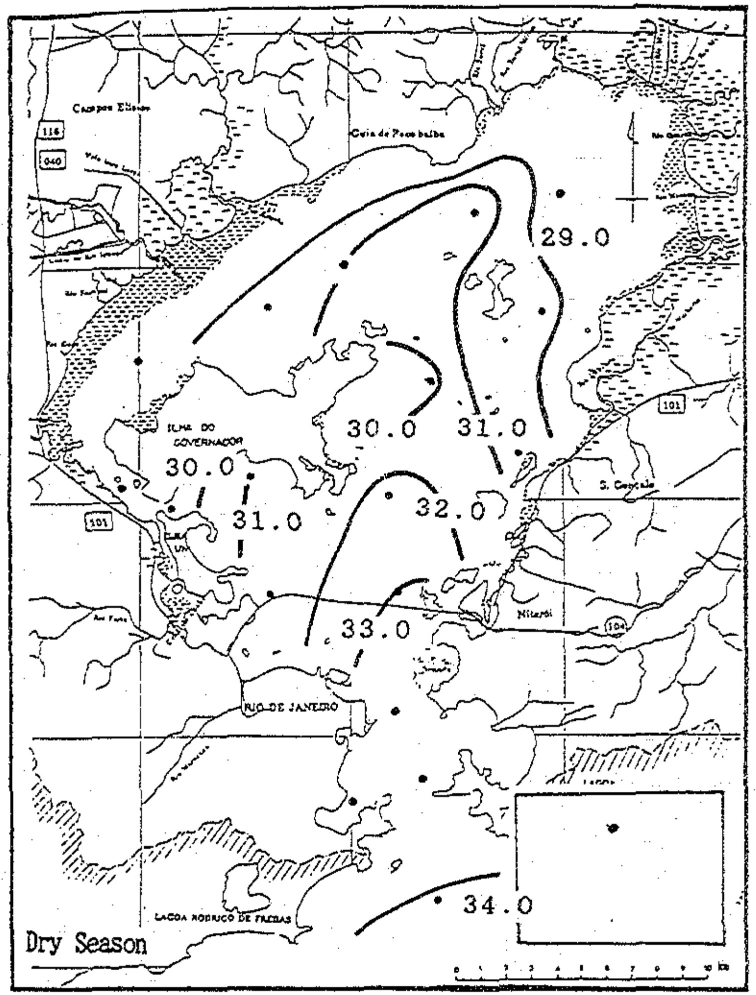
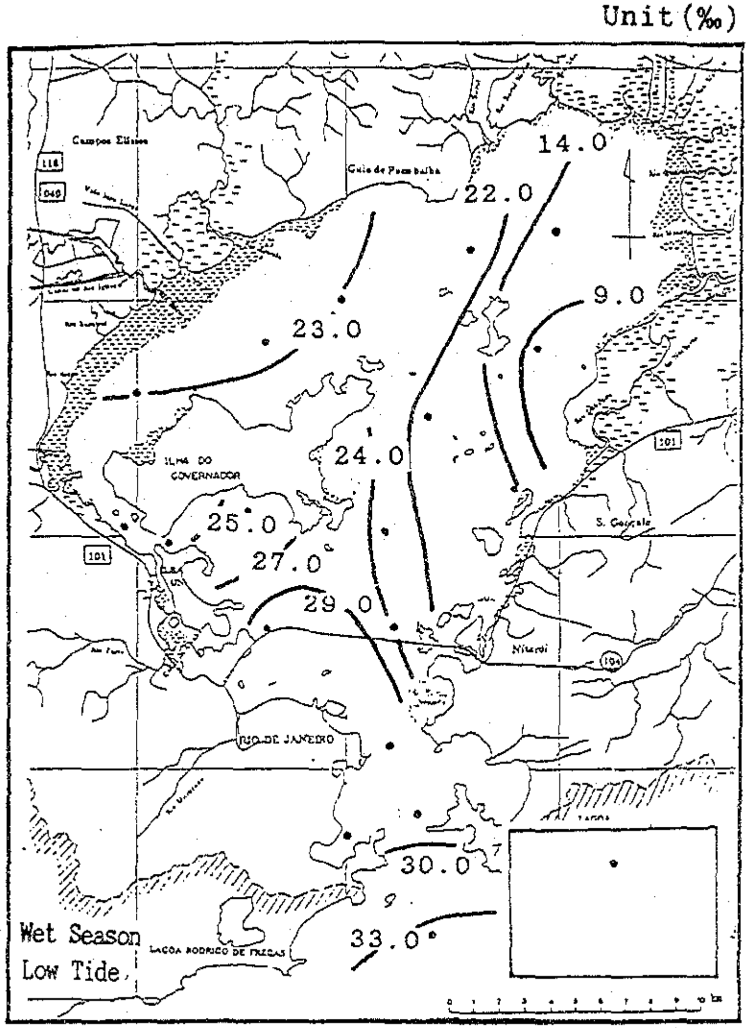


Fig. 1.2-1(1) Distribution of Salinity in the Surface Layer in the Dry Season



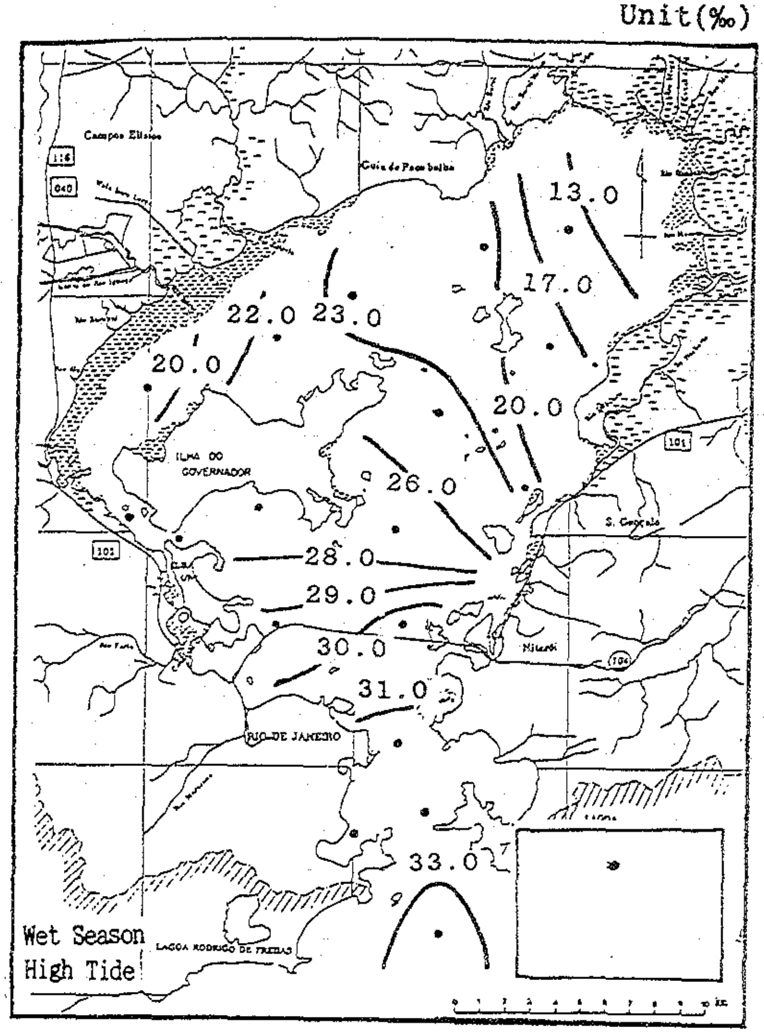


Fig. 1.2-1(2) Distribution of Salinity in the Surface Layer in the Wet Season

Fig 1.2-3 shows the salinity distribution in vertical sections as seen from the south and east. Salinity at Stns. 3 and 5 near the narrow entrance of the Bay, was always vertically homogeneous, which was due to the water the mixing of water flowing into the Bay.

The figure also shows clearly that in the wet season, even near the mouth of the Bay, around Stn. 5 and 6, the effect of the inflow of fresh water from rivers located on the northeastern side on salinity distribution is stronger than the water from outside of the Bay.

Salinity distribution in the layers indicated that stratification is well developed around this area, particularly in the layer located more than 10 meters above. The temperature distribution also supports this observation, as mentioned below.

Generally the salinity inside the Bay is affected by large volumes of water flowing deep into the Bay.

1.3 *Horizontal and Vertical Distributions of Water Temperature*

1.3.1 Horizontal Distribution

Surface water temperature increased from the mouth toward the inner part of the Bay in both seasons, however in quite small ranges; 23.9°C - 28.2 °C in the dry season and 23.4 °C - 27.7 °C in the wet season (Fig. 1.3-1, Tables APP 1.2-1 - 6).

The surface temperature in low tide was significantly higher than in high tide in both May and June as reflected in the air temperature of the survey time. However the surface temperature in November was almost the same in both tides.

The mean temperature values obtained in the dry season were also significantly higher than the mean values in the wet season.

As found in the salinity distributions, river discharge greatly affects temperature surface distribution in the wet season. It is also understood from the results that temperature in low tide during spring tide (May) was lower than that during neap tide (June).

1.3.2 Vertical Distribution

Water temperature decreased with depth at all stations in all occasions, but generally shows a tendency to decrease greatly at the inner than the outer Bay. Sharp decreasing in temperature usually occurred in the upper three meters in the inner Bay area, supposedly due mainly to the effects of river water which has warmed up (Fig. 1.3-2).

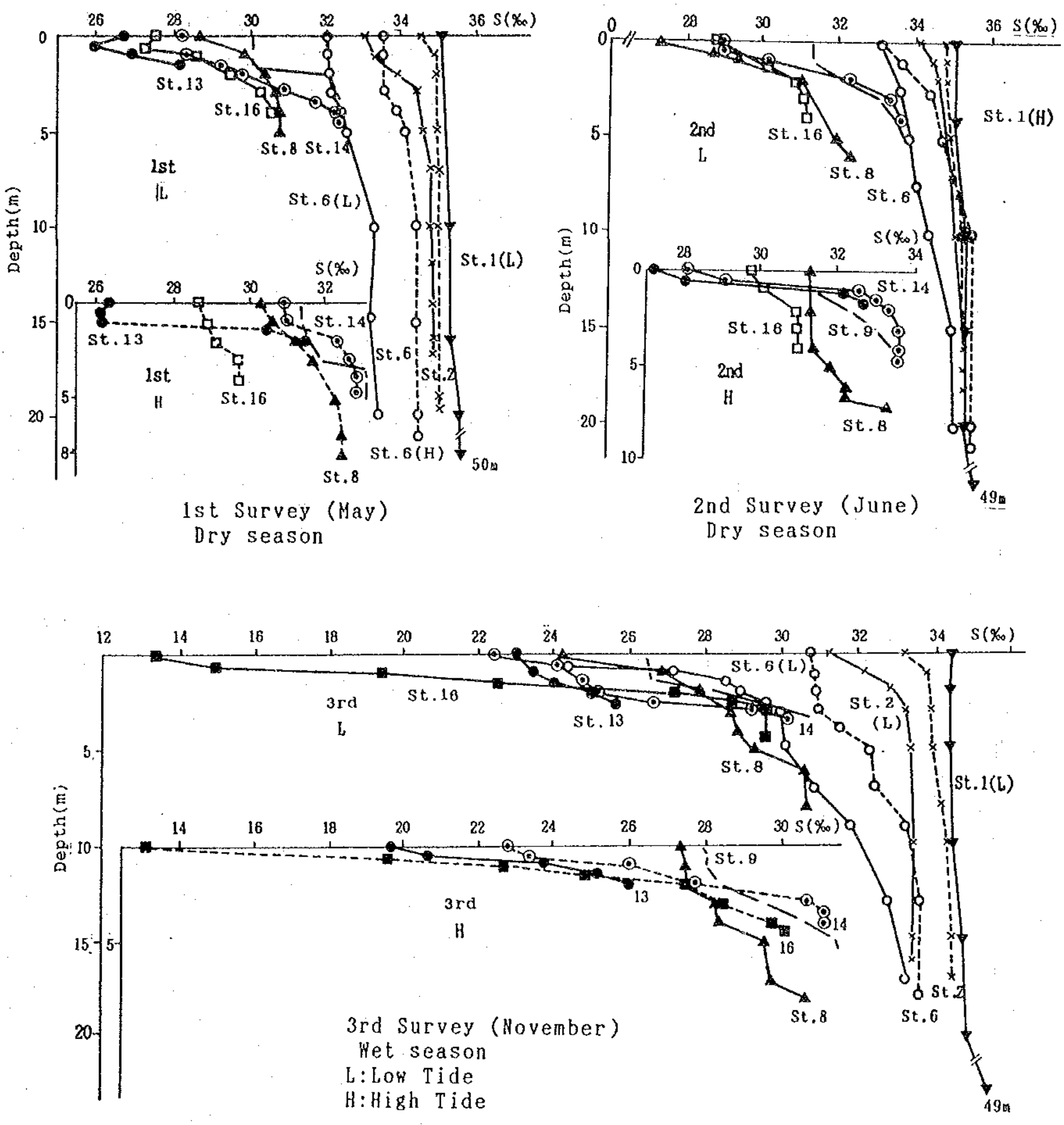
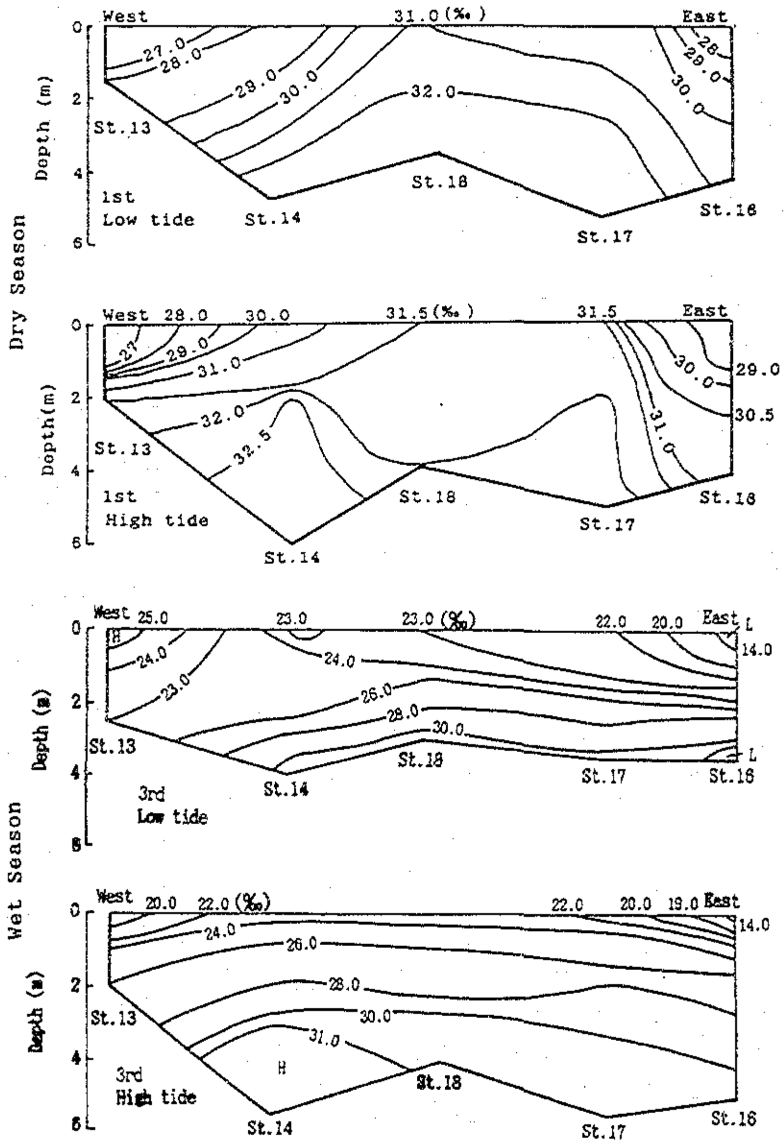
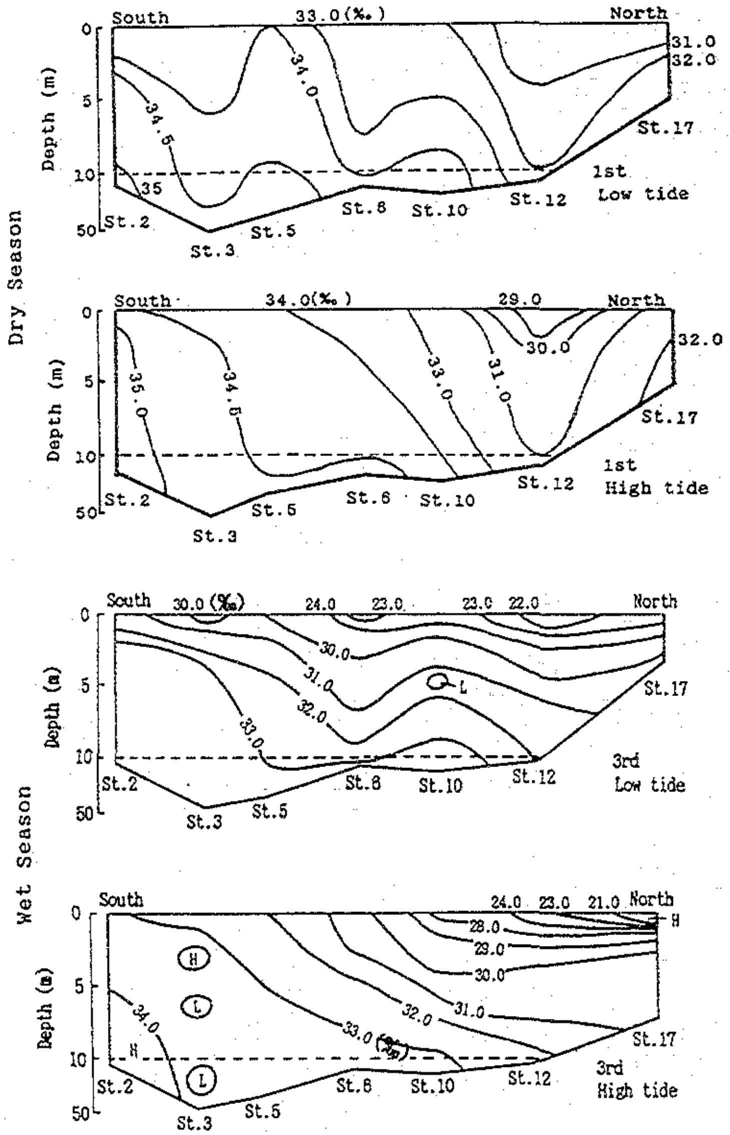


Fig. 1.2-2 Vertical Distribution of Salinity



Sections as seen from the South



Sections as seen from the East

Fig. 1.2-3 Vertical Sections of the Salinity Distributions across the Bay

Temperature in the wet season decreased greatly with depth than in the dry season (Fig. 1.3-3). Although variations among temperature values in the deeper layers were small, significant differences were observed in the dry and the wet seasons.

The slope of temperature - depth curve at St. 8 is, in each case, always different to the other stations; lower in the surface layer and only slightly decreases with depth. This may be attributed to the fact that this station is located very near the highly populated place in the small inlet and is hence affected by direct waste water discharge (Fig. 1.3-3).

The temperature distribution in vertical section showed that water from outside of the Bay penetrates strongly through the deeper layers and on its way outside through the upper layers, as found in the salinity survey. This was especially clear in the wet season (Fig. 1.3-4; Sections as seen from the East).

It was not only obvious that stratification has strongly developed in the wet season in the inner Bay area, but also in the central Bay area through the results of temperature distribution measurement.

Homogeneous vertical distribution of temperature in areas deeper than 2 to 5 meters also showed that water from St. 3 to around St.6 mix well vertically in the dry season. Vertical turnover of water may also be observed at the station.

Great differences between surface and bottom temperature were observed in the dry and the wet seasons at stations 11, 15 and 16, and sometimes even at St. 6 ; showing higher values both at the surface and the bottom in the dry season. Rainfall and great river discharge in the wet season resulted in lower temperature values, as found in salinity distribution.

1.4 Temperature - Salinity Relationship

Variations in water temperature (T) and salinity (S) values occurred depending on the seasons and areas in the Bay. T- S relationship, therefore, varied throughout the year, and from one area to another. The T-S relation curve drawn with depth and Sigma-t, the latter refers to density in situ which is mentioned in 1.5, illustrates some of the physical characteristics of the water in the Bay.

T-S relation for the low tide of the spring tide in the dry season (May, 1992) showed relatively higher temperature and salinity distributions within a smaller range than that for the neap tide (June) at the same stations (Fig. 1.4-1).

The graph clearly demonstrates that in the wet season lower temperatures obtained at all stations and the range of the salin-

Unit (°C)

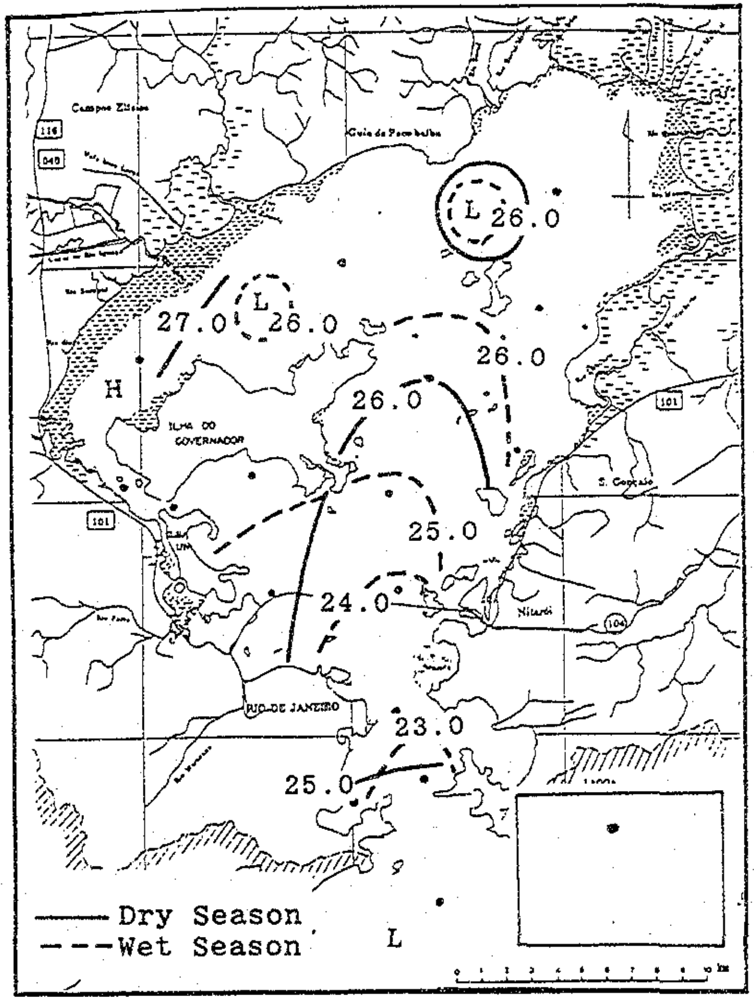


Fig. 1.3-1 Distribution of Temperature in the Surface Layer

Unit (°C)

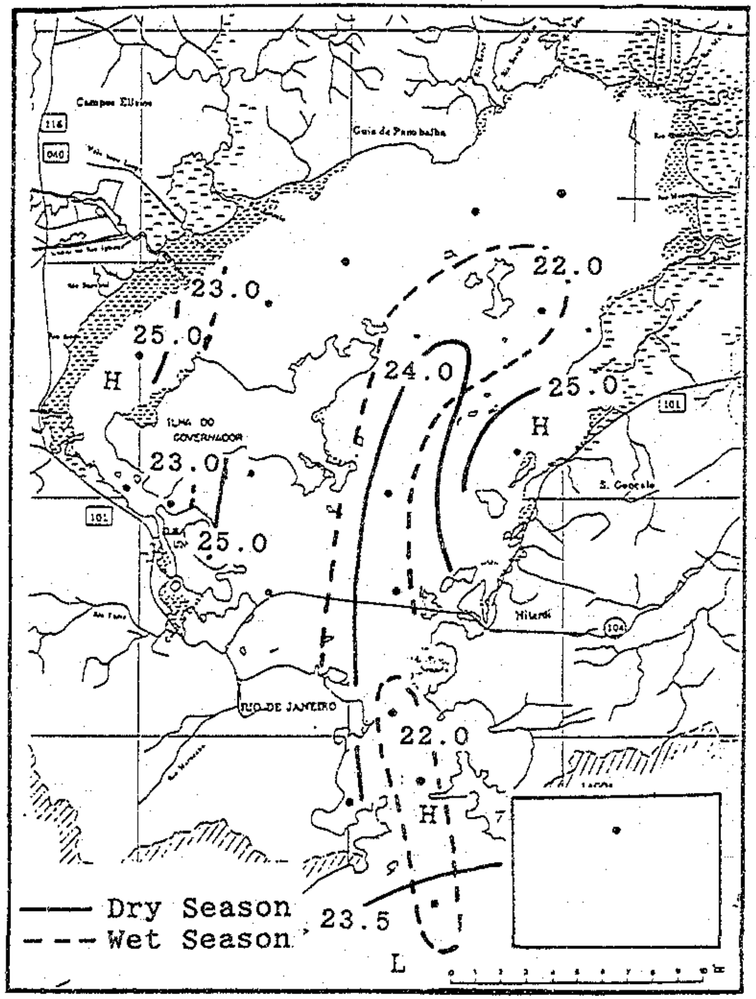


Fig 1.3-2 Distribution of Temperature at the Bottom

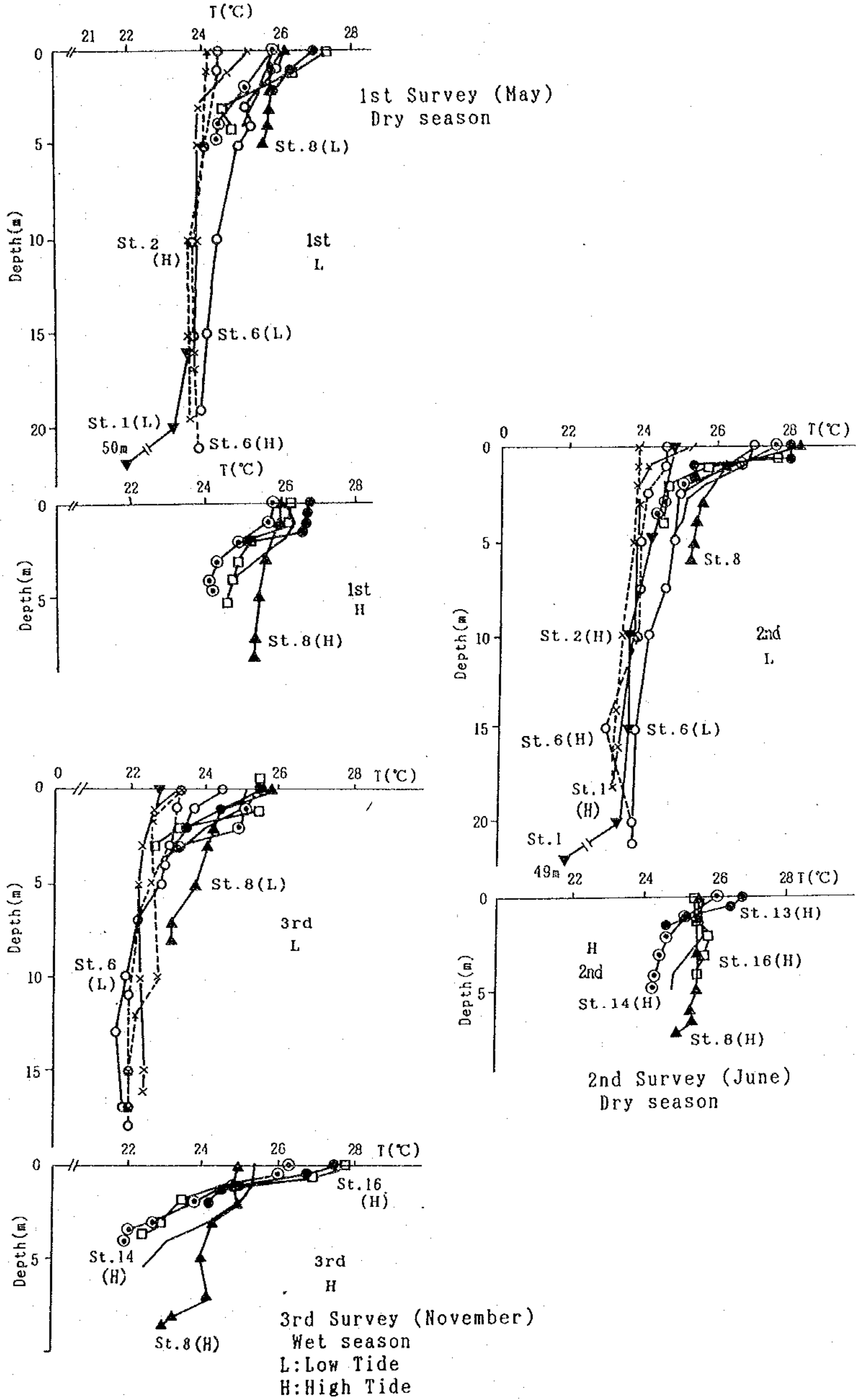


Fig. 1.3-3 Vertical Distribution of Temperature

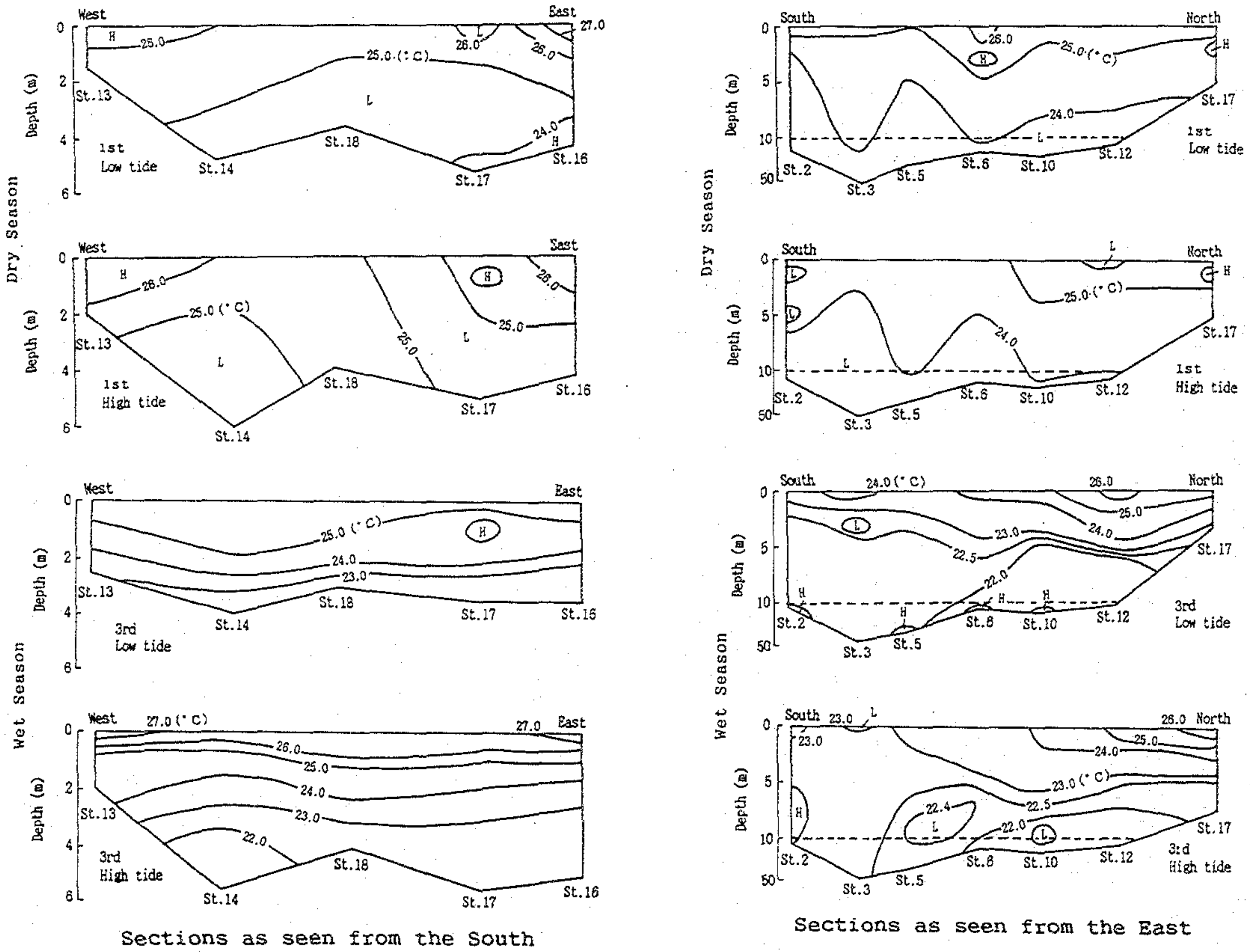


Fig. 1.3-4 Vertical Sections of the Temperature Distributions across the Bay

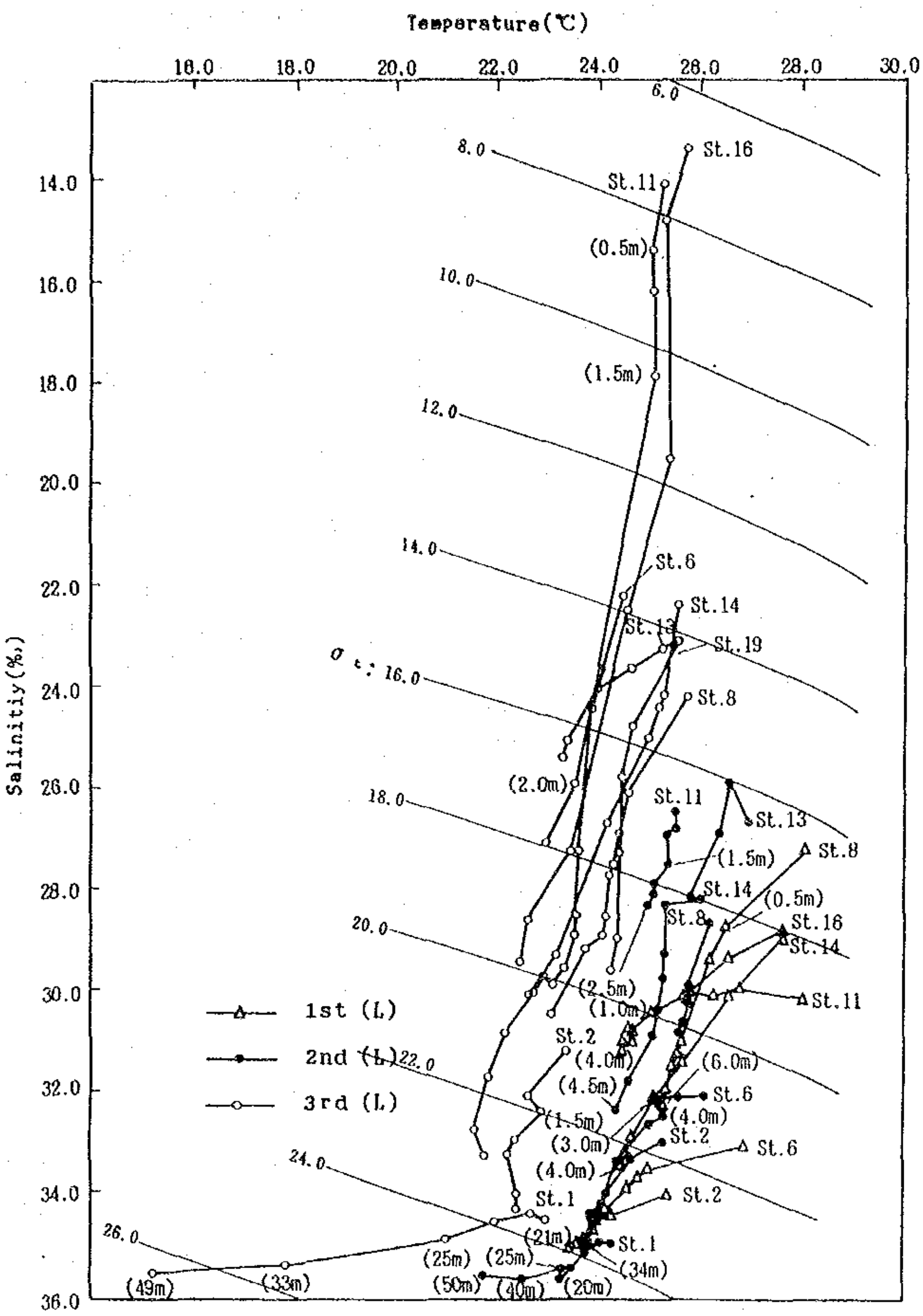


Fig. 1.4-1 Temperature and Salinity Relationship obtained from Simultaneous Surveys

ity considerably expanded toward the lower end, especially at Stns. 11 and 16.

Strong stratification develops in all cases in both seasons, except at stations near the mouth (Stns. 2 to 6) and outside of the Bay(St. 1).

The relation curve for St. 1 obviously indicates a completely different water mass in comparison with the inner Bay water characteristics.

1.5 Water Density (Sigma-t) Distribution and Stratification

Density in situ is indicated by sigma-t, which is defined as (density-1)/1000. Sigma-t was calculated using the salinity and temperature values measured in simultaneous surveys at each station.

The equation used here is as shown below :

$$\text{Sigma-t} = 20.99 + (-4.3 \times 10^{-3}(t-20) - 0.256) \times (t-20) + (2.3 \times 10^{-4}(s-30) - 1.53 \times 10^{-3}(t-20) + 0.7577) \times (s-30).$$

Although the water in the Bay had a salinity value occasionally lower than 24 ‰, which is the lower limit of salinity this equation uses (salinity : 24.0 -35.5 ‰ ; temperature : 8 - 32 °C), this value was used in all occasions.

Horizontal and vertical profiles of sigma-t are shown in Fig. 1.5-1.

Generally sigma-t increased downwards and the degree of increase per unit depth gradually developed from the mouth toward the inner Bay, mostly depending on salinity distribution.

In the inner Bay, DO discontinuous depths were found a little above the sigma-t discontinuous depth. In layers above the discontinuous depth, phytoplankton may reside for a long time without being transferred downwards. Therefore, high production seems to occur in these layers as DO values occasionally recorded were higher than 200 %.

Sigma-t in the upper layers was lower in the wet season than in the dry season, particularly in the inner Bay, mainly due to low salinity.

It seems that stratification develops on the northwestern side in the inner Bay in the dry season. In the wet season, more stable stratification develops not only in the inner Bay area but also in the central Bay area (Fig. 1.5-2, Tables APP 1.5-1(1)-(3)).

In contrast to the inner Bay, a homogeneous vertical distribution of sigma-t takes place near the mouth of the Bay, even in the wet season (Fig. 1.5-2). Formation of stratification around these stations seems to be difficult throughout the year.

Sigma-t values around Stns. 5 and 6, sometimes at St. 3, also indicate a well-mixed water state vertically.

Breakdown of the stratification decreases with depth until the water is vertically mixed well was observed in the inner Bay during preliminary survey-2, October 21st (Fig. 1.5 - 3).

The figures indicate that the layers in a well-mixed water state developed downward until 1.5 to 3.0 m. These depths were compared with the depths at most of the same stations, obtained in the third simultaneous survey, when no strong winds were recorded, resulting in stratification development.

Wind velocity was measured on the 21st of October, in Petrobras Brasileiro S.A. The previous measurements were also taken at the same place (2.5 - 5.5 m/s).

It is supposed that actual wind velocity on the Bay may be much stronger than the recorded velocity on the land. However, since actual wind velocity on the Bay was not recorded, it is difficult to obtain the relationship between sigma-t and the critical wind velocity that causes the breakdown and the developed state of layers with well-mixed water state.

It is possible, however, to consider here the period when the breakdown of stratification and well-mixed water conditions developed using the data of wind force in 1992. The degree of wind velocity, 2.5 - 5.5 m/s, which seemed to produce the breakdown and turnover of the water, was recorded in almost half of the days in November and in almost the whole of December 1992. The breakdown and turnover of the water, therefore, may occur frequently in the wet season when strong stratification develops in open areas in the Bay.

Turnover or well-mixed water supplies oxygen to the deeper layers and lifts both organic and inorganic materials from the bottom layers to the upper layers, therefore partly causing internal production.

Further detailed studies on the relation between the actual wind velocity on the Bay and the turnover of water, and the recovery of nutrients from the bottom to the surface should be carried out.

1.6 Horizontal and Vertical Distributions of Dissolved Oxygen

1.6.1 Horizontal Distribution

In surface dissolved Oxygen (DO) concentration and saturation

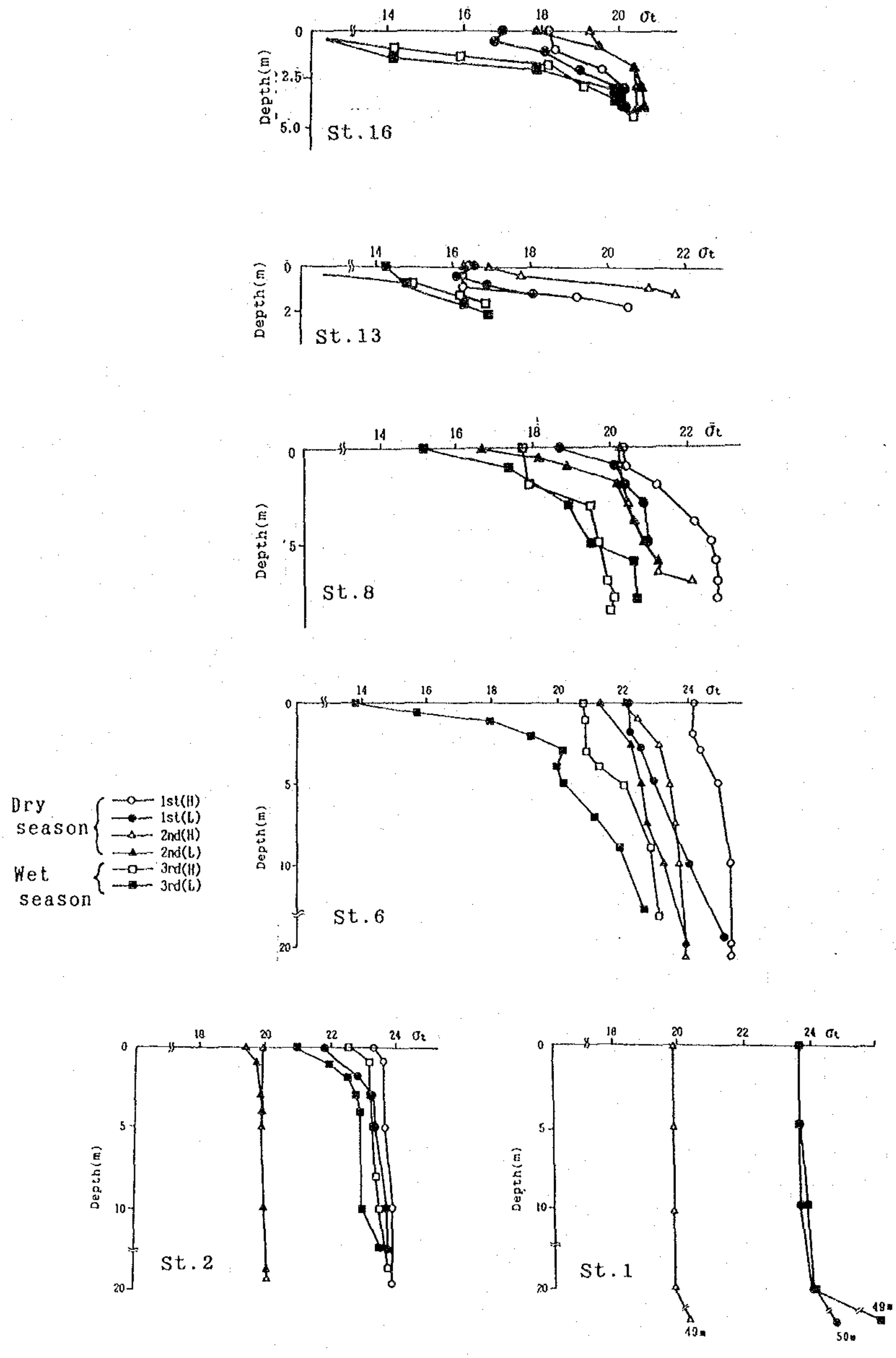


Fig. 1.5-1 Vertical Distribution of Water Density

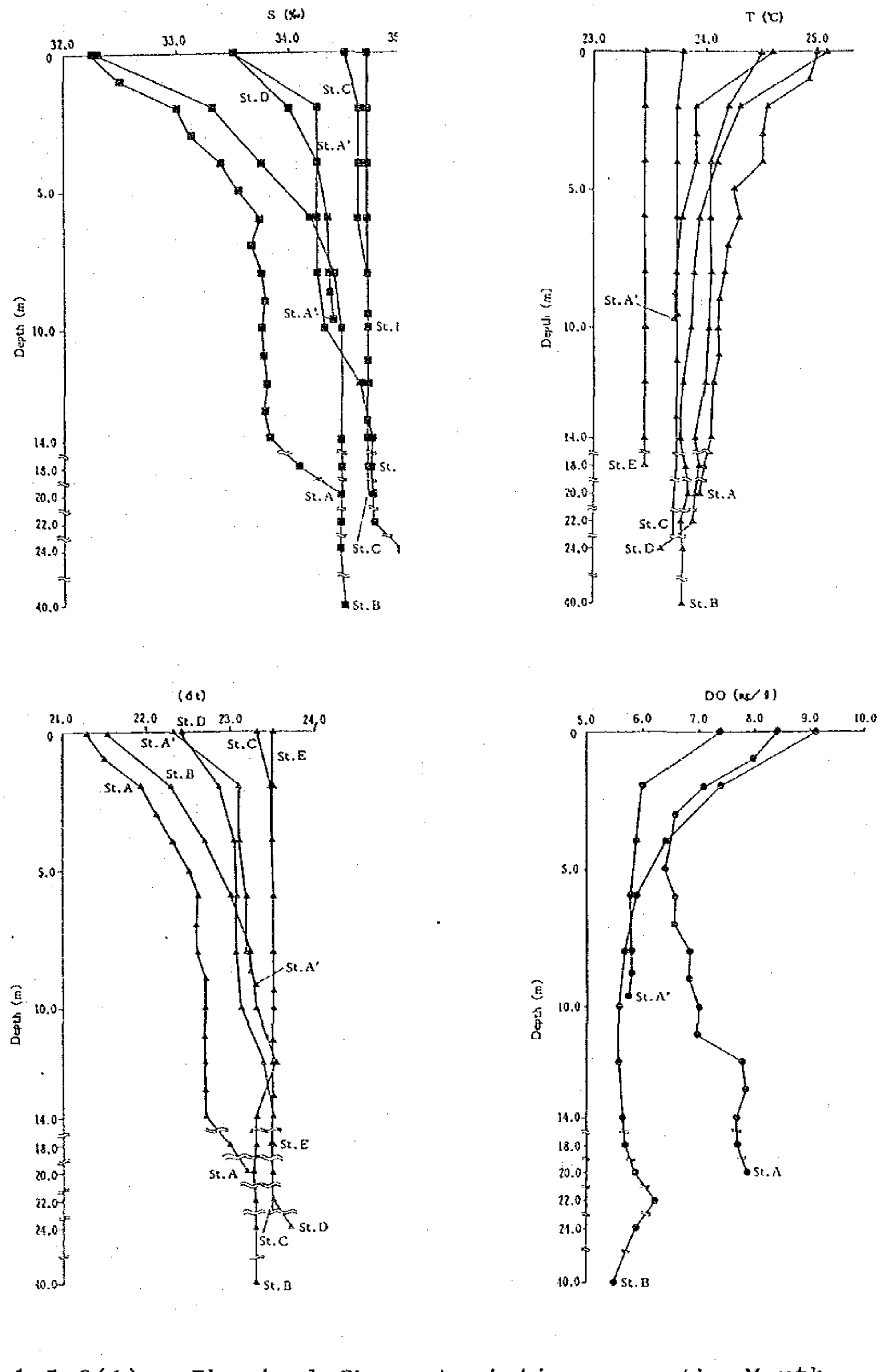


Fig. 1.5-2(1) Physical Characteristics near the Mouth of the Bay-1

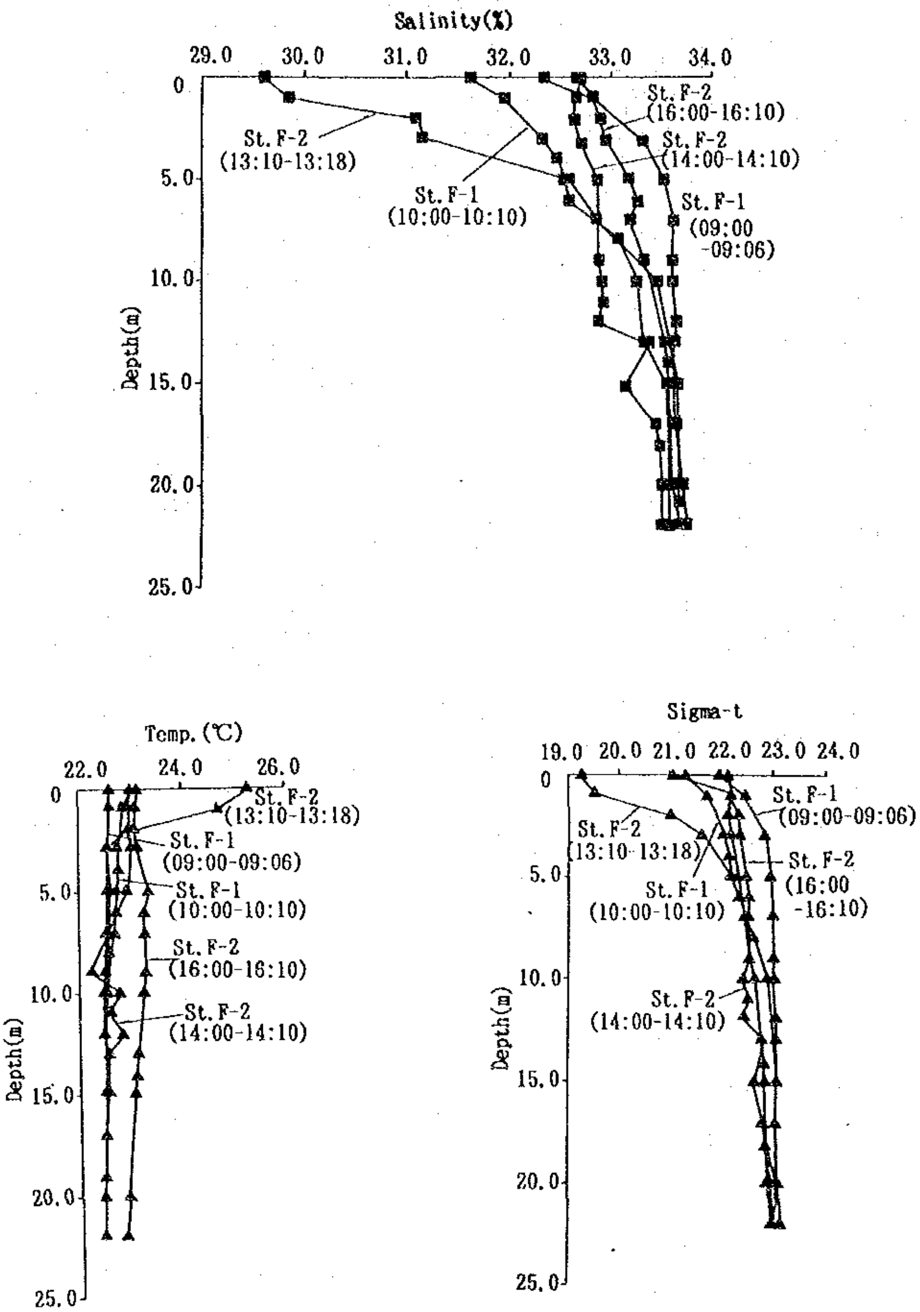
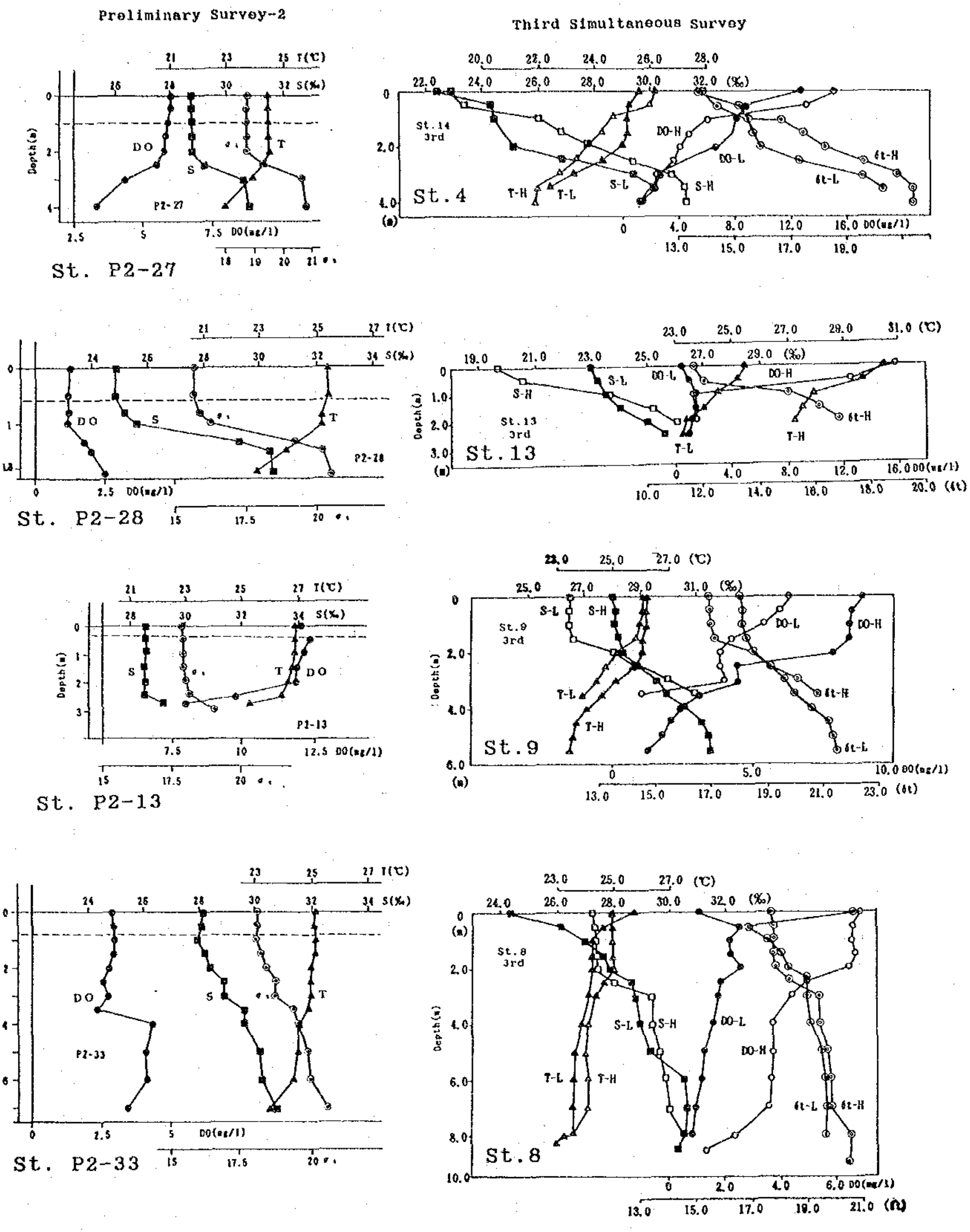


Fig. 1.5-2(2) Physical Characteristics near the Mouth of the Bay-2



T-L: Temp.(Low tide)
S-L: Salinity(Low tide)
DO-L: DO(Low tide)
σ_t-L: σ_t(Low tide)

T-H: Temp.(High tide)(°C)
S-H: Salinity(High tide)(‰)
DO-H: DO(High tide)(mg/l)
σ_t-H: σ_t(High tide)

Fig. 1.5-3 Break-down of Stratification

rates ranged widely in all areas of the Bay reflecting complicated biological, chemical and physical reaction.

Surface DO concentration was different in low and high tides in June and November; DO was higher in low tide than in high tide in June, but the opposite tendency was found in November. This was mainly due to the time of the tide ; low tide in June occurred in the afternoon and higher photosynthesis caused higher DO distribution in the surface layer. In November, however, high tide occurred in the afternoon, possibly effecting the opposite result (Fig. 1.6-1 and Tables APP 1.2-1 - 6).

Although DO in May tended to be higher in low tide than in high tide, it was not significantly different.

The mean surface concentrations in the dry season were higher on the north-western side (Stns. 13, 14 and 18) than other areas in the Bay, and tend to decrease toward the Bay mouth (Fig. 1.6-2).

Surface DO values obtained around stations 7, 8 and 9, however, were quite lower than around the Bay mouth area.

In the wet season, the mean DO values measured in the two tides was similar to these measured in the dry season. But on the south-western side, DO was not so low as in the dry season. Unfortunately the DO values were not confirmed on the north-eastern side in the wet season due to lack of data.

DO saturation percentage was occasionally higher than 200 %, and unbelievably high values of 306 % and 301 % were recorded at the shallow inner Bay area (St. 14) and at the surface layer near the mouth of the Bay (St. 5) in low tide in June, respectively (Fig.1.6-1).

In the upper layers, particularly in the inner Bay, oxygen was obviously always produced by the high photosynthesis of phytoplankton with sufficient nutrient, strong light intensity and high temperature. Surface DO distribution tending to correspond to the Chl-a distribution and phytoplankton numbers also proves that high DO in the surface layer is the result of active photosynthesis (Figs. 2.3-2 and 2.3-3 in Chapter II).

1.6.2 Vertical Distribution

In contrast to considerably high values found in the surface layers in the inner Bay area, DO sharply decreased in the deeper layers (Fig. 1.6-3). DO, particularly near the bottom, was sometimes remarkably low ; 0 mg/l near St. 16, on the northeastern side in April, 1992 (preliminary survey-1), lower than 0.5 mg/l at many stations on the western side of the inner Bay in April and May, 1992 (Figs. 1.6-3, Tables APP 1.7-1).

The DO discontinuous depths were generally found around three meters deep, usually a little above the depth where sigma-t

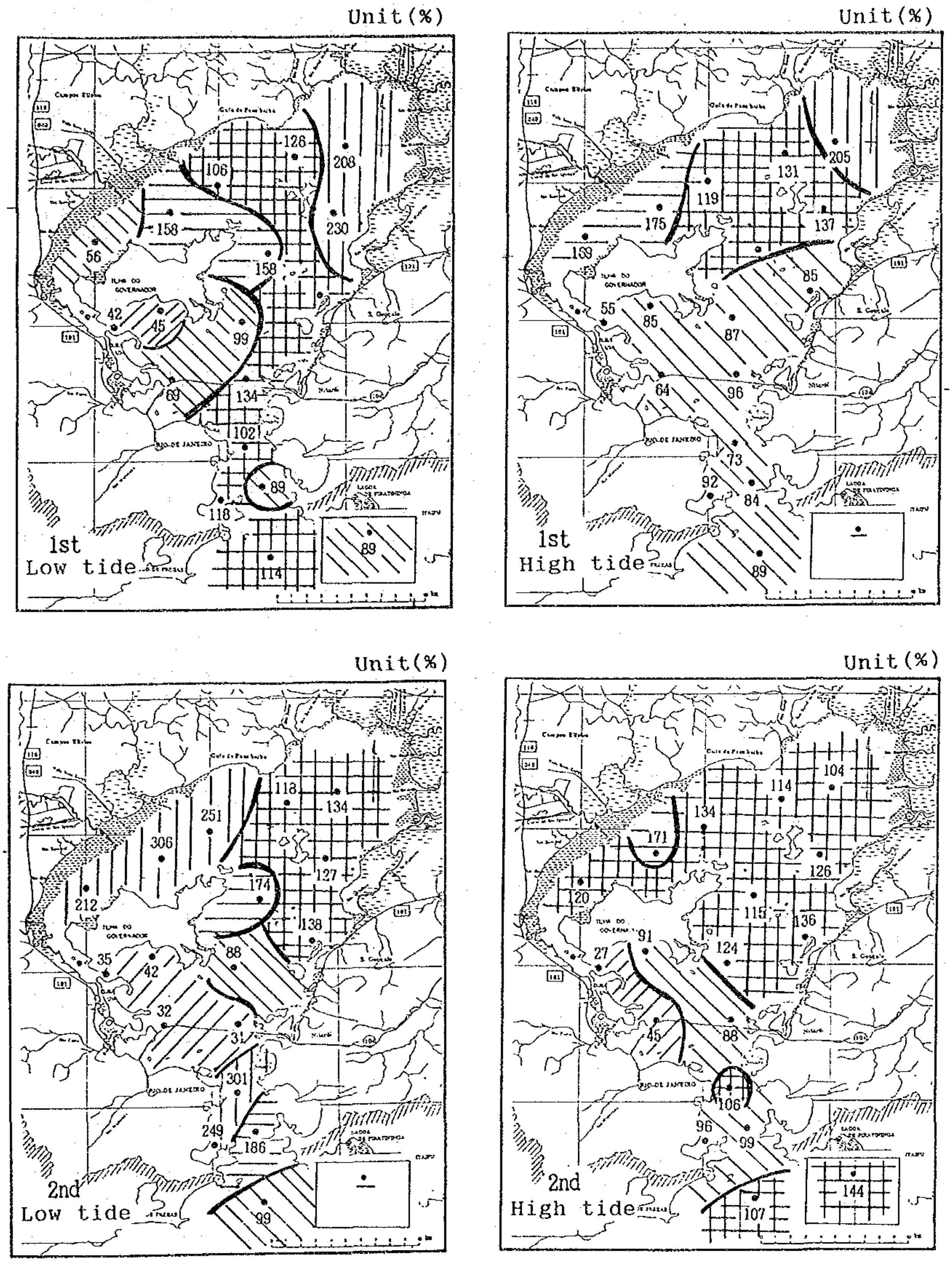
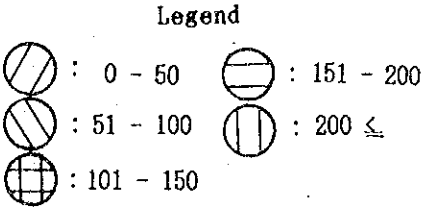
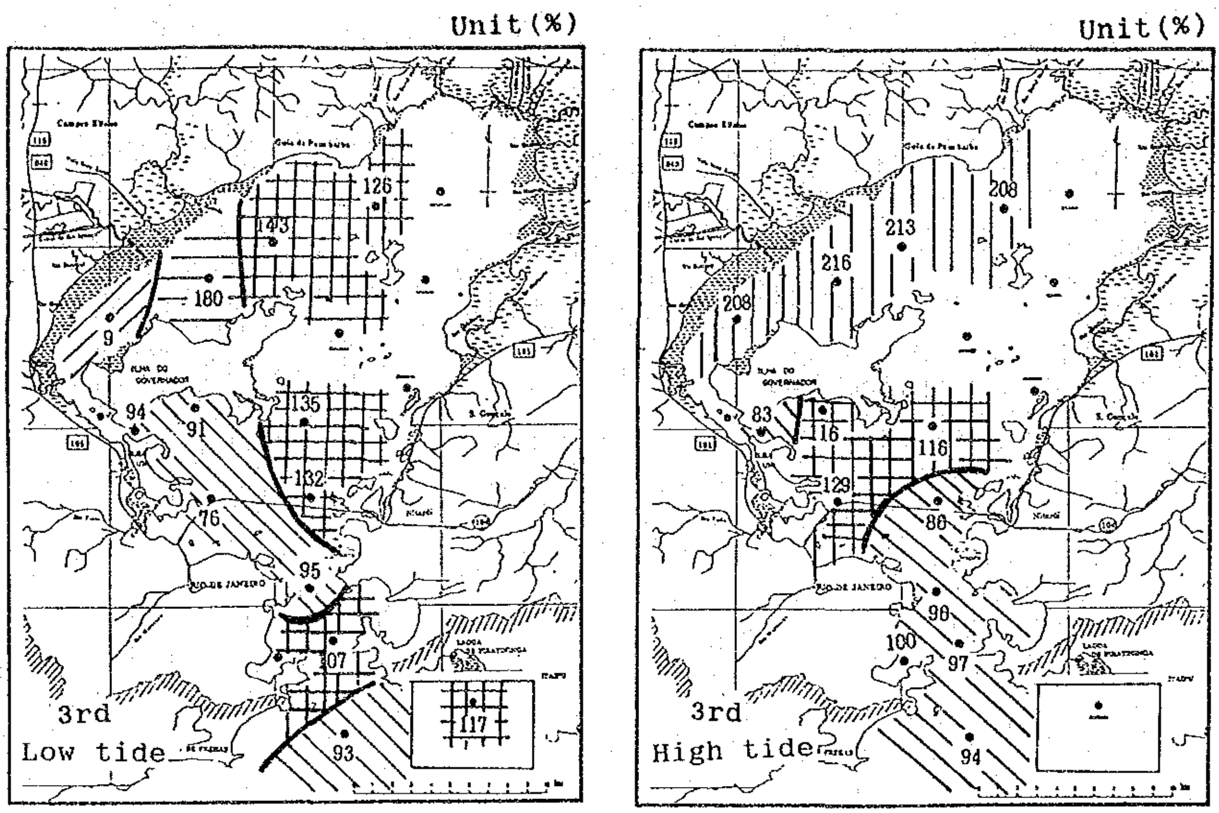


Fig. 1.6-1(1) Distribution of Dissolved Oxygen in the Surface Layer in the Dry Season





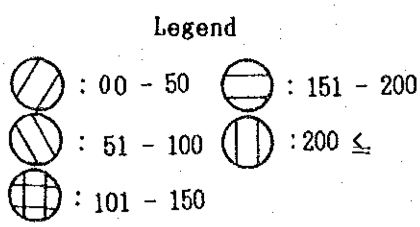


Fig. 1.6-1(2) Distribution of Dissolved Oxygen in the Surface Layer in the Wet Season

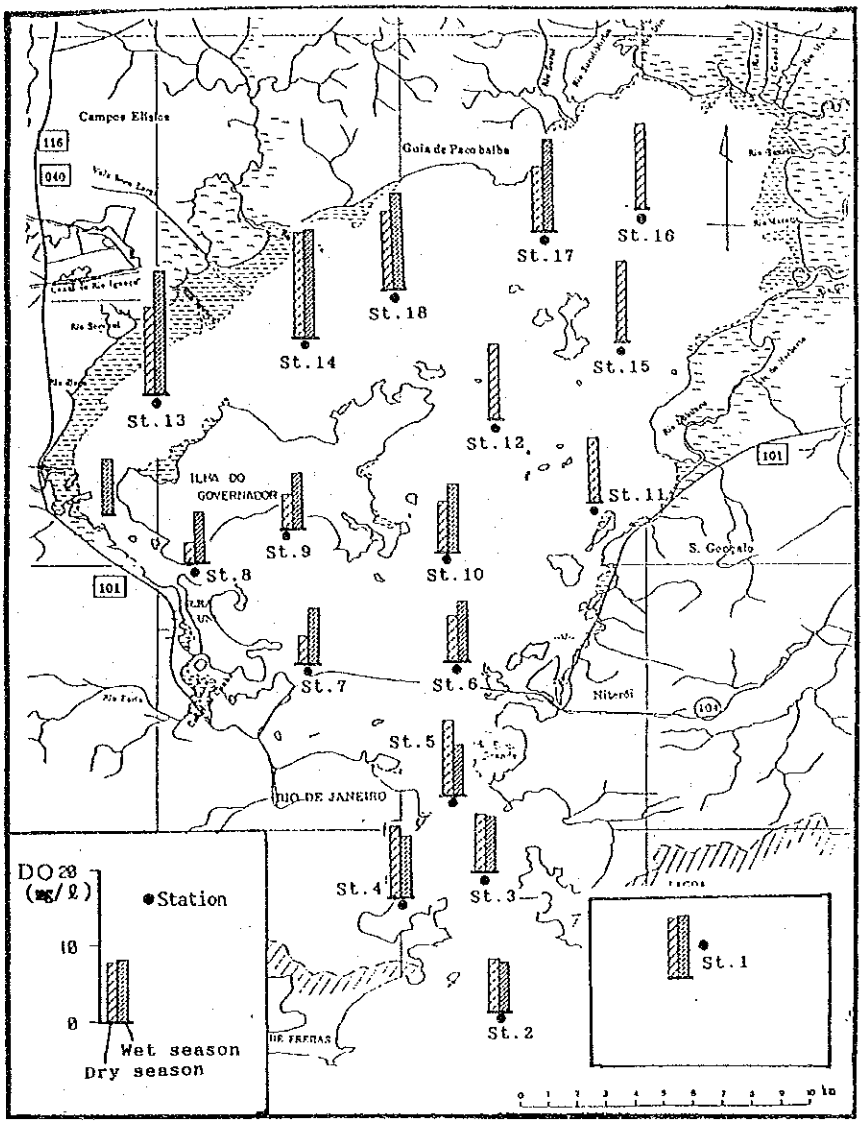


Fig. 1.6-2 Distribution of Mean Dissolved Oxygen in the Surface Layer

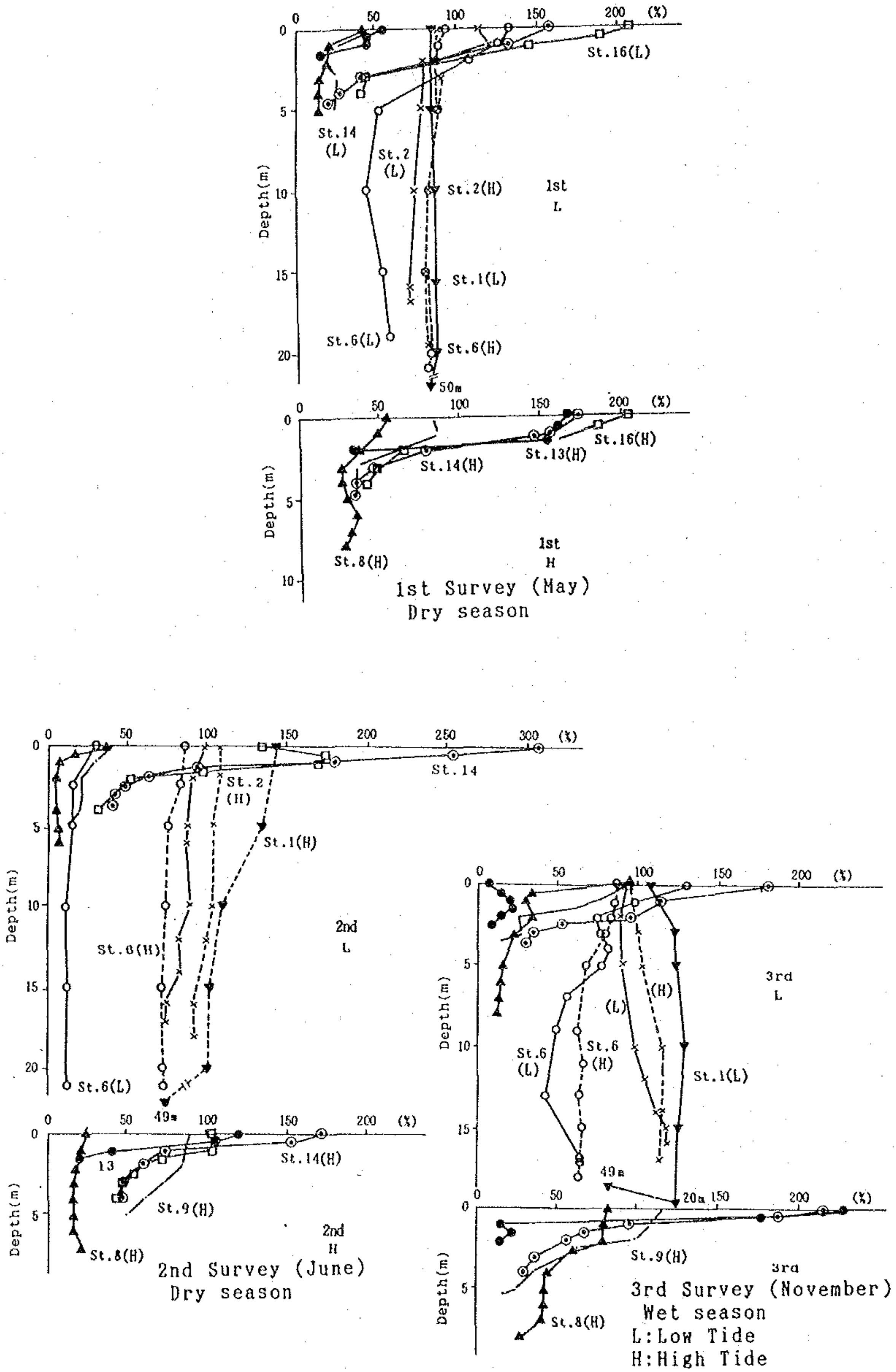


Fig. 1.6-3 Vertical Distribution of Dissolved Oxygen

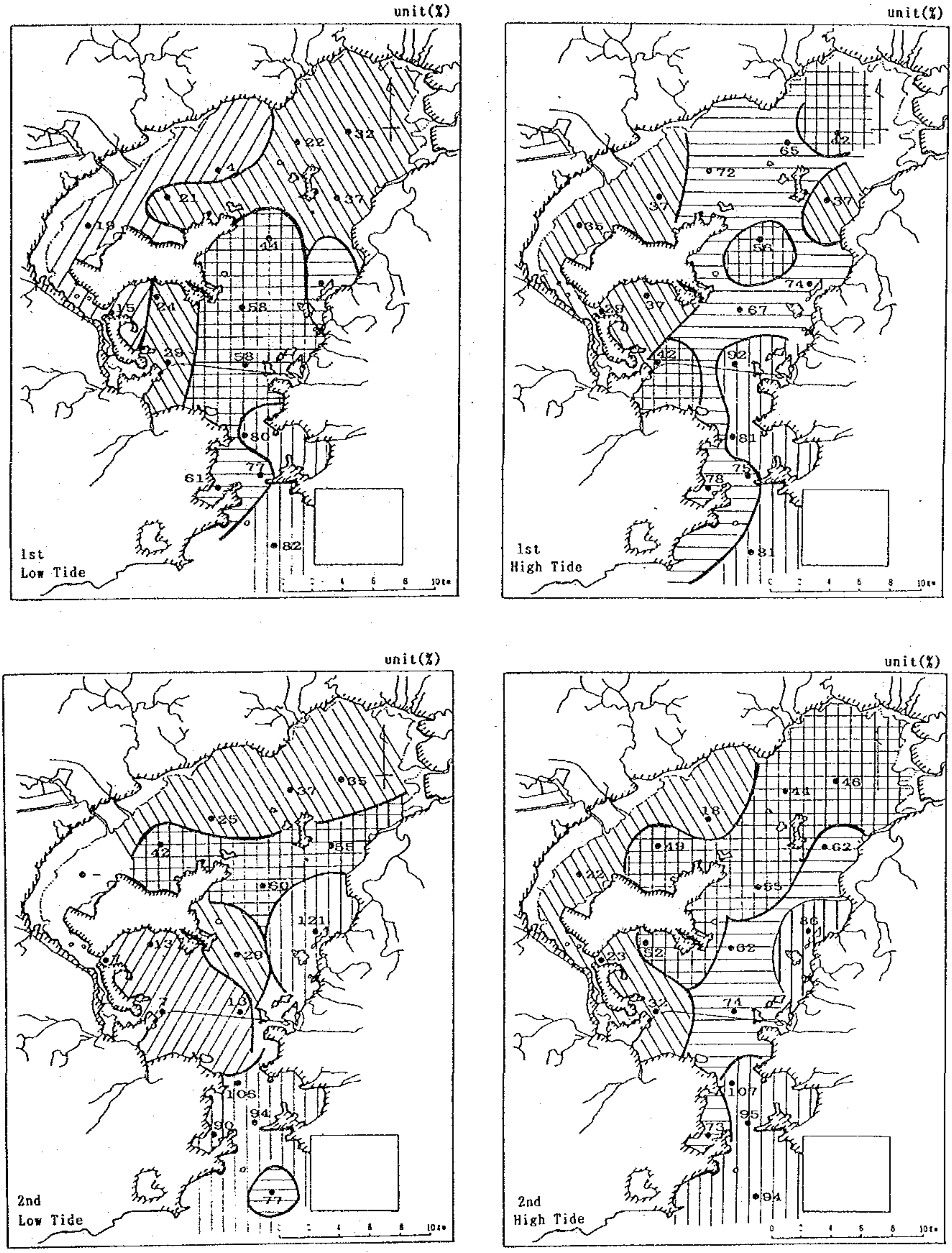


Fig. 1.6-4(1) Distribution of Dissolved Oxygen at the Bottom in the Dry Season

Legend

: 0～20
: 21～40
: 41～60
: 61～80
: 81≦

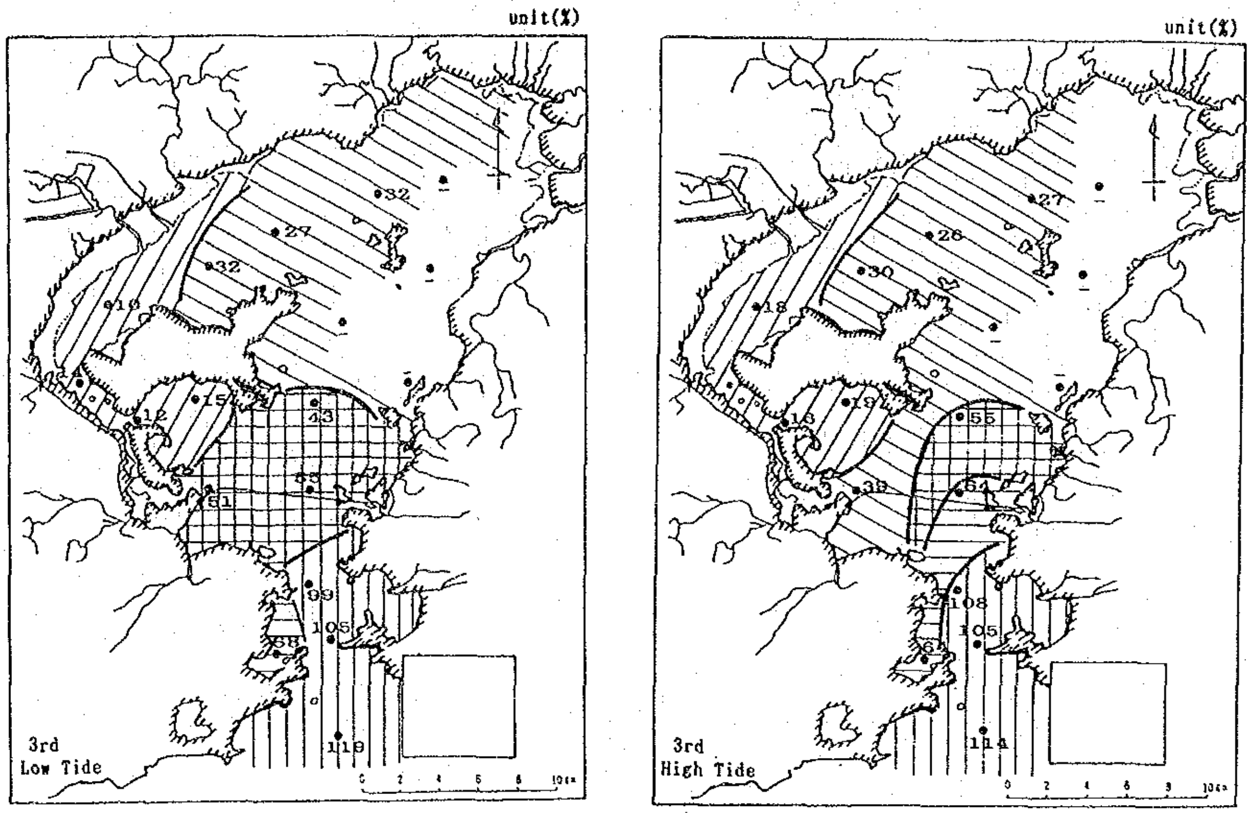
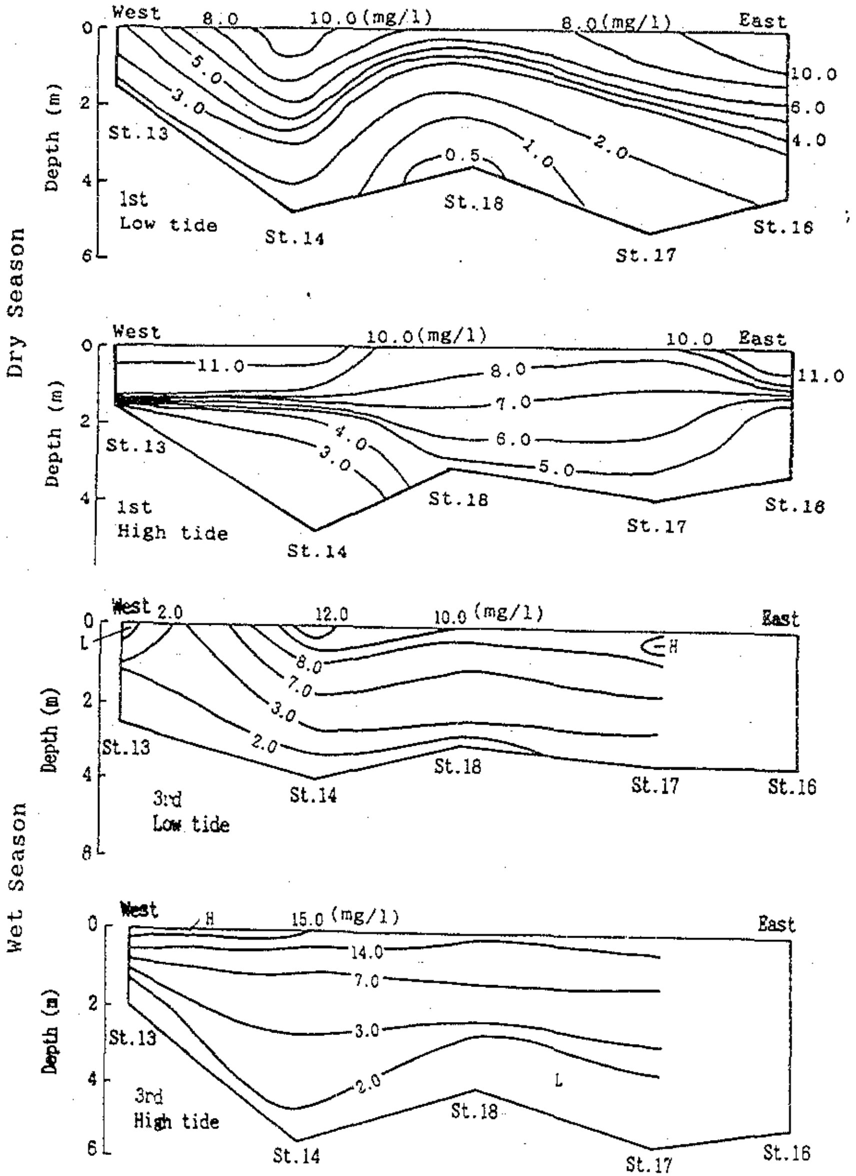


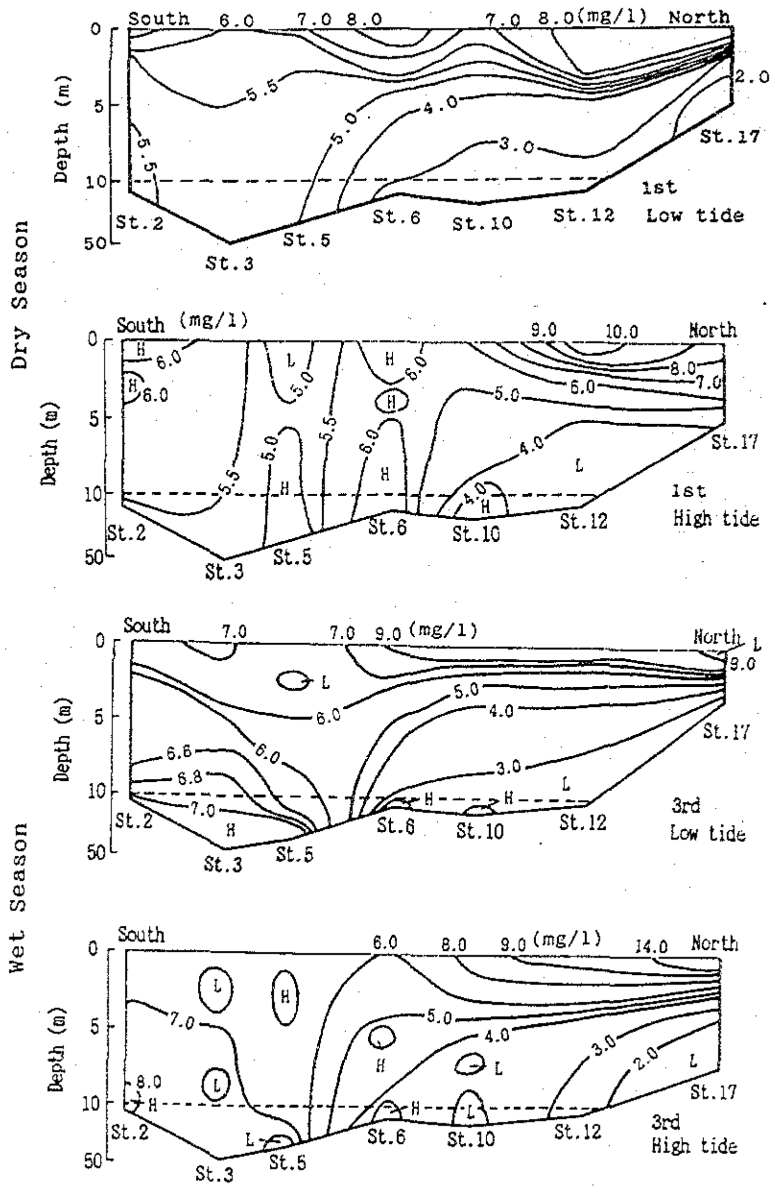
Fig. 1.6-4(2) Distribution of Dissolved Oxygen at the Bottom in the Wet Season

Legend

: 0～20
: 21～40
: 41～60
: 61～80
: 81≦



Sections as seen from the South



Sections as seen from the East

Fig. 1.6-5 Vertical Sections of the Dissolved Oxygen Distributions across the Bay greatly increased. It is obvious that phytoplankton resides and condense above this depth producing large quantity of oxygen.

However due to light inhibition, surface DO values were sometimes observed to be lower than those in layers directly below the surface layer in the inner Bay area at Stns. 2 and 9 in May, St.13 in November, St. 16 in June, and in several cases.

DO values near the bottom increased from the inner Bay area toward the outer area. Then the difference in DO values between the surface and the bottom were significantly greater in the inner Bay than the outer part of the Bay (Figs. 1.6-3, 4 and 5).

DO at the bottom is consumed by sediments due mainly to decomposition of organic matters in the sediment and oxidation of reduced materials.

Organic matters in the water also consume oxygen by decomposition in the deeper layers. On the other hand, DO is supplied from the upper layers by the mixing of water or its turnover.

It is, however, very difficult to determine to the mechanism of DO depression on the western side of the inner Bay area. The oxygen consumption rate of bottom sediments in this area did not differ from other areas (in Chapter III), but the concentrations of organic materials were very high and DO supply may have been inhibited by the well developed stratification of upper layers. Consequently despite of high DO values in the upper layers, very low DO values were observed in the deeper layers.

DO distribution near the mouth of the Bay to the St. 6 area was vertically very homogeneous, as found in the salinity and temperature distributions, especially at Stns. 5 and 6 (Fig. 1.5-2). This also proves that water in the area mixes well or that turnover of water occurs in these areas.

DO in the uppermost layers of the outer Bay area is probably mainly caused by photosynthesis. In the deeper layers, however, DO is more likely to be attributed to offshore water effects than to the process found in the inner Bay area. Therefore, higher values are occasionally measured in the deeper layers than in the upper layers.

The enormous volume of water in the Bay in areas deeper than 10 m, which was found in the central and the outer Bay areas, was considerably homogeneous with respect to DO, Temperature and salinity concentrations (Fig. 1.6 - 5).

1.7 Supplementary Results

The results obtained from preliminary surveys -1 and -2 are referred to in this section. These surveys were performed over a period of several days, and some surveys for survey-2 were done under strong wind condition. Therefore, the results were treated as supplementary to the simultaneous surveys (Tables APP 1.7-1 and 2) .

The four physical characteristics at 5 out of 47 stations represent the characteristics around each station (Fig. 1.7-1).

Fig A indicates the physical characteristics near the mouth area and figures from B to E show the characteristics toward the inner Bay area.

The discontinuous depth of each physical characteristics gradually became clearer and depths appeared to become shallower from the mouth toward the inner Bay area.

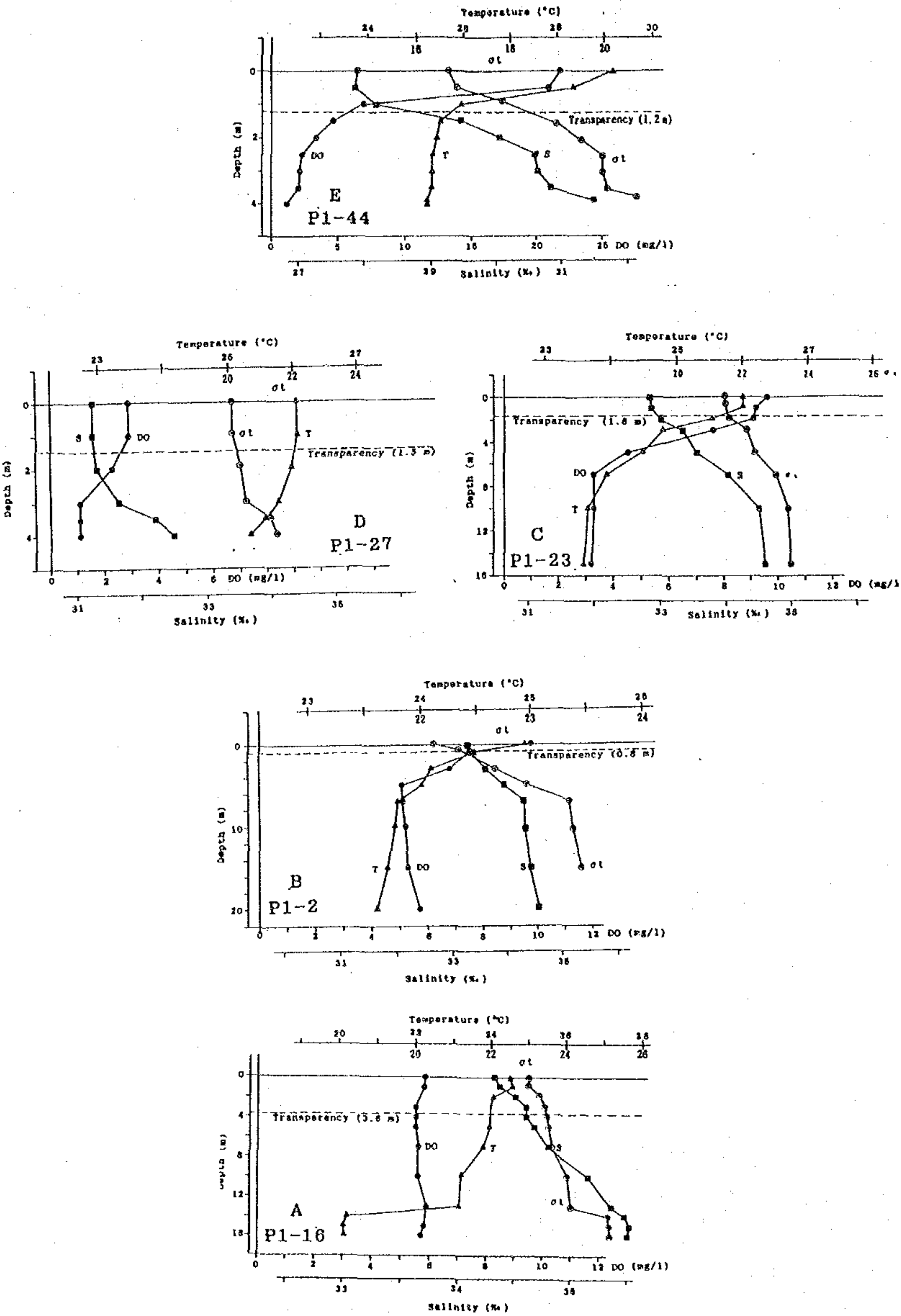


Fig. 1.7-1 Physical Characteristics at the Representative Stations

CHAPTER 2

WATER QUALITY IN THE BAY

CHAPTER 2

WATER QUALITY IN THE BAY

Water quality in the Bay had already been examined at fixed stations by FEEMA from 1968 and the results showed seriously polluted conditions.

Water quality surveys were carried out in this study period in stations more numerous than FEEMA's in the dry (April to June) and wet (October to December, 1992) seasons.

Physical, chemical and biological water properties were determined in order to consider pollution mechanism of the Bay.

Data was used for simulation analysis to propose the master plan for future anti- pollution measures in the Bay.

2.1 Surveys and Methods for Water Quality Determination

2.1.1 Simultaneous Surveys

The main survey for the water quality carried out simultaneously, three times during the dry and wet seasons.

The survey and the sampling time at each station was set as close as possible to the high and low tide levels.

Dry season
- First simultaneous survey:
  - At low (morning) and high (afternoon) tides for the spring tides of May 18, 1992
- Second simultaneous survey:
  - At high (morning) and low (afternoon) tides for the neap tides of June 8, 1992

Wet season
- Third simultaneous survey:
  - At low (morning) and high (afternoon) tides for the spring tides of November 10, 1992

18 stations were established for the first and the second surveys, and also for the third survey at high tide. These stations covered the whole Bay area, and one station was set 10 km from the Bay mouth (St.1). The results obtained at St.1 were considered as a reference for non-polluted water.

All stations were set up using as a reference previous results obtained in preliminary surveys 1 and 2. which were performed prior to the first and the third simultaneous survey (see Chapter I).

One more station (St. 19) was added at low tide for the third survey (Fig. 2.1-1).

Station 19 was located between the southwestern side of Ilha do Governadore and the main land, which is narrow and at the middle part of the water route. Water around this area is considered to be seriously polluted as it is located in a densely populated area in addition to industries and urban rivers.

Four boats were used in each survey.

The locations, the sampling depths and the parameters analyzed in the first survey are shown in Table 2.1-1. The sampling depths were decided depending on water depth.

Basically the same locations, depths and parameters were employed in the second and third surveys (Tables APP 2.1-1(1) and (2)).

2.1.2 Surveys in Small Bays and Coastal Areas

Surveys were also conducted in two small bays (Botafogo and Jurujuba) and at two coastal stations (Centro de Ilha do Engenho and Rio Porto), and their results were added to those of the water quality in the Bay previously obtained only in open areas by the simultaneous and preliminary surveys (Fig. 2.1-2).

All areas were assumed to be seriously polluted mainly because of their locations in the Bay.

Survey and the measurement methods and parameters used were similar to those in the simultaneous surveys.

2.2 Treatment and Analysis of the Sampled Water

2.2.1 Treatment of Sampled Water

The collected seawater samples were treated with chemicals and stored in ice-boxes on boats to prevent decomposition.

After the survey, they were immediately transferred to the refrigerators in the laboratory at 4 °C until they were analyzed.

2.2.2 Analytical Methods

Microbiological analysis was immediately commenced after the samples arrived at the laboratory.

Water was sampled to determine biochemical oxygen demand (BOD) at several representative stations assumed to be seriously polluted. Analysis was carried out using ordinary methods in "Standard Methods for the Examination for the Water and Wastewater" of

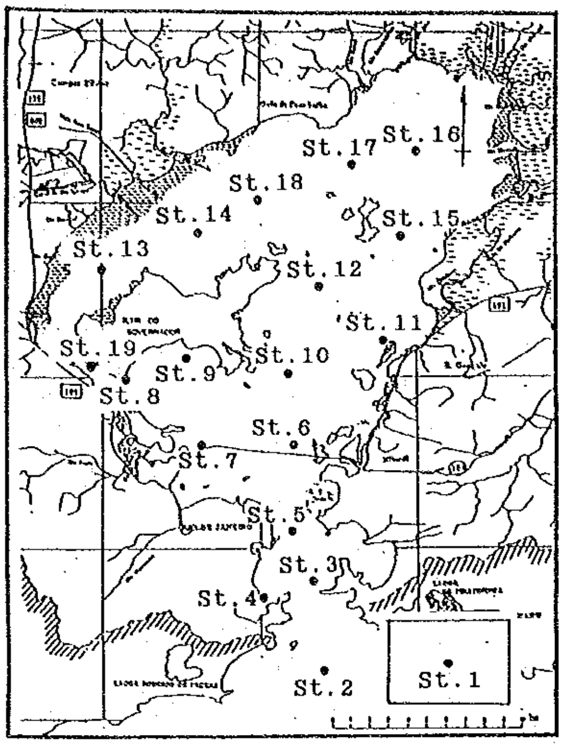


Fig. 2.1-1 Sampling Stations for Simultaneous Survey

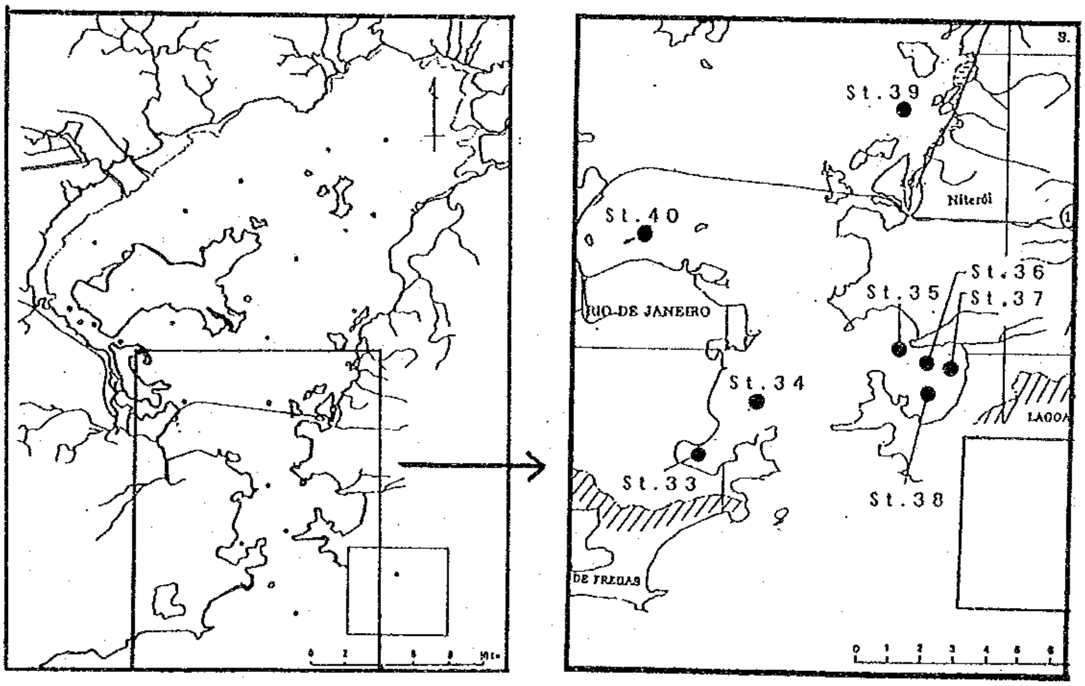


Fig. 2.1-2 Sampling Stations in Small Bays and Coastal Areas

Table 2.1-1 Location, Sampling Depth and Analytical Parameters of the First Simultaneous Survey

Spring Tides - Low Tide (morning)

Item / St.	Location South	Location West	Water Depth(m)	COD(Mn) DCOD(Mn)	BOD T-KN D-KN	SS, NH4-N, NO2-N NO3-N, TP, PO4-P Coli-forms	Phenols, CN	n. Hex. Extract	Metals, Toxic Substance	Chl-a, Phyto-plankton
1	23°04'44.7'	43°04'59.6'	51.0	0, 5, 25, B	-	0, 5, 25, B	-	0	0, B	0, 5
2	22°58'27.8'	43°08'02.4'	17.3	-	-	0, 5, B	-	0	0, B	0, 5
3	22°55'48.3'	43°08'40.0'	50.0	0, 5, B	0, B	0, 5, B	0, B	0	0, B	0, 5
4	22°56'25.5'	43°10'02.0'	12.5	0, 3, 7, B	-	0, 3, 7, B	-	0	0, B	0, 3
5	22°54'15.6'	43°09'03.3'	38.5	-	-	0, 5, 10, B	-	0	0, B	0, 5
6	22°51'52.0'	43°11'31.0'	20.0	0, 5, 10, B	0, B	0, 5, 10, B	0, B	0	0, B	0, 5
7	22°51'59.1'	43°11'57.8'	6.0	-	-	0, 3, B	-	0	0, B	0, 3
8	22°50'10.0'	43°14'11.8'	6.0	0, 2, B	0, B	0, 2, B	0, B	0	0, B	0, 2
9	22°49'33.8'	43°12'28.4'	5.0	0, B	0, B	0, B	0, B	0	0, B	0, B
10	22°50'01.0'	43°09'10.4'	24.0	-	-	0, 5, B	-	0	0, B	0, 5
11	22°49'01.0'	43°06'13.4'	2.4	0, B	0, B	0, B	0, B	0	0, B	0, B
12	22°47'49.1'	43°07'56.1'	15.4	0, 5, B	-	0, 5, B	-	0	0, B	0, 5
13	22°47'00.0'	43°15'00.0'	1.5	0, B	0, B	0, B	0, B	0	0, B	0, B
14	22°46.00.0'	43°12'00.0'	4.7	0, 3, B	0, B	0, 3, B	0, B	0	0, B	0, 3, B
15	22°46'09.1'	43°05'29.2'	7.5	0, 3, B	-	0, 3, B	-	0	0, B	0, 3
16	22°47'13.3'	43°05'41.9'	4.3	0, B	0, B	0, B	0, B	0	0, B	0, B
17	22°44.00.0'	43°07'00.0'	5.2	0, B	0, B	0, B	0, B	0	0, B	0, B
18	22°44'00.0'	43°10'00.0'	3.5	0, B	0, B	0, B	0, B	0	0, B	0, B

Spring Tides - High Tide (afternoon)

Item / St.	Water Depth(m)	COD(Mn) DCOD(Mn)	BOD T-KN D-KN	SS, NH4-N, NO2-N NO3-N, TP, PO4-P Coli-forms	Phenols, CN	n. Hex. Extract	Metals, Toxic Substance	Chl-a
1	-	-	-	-	-	-	-	0, 5
2	20.0	0, 5, B	-	0, 5, B	-	-	-	0, 5
3	50.0	0, 5, B	-	0, 5, B	-	-	-	0, 5
4	7.5	0, 3, 7, B	-	0, 3, 7, B	-	-	-	0, 3
5	34.0	0, 5, 10, B	-	0, 5, 10, B	-	-	-	0, 5
6	22.0	0, 5, 10, B	-	0, 5, 10, B	-	-	-	0, 5
7	6.5	0, 3, B	-	0, 3, B	-	-	-	0, 3
8	8.5	0, 2, B	-	0, 2, B	-	-	-	0, 2
9	5.0	0, B	-	0, B	-	-	-	0, B
10	26.0	0, 5, B	-	0, 5, B	-	-	-	0, 5
11	5.0	0, B	-	0, B	-	-	-	0, B
12	17.5	0, 5, B	-	0, 5, B	-	-	-	0, 5
13	2.0	0, B	-	0, B	-	-	-	0, B
14	6.0	0, 3, B	-	0, 3, B	-	-	-	0, 3, B
15	10.0	0, 3, B	-	0, 3, B	-	-	-	0, 3
16	4.3	0, B	-	0, B	-	-	-	0, B
17	5.0	0, B	-	0, B	-	-	-	0, B
18	4.0	0, B	-	0, B	-	-	-	0, B

USA . Results were used as parameters for the determination of material balance and for simulation. Although the number of data was not enough, it could be obtained the lack of data by correlating BOD values with chemical oxygen demand (COD(Mn)).

COD(Mn) in the first survey was not measured at several stations, but measurements were carried out at almost all stations, and layers afterwards. COD(Mn) was analyzed using the $KMnO_4$-alkaline method which was recommended by FAO for sea water; "FAO Fisheries Technical Paper No. 137, 1975 - Manual of Method in Aquatic Environment Research." However, the method is known only to oxidize some part of the organic materials and usually the values were lower than that measured by $KMnO_4$-acidic.

Kjeldahl-nitrogen analysis was carried out on the stations with gravely polluted conditions same as for BOD analysis.

The dissolved form was defined for the filtrate through a 0.45 μm pore-size filter paper.

Chlorophyll-a (Chl-a) was analyzed using the modified Strickland and Parsons methods: Chl-a was extracted into 90 % acetone after the pigment particles were filtered on 0.45 μm filter paper, then its absorption spectrophotometry was measured.

The methods for the rest of the parameters were taken from the USA "Standard Methods for the Examination for Water and Wastewater".

Due to some troubles in the second survey, few parameters of water quality were analyzed (Tables APP 2.1-1(1) and (2)).

Cyanide (CN), normal-Hexan extract (n-Hexan extract), polychlorinates Biphenyl (PCB's) and DDT were not analyzed in the third surrey, because values were not detected in the first and second surveys.

Total organic carbon (TOC) parameter used when the material cycle was considered. Unfortunately, however, the TOC analyzer did not function well enough throughout the survey period to obtain for us the data needed.

2.3 Water Quality Conditions

2.3.1 Transparency

The transparency, obtained from the Secchi-disk reading depth, was very low throughout the survey period over the whole area of the Bay (Fig. 2.3.-1, Tables APP 2.3-1 - 6).

In the inner Bay area it was always lower than 1.0 m in the dry season and 0.5 m in the wet season, mainly seeing to reflect the distribution of high Chl-a concentrations.

Despite being expected, the water around St.2 has not yet been polluted. This is due to the effect of offshore water. However, transparency was relatively low, measuring only 5.3 m for the dry season. It appears, though, that the water here had been polluted sufficiently to produce pytoplankton which have reduce the transparency.

2.3.2 Chlorophyll-a

Although Chlorlphyll-a (Chl-a) does not always express directly the amount of phytoplankton resulting from plankton production, a good correlation is usually found between the amount of phytoplankton and the Chl-a concentration.

Phytoplankton production depends on the physiological condition of plankton and its species composition of plankton population, and the environmental conditions, such as light intensity, concentration of nutrients, water temperature, salinity and water conditions (e.g. stratification, residence time, etc).

Accordingly, Chl-a randomly distribution in the space and in the sampling time, however, higher values tended to be obtained on the northwestern and western sides, particularly in the northwestern side area, around Stns.14 and 18 (Figs.2.3-2 and 3, Tables APP 2.3-1 - 6). This tendency was also found in the distribution of phytoprankton numbers in the Bay.

Higher Chl-a concentrations were more often obtained in the wet than dry season in the central and inner parts of the Bay. Near the mouth area and in Botafogo, however, Chl-a was higher in the dry than in the wet season.

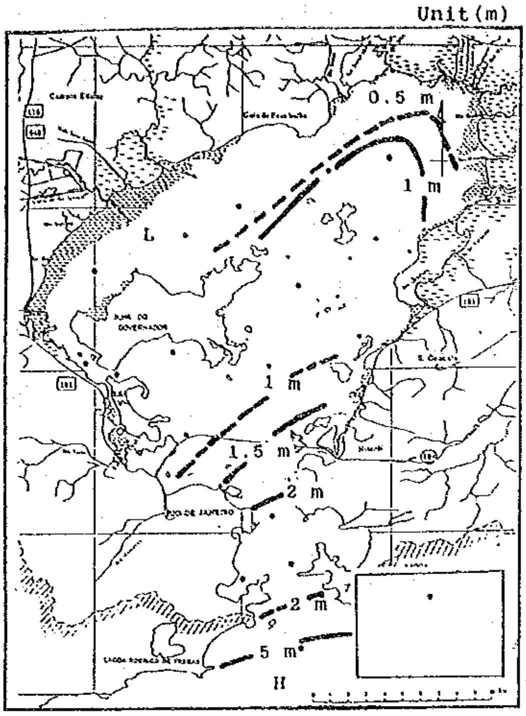
Extremely high concentrations of Chl-a were recorded at several stations in May and November; mainly in the eastern and northwestern areas (134 - 225 μg/l). Active photosynthesis due to the high Chl-a resulted in higher than 100% DO saturation, occasionally 130 - 180 %. High Chl-a concentration were mostly found at low tide.

In contrast to these results, Chl-a was relatively lower measured in June at both tides; 5 - 98 μg/l at low tide and 3 - 71 μg/l at high tide, with one exception of 139 ug/l at St.4.

It decreased sharply with depth, however, except when there was light inhibition in the surface layer wherein Chl-a at lower depth was higher than at the surface.

2.3.3 Chemical Oxygen Demand

The Chemical oxygen demand (COD(Mn)) in the surface layer is lower in the outer part of the Bay than in the inner Bay (Fig. 2.3-4 and Tables APP 2.3-1 - 6).



——— Dry Season
– – – Wet Season

Fig. 2.3-1 Transparency in the Bay

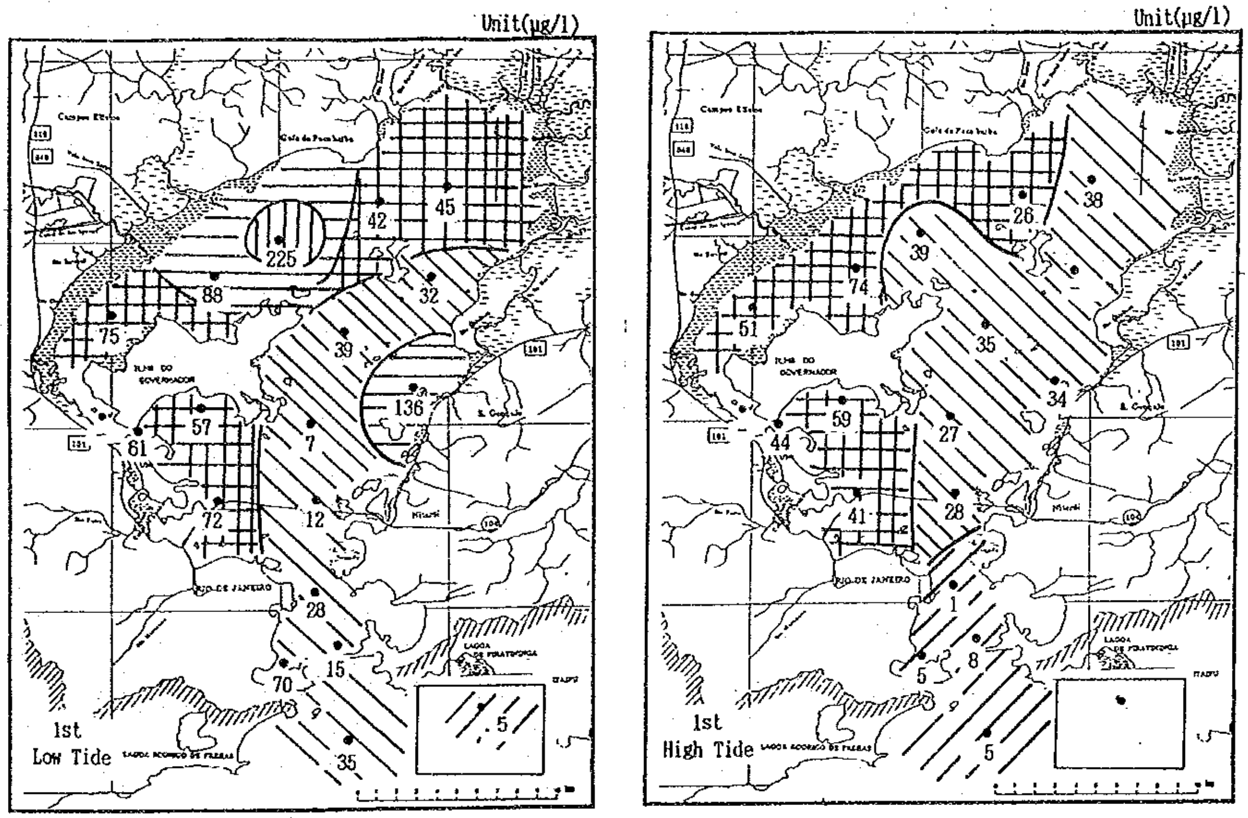


Fig. 2.3-2(1) Distribution of Chl-a in the Surface Layer (First Survey)

Legend
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: 11 – 40
: 41 – 80
: 81 – 150
: 150 <

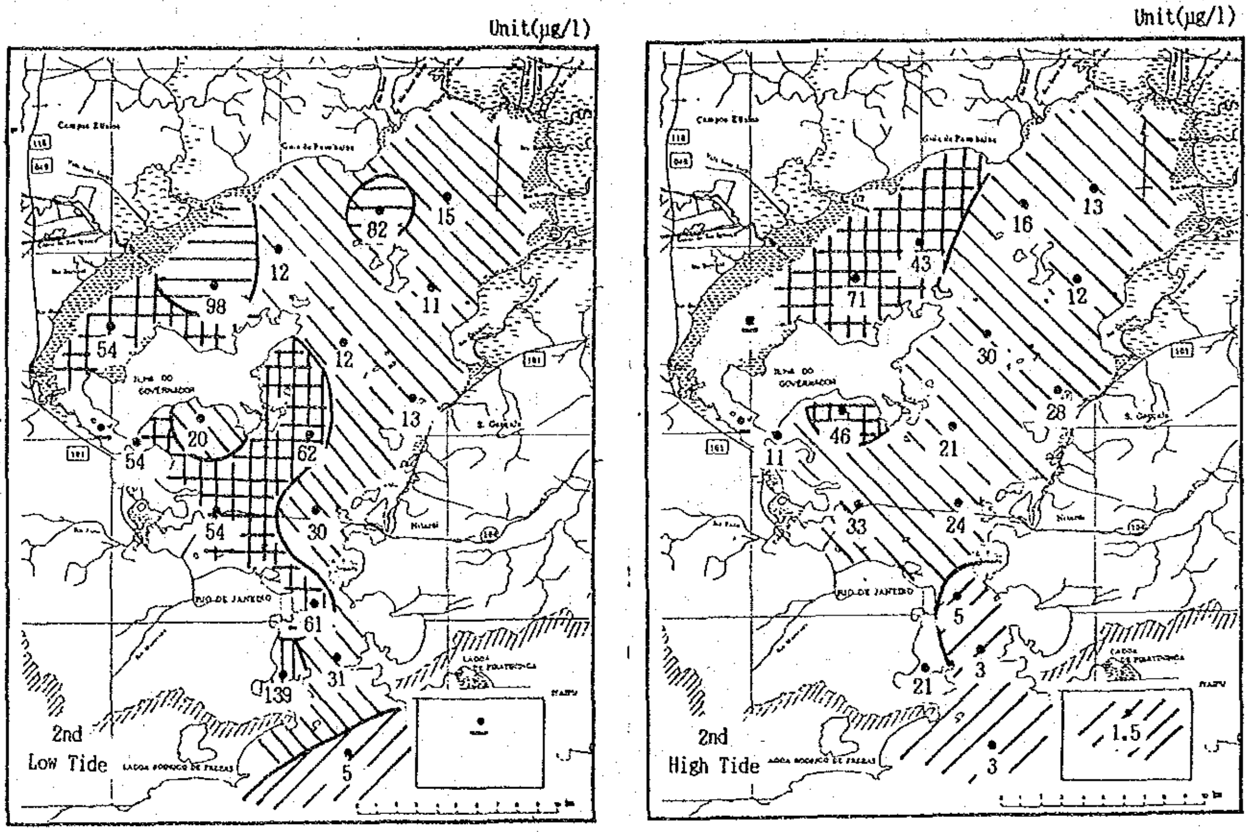
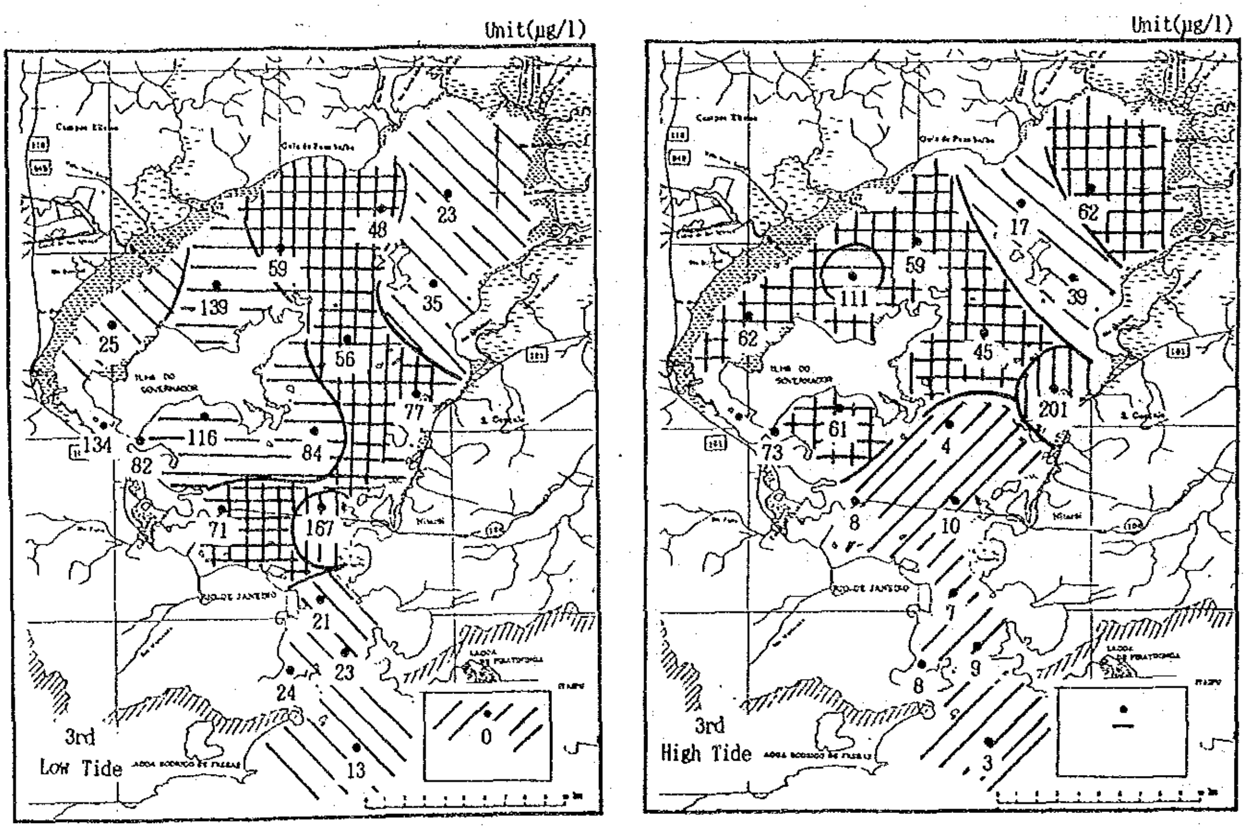


Fig. 2.3-2(2) Distribution of Chl-a in the Surface Layer (Second Survey)



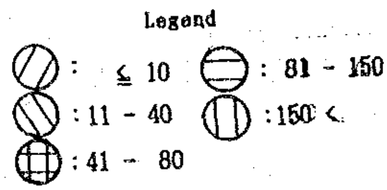
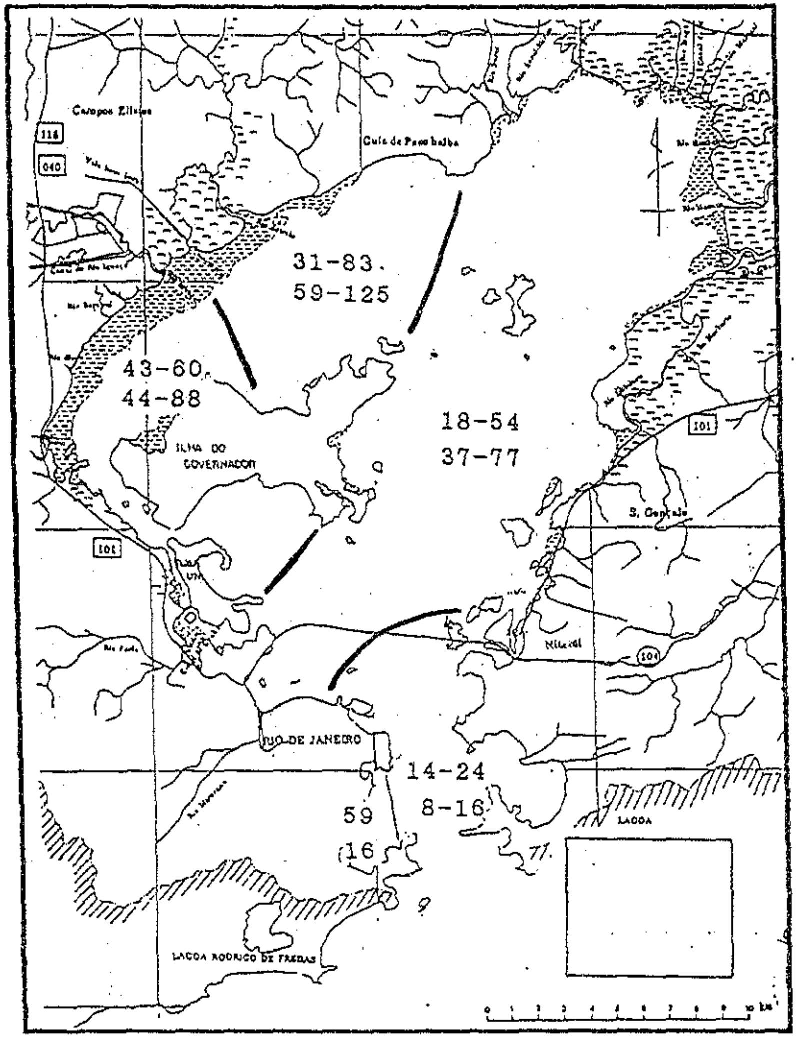


Fig. 2.3-2(3) Distribution of Chl-a in the Surface Layer (Third Survey)

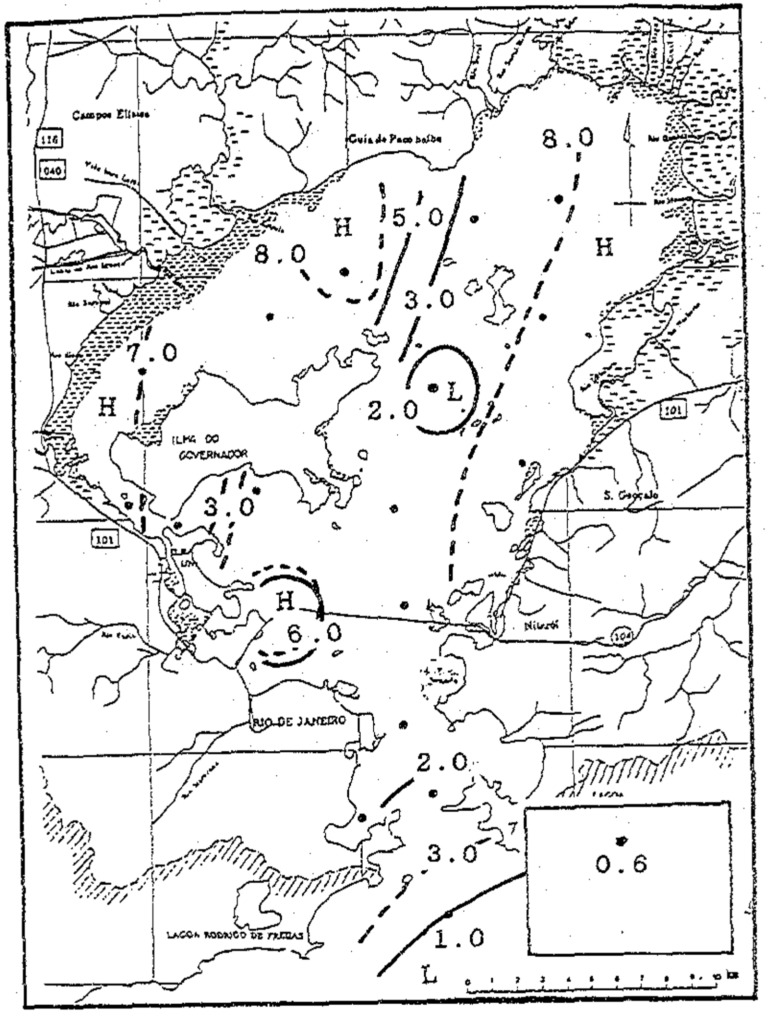
Unit (µg/l)



Dry Season (upper)
Wet Season (lower)

Fig. 2.3-3 Range of Mean Chl-a Values in the Surface Layer

Unit(mg/l)



Dry Season
Wet Season

Fig. 2.3-4 Distribution of COD(Mn)

The surface COD(Mn) values and their distribution patterns showed significant differences between the dry and the wet seasons, higher values were obtained in the northwest in the dry season, and on the north and northeast in the wet season.

Especially at the stations on the northeastern side in the wet season, the surface COD(Mn) was a lot higher (6.8 - 8.8 mg/l) than those in the dry season (1.8 - 3.4 mg/l).

The values decrease gradually in the dry season but sharply in the wet season with the depth, although the values in the deeper layers were almost same in this seasons.

These high values being found only in the surface layer and in the wet season were thought to be brought about the discharge of the big rivers (Rio Cacerebu and Rio Guapimirim), which resulted in very low salinity at these stations. Also, high phytoplankton production indicated by Chl-a concentrations may result in these high surface values in the wet season.

COD(Mn) values, amount of organic materials as well, measured by other methods are supposedly higher than the obtained values during the survey period, this is because KM_nO_4-alkaline method was used for seawater which is well known to oxidize organic matters in quite lower levels.

It is difficult to obtain the conversion factor of the COD(Mn) value to organic materials, for it changes depending on the quality of the organic materials.

Besides, it is also necessary to obtain the phytoplankton COd(Mn) when consider the internal production. However, it is said that the phytoplankton body does not get much oxidized by this method.

2.3.4 Biochemical Oxygen Demand

At the first stage of this study, TOC was expected to be used the as the main parameter when the material cycle and the simulation in the Bay. However, unfortunately the TOC analyzer did not work well and only a little reliable data were attained.

Besides, the data previously obtained for many kinds of water samples, including wastewater from industries, were measured by biochemical oxygen demand (BOD).

Therefore, BOD values were used as the pollution parameter of organic material for simulation in the basin. .

However, BOD was unfortunately measured only at the stations seriously polluted. The missing data were estimated using the correlation with COD(Mn), which gave a high coefficient for the dry season, May, 1992 (r=0.859), using all data at the surface

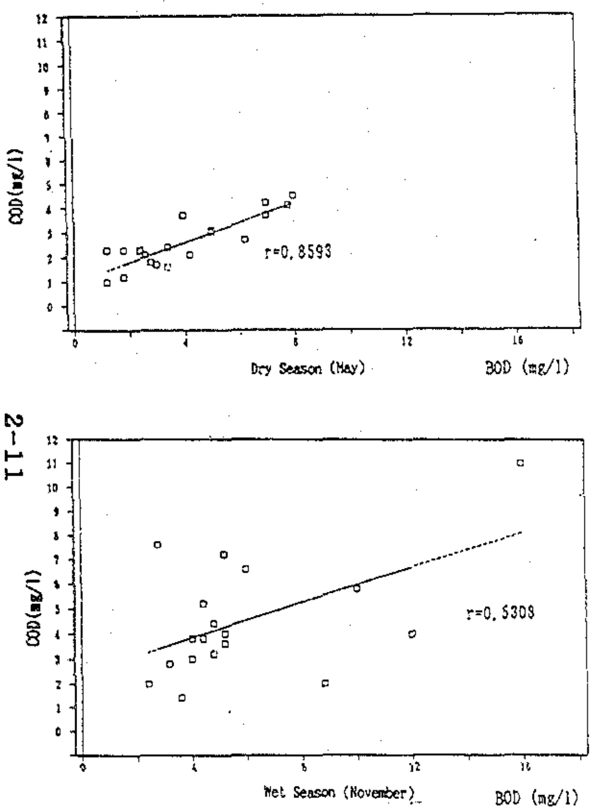


Fig. 2.3-5 Correlation between COD(Mn) and BOD

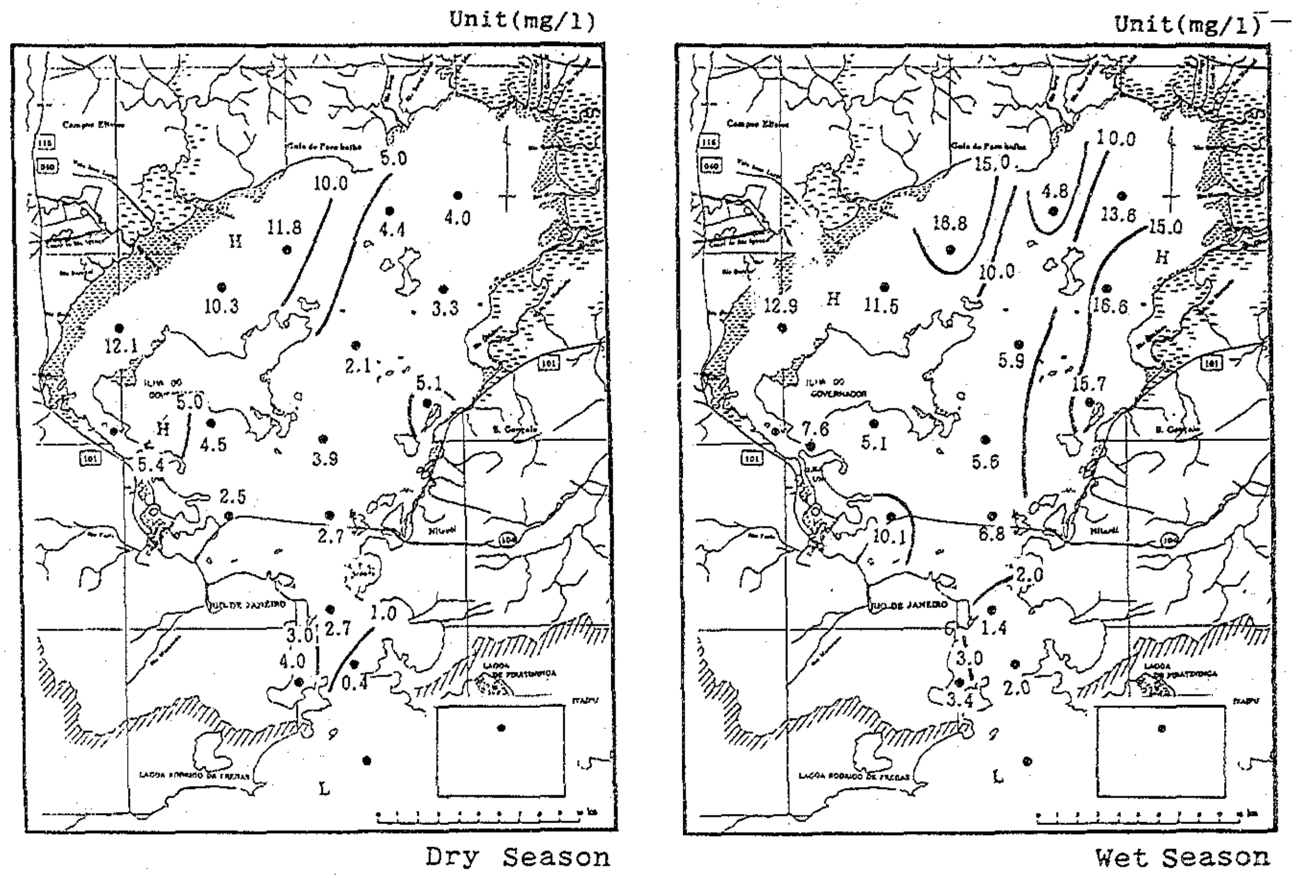


Fig. 2.3-6 Distribution of BOD in the Surface Layer

and at the bottom (COD(Mn)=0.399 BOD ; 0.987) (Fig. 2.3-5).

The correlation was lower in the wet season than in the dry season; r=0.531 (COD(Mn)=0.357 BOD ; 2.405). It supposedly resulted from the different and complicated composition of organic materials in the wet season : firstly a large quantity of phytoplankton was observed in the entire Bay and secondly the ratio of materials from rivers brought about by large river discharge was high.

BOD measured during the survey period was, however, generally higher than the COD(Mn) values. This could be attributed to the fact that $KMnO_4$-alkaline was used in the COD analysis(Fig. 2.3-6 and Table APP 2.3-7).

2.3.5 Nitrogen

(1) Total Nitrogen

Very high total nitrogen (TN) concentrations were observed in the surface layers of the Bay; concentrations increased from the outer part toward the inner Bay area, it was particularly high on the northwestern side on all occasions, although the results were missing at several stations in the central Bay. These high TN value were produced by the high ammonium nitrogen (NH_4-N) or total organic nitrogen (TON)(Fig. 2.3-7).

TN at low tide in the first survey was significantly higher than at high tide. However, this was not found in the other two surveys.

Although the distributional patterns were similar, TN in the dry season was slightly lower then in the wet season.

TN decreased with the depth at all stations, and as in the surface distribution; lower values in the outer area and higher TN on the northwestern side were found.

At. Stns. 16 and 17, however, higher TN values were obtained in the deeper layers on several occasions. Supposedly these higher values were caused by the high river discharges with high pollution load.

The surface TN showed very high correlation with the surface total phosphorus (TP) obtained from the both seasons (r=0.9217, TN=5.2 TP + 0.39) (Fig. 2.3-8).

Nevertheless, correlation between the surface TN and the surface TP may change seasonally and even regionally, and it is well supposed that behavior of each nitrogen and phosphorus form (TON, DIN, TOP and DIP) is different reflecting phytoplankton production mechanism.

Unit(mg/l)

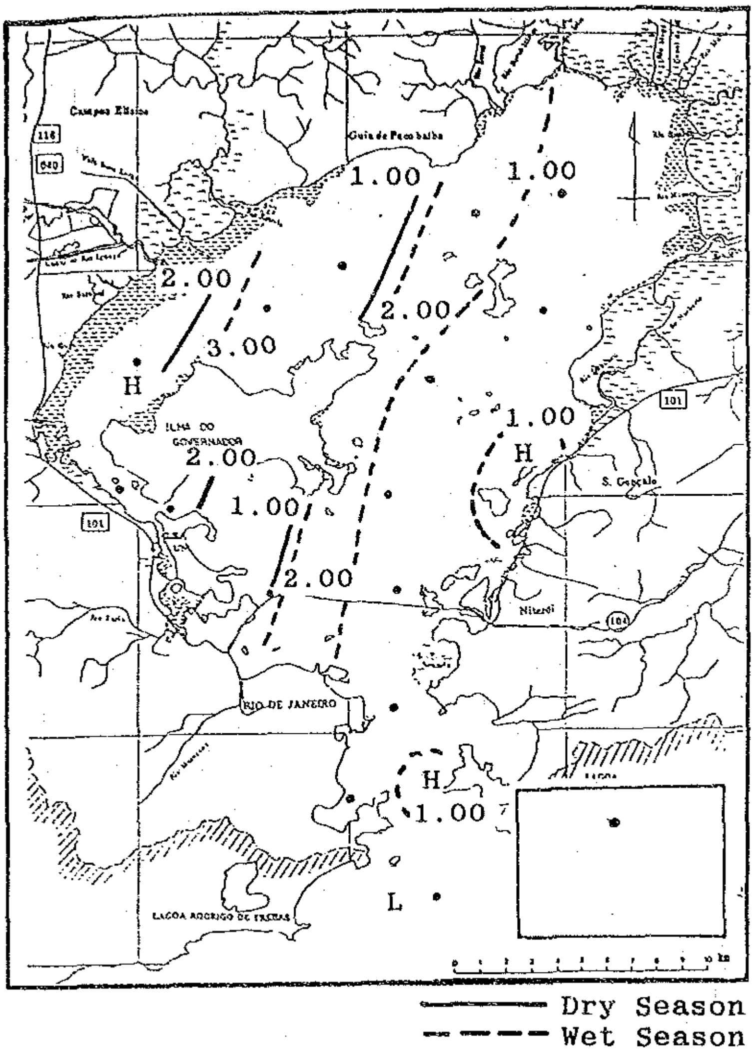


Fig. 2.3-7 Distribution of Total Nitrogen in the Surface Layer

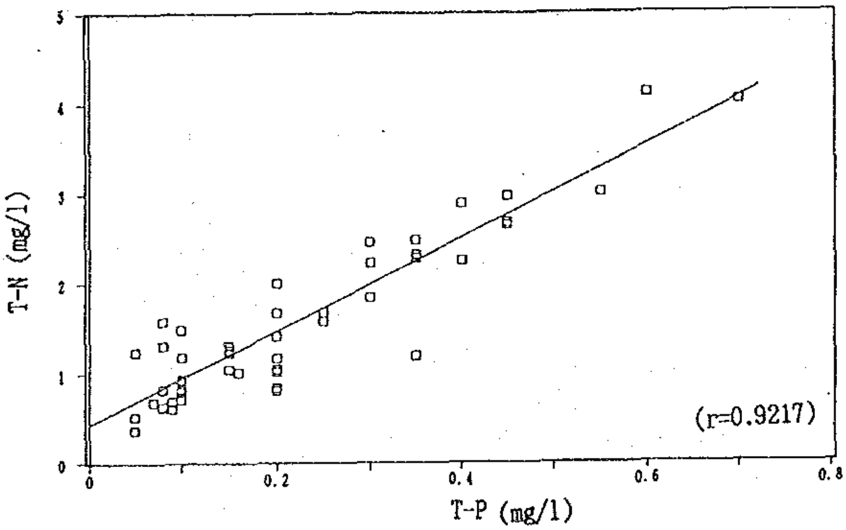


Fig. 2.3-8 Correlation between TN and TP in the Surface Layer

(2) Total Organic Nitrogen

Total organic nitrogen (TON) in the surface layers varied according to the stations and the sampling time (0.28 - 3.91 mg/l), but the range of variance is relatively smaller than other nitrogen forms. It generally decreased with depth reflecting phytoplankton occurring in the upper layer and the minimum value in the deeper layers was 0.22 mg/l (Tables APP 2.3-1 - 6).

TON was usually the main part of TN having a ratio to TN of 35 to 99 % with a mean of 77 %, however a very high concentration of HN_4-N would result in the high TN. The mean ratio in each tide of each month was high irrespective of the month or season (Table APP 2.3-8).

Further, TON concentration is also very high, particularly if TN values are exceptionally high, from 4.02 to 4.11 mg/l, and the ratios to TN ranged from 80 to 95 %.

Particulate organic nitrogen (PON), a constituent of TON, in this case is greater than in other cases, particularly in November.

PON may be mainly composed of planktonic-N, hence the high TON reflected the larger amount of phytoplankton, although a direct correlation was not obtained between Chl-a and PON.

TON tended to be higher on the western side of the Bay, around Stns. 8, 9, 13 and 14, and St. 11, in the both seasons.

TON in the wet season seems higher than in the dry season, but the difference is not significant.

(3) Dissolved Inorganic Nitrogen

The distributional pattern of dissolved inorganic nitrogen (DIN) was generally similar to TN; high on the western side and low on the northeastern side and outer part of the Bay (Fig. 2.3-9).

However, values covering a wide area from the northeastern part to the central Bay area, were lower than those near and at the outer part of the Bay, in the wet season. This was attributed to lower NH_4-N.

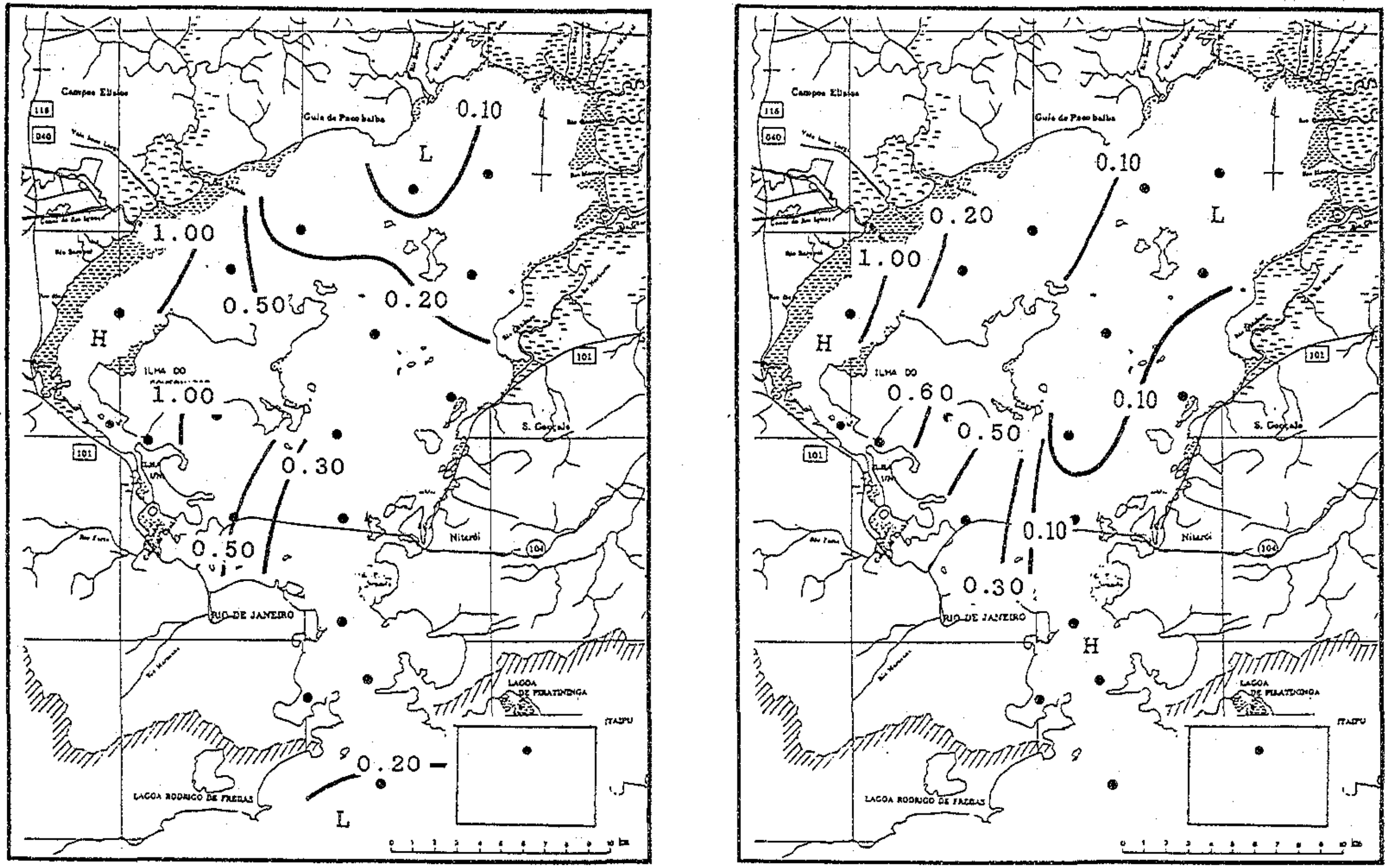
DIN was higher in the dry season than in the wet season, showing different tendencies from other water quality properties.

Of the DIN, nitrite nitrogen (NO_2-N) values were very low (0.000 - 0.060 mg/l) throughout the survey period, and sometimes it was not detectable in the outer Bay and very low on the northeastern side (Fig. 2.3-10).

The ratio of NO_2-N to DIN was always low from 1 to 17 %, and usually lower than 10 %. It was particularly low in the dry season (1-9 %) (Table APP 2.3-6).

Unit(mg/l)

Unit(mg/l)



Dry Season

Wet Season

Fig. 2.3-9 Distribution of DIN in the Surface Layer

Nitrate nitrogen (NO_3-N) values were remarkably similar on each sampling occasion, differing form other quality distributions, especially at the low tide if the first survey; NO_3 values were more even and were significantly higher than on the other three survey occasions in the dry season (0.15 - 0.35 mg/l at the low tide of May; 0.00 - 0.30 mg/l on other occasions).

In the wet season, contrary lower values form 0.01 to 0.10 mg/l were observed at all stations

As mentioned above, NO_3-N values were similar and NO_2-N values were always negligibly small. The distribution of NH_4-N, therefore, was similar to that of TN and DIN as well, in both seasons; much higher values were observed at Stns. 7, 8, 9, 13 and 19, especially at St. 13 where it was always considerably high from 0.70 to 1.75 mg/l (Fig. 2.3-10).

Nevertheless, it generally decreased with depth at all stations.

Like TN and DIN, lower NH_4-N were observed on the northeastern side and in the central Bay area (Fig.2.3-10).

Although the variation of NH_4-N values was great, there was not difference in the values in the dry and wet seasons at each station.

On the western side, urban type rivers badly polluted by domestic wastewater (Rio Meriti, Rio Iraja and Rio Sarapui), are seriously affecting nitrogen distribution, causing uneven NH_4-N distributions.

It appears that despite NO_3-N being uptaken evenly in all areas of the Bay, wide range of NH_4-N values shows that NH_4-N is selected during phytoplankton production as a nitrogen source when it exists together with NO_3-N in the water.

At several stations, NH_4-N values were very low, especially in the central and northeastern Bay in the wet season, which may be lower than the permissible low concentration for phytoplankton production.

These concentration, however, do not seem to be actually lower than the permissible low concentration, e.g., the remaining amount after active uptake during photosynthesis because very high phytoplankton production was found in the Bay, particularly on the eastern side of the Bay where lower NH_4-N values were obtained.

In the west and northwest areas, where high NH_4-N concentrations were found in the surface layers, it seems there was a large inflow of NH_4-N through rivers to those areas, particularly around Stns. 8, 9 and 13, and this inflow was a considerably

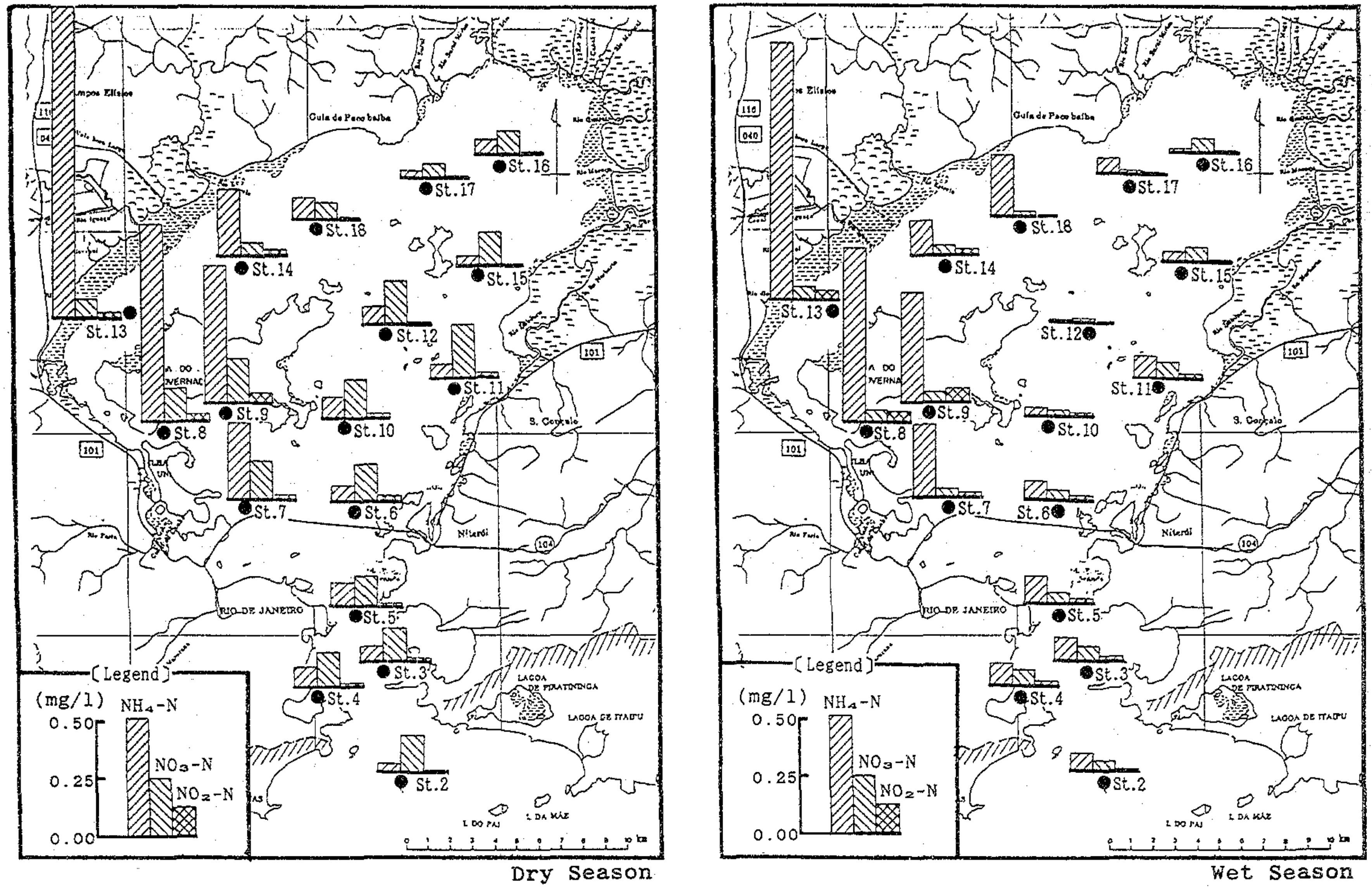


Fig. 2.3-10 Distribution of each Nitrogen Form in the Surface Layer

large amount to exceed the values uptake by phytoplankton production. Consequently high HN_4-N concentration was observed these areas.

2.3.6 Phosphorus

(1) Total Phosphorus

TP values at the surface varied widely (0.02 - 0.60 mg/l) on all occasions showing a tendency to be lower in the outer By area and near the mouth, and higher on the western side of the Bay, as was observed with the TN distribution. Very high values were obtained at St. 13 (0.25 - 0.55 mg/l) (Fig. 2.3-11 and Tables APP 2.3- 1 - 6).

The values of a wide area, from the northeast to the central Bay area, in both seasons, were only slightly higher than those obtained near the mouth.

Significant differences were observed between TP at the both tides in May, but none in June and November.

Although the distribution patterns were similar in both seasons, TP values observed in the inner Bay in the wet season were slightly but significantly higher than in the dry season. This is possibly due to the higher phytoplanktonic-P distribution in the wet season.

TP generally decreased with depth except at Stns. 1 where it occasionally increased slightly with depth.

TP concentrations are mainly attributed to articulate organic phosphorus (POP), which is mostly composed of phytoplanktonic phosphorus, except when PO_4-P values are very high. This corresponds well with the fact that TP values are higher in the wet season and that they decrease with depth in all cases.

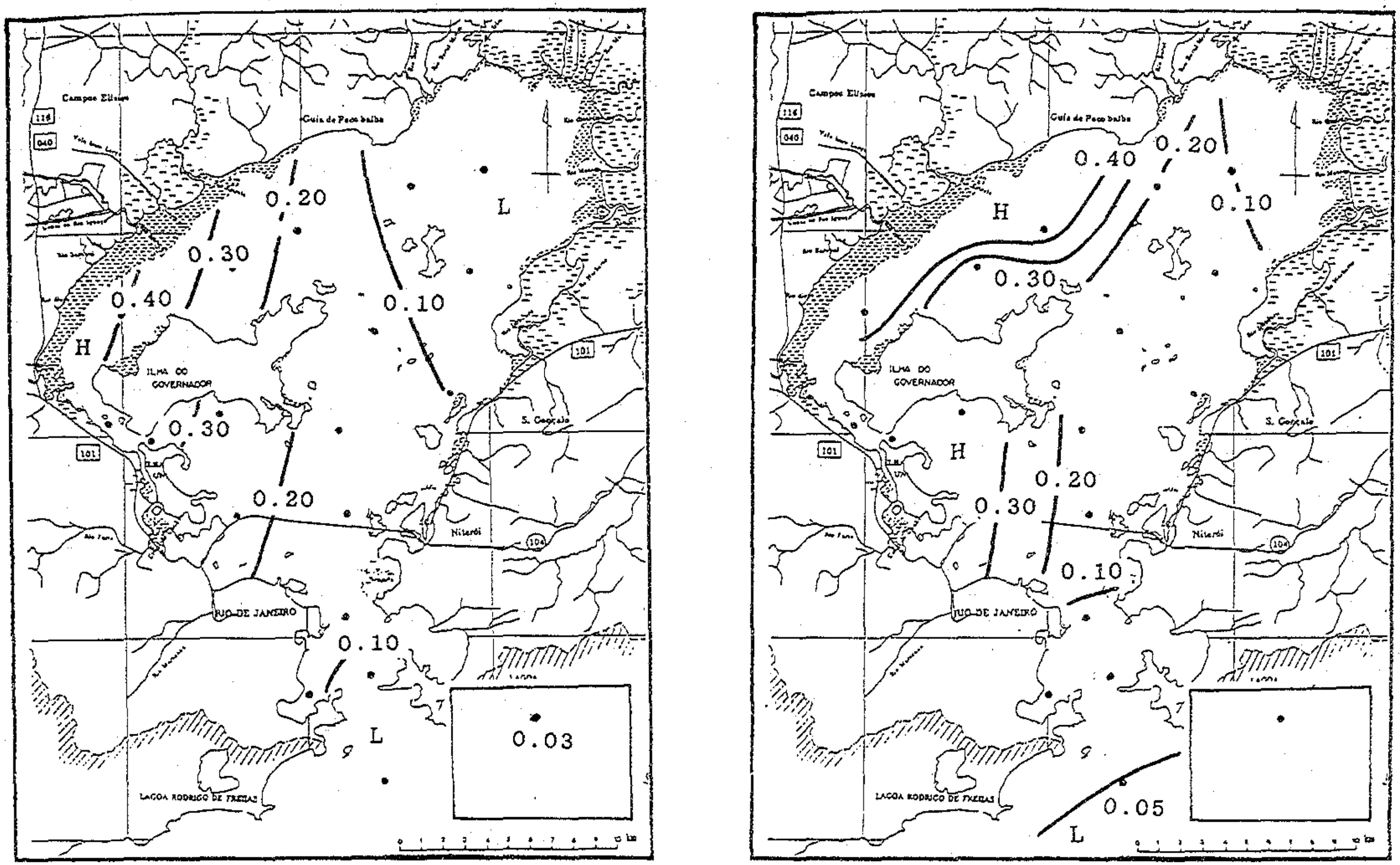
(2) Total Organic Phosphorus

Total organic phosphorus (TOP) is composed of dissolved organic phosphorus (DOP) and POP, although POP was not determined directly during the survey period but calculated through TOP-DOP (Tables APP 2.3-1 - 6).

As mentioned above, POP must be correlated with the amount of phytoplankton. A high degree of correlation was not found between POP and Chl-a, however, every time Chl-a is high, high POP was obtained; in the northwestern and western side areas in May, and at many stations in November.

In June, high Chl-a concentration was observed at only two stations (Stns. 4 and 8). POP values in June were also generally lower than in the other two months.

Unit(mg/l) Unit(mg/l)



Dry Season Wet Season

Fig. 2.3-11 Distribution of Total Phosphorus in the Surface Layer

As also mentioned in other parts, all parameters affecting the amount of phytoplankton, including Chl-a, are lower in June than in the other two months. It seems that in November nutrients being brought about by the greater discharge and larger periods of sunshine than in the dry season are attributing to the higher values.

In May, there are still some effects of the wet season, thus resulting in the higher values.

(3) Dissolved Inorganic Phosphorus

The concentration of DIP or PO_4-P in the surface layers varied widely according to the station, from 0.00 to 0.30 mg/l (Fig. 2.3-12 and Tables APP 2.3-1 - 3)).

At several stations in both the outer and inner Bay areas on the northeastern side, it was not detected (0.00 mg/l) in the first survey, particularly at high tide when it was not detected at seven stations.

It is considered that this condition in the outer Bay area, at Stns. 2 and 4, may possibly be caused by the penetration of offshore water which has low concentration of PO_4-P.

On the other hand, in the inner Bay area, at Stns. 10 and from 14 to 18, the quick uptake of PO_4-P by the condensed phytoplankton population could be the cause. It was thought that stratification usually develops in the inner Bay area, causing phytoplankton to condense and inhabit in the upper layers.

In the second survey, PO_4-P was only undetected once (St. 10, high tide), while it was detected on all occasions in the third survey.

It slightly increased or decreased with depth depending on the stations, in May and June. However, when 0.00 mg/l was observed in the surface layer, it was not detected in the deeper layers, either.

In the third survey, the values measured in the deeper layers were the same as the values at the surface or in the higher layers at many stations. Some portion of the PO_4-P may be returned form the bottom after breakdown of the stratification due to strong winds in the wet season.

The PO_4-P at the low tide in May was significantly higher than at the high tide. However, no difference in the values measured at the two tides for June and November.

The mean values for May and November were significantly lower than those for June, seeming to reflect the higher Chl-a concentrations found in May, especially in November; these low concen-

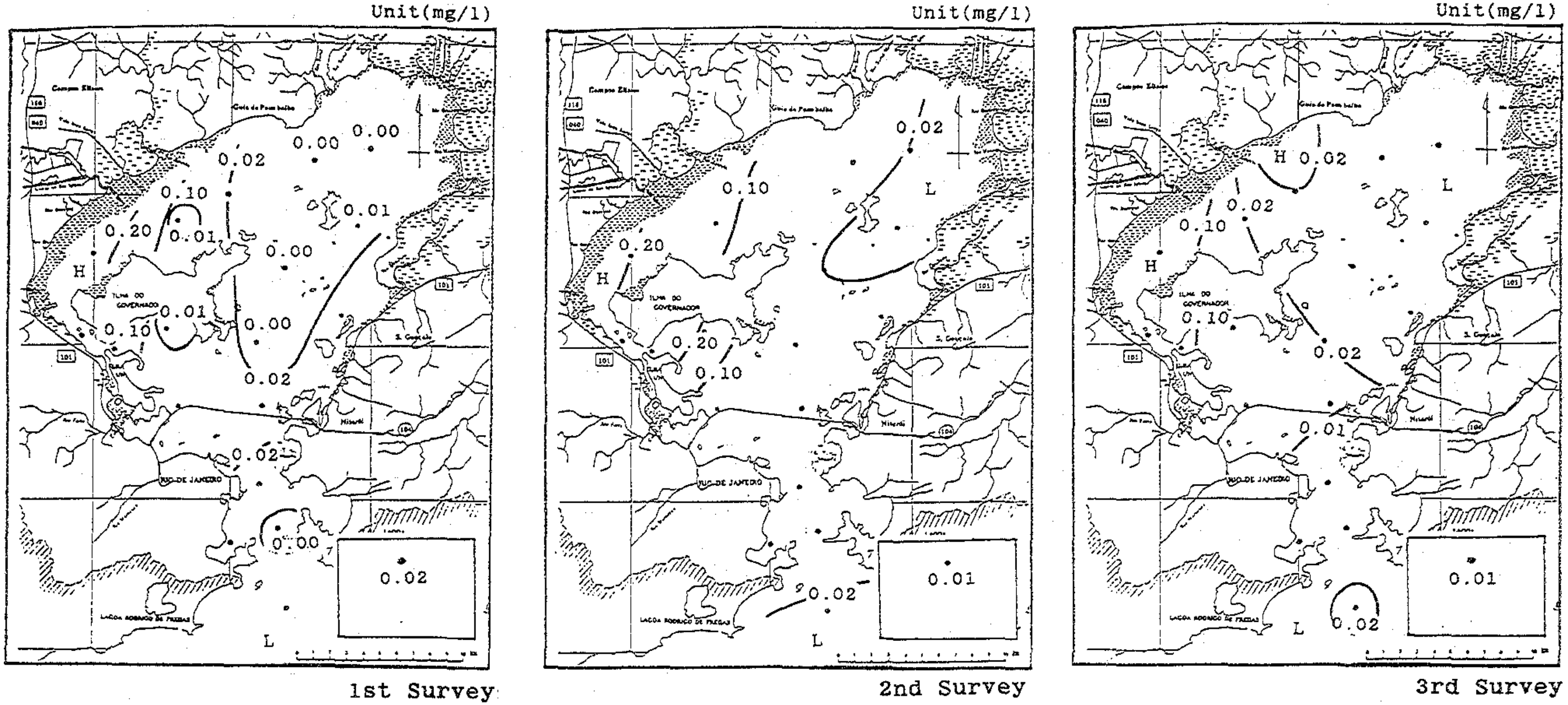


Fig. 2.3-12 Distribution of DIP in the Surface Layer

trations of PO_4-P is due to the active uptake for photosynthesis.

Generally, however, these tendencies were found in both seasons and on all occasions; very high value was obtained at St. 13, and higher values were measured at St. 8. In western (Stns. 7 and 9) and northwestern (St. 18) sides relatively higher values were found.

2.3.7 Suspended Solids

As found on the distribution of other parameters, suspended solids (SS) tended to increase from the outer area toward the inner Bay area in the dry season. Higher SS values were found consequently in the northeastern side and the northwestern side (Fig. 2.3-13).

SS also increased toward the inner Bay in the wet season although only slightly, and higher values were observed in the southern part of Ilha do Governador at Stns. 7, 8 and 9.

Contrary to other values, SS values in the dry season were generally higher than in the wet season, except in Stns. 5, 7 and 18.

2.3.8 Phenols

Low concentrations of phenols at the surface or the bottom were observed (0.002 mg/l) at only 4 stations in May (Stns. 3, 6, 8 and 16). Values lower than the analytical limit (<0.001 mg/l) were obtained at all other stations in June. There seems to be no present problems regarding Phenols at the moment (Tables APP 2.3-1 - 6).

2.3.9 Cyanide

Cyanide (CN) was not detected at all the stations (Tables APP 2.3-1 - 6).

2.3.10 Normal-Hexan Extract

Normal-Hexan extract (n-Hexan extract) were measured at several stations, twice in the low tide of the spring tides in May and November. It was lower than analytical limit (4 mg/l) at all sampled stations in May (dry season).

In November (wet season), however, higher values from 4 to 16 mg/l were obtained at 7 stations, which were located around the mouth and inner part of the Bay.

This is thought to be affected by ships around the mouth of the Bay and St. 19.

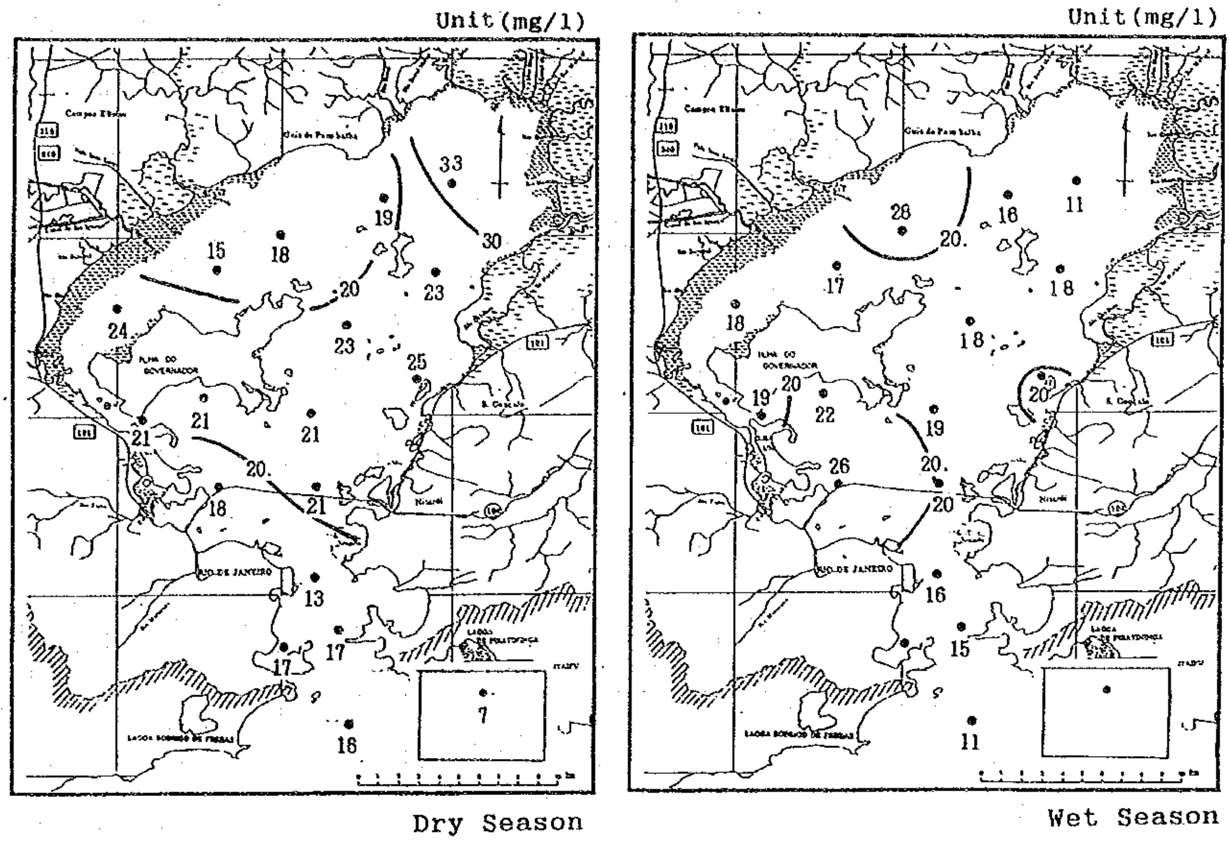


Fig. 2.3-13 Distribution of Suspended Solids in the Surface Layer

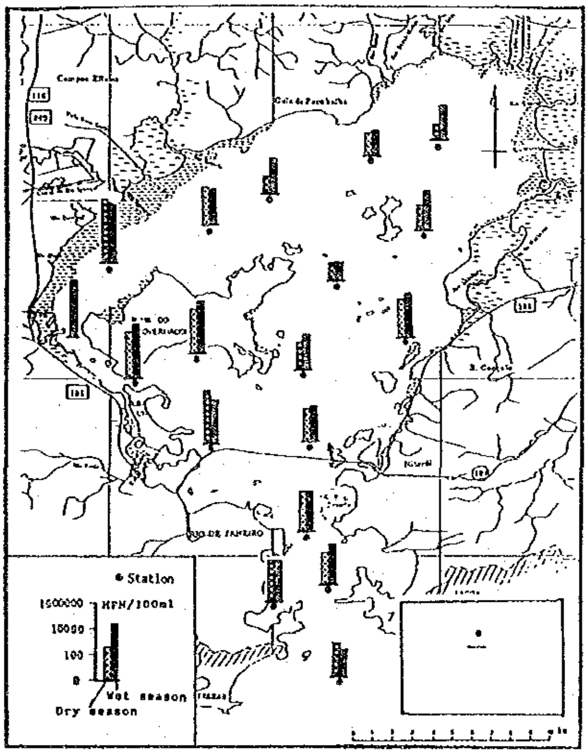


Fig. 2.3-14 Distribution of Fecal Coliforms in the Surface Layer

Table 2.3-1

Mean Number of Fecal Coliforms in the Surface Layer (MPN/100ml)

St.	1st Survey	3rd Survey
1	*2	*0
2	250	235
3	205	1050
4	800	750
5	1750	2650
6	352	230
7	*1620	9500
8	20500	27000
9	4900	16000
10	47	550
11	1620	2050
12	90	*90
13	105000	9350
14	1555	700
15	25	2535
16	26	440
17	119	165
18	25	475
19	-	*30000

* Measured once

Further analysis on the content of n-Hexan extract will give more detailed information.

2.3.11 Heavy Metals

All heavy metals, except iron (Fe) and nickel (Ni), were measured at all stations in all three surveys in the surface layers and in the bottom layers, but only once in the mornings (Tables APP 2.3-1 - 6) .

(1) Cadmium

Cadmium (Cd) values were lower than the analytical limit (<1.0 ug/l) at all stations.

(2) Lead

In the wet season, lead (Pb) were detected only at the surface of St. 15 (39.0 ug/l). On the contrary, the concentrations ranging from 5.0 to 49.0 µg/l were detected at many stations in the dry season.

However, much higher concentrations of 185.0 and 170.0 µg/l were recorded at St. 14 (5.0 m deep) in May and St. 8 (7.0 m deep) in June.

High Pb values have been measured in the past in the northwest area and so it was probable that similar results would be obtained in these measurements.

However, the standard permissible concentration for human health is 100 ug/l, therefore, except for the two Pb cases, concentrations in the Bay water are currently not too high.

(3) Copper

Copper (Cu) values were detected at many stations, but in quite low concentrations of a little higher than the analytical limit of 2.0 µg/l, except on some occasions where 13.0 to 24.0 µg/l.

In the wet season, low Cu values were obtained at several stations.

There were more cases to be observed on the bottom than in the surface layers.

(4) Chromium

Chromium (Cr) were not detected (<10 µg/l) on any stations, except at St. 12 in June: 1.60 µg/l in the surface layer and 0.10

µg/l at the bottom.

(5) Total Mercury

Total mercury (T-Hg) was not detected in all occasions, except at St. 12 in June: 1.60 µg/l at the surface and 0.10 µg/l at the bottom.

The standard permissible concentration for human health is 0.5 ug/l, therefore, these values obtained in the Bay water are not very high. However, organic-mercury, particularly alkylic-mercury is concentrated in aquatic organisms with high magnification, consequently it may be dangerous if human take in this highly concentrated mercury.

(6) Iron

Iron (Fe) was measured once in November at low tide of the spring tides.

The values were generally small except for high values observed at several stations: 460 µg/l at St. 4, 550 and 440 µg/l at Stns. 15 and 16 (Table APP 2.3-5).

The concentrations usually were higher at the surface than at the bottom.

(7) Nickel

Nickel (Ni) was measured only once of same sampling occasion as Fe was measured. All values were lower than the analytical limit of 5.0 µg/l.

(8) Zinc

Although Zinc (Zn) values were observed at many stations during the three surveys, the concentrations were not higher than the analytical limit of 10 µg/l in almost all cases except for several measurements that gave 70, 80 and 130 µg/l.

Although similar tendencies were observed in June, the values were relatively lower than other surveys.

It does not appear these concentrations are harmful at the moment.

2.3.12 Polychlorinates Biphenyl

Polychlorinates Biphenyl (PCB's) were not detected (<0.01 mg/l) at any station, although they were analyzed for only at the low tide of the May spring tide, because it was not expected to be recorded after the first survey.

2.3.13 DDT its Derivatives

All forms of dichlorodiphenytrichloroetahne (DDT) and its derivatives (pp'DDT, pp'DDE and pp'DDD) were not detected (<0.001 mg/l) at any station, when measured on the same occasions as PCB's were measured.

2.3.14 Coliforms

The distributions of both of fecal and total coliforms were higher at the western side than at the eastern and southern sides (Fig. 2.3-14 and Table 2.3-1).

Very high numbers were observed on the western and northwestern sides (Stns. 7, 8, 9, 13 and 19), and relatively high numbers was found at St. 4. As mentioned in TN section, around these areas domestic waste is directly discharged around these area into the rivers and resulting in these high coliform distributions.

The values were generally higher in the wet season than in the dry season, and higher in low tide than in high tide. Both aspects also indicate the significant influence of human activities.

2.4 Water Quality Conditions in Small Bays and Coastal Areas

This survey was carried out on April 1, 1993, the transitional period between the wet to the dry seasons. However, it was still raining in March and April.

Although it was fine for one week before this survey, low salinity were obtained in the upper layers like in the wet season (Fig. 2.4-1 and Tables APP 2.4-1).

Generally water in Jurujuba Bay, except outer part of the Bay, Centro de Ilha do Eengenho and Rio Porto was of very bad quality. The values of the water properties analyzed to determine water quality were similar to those obtained in the inner part of Guanabara Bay in the wet season, the period when the Bay is most polluted and the area which is most polluted.

Particularly at St. 37 (in Jurujuba), concentrations of all the water quality parameters were remarkably high; COD(Mn) was 11.0 mg/l at the surface, TP was 0.6 mg/l and TN was 3.04 mg/l. Chl-a was extremely high, 132.3 ug/l, causing high DO of 211 % at the surface. DO at the bottom, contrast to these values, was low of 21 % of the saturation.