PRIMARY PRODUCTION OF PHYTOPLANKTON FROM SANTA CRUZ CHANNEL (BRAZIL)

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ABSTRACT

This paper reports the results of primary production of the phytoplankton measured from March, 1976 to June, 1977 at five stations located along the estuarine system of the Santa Cruz Channel, Northeastern Brazil. The values were between 0.94 and 76.59 $mg.C.h^{-1}.m^{-3}$. The mean was 17.88 $mg.C.h^{-1}.m^{-3}$. The seasonal pattern observed at each station is presented and discussed, in relation to some available environmental factors.

RESUMO

Este trabalho apresenta os resultados da produtividade primária do fitoplâncton medido de março de 1976 a junho de 1977 em cinco estações localizadas ao longo do estuário do Canal de Santa Cruz, região nordeste do Brasil. Os valores variaram entre 0,94 e 76,59 $mg.C.h^{-1}.m^{-3}$. A média foi de 17,88 $mg.C.h^{-1}.m^{-3}$. A variação sasonal observada em cada estação é apresentada e discutida em relação aos fatores ambientais obtidos.

INTRODUCTION

The coastal area of Northeastern Brazil shows low primary and secondary productivity due to the oligotrophic conditions caused by the warm waters of the Brazilian current. At this region only the estuaries are considered rich environments.

To increase the aquatic production of this portion of the Brazilian coast many Institutions have been carring out aquaculture experiments in estuarine areas, using species of comercial value such as the bivalve *Crassostrea rhizophorae*, the fishes *Mugil curema*, *M.*

liza, Eugerres brasilianus, Centropomus undecimalis, C. parallelus, and the shrimps *Penaeus monodon, P. brasiliensis* and *P. schmitii*. To increase the production of these organisms, their biology, their productive capacity and some environmental and trophic relations have been studied. Special attention has been giving to the primary productivity of these regions and to the factors which affect the limitation of the stimulation of this production.

Despite the importance of the primary productivity to aquaculture there are few reports in Brazil regarding these aspects. This paper reports some results about the seasonal variations of the primary productivity of the estuarine system of the Santa Cruz Channel (27°49' Lat. S and 34°50' Long. W), State of Pernambuco. In this area, several geological, hydrological and biological studies have been carried out recently, as an attempt to evaluate their fishery potential resources and to stablish bases for the implantation of culture ponds of commercially important aquatic organisms.

MATERIAL AND METHODS

Water samples were collected monthly from March 1976 to June 1977 at five stations (Fig. 1), during the diurnal high tides, using a Van Dorn sampling bottle. Samples were collected at surface and at the depth of light extintion coefficient.

Primary production was measured by the radioactive carbon (^{14}C) technique (STEEMANN-NIELSEN, 1952; DOTY and OGURI, 1959; UNESCO, 1967; VOLLENWEIDER et alii, 1969 and TEIXEIRA, 1974, using 60 ml flasks, innoculated with 10μCi radioactive carbon (New England Nuclear Corp. Type).

Samples were incubated *in situ* for four hours.

The radioactivity of the filters was obtained by liquid scintilation, in scintilation flasks containing 9,0 ml of Bray solution (BRAY, 1960). To measure the amount of carbon absorbed by the phytoplankton the available carbon dioxide was estimated.

RESULTS

The amount of carbon assimilated by the phytoplankton varied from 0.94 to 76.59 $mg.C.h^{-1}.m^{-3}$, being registered at station 3 (April, 1976) and at station 5 (April, 1977), respectively. Values were always above 7 $mg.C.h^{-1},.m^{-3}$ (Table 1). The mean value calculated

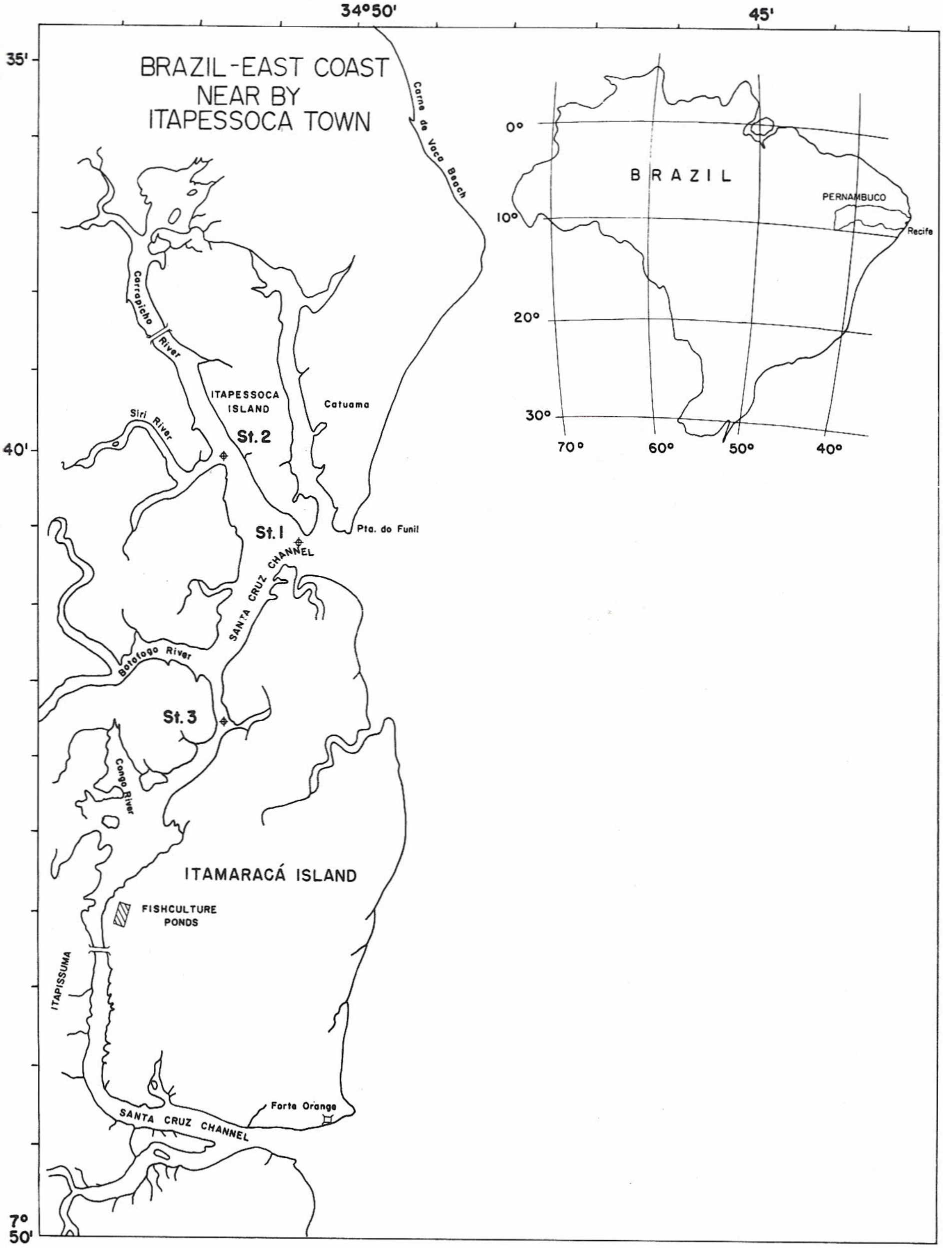

Fig. I . Localization of the studied area.

TAB. 1 - Values of carbon assimilation by the phytoplankton

S = Surface

LEC = Light Extiction Coefficient depth

Month	Collection Depth (m)	$mg.C.h^{-1}.m^{-3}$					$mg.C.h^{-1}.m^{-2}$				
		Stations					Stations				
		1	2	3	4	5	1	2	3	4	5
March		1.85	31.47	...	...	...	6.86	56.26	...	...	...
		1.81	13.54	...	...	...					
April	S	5.57	2.33	0.94	28.78	10.99	9.65	2.93	1.28	18.47	10.52
	LEC	5.46	1.86	1.20	17.39	6.54					
May	S	...	15.24	7.16	12.71	35.33	...	39.34	12.72	31.96	47.64
	LEC	...	16.23	11.68	12.36	28.19					
June	S	8.04	1.24	25.93	8.86	11.26	14.22	2.14	124.50	29.74	34.56
	LEC	6.18	1.14	41.37	10.97	19.46					
July	S	7.62	9.11	15.89	25.30	10.26	18.51	32.48	78.40	48.40	21.82
	LEC	14.16	14.51	12.62	23.10	11.56					
August	S	5.66	8.73	44.91	50.98	29.28	10.05	16.05	96.42	130.47	65.90
	LEC	4.39	6.56	32.23	43.91	23.44					
September	S	15.81	28.87	35.60	30.30	31.72	29.48	33.12	83.49	46.12	81.76
	LEC	13.67	15.29	20.06	31.19	27.74					
October	S	14.06	21.31	21.27	23.60	24.07	23.68	23.61	27.86	25.36	35.21
	LEC	9.62	16.46	10.57	16.97	16.17					
November	S	25.90	60.04	41.23	12.57	14.48	66.52	86.44	48.98	20.08	23.91
	LEC	12.11	26.40	7.75	19.56	7.26					
December	S	6.36	14.12	30.99	44.88	37.53	16.35	20.94	41.02	39.22	40.72
	LEC	6.72	6.82	15.89	33.55	16.76					
January	S	12.93	26.88	12.29	13.94	11.24	40.87	49.43	17.03	16.76	16.47
	LEC	9.16	16.10	2.85	8.40	3.40					
February	S	10.38	4.86	25.92	36.89	15.66	32.94	9.85	42.33	45.14	24.74
	LEC	8.44	3.02	11.71	23.29	6.83					
March	S	7.18	17.00	17.44	17.16	16.85	17.12	18.04	32.75	20.62	34.32
	LEC	6.52	7.06	15.31	15.84	13.66					
April	S	9.12	16.29	16.97	24.90	76.59	31.66	26.91	32.53	51.71	79.80
	LEC	6.71	3.28	21.30	35.94	51.09					
May	S	9.88	10.64	23.84	16.01	26.98	30.50	40.70	59.90	45.80	41.90
	LEC	8.89	16.49	29.40	24.70	20.92					
Mean	S	10.03	17.88	22.88	24.78	25.16	24.89	30.55	49.94	40.70	39.95
	LEC	8.13	10.98	16.71	22.66	18.07					

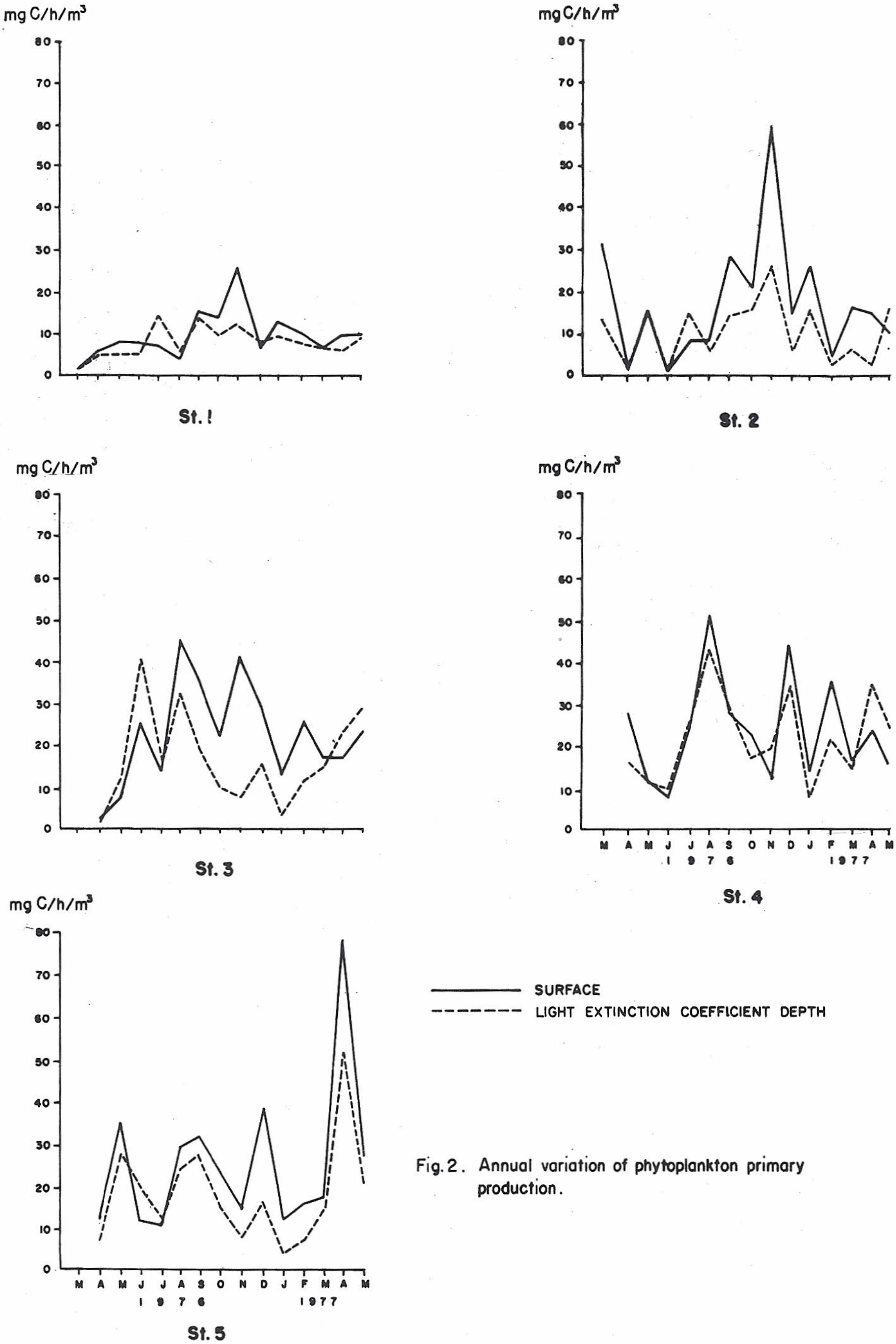

Fig. 2. Annual variation of phytoplankton primary production.

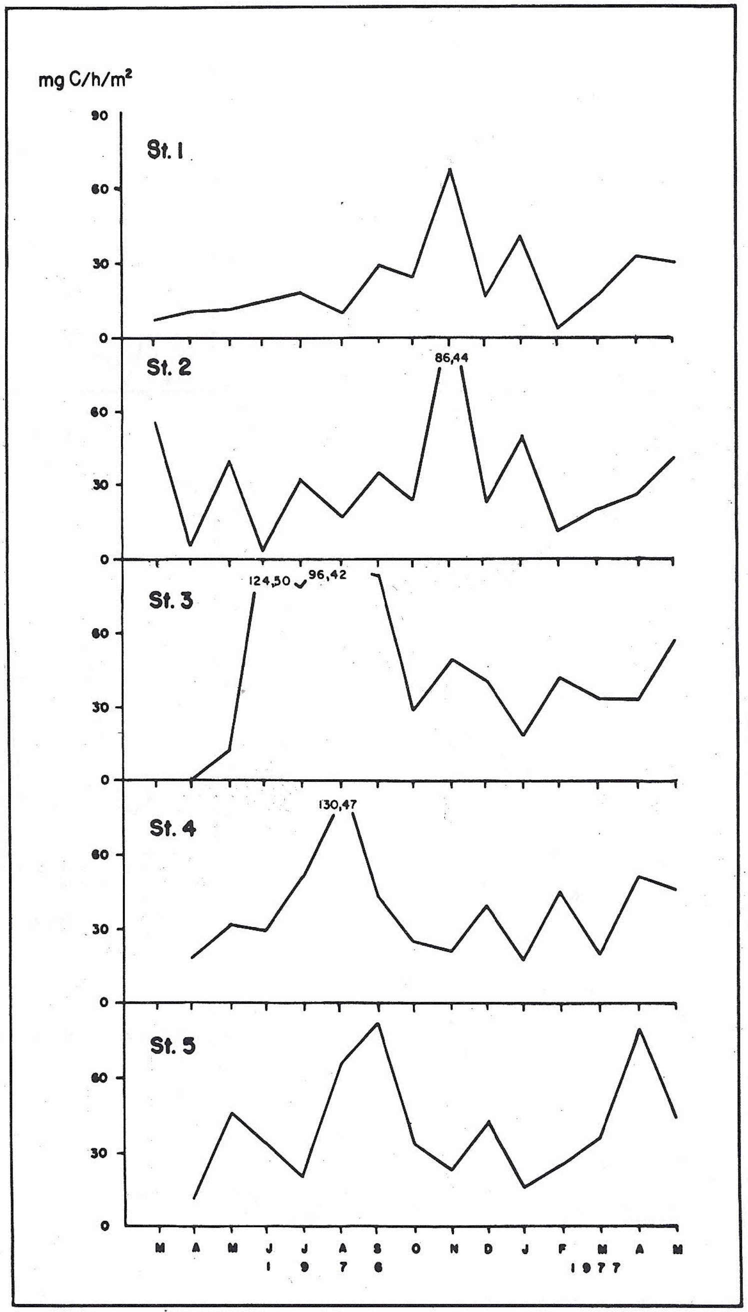

Fig.3. Annual variation of phytoplankton primary production at water column.

for all stations and for all months was 17.88 $mg.C.h^{-1}.m^{-3}$.

The spacial distribution of the primary production showed a horizontal mean gradient of 14.75 $mg.C.h^{-1}.m^{-3}$ from station 4 (located at the middle of the Channel) to station 1 (which is most influenced by the open sea) (Fig. 2).

The surface samples presented greater values of primary production than those from the light extinction coefficient depth, except in June 1976 at station 1 and 5; May and June 1976 and May 1977 at station 3; and June 1976 and May 1977 at station 2 (Fig. 2).

Regarding to the seasonal variation the most clear pattern was observed at the stations 1 and 2, where high production values were observed during winter and spring and the lowest values during summer and autumn. For stations 3, 4 and 5 no distinctive seasonal pattern was observed since several peaks of production were registered throghout the year. Maximum values were registered in October, 1976 (stations 1 and 2), August, 1976 (stations 3 and 4) and April, 1977 (station 5). A relatively high peak was also observed during April, 1976, at station 2.

The rates of carbon absorved by the phytoplankton calculated for the water column varied from 1.28 (station 3) to 130.47 $mg.C.h^{-1}.m^{-2}$ (station 4) during the studied period (Fig. 3). The mean value calculated for all stations and for all months was 37.21 $mg.C.h^{-1}.m^{-2}$. The lowest mean value (24.89 $mg.C.h^{-1}.m^{-2}$) was registered at station 1. For the other stations the means were between 30 to 50 $mg.C.h^{-1}.m^{-2}$.

DISCUSSION

In the Southern area of the Santa Cruz Channel, MACEDO et alii (1973) have observed a clear seasonal variation in the physical--chemical factors. During the rainny months quantities of freshwater coming from the Igarassu River enter this region decreasing the values of salinity, transparency, dissolved oxygen and pH and increasing the nutrients salts levels.

The available nutrients are among the many factors which influence the primary production rate. When the nutrient increases the primary production rate normally also increases. At high levels this parameter could to limit the rate of primary production (GOLDBERG et alii, 1951). However, this also occur at very poor conditions.

At Santos Bay (24°00' S and 46°26' W) GALVÃO (1978), for exemple suggests that the excess of nutrients and/or the presence of toxic compounds inhibit the phytoplankton development.

At Ubatuba ($23^{o}45'$ S and $45^{o}01'$ W) TEIXEIRA & VIEIRA (1976) found the nitrogen as the main limiting factor to the primary production. THOMAS (1969) also has verified similar results from areas of North and Southeastern Equator.

Nitrogen and phosphorous have been established as the most critical nutrients related to the algae productivity and eutrophization in aquatic environments (THOMAS, 1969; BERLAND et alii, 1973; LIN, 1974; MORRIS, 1974; SHIROYAMAT et alii, 1975; TEIXEIRA & VIEIRA, 1976; TEIXEIRA, 1980). Nevertheless the nutritional requirements for phytoplankton growth changes seasonally and regionally.

The coastal and the oceanic waters are chemically distinct environments and show different levels of production. The comparatively large amount of organic matter introducted into the coastal regions by land drainage is responsible by the highest phytoplankton production at these areas (PRAKASH, 1971).

At estuarine ecosystems the flow of the tides can retain nutrients in the sediment, promoting the eutrophization. According to ROBARTS (1976) most of these nutrients comes from the large amounts of destritus which are decomposed by bacteria and fungi and are brought into estuarines by rivers.

This decomposition releases organic and inorganic materials which are utilized by estuarine phytoplankters.

Chemical analyses of the water carried out by Roberts (op. cit.) at Swartvlei (South Africa) have indicated that nitrate was always present in relatively high concentrations ($4 - 70\ \mu g.1^{-1}$). According to him, a major source of this nitrogen probaly was the urine and the faeces from the horses and the cattles which are allowed to graze in the salt marshes. On the other hand, the phosphate reached undetectable concentration only after a large diatom bloom; many times this nutrient was available (up to $18\ \mu g.1^{-1}$) (Robarts, 1973 apud ROBARTS, 1976).

QASIM et alii (1969) studying the primary production of some estuaries in India, observed that there was a clear correlation between assimilated carbon, nitrite and nitrate, but this correlation was always highest with phosphate. This allow him to conclude that there was an alternative source of nitrogen (Amonia, for example) for the plants. On the other hand, JAWED (1973) has verified that about 90% of the nitrogen necessary for the primary production at Columbia River was released by the zooplankton. This author has also observed that in coastal waters about 36% of the nitrogen required for the algal production was suplied by zooplankton excretion.

At Tampa Bay system, large amount of biogenic salts enter through the tributaries which drain phosphate rich soil along the eastern side shores. Although also enriched by domestic and industrial wastes this natural source of phosphorous undoubtedly affects the N:P ratio in that system (TURNER & HOPKINS, 1974).

At aquatic environments the N:P relation is considered as being 15:1. Recent studies have shown that at coastal regions this relation may be variable, showing values from 5 to 10:1, specially during the autumn and the winter, when the nutrients levels reach maximum values (RILEY & CONOVER, 1956; KETCHUM et.alii, 1958; McALLISTER et alii, 1960). At the Narragansett Bay, for example, this relation rarely exceeds 4:1 and sometimes, falls to below 1:1 (PRATT, 1965).

At Itamaracá area, KEGEL (1955) has reported the presence of large phosphate deposits, located at the base of the Gramane Formation, which is a fossiliferous calcareous of grey color from the cretaceous. At the Santa Cruz Channel, calcareous stratums from the Maria Farinha and Gramame Formations, which are rich in mineral phosphorous are subject to the erosion caused by the tides as have been confirmed by LIRA (1975).

The distribution of P_2O_5 at the first thin layer of the sediment from the Channel was studied by this author. The highest values were associated with the rivers discharge and with the presence of cleyey sediments, originated from the continent. At Botafogo River, for example, it was registered the highest content of P_2O_5 reaching a percentual value of 4.60%. Between the Island and the reefs, at the outer zone, the highest contents were below 0.20% and beyond the reefs, the percentage of this phosphate was below 0.10% (LIRA, op. cit.).

The occurence of phosphatic stratums at the Gramame calcareous in the coastal area of the region is so responsible for a large increase in the natural phosphorous supply to the Santa Cruz Channel as also occur at Tampa Bay, USA (TURNER & HOPKINS, 1974). This natural phosphorous supply in the Channel probably affects the relation N:P.

Although the Channel could be considered as being wind protected due to its geographical position, the wind influence on the enrichment of the local water mass could not be discharged. The wind pushes a greater quantity of water from the open sea into the Channel and promotes a great turbulence allowing the nutrient retained in the sediment to be liberate to the water. On the other hand, the land drainage which takes place throughout the several tide channels along the mangrove Forest may also be responsable for the nutrients supply at the Channel.

LIRA (1975) also has studied the organic contents retained in the thin layer fraction of the sediment from several samples collected at Santa Cruz Channel. Although the maximum value was only 6.30%, he observed that nitrogen showed the same gradient as phosphorous (P_2O_5), with maximum values in the middle portion of the Channel and minimum values in the outer part of Itamaracá Island.

PASSAVANTE (1979) has observed a clear correlation between the amount of rainfall, nitrite and nitrate at Santa Cruz Channel. althought no correlation was observed with phosphate. The test indicated that samples collected during the rainfall season were significantly different from those collected during the dry season. These results agree with those obtained by MACEDO et alii (1973), MACEDO (1974, 1977), CAVALCANTI (1976) and CAVALCANTI et alii (1981) for the region. According to MACEDO (1977) the hydrological conditions of the Channel are similar to those observed in some fish ponds located near the shore, at the same ecosystem.

OKUDA (1960) studying the nutrients content in coastal and oceanic waters from the Northeast of Brazil has observed low values of phosphate-P ant total phosphorous from the layer up to 100 m depth, with exception of some areas influenced by the land, such as near the Fernando de Noronha Island and near the Cape of São Roque. At these areas the values were highest. Regarding the amount of amonia, nitrite and nitrate he found high values at the Central Atlantic as in some areas influenced by land. He also has observed a relation N:P of 2:4, for the upper 100 m layer directly proportional with the depth.

At Itamaracá region it was registered high phosphorous and low nitrogen contents. Unfortunately amonia was not measured, being impossible to calculate the N:P relation (PASSAVANTE, 1979).

Regarding to the nutrient availability for the aquatic environment CURL & SMALL (1965) have observed that the number of assimilation could indicate the phytoplankton nutritional necessities. Based on several researches, the aquatic environments could be classified according to such criterion. Based on this classification, PASSAVANTE (1979) has demonstrated that some coastal and oceanic areas from the State of Pernambuco show a number of assimilation between 0 and 2, so indicating that this region is oligotrophic. At Santa Cruz Channel around 43.80% of the assimilation levels show mean values above 5. This allow to conclude that this region could be considered as being rich in nutrients (Fig. 4).

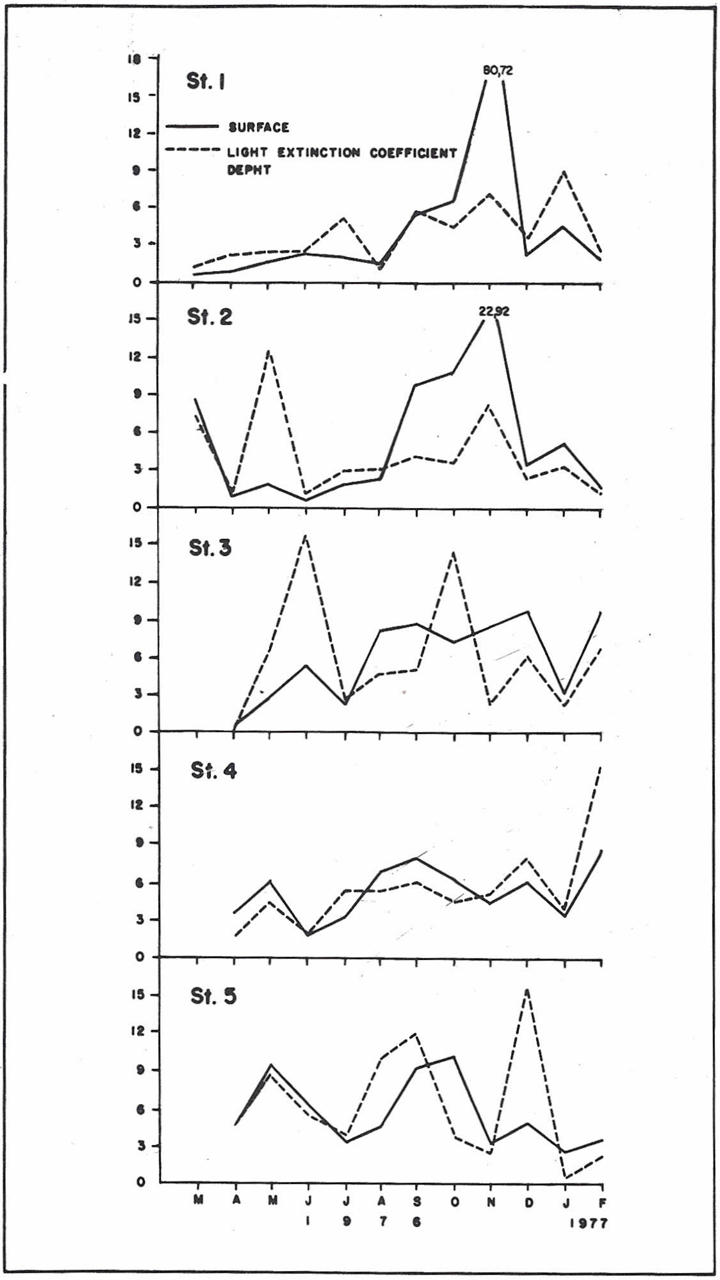

Fig. 4. Annual variation of phytoplankton assimilation rate.
(after PASSAVANTE, 1979).

The studied Channel can be considered poorly affected by organic pollutions due to the low urban development near the place and to the reduced river discharge which reach the system. Accordingly ESKINAZI-LEÇA (1978) and ESKINAZI-LEÇA et alii (1980) studying the composition of the microphytoplankton of samples collected at Botafogo and Igarassu rivers tributaries from this estuarine system, did not make reference to any kind of polissaprobian diatom which indicates organic pollution. Nevertheless, the small percentage of oxygen saturation (45%) sometimes registered by PASSAVANTE (1979) at the same Channel may be a consequence of an active organic degradation. On the other hand, some chemical pollution also could be expected to occur in the Channel, since the residuals or chemicals, cellulose and fertilizers industries are discharged along some of the rivers which reach the system. Otherwise, the high fish mortality which has occured in May 1975 at the estuary of Botafogo River probably may be caused by some pollution coming from those industries.

Although further studies should be necessary to characterize better the production levels of the Santa Cruz Channel and their daily and nictemeral variations, the following conclusions could be related with bases on the results reported from the present study:

a) The primary production of the studied region is high and can support amount of consumers. This suggests that the Santa Cruz Channel is a good area for the culture of aquatic organisms of commercial importance.
b) Despite the high values obtained for the phytoplankton production during some months it seems to be limited by nitrogen compounds, since the phosphorous values are always high, due to the natural enrichments of the Channel by the mineral P_2O_5.
c) There is a clear gradient in the carbon assimilation from the station located in the middle of the Channel towards the station most influenced by the open sea.
d) The surface phytoplankton shows higher production than the population which occurs at the layer of the light extinction coefficient.
e) The primary production presents a clear seasonal variation, despite the high values presented during the whole year.

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