PLANKTON STUDIES IN A MANGROVE ENVIRONMENT

I. First assessment of standing stock and principal ecological factors.

(Received 20/3/62)

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I — INTRODUCTION

Studies on the plankton of lagoon regions of the Brazilian coast have been rather limited. The present work considers mainly the standing stock analysis, total suspended matter, salinity, oxygen and pH.

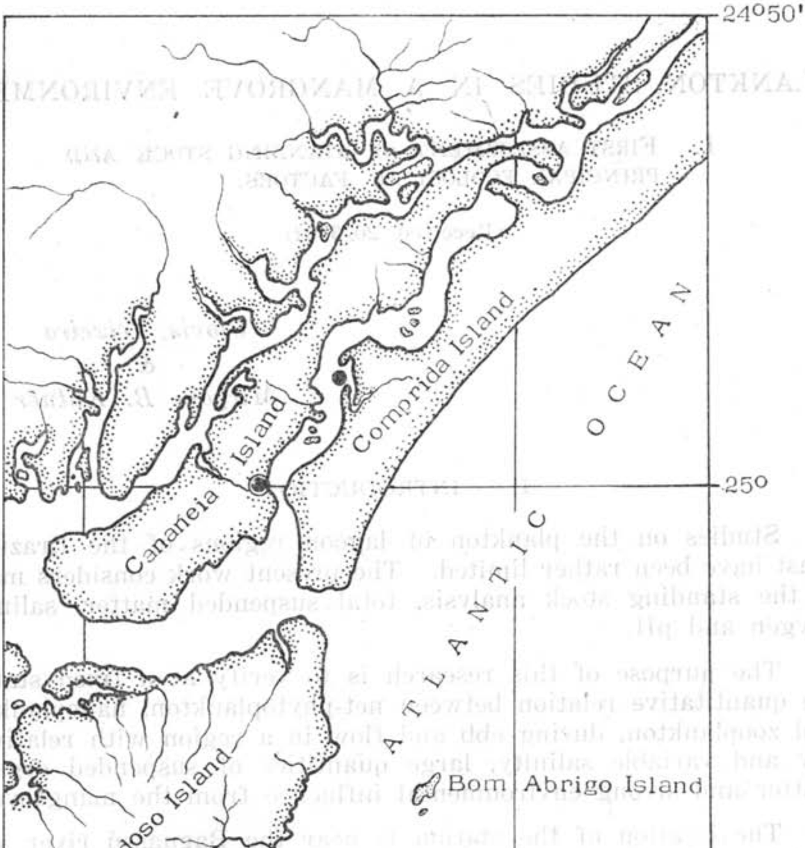
The purpose of this research is to verify at a fixed station the quantitative relation between net-phytoplankton, nanoplankton and zooplankton, during ebb and flow in a region with relatively low and variable salinity, large quantities of suspended organic matter and strong environmental influence from the mangrove.

The location of the station is near the Baguassú river (see sketch); this river is characterized by turbid water, due to organic detritus, high concentration of phytoplankton and the presence of a coloured substance originated from the mangrove, the latter being responsible for a great part of the total light extinction.

Regions of high leptopel concentratrion (e. g. river mouths) are supposed to contain dense populations of plankton and fishes, not only plankton-feeder species, but detritus-feeder as well.

Recently it has been reported that fish larvae ingest suspended particles of 20 up to 30 μ in diameter; and the size and

Publ. n.º 169 do Inst. Ocean. da USP.



Sketch of the region of Cananéia
O City of Cananéia
• Fixed station

production of the population of fish can be supposed to be affected by the amount of suspended particles (Hanaoka, 1957).

The amount of net plankton, nanoplankton, suspended matter and dry weight (inorganic + organic) was determined at the surface, 2.0 m and 4.0 m depth. Some bacteria counts were carried out using plate counts to evaluate the approximate numbers of microorganisms per liter and the degree of contamination of the water.

The work described here was undertaken during five days, between 20 and 24 September 1961.

II — METHODS AND TECHNIQUE

Cell counting — The samples were collected with an 8-liter bottle (Plankton sampler). From 8 to 50 liters were filtered at a time with a silk net no. 25 (aperture size: 65 μ).

The retained material i. e. the net plankton (phyto plus zooplankton) was preserved with Baker's formaldehyde-calcium. From each sample a sub-sample was counted with a Sedegwick--Rafter counting cell at magnification of 150 ×.

The nanoplankton i. e. the material passed through the plankton silk (300 ml) was fixed with neutral formaldehyde and filtered with a Millipore filter (AA). Later it was counted at magnification of 600 × and 1.250 ×.

The standard plate count method was used to count the bacteria.

Dry organic matter of the net plankton — The dry organic matter of the net plankton was determined by the difference between the dried weight and the ashes.

The plankton was dried at 80°C, weighed, ignited at 600°C and weighed again. Some experimental curves were drawn to determine the necessary time to dry to constant weight and ignit the plankton (Fig. 1).

Particulate organic matter — Measurements were made of total particulate matter and ashes, in the surface layer at 2.0 and 4.0 m depth. Each water sample was filtered through an AA Millipore filter and after several rinses with distilled water, the material was dried at 100°C, weighed, ignited at 600°C and weighed again. The difference after ignition is assumed to approximate particulate organic matter (Fig. 2).

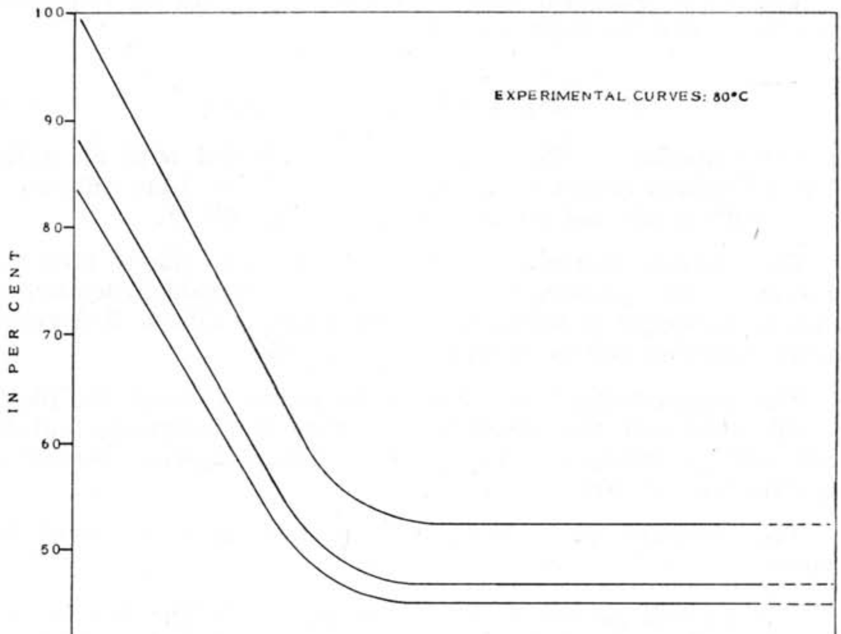


Fig. 1 — Determination of dry weight plankton.

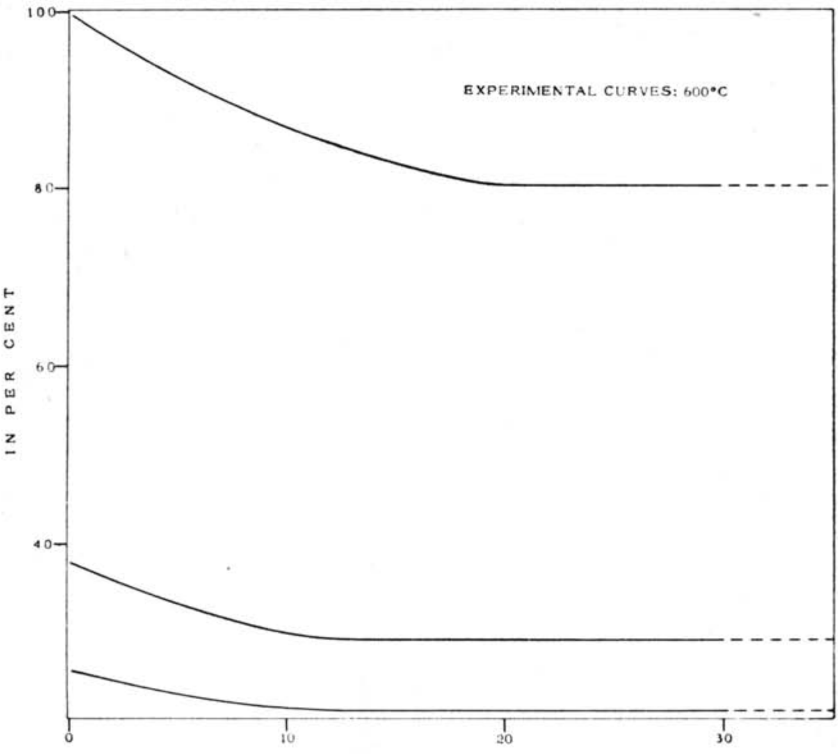


Fig. 2 — Determination of ash plankton.

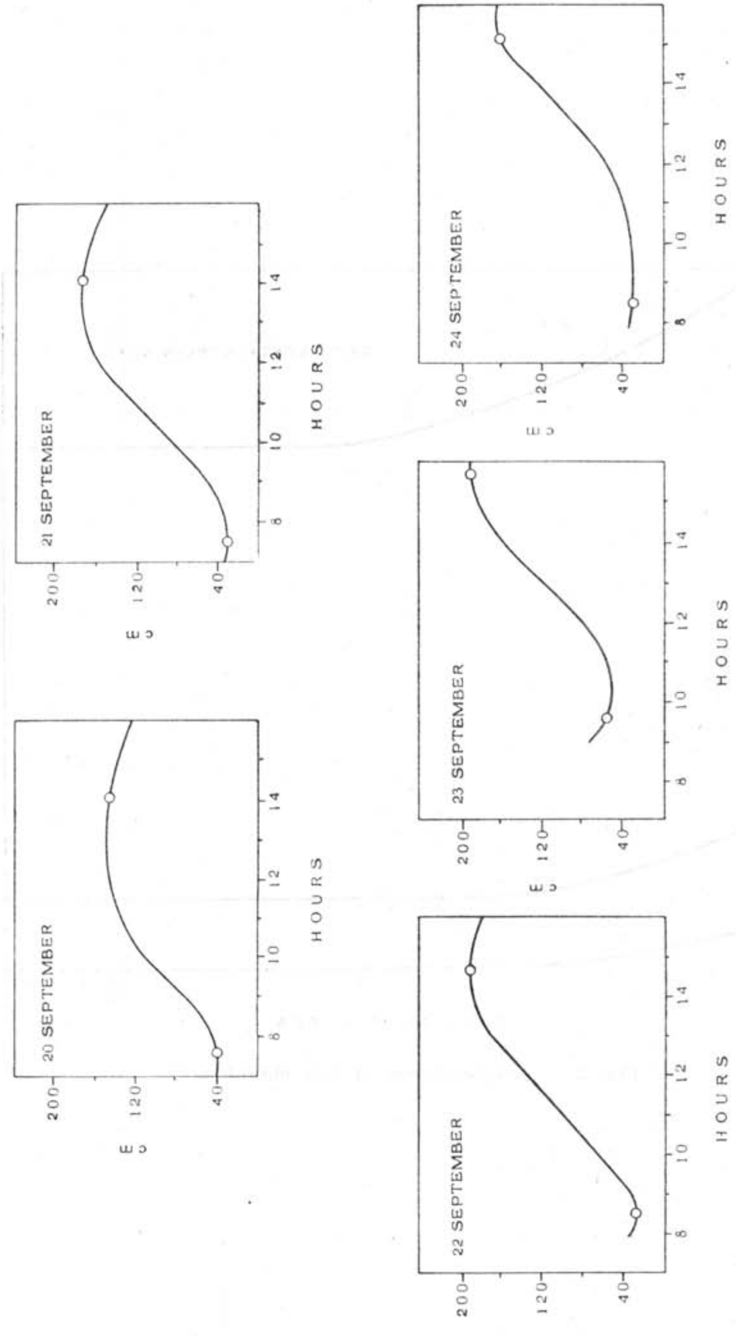


Fig. 3 — Tidal differences on the five days.

O Signs the collection hours.

Transparency — A rough measure of transparency was made by lowering a white Secchi disc (30 cm in diameter) into the water and noting the depth at which it disappeared. The Secchi disc readings were converted to extinction coefficients according to the Poole & Atkins (1929) formula:

$$K = \frac{1.7}{d},$$

where K is the extinction coefficient per meter, and d is the Secchi disc reading in meters.

Hydrographical data — The variation of the mean sea level (Fig. 3) was determined with a tide gauge placed at the Cananéia laboratory. Salinity was determined by the argentimetry method and for O_2 determination the Winkler's method was used; pH was measured with a portable Metrohm pH Meter.

III — OBSERVATIONS AND RESULTS

1. *Phytoplankton*

a) Composition of net and nanoplankton: The major part of the phytoplankton was represented by centric diatoms; the other phytoplankton elements (silicoflagellates, dinoflagellates, blue-green and green algae) were rather scarce.

The genera *Coscinodiscus, Skeletonema, Surirella, Biddulphia, Raphoneis* and *Guinardia* constituted the bulk of the net phytoplankton (Teixeira & Kutner, 1961) and *Navicula, Nitzschia, Fragillaria,* micro-flagellates and especially a small indetermined *Cyclotella* species also occurred in considerable numbers in the nanoplankton. Concerning morphological details of *Cyclotella,* all we can state is: 1) the valvar diameter varied between 5 and 8 μ; 2) tangentially the valve is strongly undulated; 3) the structure is characterized by numerous fine stripes.

b) Quantitative analysis: The number of organisms retained by the net is very reduced when compared with samples filtered through a Millipore filter. Even the larger diatoms (*Skeletonema, Melosira,* etc.) are only partially retained by the net.

Some authors have claimed that net samples are representative, but Riley (1941), Wood & Davis (1956), Steemann Nielsen (1957), Yentsch & Ryther (1959), have demonstrated that most phytoplankton organisms pass through a fine net.

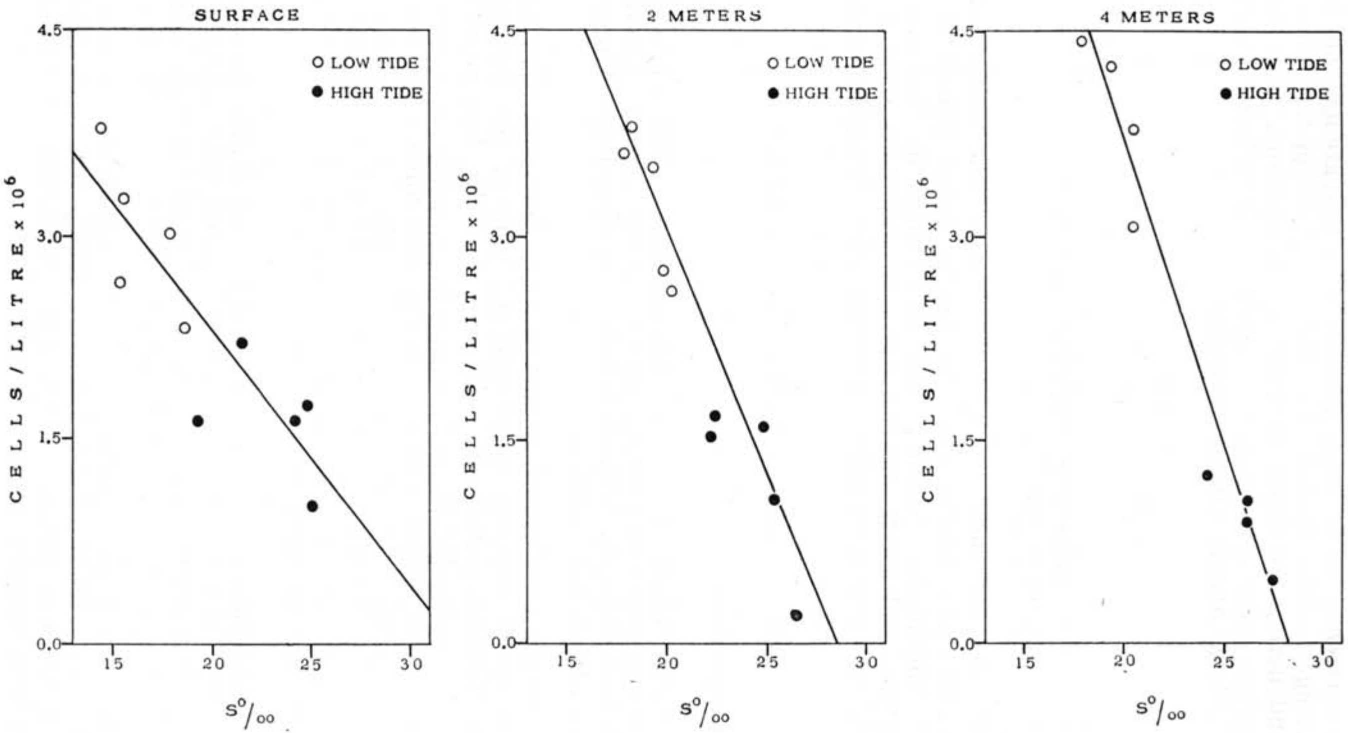


Fig. 4 — Relation between number of nanoplankton cells and tide.

In an estuary the percentage of phytoplankton retained by a fine net may be much lower still due to the prevalence of smaller forms (Yentsch & Ryther, 1959).

Comparing the net phytoplankton with the nanoplankton in our collections, the analysis confirmed the great quantitative importance of the nanoplankton.

Net phytoplankton cells counts in general and nanoplankton cells in particular were much lower during high tide than during low tide. An inverse correlation was found between phytoplankton concentration and salinity. The regression coefficients of the least square lines were calculated and the values found were: $r = -0.876$ of the surface; $r = -0.969$ at 2.0 m depth and $r = -0.985$ at 4.0 m depth (Fig. 4).

2. *Zooplankton*

a) Composition: The major part of the zooplankton was constituted by larval stages, followed by copepods; among the copepods we can mention the genus *Oithona* and *Euterpina*. The other animal groups were represented by mollusks, *Copelata* and crustaceans other than copepods.

b) Quantitative analysis: The total number of specimens of the zooplankton is considerably smaller than that of phytoplankton organisms, considered as number of organisms.

The number of organisms during high and low tide during five days showed little variation. Correlation with the tide was not found, however at high tide generally the number of animals is relatively higher.

The range of number of specimens of the zooplankton in 29 samples was from 64.000 to 431.000 per cubic meter.

3. *Bacterioplankton*

Little information is available concerning the study of bacteria in tropical inshore waters. The purpose of our study was to determine the natural flora of bacteria and verify the existence and amount of pollution.

Analysing the bacterial flora of the region, we observed some degree of pollution, indicated mainly by the water collected at high tide just when it is flowing away from the town, being a consequence of the pollution by sewage.

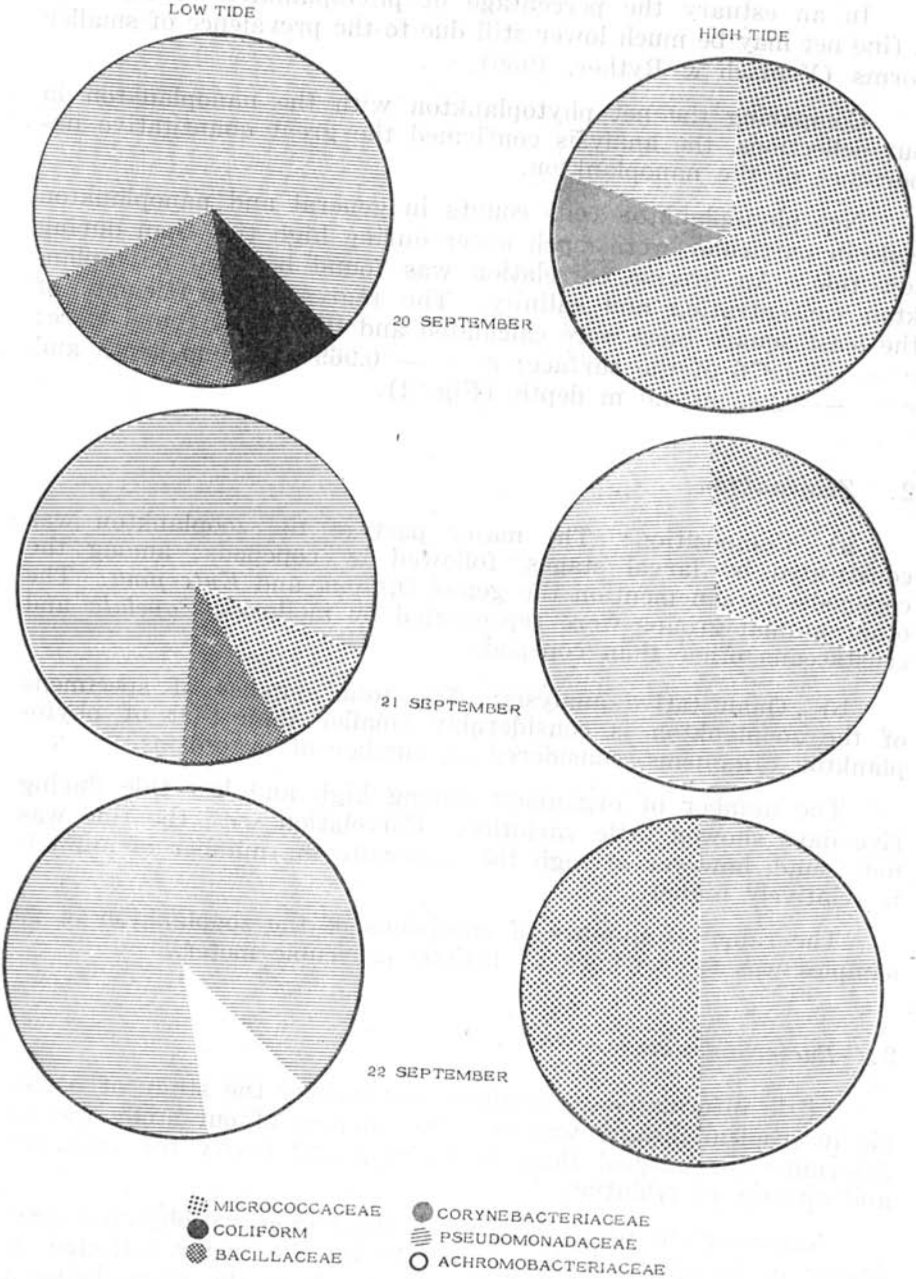


Fig. 5 — General composition of bacteria during high and low tide.

TABLE I — Total plankton (cells/l)

Date	Tide	Depth (m)	Net plankton: Zoo-plankton	Net plankton: Phyto-plankton	Nano-plankton	Bacterio-plankton
20/9	low	0.0	64	75,890	2.536,000	1.520,000
		2.0	365	150,514	2.742,500	—
		4.0	—	—	—	—
	high	0.0	266	40,866	1.683,450	1.300,000
		2.0	431	56,181	1.513,200	—
		4.0	300	63,283	1.200,800	—
21/9	low	0.0	135	79,600	3.799,360	230,000
		2.0	173	184,249	3.654,800	—
		4.0	214	38,054	3.883,200	—
	high	0.0	170	34,750	1.700,220	2.000,000
		2.0	300	34,381	1.651,200	—
		4.0	200	23,700	1.050,750	—
22/9	low	0.0	120	53,094	3.020,400	3.100,000
		2.0	118	164,949	3.512,000	—
		4.0	281	81,670	4.218,880	—
	high	0.0	110	31,900	1.146,400	9.600,000
		2.0	305	20,775	201.960	—
		4.0	102	15,481	456,000	—
23/9	low	0.0	260	28,260	2.301,160	—
		2.0	264	112,595	2.670,720	—
		4.0	150	25,612	3.093,600	—
	high	0.0	70	34,900	1.666,400	—
		2.0	95	18,299	1.092,480	—
		4.0	322	22,025	945,050	—
24/9	low	0.0	135	70,650	3.415,190	—
		2.0	300	151,253	3.832,350	—
		4.0	305	184,510	4.445,730	—
	high	0.0	94	38,525	2.187,500	—
		2.0	264	60,009	1.721,300	—
		4.0	212	79,620	—	—

The generic distribution from the plate counts is shown in Figure 5 and Table VI and the numerical determination in Table I.

4. *Organic matter*

Particulate organic matter and inorganic matter suspended in natural masses of water varies in chemical composition, in relative quantities with reference to depth, latitude and proximity to land (Fox, Isaacs & Corcoran, 1952).

Only the quantitative determination of particulate matter was considered in this paper and the approximate concentration is given in terms of milligrams per liter of filtered water.

The amounts of particulate organic matter, and the vertical distribution showed a good agreement with the distribution of the plankton population (Fig. 6). This suggests that a considerable fraction of the particulate matter may be originated from the nanoplankton and fine detritus as the amounts of net-organic matter is very small, as compared with the total organic matter. The total organic matter varied from 6.80 to 16.80 mg/l (Table II) and the dry organic matter of net plankton varied from 0.084 to 3.64 mg/m^3 (Table III).

5. *Transparency*

The water of mangrove lagoon areas is very turbid due to organic detritus, pigments from the mangrove swamp and the high concentration of phytoplankton.

The Secchi disc readings of transparency fall within the general range of 0.8 to 2.5 m depth. The readings showed a good inverse correlation ($r = -0.778$) between the total particulate matter concentration and the visible transparency depth (Fig. 7). Converting the Secchi disc readings to extinction coefficients according to the Poole & Atkins (1929) formula

$$K = \frac{1.7}{d}$$

where K is the extinction coefficient per meter, and d is the Secchi disc readings in meters, the variation of extinction coefficient was from 0.68 to 2.12 (Table IV).

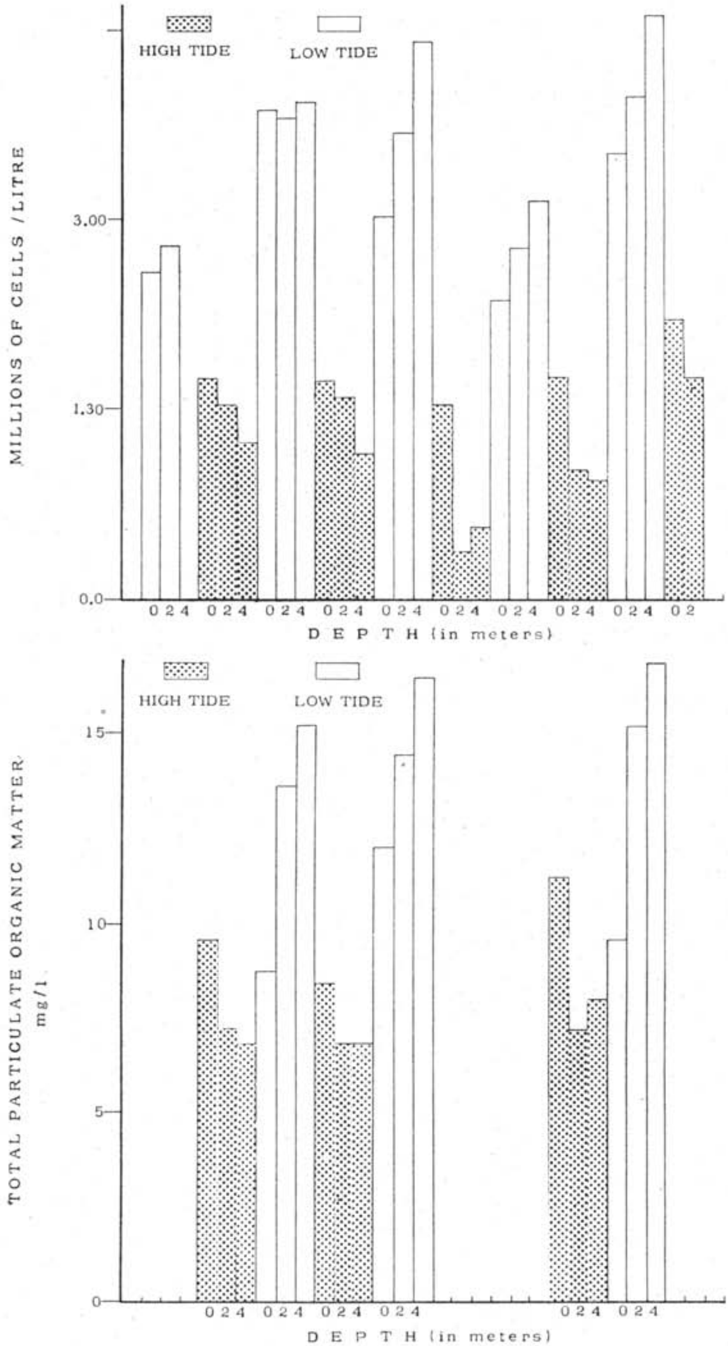


Fig. 6 — Comparison between the plankton (number of organisms) and particulate organic matter during the five days.

TABLE II — Total particulate matter

Date	Tide	Depth (m)	Organic matter (mg/l)	Inorganic matter (mg/l)	Total part. matter (mg/l)
20/9	high	0.0	9.60	22.44	32.04
		2.0	7.20	10.80	18.00
		4.0	6.80	11.76	18.56
21/9	low	0.0	8.80	19.60	28.40
		2.0	13.60	24.80	38.40
		4.0	15.20	21.60	36.80
	high	0.0	8.40	16.00	24.40
		2.0	6.80	14.00	20.80
		4.0	6.80	14.40	21.20
22/9	low	0.0	12.00	23.60	35.60
		2.0	14.40	24.80	39.20
		4.0	16.40	28.68	45.08
23/9	high	0.0	11.20	22.40	36.60
		2.0	7.20	18.80	26.00
		4.0	8.00	20.00	28.00
24/9	low	0.0	9.60	24.16	33.76
		2.0	15.20	27.00	42.20
		4.0	16.80	29.28	46.08

TABLE III — Total organic matter of the total net plankton

Date	Tide	Depth (m)	mg/m3
20/9	low	0.0	0.3450
		2.0	0.5434
		4.0	—
	high	0.0	0.3000
		2.0	0.0840
		4.0	0.6720
21/9	low	0.0	0.4720
		2.0	—
		4.0	0.2340
	high	0.0	0.5005
		2.0	—
		4.0	0.2380
22/9	low	0.0	0.5392
		2.0	1.1480
		4.0	0.8680
	high	0.0	0.1914
		2.0	0.2240
		4.0	0.0980
23/9	low	0.0	0.5214
		2.0	1.6940
		4.0	0.4280
	high	0.0	0.3234
		2.0	0.1120
		4.0	0.1280
24/9	low	0.0	0.3600
		2.0	2.1600
		4.0	3.6400
	high	0.0	0.3432
		2.0	0.4480
		4.0	0.5600

TABLE IV — Variation of extinction coefficient

Date	Tide	d (m)	K
20/9	low	2.0	0.85
	high	2.5	0.68
21/9	low	2.0	0.85
	high	2.2	0.77
22/9	low	1.5	1.33
	high	1.5	1.33
23/9	low	1.2	1.41
	high	1.5	1.33
24/9	low	0.8	2.12
	high	1.0	1.70

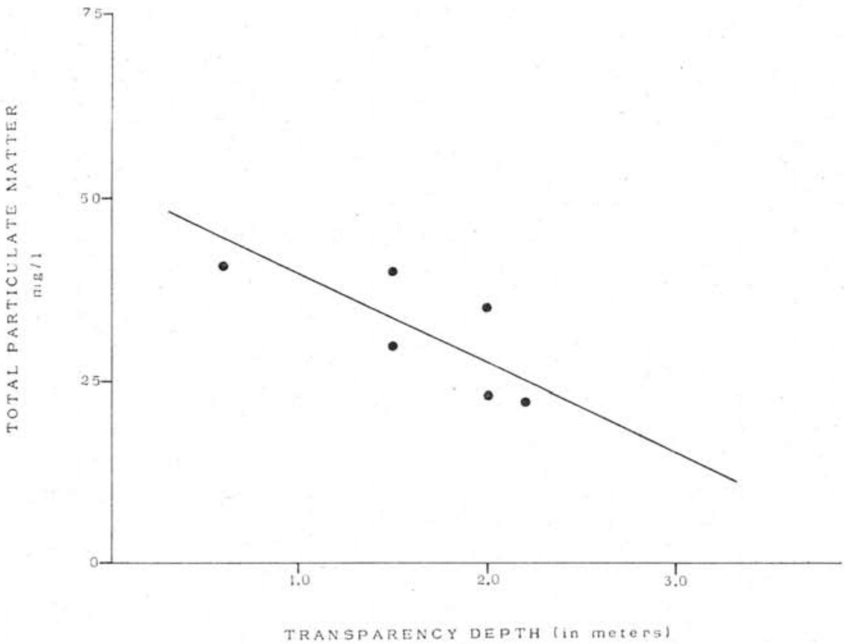


Fig. 7 — Relation between particulate organic matter and Secchi disc depth.

6. *Hydrographical data: tide, salinity, temperature, oxygen and pH*

At any point in this region the influence of tide on salinity is very strong. The effects of tidal currents are indicated by a gradient of salinities from the inner mangrove waters towards the open sea (Teixeira & Kutner, 1961) as well as a great range of variation between high and low tide. The salinity at the station occupied ranged from 14.64 to 27.75 °/₀₀ showing obvious correlation with the tide; the vertical salinity gradient is also evident (Table V).

During flow, oceanic water invades the inland waters the density of which is lower due to their higher temperature and lower salinity, thus causing a counter-current at the surface which runs towards the exit of the lagoon system (Garcia Occhipinti, Magliocca & Teixeira, 1961).

The difference in height between high and low tide in a five-day period was in the average of 145.6 cm; the minimum value was 112 cm and the maximum 158 cm (Fig. 3). The tide graphs were drawn from values recorded at the Cananéia Marine Station.

Temperature was measured only at the surface (Table V). During the period studied and in the daytime it remained nearly constant, showing a small range of variation: from 20.60 to 23.40°C.

The values found for dissolved oxygen showed similar values that somehow correspond to increase or decrease in the phytoplankton population, suggesting photosynthetic activity (Tables I and V).

The pH reaches a minimum of 7.5 during low tide and a maximum of 8.1 at high tide. The values in relation to the same tide level ranged from 7.5 — 7.8 (low tide) to 7.8 — 8.1 (high tide).

IV — DISCUSSION

An attempt is made here to analyse the standing-stock of the plankton collected by nets and the whole plankton, including the ultra-plankton (bacteria and micro-flagellates) in relation to some environmental conditions considered to have detectable influence on plankton population in the mangrove environment.

From the results obtained in the samples taken with the 8-liter bottle and from comparisons made between nanoplankton

TABLE V — Hydrographical data: tide, salinity, temperature, oxygen and pH

Date	Tide	Depth (m)	S ‰	T°C	O_2 cc/l	pH
20/9	low	0.0	15.44	20.60	4.61	7.7
		2.0	20.07	—	4.62	—
		4.0	—	—	—	—
	high	0.0	19.31	23.40	4.86	8.1
		2.0	22.62	—	4.85	—
		4.0	24.39	—	4.37	—
21/9	low	0.0	14.64	22.80	4.65	7.8
		2.0	17.92	—	4.97	—
		4.0	20.67	—	5.32	—
	high	0.0	24.88	22.60	4.73	8.1
		2.0	24.96	—	4.76	—
		4.0	26.29	—	4.76	—
22/9	low	0.0	17.92	22.24	4.22	7.7
		2.0	19.62	—	5.01	—
		4.0	19.42	—	5.08	—
	high	0.0	25.32	22.70	4.47	7.8
		2.0	26.64	—	—	—
		4.0	27.75	—	—	—
23/9	low	0.0	18.87	22.00	4.22	7.6
		2.0	20.38	—	4.32	—
		4.0	20.76	—	4.44	—
	high	0.0	24.42	22.20	4.43	7.8
		2.0	25.71	—	4.43	—
		4.0	26.36	—	4.42	—
24/9	low	0.0	15.84	22.40	4.72	7.5
		2.0	17.98	—	4.19	—
		4.0	18.02	—	4.20	—
	high	0.0	21.24	22.60	5.06	8.0
		2.0	22.62	—	4.81	—
		4.0	22.54	—	—	—

TABLE VI — General composition of bacteria during high and low tide

Date	Tide	Number of colonies tested	*Pseudomonadaceae* (%)	*Achromobacteriaceae* (%)	*Bacillaceae* (%)	*Micrococcaceae* (%)	*Corynebacteriaceae* (%)	Coliform (%)
20/9	low	10	70	0	20	0	0	10
	high	10	20	0	0	70	10	0
21/9	low	10	80	0	10	10	0	0
	high	10	70	0	0	10	0	0
22/9	low	10	90	10	0	0	0	0
	high	10	50	0	0	50	0	0
23/9	low	10	100	0	0	0	0	0
	high	10	80	10	0	0	0	0

and net phytoplankton, net phytoplankton and zooplankton it can be seen that in the average the nanoplankton was 97% more abundant than the net phytoplankton and the net phytoplankton was in the average 99,7% more abundant than the zooplankton, considered in numbers of organisms per liter.

The study of nanoplankton has been underestimated by many authors because of the difficulties and limitations of the usual methods of plankton countings. However the present countings especially for such tropical inner water readily show the importance of the small organisms of the phytoplankton (nanoplankton). Unquestionably the nanoplankton must contribute with a significant proportion of the organic production in this region.

The zooplankton is otherwise very poorly developed relatively to the phytoplankton and to particulate organic matter.

The vertical distribution of the phytoplankton within the small water column studied showed an inverse behaviour at low and high tides. During low tide the number of organisms increases from the surface downwards; the inverse prevailing at high tide (Table I). Probably the vertical distribution found during low tide is the result of a situation in which the population suffers the consequence of strong light intensity and during the high tide the vertical distribution is a result of the tidal current: the offshore waters (denser waters) inflow under the inshore waters (lighter water) and the latter remain on the surface and are characterized by a population denser than the oceanic waters.

At any given point the concentration of phytoplankton is extremely variable in lagoon waters, there is also a great variation of species, caused among other factors by mixing of different water masses. These results show that it is very important to take all size groups into consideration, as well as the hour of sampling, when population studies are undertaken for use in works of production in such environment as mangrove regions inshore or estuarine waters, especially in the tropical belt.

The bacterioplankton countings ranged from 230.000 to 9.600.000 bacteria per liter at the surface. The number of bacteria was always greater during high tide than at low tide.

The richness of bacterial flora must be associated to the quantity of organic matter in the water, but the results found (Table I) do not agree with the amounts of particulate organic matter. As stated before, the greater number of bacteria occurred during high tide when the amounts of organic detritus were lower.

The high number of bacteria at this period must thus be attributed to a certain degree of pollution by sewage waters that are carried to the station from the town of Cananéia.

Another important characteristic of the region is the richness of particulate matter. The particulate matter can be assumed to be originated from multiple sources: 1) from detritus and decayed vegetation from the mangrove; 2) from the planktonic population (including the dead plankton); 3) from the sediment resuspended from the bottom by turbulence; 4) from the detritus carried by rivers.

Riley (1959) measured total organic matter in surface waters at Long Island Sound where he found values varying from 1.2 to 3.1 mg/l. Fox, Isaacs & Corcoran (1952) showed that the concentrations of organic matter in shallow waters near the shore are relatively high: values from 7.5 to 35 mg/l or more. The present data vary from 6.80 to 16.80 mg/l.

The great abundance of phytoplankton in this region must be attributed, among other factors to dissolved organic matter, as according to Saunders (1957) the dissolved organic matter may be the source of accessory growth factors, i. e, substances required by the organisms for their growth or stimulate growth by supplementing a limiting system and ability to influence the availability of trace metals by chelation.

V — ACKNOWLEDGEMENTS

The authors are indebted to Dr. Marta Vannucci whose criticism has been of great help during the investigations, to Dr. Ko Watanabe for the bacteria studies and to Mr. J. Tundisi for the zooplankton countings.

VI — SUMMARY

1 — The quantitative relation between net phytoplankton, nanoplankton and zooplankton during the high and low tide for five days at a fixed station is reported here. The samples were collected at surface, 2 and 4 m near the Baguassú river, a typical region of mangrove environment.

2 — Measurements were made of transparence, salinity, temperature, pH, dissolved oxygen, suspended matter and dry weight (inorganic + organic). Culture of bacteria was also carried out to determine the degree of contamination of the water.

3 — Total phytoplankton cell counts were lower during high tide showing a good inverse correlation to salinity.

4 — The total organic matter varied from 6.80 to 16.80 mg/l and the dry organic matter of net plankton varied from 0.084 to 3.64 mg/m^3. These results are presumably due to a great portion of the particulate matter that may be originated from nanoplankton and fine detritus.

5 — The average of nanoplankton was 97% greater than net phytoplankton and the net phytoplankton was in average 99,7% greater than zooplankton.

VII — RESUMO

1 — Os autores fizeram um estudo sôbre a variação quantitativa entre o "net" fitoplâncton, nanoplâncton e zooplâncton numa estação fixa junto à barra do Rio Baguassú, região que sofre forte influência do mangue.

As amostras foram coletadas durante cinco dias sucessivos, na preamar e baixa-mar em três profundidades: superfície, 2 e 4 m.

2 — Foram levados em conta os seguintes fatôres: transparência da água, salinidade, pH, temperatura, oxigênio dissolvido e pêso do material sêco (matéria orgânica + matéria inorgânica). Foram feitas culturas de bactérias para se determinar o grau de contaminação da região estudada.

3 — O fitoplâncton apresentou menor número de células durante a maré alta, mostrando uma correlação inversa com a salinidade.

4 — A quantidade de matéria orgânica total variou de 6,80 a 16,80 mg/l, ao passo que a quantidade de matéria orgânica do "net" plâncton mostrou uma variação de 0,084 a 3,64 mg/m^3. Êstes resultados são devidos ao fato de que uma grande parte da matéria em suspensão é originada do nanoplâncton e microdetritos.

5 — O número de indivíduos do nanoplâncton foi em média 97% maior do que o do "net" fitoplâncton. Êste, por sua vez, apresentou um número 99,7% maior do que aquele do zooplâncton.

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