The blackwater river estuary of Rio Una do Prelado (São Paulo, Brazil) : preliminary hydrobiological data [1]

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Summary

A preliminary general picture of the hydrobiology of the Rio Una estuary is presented. Rio Una is a lowland stream extremely influenced by the heavy rainfall of the region and by the tides which are penetrating far upstream. During the rainy period and at neap tides, Rio Una functions as typical "blackwater" river with freshwater of very low pH (minimum 3.3) and high humic content. During the dry period and at spring tides, Rio Una turns into a typical estuary invaded by normal salinity and well buffered sea water. In accordance with this, the phyto- and zooplankton of the estuary present a very fluctuating picture. The zoobenthos of the surrounding mangrove forest is extremely depleted both in number of species and in population densities. The phytobenthos of macroalgae is fairly well developed.

Rio Una is compared on one hand with the blackwater rivers of Amazonia and on the other with the nearby estuarine system of Cananeia. The faunal depletion of the Rio Una mangrove is seen as an effect of the acid humic freshwaters.

Key words : Brazil — Estuaries — Blackwaters — Mangroves — Seasonal cycle.

Résumé

Les eaux noires de l'estuaire du Rio Una do Prelado (São Paulo, Brésil) : données hydrobiologiques préliminaires

Cet article est une description générale préliminaire dé l'hydrobiologie de l'estuaire du Rio Una (État de São Paulo, Brésil). Cette rivière de plaine est fortement influencée par les fortes pluies de la région et les marées qui remontent très en amont.

Durant la saison des pluies, lors des marées de morte eau, la rivière Una fonctionne comme une rivière typique à « eaux noires », avec des eaux de pH très faible (minimum 3,3) et une forte teneur en matières humiques. Durant la saison sèche et lors des grandes marées, la rivière Una devient un estuaire typique avec une eau de mer bien tamponnée. Il en résulte des fluctuations très importantes du phyto- et du zooplancton de cet estuaire. Le zoobenthos de la mangrove environnante est très appauvri du point de vue de la richesse et de la densité des espèces. Les algues macroscopiques benthiques sont assez bien développées. La rivière Una a été comparée avec les rivières à « eaux noires » d'Amazonie et le système estuarien voisin de Cananeia. L'appauvrissement de la mangrove serait le résultat des apports d'eaux douces riches en acides humiques.

Mots-clés : Brésil — Estuaires — Eaux noires — Mangroves — Cycle saisonnier.

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INTRODUCTION

The establishing of an Ecological Reserve in the area of Juréia (state of São Paulo) (fig. 1), which includes a coastal stretch of about 40 kilometers and its rivers, provided the opportunity for a series of studies, starting with the aquatic ecosystems. The Juréia area is situated some 100 km NE from the well investigated estuarine complex of Cananeia (Por *et al.*, 1984). Like this, it belongs to the Atlantic floodplain of the Baixada do Ribeira delimited by the foothills of the coastal mountain range, Serra do Mar (Godoy Camargo *et al.*, 1972; Por and Imperatriz Fonseca, 1984).

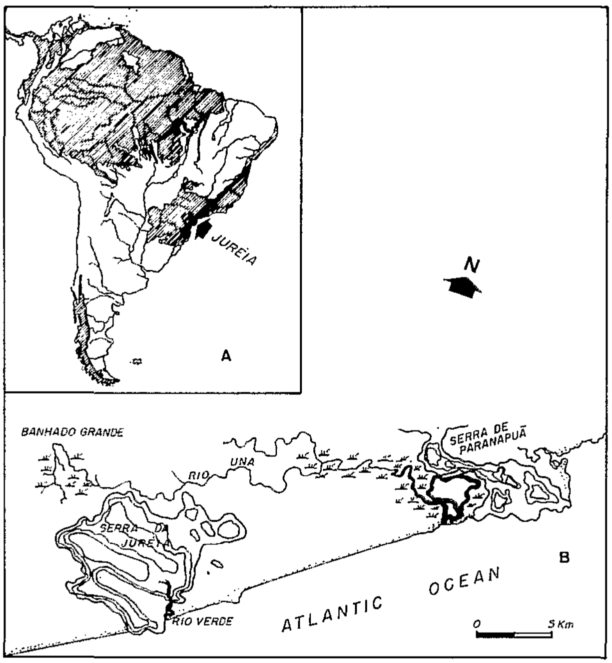


Fig. 1. — A: Geographical location of the Juréia Reserve. The original areas of Atlantic rainforest and Amazonian rainforest cover are indicated. B: Detail map of the Juréia Reserve with Rio Una and Rio Verde

The main riverine basin of the Juréia area is the medium-sized river Rio Una do Prelado, or Rio Comprido, long of about 80 km and with a big catchment area. The name "Una" in the Tupi-Guarani language signifies "black": this is a black-water river unlike a neighbouring smaller river Rio Verde, which is a "clearwater" river. The estuarine area of Rio Una has a fairly well developed mangrove and the present study deals with this estuarine area.

Much has been written since Sioli (1950) on the "black" rivers of the Amazonian basin and also on the two other types of rivers there (see also Junk, 1982, 1983). On a worldwide scale, the only attempt known to us, to deal with the blackwater rivers, is that of Janzen (1974). As for the blackwater rivers of the Brazilian Atlantic shores, there is no previous reference, although local geographical onomastics indicate black rivers and such rivers can be clearly distinguished from other rivers on the aerial photographic surveys.

The purpose of this paper is to present a first and preliminary picture of the geological setting and the morphology of the lower Rio Una as well as a first evaluation of the hydrobiological information collected during 1982-1983. The first appraisal exposed here, represents chiefly the views of the first author, who has been in charge of initiating the research program. Separate studies will follow by the different coauthors of this paper. These specific papers will supply all the tabulated data and the quantitative biological information on which the preliminary conclusions of this paper are based. Furthermore, several specialized taxonomic studies on particular taxa as well as a sedimentological study are in preparation. For data from these studies in preparation, we are indebted to Mr. Claudio Navarra and Mr. Claudio Sarti (Oceanographic Institute University of São Paulo), to Dr. Carlos E. F. Rocha, and Prof. Eurico C. de Oliveira (Institute of Life Sciences, University of São Paulo). Thanks are due for the help of the Department of Ecology University of São Paulo.

Hydrobiological work on Rio Una started in April 1982. However, only in August 1982 were the sampling stations definitively fixed and collecting started in a standard pattern. An annual cycle of observation, from August 1982 to July 1983 forms the basic framework for this paper and for the forthcoming contributions. There has been no collecting in October 1982, because of technical problems. Data from both before and after the one year cycle have also been used.

MATERIALS AND METHODS

Six permanent stations were established on the lower Rio Una, st. U 1 to st. U 6, from the mouth of the river to the farthest upstream presence of mangrove. The distance between U 1 and U 6 has been calculated at 6 km. This does not include the big meander of Ilha do Ameixal which is 11 km long. Our St. U 4 is situated in this meander (figs. 2 and 3).

The following parameters were measured on a monthly basis, both at high and low tide: Secchi transparency; temperature and salinity (Beckmann thermo-salinometer); pH (Micronal B 287 field kit); DO_2 (Winckler titration); suspended matter; chlorophyll; nutrients ($P\text{-}PO_4$, $N\text{-}NO_3$, $N\text{-}NO_2$) according to Strickland and Parsons. Dissolved organic matter

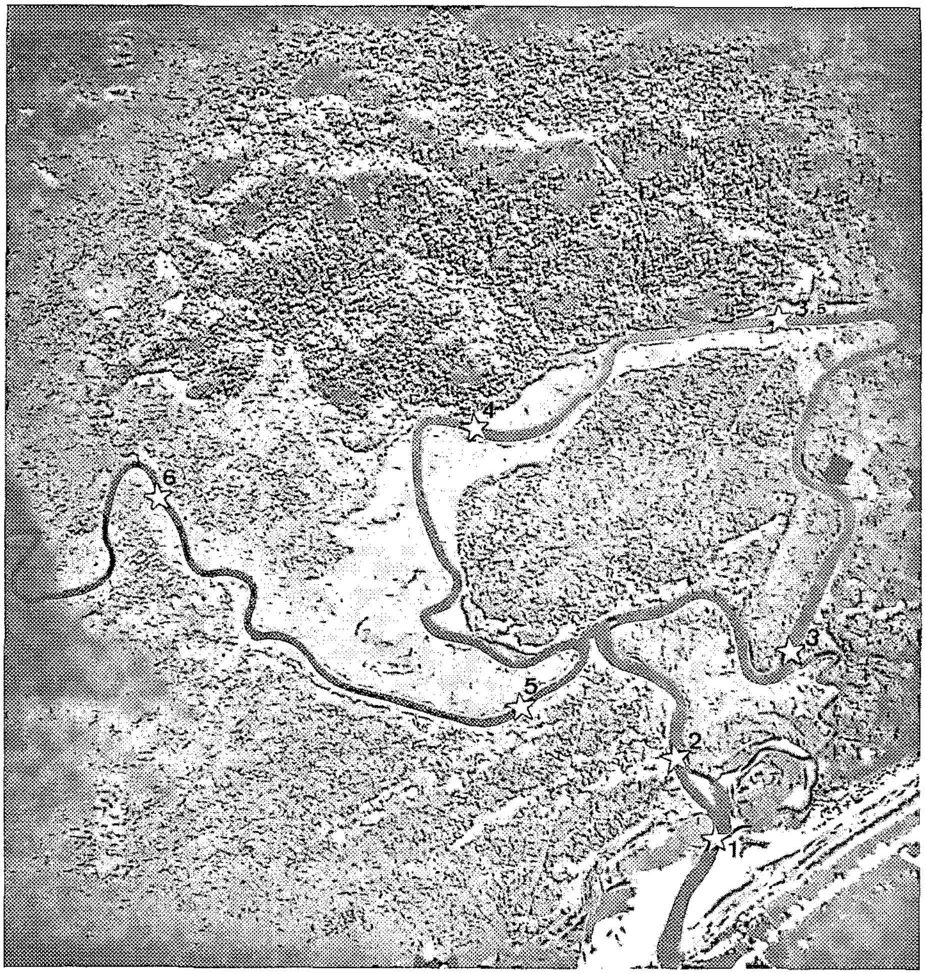


FIG. 2. — Aerial photograph of the lower Rio Una. The six hydrological stations of the study are marked. Station 3.5 has been covered only on occasion. The arrow indicates the direction of the photograph in fig. 3 (Aerophotographic Survey Transbrazil, 1962)

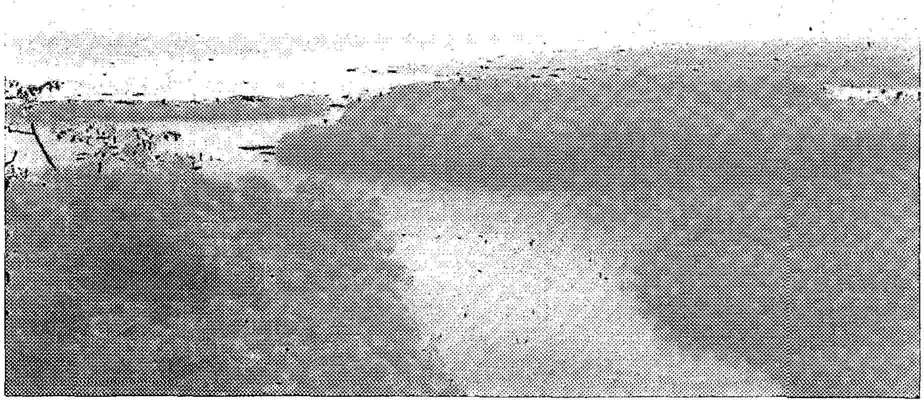


FIG. 3. — View of the Rio Una mangrove towards SW (see arrow in fig. 2)

has not been calculated yet. Horizontal tows of 5′ were taken for phytoplankton (20 μ mesh) and zooplankton (75 μ mesh). Bottom plankton has been sampled with a sledge net ("D net", ALMEIDA PRADO, 1973). Benthos from the river was sampled by a small Van Veen grab and from the river banks with a 75 μ handnet. Littoral sampling has been performed only 5 times during the one year period. Algae and especially the 'Bostrychietum' were sampled separately. Lots of 20 fallen leaves from the different mangrove tree species were sampled and analyzed for fauna. Several 1 square meter samples were taken on the intertidal mud flats. Tidal conditions were noted in accordance with the tide prediction tables for the Port of Santos and based also on the observations of the local fisherman Silvio Ribeiro, who accompanied our work.

HYDROBIOLOGICAL DATA

Morphological and geological background

Rio Una has a main NW course through a sedimentary plain of extremely low elevation (around 4 m) delimited by the Precambrian mountain ridge of the Serra dos Itatins. The headwaters of the river are in an extensive swampy area, the Banhado Grande, situated NE, behind an "Inselberg", the isolated Serra da Juréia. The swampy Banhado is drained in the opposite direction by Rio das Pedras, an affluent of Rio Una da Aldeia, which is tributary of the Ribeira do Iguape.

The whole area crossed by Rio Una is a "Paleobay" of the postglacial marine transgression (AB' SABER, 1965). The Flandrian Transgression, locally called "Cananeia Transgression" reached a level of +6-7 m about 5-6000 B.P. The latest transgressive sea level at +1.5-2.5 m has been dated ±2000 B.P. The arenitic soil of this subrecent flood-plain developped into a typical podzol, covered on the higher and dry areas by a typical shoreland forest, the "Restinga". In the flooded areas this is replaced by a forest type called "Capões" and near the sea and the lower stretches of the rivers, by a mangrove forest. The soil, as well as the brittle arenite produced by this vegetal cover is called "Piçarra" (NAVARRA, 1982) are rich in humic compounds.

Despite being situated in nearly pristine surroundings, Rio Una underwent a major hydrological change when in 1949 a short-cut has been dug to bypass the big meander. Thus the Island of Ameixal and the surrounding backwaters were created largely by human interference. According to local residents, the shortcut resulted in an advance of more than 10 km, of the sea-water influx (see below) and a corresponding readjustment between the mangrove and the capões in the upstream area.

Climate

The climate of the Atlantic lowlands of São Paulo is humid-subtropical. Between 1944 and 1962, the annual average temperatures in the nearby Baixada Santista were of 22 °C (OLIVEIRA SANTOS, 1965). The warmest month of the year is February (medium 25.3 °C) and the coldest month is July (medium 18.2 °C). Minimum temperature reported for the above period was 4.3 °C. Air humidity is as a rule above 80 %. Annual average rainfall in all the area is well over 2,500 mm, though more than 3,000 mm are also known from neighbouring sites. The rainiest months of the year are February and March and the driest months July and August (OLIVEIRA SANTOS, 1965).

There are however frequent and considerable deviations from this long-range patterns of rain distribution. For instance, September 1982 was a typically dry winter months, whereas September 1983 had three times as much rain and turned pluviometrically into a summer months.

Tides are semidiurnal. The nearest point of tide-recording and prevision is in the Port of Santos. Maximum tidal differences are of 1.5 m and minimum ranges of nearly 0.1 m. In Rio Una the resulting tidal currents are very strong and the tidal wave is reportedly felt almost all of the 80 km length of this river. While this is basically a tidal heave, the salt water input is reportedly felt for 15 km upstream. Before the cutting of the meander, saltwater reached only till our st. U 5. In the old meander the tidal current is presently non-existent and only the tidal heave is being felt.

Water temperatures

During the one-year study cycle, the lowest recorded temperature was of 19 °C in September 1982 and the highest, of 32 °C in February 1983. The average temperatures measured in September 1982 and March 1983 were respectively 21.8 °C and 25.2 °C. The temperature did not show significant gradients along the river which in the studied stretch is thermically uniform. However there was a consistent tidal pattern, where temperatures at high tide were higher than those at low tide. This difference found both at the surface and on the bottom and at different hours of the day, sometimes reaching as much as 2 °C.

Dissolved Oxygen has a peculiar behavior in Rio Una. The vertical gradient may often show an increase in DO_2 from the surface to the bottom. The lowest values found were below 1 mg/l at the surface,

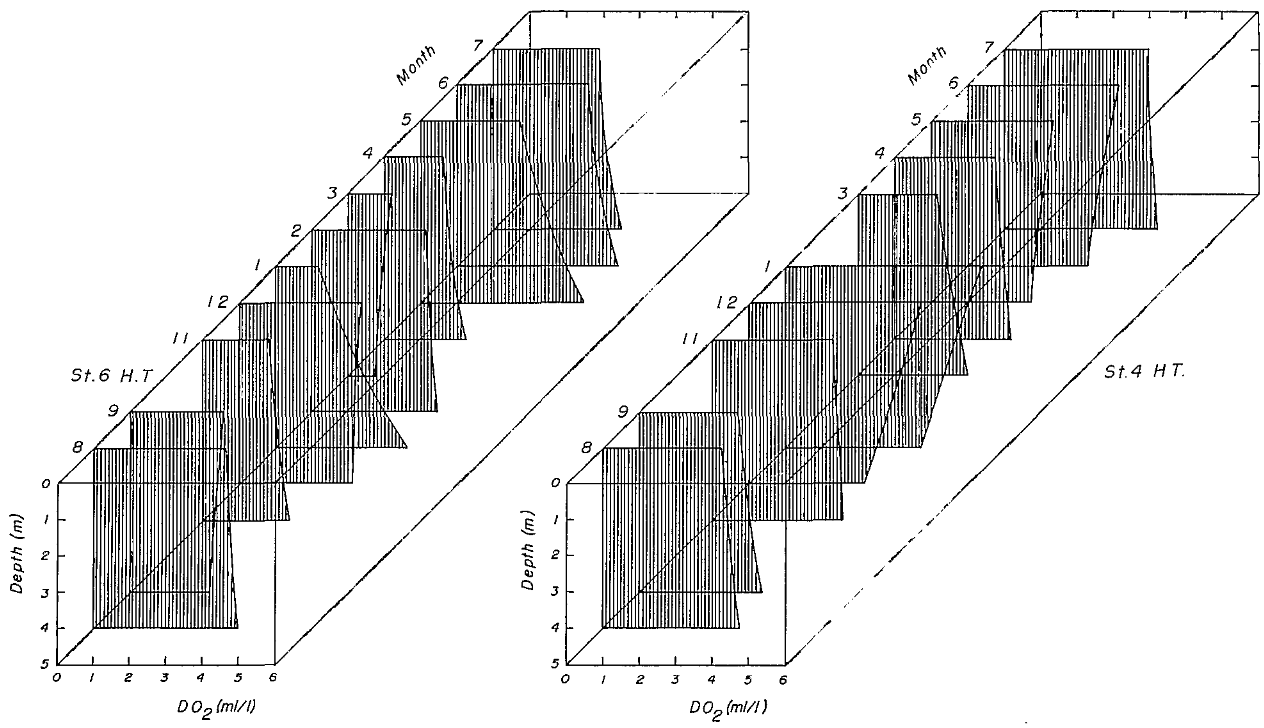


FIG. 4. — Surface and bottom values of oxygen at high tide in stations U 6 and U 4 during the period August 1982-July 1983

and were characteristic for the freshwater situation of March 1983. On the contrary, the incoming sea water had as a rule DO_2 values of over 4 mg/l. Such situations of inverse vertical stratification are shown in fig. 4.

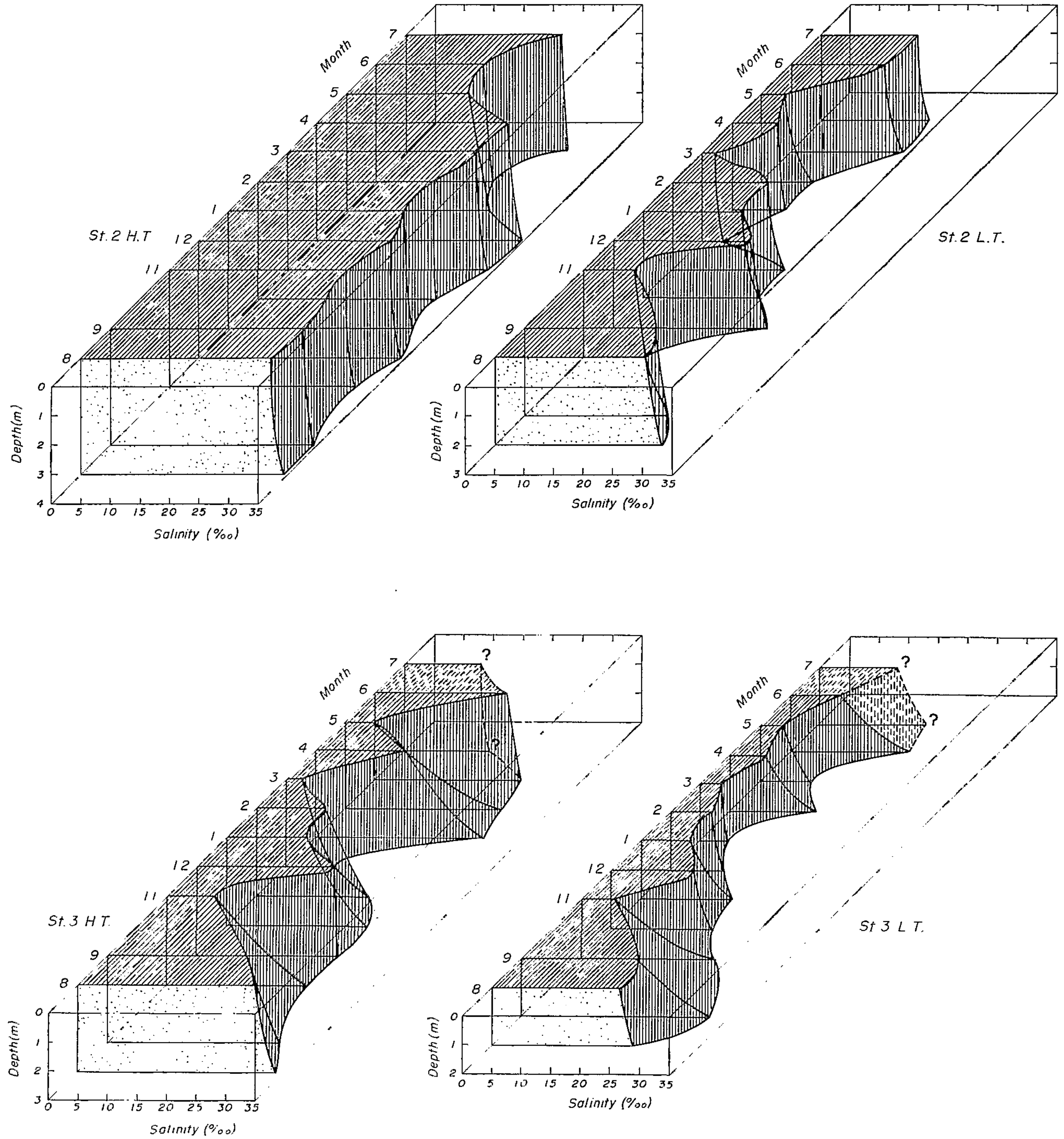
It seems that there is no photosynthetic oxygen enrichment of the surface waters, especially in the freshwater stage and that the more saline bottom water maintains its original DO_2 fairly unmodified by biological oxygen consumption.

Salinity shows a highly dynamic picture, presented in detail in fig. 5. Half to half meter sampling has been performed only in August and September 1982. For the rest of the months only surface and bottom values were available.

Within the range of the six stations, salinity fluctuated from almost pure sea water values to full freshwater. As expected, there is a gradient of decreasing salinity from the mouth to U 6. However in the very rainy month of March 1983 and especially at low tide, the whole system down to U 1 was taken over by nearly fresh water. In contrast in the dry month of September 1982 this trend was almost reversed with waters of around 30 ‰ penetrating far upstream. In May 1982, during the period that preceeded the one-year collecting cycle, we found at U 6 at high tide salinities of 33 ‰. In general the low salinity months are from January to May and the rest of the year is characterized by high salinity. However, as mentioned above, in the very rainy September 1983 was characterized by very low salinity. In general in the more isolated U 4 the annual cycle of the salinities is more smooth and regular. There, even in the extreme fresh month of March 1983, surface values did no fall below 2 ‰.

The vertical movement of the water masses is illustrated also in fig. 6. It appears that at U 1, U 2 and U 5 the whole water column moves in accordance with the tides, whereas in the shallow U 3 and the upstream U 6 there is a tendency to stratify. The stratification is constant at U 4.

pH seems to be salinity-related, though in an indirect way. While sea water is well-buffered and even somewhat alkaline, the low-salinity and fresh waters have values below 6. Fig. 7 shows the distribution of the pH values over the year, in the different stations and at high tide. It is evident from this table that low pH values are accompanying low salinity waters. The lowest recorded pH was 3.3. Fig. 8 attempts to further exemplify the correlated



St. 2 H.T
Month
Depth (m)
Salinity (‰)
St. 2 L.T.
Month
Depth (m)
Salinity (‰)
St. 3 H T.
Month
Depth (m)
Salinity (‰)
St 3 L T.
Month
Depth (m)
Salinity (‰)

FIG. 5

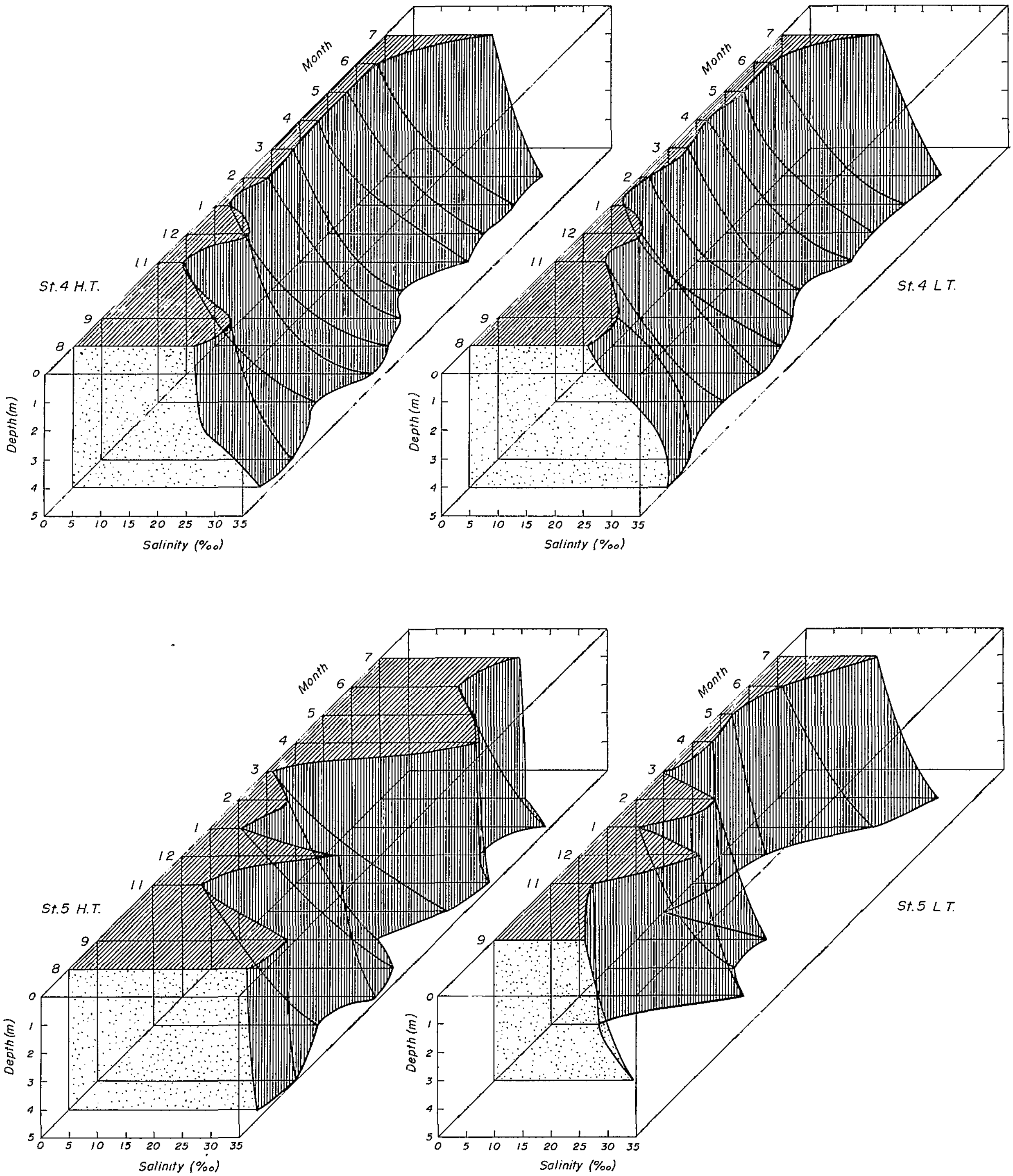

St.4 H.T.
St.4 L.T.
St.5 H.T.
St.5 L.T.
Month
Depth (m)
Salinity (‰)
0 5 10 15 20 25 30 35

FIG. 5

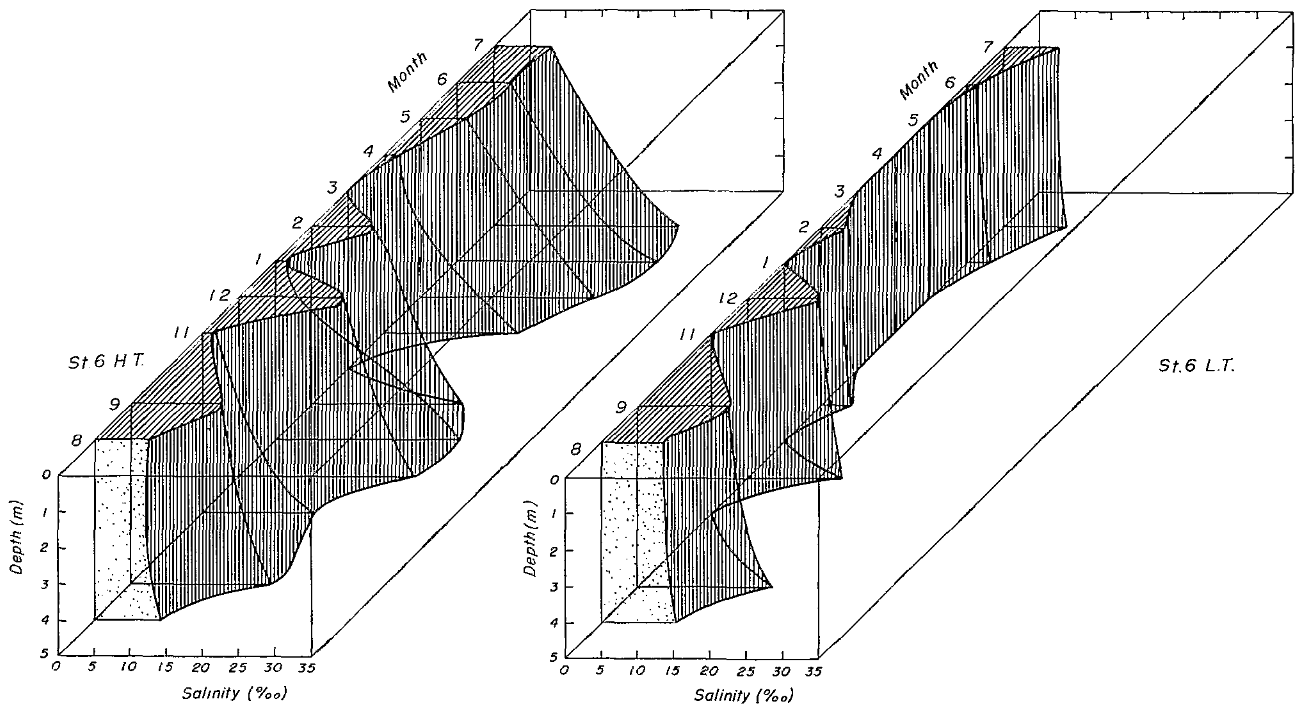


FIG. 5 (continuation)

FIG. 5. — Surface and bottom salinities at High and Low Tides in stations U 2 to U 6 during the period August 1982-July 1983. For August and September 1983 there are complete depth profiles. The July 1983 values for U 3 are questionable

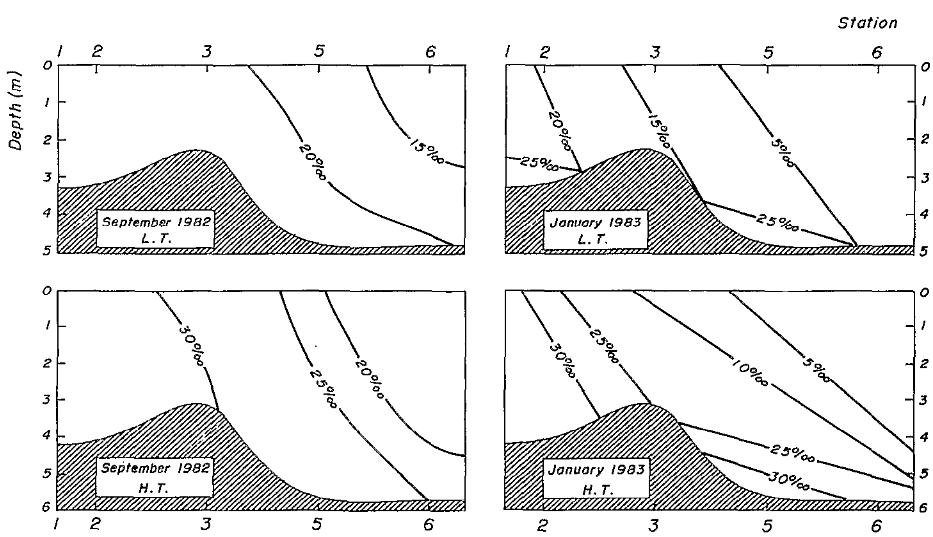


FIG. 6. — Selected vertical isohalines along Rio Una: September 1982 complete profile, January 1983 only surface and bottom values known. Station U 4 has not been included

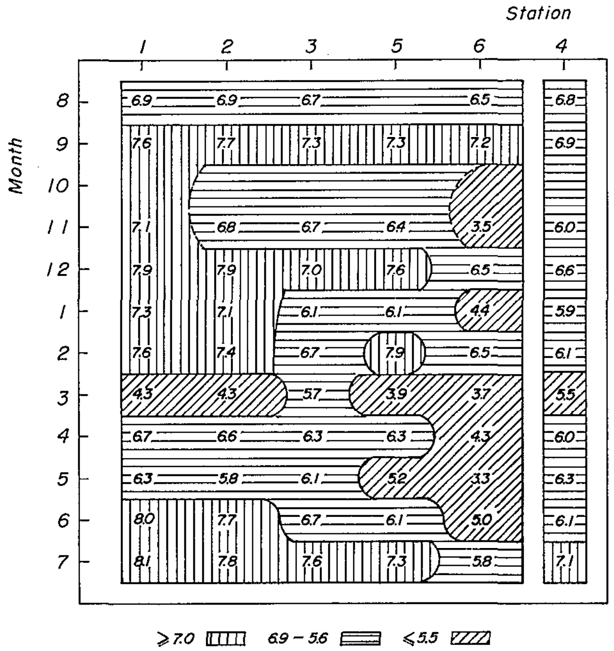


FIG. 7. — Table diagram of pH values on the surface and at high tide during the period August 1982-July 1983. Values for U 4 are separated from the sequence

nature of salinity and pH in the Rio Una estuary: in September 1982, all the waters in the system have marine salinities and relatively high pH; in November 1982, the waters have a mixed character, while in March 1983 there are clearly two water masses in the estuary: the marine one with high pH and the fresh one with low pH.

Nutrients ($P\text{-}PO_4$ and $N\text{-}NO_3$)

A preliminary look at the tabulated data of the nutrients in Rio Una (ROCHA OLIVEIRA, *in prep.*) shows that for the three months August, September and November 1982 the average values of $P\text{-}PO_4$ were of 0.42 μg at./l and $N\text{-}NO_3$ of 2.10 μg at./l. Extremely low values of $P\text{-}PO_4$ were found, below the analyzable level and for NO_3 the lowest recorded level was 0.42 μg at./l. While for the period of these three months there was no visible trend in the NO_3 content, the PO_4 showed a decline in its values from August to September. There was also a spatial decrease in PO_4 values from U 1 towards U 6. If one adds to this the fact that the bottom water at U 4 had the highest values, one may find an indication for the fact that PO_4 enrichment is related to the influx of marine water.

Dissolved humic organic matter

As mentioned above, no quantitative analysis of DOM has been made. The dark brown color of the dissolved humic matter appears as a rule associated with fresh- to low salinity waters. In fig. 2 an aerial photograph taken at an unknown date in 1962, the dark colour appears clearly. It avoids the meander, where waters of clearer colour are seen. The "black water" streaming out into the sea and to the left can also be seen on this photograph.

According to visual calibration (NAVARRA, pers. comm.), the maximum value for dissolved humic acid found till now has been estimated at over 40 mg/l.

Secchi transparency and suspended matter

While annual values will be tabulated in ROCHA OLIVEIRA *(in prep.)*, here we compared in fig. 9 the Secchi transparency values at high and low tides. As a rule, transparence of the outgoing tide is higher than that of the incoming tide. As expected, "black-water" conditions in March 1983 show lower transparency (Secchi below 0.5 m). In a saline months like September 1982, minimum transparency was of 1.0 m. In november 1982, we found a maximum transparency of 3.5 m at U 2.

Suspended matter increased from the mouth to the upstream stations and from surface to bottom. Maximum values are found in the low salinity months of January 1983 and March 1983.

BIOLOGICAL DATA

Our preliminary conclusions are based on comparison with the knowledge existing from the neighbouring Cananeia lagoons and their mangroves. This knowledge has been monographically presented in a previous paper (POR *et al.*, 1984).

Higher aquatic vegetation

Mangrove vegetation accompanies the banks of Rio Una up to U 6. It is a typical mangrove association of the Brazilian subtropical shores (OLIVEIRA, 1984 ; POR *et al.*, 1984). The mangrove trees belong to the three species *Rhizophora mangle*, *Avicennia schaueriana* and *Laguncularia racemosa.* There are also two associated mangrove shrubs, namely the fern *Acrostichum aureum* and the flowering plant *Hibiscus tiliaceus*. The waterfront banks of the mangrove are locally covered with meadows of *Spartina brasiliensis* and at a lower

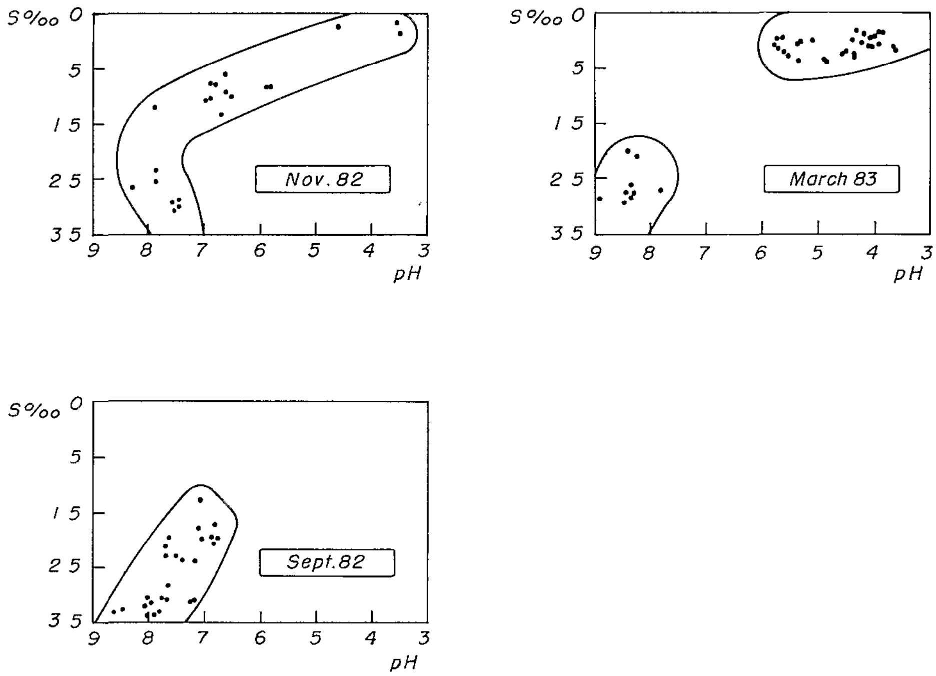


FIG. 8. — Cummulative data on salinity and pH relationship in the selected months of September 1982, November 1982 and March 1983. The points represent all the data for one month disregarding stations, depth and tidal situation

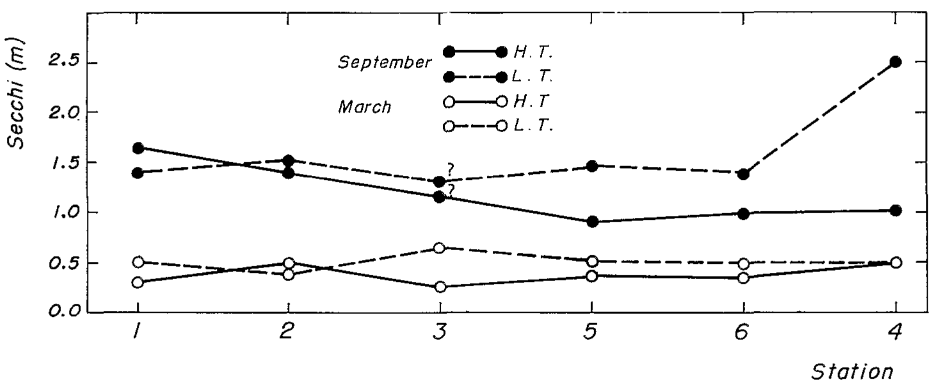


FIG. 9. — Secchi transparence measurements in September 1982 and March 1983 at High and Low Tides. September readings at station U 3 are questionable. St. U 4 is separated from the sequence

intertidal level by the cyperacean *Fimbristylis glomerata*. A few populations of the cord-grass *Ruppia maritima* are also found and locally on the higher sandy banks there are stands of *Crinum alternatum* (E. C. OLIVEIRA, pers. comm.).

The tidal mangrove forest is best represented along the meander of Ilha do Ameixal, where a network of "gamboas", tidal channels is developed.

Because of the linear gradients of the Rio Una estuary, a fairly clear longitudinal and transversal zonation of the mangrove vegetation can be recognized (fig. 10). In the much bigger mangrove of Cananeia, where morphology and hydrography is more complex and mosaic-like, this zonation is not at all clear (POR *et al.*, 1984). In Rio Una *Rhizophora* characterizes mainly the lower course of the river estuary and it is best developed on the low depositional banks. *Laguncularia* advances more upstream than *Rhizophora* and prefers the more sandy and higher errosional banks. If behind the errosional bank there is again lower ground, a second *Rhizophora* belt may appear. *Avicennia* is rare and appears only

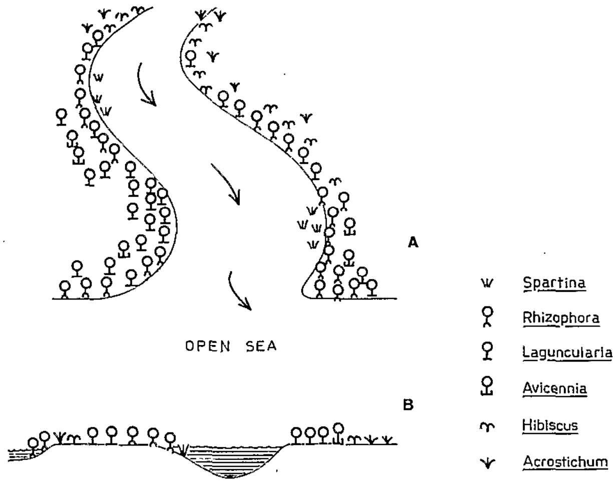


FIG. 10. — Schematic horizontal and transversal distribution of the mangrove vegetation along the Rio Una estuary

in a few stands in the tidal channels of Ilha do Ameixal. *Hibiscus* that usually accompanies *Laguncularia* replaces this tree completely in the upstream area beyond U 6. At the upstream stations and on the higher banks, the mangrove fern *Acrostichum* may form clean stands too. The mangrove forest is gradually replaced upstream by the riverine forest of the "capões" type, typically represented by the bignoniaceae *Tabebuia cassinoides*. Around U 6 there are still many dead trees of this impressive plant, probably a result of the meander shortening of Rio Una, more than 30 years ago.

Phytoplankton (ROCHA OLIVEIRA, *in prep.*) has a species diversity and composition normal to the Brasilian mangrove lagoons (see also KUTNER, 1975 ; RICARD, 1984). The brackish water species are dominant, namely *Skeletonema costatum*, *Thalassionema nitzschioides*, *Asterionella glacialis*, *Cyclotella stylorum*, *Nitzschia closterium* and *Paralia sulcata*. Several freshwater diatoms such as *Pinnularia* sp. and *Eunotia* spp. may also appear in the low-salinity phases.

Besides the above mentioned diatoms, phytoflagellates can also be widespread; in U 4 which has a lower diversity of phytoplankton, the flagellates may occasionally reach predominance.

There is a tendency of decrease in the phytoplankton biomass, from the mouth to the upstream stations. Biomasses are lower at low tides than at high tides and lower in rainy months as compared with the dry months. Till now, the largest biomass has been found at U 4 in December 1982.

Zooplankton (LANSAC TÔHA and ALMEIDA PRADO POR, *in prep.*). The zooplankton of the mangrove estuaries of the Southeastern Brazilian coast is well known, especially that of the Cananeia region (TUNDISI, 1970; ALMEIDA PRADO POR and LANSAC TÔHA, 1984 ; POR *et al.*, 1984). The estuary of Rio Una is characterized by very low biomass of zooplankton. The species diversity however is relatively high. The tidal influx carries marine species rarely found in other Brazilian estuaries, such as the cladoceran *Penilia avirostris* and the copepods *Clausocalanus furcatus* and *Oithona plumifera*. These species, additional to the normal zooplankton of the estuary can be found many kilometers upstream. On the contrary, the dark coloured freshwater carries a "potamoplankton", most probably a drift, which contains chydorid cladocerans, freshwater cyclopoids as well as larvulae of trichopterans, chironomids and ephemeropterans. In general, the freshwater phases are the poorest in zooplankton biomass.

It seems that near the bottom, the zooplankton populations are richer, eventually because of the more stable salinity conditions there. Mysid crustaceans, usually important constituents of the near-bottom plankton in the Brazilian estuaries are almost completely missing. From the several species known from Cananeia (ALMEIDA PRADO, 1973) only *Mysidopsis elongata* has been found in small numbers. The situation is somewhat reminiscent of that of the tidal channels of Cananeia which are avoided by the mysids. Similar conditions of low pH and humic waters may induce a similar avoidance by the mysids of the whole Rio Una estuary.

Benthic algae

The preliminary observations by E. C. de OLIVEIRA (pers. comm.) indicate that the algal vegetation of the Rio Una estuary is different in some aspects from that of Cananeia (OLIVEIRA, 1984; POR *et al.*, 1984). The green-algae carpet usually found on the muddy bottom around the bases of the aerial roots of the mangrove trees is very weekly developed and even absent. No such depauperations seems to exist in the populations of the free-living diatoms of the muddy bottoms. Regarding the red-algae epiphytes of the aerial roots, the Rio Una mangrove is characterized by an extreme abundance of *Catenella repens*. This species sometimes forms pure associations on the upstream mangrove trees. Among the species of *Bostrychia*, in Rio Una *B. calliptera* and *B. radicans* predominate, whereas in Cananeia the dominant species is *B. scorpioides*.

Macrobenthos

Compared to the Cananeia mangrove, Rio Una stands out by the extreme depletion of the macrobenthos. The mangrove oyster *(Crassostrea rhizophorae)* and the mangrove barnacle *(Balanus amphitrite)* are practically absent from the mangrove and only at U 2 there is some covering of the trees by these animals. Further upstream there are only few sites of settlements of young barnacles. Mytilid mussels are also extremely rare. The tree trunks and aerial roots are however densely inhabited by teredinid shipworms and the woodboring crustaceans *Limnoria* and *Chelura*. At U 4 this infestation is maximal and many mangrove trees are fallen or topple over easily when touched. One is tempted to associate this dense infestation with wood borers with the lack of the usual "protecting" crust of oysters and barnacles.

The fidler crabs of the mangrove floor are virtually absent and only one species, the small and very eurytopic *Uca uruguayensis* appears here and there in small populations. As a comparison in the Cananeia mangrove there are six species of fidler crabs and the densities are the normal huge ones to be expected in every mangrove (Por *et al.*, 1984). Interestingly, the supralittoral crabs, the tree-living *Aratus pisoni* and the very motile *Goniopsis cruentata* are the only crab species that appear in the usual population density.

From the supralittoral tree-living snails, *Littorina angulifera* is present at an abundance normal for any mangrove environment, while *Melampus coffaeus* another widespread species has not been found till now.

Meiobenthos

When compared with the meiobenthos of the Cananeia mangrove the meiobenthos of Rio Una presents a peculiar picture. In general this fauna is poor in numbers of specimens and in taxa. There are however some taxa which are more abundant or more diversified than in Cananeia.

Speaking of the Copepoda, well studied by one of us (Por, 1983 ; Por, 1984), the Harpacticoida are poorly represented but the Cyclopoida are diversified. Harpacticoids are rare among algae and in the open water benthos. For instance the dominant species in Cananeia, *Diarthrodes falcatus* is entirely absent from our Rio Una material. The densities and the diversity of the harpacticoids living in the decaying plant material are however normal: the typical species of *Darcythompsonia* and *Leptocaris* are abundant.

Cyclopoids have a characteristically rich representation by no less than 7 species of *Halicyclops* (C. E. Falavigna-Rocha, pers. comm.), one species of *Eurycyclops* and a very abundant benthic species of the clausiid *Pontoclausia* sp. Among the *Halicyclops*, *H. crassicornis* seems to prefer the benthos of the estuary and the river banks, while *H. spinifer* is preferentially found among the decaying leaves. While it might be possible that in Cananeia there are more than the one species of *Halicyclops* reported (Por *et al.*, 1984), *Pontoclausia* has never been found there.

Like the cyclopoids, the Ostracoda are also richly diversified. The small hydrobiid snail *Littoridina australis*, probably the most abundant benthic species of the Cananeia mangrove is only sparsely represented in Rio Una.

Water mites are abundant in Rio Una: hydracarians predominate among decaying leaves on the forest bottom and halacarids and oribatids among algae. Likewise, chironomids are especially represented among decaying leaves and ceratopogonids among algae.

Quantitative data on the meiobenthic populations, representing different environments are being prepared for publication by G. Y. Shimizu. Data on the differences among the meiobenthic populations living on decaying leaves of the different tree species as well as on the relative decaying rate of these leaves, will also be included in this paper under preparation.

DISCUSSION

The estuary of Rio Una is an extremely fluctuating environment in which two phases alternate: *A*. The marine water of neutral pH; *B*. The humic freshwater with low, acid pH. The dimensions of the fluctuation, the time and geographic range of the alternation depend on season and tidal cycle.

Rio Una is a medium-sized river, the catchment area of which is situated almost entirely in a lowland area subject to annual rainfall of nearly 3,000 mm. The river therefore, carries almost exclusively rainwater, poor in nutrients and rich in washed-out humic substances. Deviations from the seasonal curve of rainfall have a considerable influence on the degree of prevalence of the fresh and humic low acidity waters in the system.

On the other hand, the extremely small elevation of the Rio Una drainage basin exposes almost the whole length of the river to tidal influence. Spring tides combined with stormy sea and dry weather drive saline sea water many kilometers into the river. A few days of strong rain, if combined with neap tides and a quiet sea lead to a complete overtake of the river by fresh and black waters.

The origin of the humic substances is to be found probably in the secundary chemical products of the Restinga vegetation (Janzen, 1974). The sandy alluvional soil of the Baixada do Ribeira does not retain the humic substances and these are washed-out by the heavy rains into the river.

The blackwater estuary of Rio Una can be compared on one hand with the blackwaters rivers of the Amazonian river system and on the other hand with the nearby Cananeia lagoons and estuaries that are devoid of black water.

The Amazonian black water rivers, although exhibiting strong fluctuations in the water level have relatively stable hydrographic conditions, i.e. they do not have fluctuating salinity and the low pH blackwater conditions are permanent. The combination of conditions presented by a blackwater estuary like Rio Una is a situation still unknown in hydrobiological literature. The biotic depletion of the Amazonian black rivers is considered by the authors (see for instance JUNK, 1983) to be the effect of very low nutrient content plus low pH and humic content. The impoverished aquatic life in Rio Una cannot be caused by lack of macronutrients: they show relatively normal concentrations, chiefly due to a permanent supply of sea water.

The estuarine lagoon system of Cananeia has nutrient levels similar to those of Rio Una: SARTI (1980) indicates from one station in the open lagoon of Cananeia average values of 0.31 μg at./l P-PO_4 and 3.48 μg at./l N-NO_3. If thus, the Cananeia system has an aquatic flora and fauna so much more diversified and richer than Rio Una, the reason must be different. Indeed, in Cananeia the minimum value of pH, reported by AIDAR ARAGÃO (1980) was of 6.6. Most of the freshwaters of the Cananeia system comes from the highland rivers and the Atlantic rainforest and carry buffered water. Humic acid production is eventually restricted to the mangrove belt and influences only the tidal channels, the gamboas. The water mass of the Cananeia system, many times larger than that of Rio Una estuary is uninfluenced by the marginal tidal channels. At the same time, the large water volume of the Cananeia lagoons have a relatively stable "osmotic climate", i.e. salinity conditions are much more constant. Whereas in Rio Una a narrow interphase of brackish water and its respective fauna and flora is alternatively displaced over many kilometers by tidal inflow or rainwater outflow, Cananeia lagoons and estuaries contain a relatively stable body of brackish water (ALMEIDA PRADO POR and LANSAC TÔHA, 1984).

However saline fluctuation, strong as it might be in Rio Una, cannot explain the extreme biotic depauperation there: rapid changes and wide amplitude fluctuations in salinity are normal for many estuaries over the world and estuarine biota have long since adapted to them. What makes the environment of Rio Una especially intolerable to many organisms is probably the superposition of the fluctuation in pH and in humic content. JANZEN (1974) reviews several instances of circumstantial evidence for the outright toxicity of the humic "blackwaters". The qualitative and quantitative distribution of the biota in the Rio Una estuary bears further circumstantial evidence for this:

During the saline phases, the phyto- and zooplankton of Rio Una present normal and even somewhat increased diversity owing to the addition of off-shore marine and of freshwater species to the basic stock of estuarine species. Freshwater phases are extremely poor both in biomass and species. The populations of the plankton are probably mainly "expatriates" that move in and out with the saline waters and this may explain in part also their low biomasses.

The macrobenthic animals, both sessile and vagile are unable to follow the optimal watermasses: they are exposed to the pH fluctuations in addition to the saline ones. The extreme depletion of these animals both in diversity and in density of specimens—or size in the sessile ones—can be explained only by the toxic effect of the blackwaters. Supralittoral macrobenthos, beyond the reach of the humic water is well developed.

The toxic effect of the humic acids goes hand in hand with the effect of the low pH; however experimental work on this aspect has not been done till now and is not reported in literature.

A similar situation may be found among the macroalgae. The green-algae carpet of the mangrove mud flats, exposed to the humic surface waters is very poor. The "Bostrychietum" the red-algae growing on the vertical roots are bathed by the open waters and therefore better developed.

Nektonic animals seem to avoid the estuary of Rio Una. Penaeid shrimps are lacking altogether and palaemonid prawns are rare. The case of the avoidance by Mysidacea has been mentioned above. According to local fishermen fish catches in Rio Una are very poor. The meiobenthic animals respond in a differentiated way to the peculiar hydrographic conditions of Rio Una: while harpacticoid copepods for instance are restricted both in species and numbers, *Halicyclops* and watermites seem to thrive well. It would be interesting to assume that some biota of the blackwater estuary may be positively adapted to low pH conditions like some species of the Amazonian blackwater rivers or of the peat bogs of the temperate climates.

On a smaller geographical scale Rio Una can be compared with several other river estuaries of the Baixada do Ribeira and the adjacent Baixada Santista (POR *et al.*, 1982). One of the likely cases of extremely different hydrological conditions is the neighbouring Rio Verde (Green River) (fig. 1) which has a catchment area limited to a Precambrian mountain horst covered by Atlantic Rainforest.

From an entirely different region of the globe, OTTO and SVENSON (1983) report that in the area of Scania (Southern Sweden), within a distance of 50 km a variety of rivers are known with pH values ranging from pH 4 to pH 7. According to these authors there is a positive correlation between pH and species diversity.

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