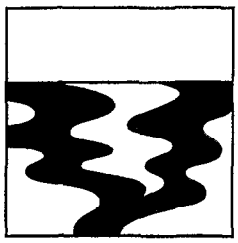

Zooplankton seasonality in the Rio Verde estuary (Juréia, São Paulo, Brazil)(1)

R. M. Lopes (2), M. S. Almeida Prado-Por (3), F. D. Por (4)

Abstract

Rio Verde is a short and unpolluted clearwater estuary, the physiography and hydrodynamics of which are controlled mainly by the distribution of the rains throughout the year.

Seasonal variations in the zooplankton composition characterize four hydrobiological phases in the annual cycle.

Key words : Brazil — Estuaries — Seasonal cycles — Zooplankton — Copepods.

Resumen

Variacion estacional del zooplancton del estuario del Rio Verde (Juréia, São Paulo, Brasil)

Rio Verde es un pequeño estuario no poluido de aguas claras cuja fisiografia e hidrodinamica son controladas principalmente por la cantitad de lluva que cae durante el año.

Las variaciones estacionales de la composición y dinámica del zooplancton caracterizan quatro fases hidrobiologicas sazonales.

Palabras claves : Brasil — Estuarios — Ciclos sazonales — Zooplancton — Copepodos.

Résumé

Les variations saisonnières du zooplancton dans l'estuaire du Rio Verde (Juréia, São Paulo, Brésil)

Rio Verde est un petit estuaire non pollué alimenté par une rivière d'eaux claires. La physiographie de l'estuaire est dominée par la distribution annuelle des pluies.

On distingue quatre saisons hydrobiologiques caractérisées par la composition du zooplancton.

Mots-clés : Brésil — Estuaires — Cycles saisonniers — Zooplancton — Copépodes.

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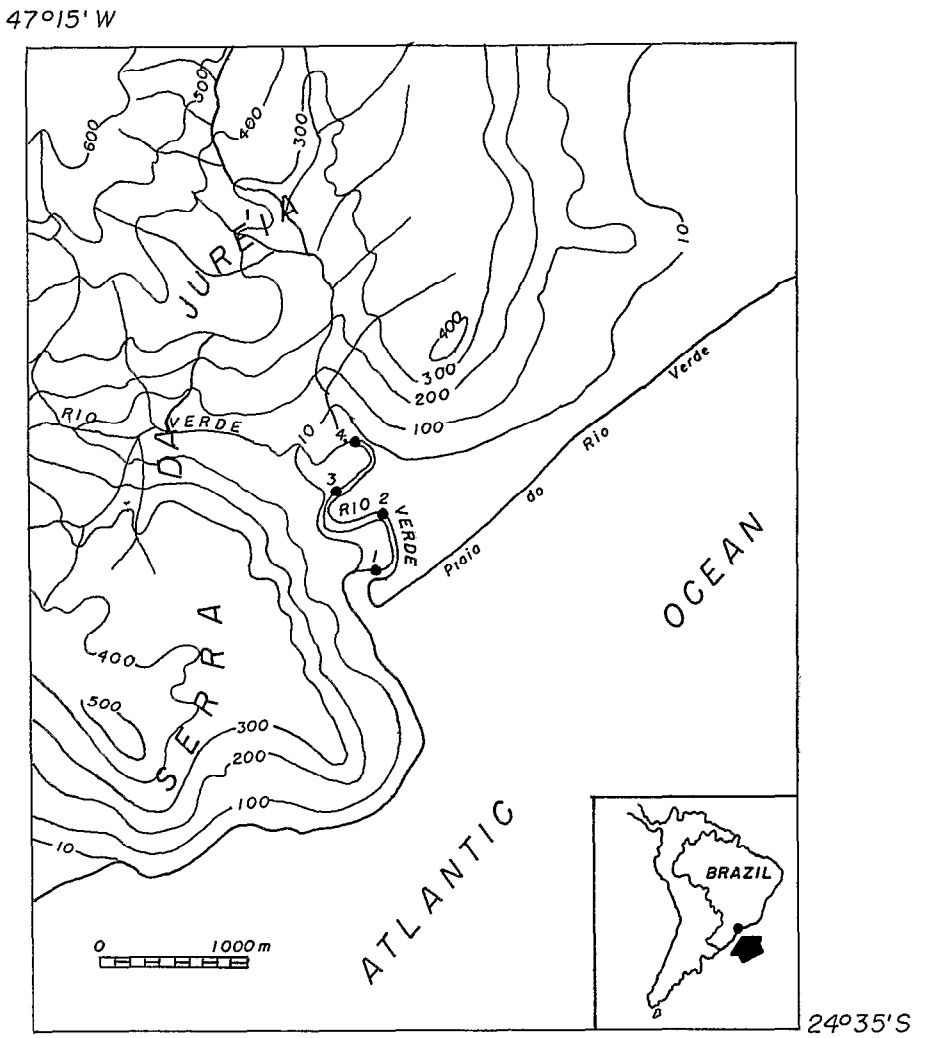

FIG. 1. — Map of Rio Verde and surroundings, showing the positions of the four sampling stations.
Carte du Rio Verde et des environs, avec la situation des 4 stations de prélèvement.

INTRODUCTION

The Juréia area is a Nature Reserve containing an isolated mountain horst, the Serra da Juréia, which is covered by an intact Atlantic rainforest. The hydrobiology and the zooplankton of the major river of this reserve, Rio Una do Prelado, has been studied recently (POR *et al.* 1984b, LANSAC TOHA, 1985).

Rio Verde is a short mountain stream originating on the top of the Serra da Juréia. It descends from there through a series of waterfalls ending in a short lowland stretch open to the ocean. This lower stretch is bordered by sparse mangroves. Rio Verde collects the heavy rains of the mountain. In the dry months its access to the sea is nearly closed by a bank of sand.

The present paper summarizes a one-year study of the zooplankton dynamics in this short river, with emphasis on the seasonal aspects. A comparison is being made with the zooplankton distribution of neighbouring estuaries and especially with the black-water river Una do Prelado and with the Cananéia lagoon region.

MATERIALS AND METHODS

Four stations were established along a 2 km distance of the lower Rio Verde (Fig. 1). The stations were visited monthly, between September 1984 and

TABLE I

List of species (frequently appearing taxa are marked by an asterisk)

Liste des espèces (les taxons les plus fréquents sont signalés par une astérisque)

Foraminifera
Tintinnina*
Medusae
Turbellaria
  Convoluta sp. *
Rotifera
Nematoda
Gastropoda veliger
Bivalvia veliger
Polychaeta larvae*
Acari
Cladocera
  Penilia avirostris Dana
  Podon sp.
  Evadne sp.
  Chydoridae
Cirripedia Larvae*
Luciferidae
Brachyura*
  Zoea
  megalopa
Other Decapod Larvae
Mysidaceae
  Metamysidopsis elongata atlantica Bacescu
Ostracoda
Tanaidaceae
Isopoda
Amphipoda
Insecta larvae
  Ephemeroptera
  Chironomidae
  Trichoptera
Chaetognata
  Sagitta friderici* Ritter Zahony
Appendicularia
  Oikopleura dioica* Fol
Fish eggs
Fish larvae

Copepoda
  Eucalanus pileatus Giesbrecht
  Paracalanus crassirostris* F. Dahl
  Paracalanus quasimodo Bowman
  Calocalanus contractus Farran
  Ctenocalanus vanus Giesbrecht
  Clausocalanus furcatus Brady
  Temora stylifera Dana
  Centropages velificatus Oliveira
  Pseudodiaptomus acutus* F. Dahl
  Pseudodiaptomus richardi* F. Dahl
  Labidocera fluviatilis F. Dahl
  Acartia lilljeborgi*Giesbrecht
  Acartia tonsa Dana
  Oithona hebes* Santos
  Oithona nana Giesbrecht
  Oithona oswaldocruzi Oliveira
  Oithona plumifera Baird
  Oithona simplex Farran
  Oncaea media Giesbrecht
  Oncaea venusta Philippi
  Corycaeus amazonicus* F. Dahl
  Corycaeus giesbrechti F. Dahl
  Clytemnestra scutellata Dana
  Euterpina acutifrons* Dana
  Tisbe sp.
Parasite Cyclopoida
Fresh-water Cyclopoida
Benthonic Harpacticoida

August 1985. Zooplankton was collected during the day at consecutive high — and low tides. Night samples were taken at st. 3 only. Horizontal surface samples were collected with a WP 2 net with a 75 μ mesh size and a 40 cm diameter opening (FRASER, 1968). The standard size of this net has been reduced in order to allow collecting in shallow water. Zooplankton samples close to the bottom were collected with a sledge net of 75 μ mesh and a similar opening ("D net" ALMEIDA PRADO, 1972). Towing time for both nets was 5 minutes.

Temperature and salinity were measured simultaneously with a Kahlsico RS5-3 Thermosalinometer. pH was measured from the surface water with a portable Micronal pH meter. Oxygen concentrations were not measured.

Relative percentage of the species was calculated for the surface samples. For the non-quantitative bottom water samples, the abundance was evaluated according to an abundance scale (rare; frequent; abundant; very abundant).

RESULTS

Hydrography

The tides are semidiurnal and high tide levels varied between 0.25 and 1.50 m. The stations have the following depths (at low tide): St. 1. 1.10 m; St. 2. 1.70 m; St. 3. 1.00 m; St. 4. 1.60 m. Lowest water temperatures (minimum 15.8 °C) were measured in August-September and highest temperatures (maximum 31.1 °C) in March. pH values were above 5.5.

As a rule, salinities were very stratified and showed considerable seasonal variability in accordance with rainfall and tidal regime (Fig. 2). Rio Verde has a very reduced base flow and the effect of rainfall which may reach over 300 mm in a month is of crucial importance. The salinity of the river estuary therefore faithfully follows the seasonal pattern of the rains. In accordance, the following hydrological seasons could be recognized:

A. September-December. With the beginning of the rains, the river mouth opened to the sea. Inflow and

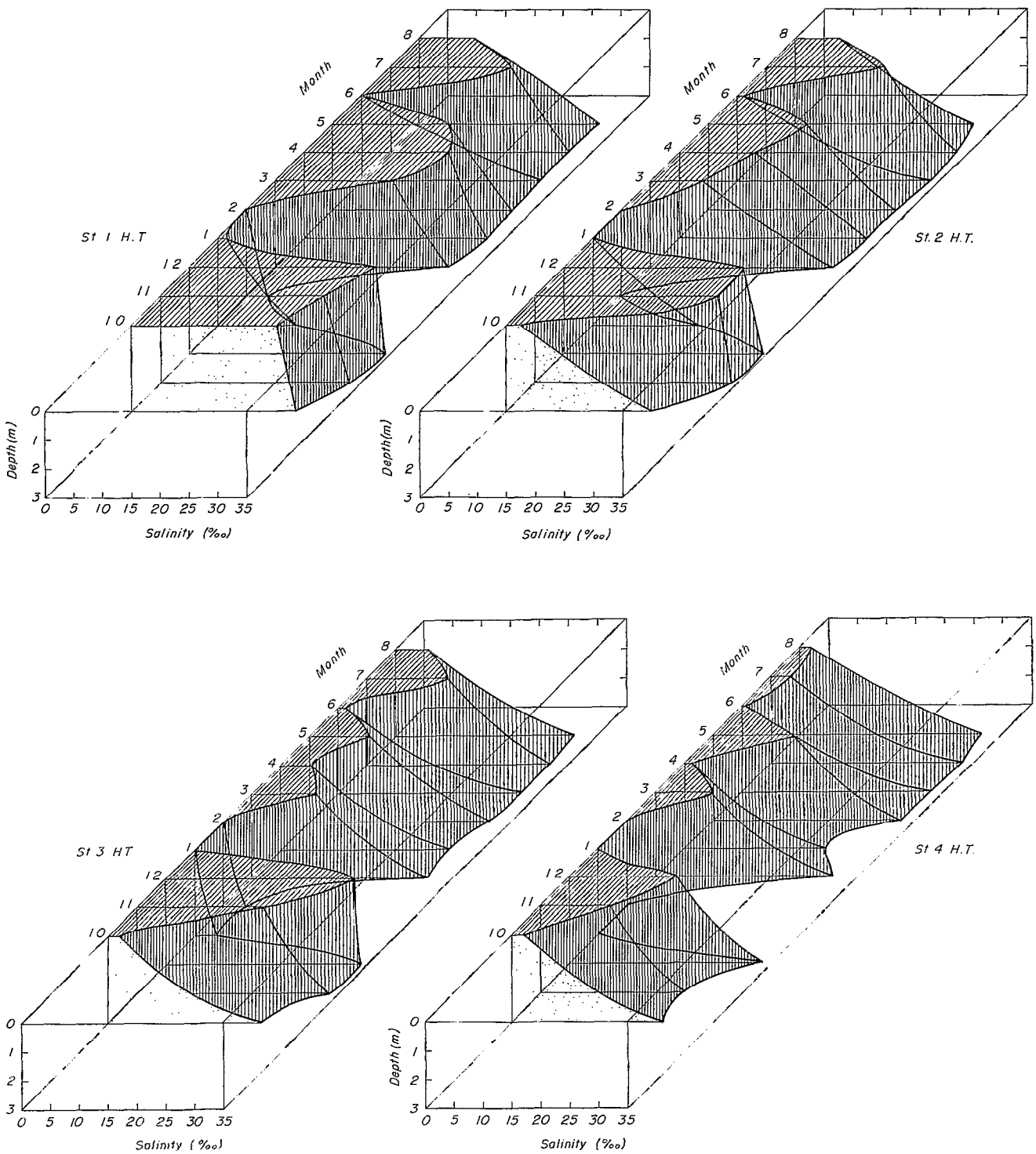

FIG. 2. — Surface and bottom salinities at high tide in the four sampling stations of Rio Verde, during the period October 1984-August 1985.

Salinités de surface et de fond à marée haute, aux quatre stations, durant la période: Octobre 1984 - Août 1985.

outflow from the estuary were good and towards the end of the period there was a tendency to break stratification.

B. January-February. The heavy summer rains which fell during these months, led to a complete flushing of the estuary by freshwater. During January a thin layer of marine water was still found near the bottom.

C. March-May. This was the end of the rainy season and the physiography of the estuary was similar to the September-December period. The marine influx was eventually even stronger, owing to the larger opening of the river mouth as a consequence of the summer rains.

D. June-August. This was the dry season with low rainfall and the mouth of the estuary was almost closed, preventing marine influx. The channel connecting with the sea was only 4 m broad and only a thin layer of +/— 15 cm of brackish water flowed out to the sea. Almost all the depth of the estuary was taken over by saline water and stratification was extreme. In fact, the estuary could be considered at this stage as filled mainly with water of about 30 ‰ salinity, isolated from the sea by a bank of sand.

A model for the seasonal physiographic pattern of the Rio Verde estuary is shown in Fig. 3.

Because of the shortness of the estuary, there were no significant hydrological differences between the four collecting stations, though the composition of the zooplankton showed some differences.

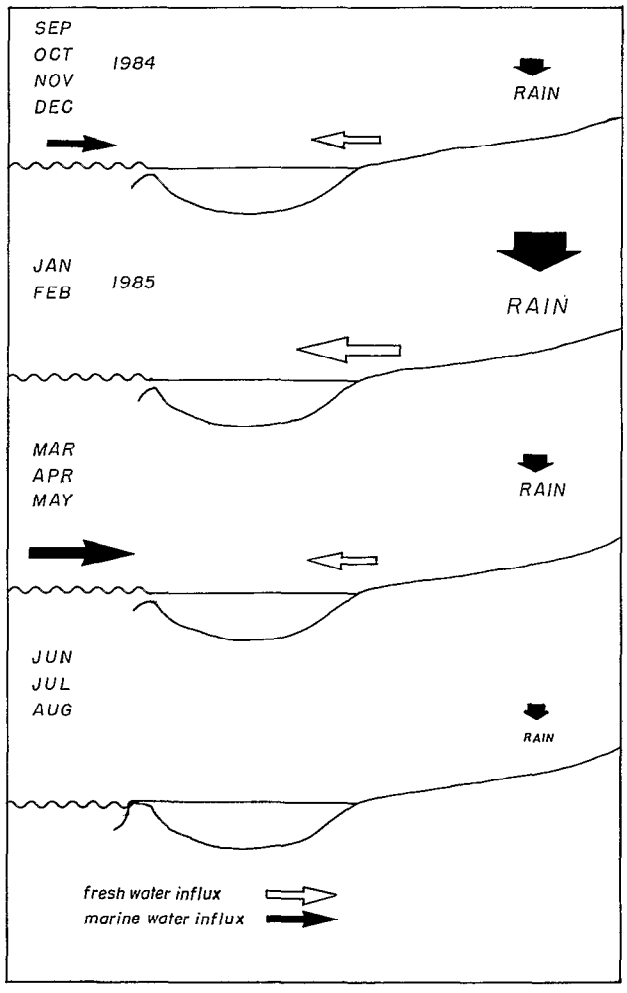

FIG. 3. — Model of the seasonal physiography of the Rio Verde estuary during the annual period of sampling.

Schéma du fonctionnement saisonnier de l'estuaire du Rio Verde au cours de l'année d'étude.

Qualitative composition of the zooplankton

The list of the species and some higher taxa is presented in Table 1.

Besides holoplanktonic and meroplanktonic organisms, the list contains meiobenthic organisms too. This last circumstance is due to the shallowness of the estuary and to the turbulent freshwater inflow.

The zooplankton was essentially composed of typical estuarine organisms. The number of marine species was relatively high. This is due to the shortness of the Rio Verde estuary. The most diversified taxon was that of the Copepoda. Here the identifications were made to the species level, counting female, males and copepodites separately. For other taxa, most identifications were on a higher taxonomic level and therefore they have to be used with utmost care.

Among the copepods we distinguished a "central group" of euryhaline species. These are: *Paracalanus crassirostris*, *Pseudodiaptomus richardi*, *Acartia lilljeborgi*, *A. tonsa*, *Oithona hebes*, *O. oswaldocruzi* and *Euterpina acutifrons*. Our analysis is first of all based on the densities and dynamics of these speecies, both at the surface and the bottom. For other copepod species as well as the rest of the organisms found in the plankton samples, we merely emphasize the occurrence.

Small benthic organisms such as cyclopoids, harpacticoids, peracaridan crustacea and insect larvae mentioned in the list are merely presented for the completness of the faunal composition of our samples as well as in some cases, in order to show for instance, the predominance of the freshwater influence. There is no species which can be considered as belonging to a true freshwater plankton.

Seasonal changes in the zooplankton (Fig. 4)

In an attempt to correlate the population changes found, with the above mentioned hydrographical

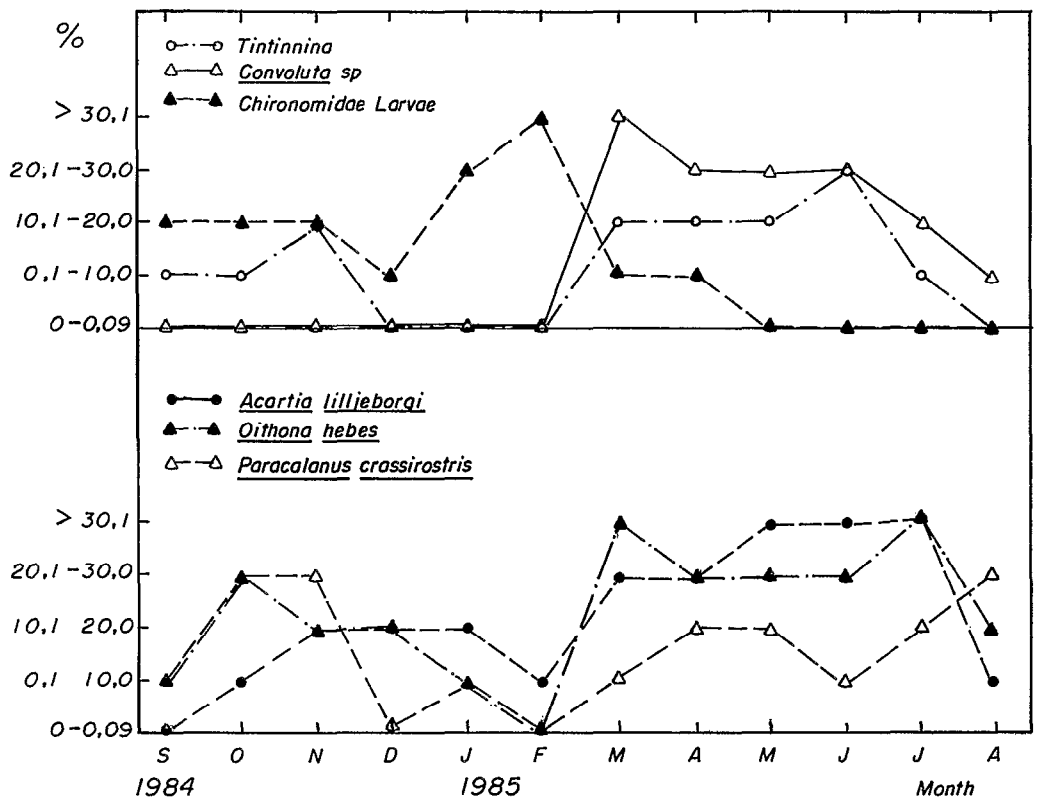

FIG. 4. — Seasonal variation of representative taxa in the Rio Verde estuary, from October 1984 to August 1985, in percentages of individuals out of the total population.
Absolute maximal counts par sample are given below.

Évolution saisonnière des principaux taxons dans l'estuaire du Rio Verde. Pourcentages, en nombres, du peuplement total. Les nombres maximaux observés sont donnés ci-dessous:

Acartia lilljeborgi—83,220 ind. June 1985.
Oithona hebes—62,430 ind. March 1985.
Paracalanus crassirostris—16,039 ind.—October 1984.
Convoluta sp.—70,890 ind.—March 1985.
Tintinnina—64,050 ind.—June 1985.
Chironomidae larve—550 ind.—February 1985.

seasonality, the following schematic picture emerges: *Season A*. With the opening of the estuary to the sea in the spring months, the "central group" of copepods reestablished itself in the estuary. This is the period when *Paracalanus crassirostris* had peak abundance. Several species of more stenohaline marine copepods entered the estuary. Such were *Paracalanus quasimodo*, *Clenocalanus vanus*, *Calocalanus contractus*, *Temora stylifera*, *Centropages velificatus*, and *Clytemnestra scutellata*. All these species did not reach however high densities.

Also for the other taxa this was a period of major marine influx. Marine cladocerans of the genera *Podon*, *Evadne* and *Penilia* were found. The arrow worm *Sagitta friderici* and the appendicularian *Oikopleura dioica* were present in the whole water column. Tintinnids were frequent at the water surface and the mysid *Metamysidopsis elongata* appeared in the deeper samples.

Season B. The heavy rains of January and February led to the near disappearance of the estuarine plankton. In January, *Acartia lilljeborgi* and *P. crassirostris* still appeared in low abundance at the stations 1 and 2, nearer to the sea. Stray specimens of *C. velificatus*, *P. acutus*, *P. richardi* and *O. plumifera* were found in the deeper samples. In the following month the only species found was rare *A. lilljeborgi*.

During these months the bottom samples were rich in cirripede nauplii and brachyuran zoeae. The water column contained predominantly chydorid cladocerans, freshwater cyclopoids and insect larvulae (Chironomidae, Trichoptera and Ephemeroptera), as well as benthic harpacticoid copepods. This material has been obviously washed into the estuary from the upper course of the Rio Verde.

Season C. With decreasing rainfall an increase in the diversity and in the population densities occurred. At the surface, the first to became established was *Oithona hebes* followed at somewhat lower density by *Euterpina acutifrons*. The populations of *A. lilljeborgi* and thereafter of *A. tonsa* increased in density on the bottom. Several marine copepods entered the estuary again, such as *Eucalanus pileatus*, *P. quasimodo*, *C. vanus*, *T. stylifera*, *C. velificatus* and *O. plumifera*.

In March, concomitantly with the increase of the *O. hebes* population a bloom of the turbellarian *Convoluta* sp. occurred. The population of this organism rapidly decreased during the following months.

Season D. With the confinement of the zooplankton population in the estuary during the near-closure to the sea (June-August) there occurred a new reduction in diversity. Nauplii and copepodites of *O. hebes* with only few adults dominated the surface layer. *E. acutifrons* followed with lower densities. Peak numbers of *P. quasimodo* were found at the surface, even outranking *O. hebes*. The populations of the two *Acartia* species, still abundant on the bottom at the beginning of the period, collapsed in the month of August. This phenomenon repeated itself both in 1984 and in 1985. These copepods were frequently found overgrown with a diatom (*Pseudohimantidium* sp. as identified by P. RIVERA, University of Concepcion, Chile), as well as by a fungus. The samples were rich in dead "exuviae" of *Acartia*. Possibly, the confined populations of the estuary were more prone to epidemies. In August 1985 also a heavy bloom of ctenophorans was observed in the estuary. Predation on the copepods can thus be a second possible reason for the collapse of the populations. Finally, in this season with extreme salinity stratification of the estuary, existence of anoxic conditions on the bottom are probable. This might be a further cause for the depletion of the deeper dwelling populations of *Acartia*.

DISCUSSION

Rio Verde is one of the many estuaries of the Baixada do Ribeira, the large alluvial plain of the State of São Paulo (POR, 1986). Among these, the lagoon system of Cananeia has been fairly well studied (among others by TUNDISI, 1972; POR *et al.* 1984a). The rivers of the area can be characterized according to their pH regime and mineral content as "clearwater", "blackwater" and "whitewater" rivers. Rio Verde, which is a clearwater estuary can be compared with the fairly well known Rio Una (POR *et al.* 1984b; LANSAC TOHA, 1985; POR, 1986), which is a blackwater river and river-estuary.

Rio Verde has a stable, slightly acid pH regime with values of above 5.5, whereas Rio Una frequently has pH values as low as 4. It seems that despite this difference, the estuaries of the two rivers have much in common. First of all, they present low zooplankton densities, unlike Rio Ribeira, a whitewater river (POR and TORT NAVARRA, *in prep.*) and unlike the Cananéia estuary. Furthermore, the two rivers do not contain a freshwater zooplankton component. In Rio Ribeira this is characteristically composed of bosminid and other cladocerans as well as by a variety of rotiferans.

Rio Verde is a very small and rectilinear estuary. It can be characterized as a "B type estuary" (ALMEIDA PRADO-POR and LANSAC TOHA, 1983). Because of this, the seasonal variation between high rainfall and low rainfall is well expressed. The freshwater "crisis" of the summer rains eliminates the estuarine plankton. Recolonization follows, which in turn is disrupted by a winter "crisis" when, during the low pluviosity phase, the estuary becomes semi-isolated from the sea. A second repopulation occurs in the spring and ends cyclically with the floods of the summer rains of the following year.

The details of this cycle have to be further investigated. However, it is evident that seasonality in Rio Verde is more extreme than in the larger and more complicated estuaries of the Baixada do Ribeira which carry clear — or blackwater. While the flushing with fresh rainwater is the evident cause for the summer crisis, the mixture of causes which leads to the winter collapse has yet to be elucidated.

Because of its small size and strong marine penetration, Rio Verde contains ocasionally marine species not reported before from other estuaries of the region, such as *Clausocalanus furcatus* and *Ctenocalanus vanus*. Marine species, such as *Paracalanus quasimodo* and *Oithona plumifera* are much more frequent components of the zooplankton than in other estuaries of the region known till now.

ACKNOWLEDGMENTS

The present short contribution is part of a research project under the responsability of the third author and financed partly by FAPESP grant 01503.81/1569.4 and by a SEMA/CNEN research agreement. The authors wish to acknowledge the help of the Department of General Ecology of the University of São Paulo and especially of Dr. Paulo NOGUEIRA NETO and Dr. Vera IMPERATRIZ FONSECA from this department. Thanks are due to Dr. Yoko WAKABARA from the Oceanographic Institute USP, for the identification of the Peracarida.

Manuscrit accepté par le Comité de Rédaction le 23 décembre 1986

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