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THE LAGOA DOS PATOS ESTUARINE ECOSYSTEM (RS, BRAZIL)

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SINOPSE

A Lagoa dos Patos, um enorme sistema lagunar estuarino (10.360 Km²), e a barreira arenosa, múltipla e complexa que a separa do Oceano Atlântico são partes de uma ampla planície costeira onde aflora a porção superficial da seqüência sedimentar da Bacia de Pelotas. São areias praiais e eólicas, areias síltico-argilosas lagunares, areias e cascalhos fluviais que ali se acumularam durante o Quaternário sob a forte influência das variações do nível do mar. Os sedimentos de fundo são predominantemente lamosos, trazidos pelos rios, depositados entre faixas marginais areno-quartzosa originadas pelo retrabalhamento dos depósitos pleistocênicos e holocênicos que bordejam o corpo lagunar. Zonas com misturas texturais em variadas proporções são encontradas entre os dois domínios. Altas taxas de material em suspensão refletem, ao norte, a predominante influência fluvial e, ao sul, próximo ao único canal de ligação com o mar, a predominância das condições estuarinas. A ação do vento, a precipitação pluvial e o longo e estreito canal de desembocadura determinam grandes flutuações de salinidade e intensas ações hidrodinâmicas que se refletem nos padrões das comunidades de flora e fauna. Elevados níveis de seston e biomassa fitoplanctônica eutroficam a região estuarial e o ambiente marinho adjacente. No verão, o zooplancton abundante exerce uma forte pressão de pastagem sobre a comunidade fitoplanctônica, alterando o comportamento e a dominância entre as espécies.

Os pântanos irregularmente inundados e a alternância sazonal dos picos de biomassa das macroalgas e gramíneas submersas proporcionam um contínuo suprimento alimentar, habitat e proteção para a macrofauna. Uma fauna bentônica pobre em espécies mas abundante, constitui-se

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num elo fundamental entre o detrito depositado e os consumidores de grande mobilidade. A predação exerce um forte impacto na estrutura das comunidades de fundos moles e incrustante. A comunidade de peixes está composta pelo menos por três assembléias e pode ser agrupada em cinco categorias bioecológicas, baseadas na sua abundância sazonal e estratégias de vida.

ABSTRACT

The Lagoa dos Patos a large lagoonal estuarine system (10.360 Km^2) and the associated multiple barrier complex, are part of a broad coastal plain where the upper sedimentary sequence of the Pelotas basin outcrops. Beach and eolian sands, some lagoonal clayey silty sands and river deposits, were accumulated there under the strong influence of Quartenary sea-level changes. Lagoon bottom sediments are predominantly muddy and of modern fluvial origin with quartzose sand strips along both margins, originated from Pleistocene and Holocene deposits. Areas of textural mixtures are found between these two realms on varied proportions. High rates of suspension load, reflects the prominent fluvial influence at north and the estuarine conditions at south in the vicinity of the unique inlet. Wind action, precipitation and a long narrow channel at the mouth, determine marked salinity fluctuations and intense hydrodynamic actions reflected in the flora and fauna community patterns. High phytoplankton biomass and seston levels cause an eutrophication of the estuarine and adjacent marine environment. In summer, an abundant zooplankton can reduce phytoplankton biomass determining species dominance rations and grazing escape response. Irregular flood marshes and an alternate macroalgae sea grass biomass peaks provide a continuous food supply, habitat and protection for the macrofauna. A low diverse but abundant benthic fauna represents a fundamental link between the detritus, several fishes and decapods. Predation plays a significant role on both: fouling and soft bottom communities structure. The fish community is composed by at least three assemblages and may be grouped into five bioecological categories, based on their sesonal abundance and life history patterns.

1. INTRODUCTION

The present paper was prepared with the purpose to give an overall picture about the actual knowledge of the lagoonal estuarine system of the Lagoa dos Patos, Brazil.

It is based on studies developed by the authors and on published data from other several researches conducted in the region (see references).

The Lagoa dos Patos, the largest coastal lagoon of the Latin America (10.360 Km^2) is situated along the Rio Grande do Sul coastal plain, south Brazil between the latitudes of 31º41'S and 32º12'S and the longitudes of 51º49'W and 52º15'W., with a length of 250 km and a medium width of 60 Km.

The channel located at south in the vicinity of the town of Rio Grande is the unique inlet that connects the lagoon with the Atlantic Ocean.

Another large southern coastal lagoon in the border with Uruguay — Lagoa Mirim (3.750 Km^2) — is connected with the Lagoa dos Patos through a channel (São Gonçalo) of 70 Km long, forming the Patos-Mirim coastal lagoon system (Fig. 1).

The discussed topics related to the geological evolution and sedimentation refer to the entire lagoon while the concepts considered about the biological aspects refer to mainly to the estuarine area (from Feitoria to the inlet).

2. GEOLOGICAL SETTING

The Rio Grande do Sul Coastal Province is formed by two large geologic units: the Basement and the Pelotas Basin (Fig. 2). The sedimentary sequence accumulated in the Pelotas Basin seats on rocks of its basement whose largest part is formed by the Sul-Rio-Grandense and Uruguaian Shield and, in the northern part of parallel 30º, by the sedimentary and volcanic sequences of the Paraná Basin.

According to FRAGOSO-CESAR et al. (1982) the Sul-Rio-Grandense Shield is formed by a geotectonic unit generated in the Brasiliano Cycle (Late Proterozoic/Early Paleozoic), the Don Feliciano Belt a NE-SW mobile belt developed on the east border of the La Plata River Craton (Archean/Lower Proterozoic). Both form the South American Platform pre-Devonian basement. The large faults and folds maintain NE-SW subordinately. On this shield settled the Parana Basin from the Devonian period onwards after the South American Platform stabilization.

The Pelotas Basin is related to the subsequent geoteotonic events that led to the opening of the South Atlantic Ocean from the Jurassic Period onwards which resulted in the Gondwanic continental block rupture and subsequent separation of the African and South American continents. About 8.000 meters of continental, transitional and marine sediments have been accumulated in the Pelotas Basin during the Cenozoic through sucessive downwarpings towards the sea.

The superficial portion of this sequence is exposed on the Rio Grande do Sul Coastal Plain, a large lowland area (33.000 Km^2) which is largely taken by a well developed coastal lagoon system.

The Coastal Plain is geomorphologically a large area where the Cenozoic units crop out whose elevations do not excede 200 meters. In a preliminary attempt, VILLWOCK (1984), established the plain geomorphologic compartmentation which comprehends the Inner Alluvial Plain, the Lombas Barrier, the Guaíba-Gravataí Lagoon System, the Multiple Complex Barrier, the Patos-Mirim Lagoon System and the Continental Shelf (Fig. 3).

The land strip that lies between the Sul-Rio-Grandense Shield and the large lagoon bodies of the Patos-Mirim Lagoon System forms the Inner Alluvial Plain. It is a lowland plain, slightly inclined to the East where rounded hills, near the Shield hillside, give way to a sucession of terraces very dissected by the present drainage.

The sedimentary facies that outcrop there constitute an alluvial fan depositional system. They are formed next to the slopes of the highlands from gravitational and alluvial transport processes. The sediments graduate from alluviums and colluviums, in the proximal regions, into alluviums deposits, in general associated to braided channels, in distal regions.

The lithologies formed by these processes correspond to conglomerates, diamictites, sandstones, and mudstones. They are massive or have a little developed cross-stratification.

The Lombas Barrier is a long Northeast — Southwest strip edified by aeolic sandy deposits distributed in groups of roundes hills that occasionally exceed the 100 meters of elevation.

The Lombas Barrier isolated the Guaíba-Gravataí Lagoon System which is today the Gravataí River Basin and the Guaíba River.

It corresponds to the oldest depositional system of the kind "lagoon/barrier" that has been formed in the region. Its development ocurred in the northeast of the Coastal Plain as the result of a first Pleistocenic trans-regressive event. The Barrier I ("Lombas Barrier") grew as a long strip 250 Km long with NE-SW orientation mainly from the accumulation of eolian sediments that anchored preferably on the heights of the basement. It corresponds litholoigcally ot quartzose sands, fine to medium grained, well rounded, reddish, semi-consolidated and with a siltic clayish matrix of pedogenetic origin.

This sedimentary body isolated a depression on the continent side (Guaíba-Gravataí Lagoon System) where the detrital charge brougth by the rivers form the highlands accumulated in lagoonal, fluvial and paludal environments. Some parts of this depression were gradually filled with lagoonal sediments and after with paludal sediments, from which important peat deposits were formed.

From the Lombas Barrier foothill towards the Atlantic Ocean a sucession of fairly even crests and elongated depressions produces a characteristic morphologic aspect. It exists in the North between the Plateau hillside and the Atlantic Ocean and in the South in a strip that isolates the latter from the Patos-Mirim Lagoon System. Initially called Sandy Plain (DELANEY, 1965), it edifies what VILLWOCK (1972) called the Multiple Complex Barrier.

The first depression of the Multiple Complex Barrier, the largest of all, is taken by the Patos-Mirim Lagoon System.

Without structural discontinuities the emersed plain and the adjacent continental shelf form the same geological unit.

The multiple Complex Barrier was built by three more lagoon/barrier depositional systems each one corresponding to a trans-regressive event related to the last major global sea-level changes.

Systems II and III show barrier deposits constituted by beach and eolian facies. The beach sediments are composed of quartzose sands, clear, fine, well selected, with very well developed stratification. There is a remarkable occurrence, in certain places, of **Ophiomorpha** burrows and shell moulds. The sands or the aeolic covering shows a reddish colouring, and a massive aspect. Sometimes they are bioturbated by roots and commonly intercalate centimetric levels of palaesoils.

Paludal, fluvial and lagoonal depositional environments, some of them still existing today, settled on the adjacent lagoonal depression, isolated partly by Barrier II and mainly by Barrier III. The deposits accumulated in these environments correspond to silt-clayey sands, poorly selected, cream colored, with even parallel lamination and showing calcareous and ferruginous concretions disseminated. Associated to this unit were found Pleistocenis mammal fossils (PAULA COUTO, 1953: SOLIANI Jr., 1973).

The most recent depositional system of the kind "lagoon/barrier" of the Rio Grande do Sul Coastal Plain developed during the Holocene.

The Barrier IV is constituted by the sands of the present beach strip and by the adjacent eolic dune field. In some places the progradation of this barrier was remarkable through the construction of regressive beach ridges (GODOLPHIM, 1976). The beach sands are quartzose, fine to very fine grained, (MARTINS, 1967) and show, in certain places, high concentrations of heavy minerals. (VILLWOCK et al. 1979). The dune field is quite developed, showing a variable width of 2 to 8 km and extends practically along the whole coastline. In responde to a unidirectional effective wind (Northeast) the dunes are mainly of the barchan and transversal kind. (MARTINS, 1967).

The lagoonal depression isolated by Barrier IV consists presently of a necklace of small lagoons which present different phases of segmentation in response to the northeast direction wind. Some of these ancient lagoons find themselves completly filled by sediments becoming paludal environments favorable to the peat development.

3. PHYSICAL PROCESSES

3.1. Physico-Chemical Aspects

Having about 11,000 square km in area, 250 Km long with an average of 60 Km, Lagoa dos Patos is permanently linked to the Atlantic Ocean by one single inlet. It behaves essentially like an estuarine system, in the sense of BIRD (1968).

Bathymetry, although gentle, is diversified (Fig. 1). Most of the banks are shallow, between 0,5 and 1,0 meter, with the deepest parts confined to the central zones, 7,0 to 8,0 meters, and to Rio Grande inlet, where it varies between 10,0 and 15,0 meters. In cross sections, the western bank has a gentler slope than the eastern.

Water circulation is weakly influenced by diurnal ocean tides, mostly felt in Rio Grande, where the mean amplitude is about 0,47 meter.

However, appreciable changes in water level are a result of flow variations in the tributary rivers which drain a surface of approximately 175,000 square Km, obviously exposed to different rainfall regimens. The drainage flow causes current jets into the lagoon and their effects can be observed over long distances, in particular during the rainy seasons and periods of floods.

The wind regimen is also responsible for large variations in water level, resulting in level differences of up to 2 meters between the north and south ends of the lagoon.

Under these conditions currents are influenced by the lagoon coast configuration, but they are not effective as far as erosion and sediment transport through the lagoon is concerned. In general they are responsible only for keeping in suspension the fine sediments brought by rivers, redistributing it throughout the lagoonal basin and taking it of the southern parts, where increasing salinities promoves its deposition by flocculation processes.

On the other hand, it is clear that wind-generated waves action plays a prominent role in the erosion/deposition balance along the shores which causes the lagoon coast configuration. In the coastal region of Rio Grande do Sul, prevailing winds blow from NE, and normal to this direction the lagoonal banks show a sucession of broad bays and sandy spits resulting from the action of waves and longshore currents, trying to build sandy beaches at right angles to the direction of prevailing winds. In this way it can be stated that Lagoa dos Patos is undergoing a real segmentation process through the formation of sandy spits, according the mechanisms described by ZENKOVICH (1967).

The water circulation briefly described above, is responsible for variations in salinity which are observed there. Usually it is fresh water and only in the southernmost parts are found increasing salinities values and there they present poly, meso and oligohaline behaviour. KANTIN (1983) shows that salinities are essentially related to the meteorologic conditions (rainfall and wind strength and direction). A general model for seasonal variations is delicate to determine, but there are some tendencies to remark, and they are related to high salinities corresponding to summer and fall months when there are low rainfall and prevailing winds from south.

Water temperature ranges from 13ºC in Winter and 27ºC in Summer. From May to September the temperature is below 20ºC, and from October to April above 20ºC.

3.2. Sediments

Previous studies about the lagoon sedimentation were developed by MARTINS (1963, 66), MARTINS and GAMERMANN (1967) when were published the first maps regarding the distribution of the surface sediments.

HERZ (1977) using a series of orbital images develop an analysis of hydrodynamic conditions of the lagoon surface waters.

More recently, CALLIARI (1980) carried out a detailed study of the lagoon inlet sedimentary conditions, while ALVAREZ et al. (1981), MARTINS et al. (1981) discussed the distribution of the bottom sediments in relation to some physical and chemical parameters like depth, salinity, temperature, turbidity, wind regime, dry and wet seasons conditions.

The actual knowledge about the sedimentation conditions of the Lagoa dos Patos, is based on the study of surface bottom samples and cores, obtained on several missions done along the lagoonal body.

The lagoonal sedimentation is predominantly muddy with a sand coverture along the continent and barrier margins. A transitional bottom cover appears between the pelitic and the sandy realms.

As a consequence of its great hydrographic basin (200.000 Km^2) there are several types of source areas and materials, dominantly terrigenous, influencing the distribution of the bottom sediments.

Five main rivers (Jacuí-Taquari, Cai, Gravataí, Sinos), that mets in the Guaíba complex area at the north, are responsible for the main fine sediment load transmitted to the lagoon. Other fluvial supply is promoted by rivers that discharge along the continent margin.

Two sources of coarse material are responsible for the sediments found on the two marginal sand strips.

The barrier or ocean flank has the Quaternary Chuí Formation (quartzose, mature, well sorted beach and shallow marine sands) and recent eolian fine sands as responsible to the fine sand deposition.

The Quaternary Graxaim Formation (subarkosic, coarse, moderately sorted submature coarse to medium sand) and granules and coarse sand coming from directly the rocks (granites, gnaisses) of the Precambrian shield furnishes the material that covers the shallow bottom area along the continent margin.

The suspension load studied on several opportunities, shows a high concentration (70 to 30 mg/l) at the north fluvial supply influenced area, with a plume of expressive concentration extending up to 32 Km south.

In the middle or classical lagoonal area, the concentration, due to the decantation of part of the load decrease to 15 mg/l while in the south or estuarine area there are an increase of the clay particulate material with well marked gradient of concentration from 4 mg/l at the surface to 32 mg/l near the botton.

Few material escape through the lagoon inlet and are deposited the inner shelf in a very restricted area.

No by passing of fine material to the continental shelf deeper parts or slope are actually observed.

According to KANTIN (1983) the suspension load that arrives to the estuarine area is $4,5.10^6$ ton/year which is less expressive than that for example of Amazon (500.10^6 ton/year) and La Plata (130.10^6 ton/year).

Observations done during the present work shows that large part of the suspension load transmitted to the Lagoa dos Patos through fluvial supply is trapped along the extensive lagoonal body.

Evaluations regarding the sedimentation rates in the lagoon were preliminary started using the radiochemical method of U^{238} (KIM & BURNETT), with the first results showing a rate of 8 mm/year in the lagoonal area changing to 5mm/year near the estuarine zone.

Facies distribution

The mineralogical analysis of the bottom sediments (coarse and clay mineralogy), the mechanical composition associated with observations done on the suspension load, sedimentary structures and sedimentation rates, permits to establish a preliminary bottom facies distribution, showed by the lagoon sediments.

Facies I, situated at the north area show a strong fluvial influence with high concentration of suspension load at the three measured levels. It is a zone of material transference to the lagoon and estuarine regimes.

The coarse associated fraction has besides the quartz (dominant), wood fibers and lateritic aggregates.

Facies II, oceanic or barrier west shallow zone with a coverture of fine sand interstraified with mud laminae, textural and mineralogical mature, well sorted, sometimes laminated, Bioclastic carbonates associated shows usually reworked morphoscopic aspects.

Heavy minerals with high mature indices.

Facies III, continental or east flank zone, covered by coarse to medium sand and granules of continental origin, coarse bioclastic carbonate is also found.

It is a submature sediment deposited on moderate to high energy conditions with the sand and granule grains showing a sacaroid to mamelonar surface texture and are subrounded.

Associated heavy minerals with submature indices.

Facies IV, occupies the middle area with a characteristic muddy lagoonal sedimentation with moderate to low rates of suspension load. Bioclastic material is found interbedded with the terrigenous muddy material.

No depositional structures were identified and just bioturbation is the main internal organization of the beds.

Facies V, estuarine zone with and increase in the suspension load specially in the deeper portions, showing a great deposition of fine sediments (clayey mud) that were not accumulated in the lagoonal region.

4. BIOLOGICAL PROCESSES

4.1. Plankton Community

The studies related to estuarine phytoplankton are rather still recents, and several works are in development at present. In a recent work ABREU (1987) recorded a short variability on time (24 hours) for the Chlorophyll-a when comparing to the levels frequently found in the adjacent marine environment. This, reflects a settled situation from the hydrological conditions of the estuary and the shape of the mouth, that make intenses the relations between the abiotic factors and the phytoplankton.

The analyses of the phytoplankton size spectrum showed a striking dominance of the nanoplankton comprised by monads and flagelates. The nanoplankton Chlorophyll-a values ranged between 62% in spring and 82% in fall of the total amount of the registered Chlorophyll-a values along the study year.

The highest Clorophyll-a values ($x = 7{,}39\ \mu g/l$; maximum of 71 $\mu g/l$) were recorded in Spring, soon after a salt wedge intrusion. The increase in light disponibility in the channel as a result of higher stabilization in the water column gives better conditions for the phytoplankton development (ABREU, 1987). The salt wedge intrusion removes the bottom sediments and suspends trapped nutrients such as phosphates (KANTIN, 1983).

At Spring, ABREU (1987) detected a high exportation level of Chlorophyll-a to the sea (8 g Cl-a/m²/hour). The dominant microphyto plankoton species of the spring forations was the diatom **Skeletonema costatum** (3.10^6 cels./l). At the summer the biomass was lower ($x = 4{,}27\ \mu g/l$), **S. costatum** links being changed to the autotrophic ciliate **Mesodinium rubrum.** In this occasion, it was found feccal pellets, high heterotrophics ciliates number, tyntinids, nauply and copepodites of **Acartia tonsa.** This copepod, know as a great phytoplankton consummer, occurs in high concentrations in estuary during summer (DUARTE, 1987; MONTU, 1980).

According to ABREU (1987) the dominance of **M. rubrum** during summer may be associated to its high mobility, which enables the specie better survive at severe grazing pressures.

Usual phytoplankton consumers are abundant in summer such as zooplankton species (MONTU, 1980); ichyoplankton (WEISS, 1981); young fishes (CASTELLO & KRUG, 1978; CHAO et al.,1987) and benthic suspension feeders (ASMUS, 1984); BEMVENUTI, 1983; 1987 a,b). In this period the Chlorophyll-a exportation level (0,4 g Cl-a/m²/hour) was the lowest of the year. In the Fall, the lower biomass ($x = 2{,}14\ \mu g/l$) was influenced by the grazing pressure and the exportation level (1,3 g Cl-a/m²/hour). During Winter with a low grazing pressure, biomass ($\bar{x} = 3{,}15\ \mu g/l$) and exportation level (1,6 g Cl-a/m²/hour) were higher despite the lower temperature and less light incidence.

BERGESCH & ODEBRECHT (1987) working in a shallow bay also found during Spring, the highest Chlorophyll-a values of the year, with (x =14,5 μg/l) at 0,5 m depth and (x = 8,7 μg/l) at a 3 m depth. The Fall and Summer months with more grazing pressure, were of the lowest biomass. The high biomass values recorded, mainly in Spring, reflect the physical stability of the shallow water bays (KANTIN, 1983), a probably phytobenthos resuspension, a grat penetration of light, and the outflowing water carrying nutrients with, and also the urban rests that give nutrients to the shallow bays (KANTIN & ZEPKA, 1982).

The analyses of the phytoplankton size spectrum showed the dominance of the nanoplankton comprised by monads and flagellates. The nanoplankton Chlorophyll-a values ranged between 62% (spring) and 82% (fall) of the total amount of the registred Chlorophyll-a in the year study.

As a result of the analysis of biomass and the exportation level of phytoplankton ABREU (1987) considers the estuarine biota as an eutrophic system with also eutrophic influence on the coastal region. The same conclusion was found by KANTIN (1983) who worked with water quality and hydrology in the area.

MONTU (1980) studying the zooplankton community over 312 monthly samples recorded 84 spp. (50 marine and 34 fresh-water). The samples were taken in inflowing, outflowing and mixohalinization hydrological conditions.

Marine species were located at the east side, at the areas A and part of F (Fig. 4), while the limnetics were distributed at the west side, at the D, E, F areas. Areas C and D received species from one or other origin depending of the marine or freshwater flow.

Most species (65 spp) and highest abundance (individuals maximum density $\bar{x}$ = 527 ind/m³) were found in Summer. During the Winter the lowest species number (25 spp) and abundance (individuals maximum density $\bar{x}$ = 250 ind/m³) were registered.

The copepods and freshwater cladocerans were dominants in species richness and in organisms number. The marine copepod **Acartia tonsa** (maximum density 3369 ind/m³ during Spring) and **Balanus improvisus** larvae (maximum density 12743 ind/m³ during Summer) dominated during the periods of marine water inflow and mixohalinization. Freshwater copepod **Notodiaptomus imcompositus** dominated during outflowing periods (common in Winter/Spring) in all estuarine sub areas. MONTU (1980) observed that the hydrodinamics conditions and salinity play an important role on diversity and distribution of zooplankton, temperature being the main parameter for the occurrence of freshwater species.

At one shallow water bay DUARTE (1987) found high densities of **A. tonsa** during Summer and Autumn (values between 10,995 and 40.016 ind/m²) simultaneously to the highest salinities registered in the area. Copepods abundance sudden drops with salinities lower than 3%, this value may be the inferior limit for the **Acartia** reproduction in the area (DUARTE, 1987). During summer, sudden drops in **Acartia** population were probably due to predation of (ctenophores), that ingress in the bay with the salt water inflow.

The highest zooplankton numbers in the warmer months intensify the phytoplankton consumption and promotes a greater food disponibility for several secundary consummers in the area.

4.2. Benthos Community

Studying the benthic macroalgae, COUTINHO & SEELIGER (1986) mentioned 94 spp for the estuary: 40 Cyanophyta, 25 Chlorophyta, 1 Xantophyta, 3 Phaeophyta and 25 Rodophyta. An aseazonal group of 46 spp was present throughout the year and two groups of 24 spp each occurred either during Summer/Fall or Winter/Spring.

The seasoned growth of 55 green, brown and red algae related to monthly variations of salinity, water temperature, day lenght and light radiation energy (COUTINHO & SEELIGER, 1986). Summer/Fall peak growth was observed in 15 spp most of which correlated significantly with high salinities. Growth peak of 11 species in Winter/Spring was mainly a function of water temperature alone or together with a reduce light regime. Maximum diversity of green, brown and red algae (COUTINHO, 1982) was observed in late Fall. Cyanophyta represented the largest simple component of the flora throughout the year.

COUTINHO (1982) determined two algae associations in the estuary: one with predominant perennial species at the mouth, with hard bottom and a strong marine influence; another inside the estuary with lower physical previsibility, with more annual species. The shallow bays showed the best conditions for algae development, mainly because of an increase in both the hydrodynamical stability and the nutrients level (KANTIN, 1983). In this environment, COUTINHO (1982) registered 817 g/m² dry weight for **Rhizoclonium riparum.** A monthly average of algae biomass, with the seazonal peaks coinciding with the seagrass **Ruppia maritima** lower biomass months, provide a continuous produtors high biomass levels around year (COUTINHO, 1982).

COUTINHO & SEELIGER (1986) observed that both periodicity of benthic algae and their seazonal growth, as a more sensitive measure of the floristic affinity, indicate the presence of cold temperature and tropical elements in this flora characteristic of warm temperature regions.

The benthic fauna studied by CAPITOLI et al. (1978) and BEMVENUTI et al. (1978) during two years of a soft bottom macrobenthic survey (180 quantitative grab samples) were collected 44 spp of both infauna and a sessile and sedentary epifauna. The peracarids crustaceans (17 spp) and polychaets (13 spp) were the highest number species groups.

The low diversity was related to the small number of marine organisms in the estuarine mouth. The long and narrow channel presents a great physical instability and a high hydrodynamic, that do not allowed a persistent colonization of marine benthic fauna (CAPITOLI et al., 1978).

In supra and mesolittoral levels occur irregularly flooded marshes dominated by **Juncus acutus, Spartina densiflora, S. alterniflora** and **Scirpus robustus** grasses. During Winter the marsh flooding produces a great amount of detritus that are exported along the estuary. In the marsh, the crab **Chasmagnathus granulata** seems to overcompete on **Metasesarma rubripes**, but this last one with its smaller size has more agility and can use with more hability the third dimension of their habitant (sleeves and trunks of marsh grass) (CAPITOLI et al., 1977).

Along the central part of the estuary, the infralittoral is dominated by a small number of species with increasing diversity as sea water inflows during Summer and early Autumn.

The following, estuarine species are dominant in the infralittoral (BEMVENUTI et al., 1978): the bivalve **Erodona mactroides** (average biomass at the north part of the estuary: 281 g/m^2); the gastropod **Heleobia** sp. (with densities up to 40000 ind/m^2 from shallow water to the channel); the tanaidacean **Kalliapseudes schubartii** (with highest average densities of 1013 ind/m^2 at the shallow bays); the polychaets **Laeonereis culveri** (from tidal flats until 1 m depht) and **Heteromastus similis** and **Nephtys fluviatilis** that have a wide vertical distribution. Between the mobile epifauna the blue crab **Callinectis sapidus** and the shrimp **Penaeus paulensis** are important fisheries resources, the shrimp being the greatest economic fishery of the region. An interesting revision about the secundary consummers in the estuary (CASTELLO, 1987) included several informations about the status of fisheries in the area.

At the shallow bays the increase of benthic diversity is probably due to a more environmental stability, and to a development of macroalgae patches as well as **Ruppia maritima** beds.

The seagrass beds occur in the shallow bays in the Summer months. ASMUS (1984) observed that high biomass of **Ruppia** does not constitute an indispensable factor for the benthic fauna, but determines good conditions for the zoobenthos development. The fact that **Ruppia** is not perennial (CAFRUNI et al., 1978) is not advantageous for zoobenthos seagrass strictly dependent, but it is important for those organisms abble to settle the available niche (BEMVENUTI, 1987a). ASMUS (1984) mentions the protection of the seagrass for **K. schubartii** and **E. mactroides** yougs, and a stratification of community where **Heleobia** utilizes the plants sleeves as substract. It is also mentions a significant correlation between the development of **Ruppia** and the abundance of **Penaeus Paulensis** youngs, that with several juvenils of fishes utilize the beds as nursery.

In a soft bottom field experiment, at the control in the natural environment, BEMVENUTI (1987b) found as dominant three infaunal species: **K. shubartii, H. similis** and **N. fluviatilis.** These species had their highest densities during Summer and early Autumn, along with an intense reproductive rate and the highest predation pressure in the area. The epifaunal peracarids, more exposed to predation, were more abundants during Autumn and Winter when number and activity of predators were reduced and the presence of macroalgae patches offer habitat, shelter and food.

In exclusion cages the macrofauna densities (49,248 ind/m²) were three times higher than the control, four months later. After this peak the density in the cages decreased to levels near to the control.

At monthly exclusion cages, sucessive increases of density were observed due to increasing of reproduction and by the cage protection. At these conditions it was observed that space and food are not limiting conditions for zoobenthos in the natural environment. The impact of epifaunal predators seems to mantain the soft bottom community below the carrying capacity of the system.

BEMVENUTI (1987b) also observed that diversity, equitativity and species richness were greater under cumulative exclusion. Diversity curves and the conformation of rank frequency species diagram (FRONTIER, 1977), indicated a more complex structure within the cages. The soft bottom community showed its adjustment stability (SUTHERLAND, 1981) through the return, under cumulative exclusion, at similar conditions of the control. It has happened after changes in the structural characteristics of the community caused by the disturbance due to predators exclusion.

CAPITOLI (1983) studied the seazonal settlement and development of the estuarine fouling community. The author observed that seazonal settlement is dominated in frequency and number by **Balanus improvisus**, with an increase in Summer and low densities during Spring. The seazonal settlement and complementary short durations experiments showed the high similarity of the seazonal progressions, due to the low availability of colonizers.

No evidence of biotic succesion was found for the macrofauna. The intense salinities flutuactions would be responsible for a small marine euryhaline species numbers, which determines a low species richness and a relative simple community, i.e., low complexity structure (CAPITOLI, 1983).

Predation was the biological factor which most influenced the organization of the community, **Stylochus** sp was the main predator on **B. improvisus**; a mortality rate of about 75% was observed in a four months period. The competition was less important due to the low availability of marine euryhaline colonizers capable to substitute the barnacle dominance (CAPITOLI, 1983).

4.3. Fishes Community

The fish community in the estuary has been studied by L. CHAO and collaborators since 1978 in a long term ecological survey. For the three first years it was found about 100 spp, that are dominated by small group of organisms in abundance and biomass.

In bottom trawls CHAO et al. (1987) registered 82 spp, of which 28 were not caught in mid-water trawls or beach trawls. About 90% of organisms in number and weight were represented by 7 spp of sciaenids: **Micropogonias furnieri, Macrodon ancylodon, Cynoscium striatus, Paralonchurus brasiliensis, Ctenosciaena gracilicirrhus, Umbrina canosai** e **Menthicirrhus americanus**; two ariids: **Netuma barba** and **N. planifrons**; and **Porichtys porosissimus**. Fourteen elasmobranchs were exclusively captured by the bottom trawls.

In mid-water trawls 42 spp were caught, being **Hippocampus** caught with this method exclusively. **M. furnieri, Anchoa marini, Lycengraulis** sp. and **Trichiurus lepturus** were the dominant species.

Beach seining caught 60 spp, included 22 spp not captured in the trawl catches. Youngs of **Mugil platanus, M. curema, M. gaimardianus, Brevortia pectinata, Platanichtys platana** and **Ramnogaster arcuata**; and plus **Odontesthes** sp, **Xenomelaniris grasiliensis, Jenynsia lineata** and **M. furnieri** represented 95% of catches.

Therefore, CHAO et al. (1987) observed that the estuarine fish community is constituted by at least three faunal assemblages, the deeper water bottom, the mid-water and the shore fauna, which correspond to the three sampling methods and their respective fishing habitats.

The increase of the abundance and number of species in Fall and Spring months (Fig. 5) were influenced by the greater number of trawls taken in the lower reaches of the estuary, where the transient and coastal marine fishes were most frequently caught during the warm months, before and after Winter. The biomass decreased and the higher species number in Summer (Fig. 5) were related to the recruitment of large number of juvenils or young-of-the-year in the community (CHAO et al., 1987). The sudden drop of catches in July and August of 1980 (Fig. 5) were probably due to the continuous increasing rainfall and outflow of freshwater, resulting in low salinities. The authors observed also, that low temperature, continuous rainfall and low salinity altogether could greatly reduce the species diversity and the richness of the fish community. These community parameters showed their highest values during autumn, period of highest salinities in the estuary.

Based on abundance, temporal and spatial distributions, and life histories, CHAO et al. (1987) grouped the estuarine fishes in the following five categories:

1. The resident estuarine fishes: those may complete their entire life cycles within the estuary. Most were caught year-round by beach seine hauls, including **Odontesthes** sp, **X. brasiliensis, J. lineata** and several species of Poecilidae. They often coexisted in the shallow sandy, muddy and vegetated habitats. Temporal and spatial distribution of their peak abundance was distinct, especially among two sympatric atherinids (BEMVENUTI, 1987). Estuarine spawning **Achirus garmani**, few gobiids and bleniid **Hypleurochilus fissicornis** also belong to this category. The ariid **Genidens genidens**, were abundant in low saline stations, and brooding males were caught during the summer from the upper part of the estuary.

2. The estuarine dependent marine fishes: those marine coastal spawners that utilize the estuary as a nursery during the first years of their life cycles. Two or three year classes of youg sciaenid fishes, **M. furnieri, M. ancylodon, M. americanus** and **P. brasiliensis** were caught year round. Juveniles of **Mugil platanus** were abundant in beach seines catches throughout the year. They might have stayed in the low saline embayments and upper parts of the Patos Lagoon until their spawning run during April and May three or four years later.

3. The regular nurslings and opportunists: large quantities of postlarvaes and young-of-the-year of **C. striatus**, **U. canosai**, **C. gracillicirrhus**, **Prionotus punctatus**, **Prepilus paru** and **Lagocephalus laevigatus** were caught during several consecutive months of the year. Both juveniles and adults of **T. lepturus** and **P. porosissimus** were common in trawl catches during the wamer months when higher bottom salinities were found in the estuary. Inversely, the freashwater catfishes **Parapimelodus valenciennesi** and **Pimelodus clarias** were often caught in the lower reach of estuary after heavy rainfall.

4. The anadromus fishes were represented by catfishes **Netuma barba** and **N. planifrons**. Adult **N. barba** (over six years old) entered the Patos Lagoon in Winter and Spring. Spawning and mouth brooding occurred in the upper parts of lagoon during summer. Juveniles moved about the estuary for first two or three years, then migrate out of the lagoon and returned upon maturation (REIS, 1986; ARAUJO, 1983). **N. planifrons** showed a similar seazonal abundance pattern to that of **N. barba**, and **G. genidens** do not have an ocean migrational life history and is considered as resident fish.

5. The occasional visitors and rovers: those marine and fresh water fishes that occurred in the estuary irregularly. Tropical fish familes of Carangidae, Serranidae, Pomacentridae, Gerreidae and Balistidae were the principal Summer visitors. Coastal marine fishes, mainly elasmobranchs. Anguilliformes, **Utophysis brasiliensis** and **Symphurus jenynsi** also roved into the lower reach of the estuary. Several species of Cichlidae and Characiformes were frequently caught along the margin of estuarine embayments with beach seines in salinities less than 20%.

5. FINAL REMARKS

The Lagoa dos Patos was isolated from the Atlantic Ocean during the Pleistocene, when a large complex multiple barrier built up.

A single permanent outflow channel shows that the south part of Lagoon behaves essentially like an estuarine system.

Bathymetry is gentle but diversified varying from 0.5 to 1.0 meter, with deepest parts confined to the central zones, 7 to 8 meters.

Tides (0.47 m of amplitude) has a weak influence in the water circulation, which is mainly related with the wind action and river flows.

Wind and fluvial discharge are also responsible in variations in the lagoon water level with differences of up to 2 meters between the north and the south limits.

The bottom sediments are dominantly muddy with two sand strips along both continent and ocean margins.

Observations on mechanical, mineralogical and depositional aspects permits to characterize five main sedimentary facies along the lagoon.

A Muddy of fluvial influence, II Fine sand of barrier margin, III Medium sand of continent margin IV Lagoonal mud and V Estuarine region.

The estuary showed a low floristic and faunistic diversity, reflecting a very unstable as well as umpredictable environment. The long and narrow channel in the mouth, difficult the entering and establishment of several marine organisms in the estuary.

An alternate seazonal vegetarion biomass peaks support a continuous high primary porduction around year. This, together with a high nutrients level establish a eutrophic system, that during intense outflowing periods — generally Winter and Spring — play an important role in the eutrophyzation of the adjacent marine environment.

The diversity and abundance of the fauna increase in the warmer months, especially in the shallow bays, that function as nursery for several estuarine dependent marine organisms. In this period the increase in the number and activity of several levels of consummers results in a severe predation pressure on the system.

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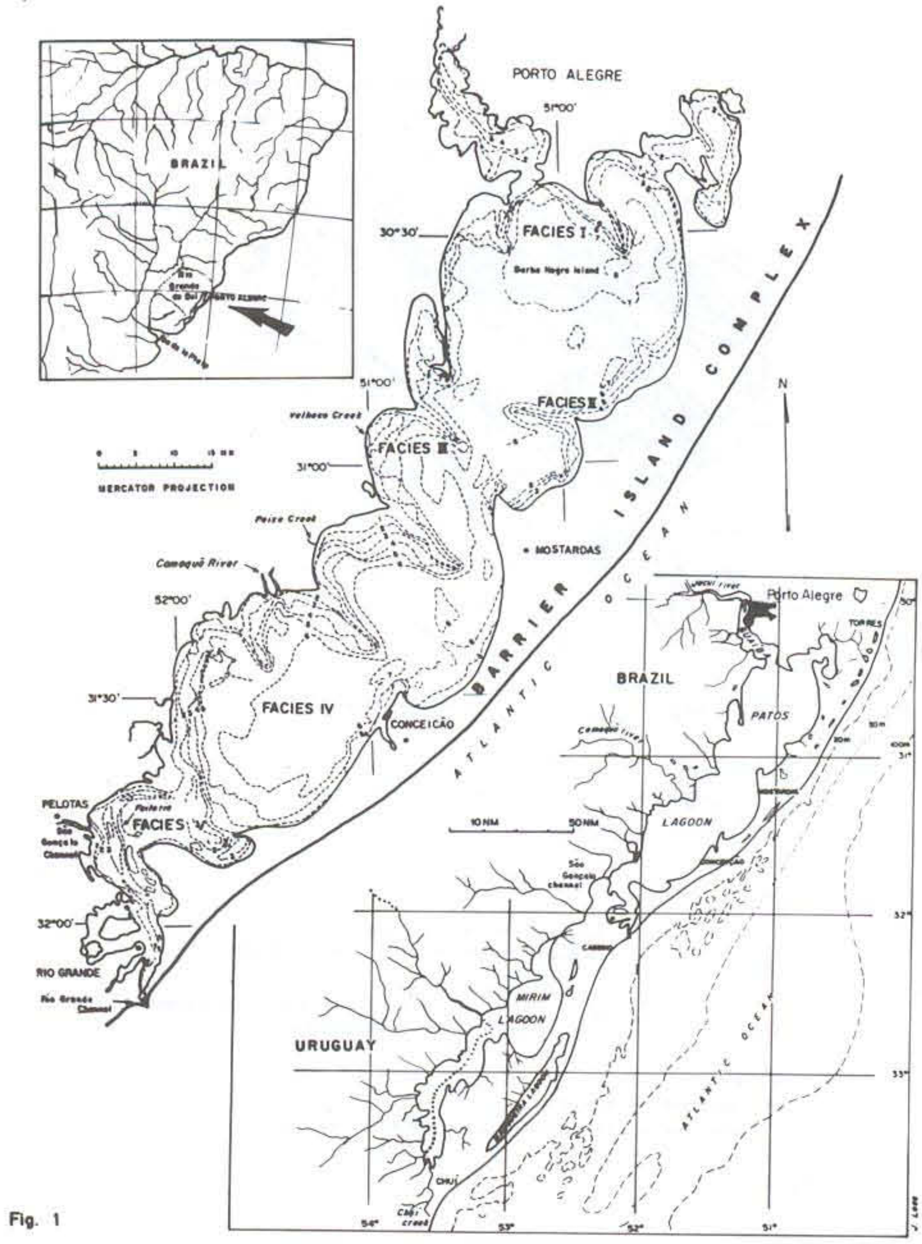

Fig. 1

Fig. 1 Lagoa dos Patos-Mirim system showing bathymetry and sedimentary facies distribution. (Adapted from MARTINS, 1981.

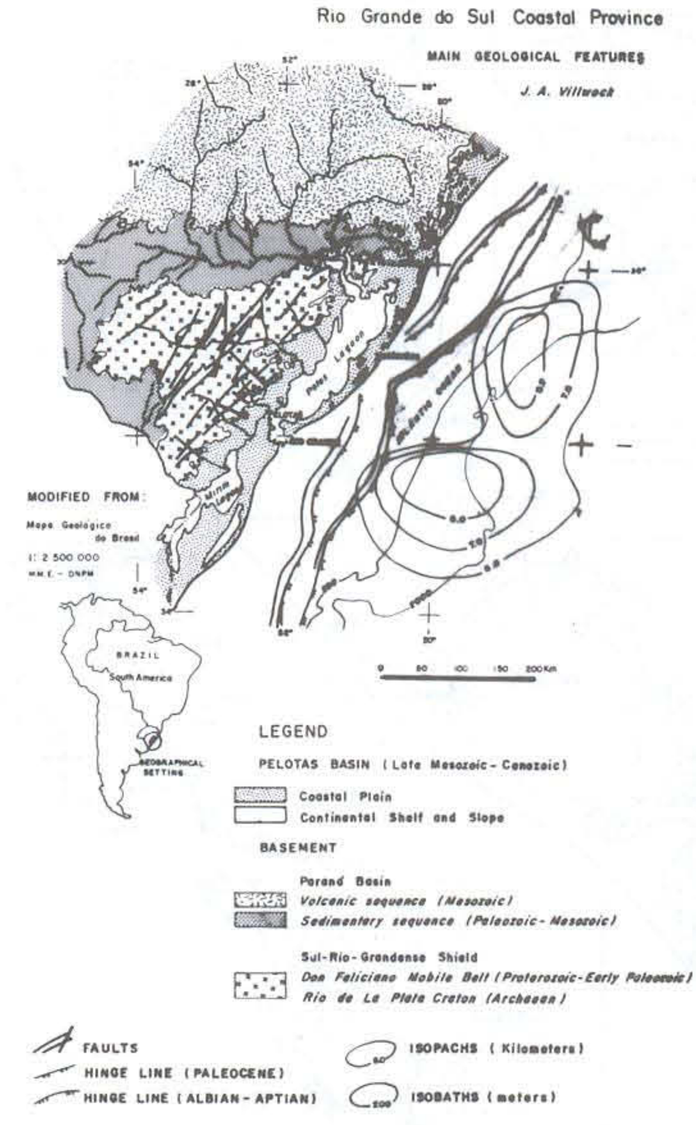

Fig. 2

Fig. 2 Main geological features of the Rio Grande do Sul coastal province. (After VILLWOCK, 1984).

Fig. 3

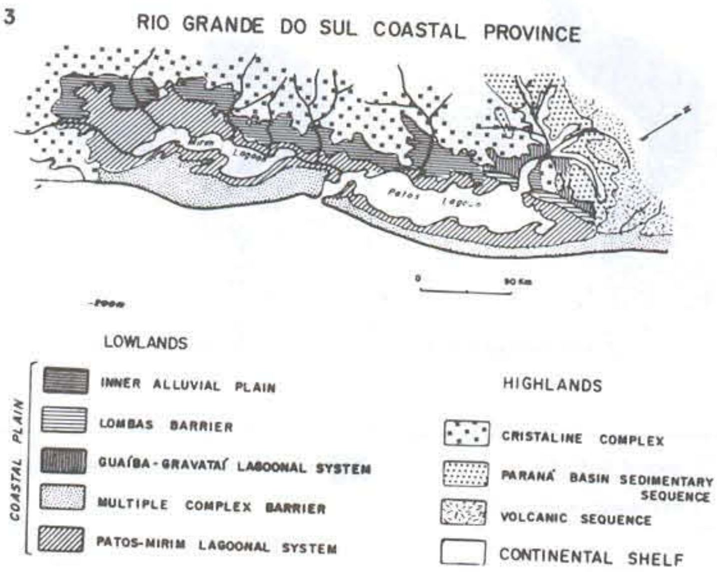

Fig. 3 Geomorphology and geologic units of the Rio Grande do Sul coastal province. (After VILLWOCK, 1984).

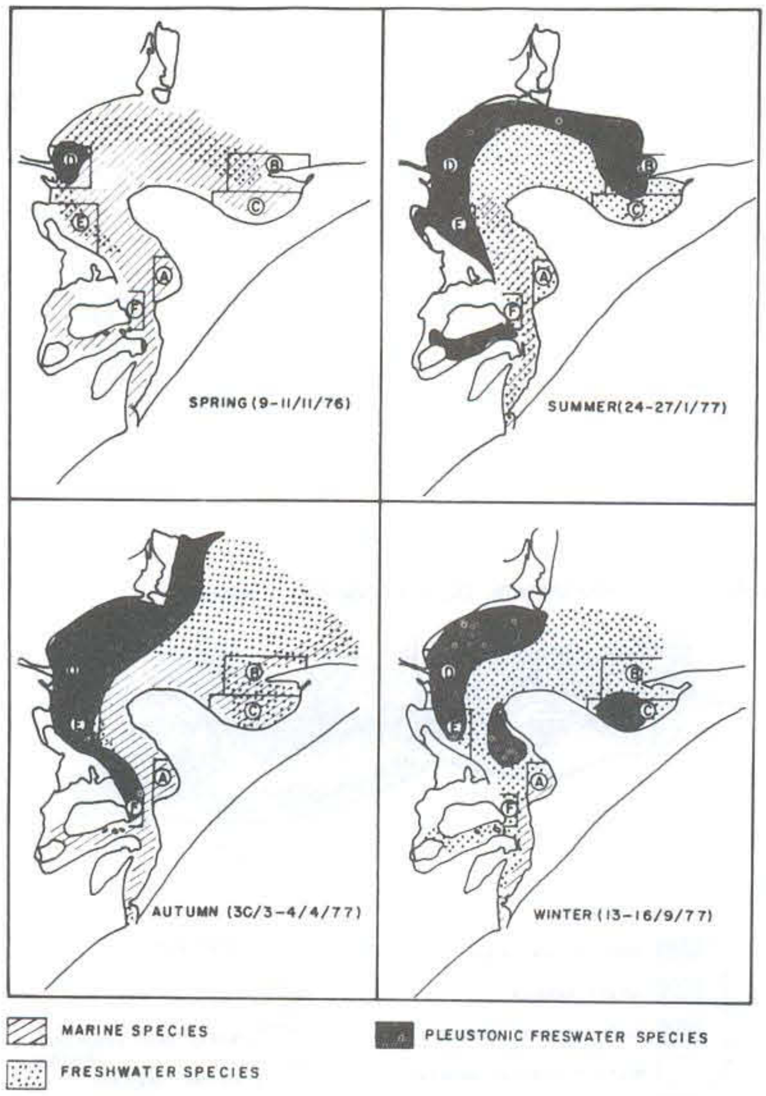

Fig. 4 Superficial distribution areas of marine, freshwater and pleustonic species, reflecting distincts hydrological conditions in the estuary.
The distribution of pleustonic species not excluded the overllaping with the two others. (After MONTU, 1980).

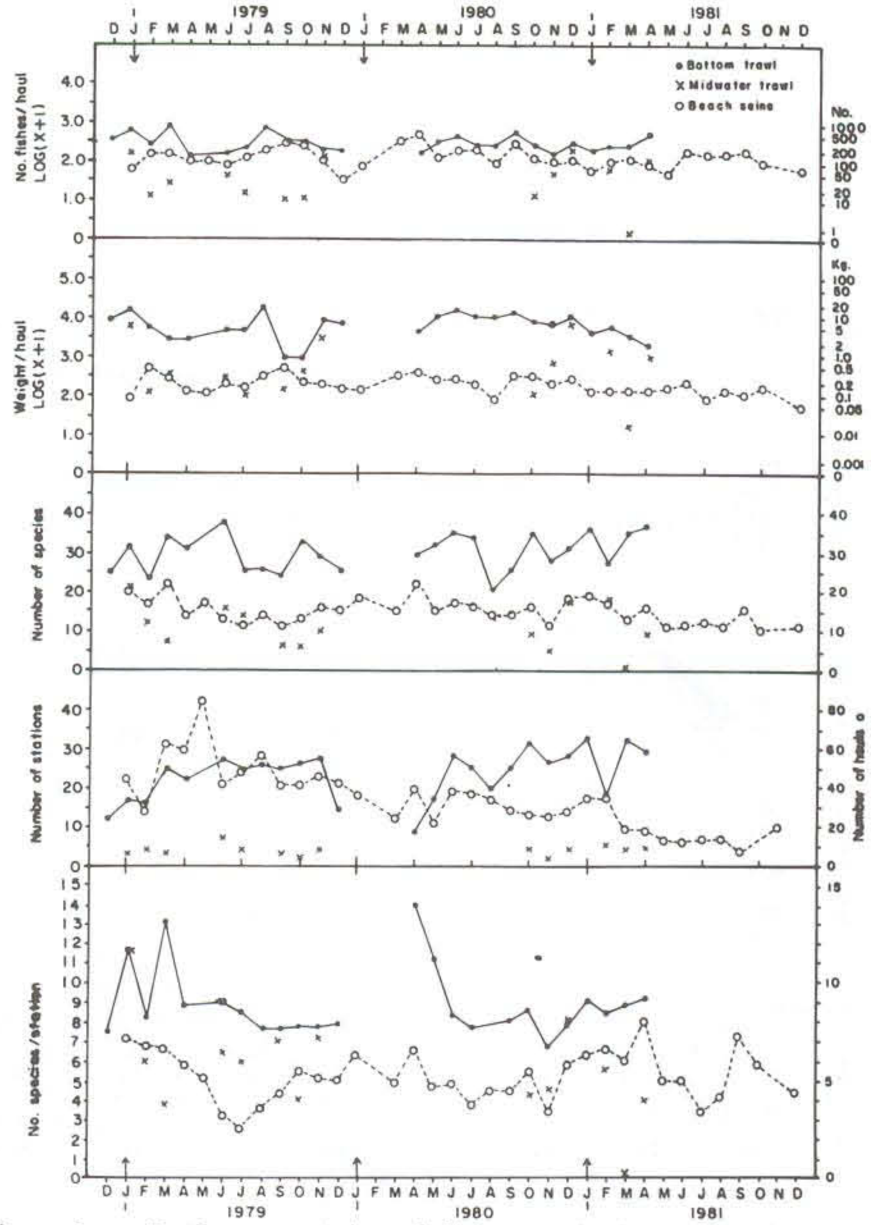

Fig. 5 Montly mean catches of fishes per haul, number of species and stations sampled in the estuary. Each station represent one bottom or mid-water trawl haul, for beach seine samples three haul seines were made for each station. (After CHAO et al. 1987).

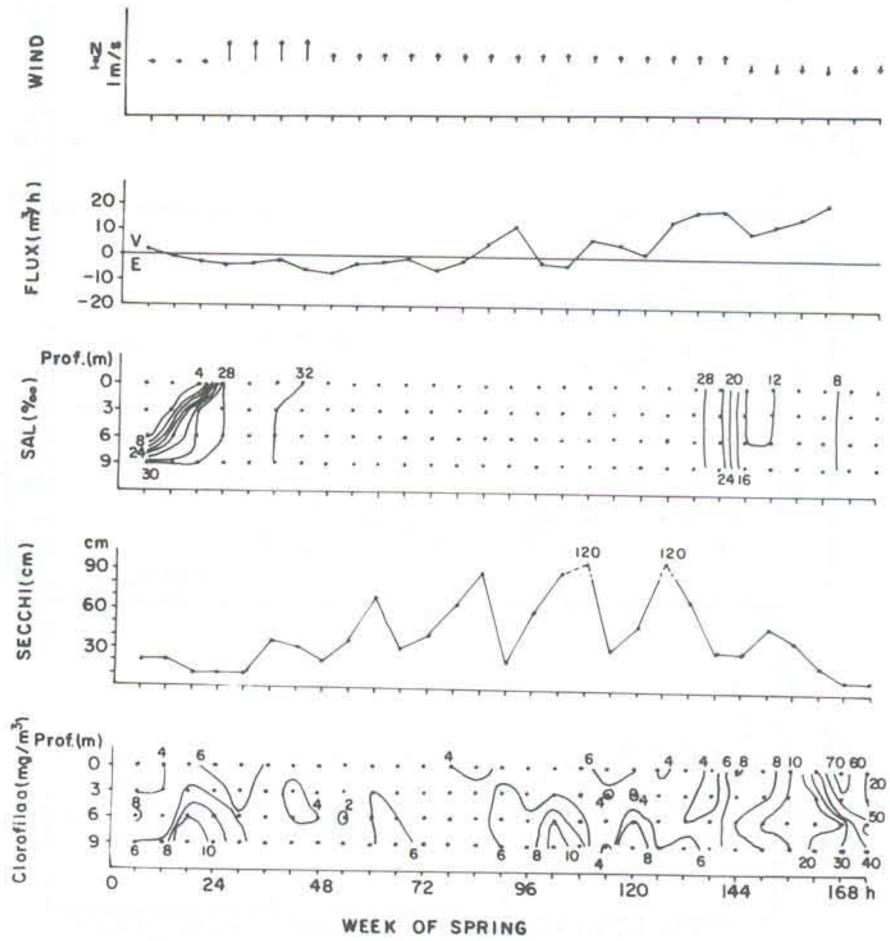

Fig. 6 Direction and intensity of wind, water flux, salinity, water transparency (Secchi disk) and Chlorophyll-a concentration for a spring week (adapted from Abreu, 1987).

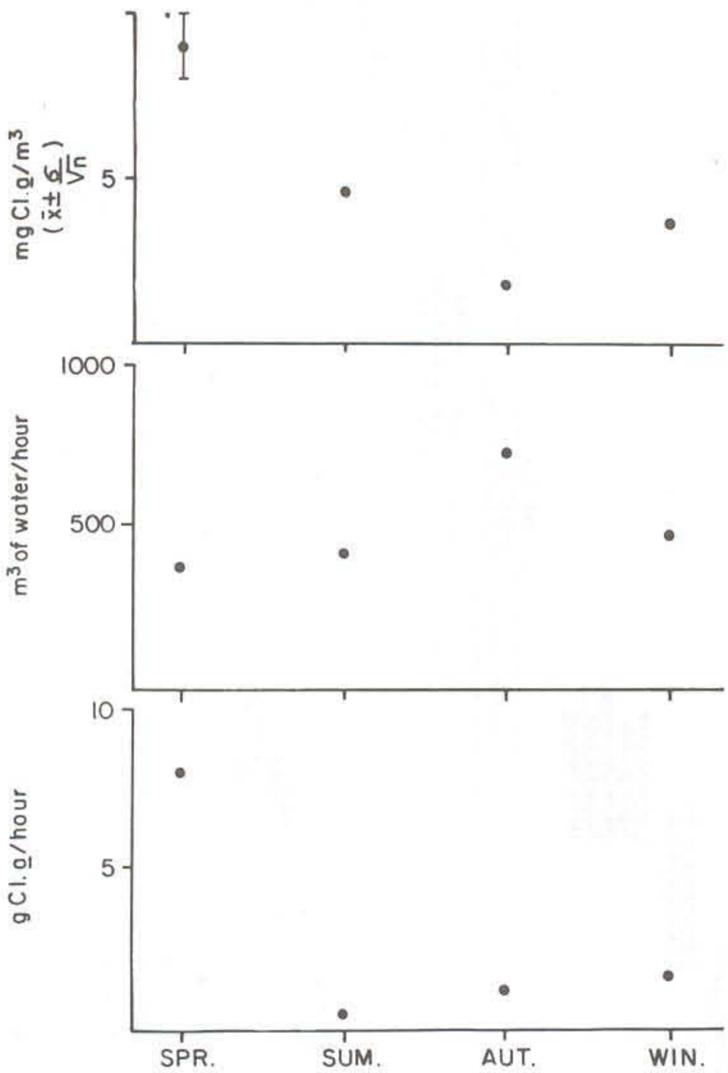

Fig. 7 Weekly mean values of Chlorophyll-a for the four stations of the year (adapted from ABREU, 1987).

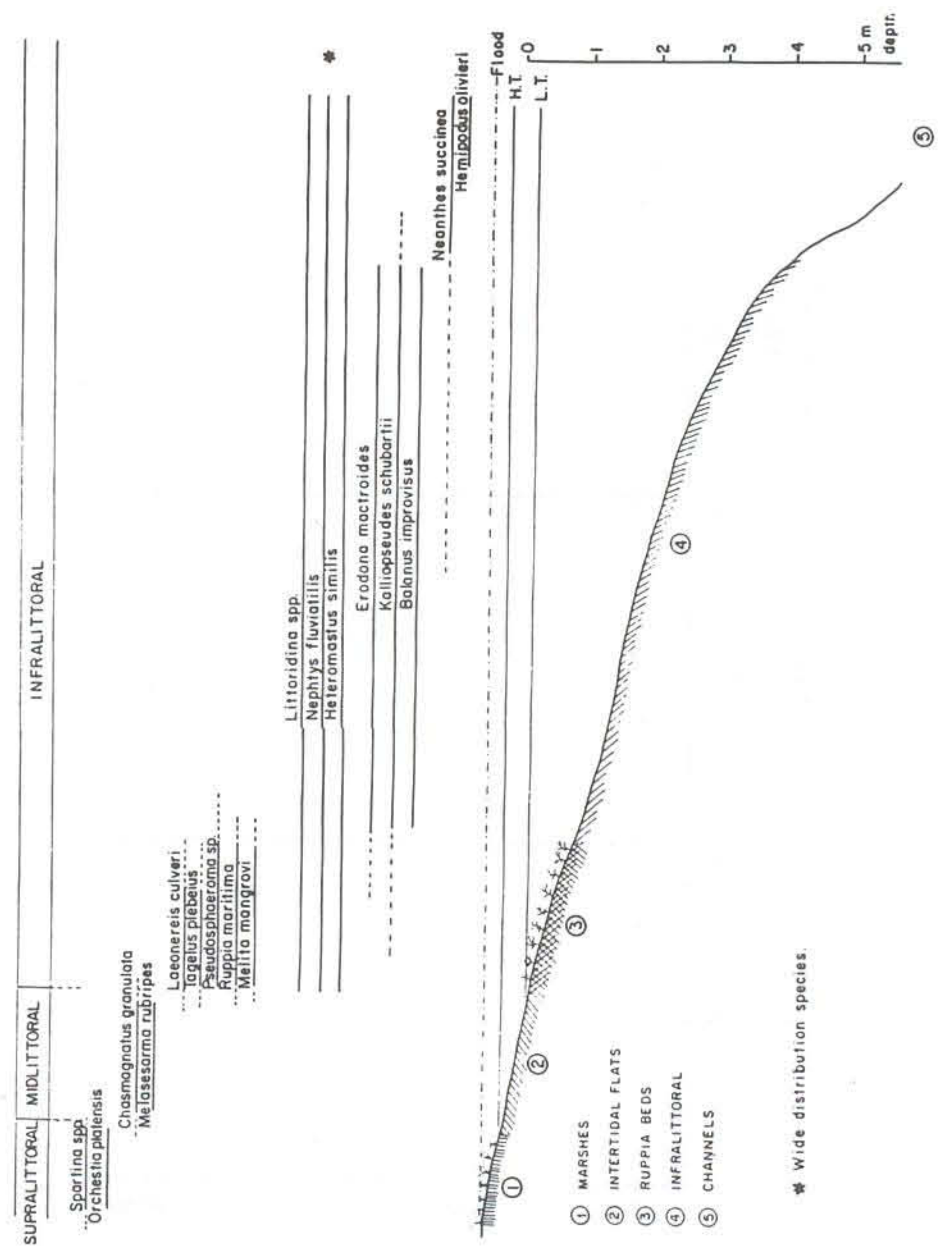

Fig. 8 Main benthic associations in the estuarine area of the Lagoa dos Patos (adapted from CAPITOLI et al., 1978).