The distribution of palynomorphs in the superficial sediments on the margin of the Patos lagoon estuary, RS, Brazil, as compared with the actual vegetation

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ABSTRACT – To study the palynomorphs distribution in superficial sediments and to establish the relationship between palynological data on plant taxonomy and botanical data on actual vegetation on the margin of the Patos lagoon estuary, five samples from a recent sandy silt sediments were examinated. Pollen and spores of terrestrial and aquatic plants, zygospores, colonies and coenobies of green algae (Chlorophyta), and fungal spores were identified. The pollen-and-spore assemblages recognized generally coincide with the composition of the actual vegetation in the wetland of the southern Coastal Plain of Rio Grande do Sul. The discrepancies between palynological and botanical data are probably due to different pollen productivity of plants, inequality in pollen and spores transportation capacity, and polen and spores morphological features, which are affected by the conservation in sediments.

Key words: palynology, vegetation, Coastal Plain, Rio Grande do Sul, Brazil.

RESUMO – **A distribuição de palinomorfos nos sedimentos superficiais na margem do estuário da laguna dos Patos, RS, Brasil, em comparação com a vegetação atual**. Para estudar a distribuição de palinomorfos nos sedimentos superficiais de uma área úmida na margem do estuário da laguna dos Patos, e estabelecer a correspondência entre dados palinológicos da taxonomia e dados botânicos da vegetação atual, foram examinadas cinco amostras coletadas em sedimentos de areia siltica. Foram identificados pólen e esporos de plantas terrestres e aquáticas, zigósporos, colônias e cenóbios de algas verdes (Chlorophyta) e esporos de fungos. As associações de pólen e esporos reconhecidas, em geral, coincidem com composição da vegetação na Planície Costeira da parte sul do Rio Grande do Sul. Discrepâncias entre dados palinológicos e botânicos podem ser causadas por diferenças na produção polínica das plantas, pela desigualdade na capacidade de transporte de pólen e esporos e pelas características morfológicas de pólen e esporos que são influenciadas pela sua conservação nos sedimentos.

Palavras-chave: palinologia, vegetação, Planície Costeira, Rio Grande do Sul, Brasil.

INTRODUCTION

The reconstruction of natural palaeoenvironmental changes, including vegetation, climate, sea-level oscillations, etc., by palynological data, depends upon the knowledge of the relationship between the pollen-and-spore assemblages from surface sediments and the actual native vegetation. The first reconstructions of Holocene palaeoenvironment and climate in the Coastal Plain of Rio Grande do Sul, based on palynological data were made by Lorscheitter (1984), Cordeiro & Lorscheitter (1994), Lorscheitter & Dillenburg (1998), Medeanic *et al*. (2001) and others. The reconstruction of past Holocene environments by palynological results was based only on botanical data of recent native plant distribution in the region, without previous investigations of correspondence between extant pollen- and-spore assemblages from recent surface sediments and corresponding present vegetation cover of dunes, wetlands, intertidal marshes, actually widespread in the Coastal Plain of Rio Grande do Sul.

The question, how pollen-and-spore assemblages coincide with vegetation cover rose from the beginning of application of Palynology for palaeogeographical reconstructions. Numerous publications were dedicated to the study of the relationship between pollen-and-spore assemblages from the surface fluvial, lagoonal, subaerial sediments and the actual vegetation at various latitudes and altitudes (Gritchiuk & Zaklinskaia, 1948; Von Post, 1967; Salgado-Labouriau, 1979; D'Antoni & Markgraf, 1980; Sheshina, 1980; Druschits *et al.*, 1986; Traverse, 1988; Caramello *et al.*, 1991; Jackson, 1994; Busk, 1997; Hjell, 1997; Paez *et al.*, 1997; Woo *et al.,*1998; Mulder & Janssen, 1999, and others). The obtained data undoubtedly demonstrate that pollen-and-spore assemblages from surface sediments generally coincide with the composition of existing vegetation and characterize the latitudinal and altitudinal vegetation.

The discrepancies between pollen-and-spore assemblages from superficial sediments and surrounding vegetation may be caused by various factors. The most important factor guiding pollen-and-spore assemblages, according to Dimbleby (1967), Berezina & Tyuremnov (1973), Arap (1975), Monoszon (1979), Grill & Guerstein (1995) is the variable pollen productivity by plants and unequal pollen and spore dispersion capacity. Faegri & Iversen (1989) presented a clear relationship between pollen production and the mode of pollination. Wind-dispersed (anemophilous) species of plants exhibit a higher pollen reproduction as compared with insect-dispersed (entomophilous) plant species.

During the pollen and spore deposition among mineral sediments, some pollen and spore types are affected by various destructive processes, including mechanical, chemical and biological agents (Berezina & Tyuremnov, 1973; Bryant, 1978; Traverse, 1988; Tauk, 1990; Brush & Brush, 1994), causing the impoverishments of taxonomic variety of pollen and spores and raising discrepancy between pollen-and-spores assemblages from surface sediments and corresponding vegetation cover.

In addition to pollen and spores, the palynologists frequently take into account fungal and algal spores referred as palynomorphs (Cross *et al*., 1966; Graham, 1971; Jarsen & Elsik, 1986; Traverse, 1988, and others).

Recently, new data on the relationship between the actual vegetation and the pollen-and-spore assemblages from fluvial, lagoon, and subaerial surface sediments from Rio de Janeiro and São Paulo States, were published (Costa *et al.,* 1999; Morais *et al.*, 1999; Barros *et al.*, 1999). The close relationship of pollen-and-spore assemblages and lithology of studied sediments was established.

The present paper represents the first palynological results in the Coastal Plain of Rio Grande do Sul, obtained from surface sediments from a wetland area compared with the present vegetation cover. The objective of the study is to determine predominant native plants, collecting the pollen of recent native and introduced plants, creating a palinoteca as comparative material, and to collect surface samples from this wetland area.

STUDIED AREA

Wetlands are widespread on the southernmost margin of the Patos lagoon and are beyond the influence of marine water. Their humid state is maintained by atmospheric precipitation and high ground-water table. The well-developed drainage system of the wetlands provides for the diverse taxonomic composition of the plant cover. According to the botanists Seeliger (1992), Cordazzo & Seeliger (1995), the wetlands in the extreme south of Rio Grande do Sul State are characterized the by presence of ferns *Azolla filiculoides* Lam., *Marsilea quadrifolia* L., *Salvinia auriculata* Aubl., and angiosperms, such as *Alternanthera philoxeroides* (Mart.) Griseb., *Bacopa monnieri* (L.) Pennel*, Bromelia antiacantha* Bert., *Cladium jamaisensis* Crantz., *Cyperus giganteus* Vahl, *Echinodorus grandiflorus* (Cham. & Schl.) Mich.., *Eichornia azurea* (Sw.) Kuntz., *Erytrina crista-galli* L., *Lemna valdiviana* Phil., *Ludwigia* sp.*, Myriophyllum brasiliense* Camb.*, Paspalum vaginatum* Sw.*, Pistia stratiotes* L.*, Polygonum hydropiperoides* Michx., *Pontederia lanceolata* Nutt., *Ranunculus apiifolius* Pers., *Sagittaria montevidensis* Cham. & Schl., *Scirpus californicus* (C. A. Mey) Steud., *S. giganteus* Kunth, *S. olneyi* A. Gray*, Senecio bonariensis* Hook & Arn., *Typha domingensis* Pers.*, Utricularia inflate* Walt, and others.

According to recent data presented in "Catálogo das algas Chlorophyta de águas continentais e marinhas do estado do Rio Grande do Sul, Brasil", a wide distribution of various species of the algae Chlorophyta was registered in the south littoral of Rio Grande do Sul (Torgan *et al*., 2001). The species, whose zygospores possess an organic sporopollenin-like wall, of the genera *Botryococcus* Kütz., *Chara* L. *ex* Vaill., *Mougeotia* (C. A. Ag.)

Witt., *Pediastrum* Meyen, *Spirogyra* Link, *Zygnema* C. A. Ag., were found in wetlands, channels, and small rivers and lagoons.

In many areas, the wetlands of this region serve as pastures for cattle and horses. At present, it is not easy to find a sector of native wetlands without anthropogenic disturbance. The wide occurrence of introduced plants here is usual. They are planted to be used for utility purposes, such as agricultural plants or decorative plants in parks and gardens. The most widespread introduced arboreous plants in these wetlands are *Eucalyptus* L., *Pinus maritima* Miller, *Salix* L., *Tamarix* L., and some others. Sometimes, introduced *Rhyzophora* species (Araceae) are encountered.

The studied area is drained by the small Bolasha River with a width of about 3-4 m. It falls into the Patos lagoon at about 8 km from this area, characterized by the predominance of native grassland vegetation. Adjacent grassland areas, beside native plants, are occupied by introduced arboreous plants, such as *Eucalyptus, Salix* and occasionally occurred *Rhizophora*.

MATERIALS AND METHODS

The studies were conducted on the margin of the Patos lagoon estuary during field work in November, 1999. In order to perform this study, a wetland area approximately 150 × 450 m^2 without any distinctive human-influenced disturbances was selected between municipality Cassino and city Rio Grande (Fig. 1). The image of the chosen wetland is given in Figure 2 and part of the Bolasha river is represented in Figure 3.

Vegetation analysis

For the taxonomic determination of the existing native plants from this wetland, "Guia ilustrado da vegetação costeira no extremo Sul do Brasil" (Cordazzo & Seeliger, 1995) was used. The plants were examinated, using the Braun-Blanquet phytosociological method, highlighting the percentage cover of each determined taxon (Caramello *et al*., 1991). The values in the phytosociological tables are given in terms of the Braun-Blanquet abundance-dominance indices, where:

+ – corresponds to the presence of the species;
1 – to a plant cover varying from 1 to 5% of the surface;
2 – to a plant cover varying from 5 to 25% of the surface;
3 – to a plant cover varying from 25 to 50% of the surface;
4 – to a plant cover varying from 50 to 75% of the surface,
5 – to a plant cover varying from 75 to 100% of the surface.

The most important identified taxa in the chosen wetland area are given in the Table 1, and the full list of all identified plant taxa is given in Table 2.

Sampling for palynomorph analysis

Five samples were collected from five sites within the study area (Figs. 1-3). Three of them were sampled from the surface of sandy soil, and the other two silty sand samples were collected from the bottom of the river and at a distance of approximately 0.50 cm from the shore. The sampling was executed by soil knife. At first, the local of sampling was refined from growing vegetation. Soil and silty sand samples were collected from the superficial layer at a depth of 1 to 3 cm. The collected samples were dried in an electric furnace at 60ºC. The dry samples were passed through a sieve (D = 200 mm) in order to remove the different plant remains.

The dry samples, 50 g in weight, were treated as follows: cold HCl (10%) and boiling NaOH (5%) for 15 minutes. Inorganic substances in treated samples were separated from the organics by dense liquid – an aquatic solution of $ZnCl_2$ (density about 2.2 g/cm^3). The residual organics were mounted in glycerine-jelly to prepare the microscope slides.

These slides are maintained in the Department of Palaeontology and Stratigraphy, Institute of Geosciences, Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS.

The examination of the obtained palynomorphs includes the taxonomic identification of pollen and spores of terrestrial and aquatic plants, zygospores, colonies and coenobiums of green algae of Chlorophyta, and fungal spores, and the determination of the relationship (%) between different taxa. For each sample, at least, 200 grains of palynomorphs including pollen, spores, algae and fungal spores were counted. The palynomorph percentage in relation to the absolute palynomorphs frequency was calculated for each sample (Tab. 3). All of the palynomorphs were counted together (total palynomorph sum) in order to determine the percentage of arboreous pollen (AP), nonarboreous pollen (NAP), pollen of aquatic plants (NAP aquatic), spores of Bryophyta and Pteridophyta, zygospores of Chlorophyta and fungal spores. Percentages of zygospores, colonies and coenobias of Chlorophyta, given in Table 4 were calculated in relation to the palynomorph sum. The pollen sum includes only pollen and spores of vascular terrestrial and aquatic plants, which percentage in each sample was calculated in order to establish the representativity indices (Tab. 5). Using the index of representativity, we try to evaluate the relationship between the predominant pollen in the samples and the most abundant plants of the vegetation cover of wetland.

The taxonomic identification of pollen and spores was made using the palynoteca preserved at the Department of Palaeontology and Stratigraphy, Institute of Geosciences, UFRGS, Porto Alegre, RS. Also, some publications on pollen and spore morphology of recent plants were used for taxonomic determination (Barth *et al.*, 1976; Barth & Melhem, 1988; Neves & Lorscheitter, 1995; Garcia, 1997, 1998; Pickett & Newsome, 1997; Coelho & Barth, 2000). In many cases, pollen and spores were identified *sensu lato* (in broad sense) as family or genus, in order to avoid invalid definitions.

The taxonomic determination of zygospores of freshwater green algae was based on publications by Van Geel (1976), Van Geel & Van der Hammen (1978), Van Geel *et al.* (1980-1981), Van Geel *et al.* (1986), Canter-Lund & Lund (1995).

The taxa of fungal spores were not determined, because the recent taxonomy of species in the Coastal Plane of Rio Grande do Sul is still poorly known and needs improvement. The fungal spores were counted together with the other palynomorphs.

The obtained results on palynomorph distribution were plotted in a percentage palynodiagram, using the Tilia Software designed by Grimm (1987) and are shown in Figure 4.

The obtained data are illustrated by photomicrographs of the most abundant pollen and spores of native terrestrial and aquatic plants of this wetland, encountered in the surface samples (Figs. 5-33).

RESULTS

Vegetation analysis

The predominance of herbaceous plants, especially of species of the genus *Eryngium* (Apiaceae), is notable. This wetland area is characterized by the presence of *Erytrina crista-galli*, the most widespread trees or shrubs in this region (Fig. 3). Species of Poaceae, represented by the genera *Briza, Imperata, Luziola, Panicum* are abundant too. On the shore of the river, *Polygonum hydropiperoides* and *Salvinia* are well represented. The abundance of Cyperaceae species (*Scirpus californicus* and *S. marimus*) is insignificant. The family Asteraceae, less numerous and various, is represented by species of *Baccharis, Conyza,* and *Senecio bonariensis.* Within the humid part of this wetland, *Ludwigia* sp. and *Typha domingensis* occur (Tab. 1). The arboreal plants such as *Eucalyptus* sp. and *Salix* sp. are introduced in areas, adjacent of the studied area. In some places, introduced *Rhizophora* sp. (Araceae) occurs.

TABLE 1 – List of the most frequent plant taxa identified in the studied area and their correspondence to the Braun-Blanquet abundance-dominance indices.

Taxa	Braun-Blanquet indices
Tree and shrub taxa	2
Erytrina crista-galli	2
Herbaceous taxa	5
Eryngium	3
Ludwigia	1
Polygonum hydropiperoides	1
Typha dominguensis	1
Cyperaceae	2
Poaceae	2
Other herbaceous taxa	3

The full list of identified plant taxa from this wetland and the comparison between pollen and spore taxa recognized in surface sediments and the vegetal cover is given in Table 2. Introduced plants, such as *Eucalyptus* sp.*, Pinus maritima, Salix* sp. and Cereales*,* widespread in this region, are not included.

Palynomorphs from subaerial sediments

These sediments, represented by sandy soils, were observed in samples 1-3. The pollen of arboreal plants and shrubs (AP) makes up about 20.3-34.9%. The pollen of herbaceous plants (NAP) accounts for 36.7-60.0%. The pollen percentages of aquatic plants (NAP aquatic) are varying between 3.2-18.9%. The quantity of Bryophyta and Pteridophyta spores is insignificant, approximately 2-5% (Fig. 4).

The pollen grains of *Erytrina crista-galli* predominate (9.4-12.2%) between the arboreal plants and shrubs, whereas the pollen of *Alchornea* is less abundant (0.2-2.2%). The pollen of introduced plants comprises *Eucalyptus* (2.8-5.1%), *Salix* (0.6-1.3%) and *Pinus* cf. *maritima* (3.2-13.4%) (Tab. 3). The pollen of Apocynaceae, Anacardiaceae, Annonaceae, cf. Ebenaceae, *Ephedra, Ilex,* Lauraceae, Mimosaceae, Palmae, *Rapanea, Smilax* is rare, and occurs usually as isolated pollen grains.

In regard to herbaceous plants, the pollen of Poaceae is abundant (13.1-32.1%). The pollen of *Eryngium* makes up 5.0-12.1%, Amaranthaceae-Chenopodiaceae (2-6%), Asteraceae (1.1-9.4%), Brassicaceae (0-1.3%), Verbenaceae (0-2.7%). The pollen of Cereales, cultivated plants, differs from the other Poaceae in morphology and size. In the studied samples, it accounts for 1.1-2.2%. Rare pollen of other herbaceous plants, such as *Alternanthera,* Amaryllidaceae, Brassicaceae, Convolvulaceae, Dipsacaceae, Euphorbiaceae, Malvaceae, Primulaceae, Scrophulariaceae, Solanaceae, Valerianaceae, and Verbenaceae are observed (Tabs. 2, 3). The pollen of aquatic plants is represented by various species of Cyperaceae (1.3-15.6%), Onagraceae, *Ludwigia* (0.2-3%), and Typhaceae (0.2-1.3%).

The spores of Pteridophyta and Bryophyta are rare; they are represented by various species of *Anthoceros* (0-0.7%), *Phaeoceros* (0-0.2%), *Blechnum* (0-2.6%), *Dicksonia* (0-0.2%), *Dicranoglossum* (0-0.2%), and *Microgramma* (0-0.6%). All three samples of sandy soil contain algal zygospores (Chlorophyta – 2.0-5.6%) (Tab. 3). Rare colonies of *Botryococcus* (0-1.3%), zygospores of *Debarya* (0-0.3%), *Zygnema* (0-0.9%), and *Mougeotia* (0.2-0.7%), coenobias of *Pediastrum* (0-0.7% are registered. The zygospores of *Spirogyra* (0.7-1.3%) are always present in all samples (Tab. 4). Fungal spores (6.7-8.8%), represented by diverse morphological types, are found in all studied samples.

TABLE 2 – Comparison of the available plant taxa of the southern part of the estuary of the Patos Lagoon, established by Cordazzo & Seeliger (1995) and Seeliger (1992) with pollen and spores, identified from surface sediments and vegetation cover of studied wetland: (+ = present, – = absent).

Plant taxa	Pollen and spores	Vegetation cover
Bryophyta		
Anthoceros	+	–
Phaeoceros	+	–
Pteridophyta		
Azolla filiculoides Lam.	+	–
Blechnum sp.	+	–
Dicksonia sp.	+	–
Dicranoglossum sp.	+	–
Equisetaceae	+	–
Microgramma sp.	+	–
Polypodiaceae	+	–
Salvinia sp.	+	+
Magnoliophyta		
Alchornea sp.	+	–
Alismataceae	+	+
Alternanthera sp.	+	+
Amaranthaceae	+	+
Amaryllidaceae	+	+
Anacardiaceae	+	–
Annonaceae	+	+
Apiaceae	+	+
Asteraceae	+	+
Brassicaceae	+	+
Bromeliaceae	+	+
Chenopodiaceae	+	+
Convolvulaceae	+	+
Cyperaceae	+	+
Dipsacaceae	+	–
Ephedra sp.	+	–
Eryngium sp.	+	+
Erytrina crista-galli L.	+	+
Euphorbiaceae	+	+
Fabaceae	+	+
Gentianaceae	–	+
Gunneraceae	–	+
Hypericaceae	–	+
Ilex sp.	+	–
Iridaceae	–	+
Juncaceae	–	+
Juncaginaceae	+	–
Lauraceae	+	–
Malvaceae	+	+
Menyanthaceae	–	+
Mimosaceae	+	–
Onagraceae (*Ludwigia*)	+	+
Orchidaceae	–	+
Plantaginaceae	–	+
Poaceae	+	+
Polygalaceae	–	+
Ponteridaceae	+	+
Primulaceae (*Anagallis*)	+	+
Rosaceae	–	+
Solanaceae	+	+
Typhaceae	+	+
Valerianaceae	+	+
Verbenaceae	+	+

TABLE 3 – Palynomorph percentages and total sum of counted palynomorphs from sandy soil (1-3) and fluvial sediments (4, 5) samples from the studied area (AP – arboreal pollen, NAP – nonarboreal pollen, NAP aquatic – nonarboreal pollen of aquatic plants, S – spores of mosses and ferns).

Taxa	samples				
	1	2	3	4	5
AP					
Alchornea sp.	2.2	0.2	1.3	0.7	2.9
Apocynaceae	–	0.2	–	–	–
Anacardiaceae	–	0.5	1.3	–	–
Annonaceae	0.6	0.2	–	–	–
cf. Ebenaceae	0.6	–	0.9	–	0.4
Erytrina crista-galli	12.2	9.4	10.1	0.4	0.7
Eucalyptus	2.8	5.1	4	2.1	0.7
Ephedra	–	0.2	–	–	–
Fabaceae	1.1	–	1.3	–	–
Ilex sp.	–	0.2	–	–	–
Lauraceae	0.6	0.2	–	–	–
Mimosaceae	0.6	–	1.3	–	–
Palmae	–	0.2	–	–	–
Pinus cf. *maritima*	3.3	3.2	13.4	2.5	0.7
Rapanea	–	–	–	–	0.4
Salix	0.6	0.9	1.3	–	–
Smilax	1.1	0.2	–	–	–
Total (%)	25.6	20.3	34.9	5.7	5.8
NAP					
Alternanthera	1.1	–	1.3	16.4	–
Amaryllidaceae	–	–	0.7	-	–
Amaranthaceae-Chenopodiaceae	1.7	6.0	2.0	5.3	13.1
Apiaceae	1.1	0.2	0.7	5.3	–
Asteraceae	1.1	9.4	1.3	0.4	0.3
Brassicaceae	1.1	–	1.3	0.4	0.3
Bromeliaceae	1.1	0.2	–	–	0.7
Cereales	1.1	2.2	2	2.8	1.8
Convolvulaceae	1.1	–	–	–	–
Dipsacaceae	1.1	0.2	0.7	0.4	–
Eryngium	5.5	5.0	12.1	5.3	2
Euphorbiaceae	–	0.2	0.7	0.4	–
Malvaceae	1.1	–	0.7	–	0.7
Poaceae	14.5	32.1	13.1	1.8	18.6
Polygonaceae (*Rumex*)	1.1	–	–	–	–
Polygonum hydropiperoides	1.1	4.0	0.7	3.6	4.7
Primulaceae	–	0.2	–	0.7	0.4
Scrophulariaceae	1.1	–	0.7	0.4	–
Solanaceae	1.1	–	0.7	1.8	2.4
Valerianaceae	–	0.2	–	0.4	0.9
Verbenaceae	–	–	2.7	0.4	5.1
Total (%)	36.7	60	43.3	46.3	51

TABLE 3 (Cont.)

Taxa	samples				
	1	2	3	4	5
NAP aquatic					
Alismataceae	–	–	–	1.4	0.9
Cyperaceae	15.6	1.3	5.7	14.2	8.9
Onagraceae (*Ludwigia*)	1.1	0.2	3.0	2.1	0.9
Ponteridaceae	1.1	1.5	–	2.1	1.8
Typhaceae	1.1	0.2	1.3	1.4	0.9
Total (%)	18.9	3.2	10	21.2	13.4
S					
Anthoceros	–	0.7	–	–	0.2
Azolla filiculoides	–	0.7	–	0.4	0.9
Blechnum	2.6	0.4	–	–	–
Dicksonia	–	0.2	–	–	0.2
Dicranoglossum	–	0.2	–	–	0.9
Dicranopteris	0.6	0.2	–	–	–
Microgramma	0.6	0.2	–	–	0.9
Phaeoceros	0.6	0.2	–	0.4	–
Polypodiaceae	0.6	–	2	–	–
Salvinia	–	0.2	–	0.4	2.7
Pterideae	–	–	–	0.4	0.2
Total (%)	5	3	2	1.2	6
Fungi (%)	8.8	6.7	7.8	1.2	1.4
Algae (%)	5.0	5.6	2	22.8	22.4
Total of counted palynomorphs	180	448	149	281	451

Palynomorphs from fluvial silty sand sediments

The palynological data obtained from two fluvial sediment samples are different from the three samples of subaerial sediments by the following aspects: a) a low number and diversity of pollen of arboreal plants; b) a high variety and number of pollen of herbaceous and aquatic plants; c) a low variety and quantity of zygospores of green algae; d) a low proportion of fungal spores (Tab. 3). The pollen of arboreal plants (AP) makes up 5.7-5.8%; herbaceous plants (NAP), 46.3-51.0%; herbaceous aquatic plants (NAP aquatic), 13.4-21.2% (Tab. 3). The pollen of arboreal plants is represented by rare *Alchornea* (0.7-2.9%), *Erytrina crista-galli* (0.4-0.7%), and the pollen of introduced *Eucalyptus* (0.7-2.1%), and *Pinus* cf. *maritima* (0.7-2.5%).

The pollen of Poaceae varies from 1.8 to 18.6%. The pollen of *Eryngium* accounts for 2-5.3%. The pollen of other herbaceous plants is represented by various species of Asteraceae, Brassicaceae, Primulaceae, Solanaceae, Valerianaceae, Verbenaceae, and others. Pollen of xerophylous and halophylous species of Amaranthaceae-Chenopodiaceae makes up to 5.3-13.1%. A significant increase in the percentage and variety of aquatic plants is observed. The total sum of pollen of aquatic plants is 21.2%. The pollen of *Polygonum hydropiperoides* predominates (3.6-4.7%). The pollen of other aquatic plants is represented by Alismataceae (0.9-1.4%), Cyperaceae (8.9-14.4%), Onagraceae, *Ludwigia,* (0.9-2.1%), Ponteridaceae (1.8-2.1%) and Typhaceae (0.9-1.4%). Spores of aquatic ferns are represented by *Azolla filiculoides* (0.4-0.9%) and *Salvinia* (0.4-2.7%). The pollen of cultivated Cereales makes up 1.8-2.8%.

The silt and silty sand samples are characterized by constant presence and relate abundance of zygospores, colonies and coenobias of green algae, Chlorophyta (22.4-22.8%) (Tab. 3). The zygospores of Zygnemataceae are represented by *Spirogyra*

(5.9-9.6%), *Mougeotia* (0-5.3%), *Debarya* (3.6-4.0%), and *Zygnema* (0.7-0.9%). The coenobias of Chlorophyceae are less frequent, only species of *Pediastrum* (3.1-3.5%) are detected. In one sample, the coenobia of *Chara* (Charophyceae) composes up to 0.2% (Tab. 4).

The samples from fluvial sediments contain lower percentages of fungal spores 1.2-1.4% in comparison with suabaerial sediments.

Using the index of representativity, we try to evaluate the relationship between the predominant pollen grains in the samples and the most abundant plants of the vegetation cover of wetland (Tab. 5). The fact that every group of plants, according to different index values may be over, equi or under-represented is obvious from the R/P ratio in Table 5, where R is the plant species percentage in vegetation cover, P – pollen percentage in the sample. In this table, only pollen grains and spore ("pollen sum") are taken into consideration. There were avoided any other palynomorphs (zygospores, colonies, coenobiams of algae and fungal spores).

The representativity index of the widespread trees of *Erytrina crista-galli* (0.7-20) may be considered as equi- and under-represented. *Eryngium* is another widespread plant with an representativity index of 3-7.6. The widespread aquatic plant, *Polygonum hydropiperoides* is characterized by varying indices, suggesting that this pollen may be over, equi- and under- represented in various samples (0.7-3.7). The indices of the analyzed pollen of other wide spread plant taxa are also varying from over- to under-represented (Tab. 5). *Ludwigia* sp. and *Typha domingensis* are the most common taxa. The pollen of introduced plant *Rhizophora* (Araceae) was not encountered in our examinated material.

TABLE 4 – Percentages of zygospores, colonies and coenobias of Chlorophyta in surface soil (samples – 1-3) and fluvial sediments (samples – 4, 5) from the studied wetland area.

Genera	samples				
	1	2	3	4	5
Botryococcus	–	1.3	–	–	–
Chara	–	–	–	–	0.2
Debarya	1.2	0.3	–	3.6	4.0
Mougeotia	1.7	0.2	0.7	5.3	0.2
Pediastrum	0.7	–	0.7	3.6	3.1
Spirogyra	0.2	1.3	0.7	9.6	5.9
Zygnema	–	0.9	–	0.7	0.9

TABLE 5 – Vegetation cover percentages (R, %) and vegetation cover/pollen (R/P) indices of representativity of the main taxa in the studied wetland. (P_{1-5} – pollen taxa, %, in the samples (1-5).

Taxa	R(%)	R/P_1	R/P_2	R/P_3	R/P_4	R/P_5
Arboreal plants	10	0.4	0.4	0.2	1.3	1.3
Herbaceous plants	90	1.4	1.3	2.4	1	1
Erytrina crista-galli	10	0.7	1	0.6	20	11
Eryngium	40	5.7	7.6	3	6	4.7
Polygonum hydropiperoides	3	2.3	0.8	3.7	0.7	0.5
Ludwigia	3	2.3	15	0.7	1.1	1.8
Typha domingensis	3	2.3	15	2	1.5	2.5
Poaceae	10	0.5	0.3	0.7	4.3	0.5
Cyperaceae	10	0.5	6.6	1.4	0.6	0.9
Other herbaceous taxa	11	*	*	*	*	*

* not counted.

DISCUSSIONS AND CONCLUSIONS

All identified pollen and spores of terrestrial and aquatic higher plants from the superficial samples were compared with botanical data on characteristics of wetland vegetation cover. The differences between palynological and botanical data may be caused by the different pollen productivity, dispersion capacity, favorable or unfavorable deposition and conservation conditions. The relatively low frequency of pollen in comparison with the recent plant predominance in wetland can be explained by small pollen productivity of plants and lower dispersal power of pollen.

The spores of Bryophyta and Pteridophyta in surface sediments of all examined samples are more various than those observed in wetland vegetation cover (Tabs. 2, 3). In surface samples from sandy soil, they are more diverse, than in fluvial sediments. The spores of *Blechnum* are present in the sandy soil and may be descendant from the areas adjacent to the studied wetland. The spores of aquatic ferns represented by *Salvinia* and *Azolla filiculoides* are in accordance with the presence of this species in the vegetation cover of the studied wetland.

Increased quantity of *Erytrina crista-galli* pollen is observed in sandy soil, especially in the sample collected directly near the tree. Lower percentage of this species is detected from fluvial sediments, suggesting a relatively low capacity of *E. crista-galli* pollen for transport. This fact may be reason of low frequency of subfossil pollen of this specie in Holocene sediments.

Low frequency of pollen grains o*f Eryngium* in surface sediments does not correlate with the predominance of this plant in stdied wetland and wide spreading of this plant in vegetation cover of wetlands in the Coastal Plain of Rio Grande do Sul State. Probably, it is explained by small pollen reproductivity of this plant and low dispersion capacity of pollen.

Polygonum hydropiperoides is characterized by high pollen productivity. Its pollen presents in all studied samples. The varying representativity indices suggest that this pollen is over, equi- and under- represented in various samples. This pollen is likely to be encountered in the Holocene sediments of any widespread wetland.

The presence in all samples of the pollen of introduced arboreal plants widespread in adjacent areas, such as *Eucalyptus, Pinus* cf. *maritima* and *Salix* can be explained by high pollen productivity of these plants and their high dispersion capacity.

The percentage composition and distribution of palynomorph taxa from fluvial and subaerial sediments are differed. Fluvial sediments, represented by sandy silt or silty sand in comparison with terrestrial sandy soil, are characterized by a higher taxonomic diversity and percentage of pollen and spores of terrestrial plants, especially pollen of herbaceous plants (Tab. 3). In fluvial sediments, more quantity and variety of pollen of aquatic plants (Alismataceae, *Azolla filiculoides,* Cyperaceae, *Ludwigia*, *Typha domingensis*) are observed. In subaerial sediments, the content and variety of Pteridophyta, Bryophyta and fungal spores increase. High quantity and variety in pollen-taxa in fluvial sediments are evidence of favorable conditions for conservation of palynomorphs (without access of oxygen) and presence of allochthonous pollen and spores from neighboring regions.

All of the studied sediments are characterized by a constant presence of pollen of xerophylous and halophylous species of Amaranthaceae-Chenopodiaceae, which have not been found in the actual vegetation cover. These species, according to Cordazzo and Seeliger (1995), are usually encountered on the dunes surrounding the estuarine part of the Patos lagoon. The presence of this type of pollen both in fluvial, and in subaerial sediments can be easily explained by a high pollen productivity these plants and the pollen dispersion capacity by wind and water streams over large distances, in agreement with with Monoszon (1979).

In addition to pollen and spores of terrestrial and aquatic plants, the zygospores, colonies and coenobias of green algae (Chlorophyta) are present in all studied samples. They, less abundant and diverse, represented by species of *Botryococcus, Debarya, Mougeotia, Pediastrum, Zygnema,* and *Spirogyra,* are encountered in the surface samples of recent sandy soil. Their presence in the subaerial sediments of wetland is easily explained by transportation by ephemeral streams during the pluvial periods.

In surface fluvial sandy silt samples, the algal spores increase in number and taxonomic diversity. Except *Botryococcus,* all above mentioned freshwater species are frequent in fluvial sediments. Sometimes, *Chara* appears. The subrecent green algae zygospore, colonies and coenobias taxa, recognized in the surface sediments in the studied wetland area coincide with the phycological data on the present-day Chlorophyta distribution in the Coastal Plain of Rio Grande do Sul, as reported by Torgan *et al.* (2001).

Fungal spores are frequent and more diverse in sandy soil and rarer in sandy silt samples (Tab. 3). This fact confirms the relatively low dispersion capacity of fungal spores, which are therefore more likely to be found in subaerial sediments, than in fluvial ones.

The described palynomorph assemblages resemble with the palynomorph assemblages from Holocene sediments in the Coastal Plain of Rio Grande do Sul (Lorscheitter, 1984; Cordeiro & Lorscheitter, 1994; Medeanic *et al*., 2001), proving the existence of wetlands in the past, which decreased or increased, dependinding on climatic oscillations.

The obtained palynological data generally correspond to the actual native vegetation cover of the selected wetland area in the south of the Coastal Plain of the State of Rio Grande do Sul. Some discrepancies may be caused by the different pollen productivity of plants, differences in pollen and spore capacity to transport, and the specific morphologic features that account for good or poor conservation in sediments.Our observations suggest of a generally close relationship between local taxonomic plant composition of wetland and the pollen and spores assemblages buried in sediments.

Some herbaceous plants in this region exhibit a low pollen productivity combined with its low dispersion capacity and are relatively rare in surface sediments.

The surface soil sediments are characterized by low pollen and spores concentration in sediments and their relatively low taxonomic diversity with a constant presence of the spores of fungi. The predominance and elevated diversity of fungal spores have been observed in sandy soil.

The fluvial sediments include more variable and numerous palynomorphs represented by the pollen and spores of terrestrial and, especially, aquatic plants but contain a small quantity of fungal spores, obviously as a result of their poor transportability.

The obtained data are important for the palaeoenvironmental reconstruction of wetland development on the Coastal Plain during the Holocene, when climate and sea-level changes induced changes in vegetation from time to time. These data may be applied for the reconstruction of native wetland distribution on the Coastal Plain of Rio Grande do Sul during the Holocene and for comparisons with actual wetlands, subjected to anthropogenic disturbance.

It would be useful to continue such studies on palynomorph distribution in surface sediments from the different localities. It may improve our understanding of palynomorph deposition of different ecosystems and establish of their correspondence to lithological characteristic of sediments for the Holocene paleoenvironmental reconstructions.

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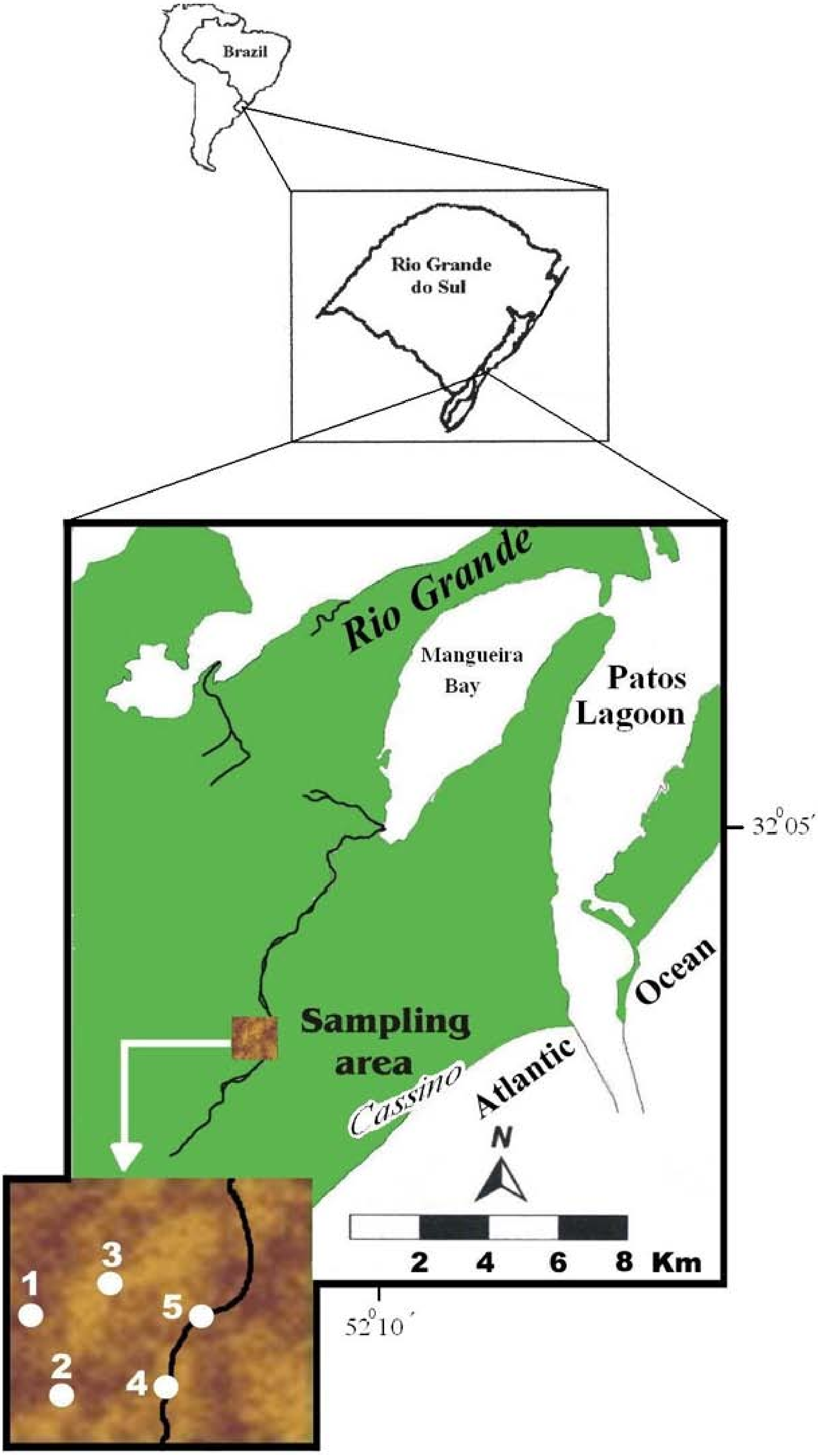


Fig. 1. Map, showing the location of studied wetland area on the margin of the Patos lagoon.

Fig. 2. **T**he Bolasha River at the studied area and the red flowering tree of *Erytrina crista-galli.*

Fig. 3. The wetland area where *Eryngium* predominates.

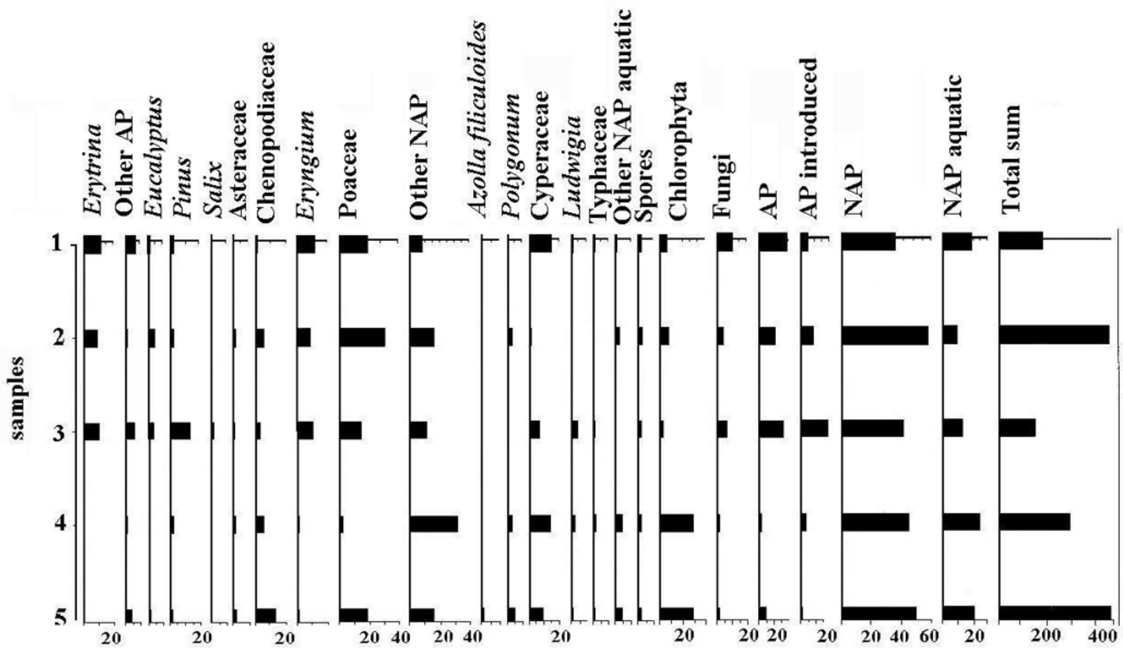
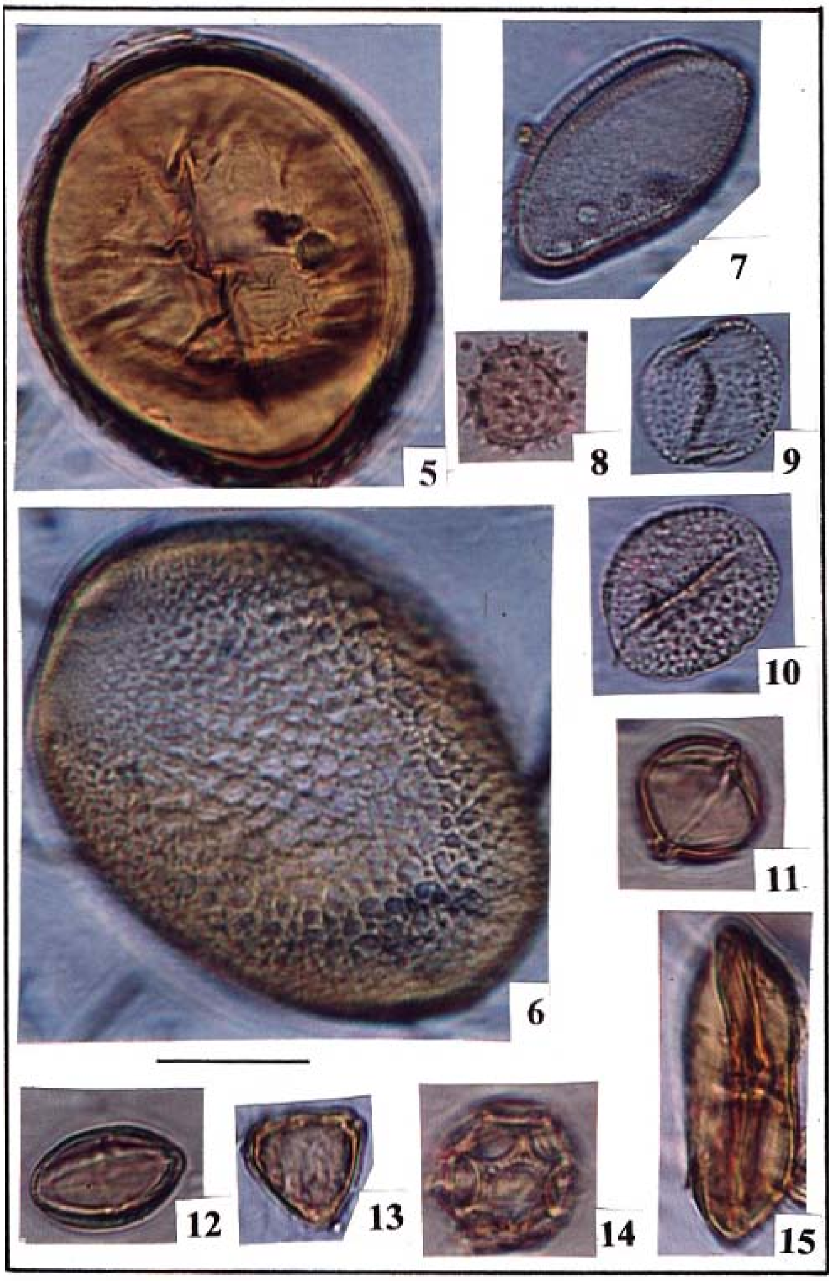
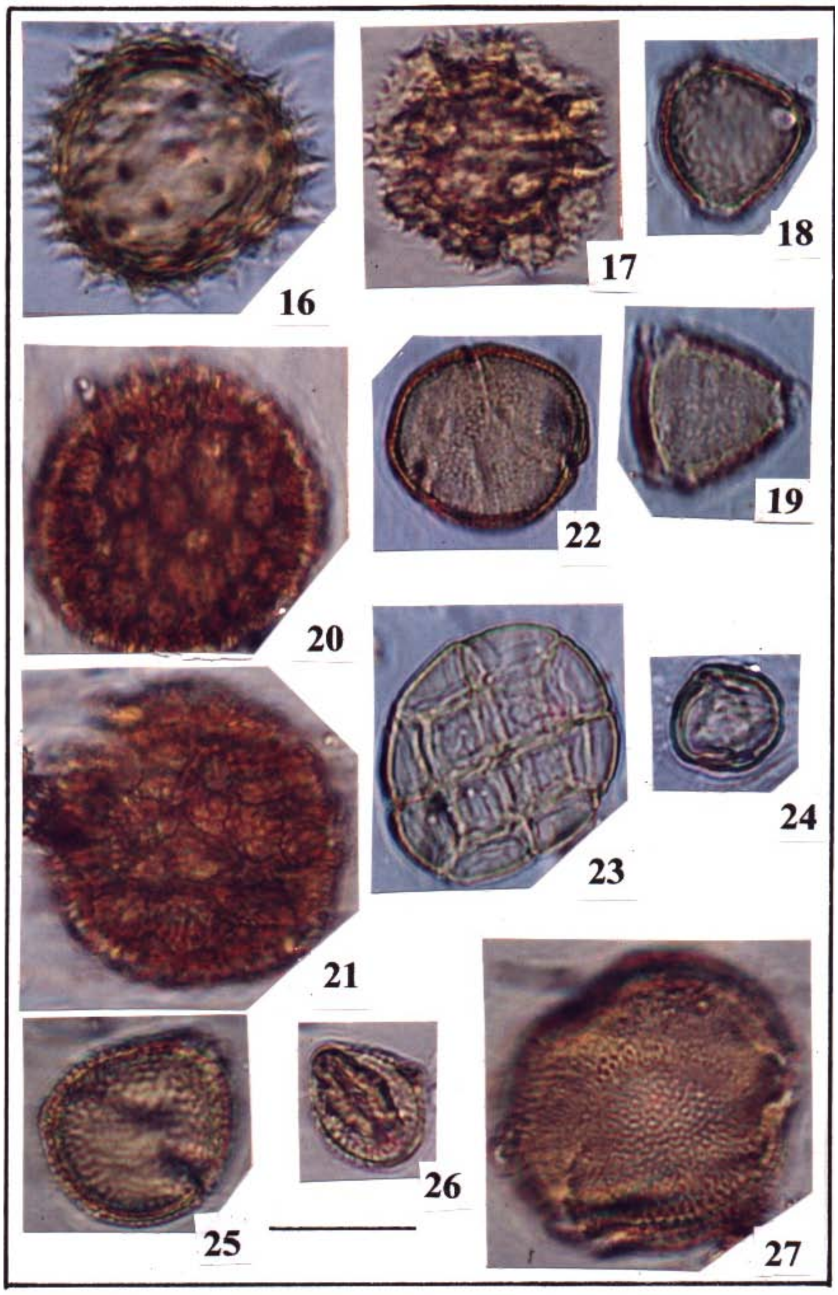


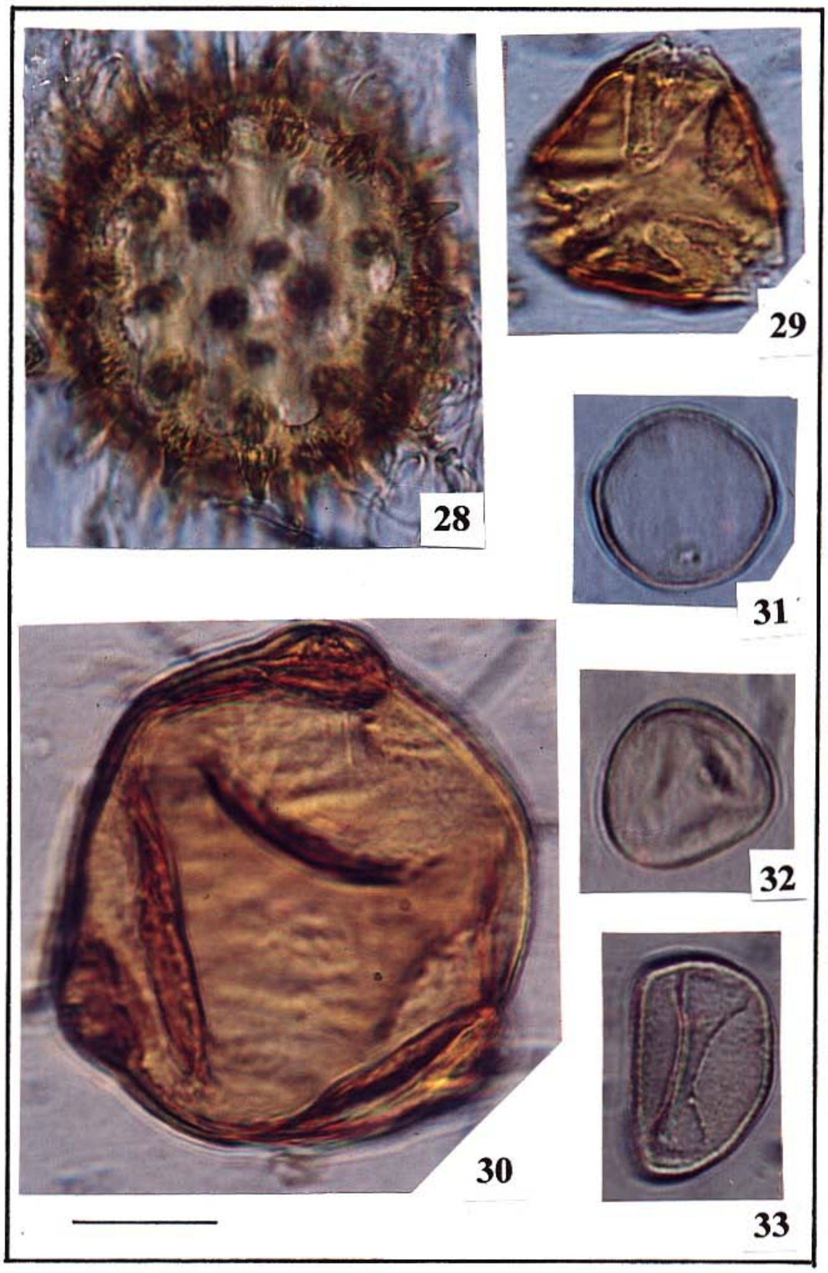
Fig. 4. Palynomorph percentage diagramme of the surface samples (1-5) from the studied wetland area. X axis = percentage of identified palynomorph taxa, Y axis= studied samples.



Figs. 5-15. LM. **5.** Blechnaceae, *Blechnum* type; **6.** Amaryllidaceae type; **7.** Alismataceae type; **8.** Asteraceae, *Bacharis* type; **9.** Cyperaceae type; **10.** Bromeliaceae type; **11.** Solanaceae type; **12.** Apiaceae type; **13.** Myrtaceae, *Eucalyptus* type; **14.** Amaranthaceae, *Alternanthera* type; **15.** Apiaceae, *Eryngium* type. Scale: 20 µm.



Figs. 16-27. LM. **16.** Asteraceae, *Senecio* type; **17.** Asteraceae, *Vernonia* type; **18, 19.** Fabaceae, *Erytrina crista-galli*; **20, 21.** Polygonaceae, *Polygonum hydropiperoides* type; **22.** Polygonaceae, *Rumex* type; **23.** Mimosaceae type; **24.** Primulaceae type; **25.** Typhaceae, *Typha domingensis* type; **26.** Scrophulariaceae type; **27.** Convolvulaceae, *Convolvulus* type. Scale: 20 µm.



Figs. 28-33. OM. **28.** Malvaceae type; **29.** Verbenaceae type. **30.** Onagraceae, *Ludwigia* type; **31, 32.** Poaceae type; **33.** Palmae type. Scale: 20 µm.