

LAGOA DE SANTO ANDRÉ (SW PORTUGAL): PHYTOPIGMENTS AS SEDIMENTARY TRACERS

L. Cancela Da Fonseca*; A. M. Costa**; J. M. Bernardo** y R. Fonseca***

* Dept. Zool. Antropol., Fac. de Cienc. Lisb., Lab. Marit. Guia, P-2750 Cascais

** Dept. Ecologia, Univ. Evora, P-7000 Evora

*** Laboratório Marítimo da Guia, P-2750 Cascais

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ABSTRACT

During the last years, the study of chlorophyll *a* and its derivatives is increasingly used in the understanding of productivity phenomena of aquatic sediments. St. André is a coastal brackish lagoon, with large amounts of organic matter in the surface sediments. This paper deals with phytopigments, organic matter (loss on ignition), water content and granulometry of the sediments. Two distinct zones of productivity are closely related with the main sediment types: sands and muds. Phaeopigments correlate well with organic matter emphasizing its vegetal origin. Muds present a larger pigment concentration but it seems that also in the sandy zone production prevails over sedimentary processes.

INTRODUCTION

In recent years, the study of chlorophyll *a* and its derivatives have been increasingly used in the understanding of microphytobenthos productivity (Plante Cuny, 1977, 1979; Colijn & Jonge, 1984). Many authors have reported sedimentary processes of chlorophyll *a* and its decaying products (Sanger & Gorham, 1972; Shuman & Lorenzen, 1975; Brown *et al.*, 1977; Birch *et al.* 1980).

Benthic food chain of lagoons starting with microphytobenthos have a significant function on systems dynamics (Plante - Cuny, 1977).

Bottom pigments from microphytobenthos,

sunken phytoplankton, macrophytes and organic detritus deposition, have shown to be useful tracers of important phenomena in aquatic ecosystems (Fogg & Belcher, 1961; Daley *et al.* 1977; Reynolds *et al.* 1982; Duxin, 1984).

Recently, microbenthic photosynthesis was related to eutrophication processes and biogeochemical dynamics at the sediment level (Sundback, 1986; Graneli & Sundback, 1986).

Usually, the benthic phytopigments are studied from a paleolimnologic point of view as some of them persist through time as biochemical

fossils (Brown et al., 1977). They can often describe past environments (Lubienko & Rauser-Cernoussova, 1930; Fox & Anderson, 1941; Vallentyne 1954, 1955; Vallentyne & Crastow, 1957; Carpenter, 1986). From this point of view the interpretation of the past depends on the knowledge of present situations (Selley, 1976).

Detritus accumulating and non accumulating zones can be detected by sedimentary pigments. The origin of bottom organic matter is also detectable.

Santo André is a brackish water coastal lagoon located on the SW coast of Portugal, separated from the sea by a sand barrier. The main phenomena in its annual cycle are precipitation (November to March) and the artificial connection to the sea (usually in early Spring, after the more intense run-off period, when the water level reaches its maximum).

In 1981 and 1982, the lagoon was permanently isolated. In 1983 the connection with the sea was formed very late in the year (July). No effective washing process took place and extreme eutrophication extended throughout the lagoon. After 1984, the inlet was opened every year at the right period (March). The 1984 opening period was very short. This fact may be related with unfavorable sea conditions and insufficient water in the lagoon. In 1985, with a large water volume and no storm tides, the lagoon was connected to the sea for one and a half months.

Since 1984 a research project has been carried out concerning water, sediments, benthic and fish communities.

This study concerns grain-size distribution of surface sediments and its relations with water content, phytopigments and loss on ignition as an organic matter approach.

METHODS

Samples from 17 sampling points (Fig. 1) were taken each month from February 1984 to May 1985. During this period the connection with the sea was formed twice – March 1984, March-April 1985. For this study 9 months data was considered – February, March, April, July, September, October 1984 and February, March, May 1985.

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A modified Van Veen grab (0.05 m² – Sousa Reis model, L.M.G. 1983) was used. Two subsamples were separated: 1) a 10 cm section for the grain-size study; 2) and an upper layer (1 cm) for water content, organic matter and phytopigments analysis (aliquotes frozen at –20°C).

Methods used were:

- 1) – Separation of mud (>62µ), sand (62µ–2000µ) and gravel (>2000µ) by wet sieving (Buller & McManus, 1979).
 - Determination of sand grain-size distribution by dry sieving in the size grade –20 to 40 Wentworth scale, after destruction of organic matter (H₂O₂, 130 vol.).
- 2) – Estimate of sediment organic matter content (OM) by loss on ignition (450°C and 650°C during a 24hr period).

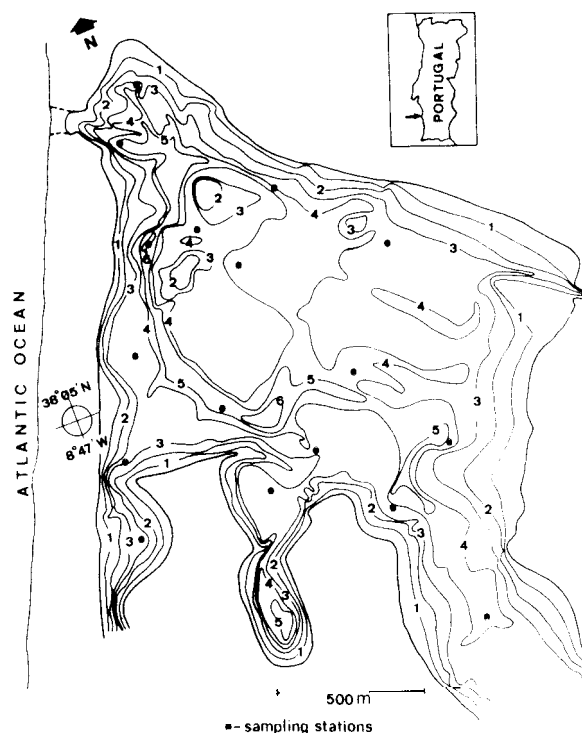


Figure 1. – St^o André Lagoon: February 1985 bathymetric survey.

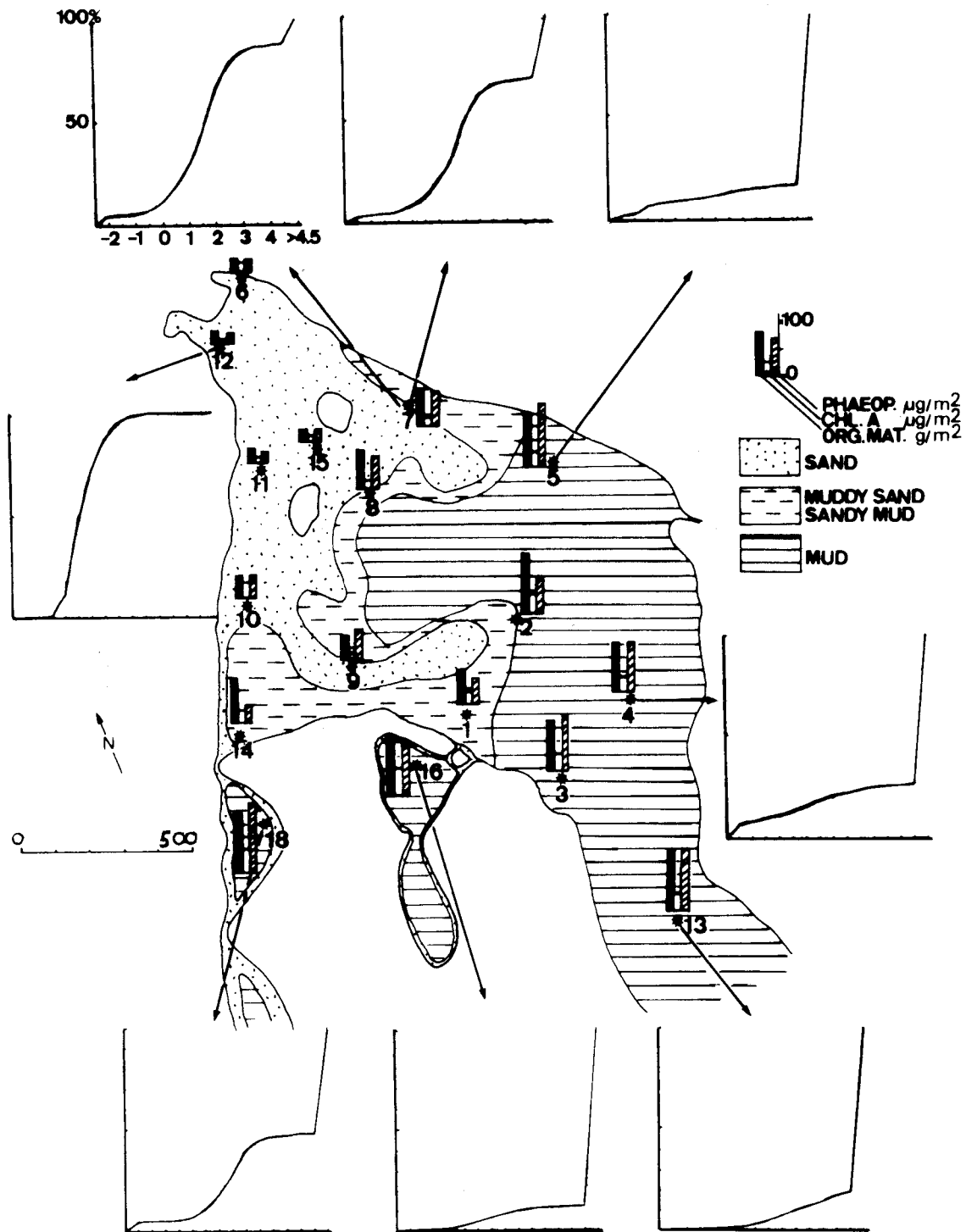


Figure 2.-St^e André Lagoon: lithofacies, distribution of chlorophylla, phaeopigments and organic matter and representative average cumulative frequency curves.

- Sediment water content estimation (%H₂O) by 24hr drying at 65°C.
- Evaluation of phytopigments concentration by spectrophotometry after 24 hr, cool extraction in 90% acetone.

Chlorophyll a (chl_a) and phaeopigments (phaeop) concentrations (g/g dry sediment) were calculated by modified Lorenzen equations (Planete-Cuny, 1974).

Abs₄₁₀ (Abs_{410nm}-Abs_{750nm} x acet. vol./ weight dry sediment) and Abs_{430nm}/Abs_{410nm} (Moss, 1967) were calculated.

To obtain phytopigment values per unit area (mg/m²) from phytopigment values per weight (µg/g), a sediment specific weight was developed. Linear regression and correlation analysis was established between water percentage of several types of sediment and its respective sediment specific weight.

Cluster analysis (Bravais-Pearson coefficient and the single linkage clustering method) was used to group parameters and stations.

In order to summarize the information Principal Components Analysis (PCA) was utilized on the average values of parameters for each sampling point. Data analysis was performed at Laboratório Mantimo da Guia with programs by Andrade (1986). Echo-sounding was used for the bathymetry. Transects were taken in February 1985 when water reached maximum level for the study period.

RESULTS

Annual average depth is 1.78m. Maximum depth occurred in February 1985-4.02m average depth- when the bathymetric survey was carried out (Fig. 1). A channel, approximately 2m deeper than the rest of the lagoon, is the ancient river bed of an estuary. This channel is intensively washed when the lagoon is subject to tidal action.

From the results of grain-size analysis, the distribution of lithofacies was mapped (Fig. 2). Organic matter content, chlorophylla and phaeopigments and cumulative curves of sediment are also presented in Fig. 2.

Average grain-size decreases from areas influenced by the sea, near the sand bar, to the interior, where deposition of finer particles predominantly takes place (Fonseca, 1985).

Along the annual cycle, the grain size modifications of the mud stations correspond, almost exclusively, to the coarser fraction (mainly bioclasts).

Energy and transport changes result in grain-size variation increase of fines or coarse material. These processes are related to the entry of silts and clays, macrophyte decomposition and communication with the sea.

Cluster analysis discriminates two main groups of sampling stations - sands and muds. The composition of each group is considerably constant when comparing each month analysis.

The same multivariate treatment applied to parameter monthly data showed a remarkable persistence of group composition. Due to this fact we considered the parameters average values for the cluster analysis and the PCA treatment.

Cluster analysis on the averages values of parameters (Fig. 3) shows an inverse correlation (p<0.05) between sand percentage, 430/410 and all the other parameters. Chlorophyll a, phaeopigments, Abs₄₁₀, OM 450, OM 650, and water percentage are positively correlated with mud percentage (p<0.001) and with Margalef's index (p<0.05).

In Axis 1 of PCA (Fig. 4) sand percentage opposes to mud percentage and all the other associated parameters except 430/410. Axis 2 mainly reflects the opposition between 430/410 and phaeopigments.

In Axis 1 several distinct groups of stations are sequentially placed, from sands to muds, with two intermediate situations:

- sands (stations 6, 11, 12 and 15)
- sand stations changing in time and becoming more or less muddy (stations 7, 9 and 10).
- muds changing to sandy muds in some periods (stations 1, 8 and 14).
- muds (stations 2, 3, 4, 5, 13) emphasizing the specific character of 16 and 18, located in the small lateral bays and so suffering much less the effect of the spinning washing process when ocean waters enter the lagoon.

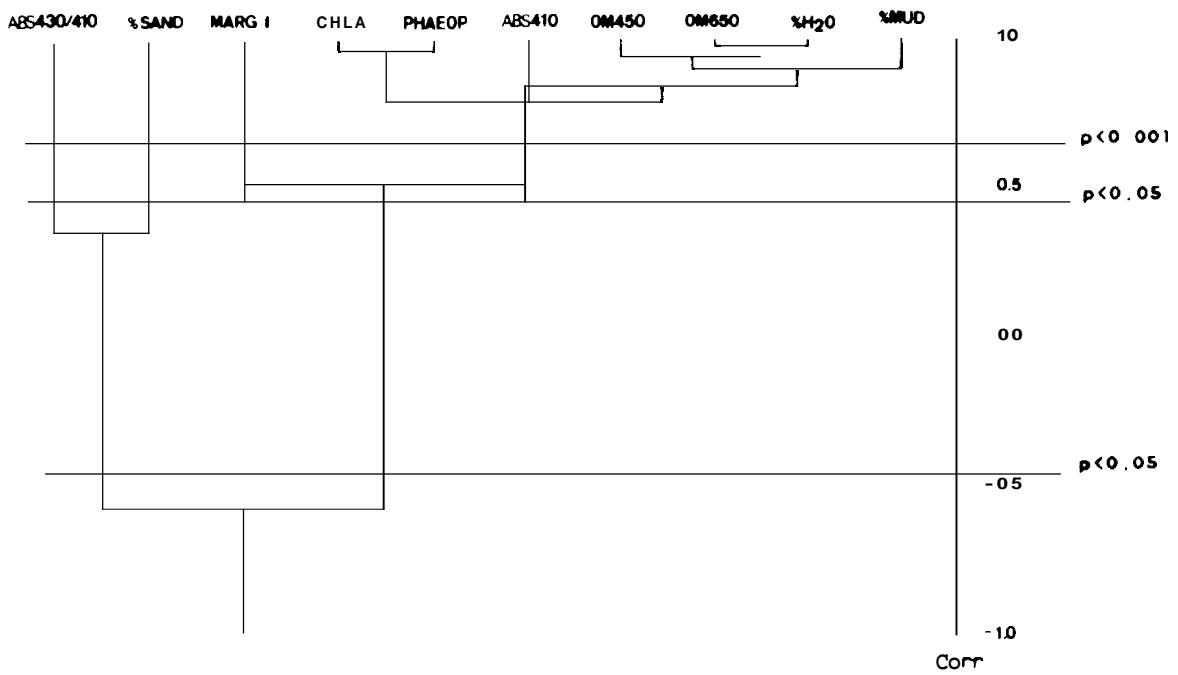


Figure 3.- Cluster analysis on sediment parameters (average values)

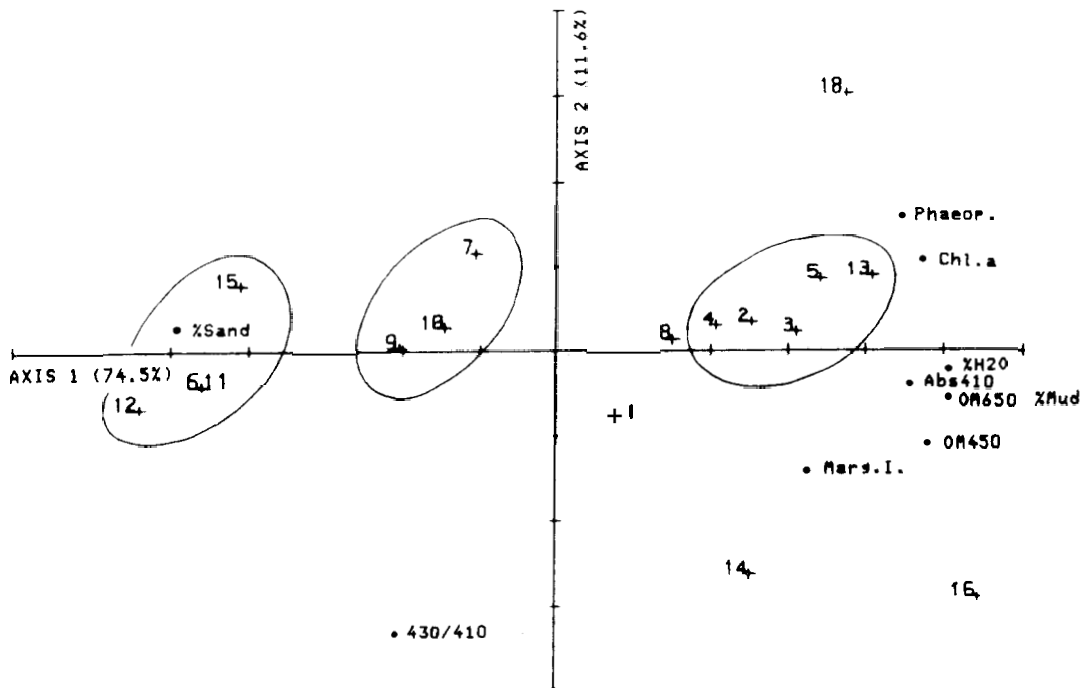


Figure 4.- Principal Components Analysis on sediment parameters (average values)

OM 450 and Om 650 are strongly correlated ($p < 0.001$) suggesting a similar distribution of the factors responsible for differences at the two temperatures (e.g. carbonates). Organic matter is generally high especially in mud sediments. There is a strong correlation ($p < 0.001$) between OM and mud %.

As with organic matter, sediment water content follows the grain-size variation, being positively correlated ($p < 0.001$) with mud % and negatively ($p < 0.001$) with sand %.

The regression line between sediment water content (13%-83%) and its dry specific weight (DSW) is expressed by:

$$DSW = -0.023 \times \%H_2O + 2.043$$

$$(n=12, r^2=0.99)$$

Phytopigments, both chlorophylla and phaeopigments, are present in larger concentration in muds than in sands. Average values for sands are 52.6 mg/m² chl a and 126.8 mg/m² phaeop and for muds 256,6 mg/m² and 775,8 mg/m², respectively.

DISCUSSION

Sediment water content, because of its strong correlation ($p < 0.001$) with mud % and with sand %, undoubtedly represents an effective physical index. Its value is necessary for phytopigment determination and was used to obtain phytopigment concentration per unit area from concentration per sediment weight. Providing an excellent correlation with DSW it makes the diagnosis of sediment granulometric type possible. Very easily and rapidly obtainable it is a practical and useful instrument in sediment characterisation.

The position of 430/410 vector in PCA (Fig. 4), separated from mud and related parameters, and the negative correlation between 430/410 and mud and its grouping with sands in cluster analysis (Fig. 3), suggests the applicability of this ratio in the understanding of production-deposition processes, confirming Moss (1967). According to this author, 430/410 may be considered a productivity indicator. In sand areas of St André lagoon the degradation index is lower than in muds and

430/410 values are close to 1. For monthly results of 430/410 > 1, 64% were recorded in sands, 15% in sandy-muds and 21% in muds. These values confirm the fact that, when comparing productive processes with deposition ones, the former are relatively more important in sand than in mud stations. The ecological meaning of 430/410 ratio is supposed to be rather similar to Degradation index or Margalef's index, with 430/410, Moss (1967) pretended to get a chlorophyll/phaeopig-

Table I. Comparison of chl a data in coastal sediments

Loch Ewe - sand	3-20 µg/g	Steele* Baird (1978)'
Ythan Estuary - mud intertidal	25-34 µg/g	Leach (1970)*
South New England - mixed, intertidal	100 mg/m ²	Marshall <i>et al</i> (1971)*
Mediterranean - sand, >12m	24-64 mg/m ²	Colocoloff (1972)*
Chuchi Sea - mud and sand, >5m	40-320 mg/m ²	Matheka & Horner (1974)'
Wadden Sea - sandy-mud, intertidal	40-440 mg/m ²	Cadée & Hegeman (1977)'
Lynher Estuary - mud, intertidal	30-80 µg/g	Joint (1978)'
Ems Dollard Estuary - mud, intertidal	33-184 mg/m ²	Colijn & Yonge (1984)
Laholm Bay - sand & silty sand, >20m	5-75 mg/m ²	Sundback (1986)
Tejo Estuary - mud, intertidal	130-180 mg/m ²	Brotas & Catarino (1984)
Bretagne - mud, intertidal	19.5 µg/g	Riaux (1982)
Ebrié Lagoon - sand,	0.5m: 178 mg/m ² 5m: 6 mg/m ²	Plante-Cuny (1975)
Nosy-Bé - sand (5m) - muddy sand (5m)	11.95 µg/g 4.99 µg/g	Plante-Cuny (1977b)
St ^e André Lagoon - sand - mud	53.6 mg/m ² (2.18 µg/g) 256,6 mg/m ² (46.26 µg/g)	this study (average values)

* In Colijn & Yonge (1984)

ments ratio. however, no positive correlation was observed **between** them (Fig. 3).

The division of sediments in rich **organic** and productive muds and clean, **less** productive sands seems to support a nutrient limitation hypothesis for this last case, as Sundback (1986) **also** suggest.

Average phytopigment concentration –182.9 mg/m² chl a, 535.3 mg/m² phaeop is **considerably** larger than in the water column –27.6 mg/m² chl a, 15.5 mg/m² phaeop (unpublished data). In coastal lagoons, unlike lakes, processes at the sediment level are more important than those in the water column. Sediment is a nutrient deposit **of utmost importance** and much of the systems productivity relies on microphytobenthos based food-chains. The high sediment productivity in a shallow lagoon such as St André is an essential part of the production of the system as a whole.

Average phaeopigment concentration of the sediment is three times larger than chl a. Phaeopigment concentration depends on phytoplankton sinking, macrophyte decomposition, perphyton and microphytobenthos. An accumulation process is observed along the annual cycle (Cancela da Fonseca et al, *in litt*).

RESUMEN

LAGUNA DE SANTO ANDRÉ (S.O. PORTUGAL): FITOPIGMENTOS DEL SEDIMENTO COMO MARCADORES

Durante los últimos años, el estudio de la clorofila y sus derivados en el sedimento ha venido siendo cada vez más utilizado para entender la producción de los sedimentos. St. André es una laguna costera de agua salobre con gran cantidad de materia orgánica en el sedimento superficial. En este trabajo se analizan los datos de fitopigmentos, materia orgánica (determinada por combustión), contenido de agua y **granulometría** del sedimento. Dos zonas de distinta productividad han resultado muy relacionadas con los principales tipos de sedimentos: arenas y fangos.

Los fitopigmentos resultaron muy correlacionados con la materia orgánica confirmando su origen vegetal. Los sedimentos fangosos presentan una concentración mayor de pigmentos, pero también en la zona arenosa predomina la producción sobre los procesos de sedimentación.

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In Spring, superficial sediment is washed out, at first by the lagoon water discharge and after by **tides**. **Consequently** there is a **decrease** in phytopigment concentrations. Once the lagoon seals off, pigment values are approximately half the previous ones (Cancela da Fonseca, et al, *in litt.*). The effect is particularly noticeable for sands as most of **the** sand area is located in the lagoon channel.

There is not much data on sediment phytopigments of coastal lagoons. Most of the literature concerns open **systems** such as estuaries. Table 1 presents data on open and closed, marine or brackish, environments. Santo André chlorophyll a has among the highest concentrations.

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