Microphytobenthic primary production of two tropical shallow lagoons using oxygen micro-sensors.

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ABSTRACT: Microphytobenthic primary production of two tropical shallow lagoons using oxygen micro-sensors. The aim of this study was to evaluate the microphytobenthic primary production of two tropical shallow lagoons using a high precision technique with oxygen micro-sensors. These lagoons are shallow and not colonized by aquatic macrophytes, what enhances the relative importance of the microphytobenthic community to total primary production. Gross primary production (GPP), net primary production (NPP) and sediment respiration (SR) were similar in Visgueiro and Catingosa lagoons. NPP values two to three orders of magnitude lower than GPP and SR, while these last rates very similar. Visgueiro lagoon showed a steeper profile with distinctive oxygen and photosynthetic rate peaks due to lower porosity that may reduce microalgae vertical migration in the sediment. Studies with a micro-scale approach can reveal subtle differences between ecosystems, indicating a qualitative rather than only quantitative contribution of the benthic primary producers.

Key–words: Microphytobenthos, Primary Production, Shallow Lakes, Micro-sensors.

RESUMO: Produção primária microfitobentônica de dois lagos rasos tropicais utilizando micro-sensores de oxigênio. O objetivo desse estudo foi avaliar a produção primária microfitobentônica em duas lagoas costeiras tropicais rasas (lagoas Visgueiro e Catingosa, Macaé, RJ) utilizando uma técnica de alta precisão com micro-sensores de oxigênio. Estas lagoas são rasas e não são colonizadas por macrófitas aquáticas, aumentando a importância relativa da comunidade microfitobentônica na produção primária total destes ambientes. A produção primária bruta (PPB), a produção primária líquida (PPL) e a respiração do sedimento (RS) foram similares nas Lagoas Visgueiro e Catingosa, sendo os valores de PPL de duas a três ordens de grandeza mais reduzidas da que os valores de PPB e RS. A lagoa Visgueiro apresentou um perfil mais acentuado, com picos distintos de oxigênio e taxa fotossintética, devido menor porosidade de seu sedimento, fato que provavelmente causou uma diminuição da migração vertical de microalgas no sedimento. Estudos em micro-escala podem revelar sutis diferenças nestes ecossistemas, indicando a importância qualitativa e não somente a quantitativa do papel ecológico do microfitobentos.

Palavras-chaves: Microfitobentos, Produção Primária, Lagos Rasos, Micro-sensores.

Introduction

The term microphytobenthos is related to the photosynthetic eukaryotic algae and cianobacteria that live on sediments, organisms that can be classified as free living epipelon or particle-attached episammon (Macintyre et al., 1996). Several factors as sediment composition, temperature, predation and nutrients availability are known as regulators of microphytobenthic biomass, but one of the most limiting factor is photosynthetically active radiation (PAR) availability (Hansson, 1992). PAR usually penetrates sediments to a depth of only 2-3 mm (Macintyre et al., 1996), but depending on water characteristics of pelagic zone, PAR penetration can be reduced. Besides water color, turbidity and mean depth, phytoplankton biomass can be responsible for PAR attenuation and a consequent negative influence on microphytobenthic biomass being known as "phytoplankton shading effect" (Havens et al., 1996; Sand-Jensen & Borum, 1991).

Fine-grained lake sediments when colonized by a high algae biomass tend to support the formation of an algal biofilm, that has a great influence on nutrient fluxes between sediment and water column (Woodruff et al., 1999). In this site, microphytobenthic nutrient uptake from both water column and sediment groundwater (Hagerthey & Kerfoot, 1998), what turns these benthic algae less sensitive to changes in water column nutrient concentrations when compared to planktonic algae. Besides nutrient flux modulation, algal biofilm formation also have great importance due to sediment stabilization against re-suspension (Delgado et al., 1991). Re-suspension can reduce benthic photosynthetic rates because less PAR reaches the sediment and microphytobenthic biomass is removed (Macintyre et al., 1996).

Recent studies showed that microphytobenthos primary production rates in shallow lakes may represent almost 80% of total primary production (Liboriussen & Jeppesen, 2003; Vadeboncoeur et al., 2001), being important and representative for food web (Miller et al., 1996). In these lakes, most part of the PAR reaches the sediment without substantial attenuation, what makes benthic microalgae colonization possible. In spite of its importance, fewer studies focus on microphytobenthic primary production, especially in tropical ecosystems, due to methodological problems and the relative difficulty to work with sediment samples (Hansson, 1992; Vadeboncoeur et al., 2002).

Shallow conditions are common characteristic of the majority of world lakes (Downing et al., 2006), what enhances PAR availability to the benthic compartment, favoring the establishment of aquatic macrophytes (Wetzel, 1990). Among aquatic ecosystems, coastal lagoons are shallow and separated of ocean waters by a sand barrier, being connect to it by one or more temporary or permanent channels (Kjerfve, 1994). One important characteristic of these ecosystems is the high variation in salt concentrations. Due to the proximity with the ocean, coastal lagoons often receive inputs of saline water and depending on the geomorphology of the environment, some are hypersaline. The salt influence creates difficulties to the colonization by aquatic macrophytes (Glenn et al., 1995). Without aquatic macrophytes shading, the benthic compartment can be colonized by microalgae, especially in lagoons that do not have any influence from rivers.

The objective of this study was to evaluate the microphytobenthic primary production of two tropical shallow lagoons using a high precision technique with oxygen micro-sensors.

Material and methods

Study Area

Visgueiro (22° 11' S and 41° 24'W) and Catingosa (22° 11' S and 41° 23'W) lagoons are located at the Jurubatiba National Park, in the North of Rio de Janeiro state (Fig. 1). Both lagoons are characterized as hypersaline, since salinity is always higher than the ocean, reaching levels such as 100 US. They are shallow lagoons (mean depth of 0.5 m) orientated in a parallel way to the coast, being classified as lagoons formed in the depressions between areas that constitute the restinga vegetation (Martin, 1994). Sediment of both lagoons is silty.

Sampling and analysis

Three sediment samples were collected in the marginal area of each lagoon at the first week of October in 2004 by hand using plexiglass tubes. Water samples for pelagic parameters measurement were collect with pre-washed (HCl 0.5M) plastic bottles. pH was analyzed with a pHmeter Analion PM 608 and total alkalinity was determined from Gran titration. Temperature, salinity and conductivity were measured with a Termosalinometer YSI-30. Color was measured from absorption coefficient at 430 nm in a Shimadzu spectrophotometer with a 1cm length cuvette.

All sediments cores were taken right after sampling to the field lab and stabilized with water from the environment in a minimum period of 1h before the measurements, being illuminated by a halogen lamp ($200mW.cm^{-2}s^{-1}$) during the measurements. Sediment oxygen profiles were measured with an oxygen micro-sensor (OX-50-UNISENSE) with an outside tip diameter of approximately 50mm. The oxygen concentrations were measured in equal depth intervals (200mm) and registered in a picoammeter (PA 2000-UNISENSE) connected to a recorder.

Microphytobenthos gross and net primary productivity were computed using the oxygen micro-profiles technique (Revsbech & Jorgensen, 1983). This method was primarily described by Revsbech et al. (1981) and, is based on the determination of oxygen concentrations in several sediment depths during light-dark shifts with an oxygen micro-sensor. The main premise of this method is that oxygen concentration in the algal biofilm is constant during illumination time and after light shut off, oxygen concentrations decay linearly. Therefore, photosynthetic rates are measured from the rates of oxygen decrease after 1 or 2 seconds of dark period that the sample is submitted after light turning off at each depth of the oxygen profile (Revsbech et al., 1986). Microphytobenthic net primary productivity is the sum of upward and downward fluxes of oxygen in the sediment, calculated from the oxygen concentrations in each depth when they were illuminated, before the dark shift. The experimental design of this study followed the one illustrated by Revsbech et al. (1981).

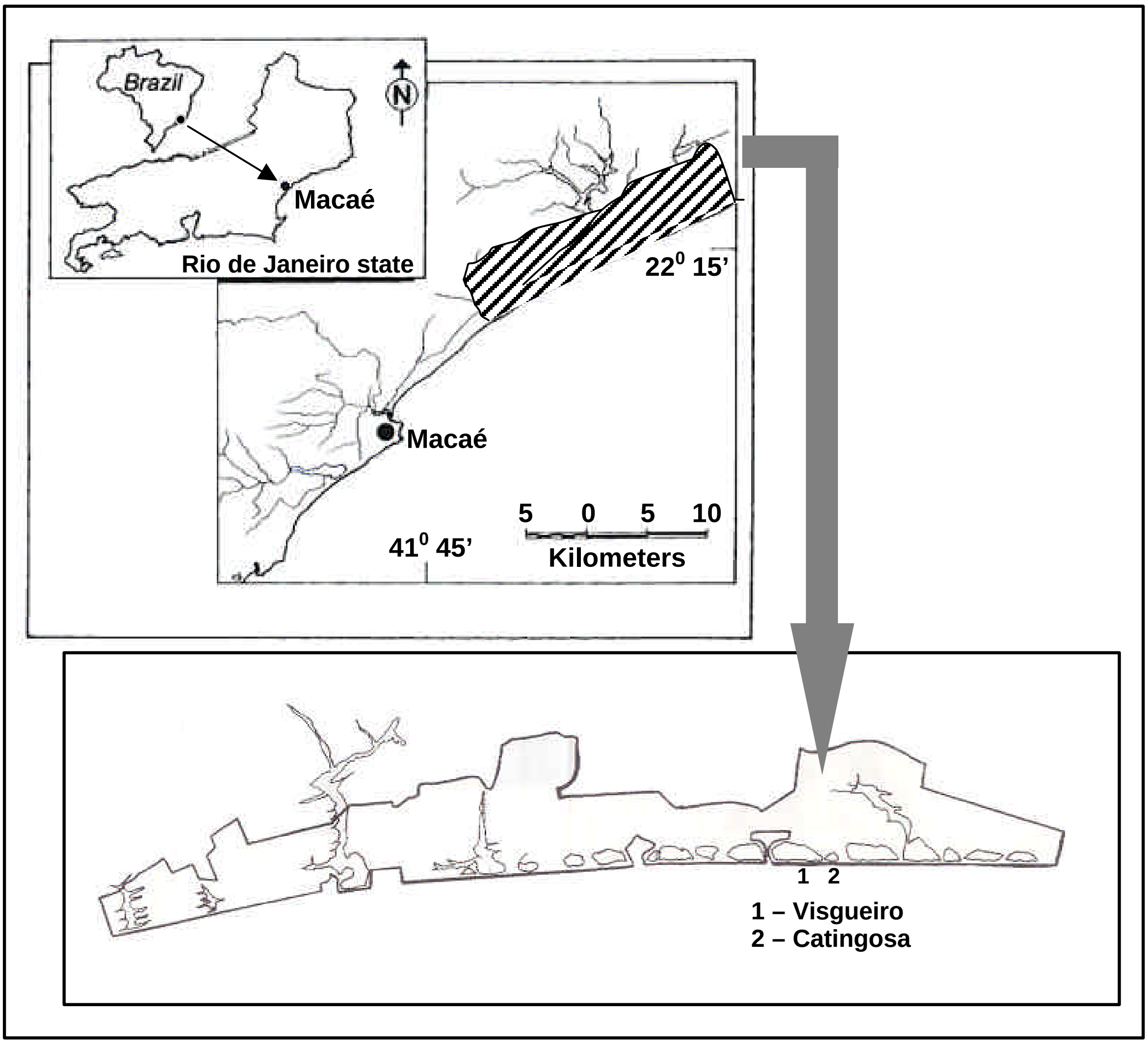

Figure 1: Localization of the studied lakes in the Jurubatiba National Park, in the northeast of Rio de Janeiro state, Brazil

Results

The pelagic limnological parameters of Visgueiro and Catingosa lagoons are shown in Table I. These lagoons presented great similarity in some of these parameters like pH, CO_2 saturation and salinity. Water color was remarkable higher (ca. 100%) in Catingosa lagoon.

Oxygen and gross primary productivity micro-profiles of Visgueiro lagoon was marked by a distinct peek at 0.4cm depth (Fig. 2A). The highest peaks at depths 0.2 and 0.4 cm were significantly different (Tukey, $p<0.05$) from all others depths for both parameters. At Catingosa lagoon, the same pattern was not observed, being its sediment characterized by homogeneous and deeper profiles (Fig. 2B). The highest values of Gross primary production (depths 0.4, 0.6 and 0.8 cm) were not significant different (Tukey, p›0.05). The same pattern was even more clear for oxygen profiles, since only depths 0.2 and 0.4 (the highest and lowest values, respectively) were significantly different (Tukey, p‹0.05).

Gross primary production (GPP) and Sediment respiration (SR) were not significantly different at Visgueiro and Catingosa lagoons (t-test, p›0.05) (Tab. II). Net primary production (NPP) was 2 to 3 orders of magnitude lower than GPP at both environments.

Table I: Some limnological parameters of Visgueiro and Catingosa lagoons.

	Visgueiro	**Catingosa**
pH	9.15	8.98
Salinity (US)	120	124
Conductivity (mS)	147.3	119.3
Alcalinity (mEq/l)	3.24	3.87
CO_2 saturation (%)	‹ 1	‹ 1
Dissolved Oxygen (mg/l - %)	8.53 163	5,43 104
Temperature (°C)	25.4	24.6
Water color (430nm)	0.036	0.076
Mean depth (m)	0.4	0.4
Total lagoon area (km²)	1.2	0.1

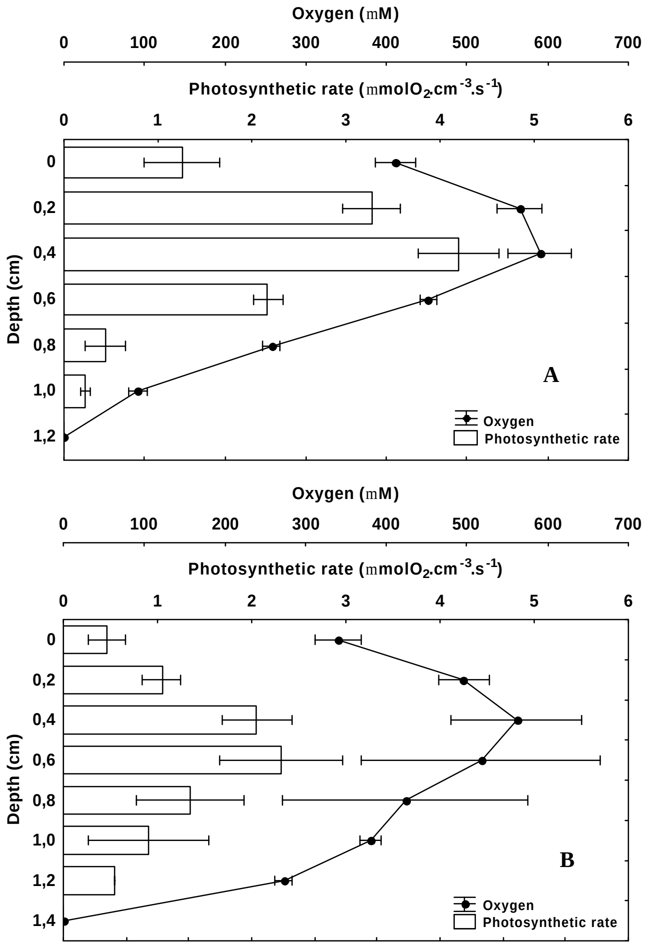

Figure 2: Sediment oxygen profiles (lines) and gross primary production (bars) from Visgueiro (A) and Catingosa (B) lagoons. Values represent Mean ± SE (n=3).

Table II: Gross primary production (GPP), net primary production (NPP) and respiration rates (SR) from the sediment colonized by microphytobenthos at Visgueiro and Catingosa lagoons. Values represent Mean ± SE (n=3).

Measured rates at the sediment (mmol $O_2.cm^{-3}.s^{-1}$)	**Visgueiro**	**Catingosa**
Gross primary production	11.14±0.797	8.10±1.580
Net primary production	0.03±0.005	0.02±0.003
Sediment aerobic respiration	11.11±0.792	8.08±1.581

Discussion

The studied ecosystems have similar limnological conditions that can be attributed to their proximity and similar formation. However, higher values of water color at Catingosa lagoon attenuates PAR penetration and consequently PAR availability for primary production at the sediment of this ecosystem. Those differences can partly explain distinctions in oxygen and primary production micro-profiles shapes from both environments.

Visgueiro Lagoon showed a steeper profile with distinctive oxygen and photosynthetic rate peaks. Despite having clear water column that would favor light penetration in relation to Catingosa Lagoon, Visgueiro probably showed lower light availability in the sediment profile due to a possible lower porosity of this compartment. In that case, light would have a lower penetration, being responsible for the differentiation of the profiles. Visgueiro and Catingosa lagoons area characterized by silty sediments, but small differences in porosity could be responsible for differentiations in microalgae distribution. Sediments with lower porosities are characterized by less microalgae vertical migration due to lower light sediment penetration (Yallop et al., 1994). Even with less PAR availability, GPP and oxygen profiles were deeper and homogenous at Catingosa lagoon, probably because of higher vertical migration of microalgae favored by higher porosity.

Regarding to the sediment production rates, Visgueiro showed higher GPP and SR than Catingosa, but NPP values were very similar in both environments. Even with singularities that are translated by different sediment respiration rates, the importance of microphytobenthos to the carbon budget of both ecosystems is almost the same. This similarity shows that only quantitative data (primary production rates) do not show the real differences between these two environments.

Microphytobenthic primary production rates measured in these coastal lagoons are at the same order of magnitude than other aquatic ecosystems (Schindler, 1978). Temperate ecosystems like acid lake Plessa (Kapfer, 1998) and Grado/Marano coastal lagoons (Blasutto et al., 2005) showed similar results to Visgueiro and Catingosa (10 mmolO$_2$.m^{-2}.h^{-1}). Tropical Illawarra lake (Qu et al., 2006) showed lower results (mean annual values of 3.6mmolO$_2$.m^{-2}.h^{-1}), with negative NPP. Other ecosystems like the oligotrophic Eckarfjärden lake (Andersson & Brunberg, 2006) can have a very high benthic primary production (448mmolO$_2$.m^{-2}.h^{-1}). Many regulatory factors can explain differences in benthic primary production, being light availability and algae density the main.

In conclusion, the micro-profiles technique can be an important tool in ecological studies, since very similar ecosystems like Visgueiro and Catingosa lagoons could have different vertical oxygen and photosynthetic rate profiles. Studies with a micro-scale approach can reveal differences between ecosystems that would be hardly distinguish with general approaches, giving a qualitative idea rather than only quantitative of the ecological role of this compartment. Therefore, this study showed that two very similar ecosystems could be very different in a micro-scale and more studies with this technique could reveal differences that could regulate microphytobenthos primary production.

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