Primary production of *Egeria densa* Planch. (Hydrocharitaceae) in a coastal lagoon with high biogenic turbidity

Produção primária da macrófita submersa *Egeria densa* Planch. (Hydrocharitaceae) em uma lagoa costeira com elevada turbidez biogênica

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Abstract: The aim of this study is to evaluate primary production of *E. densa* in Campelo Lagoon (21° 37' S 41° 10' W and 21° 41' S 41° 11' W), a shallow coastal lagoon which presents high turbidity of biogenic origin (phytoplankton), and the relationship of seasonality and limnologic variables on this process. Primary production and hydrologic variables were evaluated within three hydrologic periods (Dry 2003, Rainy 2004, Dry 2004). It was not noticed any seasonal difference of net primary production that varied between 3.31 $mgO_2.g^{-1}DW.h^{-1}$(Dry 2003) and 5.27 $mgO_2.g^{-1}DW.h^{-1}$ (Dry 2004). Chlorophyll high values (26.7 and 34.1 $\mu g.L^{-1}$, Dry 2003 and Rainy 2004) did not affect primary production of *E. densa*. Nutrient concentration stability during the whole period and the use of sediment nutrients by *E. densa* allowed the coexistence of macrophyte and high phytoplankton biomass in Campelo lagoon.

Keywords: coastal lagoon, aquatic macrophyte, net primary production, biogenic turbidity.

Resumo: A lagoa do Campelo é uma lagoa rasa de planície costeira que apresenta elevada turbidez de origem biogênica (fitoplanctônica), margens colonizadas por *Typha dominguensis* e o sedimento quase inteiramente coberto pela macrófita aquática submersa *Egeria densa*. O objetivo deste trabalho é avaliar a produção primária da *E. densa* na lagoa do Campelo e verificar a influência da sazonalidade e das variáveis limnológicas neste processo. A produção primária e as variáveis hidrológicas foram obtidas em três períodos hidrológicos (Seco 2003, Chuvoso 2004, Seco 2004). Não foi observada diferença sazonal da produção primária variando entre 3,31 $mgO_2.g^{-1}PS.h^{-1}$(Seco 2003) e 5,27 $mgO_2.g^{-1}PS.h^{-1}$ (Seco 2004). Os valores elevados de clorofila (26,7 e 34,1$\mu g.L^{-1}$, Seco 2003 e Chuvoso 2004, respectivamente) não afetaram a produção primária da *E. densa*. A estabilidade da concentração de nutrientes durante todo o período estudado e a utilização dos nutrientes do sedimento pela *E. densa* permitiu a coexistência da macrófita e da elevada biomassa fitoplanctônica na lagoa do Campelo.

Palavras-chave: lagoa costeira, macrófita aquática, produção primária líquida, turbidez biogênica.

1. Introduction

Aquatic macrophytes play an important ecologic role mainly in shallow environments such as the littoral zones of the lacustrine ecosystems and wetlands. In general, macrophytes are basically related to the increase of space heterogeneity, which provides diverse habitats for macroinvertebrates (Albertoni et al., 2001), birds (Sandsten et al., 2005) and fishes (Nakatani et al., 1997; Cassatti et al., 2003). Besides, they serve as substratum for periphyton (Fernandes and Esteves, 2003) as well as to enlarge the littoral zones and to protect the margins (San-Jensen, 1998); they may also act in nutrient and pollutant retention (Engelhardt and Ritchie, 2001; Klumpp et al., 2002; Rigollet et al., 2004).

In temperate regions it is clearly noticed the seasonal variations of biomass, organic and inorganic chemical composition of the aquatic macrophytes and, therefore, primary productivity (Duarte and Ferreira, 1997; Fernández-Alaez et al., 2002). Nevertheless, in tropical regions the seasonal variations are not always noticed (Camargo and Esteves, 1995; Esteves et al., 2005). However, in environments with a wide water level variation there are evident seasonal fluctuations, which may cause changes in chemical composition and biomass in aquatic macrophytes (Da Silva and Esteves, 1993; Santos and Esteves, 2002).

Egeria densa is a rooted macrophyte species, with rapid growth, that reaches the top of water column. It is some-

what demanding to the sub aquatic radiation, and it also tolerates habitats with high turbidity (Bini et al., 1999). When finding optimal conditions to grow, this species forms monospecific banks, eliminates native species and reduces species diversity in the community (Hamoroto and Ikusima, 1988).

The aim of this study is to evaluate primary production of submerged aquatic macrophyte *E. densa* in Campelo lagoon, located in the north of Rio de Janeiro State and characterized by high biogenic turbidity, as well as the influence of seasonality and limnologic variables on primary production.

2. Material and Methods

2.1. Study area

Campelo lagoon origin is related to the delta formation of the Paraíba do Sul River, geologically based over quaternary fluvial-marine deposits (Figure 1). Along its littoral zone, it can be noticed that the sediment extension is almost entirely covered by *Egeria densa* meadows and there is dense colonization of emergent macrophyte *Typha dominguensis* Pers.

Located in a sub-humid-dry region, the Campelo Lagoon lies near the city boundaries of Campos dos Goytacazes and São Francisco do Itabapoana (21° 37' S 41° 10' O and 21° 41' S 41° 11' O). The Campelo lagoon watershed is covered by pastures and subsistence agriculture. In its southern part, the lagoon receives freshwater from the Paraíba do Sul River through Vigário channel. In its northern part, there is Antonio Resende channel, through which the lagoon receives water from the sea. In 2001 this channel was blocked, which promoted the hydrochemical changes in the lagoon and permitted *E. densa* colonization that covered almost all the lagoon sediment.

2.2. Methodology for primary production measurements

E. densa primary production was evaluated at three time periods: dry 2003 (June-August), rainy 2004 (January-March) and dry 2004 (June-August).

For primary production quantification, in situ incubations were performed, utilizing light and dark bottles, incubated at 30 cm depth, five times in each period. The bottles (200 mL glasses) were filled up with Campelo's lagoon water previously filtered (Whatman GF/F, under vacuum) to remove phytoplanktonic organisms. Macrophyte apical branches (~7 cm) were carefully washed to remove periphyton and then, incubated in triplicate during two-hour intervals (10-12 hours - morning, 12-14 hours - afternoon).

After incubation, one water sample from each bottle was collected to determine dissolved oxygen content through Winkler method (Golterman, et al., 1978). Initial oxygen concentration (filtered water before incubation) was also determined. Dry weight of macrophyte branches was determined after they had been dried at 60 °C in an air circulation oven until they reached constant weight (ca. 24 hours).

Net primary production, respiration and gross primary production were calculated by using the following equations described in Vollenweider (1974) (Equation 1):

$$\text{NPP} = (c\text{-}i)\ v/(t*PS);\ R = (i\text{-}e)\ v/t*PS) \text{ and,}$$
$$\text{GPP} = \text{NPP} + R \qquad (1)$$

where: NPP-net primary production in $mgO_2\ g^{-1}DW\ h^{-1,}$ R: respiration $mgO_2\ g^{-1}DW\ h^{-1}$, GPP: gross primary production $mgO_2\ g^{-1}DW\ h^{-1,}$ c: dissolved oxygen concentration

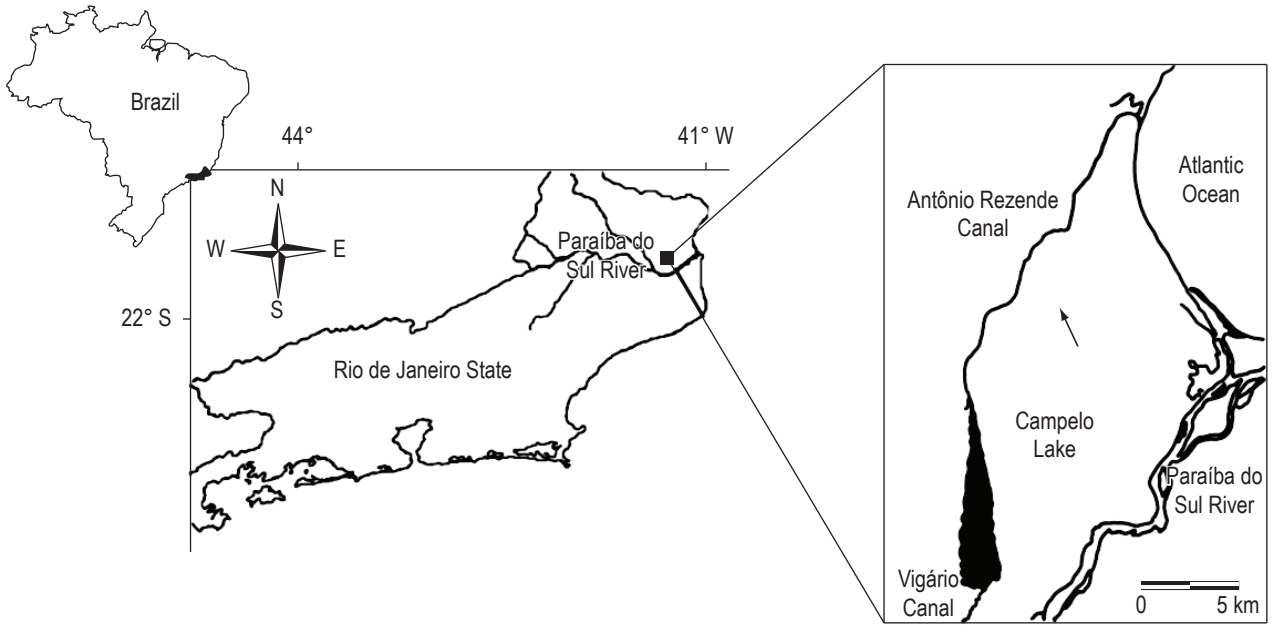

Figure 1. Study area.

in light recipient ($mg.L^{-1}$), and: dissolved oxygen in dark recipient ($mg.L^{-1}$), i: initial dissolved oxygen concentration ($mg.L^{-1}$), v: recipient volume (L), t: incubation time (hours) and DW: dry weight of macrophyte (g).

On each sampling day, initial and final values of water temperature (°C) and electric conductivity ($\mu S.cm^{-1}$) were determined by using the WTW model LF96 conductivity meter, pH with Digimed DM-PV potentiometer and photosynthetically active radiation-PAR with spherical sub aquatic sensor LiCor 193SB radiometer in the incubation depth (30 cm deep). Total alkalinity was determined according to Gran´s procedures (1952). Temperature, pH and alkalinity data were utilized to determine availability of dissolved inorganic carbon with the use of Carbdoc1 algorithm (Carmouze, 1994).

At the same depth, a water aliquot was collected and filtered in duplicate through vacuumed Whatman GF/F filter for chlorophyll *a* and N and P determination. Filters were frozen at –20 °C and used to determine chlorophyll-*a*, as described by Nusch (1980). Filtered water samples were frozen at –20 °C to determine dissolved inorganic nutrients (N and P). A non filtered sample aliquot was also stored for total phosphate and nitrogen analyses. Orthophosphate concentration (P-orto) was determined by molybdenum-blue colorimetric method (Carmouze, 1994). Ammoniacal nitrogen was determined by indophenol blue colorimetric method (Grasshoff et al., 1983). Nitrate was determined by reducing to nitrite in Cd-Cu column (N-naphthyl sulfanilamide coloured complex) through the Flow Injection Automatic Analyzer (FIA) ASIA Ismatec System. The dissolved inorganic nitrogen (DIN) was determined by adding ammonium and nitrate. Total phosphate (TP) was determined after acid digestion by potassium persulfate (Carmouze, 1994) and determination as per P-Orto. To determine total nitrogen (TN), the sample was subjected to basic digestion by potassium persulfate and determination performed to nitrate likewise (Carmouze, 1994). All values are presented as averages of time- period subject to study (n = 5).

ANOVA (one way) was applied to test for significant differences of primary production and respiration values of *E. densa* between the sampling time and the seasonality effect over limnological variables. The post hoc Tukey test was applied with a significance level of 0.05 (Zar, 1999).

3. Results

Net primary production variation, respiration and gross primary production of *E. densa* macrophyte in Campelo lagoon in the Dry 2003, Rainy 2004 and Dry 2004 periods are indicated in Figure 2. In the sampling performed in the morning (10-12 hours), no significant differences between the sampling periods regarding NPP, R and GPP were noticed. NPP varied between 4.63 $mgO_2\,g^{-1}DW.h^{-1}$ for the Dry 2003 period and 5.27 $mgO_2\,g^{-1}DW\,h^{-1}$ for

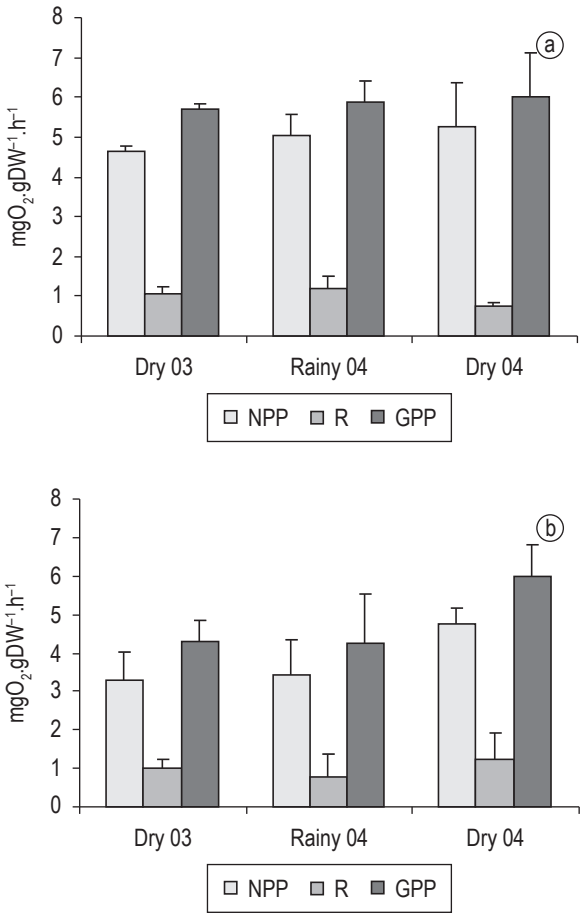

Figure 2. Net primary production of *E. densa* in the a) morning and b) afternoon during period sampling. The bar error indicates standard deviation.

the Dry 2004 period (F = 0.177, p = 0.844). Respiration maximum values (1.26 $mgO_2\,g^{-1}DW\,h^{-1}$) were observed in the Rainy/2004 period, whereas minimum ones in the Dry/2004 period (0.73 $mgO_2\,g^{-1}DW\,h^{-1}$). Gross primary production varied from 5.68 $mgO_2\,g^{-1}DW\,h^{-1}$ (Dry/2003) to 5.99 $mgO_2\,g^{-1}DW\,h^{-1}$ (Dry/2004). (Figure 2a). ANOVA didn't show difference in either respiration or gross primary production (F = 0.943, p = 0.418, to R and F = 1.56, p = 0.267 to GPP (F = 0.93, p = 0.433).

The afternoon sampling interval, between 12-14 hours, followed the same pattern observed in the morning, with higher values in the Dry 2004 (Figure 2b). NPP values varied from 3.31 $mgO_2\,g^{-1}DW\,h^{-1}$(Dry/2003) to 4.75 $mgO_2\,g^{-1}DW\,h^{-1}$ (Dry/2004). Respiration varied between 0.79 $mgO_2\,g^{-1}DW\,h^{-1}$(Rainy/2004) and 1.25 $mgO_2\,g^{-1}DW.h^{-1}$ (Dry/2004). GPP varied from 4.23 $mgO_2\,g^{-1}DW.h^{-1}$ (Rainy/2004) to 6.23 $mgO_2\,g^{-1}DW\,h^{-1}$(Dry/2004). ANOVA did not show any difference in NPP (F = 2.72, p = 0.114), R (F = 2.70, p = 0.111) between the periods.

Water temperature was about 6 °C lower in the dry 2003 and 2004 periods than in the rainy 2004 period. Electric conductivity and total alkalinity had higher

values in the dry 2003 and 2004 periods (294 µS cm^{-1} and 221 µS.cm^{-1} and 1,691 µEq.L^{-1} and 911 µEq.L^{-1} respectively) with reduction in the rainy 2004 period (123 µS.cm^{-1} and 582 µEq.L^{-1} respectively). ANOVA showed that the sampling periods are different for electric conductivity and total alkalinity (electric conductivity $F = 410.4$; $p < 0.0001$; total alkalinity $F = 258.8$, $p < 0.0001$).

During the study period, pH values were generally above 8.3 and did not show significant differences between dry and rainy periods. Dissolved oxygen concentration was higher in the dry periods (9.6 mg.L^{-1} in dry 2003 and 12.9 mg.L^{-1} in dry 2004) when compared to the rainy 2004 period (average of 8.2 mg.L^{-1}). Statistics analysis showed significant difference between the rainy 2004 and dry 2004 periods ($F = 8.7$; $p < 0.05$) (Table 1).

Dissolved inorganic carbon (DIC) is strongly influenced by pH and alkalinity. Then, values followed alkalinity standard, with maximum value of 1536 µmol.L^{-1} in the dry 2003 period, reduction in the rainy 2004 period (543 µmol.L^{-1}) and later increase in the dry 2004 period (803 µmol.L^{-1}), with relevant difference among the three sampling periods ($F = 129.2$, $p < 0.0001$). Statistics analysis ANOVA did not show significant difference among the sampling periods for PAR which always presented values above 450 µmol.photons.$m^{-2}.s^{-1}$ (Table 1).

Chlorophyll-*a* values showed small variation between the Dry 2003 and Rainy 2004 periods (25.7 µg.L^{-1} and 34.1 µg.L^{-1}, respectively – Table 1). In the Dry 2004 period lower values of chlorophyll a were noticed (6.3 µg.L^{-1}), and they were significantly different from the others ($F = 29.5$, $p < 0.001$) .

Dissolved inorganic nitrogen (DIN) varied between 2.9 µmol.L^{-1} (Rainy 2004) and 5.0 µmol.L^{-1} (Dry 2003). Total nitrogen concentration (TN) presented the highest value in the Dry 2003 period (54.2 µmol.L^{-1}) as well as similar values in the Rainy 2004 and Dry 2004 periods (32.7 µmol.L^{-1} and 34.1 µmol.L^{-1}, respectively). Statistic test showed that for DIN as well as for TN the first sampling period (Dry 2003) differed from the others ($F = 5.86$, $p < 0.01$, for DIN and $F = 16.35$, $p < 0.0001$, for TN, Figure 3).

There was not relevant difference of the phosphate forms among the sampling periods for orthophosphate and total phosphate with mean values of 0.16 and 0.77 µM, respectively ($F = 2.22$; $p > 0.05$, to ortophosphate and $F = 3.42$; $p > 0.05$ total phosphate, Figure 4).

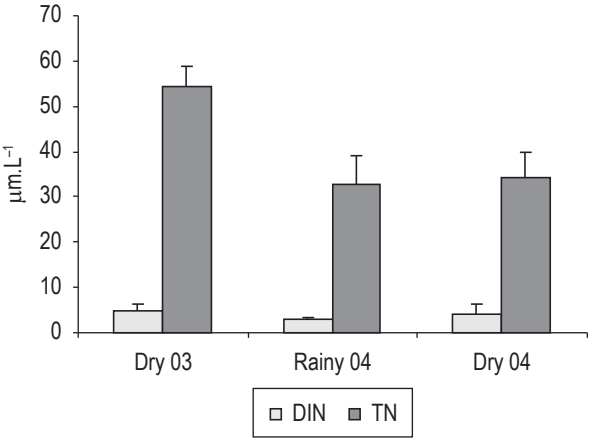

Figure 3. Dissolved inorganic nitrogen and total nitrogen concentration during period sampling. The bar error indicates standard deviation.

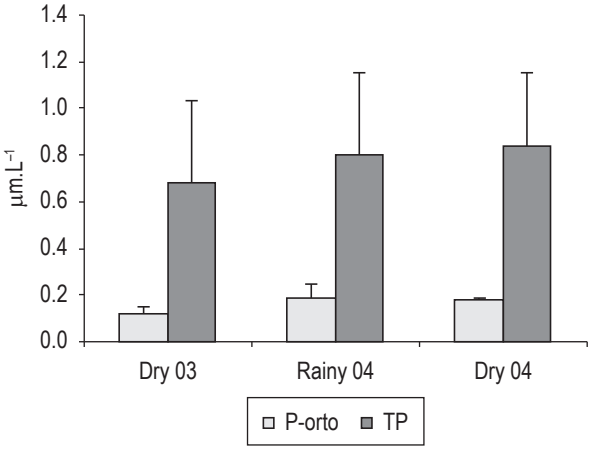

Figure 4. Ortophosphate and total phosphate during sampling period. The bar error indicates standard deviation.

4. Discussion

A primary production reduction between morning and afternoon had already been described in other lab studies on macroalgae and macrophytes (Pezzato, 2002) According to Wetzel (1993), reduction of primary production in aquatic environments is related to the photorespiration process, which possibly increases in the afternoon period due to the rise of luminous intensity and oxygen growing tension from photosynthesis and temperature origin.

The prevailing form of DIC in the lagoon is bicarbonate, as it can be inferred by high pH values. This available DIC form may influence photosynthesis activity, since bicarbonate utilization requires energetic consumption, which reduces photosynthesis activity (Pezzato, 2002; Pierini and Thomaz, 2004b). DIC lowest values were noticed in the Rainy 2004 period (548 µmol.L^{-1}), presumably due to dilution process caused by rains. According to Browse et al. (1979), photosynthesis saturation point for *E. densa* – when CO_2 addition does not reflect an increase in the photosynthetic rate – varies 350-400 µmol. Thus, DIC did not seem to be a limiting factor to primary production.

According to alternative state theory proposed by Scheffer et al. (1993), in shallow aquatic ecosystems,

Table 1. Physical and physicochemical variables and Chlorophyll-*a* in a Campelo Lagoon, during sampling period. Values mean and standard deviation (in parenthesis). Values followed by different letters indicate significant differences ($p < 0.05$), among periods, n = 3.

	Water temperature (°C)	pH	Electric cond. ($\mu S.cm^{-1}$)	O_2 ($mg.L^{-1}$)	Total alcalinity ($\mu Eq.L^{-1}$)	DIC ($\mu mol.L^{-1}$)	PAR ($\mu mol.photons.m^{-2}.s^{-1}$)	Chlorophyll *a* ($\mu g.L^{-1}$)
Dry 2003	23[a]	9,1[a]	295[c]	9.58 [b]	1691[c]	1536[c]	467[a]	25.7[b]
	(1.7)	(0.7)	(11.6)	(1.9)	(50)	(60)	(120)	(6.9)
Rainy 2004	29[b]	8,7[a]	123[a]	8.17[a]	582[a]	543[a]	818[a]	34.1[b]
	(1.3)	(0.9)	(9,9)	(1.8)	(30)	(75)	(210)	(7.6)
Dry 2004	23[a]	9,4[a]	221[b]	12.9[b]	911[b]	803[b]	551[a]	6.3[a]
	(2.4)	(0.4)	(17.7)	(2.5)	(59)	(82)	(189)	(1.6)

Table 2. Minimum and maximum values of the net production primary (NPP) in different species of submerged macrophytes in field experiments.

	NPP ($mgO_2.g^{-1}DW.h^{-1}$)		
Species	Minimum	Maximum	Author
Utricularia breviscapa	0.83	18.80	Menezes (1984)
Utricularia gibba	2.23	15.20	Pompeu and Moschini-Carlos (1997)
Utricularia foliosa	3.24	25.55	Assumpção (2001)
Egeria densa (Mambu River)	2.76	5.40	Pezzato and Camargo (2004)
Egeria densa	2.24	6.18	This study

submerged macrophytes would act to remove dissolved nutrients from water and keep clear water state. As eutrophication increases, phytoplankton would be dominant, reducing macrophyte biomass especially by shading. However, in Campelo lagoon high values of chlorophyll-*a* were observed, but such factor did not affect *E. densa* primary production.

Although the environment presents high biogenic turbidity, incident radiation (above 450 $\mu mol.photons.m^{-2}.s^{-1}$) and nutrient availability throughout the studied period allowed the coexistence of macrophyte and phytoplankton. Besides, sediment can provide nutrients to *E. densa*, which reduces competition mainly by phosphorus that presents reduced values in the water column.

Few macrophyte species were measured for primary production in field experiment (Table 2). The highest values that varied from 3.24 to 25.55 $mgO_2.g^{-1}DW.h^{-1}$were observed by Assumpção (2001). *E. densa* values were close to the lowest limits of variation. Values of this study are similar to those observed by Pezzato and Camargo (2004), when studying NPP of *E. densa* in a coastal clear water river in São Paulo state (Mambu river).

In summary, we found that high incident radiation in the region, nutrient availability in water and sediment allowed coexistence of this submerged macrophyte with high biogenic turbidity due to phytoplankton activity. However, such interaction deserves proper evaluation and opens up new perspectives of study around this ecological interaction.

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References

ALBERTONI, EF., PALMA–SILVA, C. and ESTEVES, FA. Macroinvertebrates associated with Chara in a tropical coastal lagoon (Imboassica lagoon, Rio de Janeiro, Brazil). *Hydrobiologia,* 2001, vol. 457, no. 1-3, p. 215-224.

ASSUMPÇÃO, AM. *Produção primária da macrófita aquática Utricularia foliosa Linnaeus (1752) em um rio de águas pretas de bacia do Rio Itanhaém, SP.* Rio Claro: Universidade Estadual Paulista - UNESP, 2001. 34p. Monografia.

BINI, LM., THOMAZ, SM., MURPHY, KJ. and CAMARGO, AFM. Aquatic macrophyte distribution in relation to water and sediment condition in the itaipu reservoir, Brazil. *Hydrobiologia,* 1999, vol. 415, no. 0, p. 147-154.

BROWSE, JA., BROWN, JMA. and DROMGOOLE, FI. Photosynthesis in the aquatic macrophyte *Egeria densa*. III. Gas exchange studies. *Aust. J. Plant Physiol.* 1979, vol. 6, no. 4, p. 499-512.

CAMARGO, AFM. and ESTEVES, FA. Biomass and productivity of aquatic macrophytes in brasilian lacustrine ecosystems. In Tundisi, JG., Bicudo, CEM. and Matsumura-Tundisi, T. (Orgs.). *Limnology in Brazil.* São Paulo: Academia Brasileira de Ciências; Soc. Bras. Limnologia, 1995. p. 137-149.

CARMOUZE, JP. *Metabolismos dos ecossistemas aquáticos:* fundamentos teóricos, métodos de estudo e análises químicas. São Paulo: Edgard Blucher; Fapesp, 1994. 254p.

CASSATTI, L., MENDES, HF. and FERREIRA, KM. Aquatic macrophytes as feeding site for small fishes in the Rosana Revervoir, Paranapanema river, Southeastern Brazil. *Braz. J. Biol. = Rev. Bras. Biol.* 2003, vol. 63, no. 2, p. 213-222.

Da-SILVA, CJ. and ESTEVES, FA. Biomass of three macrophytes in the pantanal of the Mato Grosso, Brazil. *Int. J. Ecol. Envir*. 1993, vol. 19, no. 1, p. 11-22.

DUARTE, P. and FERREIRA, JG. A model for the simulation of macroalgal population dynamics and productivity. *Ecol. model.* 1997, vol. 98, no. 2-3, p. 199-212.

ENGELHARDT, KAM. and RITCHIE, ME. Effects of macrophyte species richness on wetland ecosystem functioning and services. *Nature,* 2001, vol. 441, p. 687-689

ESTEVES, BS., TAOUIL, A. and SUZUKI, MS. Nutrient composition of macroalgae and macrophytes of the Açu lagoon, Rio de Janeiro State, Brazil. *Acta Limnol. Bras.* 2005, vol. 17, no. 3, p. 233-244.

FERNANDES, VO. and ESTEVES, FA. The use of indices for evaluating the periphytic community in two kinds of substrate in Imboassica lagoon, Rio de Janeiro, *Brazil. Braz. J. Biol.* = *Rev. Bras. Biol.* 2003, vol. 63, no. 2, p. 233-243.

FERNÁNDEZ-ALAEZ, M., FERNÁNDEZ-ALAEZ, C. and RODRÍGUEZ, S. Seasonal changes in biomass of charophytes in shallow lakes in the northwest of Spain. *Aquat. Bot.* 2002, vol. 72, no. 3-4, p. 335-348.

GOLTERMAN, HL., CLYMO, RS. and OHSNTAD, MAM. *Methods for chemical analysis in freshwaters*. Boston: Blackwell, 1978. 214p.

GRAN, G. Determination of equivalent point in potentiometric titration. Part II. *Analyst,* 1952, vol. 77, no. 920, p. 661-671.

GRASSHOFF, KA., EHRHARDT, M. and KREMLING, K. *Methods of seawater analysis*. Weihim: Verlag Clemie, 1983. 419p.

KLUMPP, A., BAUER, K., FRANZ-GERSTEIN, C. and MENEZES, M. Variation of nutrients and metal concentration in aquatic macrophytes along the rio Cachoeira in Bahia (Brazil). *Environ. Intern*. 2002, vol. 281, no. 3, p. 65-171.

NAKATANI, K., BAUMGARTNER, G. and CAVICCHIOLI, M. Ecologia de ovos e larvas de peixes. In Vazzoler, EAM., Agostinho, AA. and Hahn, NS. (Eds.). *A planície de inundação do alto rio Paraná:* aspectos físicos, biológicos e socioeconômicos. Maringá: EDUEM; NUPELIA, 1997. p. 281-306.

NECCHI Jr, O. and ZUCCHI, MR. Photosynthetic performance of freshwater Rhodophyta in response to temperature, irradiance, pH and diurnal rhythm. *Phycological research,* 2001, vol. 49, no. 4, p. 305-318.

NUSH, E. Comparison of differents methods for chlorophyll and phaeopigments determinations. *Arch. Hydrobiol.* 1980, vol. 14, no. 1, p. 14-36.

PEZZATO, MM. *Efeitos da Radiação Fotossinteticamente ativa, temperatutra, pH e concentrações de carbono inorgânico na fotossíntese e respiração da macrófita aquática Egeria densa Planch.* Jaboticabal: Universidade Estadual Paulista – UNESP, 2002. 45p. Dissertação de Mestrado.

PEZZATO, MM. and CAMARGO, AFM. Primary production of the aquatic macrophyte, *Egeria densa* Planch. (Hydrocharitaceae) in two rivers from the Itanhaém River basin in São Paulo State, *Brazil. Braz. Arch. Biol. Technol.* 2004, vol. 47 no. 1, p. 153-162.

PIERINI, SA. and THOMAZ, SM. Effects of inorganic carbon source on photosynthetic rates of *Egeria najas* Planchon and *Egeria densa* Planchon (Hydrocharitaceae). *Aquat. Bot.* 2004, vol. 78, no. 2, p. 135-146.

PÔMPEU, MLM. and MOSCHINI–CARLOS, V. Produtividade primária das macrófita aquática submersa livre *Utricularia gibba* L. na lagoa dourada (Brotas, SP). *Acta Limnol. Bras.* 1997, vol. 9, no. 1, p. 1-9.

RIGOLLET, V., SFRISO, A., MARCOMINI, A. and De CASABIANCA, ML. Seasonal evolutions of heavy metal concentrations in the surface sediments of two mediterranean *Zostera marina* L. Beds at Thau lagoon (France) and Venice Lagoon (Italy). *Bioresour. Technol.* 2004, vol. 95, no. 2, p. 159-167.

SAND-JENSEN, K. Influence of submerged macrophyte on sediment composition and near –bed flow in lowland stream. *Freshw. Biol.* 1998, vol. 39, no. 4, p. 663-667.

SANDSTEN, H., BEKLIOGLU, M. and INCE, O. Effects of waterfowl, large fish and periphyton on the spring growth of *Potamogeton pectinatus* L. in Lake Mogan, Turkey. *Hydrobiologia,* 2005, vol. 537, no. 1-3, p. 239-248.

SANTOS, AM. and ESTEVES, FA. Primary production and mortality of *Eleocharis interstincta* in response to water level flutuations. *Aquat. Bot.* 2002, vol. 74, no. 3, p. 189-199.

SCHEFFER, M., HOSPER, SH., MEIJER, ML., MOSS, B. and JEPPESEN, E. Alternative equilibria in shallow lakes. *Trends in Ecology and Evolution* 1993, vol. 8, no. 8, p. 275–279.

VOLLENWEIDER, RA. *A manual on methods for measuring primary production in aquatic environments.* Oxford: Blackweel Scientific Publications Osney mead, 1974. 225p.

WETZEL, RG. *Limnologia*. Lisboa: Fundação Calouste Gulbenkian, 1993. 919p.

ZAR, JH. *Biostatistica analysis*. New Jersey: Prentice Hall, 1999. 663p.

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