THE USE OF INDICES FOR EVALUATING THE PERIPHYTIC COMMUNITY IN TWO KINDS OF SUBSTRATE IN IMBOASSICA LAGOON, RIO DE JANEIRO, BRAZIL

FERNANDES, V. O.[1] and ESTEVES, F. A.[2]

[1]Universidade Federal do Espírito Santo, CCHN, Departamento de Ciências Biológicas, Setor: Botânica, Av. Marechal Campos, 1468, CEP 29060-900, Maruípe, Vitória, ES, Brazil

[2]Universidade Federal do Rio de Janeiro, Instituto de Biologia, Departamento de Ecologia, Ilha do Fundão, CEP 21541-590, Rio de Janeiro, RJ, Brazil

Correspondence to: Valéria de Oliveira Fernandes, Rua João Joaquim da Mota, 356, apto. 1601, Ed. Plaza Gimenez, Praia da Costa, CEP 29101-200, Vila Velha, ES, Brazil, e-mail: valeriaes@uol.com.br

Received Juny 10, 2002 – Accepted October 22, 2002 – Distributed May 31, 2003

(With 1 figure)

ABSTRACT

Biological indices based on the biomass (dry weight, ash content, and chlorophyll-*a*) of the periphyton in a natural (submersed leaves of *Typha domingensis* Pers) and in an artificial (plastic hoses) substrate were compared, in experiments performed in summer and winter, in two sampling stations of Imboassica Lagoon, Macaé, Rio de Janeiro. The periphytic community exhibited low biomass at the beginning and end of the experiments, and moderate biomass in the intermediate period of the experiment, whatever the kind of substrate, sampling station, and season. In both seasons, there was a spatial variation regarding the degree of trophy of the periphyton, due to the difference of nutrient availability among the sampling stations. The alternation of inorganic and organic periphyton, as well as of their heterotrophic, hetero-autotrophic, auto-heterotrophic and, autotrophic character was due to changes in the abiotic factors of the sampling periods. The Lakatos index proved more sensitive than the Autotrophic Index to variations in the composition of the periphytic community.

Key words: periphyton, natural and artificial substrate, index, coastal lagoon.

RESUMO

Aplicação de índices para a avaliação da comunidade perifítica em dois tipos de substrato na lagoa Imboassica, Rio de Janeiro, Brasil

Índices biológicos baseados na biomassa (peso seco, conteúdo de cinzas e clorofila *a*) do perifíton em substrato natural (folhas submersas de *Typha domingensis* Pers) e artificial (mangueiras plásticas) foram comparados, em experimentos realizados durante o verão e o inverno, em duas estações de amostragem da lagoa Imboassica, Macaé, Rio de Janeiro. A comunidade perifítica apresentou baixa biomassa nas fases iniciais e finais dos experimentos e biomassa média nas fases intermediárias, independente do tipo de substrato, estação de amostragem e período estudado. Em ambos os períodos, houve variação espacial com relação ao grau de trofia do perifíton em razão da diferença de disponibilidade de nutrientes entre as estações de amostragem. As alternâncias do perifíton inorgânico e orgânico, heterotrófico, hetero-autotrófico, auto-heterotrófico e autotrófico se deveram a mudanças nos fatores abióticos nas estações de amostragem nos períodos estudados. O índice de Lakatos mostrou-se mais sensível às variações na composição da comunidade perifítica do que o Indíce Autotrófico.

Palavras-chave: perifíton, substrato natural e artificial, índices, lagoa costeira.

INTRODUCTION

According to Kjerfve (1994), coastal lagoons are shallow bodies of water, found in all continents, usually parallel to the shoreline, and separated from the sea by a sandbar or connected by one or more channels. Differences in the degree of marine influence, morphometry, and extension are charac–teristics of Brazilian coastal lagoons especially regarding the communities inhabiting them and environmental variables (Esteves *et al*., 1990).

In the coastal lagoons the photic zone often reaches the sediment and, thus, submersed and floating aquatic macrophytes, as well as submersed structures of emergent macrophytes and dead substrates are densely colonized by sessile microflora (Fernandes, 1997).

The periphyton is represented by a bioderm composed of microorganisms (bacteria, fungi, algae, protozoa, and microcrustaceans), as well as organic and inorganic detritus, that may have adhered to or be associated with a substrate, living or dead (Wetzel, 1983a; Moschini-Carlos & Henry, 1997). Functionally, it is a microcosm where internal (autotrophic and heterotrophic) processes and exchanges with the external environment (surrounding water) occur simultaneously (Wetzel, 1983b). The community composition varies in relation to such diverse factors as the nature of the substrate and the trophic state of the environment (Moschini-Carlos & Henry, 1997).

In coastal lagoons subjected to anthropogenic stress, periphytic biomass growth may be explained by nutrient inputs (e.g., domestic effluent dumping) and modifications of abundance development may be controlled by opening the sandbar (Fernandes, 1997). According to Watanabe (1985), many indices based on dry weight, organic matter, and chlorophyll-*a* may be used for classifiying periphyton during the substrate colonization phases, according to autotrophic or heterotrophic state, organic or inorganic nature, and biomass.

The aims of this research were to classify and compare the development of the periphytic community, using different biological indices, in experiments performed with natural and artificial substrates in a Brazilian coastal lagoon.

STUDY AREA

Imboassica Lagoon is located inside the urban perimeter of Macaé, in northern Rio de Janeiro State, between 23°25' and 23°35'S, 42°35' and 42°45'W. The great surface:depth ratio is a positive characteristic for colonization of several aquatic macrophyte species, mainly *Typha domingensis* Pers (Furtado, 1994). The lagoon is separated from the sea by a sandbar approximately 50 meters wide. At the opposite end, where the Imboassica River reaches the lagoon, a salinity gradient between the mouth zone of the river was detected (Fernandes, 1997) (Fig. 1).

Within the last few years a great number of houses with unsuitable sewage systems have been constructed on the shores of the Imboassica Lagoon and untreated domestic sewage dumping occurs in this aquatic ecosystem.

Artificial openings of the sandbar also greatly impact this ecosystem and occur after intense rain, when flooding occurs in the shore regions and sewage effluents accumulate in the lagoon. A drastic decrease in lagoon water volume is then observed, since most of the water is drained into the sea, with the lacustrine sediment being exposed in many places and considerable loss of emergent and submersed aquatic macrophyte organisms, as well as associated periphytic communities.

MATERIALS AND METHODS

Two sampling stations were selected: station 1, in the mouth zone of the main sewage channel, and station 2, approximately 200 meters from station 1, in a region less densely colonized by aquatic macrophytes and more exposed to wind effects (Fig. 1).

The experiments were performed in summer (February and March 1994) and in winter (July and August 1994). In the summer, beginning from February 2, samples were taken after 1, 3, 5, 8, 15, 20, 24, and 32 days; in the winter, from August 2 on, the periphyton was collected after 1, 3, 5, 8, 15, 22, 29, and 35 days.

In both sampling stations, water samples collected at the subsurface (about 20 cm depth) were used for determining pH (Micronal B278 pHmeter), salinity and electrical conductivity (H-01474-00 salinometer-conductivimeter), dissolved oxygen (TOA oxymeter), and total phosphate (Golterman *et al.*, 1978), and then filtered in Whatman GF/C filters for dissolved nutrients (amonniacal nitrogen, Koroleff, 1976; nitrate, Zagato *et al.,* 1981; dissolved total phosphorus and total phosphate, Golterman *et al.*, 1978). Water temperature and transparency were also measured using a FAC 400 thermistor and Secchi disk, respectively.

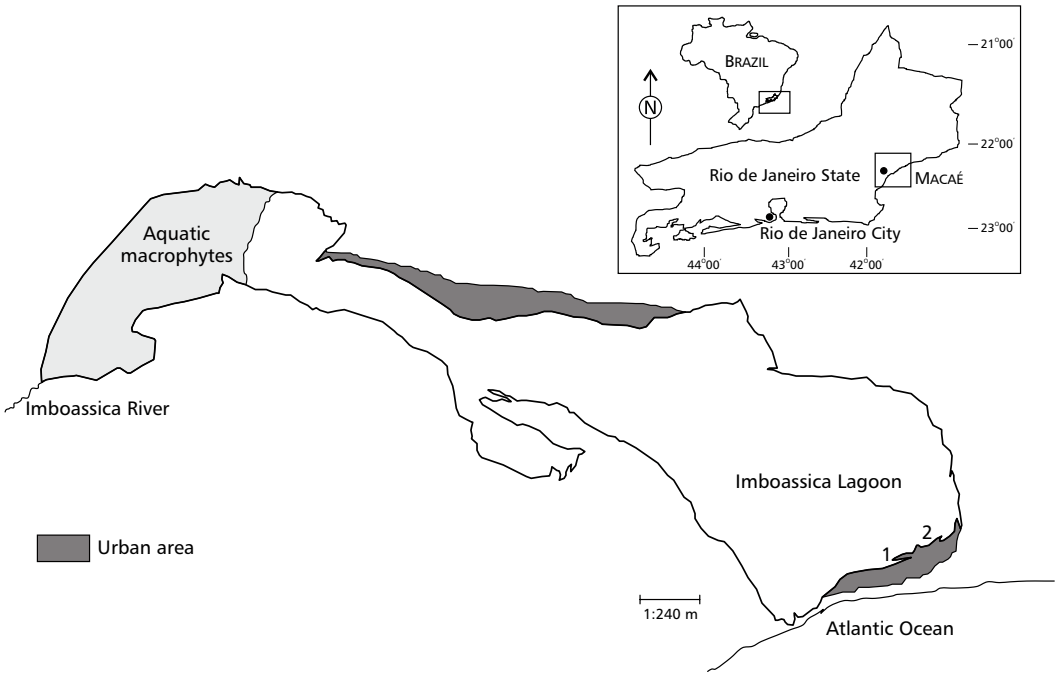

Fig. 1 — Location of Imboassica Lagoon and sampling stations (1 and 2).

In each period, we selected as a natural substrate about 100 leaves of adult, green, emergent leaves (from 2.5 to 3.0 meters, at station 1, and from 1.5 to 2.0 meters, at station 2), of *Typha domingensis*, which were marked at the water-air interface with plastic-covered wires. They were incubated thereafter at a 20 cm depth, for periphyton colonization.

At both sampling stations, as an artificial substrate, we used plastic hoses 1.0 cm in diameter attached to a 1.5 by 0.80 m rectangular wooden frame, and fixed in the sediment.

In each sampling, periphyton samples from the natural and artificial substrates were removed and transfered in glass containing previously filtered water. The periphyton was then separated from the substrates by scraping and the substrate surface areas were determined with a pachymeter.

For the dry weight (DW) and ash-free dry weight (AFDW) periphyton determinations, the material was diluted in water and homogenized, after scrubbing. Replicates of 100 ml of the samples were vacuum filtered in pre-burned Whatman GF/C filters. Afterward, the filters were dried on a stove (at 70°C) until a constant dry weight. They were subsequently burned for three hours using a muffle furnace (at 450°C). The filters were weighed again and the ash-free dry weight (AFDW) was determined by the difference between the DW and the remaining weight.

From the same periphytic material, other 100 ml samples were strained with filters which had not been pre-incinerated and were immediately frozen. After, chlorophyll-*a* was determined according Nusch & Palme (1975) using warm ethanol (80°C) as a solvent. For the periphyton classification, two indices were adopted:

a. The Autotrophic Index (AI), which represents the quotient between ash-free dry weight and chlorophyll-*a* values (Apha, 1985) used for characterizing periphytic colonization stages on substrates, and related to the trophic state of the community.

b. The index proposed by Lakatos (1989) based on chlorophyll-*a* (%), ashes (in % of DW), and dry biomass ($g.m^{-2}$) values, as shown in Table 1.

TABLE 1
Classification of the periphyton (Lakatos, 1989).

Type	Dry Biomass (DW)	($g.m^{-2}$)
I	high biomass periphyton	> 40
II	average biomass periphyton	20-40
III	low biomass periphyton	< 20
	Ash Content (A)	**(%)**
I	inorganic periphyton	> 75
II	inorganic-organic periphyton	50-75
III	organic-inorganic periphyton	25-50
IV	organic periphyton	< 25
	Chlorophyll-*a* Content (cl. *a*)	**(%)**
I	autotrophic periphyton	> 0.60
II	auto-heterotrophic periphyton	0.25-0.60
III	hetero-autotrophic periphyton	0.10-0.25
IV	heterotrophic periphyton	< 0.10

The sampling stations were chosen to test the hypothesis that the periphytic community would be different in stations, substrates, and seasons as a consequence of observed alterations in environmental conditions.

RESULTS

Table 2 shows the physical, chemical, and physicochemical factors in two sampling stations of Imboassica Lagoon.

In summer, water temperatures were high, ranging from 24.1°C to 29.8°C at station 1 and 24.1°C to 30.5°C at station 2. In winter, the water temperatures varied between 18.7°C and 24.1°C (station 1) and 17.9°C to 24.0°C (station 2). Generally, the transparency was high considering the total Imboassica Lagoon depth. In summer, water transparency reached the sediment in both sampling stations (from 0.80 to 1.20 m). In winter, water transparency ranged from 0.04 m (after rain) to 1.15 m at station 1 and from 0.85 m to 1.10 m at station 2.

Electrical conductivity was higher in winter than in summer, mainly at station 2. The average electrical conductivity value was 2.6 mS/cm in summer and 5.2 mS/cm in winter.

The pH results showed that Imboassica Lagoon was slightly alcaline to alcaline at both sampling stations and in both periods, with an average pH value of 7.5 at sampling station 1 and 7.6 in sampling station 2 (in summer), and pH values of 7.2 and 7.6 at sampling station 1 and 2, respectively (in winter).

The total alkalinity values were considerably higher in summer (more than twice those registered in the winter), ranging from 1.03 meq/L to 1.38 meq/L at station 1; at station 2, the variation was from 1.01 meq/L to 1.55 meq/L. In winter at station 1 the total variation ranged between 0.19 meq/L and 0.56 meq/L and at station 2, the total variation ranged from 0.15 meq/L to 0.83 meq/L.

Salinity values were higher in winter than in summer due to marine influence in the lagoon after an opening in the sandbar. Imboassica Lagoon was characterized as oligohaline to oligo-mesohaline in summer and winter, respectively.

Table 3 presents the concentrations of dissolved nutrients and total nutrients in the two sampling stations in the different samplings. In summer, as well as in winter, on most sampling days, station 1 exhibited higher nutrient concentrations when compared to station 2.

TABELA 2

Temporal variations of some physical, chemical, and physico-chemical characteristics in two sampling stations of Imboassica Lagoon in summer and winter, 1994.

Day/station	Water temp. (°C)	pH	Electrical cond. (mS/cm)	Alkalinity (meq/L)	Salinity (u.s.)	Transparency (m)	Total depth (m)
SUMMER							
Station 1							
02/02	29.8	–	–	–	–	1.10	1.10
03/02	28.8	7.7	2.7	1.03	1.5	1.20	1.20
05/02	27.5	7.4	2.2	1.09	1.5	1.20	1.20
07/02	28.9	7.3	2.4	1.13	1.5	1.15	1.15
10/02	29.3	7.4	2.2	1.16	1.0	1.10	1.10
17/02	28.0	7.3	2.5	1.26	1.0	1.10	1.10
22/02	28.2	7.8	2.9	1.38	1.0	0.80	0.80
26/02	26.6	7.5	3.3	1.31	1.0	0.80	0.80
06/03	24.1	7.8	2.5	1.06	1.0	0.90	0.90
Station 2							
02/02	30.5	–	–	–	–	1.00	1.00
03/02	28.9	7.7	2.8	1.02	1.5	1.00	1.00
05/02	27.6	7.4	2.2	1.07	1.5	1.10	1.10
07/02	29.5	7.5	2.3	1.22	1.5	0.85	0.85
10/02	29.5	7.5	2.3	1.09	0.5	0.90	0.90
17/02	28.3	7.3	2.5	1.25	0.5	0.90	0.90
22/02	28.9	7.9	2.9	1.41	0.5	0.80	0.80
26/02	26.9	7.8	3.2	1,55	1.0	0.80	0.80
06/03	24.1	7.8	2.7	1.01	1.0	0.90	0.90
WINTER							
Station 1							
02/08	24.1	8.6	5.8	0.45	3.0	1.15	1.15
03/08	22.4	7.7	5.7	0.47	3.5	1.00	1.00
05/08	19.7	6.8	4.9	0.51	3.0	0.70	1.10
07/08	18.7	7.0	4.7	0.44	5.0	0.90	0.90
10/08	20.0	7.6	5.6	0.48	4.0	1.00	1.00
17/08	21.6	7.0	5.4	0.56	4.0	1.10	1.10
24/08	22.6	7.0	5.2	0.30	3.5	0.85	0.85
31/08	22.0	7.2	5.9	0.39	4.0	1.00	1.10
06/09	23.0	6.2	1.8	0.19	0.0	0.04	1.20
Station 2							
02/08	24.0	8.2	5.8	0.53	3.0	1.00	1.00
03/08	22.6	8.0	5.8	0.49	3.5	0.90	0.90
05/08	19.3	7.4	4.9	0.38	2.0	0.95	1.10
07/08	17.9	7.6	4.8	0.45	4.0	0.85	1.10
10/08	20.2	7.6	5.6	0.50	4.0	1.10	1.10
17/08	21.7	7.8	5.5	0.54	4.0	1.10	1.10
24/08	22.6	7.0	5.2	0.40	3.5	1.00	1.00
31/08	22.0	7.2	5.9	0.83	1.0	0.90	1.00
06/09	22.5	7.5	5.5	0.15	3.0	1.00	1.00

TABLE 3

Temporal variations of total and dissolved nutrients of the subsurface of the water columm in two sampling stations in Imboassica Lagoon, in summer and winter 1994.

Days/stations	N-amoniacal (µg/L)	Nitrate (µg/L)	P-total (µg/L)	P-dissolved (µg/L)
SUMMER				
Station 1				
02/02	44	12	12	9
03/02	20	5	15	9
05/02	47	17	17	8
07/02	80	17	32	8
10/02	74	11	44	11
17/02	202	12	44	13
22/02	217	12	40	18
26/02	492	21	135	25
06/03	601	55	74	16
Station 2				
02/02	23	5	19	6
03/02	89	17	32	6
05/02	59	11	12	7
07/02	43	16	15	9
10/02	40	13	26	9
17/02	32	17	46	10
22/02	34	14	33	13
26/02	14	34	40	35
06/03	40	9	22	9
WINTER				
Station 1				
02/08	14	1	10	6
03/08	100	1	22	6
05/08	112	3	25	8
07/08	178	3	26	8
10/08	52	0.4	23	6
17/08	164	3	18	10
24/08	144	2	29	9
31/08	194	2	21	8
06/09	1422	36	105	32
Station 2				
02/08	47	0.4	11	8
03/08	63	0.5	14	6
05/08	66	0.3	8	5
07/08	58	0.3	9	7
10/08	93	0.5	8	5
17/08	38	0.3	8	8
24/08	44	0.4	8	9
31/08	80	1	15	6
06/09	122	1	16	6

Tables 4 and 5 show the variation of periphytic biomass (based on ashes, chlorophyll-*a,* and dry weight values) in summer and winter, in the natural and in the artificial substrates at the sampling stations and the corresponding classification according to Lakatos (1989) and Apha (1985).

In summer, the periphytic community of the natural substrate presented low biomass at station 1 (Table 4) as it did in the first and last stages of the experiment in the artificial substrate. In station 2, the periphyton of the natural substrate presented low biomass values except on the 20th day. In the artificial substrate, the biomass was high only from the 8th to the 20th day (Table 4).

In winter, the periphyton showed low biomass until the 29th and 22nd day of exposition of natural substrates of stations 1 and 2, respectively, increasing from then on until the final stages (Table 5). The artificial substrate of station 1 showed low biomass in the first and last stages and increased in the intermediate stages. The artificial substrate of station 2 presented low biomass up to the 22nd day, and increased from that day on.

During the summer at station 1 the natural substrate showed organic fraction predominance in the first and final stages of the experiment, and organic-inorganic fractions occurred from the 8th to the 15th day. In the artificial substrate the inorganic-organic fraction predominated until the 15th day, being replaced by the organic fraction until the end of the experiment. In station 2, the periphyton was characterized as predominantly organic until the 8th day of exposition of the substrate (in the natural substrate) and the 5th day (in the artificial substrate). From then on, deposition of inorganic material occurred and the periphyton was characterized as being inorganic-organic (Table 4).

In winter, independently of substrate or sampling station, there was an alternation of the inorganic-organic fractions of periphyton in both substrates and both sampling stations.

Using the percentage of chlorophyll-*a* to characterize the periphyton which had adhered to the natural substrate of station 1 in summer, the biomass was labeled as heterotrophic for the first few days, then characterized as heterotrophic-autotrophic until the 15th day and, from then on, as autotrophic. The periphyton in the artificial substrate of this same sampling station presented characteristically heterotrophic initial stages; there then occurred a gradual algae colonization increase in the community, characterizing autotrophic periphyton. In summer, both the natural and artificial substrate in station 2 exhibited a community with heterotrophic characteristics throughout the experiment (Table 4).

In winter, the natural substrate of station 1 showed autotrophic periphyton from the 15th to the 29th day of substrate exposition during which the artificial substrate presented heterotrophic-autotrophic characteristics. In both substrates, the first and last days of the experiment exhibited more heterotrophic characteristics. In station 2, heterotrophy was dominant in both substrates in such a way that, in the natural substrate, in the intermediate stages (5th to 22nd day) the periphyton was characterized as heterotrophic-autotrophic; in the artificial substrate this kind of community developed only on the 15th day of colonization (Table 5).

Tables 4 and 5 also show the fluctuations in the Autotrophic Index in the different stages of periphyton colonization in both substrates and sampling stations where, by the way, in summer and winter the periphyton was generally heterotrophic.

DISCUSSION

The differences of the abiotic factors in Imboassica Lagoon became evident in both spatial and temporal scales. The temporal heterogeneity may be explained by sandbar openings on two occasions a few months before the winter experiment. The consequent marine influence resulted in higher values of salinity and electrical conductivity.

Spatial heterogeneity was due to the variation in concentrations of ammoniacal-N and total-P, which exhibited, on most sampling days and in both periods, higher values at station 1, located in the mouth of the sewage channel.

In the rainy season a water level increase in the sewage channel occurred and nutrient input and water transparency was reduced in station 1.

Imboassica Lagoon presented fresh-to-oligohaline water, since the sandbar had been closed for 1 year and 4 months prior to the first experiment. The sandbar was then opened for a short period of time. Later, due to continued rain, the sandbar was opened again (in the beginning of May). The second experiment was, therefore, performed at a time when the lagoon exhibited mesohaline characteristics.

TABLE 4

Classification of periphyton in two substrates in SUMMER experiment, according the two indices employed: Lakatos (1989) and Autotropic Index (AI) (Apha, 1985).

Days/stations	Exposition time	Ash		Chlorophyll-*a*		Dry weight		Autotrophic index	
		(%)	Classification	(%)	Classification	(g/m^2)	Classification	I.A.	Classification
P1 nat. subst.									
03/02	1 day	12	IV	0.00	IV	0.6	III	0	–
05/02	3 days	21	IV	0.00	IV	0.7	III	0	–
07/02	5 days	22	IV	0.06	IV	1.4	III	1166	HET.
10/02	8 days	31	III	0.10	III	3.4	III	894	HET.
17/02	15 days	42	III	0.16	III	6.7	III	592	HET.
22/02	20 days	26	III	0.43	II	6.9	III	232	HET.
26/02	24 days	32	III	0.86	I	8.4	III	1090	HET.
06/03	32 days	11	IV	0.73	I	6.7	III	1338	HET.
P1 art. subst.									
03/02	1 day	27	III	0.00	IV	1.2	III	0	–
05/02	3 days	51	II	0.07	IV	2.4	III	1500	HET.
07/02	5 days	46	III	0.03	IV	4.1	III	2411	HET.
10/02	8 days	55	II	0.04	IV	4.7	III	2136	HET.
17/02	15 days	64	II	0.11	III	23.1	II	95	AUT.
22/02	20 days	6	IV	0.25	II	11.8	III	404	HET.
26/02	24 days	13	IV	0.88	I	5.6	III	1064	AUT.
06/03	32 days	26	III	0.45	II	13.2	III	220	HET.
P2 nat. subst.									
03/02	1 day	16	IV	0.00	IV	0.5	III	0	–
05/02	3 days	6	IV	0.22	III	0.9	III	409	HET.
07/02	5 days	33	III	0.09	IV	1.3	III	2222	HET.
10/02	8 days	44	III	0.05	IV	5.4	III	1687	HET.
17/02	15 days	63	II	0.08	IV	11.2	III	556	HET.
22/02	20 days	63	II	0.04	IV	23.7	II	2790	HET.
26/02	24 days	54	II	0.24	III	9.9	III	2033	HET.
06/03	32 days	52	II	0.06	IV	12.9	III	1780	HET.
P2 art. subst.									
03/02	1 day	0	IV	0.00	IV	0.6	III	0	–
05/02	3 days	28	III	0.02	IV	0.9	III	3500	HET.
07/02	5 days	41	III	0.03	IV	2.7	III	3375	HET.
10/02	8 days	67	II	0.02	IV	18.1	III	2100	HET.
17/02	15 days	71	II	0.03	IV	36.7	II	3627	HET.
22/02	20 days	70	II	0.02	IV	36.8	II	6607	HET.
26/02	24 days	72	II	0.06	IV	45.1	I	1685	HET.
06/03	32 days	67	II	0.08	IV	38.1	II	1270	HET.

TABLE 5

Classification of periphyton in two substrates in WINTER experiment, according the two indices employed: Lakatos (1989) and Autotropic Index (AI) (Apha, 1985).

Days/stations	Exposition time	Ash		Chlorophyll-*a*		Dry weight		Autotrophic index	
		(%)	Classification	(%)	Classification	(g/m^2)	Classification	I.A.	Classification
P1 nat. subst.									
03/08	1 day	38	III	0.01	V	2.4	III	6667	HET.
05/08	3 days	74	II	0.02	IV	1.4	III	2500	HET.
07/08	5 days	63	II	0.89	I	1.5	III	56	AUT.
10/08	8 days	42	III	0.17	III	3.9	III	588	HET.
17/08	15 days	57	II	1.26	I	15.4	III	120	AUT.
24/08	22 days	48	III	0.48	II	15.3	III	207	AUT.
31/08	29 days	48	III	0.36	II	14.4	III	280	HET.
06/09	35 days	76	I	0.10	III	29.1	II	993	HET.
P1 art. subst.									
03/08	1 day	18	IV	0.05	IV	1.3	III	2000	HET.
05/08	3 days	84	I	0.31	II	7.5	III	327	HET.
07/08	5 days	90	I	0.16	III	16.5	III	604	HET.
10/08	8 days	48	III	0.20	III	27.5	II	491	HET.
17/08	15 days	72	II	0.24	III	21.8	II	411	HET.
24/08	22 days	60	II	0.20	III	15.1	III	497	HET.
31/08	29 days	62	II	0.55	II	18.1	III	183	AUT.
06/09	35 days	74	II	0.08	IV	21.2	II	1228	HET.
P2 nat. subst.									
03/08	1 day	23	IV	0.01	IV	1.6	III	20000	HET.
05/08	3 days	7	IV	0.04	IV	1.3	III	2500	HET.
07/08	5 days	25	III	0.15	III	1.7	III	1724	HET.
10/08	8 days	67	II	0.24	III	18.1	III	415	HET.
17/08	15 days	49	III	0.11	III	4.0	III	909	HET.
24/08	22 days	26	III	0.23	III	3.0	III	429	HET.
31/08	29 days	64	II	0.06	IV	26.0	II	1722	HET.
06/09	35 days	60	II	0.05	IV	18.0	III	2000	HET.
P2 art. subst.									
03/08	1 day	6	IV	0.00	IV	0.8	III	0	–
05/08	3 days	48	III	0.07	IV	2.3	III	1429	HET.
07/08	5 days	60	II	0.02	IV	5.0	III	4545	HET.
10/08	8 days	58	II	0.03	IV	2.8	III	4000	HET.
17/08	15 days	71	II	0.13	III	8.5	III	800	HET.
24/08	22 days	68	II	0.07	IV	19.0	III	1429	HET.
31/08	29 days	70	II	0.05	IV	30.0	II	2180	HET.
06/09	35 days	61	II	0.08	IV	28.0	II	1208	HET.

Thus, the experiments were developed in distinct climatic and environmental conditions which exerted some influence on the periphytic community structure and dynamics (Fernandes, 1997).

According to Moschini-Carlos (1996), the composition and abundance of periphytic algae are a result of abiotic factors, such as temperature, light, and nutrients. These organisms are, therefore, very sensitive to systemic modifications in water quality and hydrodynamics.

The periphytic algae may absorb nutrients, when available in the water column, while maintaining the internal nutrient pool which allows their development even in oligotrophic conditions (Chamixaes, 1991).

The influence of the sewage channel in station 1 and the openings of the sandbar between the studied periods were the factors that promoted marked effects in the biomass and on the periphytic community structure and dynamics in Imboassica Lagoon.

The periphyton may be characterized using indices, based on total biomass, chlorophyll-*a,* and ash content which allow estimating their community structure and productivity (Watanabe, 1990). The periphytic community includes autotrophic and heterotrophic organisms, as well as inorganic and organic detritus of allochthonous and autochthonous origin. According to Lakatos (1989), the periphytic biomass, estimated by the ash content, includes predominantly inorganic material and, when estimated by chlorophyll-*a*, corresponds to the photosynthetic algae community.

The low periphytic biomass found in the first and last stages of the experiment, in both substrate and sampling stations, may be explained by the P deficiency in the water column (in station 1), and of N and P in the water column (in station 2). Evidence that the low nutrient availability in the water column limits periphytic algae growth, has already been reported (Sand-Jansen, 1983; Chamixaes, 1991; Fernandes, 1997).

In the intermediate stages of the experiment (between the 8th and 24th day in summer and the 8th and the 22nd day in winter), the periphytic biomass presented high values due to the greater algae density and had more autotrophic characteristics, based on the chlorophyll-*a* values.

The temporal variation in ash and chlorophyll-*a* contents indicates a change from the predominantly autotrophic organisms to heterotrophic ones, or in the presence of organic or inorganic materials deposited on the substrates. Greater algae colonization in the periphytic community with, therefore, more autotrophic characteristics, is directly related to the degree of trophy of the environment.

In summer as well as in winter, autotrophic and autotrophic-heterotrophic conditions were found in the intermediate stages of the experiment in the substrates of station 1. In the natural substrate, the autotrophic stages lasted longer. This fact may possibly be explained by the "preference" of the organisms for colonizing living substrates and by the nutrient exchange between the substrate and the periphytic community. In this sampling station, algae colonization was made easier by the greater nutrient input (N and P) in the area around the sewage channel's mouth. In station 2, heterotrophy was characteristic of the periphytic community throughout almost all of the summer and winter, in the natural as well as in the artificial substrate. In this sampling station, the lower nutrient availability must have been one of the major factors controlling density algae in both substrates.

The more heterotrophic characteristics of the periphytic community must be directly related to various factors such as: greater density of bacteria and/or fungi, which are characteristically pioneering organisms in many experiments performed by several authors (Wetzel, 1983b; Godinho-Orlandi & Barbieri, 1983; Fernandes, 1993; Moschini-Carlos & Henry, 1997); low density of organisms in the first stages of colonization; loosening of periphytic organisms in the final stages; and storage in the substrates of inorganic material from the sewage channel or regions close to the lagoon, especially in periods of high precipitation. These combined factors should explain the change from organic-inorganic to inorganic-organic periphyton in both periods in the two substrates and sampling stations (Fernandes, 1997).

Using the Autotrophic Index, heterotrophy was shown to dominate in the periphytic community in both sampling stations and substrate types in Imboassica Lagoon. Only the intermediate stages of the experiment exhibited more autotrophic characteristics (from the 15th day of colonization).

Schwarzbold (1992) and Fernandes (1993), developing similar experiments with adhered periphyton in natural substrates in the Infernão (SP) and Jacarepaguá (RJ) lagoons and using the Autotrophic Index, classified the community as having heterotrophic characteristics. Moschini-Carlos

& Henry (1997), working with natural and artificial substrates in the Jurumirim Reservoir (SP) and using the Autotrophic Index and the Lakatos index as classification indices, characterized the periphyton as being heterotrophic-autotrophic.

On most days our study, the characteristics described in the Autotrophic Index coincided with those defined in the Lakatos index. The latter, however, was more sensitive to modifications in composition of the community.

Acknowledgments — The authors extend their thanks to Petrobrás for financially assisting this project. Our thanks to Paulo Roberto Brum for translating the manuscript into English.

REFERENCES

APHA, 1985, *Standard methods for the examination of water and waste-water*. Amer. Publications Health Association, 1268p.

CHAMIXAES, C. B. C. B., 1991, *Variação temporal da biomassa, composição de espécies e produtividade das algas perifíticas relacionadas com as condições ambientais de pequenos rios da bacia hidrográfica do Ribeirão do Lobo (Itirapina, SP).* Tese de Doutorado, USP, 334p.

ESTEVES, F. A., ROLAND, F. & BOZELLI, R. L., 1990, Lagoas costeiras do Rio de Janeiro: até quando? *Ciência Hoje, 12*(68): 68-69.

FERNANDES, V. O., 1993, *Estudos limnológicos na Lagoa de Jacarepaguá (RJ): variáveis abióticas e mudanças na estrutura e dinâmica da comunidade perifítica em* Typha domingensis *Pers*. Dissertação de Mestrado, UFSCar, 131p.

FERNANDES, V. O., 1997, *Variação temporal da estrutura e dinâmica da comunidade perifítica, em dois tipos de substrato, na Lagoa Imboassica, Macaé (RJ).* Tese de Doutorado, UFSCar, 209p.

FURTADO, A. L. S., 1994, *Contribuição das macrófitas aquáticas* Typha domingensis *Pers. (Typhaceae) e* Eleocharis *cf.* fistulosa *(Poir) Link (Cyperaceae) para o estoque de nutrientes e energia da Lagoa Imboassica (Macaé, RJ).* Dissertação de Mestrado, UFRJ, 103p.

GODINHO-ORLANDI, M. J. L. & BARBIERI, S. M., 1983, Observação de microorganismos perifíticos (bactérias, protozoários e algas) na região marginal de um ecossistema aquático. *An. Sem. Reg. Ecol., 3*: 135-155.

GOLTERMAN, H. L., CLYMO, R. S. & OHNSTAD, M. A. M., 1978, *Methods for physical and chemical analysis of freshwater*. Blackwell Scientific Publication, 213p.

KJERFVE, B., 1994, Coastal lagoons, pp.1-8. *In*: B. Kjerfve (ed.), *Coastal lagoons processes*. Elsevier Oceanography Series 60, Amsterdam.

KOROLEFF, F., 1976, Determination of nutrients, pp. 117-181. *In*: K. Grasshoff (ed.)*, Methods of seawater analysis*. Verlag Chemie Weinhein, New York.

LAKATOS, G., 1989, Composition of reed periphyton (biotecton) in the Hungarian part of lake Fertö. *Biol. Forschun. für Burg., 71*: 125-134.

MOSCHINI-CARLOS, V., 1996, *Dinâmica e estrutura da comunidade perifítica (substrato natural e artificial) na zona de desembocadura do rio Paranapanema, Represa de Jurumirim, SP.* Tese de Doutorado, UFSCar, 173p.

MOSCHINI-CARLOS, V. & HENRY, R., 1997, Aplicação de índices para a classificação do perifíton em substratos natural e artificial, na zona de desembocadura do rio Paranapanema (Represa de Jurumirim), SP. *Rev. Brasil. Biol., 57*(4): 655-663.

NUSCH, E. A. & PALME, G., 1975, Biologische Methoden Für die Praxis der Gewässeruntersuchung. *GWF-Wasser/ Abwasser, 116*: 563-565.

SAND-JANSEN, K., 1983, Physical and chemical parameters regulating growth of periphytic communities, pp. 5-10. *In*: R. G. Wetzel (ed.), *Periphyton of freshwater ecosystems*. The Hague Dr. W. Junk.

SCHWARZBOLD, A., 1992, *Efeitos do regime de inundação do Rio Mogi-Guaçu (SP) sobre a estrutura, diversidade, produção e estoque do perifíton na Lagoa do Infernão*. Tese de Doutorado, UFSCar, 231p.

WATANABE, T., 1985, *Étude de la relation entre le periphyton et la qualité chimique de l'eau des rivières: utilization de bioessais "in situ" (substrates artificiales) pour caracteriser l'etat de pollution des eaux*. L'Université Paul Sabatier de Toulouse, Toulouse, França, 127p.

WATANABE, T., 1990, Perifíton: comparação de metodologias empregadas para caracterizar o nível de poluição das águas. *Acta. Limnol. Brasil., 3:* 593-615.

WETZEL, R. G., 1983a, Opening remarks, pp. 3-4. *In*: R. G. Wetzel (ed.), *Periphyton of freshwater ecosystems*. The Hague Dr. W. Junk.

WETZEL, R. G., 1983b, Attached algal-substrata interactions: fact, myth, and when and how? pp. 207-215. *In*: R. G. Wetzel (ed.), *Periphyton of freshwater ecosystems*. The Hague Dr. W. Junk.

ZAGATO, A. O., REITS, B. F., BERGAMIN, F. H., PASSENDA, L. H. R., MORTATI, J. S. & GINE, M. F., 1981, *Manual de análises de plantas e águas empregando sistema de injeção em fluxo*. CENA, Piracicaba, SP, Brasil.