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Temporal variation of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* (Charophyceae) in the Ninféias pond, São Paulo State, southeast Brazil

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RESUMO – (Variação temporal de *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* (Charophyceae) no Lago das Ninféias, São Paulo, sudeste do Brasil). Dinâmica temporal de uma população de *Nitella furcata (*Roxburgh *ex* Bruzelius) C. Agardh emend. R.D. Wood subsp. *mucronata* (A. Braun) R.D. Wood var. *mucronata* f. *oligospira* (A. Braun) R.D. Wood foi estudada no Lago das Ninféias (23°38'18,9"S, 46°37'16,3"W), um reservatório tropical, raso, mesotrófico situado na Reserva Biológica do Parque Estadual das Fontes do Ipiranga, Município de São Paulo, sudeste do Brasil. Amostras de água foram coletadas mensalmente de outubro/1996 a outubro/1997 para análise de turbidez, condutividade elétrica, pH, alcalinidade, oxigênio dissolvido, nutrientes, biomassa e fenologia da alga. Os maiores valores médios de biomassa total da carácea (98,35-266,06 $g.m^{-2}$) foram registrados no período de chuvas e os menores (48,86-170,56 $g.m^{-2}$) no seco. A densidade populacional apresentou picos de outubro/1996 a abril/1997, isto é, durante a estação chuvosa, época em que foram registrados os maiores valores de temperatura do ar e da água, de precipitação pluvial, radiação solar, turbidez, nitrogênio total e de amônio, constituindo condições favoráveis para o crescimento das plantas. O período entre maio/1997 (final do outono) e outubro/1997 (início da primavera) mostrou-se favorável ao desenvolvimento de estruturas reprodutivas (núculas e glóbulos), com diminuição de biomassa e densidade populacional da carácea, sugerindo maior alocação de energia para a formação de estruturas reprodutivas. Este fato foi confirmado pela análise de correspondência canônica, que registrou fortes correlações entre comprimento e diâmetro das núculas, número total de núculas por planta e comprimento e diâmetro dos oósporos, com os baixos valores de pH e altos de matéria orgânica verificados no período de seca. Concluindo, fatores ambientais, como aumento de temperatura da água e disponibilidade de nutrientes, parecem exercer influência decisiva sobre o crescimento e acúmulo de biomassa da alga no Lago das Ninféias.

Palavras-chave : Charophyceae, biomassa, fenologia, macrófita aquática, *Nitella*

ABSTRACT – (Temporal variation of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* (Charophyceae) in the Ninféias pond, São Paulo State, southeast Brazil). Temporal and spatial variation of *Nitella furcata* (Roxburgh *ex* Bruzelius) C. Agardh emend. R.D. Wood subsp. *mucronata* (A. Braun) R.D. Wood var. *mucronata* f. *oligospira* (A. Braun) R.D. Wood were studied at the Ninféias pond (23°38'18.9"S, 46°37'16.3"W), a tropical, shallow, mesotrophic reservoir located in the Parque Estadual das Fontes do Ipiranga Biological Reserve, Municipality of São Paulo, southeast Brazil. Water samples were collected monthly from October/1996 to October/1997 for turbidity, electric conductivity, pH, alkalinity, dissolved oxygen, nutrients, biomass, and algal phenology analysis. Spatial distribution pattern of algal biomass showed that all four sampling stations were similar among themselves during the whole study period. Regarding the temporal variation, greatest algal total biomass values (98.35-266.06 $g.m^{-2}$) were measured during the rainy period whereas the smallest ones (48.86-170.56 $g.m^{-2}$) were detected during the dry period. Algal population density peaked at all four sampling stations from October/1996 to April/1997 (rainy period) when the greatest values of air and water temperature, precipitation, solar radiation, turbidity, total nitrogen, and ammonium were measured allowing favorable conditions for the algal growth. Period from May/1997 (late fall) to October/1997 (early spring) was favorable to the development of reproductive structures (nucules and globules) with consequent decrease of algal biomass and population density, clearly suggesting the greatest energy allocation towards the development of sexual reproductive structures. This fact was confirmed by the canonic correspondence analysis that indicated strong correlation between nucules length and width, number of nucules per plant, and oospores length and width with the low values of pH and high ones of dissolved inorganic matter detected during the dry period. Consequently, environmental factors such as increasing of water temperature and nutrients availability at the Ninféias pond acted decisively towards growth and accumulation of algal biomass.

Key words: Charophyceae, biomass, phenology, aquatic macrophyte, *Nitella*

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Introduction

Charophyceae is a very typical algal class due to the macroscopic size of its constituents and the extreme morphological complexity of both their thallus organization and the gametangia structure (van-den-Hoek *et al.* 1996). Despite of the Charophyceae being relatively frequent in ponds, rivers, creeks, etc., research aiming at their ecology, phenology, and geographic distribution are still very scarce worldwide, Brazil being not an exception.

Early papers referring to the seasonal variation of macroalgal communities (including the Charophyceae) or to aspects of their spatial distribution in lotic environments are the ones by Necchi Jr. *et al.* (1994; 1997), Branco & Necchi Jr. (1996a; 1996b; 1998), Vieira Jr. *et al.* (2002; 2003), and Vieira Jr. & Necchi Jr. (2002; 2003).

Dealing with material from lentic systems, there are the papers by Carneiro *et al.* (1994), Palma-Silva (1998), and Palma-Silva *et al.* (2000; 2002) that studied some ecological aspects of the charophyte community at Imboassica and Piratininga lagoons in the state of Rio de Janeiro.

Present research aimed at determining which environmental variables are responsible for the greatest variability in the distribution of the biological features (reproduction, algal density and biomass) of *Nitella furcata* (Roxburgh *ex* Bruzelius) C. Agardh emend. R.D. Wood subsp. *mucronata* (A. Braun) var. *mucronata* f. *oligospira* (A. Braun) R.D. Wood at the Ninféias pond, Municipality of São Paulo, southeast Brazil.

Material and methods

Ninféias pond (23°38'18.9"S, 46°37'16.3"W) is a shallow mesotrophic reservoir located at the Parque Estadual das Fontes do Ipiranga Biological Reserve (Bicudo *et al.* 2002), Municipality of São Paulo, southeast Brazil. The climate in the area is, according to Conti & Furlan (2003), tropical of altitude based on the local altitude (800 m), average of monthly maximum and minimum temperatures not surpassing 6-8 ºC, and the average precipitation in two months of the year < 60 mm.

Three sampling sites were defined according to the presence of stands of the submersed attached macrophyte *N. furcata* subsp. *mucronata* var. *mucronata* f. *oligospira*. Size of area covered by the alga at the sampling sites varied among sites and in the same site depending on the time of the year. Samplings within each sampling station were aleatory (n = 6). A total of 216 sample units were obtained. Other macrophytes present in the stands were: *Bacopa* sp., *Cyperus papirus* L., *Echinodorus grandiflorus* (Cham. & Schltdl.) Mich., *Eleocharis* sp., *Hydrocleis nymphoides* (Willd.) Buch., *Mayaca fluviatilis* Aubl., *Nymphaea ampla* (Salisb.) DC, *Nitella leptostachys* (A. Braun) R.D. Wood var. *leptostachys*, *Ricciocarpus natans* (L.) Corda, *Salvinia auriculata* Aubl., *Utricularia foliosa* L., *Utricularia gibba* L., and *Valisneria spiralis* L.

Charophyte specimens' identification followed Picelli-Vicentim *et al.* (2004).

Samplings were carried monthly from October/1996 to October/1997 to include the rainy (October/1996 to February/1997; September/1997-October/1997) and the dry period (March/1997 to August/1997) of that year. All specimens collected are deposited in the "Herbário Científico do Estado Maria Eneyda P. Kauffmann Fidalgo" (SP). Air temperature (daily maximum, minimum, and average) and rain precipitation (daily total) data measured during the five consecutive days that preceded the sampling ones and at the sampling days were provided by the meteorological station of the Astronomy, Geophysics and Atmospheric Sciences Institute of the University of São Paulo located about 800 m from the Ninféias pond.

Since reservoir depth at the sampling stations varied from 11 to 60 cm, water samples for physical and chemical variables determination were gathered only at the subsurface (30 cm below surface) of the water column (Tab. 1).

Algal biomass and phenology data were collected using a 25 cm^2 PVC square frame according to Westlake (1965, 1971). Inside the square frame, a 5 cm in diam. PVC tube (area 19.7 cm^2) was used. For biomass determination, material was dried in a drier with forced air circulation at 70 ºC until constant weight (Hunter 1976). The aboveground biomass was estimated as dry weight per surface unit.

Material collected for phenological studies was fixed and preserved in 4% formalin solution. From each individual specimen, at least five nodes were selected at random for the study of reproductive stages taking into account their maturation stage. Morphological characteristics selected were the following: (1) number of plants collected, (2) plant height (cm), (3) diameter (µm) of cauloid, (4) number and dimensions of sterile branchlets per whorl, and

Table 1. Environmental variables values measured for each station at the Ninféias pond from October/1996 to October/1997.

Variable	Unit	Method
Rain precipitation	mm	Meteorological Station located at the PEFI
Air temperature	°C	Meteorological Station located at the PEFI
Wind speed	$m.s^{-1}$	Meteorological Station located at the PEFI
Water temperature	°C	Termistor
Water turbity	NTU	Turbidimeter
Electric conductivity	$\mu S.cm^{-1}$	Conductivimeter
Dissolved oxygen	$mg.L^{-1}$	Golterman *et al.* (1978)
pH	pH	pHmeter
Ammonium (NH_4^{+1})	$\mu g.L^{-1}$	Solorzano (1969)
Nitrate (NO_3^{-1})	$\mu g.L^{-1}$	Mackereth *et al.* (1978)
Nitrite (NO_2^{-1})	$\mu g.L^{-1}$	Golterman *et al.* (1978)
Orthophosphate (PO_4^{-3})	$\mu g.L^{-1}$	Golterman *et al.* (1978)
Dissolved inorganic nitrogen (DIN)	$\mu g.L^{-1}$	Mathematical calculation
Total nitrogen (TN)	$\mu g.L^{-1}$	Valderrama (1981)
Total phosphorus (TP)	$\mu g.L^{-1}$	Valderrama (1981)
Algal biomass	$g.m^{-2}$	Hunter (1976)

(5) number and dimensions of fertile branchlets per whorl.

The following reproductive characteristics were studied: (1) number and dimensions of nucules present in at least five whorls of each individual specimen, (2) number and dimensions of oospores per individual specimen, and (3) number and diameter (µm) of mature globules per individual specimen.

Canonic Correspondence Analysis (Hall & Smool 1992) was used to correlate environment variables and morphometric data taking into consideration the weight-average and the unimodal response model (Ter-Braak & Prentice 1988) to get a more detailed response from the samplings profile. To perform the Canonic Correspondence Analysis (CCA), the following seven environment variables were used: turbidity, pH, HCO_3, electric conductivity, dissolved oxygen, dissolved inorganic nitrogen, and total phosphorus. Also, 16 biological variables (plant height, biomass, density, diameter of cauloid, length and diameter of sterile branchlets, length and diameter of fertile branchlets, total number of nucules, length and diameter of nucules, diameter of globules, total number of globules, length and diameter of oospores, and total number of oospores).

Monte Carlo test (99 permutations; $p < 0.05$) was used to inform the probability of the axes eigenvalues be distributed at random. Both analyses were performed by using the PC-ORD version 4.0 for Windows software. Data were standardized according to their variation amplitude ("ranging") using the WinMat software (Shepherd 1996).

Results

Air temperature varied from 5.6 (July/1997) to 34.2 ºC (September-October/1997). In June/1997, air temperature maximum values measured during the five days prior to sampling day varied from 15.8 to 20.3 ºC, and in February/1997 from 26.7 to 31.5 ºC. Rain precipitation monthly average varied from 7.1 (July/1997) to 54.5 mm (October/1996).

Environment physical and chemical variables considered important for the present study (Tab. 2) showed that water temperature, pH, turbidity, and dissolved inorganic nitrogen presented their greatest values during the rainy period (summer). As expected, water temperature presented its lowest values during the dry period (winter). Water turbidity presented its greatest values in February, March, and October/1997.

Greatest values of the charophyte total biomass (113-300 $g.m^{-2}$) were measured during the rainy period, whereas the lowest ones (80-217 $g.PS.m^{-2}$) occurred during the dry period (Fig. 1).

Population density peaked from October/1996 to April/1997 (5,057-8,121 $ind.m^{-2}$), *i.e.* during the rainy period when the greatest water temperature, rain precipitation, solar radiation, turbidity, total nitrogen, and ammonium values were measured, thus constituting favorable conditions to the growth of plants. The greatest average values for the plant height were measured in March/1997 (21 cm) and the smallest in September/1997 (13 cm). In April/1997 (end of the rainy period), the smallest values of plants density and cauloid diameter were detected.

Table 2. Monthly average values of the abiotic variables presently studied: accumulated rain precipitation (Prec.), water temperature (Twater); hydrogenionic potential (pH), electric conductivity (Cond.), ions bicarbonate (HCO_3), dissolved oxygen (O_2), free carbon dioxide (FreeCO_2), total phosphorus (TP), turbidity (Turb.), dissolved inorganic nitrogen (DIN). Months abbreviation are: Oct./96 = October/1996, Nov. = November/1996, Dec. = December/1996, Jan. = January/1997, Feb. = February/1997, Mar. = March/1997, Apr. = April/1997, May = May/1997, Jun. = June/1997, Jul. = July/1997, Aug. = August/1997, Sept. = September/1997, Oct./97 = October/1997.

Month	Prec. (mm)	Twater (ºC)	pH (pH)	Cond. (µS.cm^{-1})	HCO_3 (mg.1^{-1})	O_2 (mg.1^{-1})	FreeCO_2 (mg.1^{-1})	TP (µg.1^{-1})	Turb. (NTU)	DIN (µg.1^{-1})
Oct./96	158.8	17.5	6.32	55.8	13.20	4.1	11.0	7.14	5.93	50.00
Nov.	85.7	21.5	6.25	49.8	12.47	4.3	11.0	10.60	4.35	62.00
Dec.	386.4	20.8	6.21	51.8	14.42	3.6	14.6	8.20	5.50	26.87
Jan.	341.4	23.0	6.11	59.5	13.13	3.3	15.8	5.90	5.21	91.00
Feb.	108.9	20.0	5.88	64.6	9.70	3.8	15.6	5.20	15.00	313.40
Mar.	67.1	21.1	6.11	56.8	9.85	3.7	12.4	7.30	10.10	129.60
Apr.	47.8	21.1	6.50	55.0	10.95	4.5	15.9	8.20	5.40	115.20
May	80.7	19.6	6.02	56.2	13.11	3.7	22.4	6.80	4.76	97.00
Jun.	108.7	13.4	6.19	54.4	11.73	5.4	14.0	4.50	5.18	106.30
Jul.	9.4	17.1	6.22	48.0	10.00	5.7	10.6	4.80	5.15	83.30
Aug.	38.7	18.1	6.36	52.1	13.36	6.1	10.3	3.30	5.15	101.20
Sept.	130.6	18.1	6.34	48.4	12.68	6.5	9.9	2.40	5.20	48.40
Oct./97	126.4	22.0	6.14	47.1	11.63	4.3	13.7	4.50	14.10	50.90

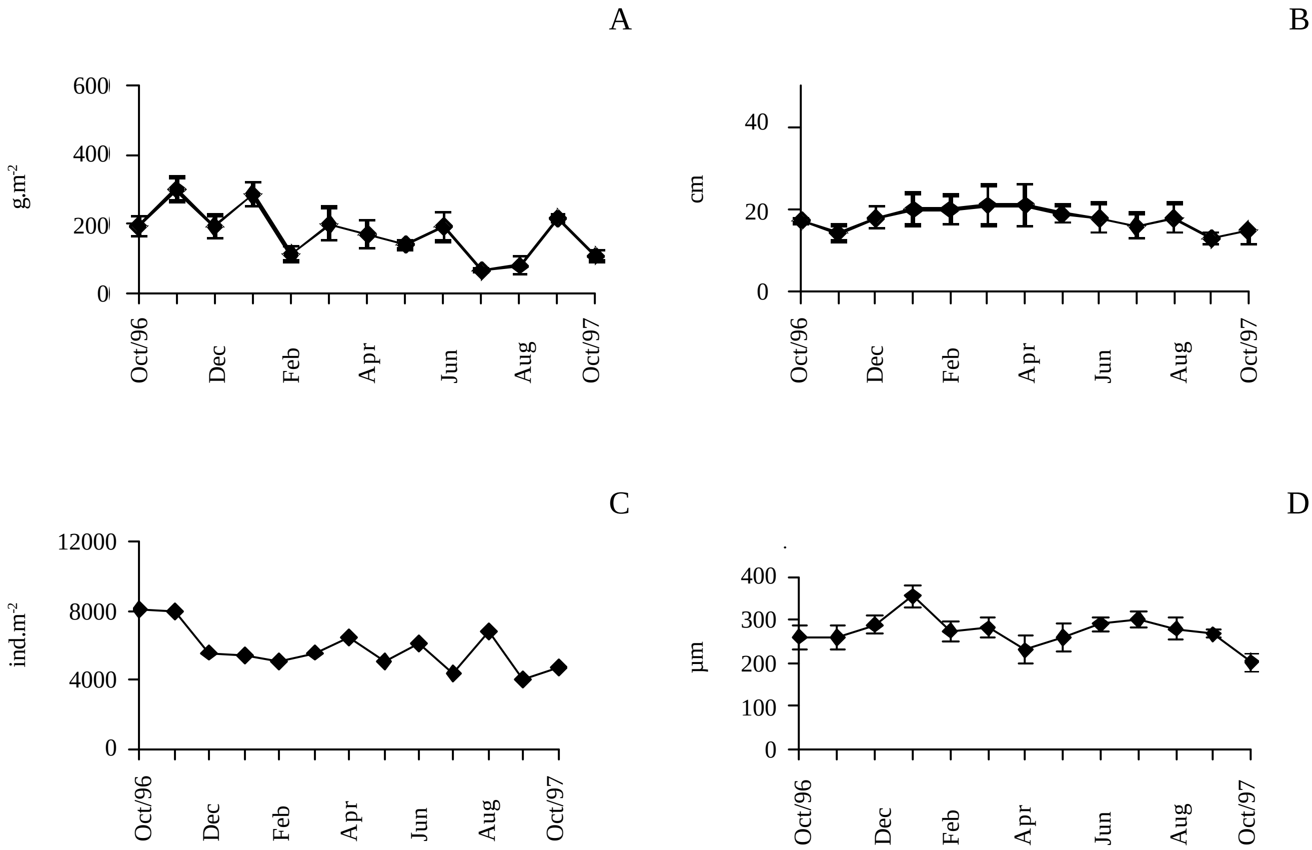

Figure 1. Temporal variation of values of (A) biomass, (B) plant height, (C) plants density, and (D) diameter of cauloid of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* during the period October/1996 to October/1997.

Sterile branchlets of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* were ca. 3 cm long and 96.1 to 158.3 µm in diameter, whereas length of fertile branchlets varied from 3 to 5 cm and diameter from 116 to 226 µm (Fig. 2).

From July/1997 on (dry period = winter), it was observed a gradual increase in the length of fertile branchlets. Length of fertile branchlets average values varied between 3.08 in May/1997 to 5 cm in September/1997, and their variation coefficient from nihil to 40.2%. It was also observed a relative increase in the diameter of fertile branchlets in February and March/1997 (rainy period = summer), but a strong decrease from April/1997 on (winter).

Reproductive features suggested some synchronism in the production and maturation of male and female gametangia, the period of greatest occurrence of these structures being May (end of fall) to October/1997 (beginning of spring). Total nucule length, including the coronule, varied from 169 (October/1996) to 448 µm (July/1997) and diameter from 89 µm (February/1997) to 284 µm (October/1997), average globule diameter values varied from 98 µm (October/1996) to 228 µm (October/1997), oospore length varied from 167 µm (October/1996) to 282 µm (May/1997), and oospore diameter from 153 µm (during the first 6 sampling months) to 230 µm (September and October/1997) (Fig. 3-4).

CCA analysis indicated the association of the environmental variables with the climatic periods, *i.e.* the dry and the rainy period (Fig. 5, Tab. 3-4).

Monte Carlo test was significant ($p < 0.05$), what indicates that events were not at random, but did represent the relationship existing among environment variables and biological information.

Eigenvalues for axes 1 ($\lambda = 0.194$) and 2 ($\lambda = 0.065$) explained 59% of biological data variance. Correlation morphometry-environment for axes 1 (0.977) and 2 (0.888) was high indicating some relationship between distribution of biological and

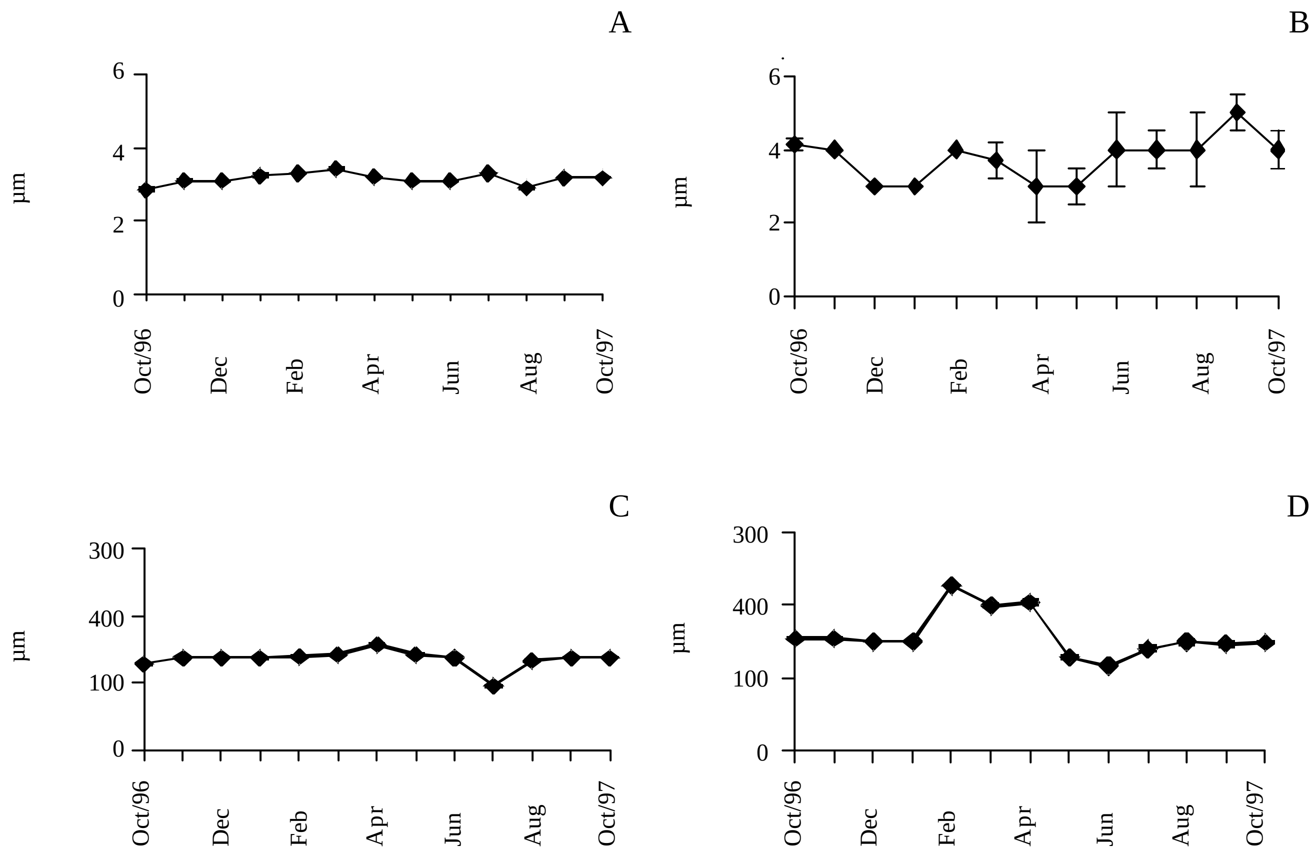

Figure 2. Temporal variation of values of (A) length of sterile branchles, (B) length of fertile branchlets, (C) diameter of sterile branchlets, and (D) diameter of fertile branchlets of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* during the period October/1996 to October/1997.

abiotic data used for ordination (Tab. 4). Canonic coefficients and intra-set correlations for axis 1 (Tab. 5) showed that electric conductivity contributes significantly towards ordination of data like turbidity and dissolved inorganic nitrogen. CCA intra-set correlations showed just some moderate contribution towards ordination of biological-environment data.

CCA pointed out that the abiotic variables most related to axis 1 were: turbidity (r = 0.916), electric conductivity (r = 0.974), dissolved oxygen (r = 0.700), total phosphorus (r = 0.885), and dissolved inorganic nitrogen (r = -0.937), all together reflecting the best growth conditions for the alga (Fig. 5, Tab. 5), and which were favored by the greatest nutrients availability during the rainy period (summer).

At the positive side of axis 1 they were located almost all biological structures (vegetative, biomass, and algal density), *i.e.* (alt) plant heigth (r = 0.499),

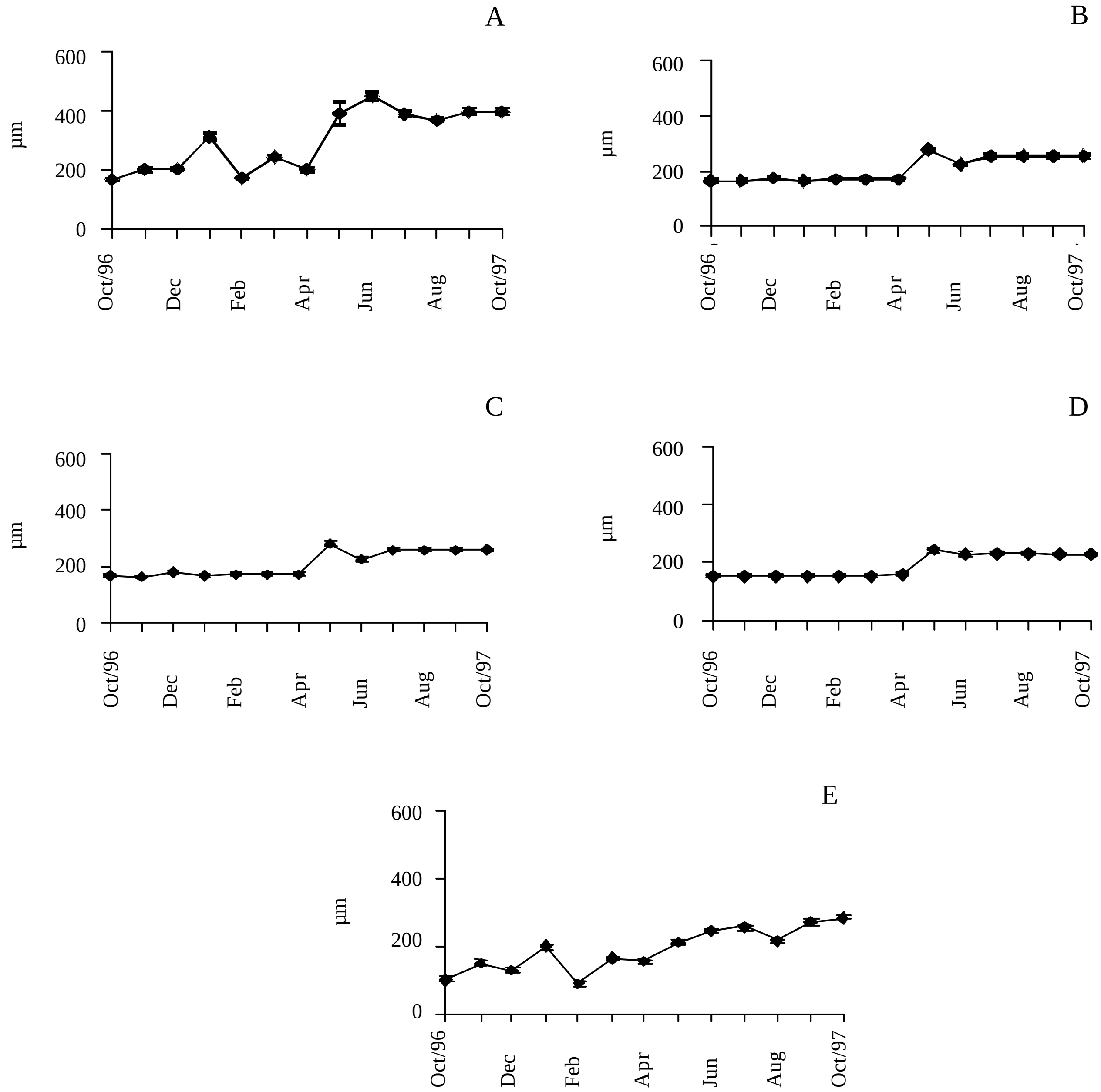

Figure 3. Temporal variation of values of (A) length of nucule, (B) diameter of nucule, (C) length of oospore, (D) diameter of oospore, and (E) diameter of globule of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* during the period October/1996 to October/1997.

(bio) plant biomass (r = 0.414), and (d) plant density (r = 0.519), and at the negative side the reproductive structures: (nc) length of nucule (r = -0,911), (nd) diameter of nucule (r = -0,926), (nt) total number of nucules (r = -0.754), (oc) length of oospore (r = -0.914), (od) diameter of oospore (r = -0.942), and (nt) total number of oospores (r = -0.807) related to the greatest dissolved inorganic nitrogen values (r = -0.937).

Sampling months were segregated in two periods at the opposite sides of axis 1. At the negative side they were May, June, July, September, and October/1997, whereas at the positive side were October and December/1996, *i.e.* months of high rain precipitation.

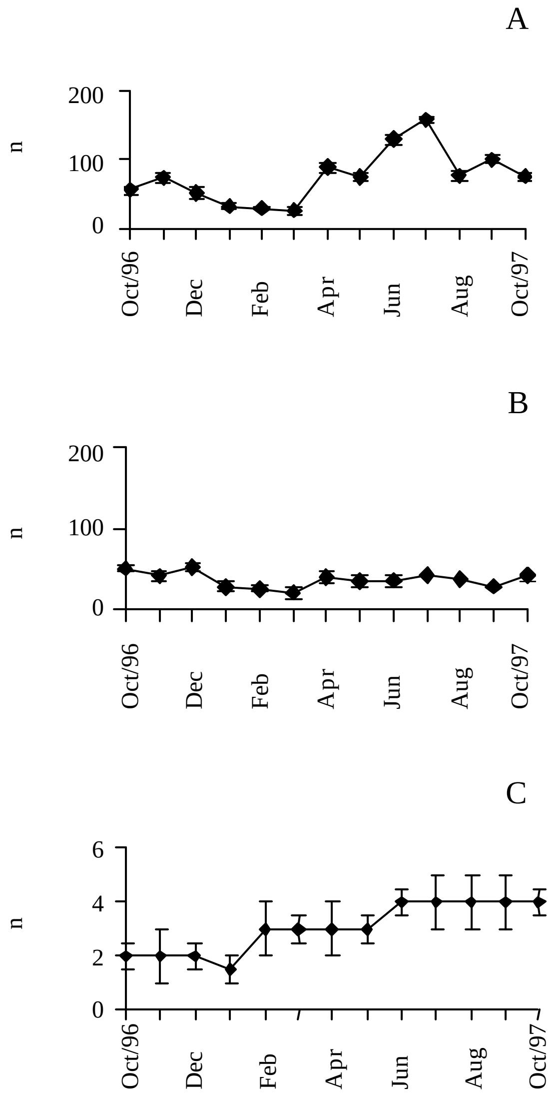

Figure 4. Temporal variation of values of (A) total number of nucules, (B) total number of globules, and (C) total number of oospores of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* during the period October/1996 to October/1997.

Table 3. Pearson and Kendall correlation coefficient among water physical and chemical variables and the two first ordination axes during PCA for the study period.

Variable	Abreviation	Principal component Axis 1	Principal component Axis 2
Abiotic			
Turbity	Turb	0.697	0.422
Total phosphorus	PT	0.192	-0.749
Water temperature	Twater	0.463	-0.526
pH	pH	-0.913	0.189
Dissolved oxygen	O_2	-0.557	0.346
Free CO_2	CO_2 L	0.594	-0.492
Ions HCO_3	HCO_3	-0.570	-0.636
Electric conductivity	Cond.	0.706	-0.066
Dissolved inorganic nitrogen	DIN	0.755	0.459
Biological			
Plant height	alt	0.499	-0.587
Biomass	bio	0.414	0.379
Algal density	d	0.519	0.634
Cauloid	cau	0.302	-0.396
Length of sterile branchlets	rec	0.085	-0.663
Diameter of sterile branchlets	red	0.272	0.011
Length of fertile branchlets	rfc	-0.234	0.388
Diameter of fertile branchlets	rfd	0.611	-0.443
Nucules total number	nt	-0.754	0.430
Length of nucule	nc	-0.911	-0.119
Diameter of nucule	nd	-0.926	-0.045
Globules total number	nt	-0.029	0.611
Diameter of globule	glo	-0.661	0.380
Oospores total number	ot	-0.914	-0.600
Length of oospore	Oc	-0.942	-0.053
Diameter of oospore	Od	-0.807	-0.263

February and March/1997 showed the greatest values of dissolved inorganic nitrogen (DIN) characterizing the end of the rainy period (summer) and the best one for algal growth. As the rain precipitation values increased (October, November, and December/1996) there was an increase in the nutrient values. Following the decrease of rain precipitation, there was an increase of nutrient and electric conductivity values, which could have interfered on the development of the alga morphological structures.

Axis 2 is strongly influenced by the pH (r = 0.983), dissolved oxygen (r = 0.960), and dissolved inorganic nitrogen (r = 0.918) (Tab. 5). One can note that reproductive structures (male and female gametangia) are weakly related with axis 2 indicating that the latter axis seems to discretely suggest a gradient related to the physical environmental conditions that dominated the dry period (winter).

Discussion

Morphological features of the charophyte showed the typical seasonal pattern of temperature region (Fernández-Aláez *et al.* 2002). Thus, period between May (end of fall) and October/1997 (beginning of spring) was favorable to the development of reproductive structures (nucules and globules), with the respective decrease of biomass and algal density, thus suggesting allocation of energetic resources towards the development of reproductive structures according to Wood & Imahori (1965), Casanova (1994), and Vieira Jr. & Necchi Jr. (2002).

During the dry period, as the reproductive structures (nucules, globules, and oospores) started to appear, the vegetative ones showed, in average, metric values lesser than the ones obtained during the rainy period, thus calling for some seasonality in regard to fertility of the population of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* at the Ninféias pond.

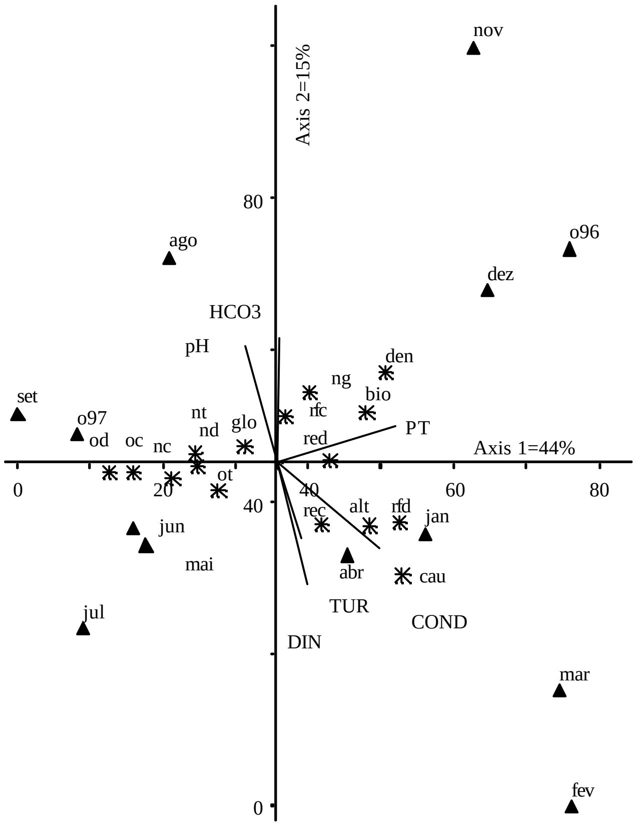

Figure 5. Canonical Correspondence Analysis (CCA) axis 1 (λ_1 = 0,194; p = 0,01) and axis 2 (λ_2 = 0.065; p = 0.02) showing distribution of the seven environmental variables: (TUR = turbidity, pH, HCO_3, COND = electric conductivity, O_2 = dissolved oxygen, DIN = dissolved inorganic nitrogen, and PT = total phosphorus), and of the 16 biological variables of *Nitella furcata* subsp. *mucronata* var. *mucronata* f. *oligospira*: (d = density, alt = height, bio = biomass, cau = cauloid, rec = length of sterile branchlets, red = diameter of sterile branchlets, rfc = length of fertile branchlets, rfd = diameter of fertile branchlets, nc = length of nucules, nd = diameter of nucules, NT = total number of nucules, ng = total number of globules, glo = diameter of globules, oc = length of oospores, od = diameter of oospores, and ot = total number of oospores measured at the Ninféias pond during the period October/1996-October/1997.

Table 4. Synthesis of results from the CCA for the environment and algal morphometric variables.

	Axis 1	Axis 2
Eigenvalue (λ)	0.1940	0.0650
Percentage of explained variance	44.0000	14.0000
Percentage of accumulated explicability	44.0000	59.0000
Pearson correlation (morphometry-environment)	0.9770	0.8810
Kendall correlation	0.9230	0.8210
Monte Carlo test (*p*) Eigenvalue	0.0100	0.0200
Morphometry-environment correlation	0.0100	0.0200

Table 5. Canonic correlation coefficients and intra-set correlations of environmental variables with axes 1 and 2 of CCA for 16 algal morphometric variables.

		Canonic coefficient		Intra-set correlation coefficient	
Variable		Axis 1	Axis 2	Axis 1	Axis 2
Turbidity	Tur	0.916	-0.856	0.148	-0.384
pH	pH	0.227	0.983	-0.197	0.591
Ion HCO_3	HCO_3	-0.209	0.606	0.015	0.628
Electric conductivity	Cond	0.974	-0.813	0.619	-0.424
Dissolved oxygen	O_2	0.700	-0.960	-0.174	0.099
Dissolved inorganic nitrogen	DIN	-0.937	-0.918	0.185	-0.615
Total phosphorus	PT	0.885	0.548	0.714	0.179

Species temporal variation in relation to fertility showed the following two distinct periods: one between October/1996 (spring) and March/1997 (summer) with sterile plants (rainy period), and the other one between May/1997 (fall) and September/1997 (winter) with fertile plants, in accordance to data in Jair Vieira Jr. (unpublished). For the latter author, environment variables that influenced most the phenological pattern of the charophyte species in tropical lotic systems were current speed, air temperature, and to a lesser degree the ammonium concentration.

Both monoiceous (*N. furcata* subsp. *mucronata* var. *mucronata* f. *oligospira*) and dioiceous species (*N. cernua*) seems to have presented some synchrony in the production and maturation of gametangia (Vieira Jr. & Necchi Jr. 2002).

The relatively low number of oospores (39) found during this study was much probably due to the fact that such structures fall from the plant as soon as they ripe to germinate in the system's sediments. Oospores were usually found loose among the verticelate branchlets that, besides sustaining gametangia and oospores, also guarantee protection and habitat for different autotrophic organisms.

Oospores occurred in the Ninféias pond during a similar period to that in Hussain *et al.* (1996) for six charophyte species (*Chara globularis*, *C.* cf. *contraria*, *C. vulgaris* var. *gymnophylla*, *C. vulgaris* var. *longibracteata*, *C. zeylanica*, and *C. zeylanica* var. *diaphana* f. *oerstediana*) in Saudi Arabia, *i.e.* with oospores production peaks from October/1996 to March/1997 (local winter). Identical behavior was verified by Sokol & Stross (1986) in *N. furcata* subsp. *megacarpa* kept in experimental conditions. Latter authors observed that light may affect production of oospores and, consequently, determines distribution of plants in nature.

During the present study, best environment conditions for the growth of and colonization by the charophyte would be greater temperatures and nutrient availability in the reservoir (rainy period). During this period, increase of plant biomass and density, of cauloid diameter, and in the sterile branchlets dimensions were detected leading to larger and more robust plants. During the dry period, however, charophytes population started to produce reproductive structures (nucules, globules, and oospores) suggesting that reproductive activity was more concentrate in this period, and followed by a decrease in size of vegetative structures.

Observations above were confirmed by multivariate analyses (CCA), which allowed a global interpretation of all abiotic and biological information and showed strong correlation between length and diameter of nucules, total number of nucules per plant, and length and diameter of oospores associated with the lowest values of nutrients, water temperature, electric conductivity, HCO_3, and turbidity measured during the dry period.

Population density peaked from October/1996 to April/1997 (rainy period), a period in which they were detected the greatest values of air and water temperature, rain precipitation, and of dissolved inorganic nitrogen, a set of conditions that favored growth of plants. The greatest average values of biomass of *N. furcata* subsp. *mucronata* var. *mucronata* f. *oligospira* during the rainy period (summer) were five times greater than those of the dry period (winter) due to the greatest nutrient availability (total nitrogen, total phosphorus, and ammonium), and greatest values of turbidity and electric conductivity during the rainy period. Similar observations were documented for the mid portion of the Paraná river by Del-Viso *et al.* (1968).

Jair Vieira Jr. (unpublished) observed, however, a different pattern that is typical for macroalgae of tropical lotic systems, *i.e.* greater abundance during the dry period and lesser biomass during the rainy one, that agreed with data in Necchi Jr. & Pascoaloto (1993), Branco & Necchi Jr. (1997), and Necchi Jr. & Branco (1999). Similar conclusion was reached by Carneiro *et al.* (1994) after studying a community of *Chara hornemanii* that presented an expansion phase during the winter and a phase in which biomass values decreased during the fall, when the height of the water column increased due to the increase of rain precipitation.

According to Fernández-Aláez *et al.* (2002), however, the temperate zone macrophyte's biomass usually increases during the spring and peaks during the summer due to the hydrological regimen and the water temperature. Still according to the latter authors, biomass of charophytes studied decreased considerably during the winter due to the increase of the water level in the studied lakes.

Analysis of the seasonal variation of the morphological characteristics of specimens presently studied showed variation along the sampling period, in accordance to Casanova (1994). Morphological modifications in plant height, cauloid diameter, and number and length of verticilate branchlets seems to be related to the environmental variables studied for each period of the year, thus agreeing with the annual life history of the species studied for the Brazilian territory.

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