ECOLOGY OF *Croasdalea marthae* (DESMIDIACEAE, ZYGNEMAPHYCEAE) IN THE AÇUDE DO JACARÉ, MOJI GUAÇU, SOUTHEASTERN BRAZIL, AND THE STABILITY OF THE ALGAL CELL BIPOLAR ASYMMETRY

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ABSTRACT: Ecology of *Croasdalea marthae* (Desmidiaceae, Zygnema-phyceae) in the Açude do Jacaré, Moji Guaçu, southeastern Brazil, and the stability of the algal cell bipolar asymmetry. An ecological study of *Croasdalea marthae* (Grönblad) C. Bicudo and Mercante (Zygnemaphyceae: Desmidiaceae) was conducted from January 1990 to March 1991 at 5 sampling stations in the Açude do Jacaré, a pond in São Paulo State, southeastern Brazil. The alga was present in the pond all year round. Average monthly density during the dry period was slightly higher than during the rainy season and abundance of the alga was significantly correlated with orthophosphate (positively) and water temperature (negatively). Horizontal distribution of the alga in the pond was not directly influenced by any of the environment variables studied. Highest total densities of individuals at 2 of the stations (n" 1 and 4) were accounted for, respectively, the accumulation and transport of the alga in constantly-moving floating mats of *Utricularia* sp. and the existence of large amounts of rooted macrophytes. Total numbers of cells were greater at the surface than at the bottom of station 2 during 10 of the 15 months. However, no definite pattern for vertical distribution could be derived from this study. Wind speed and rising and sinking velocities of cells were the main factors responsible for the change of algal cell concentration in the water column. Climatological, physical, and chemical variations in the pond did not significantly modify the alga's cell morphology during the study period, thus leading to the conclusion that bipolar asymmetry is a good criterion at the genus level.

Key words: autecology, phytoplankton, tropical pond, desmid, *Croasdalea marthae*.

RESUMO: Ecologia de *Croasdalea marthae* (Desmidiaceae, Zygnema-phyceae) no Açude do Jacaré, Moji Guaçu, sudeste do Brasil e estabilidade da assimetria bipolar da célula. O estudo ecológico de *Croasdalea marthae* (Grönblad) C. Bicudo & Mercante (Zygnemaphyceae: Desmidiaceae) foi realizado de janeiro de 1990 a março de 1991 em cinco estações de amostragem no Açude do Jacaré, que está situado no Estado de São Paulo State, região sudeste do Brasil. A alga esteve presente no açude durante todo o ano. Sua densidade média mensal durante o período de seca foi levemente maior do que a medida durante o período de chuvas; e a abundância da alga esteve significativamente relacionada com o ortofosfato (positivamente) e a temperatura da água (negativamente). A distribuição horizontal da alga no açude não foi diretamente influenciada por qualquer das variáveis ambientais estudadas. As densidades mais altas de indivíduos em duas das estações (1 e 4) foram atribuídas, respectivamente, ao acúmulo e transporte da alga pelas massas flutuantes e constantemente móveis de *Utricularia* sp. e à existência de grande quantidade de macrófitas enraizadas. Os números totais de células foram maiores na superfície do que no fundo da estação 2 durante 10 dos 15 meses do presente estudo. Entretanto, nenhum padrão especial para essa distribuição vertical pôde ser detectado. As velocidades do vento e de elevação e afundamento das células foram considerados os principais fatores responsáveis pelas mudanças da concentração da alga na coluna d'água. Variações climatológicas, físicas e químicas no açude não alteraram significativamente a morfologia celular da alga durante a presente investigação induzindo, assim, à conclusão de que a assimetria bipolar é um bom critério na identificação de gêneros em desmídias.

Palavras-chave: autecologia, fitoplâncton, açude tropical, desmídia, *Croasdalea marthae*.

INTRODUCTION

Desmid cells are generally, although wrongly, considered to be perfectly symmetrical on 3 orthogonal planes, and only symmetrical cell genera were known until the middle of this century, when Grönblad (1954) erected the genus *Amscottia* on the basis of the bipolar (univertical) asymmetry of its cell. Three other genera were subsequently proposed on the basis of bipolar asymmetry of cells, namely *Allorgeia* Gauthier-Lièvre (1958), *Prescottiella* C. Bicudo (1976), and *Croasdalea* C. Bicudo and Mercante (1993), all of them monotypic. *Amscottia* has 2 described species. However, no study was ever carried out to know how constant the character bipolar asymmetry is in nature and the possible effect of environment variables on such stability.

The present research was conducted to determine seasonal and spatial distribution patterns of *Croasdalea marthae* (Grönblad) C. Bicudo and Mercante in the Açude do Jacaré, São Paulo State, southeastern Brazil, and to evaluate what environment variables are responsible for these patterns, and how constant bipolar asymmetry is in natural populations.

METHODS

Study site. Açude do Jacaré (22° 18' S, 47° 13' W) lies in the Moji Guaçu Experimental Station and Ecological Reserve of the Institute of Forestry, São Paulo State Department of Environment. It is the fifth in a sequence of 6 artificial ponds built for irrigation water storage on a rivulet tributary of the Moji Guaçu River. Morphometric features of the pond are in Mercante & Bicudo (1996). Also see Mercante & Bicudo (1996) for more information on the pond's characteristics. *Pontederia laceolata* Nutt. and *Utricularia* sp., respectively, were the principal emergent and free-floating macrophytes in the Açude do Jacaré. The two species together accounted for more than 90% of the macrophyte biomass in the pond throughout the year. The total amount of plant biomass varied over time, and was much higher during the wet season than the dry.

Phytoplankton collection, counts and cell measurements. Samples were collected at 5 different stations, which were chosen to cover the spatial heterogeneity within the pond. Station 1 was established near the water outflow, station 2 in mid-pond, station 3 near the water input, station 4 almost opposite to station 3, where there is a large concentration of submerged and emergent attached macrophytes, and station 5 where depth was minimal and water current strongest (Fig. 1). Two 1 L samples were collected at each station, one for algal counting (preserved in Lugol's iodine solution) and the other for morphological and metrical analysis of specimens of *Croasdalea marthae* (preserved in 3% formalin solution). Counts were made with a Carl Zeiss Oberkochen inverted microscope. Utermöhl's (1958) sedimentation method was used to prepare the samples for sedimentation, and Lund *et al.* (1958) recommendations were followed for precision of counting. Samples ranging from 10 to 70 ml samples were settled for 24 hours at a constant temperature in an air conditioned room. Two complete linear, perpendicular, median transects of the chamber were counted at 320x magnification. Linear measurements were taken of the cell length (from the dorsal margin (apex) of one semicell to that of the other semicell) and breadth (from the base of the outermost spine on one side of a semicell to the base of the diametrically opposed respective spine) of at least 25 individuals per sample.

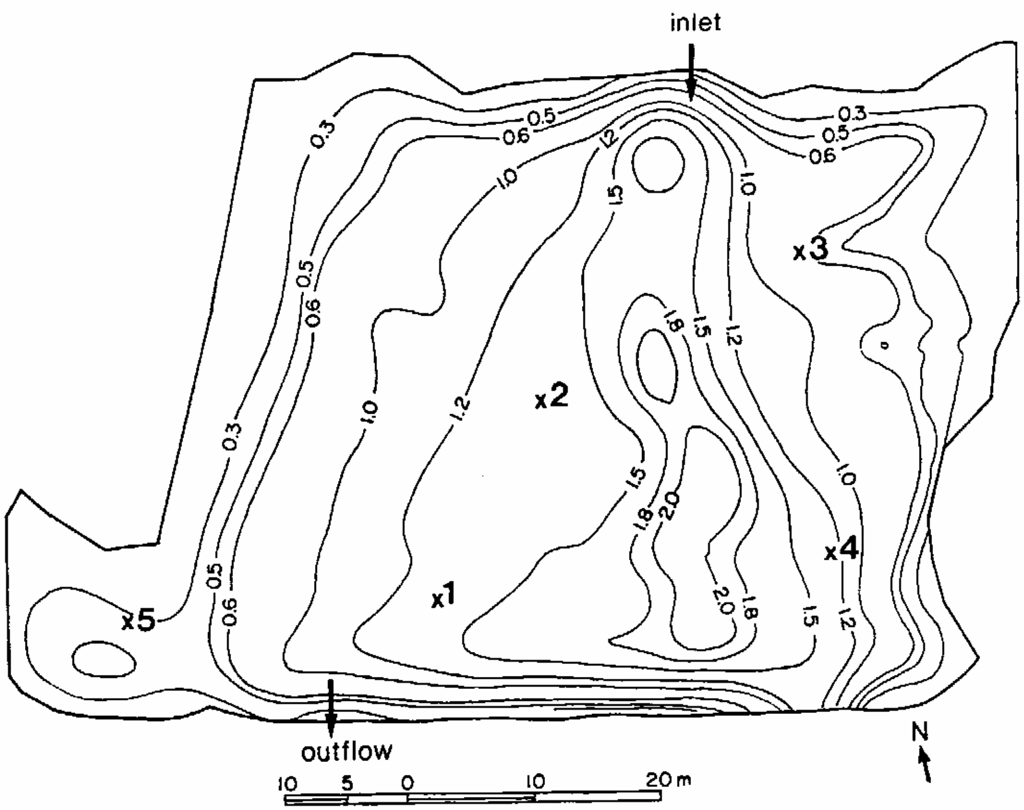

Fig. 1. Schematic representation of the Açude do Jacaré showing sampling stations 1-5. Bold face numbers indicate sampling stations. Depth contours in meters.

Ecological variables. Precipitation and air temperature data were obtained from the São Paulo State Water and Sewage Department ("Departamento de Água e Esgoto do Estado de São Paulo"). Water temperature, Secchi disk transparency, conductivity, dissolved oxygen, pH, alkalinity, total phosphorus, total dissolved phosphorus, orthophosphate, total nitrogen, nitrate, nitrite, ammonium, Ca^{2+}, Mg^{2+}, K^{+}, and total pigments were measured on each sampling date. Samples were taken monthly, from January/90 to March/91, always between 9:00 and 10:00AM. For information on methodology used, see Table 1.

Statistical analyses. All statistical analyses were performed with SYSTAT 5.0 (Wilkinson, 1987).

RESULTS AND DISCUSSION

Table 1. Physical and chemical variables studied and respective methodology.

Variable	Method used
Water temperature	Hg thermometer
Transparency	Secchi disk
Light absorption coeficient	Poole & Atkins (1929)
Pond depth	ruler
Electric conductivity	conductivimeter
Dissolved oxygen	Pomeroy & Kinschmann (1945)
Percent of oxygen saturation	Golterman *et al.* (1978)
pH	ph-meter
Alkalinity	Golterman *et al.* (1978)
Free CO_2	Cole (1979)
Total phosphorus	Valderrama (1981)
Total dissolved phosphorus	Strickland & Parsons (1960)
Orthophosphate	Strickland & Parsons (1960)
Total nitrogen	Valderrama (1981)
Nitrite	Mackereth *et al.* (1978)
Nitrate	Mackereth *et al.* (1978)
Ammonium	Koroleff (1976)
Calcium	atomic emition spectrophotometer
Magnesium	atomic emition spectrophotometer
Potassium	atomic emition spectrophotometer

1. Precipitation

Precipitation data (Table 2) show that two climatic seasons can be clearly defined for the region. The first is a rainy season, from October to March with high temperatures and precipitation. The rainy season is followed by a dry season, from April to September, with lower temperatures and precipitation. For more detailed information on the climatic seasons see Mercante & Bicudo (1996). According to Köppen's international system for climate classification, the climate in the region of the Açude do Jacaré is of the Cwa type, *i.e.* tropical with warm, wet summers and cool, dry winters.

Results of the test for independence (Table 3) clearly demonstrate that the null hypothesis (no association between rank pairs) is not accepted for twelve of the twenty-one variables. In other words, there is evidence that those variables are dependent upon average precipitation. Spearman's rank correlation coefficient (r_s) was calculated for the nine variables considered significant by the test for independence (Table 4), and shows that only the depth of the water column, the pond water temperature, and the total pigments have a positive association with precipitation. It is obvious that with rain, the water level in the pond rises. Furthermore, the water temperature is higher due to the tropical climate of the region. Conversely, during the dry season water level and, consequently, depth decline in the pond. The water temperature is also lower than in the rainy season.

For supplementary information on air temperature and wind speed, water temperature, water transparency, pond's depth, and pH values see Mercante & Bicudo (1996).

2. Nutrients

Total dissolved phosphorus, orthophosphate, ammonium, magnesium, and pH were negatively correlated with precipitation (Table 4). A considerable increase in macrophyte biomass was observed during the rainy period. This growth may have been responsible for the reduction of orthophosphate, ammonium, and magnesium in the pond water. These elements may be leached from senescing plants, then rapidly taken up by other growing plants in the same area, in what amounts to a closed system. Internal nutrient cycling was specially noticeable at the end of the dry and beginning of the wet seasons. This possibility has been intensively investigated in Brazil, among others by Barbieri (1984), Menezes (1984), and Esteves & Camargo (1986). Leaching of these same elements to the pond from neighbouring sites is considered to be comparatively very little, since the pond is surrounded by *cerrado* vegetation and soils and densely reforested areas of *Pinus* sp.; all are very low in nutrient content (Arens, 1962). Furthermore, precipitation would almost certainly dilute the nutrients, thus corroborating the decrease in their absolute concentrations in the system.

Table 2. Local precipitation (mm) during the study period.

Month	**Precipitation (mm)**
January/90	284.0
February	157.0
March	164.0
April	65.0
May	48.0
June	6.0
July	47.0
August	56.0
September	68.0
October	129.0
November	64.0
December	29.0
January/91	83.0
February	204.0
March	463.0

Table 3. Test for independence (D) between precipitation and pond averages of variables.

Variable	D	Significance
Total phosphorus	691.5	0.18 ns
Total dissolved phosphorus	992.5	0.01 *
Orthophosphate	984.5	0.01 *
Total nitrogen	513.5	0.37 ns
Nitrate	725.5	0.13 ns
Nitrite	379.5	0.11 ns
Ammonium	881.5	0.01 *
Ca^{2+}	710.5	0.15 ns
Mg^{2+}	852.5	0.02 *
K^{1+}	646.5	0.28 ns
Dissolved oxygen	789.5	0.05 ns
Percent oxygen saturation	725.5	0.13 ns
pH	841.5	0.02 *
Alkalinity	647.5	0.25 ns
Conductivity	345.5	0.07 ns
Water temperature	271.5	0.02 *
Air temperature	299.5	0.04 *
Transparency	443.5	0.22 ns
Depth	310.5	0.04 *
Total pigments	805.5	0.04 *
Cells	704.5	0.16 ns

(*) = significant at 5% level
(ns) = not significant

For supplementary information on alkalinity, dissolved oxygen, oxygen saturation, free CO_2, conductivity, total nitrogen, NO_3, NO_2, NH_4, total phosphorus, total dissolved phosphorus, PO_4, Ca, K, and Mg values see Mercante & Bicudo (1996).

3. Horizontal variation

Results of the Wilcoxon test applied to the number of algal cells and the respective physical and chemical characteristics of the six stations revealed that mean numbers of algal cells for stations 2-bottom and 4 were similar and significantly ($P < 0.05$) different from the other sites (Table 5), and that station n° 4 presented some differences that made it distinct from all the others. Test for independence was used to correlate monthly algal densities with all physical and chemical characteristics, in a search for hypotheses for the differences in populations of the alga at each station. For station 4, orthophosphate, ammonium, magnesium, and phytoplankton biomass (total pigments) were positively correlated with the abundance of the alga, whereas water temperature was negatively correlated. At station 1, there were positive correlations with total phosphorus, orthophosphate, and total nitrogen, and a negative correlation with magnesium. According to Wetzel (1983), Conjugales are largely correlated with low to very low concentrations of the divalent cations calcium and magne-

Table 4. Spearman's rank correlation (R_s) between precipitation and pond averages of variables.

Variable	R_s
Total dissolved phosphorus	-0.758
Orthophosphate	-0.772
Ammonium	-0.574
Magnesium	-0.522
pH	-0.503
Water temperature	0.515
Pond depth	0.446
Total pigments	0.438

sium. Reif *et al.* (1983), after sampling 100 lakes in northeastern Pennsylvania for desmids and chemical characteristics, found that although statistical analyses used did not single out any chemical factor as having a dramatic effect upon desmid species numbers, the trends in magnesium and a combination of magnesium and pH most nearly paralleled variations in species numbers in the 100 lakes at the time of sampling.

The Açude do Jacaré can be defined as magnesium-deficient; its concentrations varied from 0.05 $\mu g.L^{-1}$ (May/90, station 1) to 3.93 $\mu g.L^{-1}$ (June/90, station 3). At station 4 magnesium was positively correlated with the presence of *Croasdalea marthae*, whereas at station 1 this correlation was negative. Phosphorus concentrations (total phosphorus, total dissolved phosphorus and orthophosphate) were significantly distinct between stations 1 and 4, suggesting that phosphorus was not directly responsible for the population size of the alga at either station 1 or 4. There was a considerable difference in relative densities between stations 3 and 4, despite their close proximity and physical and chemical similarity. Moreover, algal density at station 2 showed a positive correlation only with alkalinity, and for station 3 there were no significant correlations with any physical or chemical variables. Consequently, it was suggested that the presence of the alga at each sampling station, and by extension in the entire pond, was not directly influenced by any of the environmental variables studied.

Desmids are more or less ubiquitous in distribution among standing or very slow-flowing waters with extensive aquatic macrophyte communities, and consequently with a high content of dissolved organic matter. Water movements in these environments are not only important for physical movement of desmids into or out of the photic zone; they are also critical to the vertical transport of mineralized matter from lower depths and littoral regions to open water. Bland & Brook (1974) have provided an elegant example of the importance of water movement in the spatial distribution of predominantly littoral desmids in two Minnesota lakes. The presence of macrophytes in the littoral zone increased the diversity of the desmid flora in the lakes. Many desmids occurred on and among macrophytes in the littoral zone throughout the year. During spring circulation, however, many desmids were dispersed, particularly to other areas of the littoral on newly growing annual macrophytes. In small water bodies, such as the Açude do Jacaré, circulation in the littoral is not as intense as in larger lakes, and the larger desmids are carried away from the littoral less frequently. The Açude do Jacaré is a typically warm polymictic pond, with circulation due almost entirely to wind action. Water flow plays a very important role in the transport of organisms, particulate organic matter, and nutrients, and the velocity of flow is inversely related to the depth of the area (Margalef *et al.*, 1976). Station 4 in the Açude do Jacaré is typically littoral (with emergent macrophytes), whereas station 1 is limnetic (with only free-floating macrophytes). However, these were the two stations to show the highest densities of the alga during the entire study period. The high density of *Croasdalea marthae* cells at station 1 can be explained by their transport and accumulation in constantly-moving floating mats of *Utricularia* sp., driven to this site by wind action. As the pond is a small man-made reservoir, water flows from the inlet to the dam. The inflow point is close to sampling station 3 and the outflow in between stations 2 and 5; the water moves through a relatively shallow channel, where the water flow velocity is relatively greater than in the rest of the pond. Stations 1 and 4 are located in somewhat deeper, more protected areas of the pond and thus experience less water movement. Consequently, of the 5, stations 1 and 4 are physically most suitable for support of higher densities of algal cells. However, while water flow is a key determinant of algal densities along the inflow-outflow channel, wind is by far the main factor responsible for circulation in the pond as a whole.

4. Vertical variation

Statistical comparison between physical, chemical and planktonic variables of surface and bottom at station 2 (Table 5) shows that mean values for conductivity, total phosphorus, orthophosphate, total nitrogen, ammonium, and phytoplankton biomass (total pigments) were higher, while temperature and dissolved oxygen were lower, at the bottom. However, differences in general were not pronounced, except for total phosphorus and total nitrogen.

Table 5. Comparison of annual means of numbers of individual cells of *Croasdalea marthae* between pairs of sampling stations (WS, Wilcoxon Test).

Station	**WS**	**Significance**
2-S and 2-B	186.0	0.05 *
1 and 2-S	240.5	0.73 ns
1 and 2-B	287.0	0.02 *
1 and 3	270.5	0.11 ns
1 and 4	199.5	0.17 ns
1 and 5	274.0	0.08 ns
2-S and 3	263.5	0.19 ns
2-S and 4	183.5	0.04 *
2-S and 5	278.0	0.06 ns
3 and 4	163.5	0.01 *
3 and 5	236.0	0.88 ns
3 and 2-B	252.0	0.41 ns
4 and 2-B	308.0	0.01 *
5 and 2-B	247.0	0.54 ns
4 and 5	386.0	0.00 *

The Açude do Jacaré showed sufficiently stable thermal stratification during the rainy season, that made impossible diurnal circulation at least during the rainy season or that led to ephemeral stratifications, with practically daily circulations or up to homogeneous temperature profiles during the dry season (Marinho, 1994). Temperature profiles showed that such stratifications varied their intensities according to the time of the day, but usually were weak, with longer or shorter mixture periods that mainly occurred from midnight to early morning (04:00 hours). Wind action was not considered significant during the entire study period. The large size, rooted macrophyte stands completely blocked wind action at the pond's surface water. The retention time of 11.4 days in relation to the pond's size, the conical shape of the pond's basin (DV = 0.9), the superficial localization of the pond's water outflow, and the only occasional register of strong winds in the area also called for making difficult the water circulation process in the pond and eased stratification in the pond at least during the rainy season.

According to Gons *et al.* (1991), the shallowness of the water body dictates that the physical characteristics of the entire water column are likely to vary rapidly under the influences of wind stress. In mixed layers, diffusivity will be almost directly related to wind speed (Spiegel & Imberger, 1987). Experimental evidence suggests that winds with speeds > 2-3 $m.s^{-1}$ are required to mix the water surface (Webster & Hutchinson, 1994). Furthermore, beyond this critical wind speed interactions between wind-generated turbulence, mean currents, and waves cause the continual ejection of floating cells downward into zones of active turbulent mixing.

The most prevalent form of phosphorus in the pond bottom was the particulate fraction. Measured values of forms adsorbed to minerals and organic aggregates in the pond were usually 10 times higher than that of orthophosphate. The orthophosphate was twice as high at the bottom than at the surface of station 2. A comparable situation was detected for total nitrogen, of which the particulate fraction was, however, up to 100 times higher at the bottom than at the surface. Such findings agree perfectly with Wetzel's (1983) statement that in most lakes the largest portion of the total phosphorus is in the organic phase and that, of the total organic phosphorus, about 70% or more is particulate. Organic nitrogen in the pond also constituted over 50% of the total soluble nitrogen. At the surface, however, the ratios of particulate to inorganic fractions were close to 1:1 for both phosphorus and nitrogen.

Total numbers of cells of *Croasdalea marthae* were quite different at the surface and bottom of station 2 during the study period; the surface had almost three times more cells than the bottom. During the whole year of study total densities of *Croasdalea marthae* were greater at the surface. However, no special pattern for distribution of the alga could be derived from the analysis of Table 6.

The rate of change in algal cell concentration in the water column was obviously not simply dependent on wind speed alone. Rising and sinking velocities of cells undoubtedly play a very important role in the vertical distribution of algal populations. The advection-diffusion equation in Webster (1990) includes floatation (or sinking) velocity of planktonic cells as one of its three terms, in addition to horizontal advection and turbulent dispersion of cells in a vertical direction. *Croasdalea marthae* is surely a species morphologically well-adapted for flotation, due to its perfectly smooth cell wall and long, strong spines, which occur at regular intervals on the angular projections of the semicells. Mucilage sheaths and, probably, processes are aids to flotation (Duthie, 1965). Cell composition and physiological state will also affect the floating velocity of the alga.

Table 6. Comparison of annual means of variables between sampling stations 2-surface and 2-bottom (WS, Wilcoxon Test).

Variable	**WS**	**Significance**
Total phosphorus	135.0	0.00 *
Total dissolved phosphorus	172.5	0.01 *
Orthophosphate	147.5	0.01 *
Total nitrogen	122.0	0.00 *
Nitrate	212.0	0.39 ns
Nitrite	242.0	0.69 ns
Ammonium	171.0	0.01 *
Ca^{2+}	211.5	0.38 ns
Mg^{2+}	198.0	0.15 ns
K^{1+}	236.5	0.19 ns
Dissolved oxygen	327.0	0.01 *
Percent oxygen saturation	330.0	0.00 *
pH	265.5	0.17 ns
Alkalinity	208.5	0.31 ns
Conductivity	184.5	0.04 *
Water temperature	292.5	0.01 *
Total pigments	150.0	0.01 *

(*) = significant at 5% level
(ns) = not significant

Table 7. Spearman's rank correlation (R_s) for the significant variables from the test for independence between annual numbers of cells and variable averages.

Variable	R_s
Total dissolved phosphorus	0.543
Water temperature	-0.468

5. Temporal variation

Croasdalea marthae was present in the pond all the year round; average monthly density during the dry period (117 cells.ml^{-1}) was slightly higher than during the rainy season (76 cells.ml^{-1}) (Table 8). The maximum density of the alga was 222 cells.ml^{-1} in June/90, and the minimum 8 cells.ml^{-1} in January/90. Of the 6 sampling stations, n° 4 had the highest annual mean density of individuals (44 cells.ml^{-1}), followed by n° 1 (23 cells.ml^{-1}), n° 2-surface (11 cells.ml^{-1}), n° 3 (6 cells.ml^{-1}), and lowest density occurred at n° 2-bottom and n° 5 (4 cells.ml^{-1}).

Statistical analyses demonstrate that there were no significant correlations between abundance of the alga and physical, chemical, or climatological characteristics at each sampling station in the pond. However, if the pond is considered as a whole (*i.e.* for all sites combined), orthophosphate and water temperature were strongly correlated with abundance of the alga. Spearman's rank correlation coeficient (Table 7) demonstrated positive correla-

tion between algal densities and orthophosphate, and negative correlation between algal densities and water temperature. Reif *et al.* (1983) found magnesium and pH were significantly related to desmid species abundance, with magnesium having the greater influence. Lund (1971) observed the annual periodicity of 3 desmid species for 25 years in Windermere, England, and concluded that their annual cycles were very regular, with a single maximum and minimum. Thus, in the great majority of years *Cosmarium contractum* reached its annual maximum in September or October, while *Cosmarium abbreviatum* and *Staurastrum lunatum* peaked in July or August. Curves for maxima and minima paralleled temperature changes more closely than incident radiation. Culture experiments with clonal isolates of 3 taxa (*Closterium moniliferum*, *Cosmarium granatum*, and *Triploceras gracile*) from an acid bog demonstrated that individual desmid taxa are affected by unique parameters (pH and calcium) and unique levels of these parameters (Gough, 1977). This conclusion was later confirmed by Howell & South (1981) after working with 5 taxa of the genus *Triploceras*.

It is important to emphasize, however, that during the entire period of study, changes in orthophosphate and water temperature neither stimulated nor threatened abundance of the alga in the pond. If averages of maximum and minimum orthophosphate concentrations for the pond (all 5 sampling stations) were considered against, respectively, the averages of maxima and minima values for densities of individual algal cells in the pond, it was possible to estimate that a concentration of about 28 $\mu g.L^{-1}$ of phosphate would be necessary to increase algal cell density, and of about 1.5 $\mu g.L^{-1}$ to decrease it. Orthophosphate values in the Açude do Jacaré varied during the period of study, however, from 3.45 to 16.43 $\mu g.L^{-1}$. Similar calculations for water temperature indicated that values of around 18°C would be needed to increase algal cell density in the pond, and of about 33°C to decrease it. Temperature variation in the pond was between 17.6 and 32.1°C. In both circumstances, variation in

Table 8. Total number of individual cells ($ind.ml^{-1}$) of *Croasdalea marthae* during the study period.

	Sampling station					
Month	**1**	**2-S**	**2-B**	**3**	**4**	**5**
January/90	1	0	1	0	5	2
February	16	19	6	7	6	0
March	84	13	11	7	21	5
April	16	3	9	1	8	2
May	69	3	0	20	42	2
June	14	52	0	2	154	0
July	1	4	2	3	31	5
August	1	6	8	2	174	0
September	0	20	3	8	36	0
October	11	8	0	0	18	0
November	20	7	0	3	0	3
December	1	2	0	13	2	2
January/91	16	3	12	17	133	17
February	1	1	7	0	9	8
March	94	17	0	0	17	11
TOTAL	**345**	**158**	**59**	**83**	**656**	**57**

the ranges of these parameters was insufficient to promote significant changes in algal cell densities. Such a conclusion must, however, be taken with some caution since the maxima and minima values calculated above were considered for the entire pond, *i.e.* by averaging the values for all sampling stations together. The 5 stations were somewhat heterogeneous among themselves, with noteworthy differences for most characteristics studied.

It is well known that phosphorus is the least abundant element in the major nutrients required for algal growth in a large majority of fresh waters. Using the mean values for total nitrogen and total phosphorus at all 5 stations in the Açude do Jacaré, the N:P ratio was 20:1. According to Schindler (1978), a ratio of 10:1 is sufficient to define any given body of water as phosphorus-limited, a condition that prevailed in the Açude do Jacaré. However, concentration of orthophosphate in the water may have little influence on the growth kinetics of the alga, because the speed with which phosphorus is recycled and exchanges between its particulate and organic and inorganic soluble phases also are of the utmost importance for indication of phosphorus availability (Wetzel, 1983).

In contrast to our results, Canter & Lund (1966) found that greatest desmid abundance in Windermere, England, coincided with temperature maxima. These warm periods of greatest algal densities were, however, also characterized by low (> 1.0 $\mu g.L^{-1}$ and usually > 0.5 $\mu g.L^{-1}$) PO_4 concentrations.

Croasdalea marthae was found to reproduce vegetatively (Fig. 2-6) at any time of the year so that algal growth can occur at all times of year, confirming Canter & Lund's (1966) observations on other species from Windermere. We found no decrease in frequency of cell division in the winter most probably because winter conditions in our area are not as severe as in temperate regions.

6. Morphological variation

Variation, although not significant (CV = 2.6421), was observed both in the length (25.3-38μm, not including spines) and total width (57.5-91.2μm, including spines) of the cell. At lower temperatures, *Croasdalea marthae* had a greater total cell width (58.5-87.5μm; average 71.3μm), mainly due to the slightly longer spines. Measurements of the cell body were very constant during the entire study period. The amplitude variation in cell body width was not significant for any one sampling station, nor among stations, neither over the whole period of study (Table 9). No variation at all was observed for the number of rays of semicells in vertical view, nor for bipolar asymmetry. In fact, only one single semicell out of the almost 5,000 cells observed was found with 10 instead of 9 rays, and one single perfect bipolarly symmetrical individual cell was collected. Due to the extreme rarity of these events, such individual cells were considered anomalous.

Climatological, physical, and chemical variations in the Açude do Jacaré during the study period did not significantly modify the expression of the genetic code that governs bipolar asymmetry. On the contrary, such a code was practically inaccessible to variation; this fact leads us to consider bipolar asymmetry a good taxonomic criterion at genus level.

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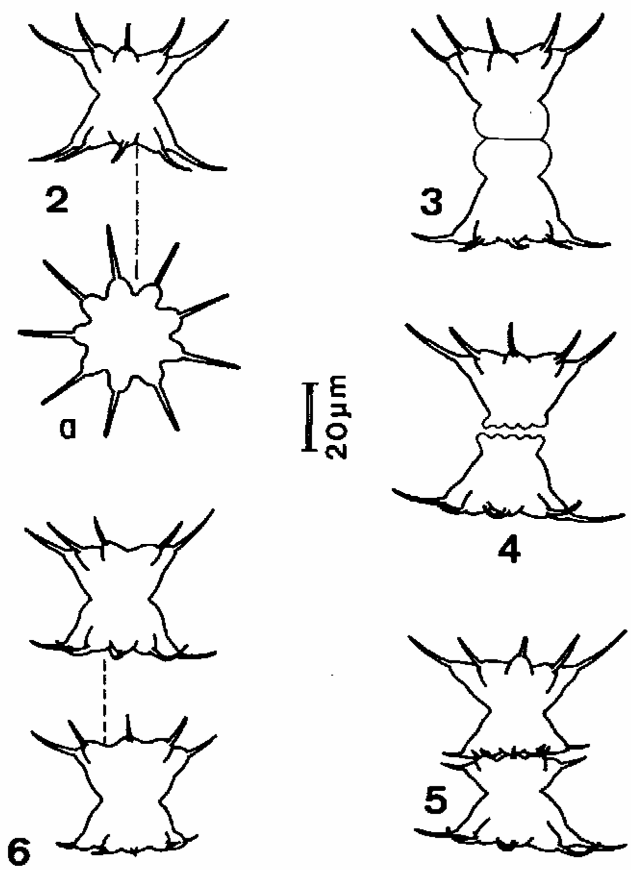

Fig. 2-6. *Croasdalea marthae.* 2: front view on adult cell, a: vertical view of the same cell; 3-6: succesive phases of the cell division process (vegetative reproduction).

Table 9. Cell measurements (length not including spines and width including spines) minima and maxima, and average minima and maxima per collecting station during the study period.

Station	Cell length (µm)		Cell width (µm)		Average (µm)	
	minimum	maximum	minimum	maximum	minimum	maximum
1	25.7	35.5	58.0	82.0	30.2	69.1
2s	25.3	32.5	58.7	82.0	31.3	69.8
2b	27.7	32.5	64.0	79.2	30.8	71.5
3	27.5	35.0	59.5	79.2	30.3	70.0
4	26.2	38.0	58.5	91.2	30.9	70.9
5	25.5	32.5	57.5	76.2	30.4	67.9

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