Acta Botanica Brasilica 27(3): 526-536. 2013.

Species richness of the genera *Trachelomonas* and *Strombomonas* (pigmented Euglenophyceae) in a subtropical urban lake in the Porto Alegre Botanical Garden, RS, Brazil

Sandra Maria Alves-da-Silva[1,3], Josemari da Cruz Cabreira[1], José Guilherme Voos[2] and Eduardo Alcayaga Lobo[2]

Received: 31 January, 2012. Accepted: 9 May, 2013

ABSTRACT

The objective of this study was to evaluate the taxonomic composition and richness of the genera *Trachelomonas* and *Strombomonas* (pigmented Euglenophyceae) in a subtropical urban lake (30°03'05"S; 51°10'34"W) within the Botanical Garden, in the city of Porto Alegre, located in the state of Rio Grande do Sul, Brazil, in order to contribute to the floristic knowledge of Euglenophyta in artificial urban lakes. From July 2007 to June 2008, we collected samples monthly from two sampling stations, using a 25-µm mesh plankton net. The samples were preserved in 4% formaldehyde. We evaluated the following environmental variables related to the water in the lake: ammonia content, silica content, organic matter content, dissolved oxygen concentration, temperature, pH, depth, transparency, electrical conductivity and rainfall. To study the species composition in relation to environmental factors, we used cluster analysis, principal components analysis, canonical correspondence analysis and indicator species analysis. At the specific and infraspecific level, 22 taxa were identified, *Trachelomonas elliptica* (Playf.) Defl. and *T. gracillima* Bal. & Dast. representing new records for the state of Rio Grande do Sul. The cluster analysis indicated seasonal variation, species richness being highest in the spring of 2007. Seven indicator species were characterized as acid-tolerant.

Key words: Euglenophyta, environmental gradient, shallow lake, species richness, southern Brazil

Introduction

Euglenophyceae is a class of microalgae composed of pigmented and colorless organisms, which, except for the genus *Colacium*, are all single-celled flagellates found in moist soil, brackish water, fresh water and marine environments. The pigmented Euglenophyta of the order Euglenales have two flagella, and only one emerges from the reservoir at the anterior pole of the cell, they show a pellicle composed of protein striae and have an energy reserve of paramylon. The pigmented genera *Trachelomonas* Ehr emend. Defl. and *Strombomonas* Defl. were studied in the Lago da Ponte, which is an artificial urban lake within the Botanical Garden, in the city of Porto Alegre, located in the state of Rio Grande do Sul, Brazil. *Trachelomonas* is the genus with the largest number of species within the division Euglenophyta, encompassing approximately 250 species that inhabit freshwater environments worldwide (Bourrelly, 1970), including marine species (Leedale, 1967), whereas *Strombomonas* encompasses approximately 50 species found only in freshwater environments (Bourrelly, 1970).

The Porto Alegre Botanical Garden**,** with an area of 39 ha, is located within an urban area and includes two lakes known locally as the Lago das Tartarugas ("Turtle Lake") and Lago da Ponte ("Bridge Lake"). We studied the Lago da Ponte, which was previously a swamp. Through the removal of grasses and the addition of more water, it was transformed into a lake in 2003. It is a shallow lake with grass carp, two swans and a number of tortoises. In its reflecting pool, *Salvinia auriculata* Abl. can be found. The decomposition of aquatic macrophytes associated with the food fed to swans and animal feces propitiate the existence of Euglenophyta, a group of algae that has been widely cited as a major indicator of water with high concentrations of organic matter, nitrogen and phosphorus (Round, 1983).

Urban lakes differ greatly in size, depth, drainage, water volume, hydrological balance, nutrient cycling and trophic status (García-Gil & Camacho, 2001). Although artificial urban lakes present environmental conditions suitable for supporting a highly diverse group of Euglenophyta, there have been few studies of these biotopes in the state of Rio Grande do Sul, although there have been some notable studies conducted by Rosa (1974), Cecy (1976; 1986; 1990), Huzsar *et al.* (1990), Franceschini (1992), Alves-da-Silva & Torres (1992; 1994a; 1994b; 1994c), Alves-da-Silva & Avila (1995) and Domingues & Torgan (2011). In Brazil as a whole,

[1] Fundação Zoobotânica do Rio Grande do Sul, Museu de Ciências Naturais, Porto Alegre, RS, Brazil
[2] Universidade de Santa Cruz do Sul, Laboratório de Limnologia, Santa Cruz do Sul, RS, Brazil
[3] Author for correspondence: alvesdasilva@fzb.rs.gov.br

studies of Euglenophyta in urban lakes or ponds include those conducted by Heckmann *et al.* (1993), Jati & Train (1994), Branco & Senna (1996), Giani *et al.* (1999), Nogueira & Rodrigues (1999), Silva (1999), Ferreira & Menezes (2000), Goulart *et al.* (2002), Kepeller *et al.* (2002), Ferragut *et al.* (2005), Nogueira *et al.* (2008) and Tucci *et al.* (2006). In this context, in order to bridge the knowledge gap on biodiversity of this group of algae in artificial urban ponds in the state and country, the objective of the present study was to study the taxonomic composition and richness of the genera *Trachelomonas* and *Strombomonas*, as well as their relationship to environmental variables, in the Lago da Ponte.

Material and methods

Study area and sampling

The geographic coordinates of the Lago da Ponte are 30°03'05"S and 51°10'34"W. It is an artificial shallow water environment with an approximate area of 0.5 ha. We collected samples of *Trachelomonas* and *Strombomonas* species at two locations: Station 1, with an average depth of 54.1 cm (max., 100 cm); and Station 2, with an average depth of 22.8 cm (max., 30 cm). From July 2007 to June 2008 encompassing all four seasons, monthly samples were collected from the two sampling stations, totaling 24 samplings. Operationally, the nomenclature used hereafter is: E1 and E2 = sampling Stations 1 and 2; 77 = month / year (July 2007); E177 = Station 1, July 2007; E277 = Station 2, July 2007; E197 = Station 1, September 2007; E297 = Station 2, September 2007, and so on.

Biological composition

The water samples for biological analyses were collected using a 25-µm mesh plankton net and were preserved in 4% formaldehyde. We analyzed slide-mounted live samples using a light microscope (Leica DMLS; Leica Microsystems. Inc., Depew, NY, USA) with a grid eyepiece, which was coupled to a *camera lucida* in order to make the drawings.

For the identification of taxa at the specific and infraspecific levels, we referred to the following basic works: Huber-Pestalozzi (1955), Németh (1980), Starmach (1983), Tell & Conforti (1986) and Shi *et al.* (1999). The samples were deposited in the collection of the *Herbário Prof. Dr. Alarich R. H. Schultz* (HAS, Prof. R. Alarich H. Schultz Herbarium) at the Museum of Natural Science of the Zoobotanical Foundation of the state of Rio Grande do Sul (Tab. 1).

Environmental variables

Simultaneously to the collection of biological material, water was collected in order to conduct measurements of physical and chemical variables important as parameters for environmental evaluation. The concentrations of ammonia (µg L^{-1}), silica (mg L^{-1}), organic matter (mg L^{-1} O_2) and dissolved oxygen (mg L^{-1}) were measured in the laboratory in accordance with the standards established by the American Public Health Association (APHA, 2005). We measured temperature (°C mercury thermometer), pH (DMPH pHmeter; Digimed, Santo Amaro, Brazil), depth (in cm), transparency (Secchi disk) and electrical conductivity (in µS cm^{-1}, CD-28 conductometer; Digimed) on site. The rainfall data were obtained from the National Meteorology Institute - 8th Meteorology District, which has a weather station near the study area.

Information Processing

Multivariate species composition data on *Trachelomonas* and *Strombomonas* in relation to environmental factors were analyzed in two different ways. First, data related to the presence and absence of taxa, at different times of the year, were analyzed using cluster analysis. Subsequently, we applied indicator species analysis to the array of biological data, defining indicator species as those that showed significance on the Monte Carlo test ($p<0.05$).

Principal component analysis was applied to the physicochemical data matrix, in order to determine the significance of the accumulated variance of the explanatory environmental variables in the ordination. Finally, to reveal the main gradients of change in the composition of the indicator species, in relation to environmental processes, we applied canonical correspondence analysis (Ter Braak, 1986). The physical and chemical data were logarithmically transformed (log x), and analyses were processed using the program PC-ORD (McCune and Mefford, 1999).

Results and discussion

Taxonomic composition

We identified specimens of the genus *Trachelomonas* in all 24 of the samples analyzed, whereas we identified *Strombomonas* in only nine. Overall, we identified 22 taxa at the specific and infraspecific level, 20 *Trachelomonas* species and 2 *Strombomonas* species, distributed among 14 typical varieties and eight atypical varieties.

Taxonomic survey

Division: Euglenophyta
Class: Euglenophyceae
Order: Euglenales
Family: Euglenaceae
Genus: ***Trachelomonas*** Ehrenberg emend. Deflandre 1926.

1. ***Trachelomonas armata*** (Ehrenberg) Stein var. ***steinii*** Lemmermann emend. Deflandre, Abh. Naturw. Ver. Bremen 18:165. 1905.
Fig. 1

Table 1. Details of samples collected from the Lago da Ponte, within the Porto Alegre Botanical Garden, and deposited in the Dr. Alarich R. H. Schultz Herbarium (HAS), in the city of Porto Alegre, state of Rio Grande do Sul, Brazil.

Accession no.	Collecting Station	Collectors	Dates	Season
107564	1	Alves-da-Silva, S. M., Friedrich, F. & Nunes, M. L.	25 Jul 2007	Winter
107565	2	Alves-da-Silva, S. M., Friedrich, F. & Nunes, M. L.	25 Jul 2007	Winter
107566	1	Alves-da-Silva, S. M. & Friedrich, F.	15 Aug 2007	Winter
107567	2	Alves-da-Silva, S. M. & Friedrich, F.	15 Aug 2007	Winter
107568	1	Friedrich, F. & Nunes, M. L.	12 Sep 2007	Winter
107569	2	Friedrich, F. & Nunes, M. L.	12 Sep 2007	Winter
107570	1	Friedrich, F. & Nunes, M. L.	10 Oct 2007	Spring
107571	2	Friedrich, F. & Nunes, M. L.	10 Oct 2007	Spring
107572	1	Alves-da-Silva, S. M. & Friedrich, F.	19 Nov 2007	Spring
107573	2	Alves-da-Silva, S. M. & Friedrich, F.	19 Nov 2007	Spring
107574	1	Alves-da-Silva, S. M. & Friedrich, F.	13 Dec 2007	Spring
107575	2	Alves-da-Silva, S. M. & Friedrich, F.	13 Dec 2007	Spring
107576	1	Alves-da-Silva, S. M., Nunes, M. L. & Cunha, G.R.	09 Jan 2008	Summer
107577	2	Alves-da-Silva, S. M., Nunes, M. L. & Cunha, G.R.	09 Jan 2008	Summer
107794	1	Alves-da-Silva, S. M., Friedrich, F. & Nunes, M. L.	13 Feb 2008	Summer
107797	2	Alves-da-Silva, S. M., Friedrich, F. & Nunes, M. L.	13 Feb 2008	Summer
107800	1	Friedrich, F. & Nunes, M. L.	14 Mar 2008	Summer
107803	2	Friedrich, F. & Nunes, M. L.	14 Mar 2008	Summer
107806	1	Friedrich, F. & Nunes, M. L.	11 Apr 2008	Autumn
107809	2	Friedrich, F. & Nunes, M. L.	11 Apr 2008	Autumn
107812	1	Friedrich, F. & Nunes, M. L.	13 May 2008	Autumn
107815	2	Friedrich, F. & Nunes, M. L.	13 May 2008	Autumn
107818	1	Alves-da-Silva, S. M. & Friedrich, F.	13 Jun 2008	Autumn
107821	2	Alves-da-Silva, S. M. & Friedrich, F.	13 Jun 2008	Autumn

Lorica ovate, 32-37 µm long; 22-23 µm wide; Rc/l = 1.4, rounded poles; flagellar pore ca. 3 µm diam., ring thickening present, collar absent; wall reddish-brown medium to dark, punctuate, smaller spinules on the anterior pole, larger curved converging spinules on the posterior pole; numerous chloroplasts, discoid, ca. 3.5 µm diam.; internal pyrenoids present. *Trachelomonas armata* differs from the typical species by its smaller spinules on the anterior pole and larger converging spinules on the posterior pole.

Material examined: HAS107570, HAS107572, HAS107573, HAS107574, HAS107575, HAS107576, HAS107797, HAS107800.

Geographic distribution in Brazil, by region (state or district): Central-West (Mato Grosso, Federal District), North (Amazonas, Acre), Southeast (Espírito Santo, São Paulo, Rio de Janeiro), South (Paraná, Santa Catarina, Rio Grande do Sul).

2. ***Trachelomonas curta*** Cunha emend. Deflandre var. ***curta***, Bull. Soc bot., 44: 286. 1927.

Fig. 2

Lorica subspherical, smooth, 18-20 µm long; 23-24 µm wide; Rc/l = 0.7-0.9; anterior-posterior flattening of the poles; flagellar pore ca. 2.5 µm diam., annular thickening present, collar absent, yellow-brown wall; more than 10 chloroplasts, discoid, 4 µm diam., numerous rod-shaped paramylon granules, ca. 2 µm length.

Material examined: HAS107566, HAS107571, HAS107572, HAS107577, HAS107797, HAS107806, HAS107809, HAS107812.

Geographic distribution in Brazil, by region (state or district): Central-West (Federal District), North (Amazonas, Acre, Rondônia), Southeast (Minas Gerais, São Paulo, Rio de Janeiro), South (Paraná, Rio Grande do Sul).

3. ***Trachelomonas curta*** Cunha emend. Deflandre var. ***minima*** Tell & Zalocar, Nova Hedwigia, 1: 364, pl. 8, fig. 21a-b, 22, pl. 14, fig. 3. 1985.

Fig. 3-4

Lorica subspherical, smooth, 4.5-8 µm long; 6-12.6 µm wide; Rc/l = 0.6-0.7; anterior-posterior flattening of the poles. *Trachelomonas curta* differs from the typical species by its smaller dimensions.

Material examined: HAS107564, HAS107566, HAS107567, HAS107569, HAS107570, HAS107571, HAS107572, HAS107573, HAS107574, HAS107575, HAS107576, HAS107577, HAS107806, HAS107809.
Geographic distribution in Brazil, by region (state): North (Amazon), Southeast (São Paulo), South (Paraná, Rio Grande do Sul).

4. ***Trachelomonas elliptica*** (Playfair) Deflandre, Bull. Soc Bot. France 74: 286. 1927.
Fig. 5-6

Lorica elliptical, 24-26 µm long, 10-11.5 µm wide; Rl/c = 2.3, slightly narrowed anterior pole; rounded posterior pole; flagellar pore ca. 2.5 µm diam., high collar, 3 µm high by 3 µm wide; wall smooth, reddish-brown; numerous chloroplasts, discoid, ca. 2 µm diameter.
Material examined: HAS107568, HAS107573, HAS107574, HAS107575, HAS107576.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso), South (Rio Grande do Sul).

5. ***Trachelomonas gracillima*** Balech & Dastugue var. ***gracillima***, Physis 12: 355, fig. 2: 7. 1938.
Fig. 7

Lorica elliptical, 40-42 µm long, 17.0-17.5 µm wide; Rl/c = 2.4; parallel sides, acuminate posterior pole, with three larger conical spinules in the posterior region, the others regularly distributed throughout the lorica; wall punctuated, reddish-brown; numerous chloroplasts, discoid, ca. 1.8 µm diam.; internal pyrenoids present.
Material examined: HAS107571, HAS107572, HAS107574, HAS107575.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso do Sul), South (Rio Grande do Sul).

6. ***Trachelomonas hemisphaerica*** Garcia de Emiliani, Rev. Asoc. Cienc. Nat. Litoral, 14(2): 241. 1983.
Fig. 8-9

Lorica hemispherical, 15-18 µm long, 22-28 µm in wide; Rl/c = 0.6 to 0.7; rounded apical view; anterior and posterior pole separated by a raised edge, rounded posterior pole and anterior hemispheric slightly convex; apical median pore, conspicuous; smooth wall, russet; numerous chloroplasts, discoid, ca. 1.8 µm diameter.
Material examined: HAS107809, HAS107812.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso, Goiás), Southeast (Rio de Janeiro), South (Rio Grande do Sul, Paraná).

7. ***Trachelomonas hispida*** (Perty) Stein emend. Deflandre var. ***hispida***, Revue gén. Bot., 38: 650, pl. 3, fig. 203, 207-208. 1926.
Fig. 10-11

Lorica elliptical, 22-25 µm long, 17-20.5 µm wide; Rl/c = 1.2-1.3; small conical spinules distributed throughout the lorica wall.
Material examined: HAS107570, HAS107571, HAS107572, HAS107573.
Geographic distribution in Brazil, by region (state or district): Central-West (Federal District, Mato Grosso, Mato Grosso do Sul, Goiás), North (Acre, Amazonas, Pará, Rondônia), Northeast (Pernambuco), Southeast (São Paulo, Rio de Janeiro), South (Paraná, Santa Catarina, Rio Grande do Sul).

8. ***Trachelomonas hispida*** (Perty) Stein emend. Deflandre var. ***coronata*** Lemmermann, *in* Pascher, Süsswasserfl. Deutsch. 2 (2): 150. 1913.
Fig. 12-13

Lorica elliptical, 35-41 µm long, 22-25 µm wide; Rl/c = 1.5-1.8; rounded poles, flagellar pore ca. 3 µm diam.; ring thickening present, collar ca. 3.5 to 4.5 high, 7-9 µm wide; punctuate wall, russet; conical spinules, distributed across the entire lorica surface, 1.6-1.8 µm long; chloroplasts, discoid, 3-4.5 µm diam.; diplopyrenoids present; numerous elliptical paramylon granules, ca. 2 µm long; conical spinules distributed across the entire lorica surface.
Trachelomonas hispida differs from the typical species by its crown-shaped collar of spinules attached to its base (Fig. 13).
Material examined: HAS107566, HAS107569, HAS107571, HAS107573, HAS107574, HAS107577, HAS107794, HAS107797, HAS107800, HAS107803, HAS107815, HAS107818.
Geographic distribution in Brazil, by region (state or district): Central-West (Federal District, Goiás, Mato Grosso do Sul), North (Pará, Acre), Southeast (São Paulo), South (Rio Grande do Sul).

9. ***Trachelomonas lacustris*** Drezepolski var. ***lacustris***, Kosmos, 50: 217, pl. 2, fig. 67. 1925.
Fig. 14

Lorica cylindrical or oblong, 25.5-36.5 µm long, 12-19 µm wide; Rl/c = 1.9-2.1; rounded poles, 2-3 µm flagellar pore diam., ring thickening present; collar sometimes present; discoid chloroplasts; internal pyrenoids present; wall punctuate, russet; conical spinules, ca. 1 µm long, regularly distributed across the surface of the lorica.
Material examined: HAS107564, HAS107569, HAS107570, HAS107571, HAS107572, HAS107573 HAS107574, HAS107575, HAS107576, HAS107794, HAS107803, HAS107809.
Geographic distribution in Brazil, by region (state or district): Central-West (Federal District, Mato Grosso do Sul, Mato Grosso), North (Rondônia) Northeast (Pernambuco), Southeast (São Paulo, Rio de Janeiro), South (Rio Grande do Sul).

10. ***Trachelomonas lemmermannii*** Woloszynska emend. Deflandre var. ***lemmermannii***, Revué gen. Bot., 38:696, pl.7, fig.397, 380, 396-398, 405-406. 1926.
Fig. 15-16

Lorica conical-cylinder, 25-26 µm long, 14-15.5 µm wide; Rl/c = 1.7; straight sides to the anterior 2/3; anterior pole slightly truncated, posterior pole abruptly attenuated, tapered-rounded, flagellar pore ca. 4 µm diam., ring thickening present, collar absent; wall punctuate, russet, conical spinules, irregularly distributed across the surface of the lorica, ca. 1 µm long; discoid chloroplasts, ca. 3.5 µm diameter.
Material examined: HAS107573.
Geographic distribution in Brazil, by region (state or district): Central-West (Federal District, Mato Grosso do Sul, Mato Grosso, Goiás), Southeast (São Paulo, Rio de Janeiro), South (Paraná, Rio Grande do Sul).

11. ***Trachelomonas lemmermannii*** Woloszynska emend. Deflandre var. ***acuminata*** Deflandre, Revue gén. Bot., v.38, p.697, pl. 7, fig.404, 407-409,1926.
Fig. 17

Lorica conical-cylinder, 36-37 µm long, 15-16 µm wide; Rl/c = 2.3-2.4; straight sides in the anterior and conical, tapered rounded posterior; flagellar pore ca. 4 µm diam.; ring thickening present, collar absent; wall punctuate, light brown; discoid chloroplasts, ca. 3 µm diam.; internal pyrenoids present.
Material examined: HAS107568, HAS107572, HAS107574, HAS107576, HAS107794, HAS107797, HAS107809.
Geographic distribution in Brazil, by region (state or district): Central-West (Mato Grosso, Federal District), Southeast (Rio de Janeiro), South (Rio Grande do Sul).

12. ***Trachelomonas oblonga*** Lemmermann var**. *truncata*** Lemmermann, Abh. Naturw. Ver. Bremen, 16: 344, 1899.
Fig. 18-20

Lorica oblong, 11-14 µm long, 10-11 µm wide; Rl/c = 1.1-1.2, truncated anterior pole; rounded posterior pole, flagellar pore ca. 2 µm diam., ring thickening present, collar absent; wall smooth, light brown to medium reddish-brown.
Material examined: HAS107569, HAS107570, HAS107572, HAS107573, HAS107574, HAS107575, HAS107576, HAS107577.
Geographic distribution in Brazil, by region (state): Central-West (Goiás), North (Amazon), South (Santa Catarina, Rio Grande do Sul).

13. ***Trachelomonas pulcherrima*** Playfair var. ***pulcherrima***, Proc. Linn. Soc. N. S. W., 40:13, pl. 1, figs.32-33, 1915.
Fig. 21

Lorica elliptical, 22-23 µm long, 10-11 µm wide; Rl/c = 2.1-2.2; pole rounded to slightly truncated, rounded posterior pole, flagellar pore ca. 2 µm diam., ring thickening present, collar absent; wall smooth or punctuate, light brown to medium reddish-brown; discoid chloroplasts, ca. 1.5 diam.; internal pyrenoids present.
Material examined HAS107572, HAS107573, HAS107574, HAS107576, HAS107577, HAS107809, HAS107818.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso), North (Amazon), Southeast (São Paulo, Rio de Janeiro), South (Rio Grande do Sul).

14. ***Trachelomonas pulcherrima*** Playfair var. ***minor*** Playfair, Proc. Linn. Soc. N.S.W., 40:14, pl. 1, figs.37-38, 1915.
Fig. 22-24

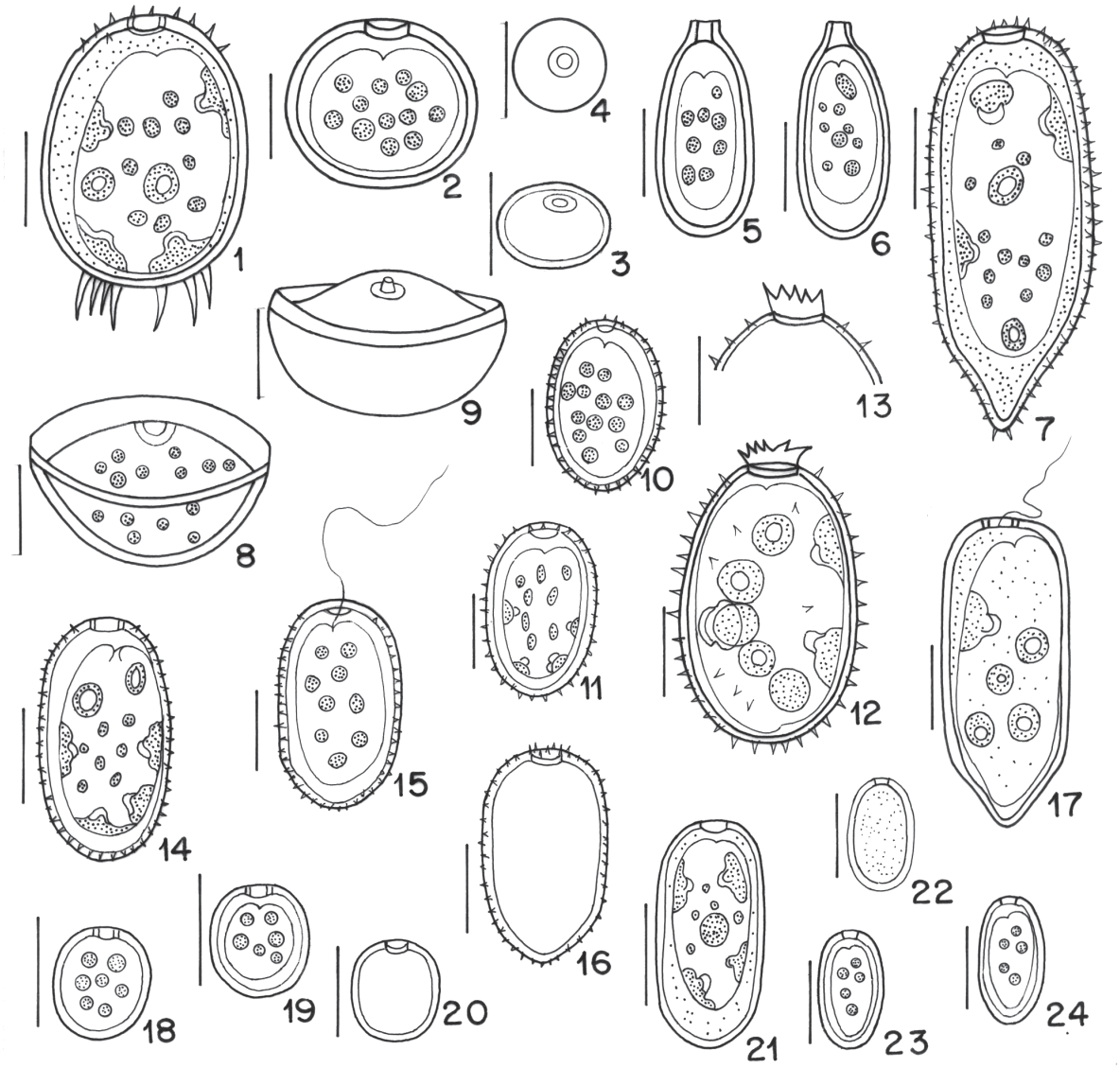
Lorica elliptical, 14-15 µm long, 7.5-9 µm wide; Rl/c: 1.7-1.9; pole rounded to slightly truncated, rounded posterior pole, flagellar pore ca. 2 µm diam., ring thickening present, collar absent; wall punctuate, light russet; chloroplasts discoid, ca. 1.8 diam.; no internal pyrenoids observed.
Trachelomonas pulcherrima var. *minor* differs from the typical species by its smaller cell dimensions.
Material examined: HAS107573, HAS107574, HAS107575, HAS107576, HAS107794, HAS107797.
Geographic distribution in Brazil, by region (state): Southeast (Rio de Janeiro), South (Paraná, Rio Grande do Sul, Santa Catarina).

15. ***Trachelomonas robusta*** Swirenko emend. Deflandre var. ***robusta***, Révue gén. Bot., 38: 657, pl. 4,fig. 257, 260. 1926.
Fig. 25

Lorica broadly elliptical, 25-26 µm long, 20-21 µm wide; Rl/c = 1.2, rounded poles, flagellar pore ca. 2 µm diam., ring thickening present; collar absent; wall russet, thickly scored, conical spinules, ≤ 2.5 µm long, irregularly distributed across the wall surface; chloroplasts discoid, ca. 2 µm diam.; internal pyrenoids present.
Material examined: HAS107567, HAS107570, HAS107572, HAS107576.
Geographic distribution in Brazil, by region (state or district): Central-West (Mato Grosso, Federal District), North (Pará, Amazonas), Southeast (São Paulo, Rio de Janeiro) South (Rio Grande do Sul).

16. ***Trachelomonas sculpta*** Balech var. ***sculpta***, An. Mus. argent. Cienc. nat., 41: 245, fig. 32, 167. 1944.
Fig. 26-27

Lorica spherical, 20-21 µm diam., flagellar pore in the interior of one depression, ca. 2 µm diam., ring thickening present; collar absent, thick wall, ca. 1.8 µm diam.; wall dark brown, depressions approximately polygonal, isometric, dense, evenly distributed; no chloroplasts or pyrenoids observed.
Material examined: HAS107567, HAS107573.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso do Sul), North (Amazon), Southeast (Rio de Janeiro), South (Santa Catarina, Paraná, Rio Grande do Sul).



Figures 1-24. *Trachelomonas* from the Lago da Ponte. **1.** *Trachelomonas armata* (Ehr.) Stein var. *steinii* Lemm. emend. Defl. **2.** *Trachelomonas curta* Cunha emend. Defl. var. *curta*. **3, 4.** *Trachelomonas curta* Cunha emend. Defl. var. *minima* Tell & Zal. **5, 6.** *Trachelomonas elliptica* (Playf.) Defl. **7.** *Trachelomonas gracillima* Bal. & Dast. var. *gracillima*. **8, 9.** *Trachelomonas hemisphaerica* Garc. de Emil. **10, 11** *Trachelomonas hispida* (Perty) Stein emend. Defl. var. *hispida*. **12, 13.** *Trachelomonas hispida* (Perty) Stein emend. Defl. var. *coronata* Lemm. **13.** Detail of collar. **14.** *Trachelomonas lacustris* Drez. var. *lacustris*. **15, 16.** *Trachelomonas lemmermannii* Wolosz. emend. Defl. var. *lemmermannii*. **17.** *Trachelomonas lemmermannii* Wolosz. emend. Defl. var. *acuminata* Defl. **18-20.** *T. oblonga* Lemm. var. *truncata* Lemm. **21.** *Trachelomonas pulcherrima* Playf. var. *pulcherrima*. **22-24.** *Trachelomonas pulcherrima* Playf. var. *minor* Playf. **22.** Detail of the wall with punctuations. Scale = 10 μm.

17. ***Trachelomonas varians*** Deflandre var. ***varians***, Revue gén. Bot.,v.38,p.525, fig.37-40,42-44,47- 50,1926.
Fig. 28-30

Lorica globose, 24-25 μm diam., ring thickening present; inner tube cylindrical, straight or slightly oblique, extended by a slightly oblique outer edge; wall smooth, dark brown, ca. 1.8 μm thick; chloroplasts numerous, discoid.

The genera *T. varians* and *T. cervicula* Stokes are quite similar and difficult to distinguish by their descriptions. The individuals examined were identified in accordance with Rino & Pereira (1991), who cite a short, truncated, conical, often oblique, inner tube extended by a flange that can be externally oblique, with numerous chloroplasts (30-50); lorica globose to broadly elliptical. Those same authors stated that *T. cervicula* possesses a spherical to subspherical lorica, has a long straight inner tube and presents 6-10 chloroplasts, all containing haplopyrenoids.

Material examined: HAS107573.

Geographic distribution in Brazil, by region (state or district): Central-West (Mato Grosso, Federal District), Northeast (Pernambuco), South (Paraná, Rio Grande do Sul).

18. ***Trachelomonas volvocina*** Ehrenberg var. ***volvocina***, Infusoria. 18, pl. 2, fig. 29. 1838.
Fig. 31

Lorica spherical, smooth, 17-20 µm diam.; flagellar pore ca. 3 µm diam., ring thickening present; collar absent; wall reddish, smooth; two shield-shaped chloroplasts, with diplopyrenoids; no paramylon granules observed.
Material examined: HAS107567, HAS107573, HAS107574, HAS107575, HAS107576, HAS107577, HAS107794, HAS107797, HAS107803, HAS107806, HAS107809, HAS107812, HAS107815.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso, Mato Grosso do Sul, Goiás), Northeast (Bahia, Pernambuco), North (Acre, Amazonas, Manaus, Rondônia), Southeast (Espírito Santo, Minas Gerais, Sao Paulo, Rio January), South (Paraná, Santa Catarina, Rio Grande do Sul).

19. ***Trachelomonas volvocina*** Ehrenberg var. ***derephora*** Conrad, Ann. Biol. Lacustre 8: 201, pl.1, fig. 3. 1916.
Fig. 32-33

Lorica spherical, 20-22 µm diam.; flagellar pore ca. 3 µm diam., ring thickening present; collar cylindrical, 2 µm long; wall reddish, smooth; chloroplasts numerous, discoid, ca. 2 µm diam., no internal pyrenoids observed.
Material examined: HAS107569, HAS107573, HAS107575.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso), North (Amazon), Southeast (São Paulo, Rio de Janeiro), South (Rio Grande do Sul).

20. ***Trachelomonas volvocinopsis*** Swirenko var. ***volvocinopsis***, Arch. Hydrobiol. Planktonk., 9: 33, pl. 19, figs. 1-3, 1914.
Fig. 34

Lorica spherical, 21.0-25.5 µm diam.; flagellar pore ca. 2.5 µm diam., ring thickening present; collar absent; wall russet, smooth; chloroplasts (> 10), discoid, ca. 3 µm diameter.
Material examined: HAS107564, HAS107565, HAS107567, HAS107568, HAS107569, HAS107570, HAS107571, HAS107572, HAS107573, HAS107574, HAS107575, HAS107576, HAS107577, HAS107794, HAS107797, HAS107800, HAS107803, HAS107806, HAS107809, HAS107812, HAS107815, HAS107818, HAS107821.
Geographic distribution in Brazil, by region (state or district): Central-West (Mato Grosso, Mato Grosso do Sul, Goias, Federal District), Northeast (Pernambuco, Rio Grande do Norte), North (Amazonas, Rondônia, Pará), Southeast (Minas Gerais, Sao Paulo, Rio de Janeiro), South (Santa Catarina, Paraná, Rio Grande do Sul).

Genus ***Strombomonas*** Deflandre 1930.

21. ***Strombomonas costata*** Deflandre var. ***costata***, Arch. Protistenk. 69(3): 589, figs. 76-80. 1930.
Fig. 35-37

Lorica ovate to elliptical, sometimes rhomboid; 53-58 µm long, 23-27 µm wide, Rc/l = 2.2-2.3; apical view, with rounded edge slightly lobed; anterior pole gradually attenuated in cylindrical collar, extended at the end, crenulated edge, 4-6.5 µm high and 6-7 µm wide; posterior pole abruptly attenuated in hyaline flow process, tapered, straight or slightly curved, 11-13 µm long; wall slightly roughened, hyaline to yellowish light brown, with longitudinal folds; numerous chloroplasts, ca. 3 µm diam., flagellum ca. the length of the lorica.
Material examined: HAS107570, HAS107571, HAS107573, HAS107574.
Geographic distribution in Brazil, by region (state): North (Pará, Amazonas), Southeast (Rio de Janeiro), South (Santa Catarina, Rio Grande do Sul).

22. ***Strombomonas fluviatilis*** (Lemmermann) Deflandre var. ***levis*** (Lemmermann) Skvortzov, Aus der Biol. Sungari Station zur Harbin 1(2): 78, pl. 6, fig. 33. 1925.
Fig. 38-39

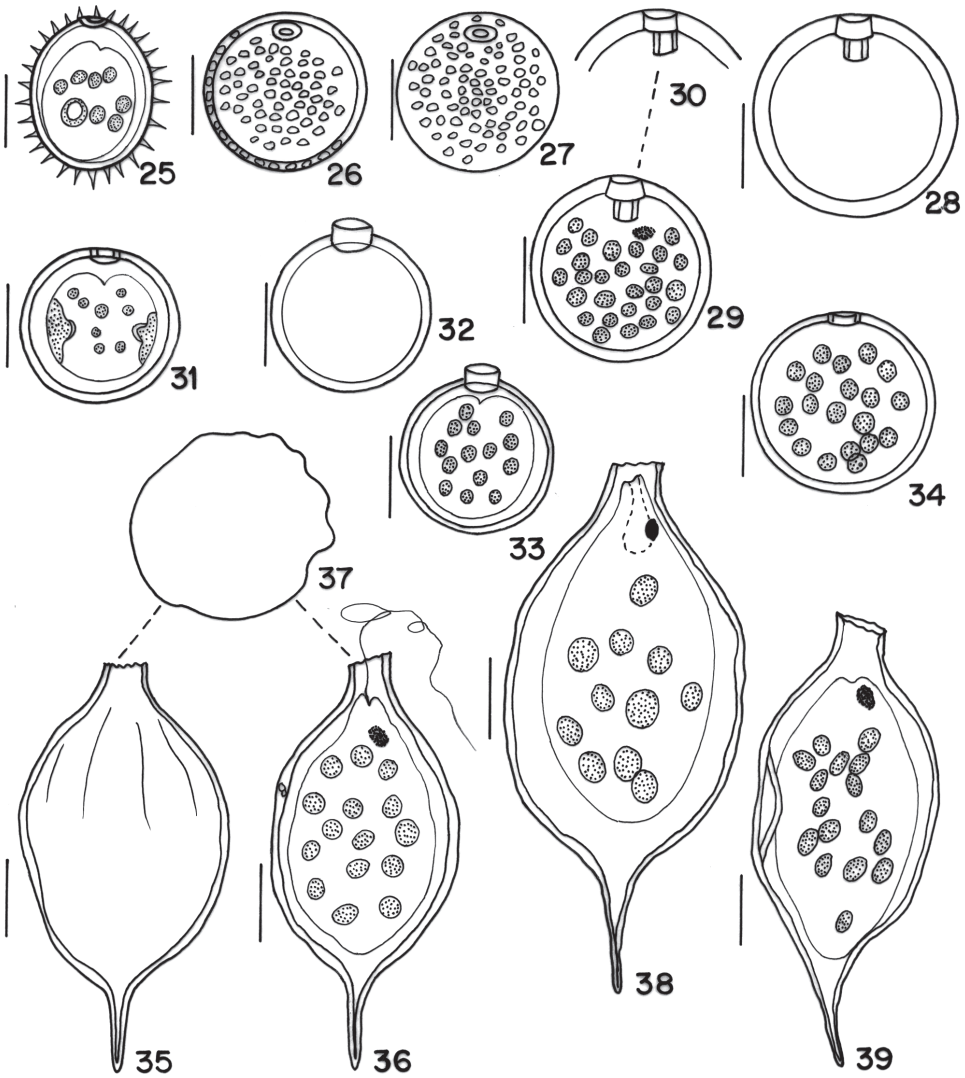
Lorica elliptical, 64-70.5 µm long, 26-30 µm wide, Rc/l = 2.1-2.5; anterior pole ending in short collar, broad at the distal region, with 4-6 µm high and 6-7 µm wide; posterior pole ending in straight caudal process, tapered, 14-17 µm long; rough wall, hyaline to greenish, with or without internal pyrenoids (8-10); chloroplasts numerous, discoid, 3-5 µm diameter.
Material examined: HAS107569, HAS107573, HAS107576, HAS107797, HAS107812, HAS107815.
Geographic distribution in Brazil, by region (state): Central-West (Mato Grosso), North (Amazon), Southeast (Rio de Janeiro), South (Rio Grande do Sul).

Geographic distribution

Of the 22 taxa identified in the lake, 54.5% have a cosmopolitan distribution, whereas the others have been recorded on two to three continents. *Trachelomonas armata* var. *steinii, T. hispida* var. *hispida*, *T volvocina* var. *volvocina* and *T. volvocinopsis* var. *volvocinopsis* are taxa with broader distribution in Brazil.

All species and infraspecies had already been cited in Brazil, although *T. elliptica* and *T. gracillima* represented new records for Rio Grande do Sul.

The most representative taxa for their occurrence in the urban lake studied were *Trachelomonas curta* var. *minima*, *T. hispida* var. *coronata*, *T. volvocina* var. *volvocina* and *T. volvocinopsis*, the last taxon being distinctive in that it was present in 96% of the analyzed samples. With the exception of *T. curta* var. *minima*, the other species are distributed worldwide. The least representative taxa in the lake were *T. hemisphaerica, T. lemmermannii* var. *lemmermannii*, *T. sculpta* var. *sculpta*, *T. varians* var. *varians* and *T. volvocina* var. *derephora*, all of which occurred in less than 11% of the samples.



Figures 25-39. *Trachelomonas* and *Strombomonas* from the Lago da Ponte. **25.** *Trachelomonas robusta* Swir. emend. Defl. var. *robusta*. **26, 27.** *Trachelomonas sculpta* Bal. var. *sculpta*. **28-30.** *Trachelomonas varians* Defl. var. *varians*. **30.** detail of the inner collar. **31.** *Trachelomonas volvocina* Ehr. var. *volvocina*. **32, 33.** *Trachelomonas volvocina* Ehr. var. d*erephora* Conr. **34.** *Trachelomonas volvocinopsis* Swir. var. *volvocinopsis*. **35-37.** *Strombomonas costata* Defl. var. *costata*. **37.** apical view. **38, 39.** *Strombomonas fluviatilis* (Lemm .) Defl. var. *levis* (Lemm.) Skv. Scale = 10 μm.

Species richness

The highest number of taxa was recorded in the spring of 2007 (Fig. 40). The richness ranged from one to 17 taxa, peaking in November 2007, when 17 taxa were cited at Station 2, corresponding to 73% of the taxa recorded.

Cluster analysis

Cluster analysis, based on data regarding the presence and absence of *Trachelomonas* and *Strombomonas*, as well as the categorical variable "seasonality" (in function of the different times of year), revealed three main clusters: the first comprising Winter samplings; the second comprising Spring samplings; and the third comprising samplings from Summer and Fall (Fig. 41). The analysis revealed seasonal differences in the richness of the two genera.

Indicator species analysis

Figure 42 shows the species that showed significance ($p<0.05$) on a Monte Carlo test, having been selected for additional tests using canonical correspondence analysis in order to reveal the main gradients of change in species composition. The indicator species *Trachelomonas armata* var. *steinii*, *T. curta* var. *minima*, *T. gracillima*, *T. hispida* var. *hispida*, *T. lacustris*, *T. oblonga* var. *truncata* and *Strombomonas costata* form the Spring subcluster, corresponding to the Spring of 2007 and showing a significant seasonal component grouping.

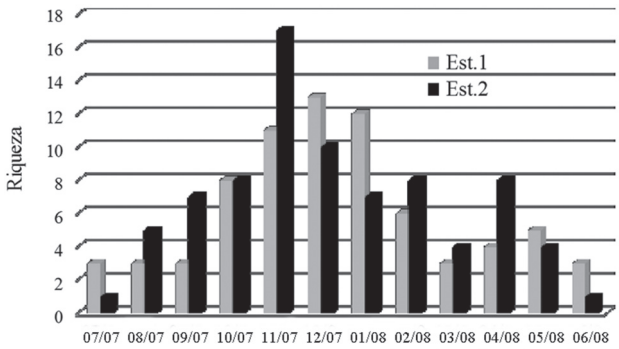


Figure 40. Distribution of the richness (no. de taxa) of *Trachelomonas* and *Strombomonas* in the Lago da Ponte, in the state of Rio Grande do Sul, Brazil, the two sampling stations (ST1= Station 1 and ST2= Station 2), between July 2007 and June 2008.

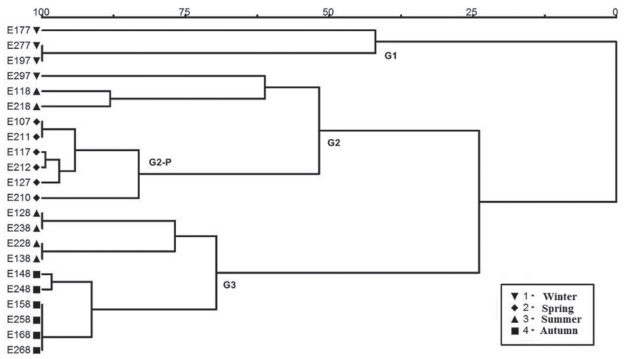


Figure 41. Cluster analysis based on monthly data related to the presence and absence of *Trachelomonas* and *Strombomonas* species and physicochemical variables for the Lago da Ponte, in the state of Rio Grande do Sul, Brazil, with seasonality as the categorical variable. G1 – Winter cluster; G2 – Spring cluster; G2-P – Spring subcluster; G3 – Summer/Autumn cluster.

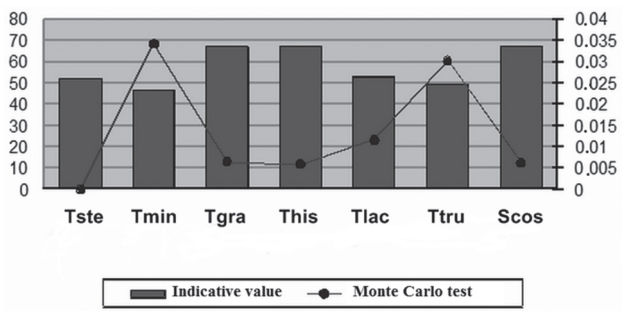


Figure 42. Indicator species analysis based on presence and absence data of *Trachelomonas* and *Strombomonas* at two stations (ST1 and ST2) in the Lago da Ponte, in the state of Rio Grande do Sul, Brazil, between July 2007 and June 2008. Tste – *Trachelomonas armata* var. *steinii*; Tmin – *T. curta* var. *minima*; Tgra – *T. gracillima*; This – *T. hispida* var. *hispida*; Tlac – *T. lacustris*; Ttru – *T. oblonga* var. *truncata*; Scos – *Strombomonas costata*.

Principal component analysis

The principal component analysis revealed that the first eight physical and chemical variables reached a cumulative percentage of variance of the explanatory order corresponding to the analysis cut-off point, 95% according to the variable selection methodology described by Delevati *et al.* (2005). The other two variables whose cumulative percentage of variance exceeded the cut-off were excluded from a second analysis to avoid the problem of multicollinearity between environmental variables, particularly in the case of multivariate analysis (Ter Braak, 1986).

Ordination: canonical correspondence analysis

The canonical correspondence analysis revealed 58.7% of the total variability of the data on its first 3 axes, with eigenvalues for axes 1, 2 and 3 of 41.6, 10.0 and 7.2, respectively. This relatively low explicability, however, is expected in the ordination analysis of ecological data, confirming the complexity of factors acting in determining the composition of ecosystems (Ter Braak and Prentice, 1988). However, the species-environment correlations for axes 1, 2 and 3 ($r = 0.939$, $r = 0.847$ and $r = 0.780$, respectively) indicated a strong relationship between species distribution and the environmental variables used in the ordination. The Monte Carlo permutation test revealed that sequence axis 1 was statistically significant ($p<0.05$), indicating a high likelihood of not being a result of chance.

With respect to canonical correspondence analysis axis 1 (which explained 41.6% of the variance), the most important environmental variable in the sequence was, in conformity with the intra-set correlation coefficients, ammonia ($r = 0.581$), which correlated with the positive quadrant of axis 1 (Fig. 43), revealing an environmental gradient for this nutrient, which ranged from 33.2 ± 38.8 μg L^{-1} in Winter to 56.7 ± 12.1 μg L^{-1} in the Spring, highlighting that the pH remained relatively acid throughout the year, with an average value of 6.0 ± 0.05 (coefficient of variation=0.8%). The ammonia concentrations observed, however, are relatively low in comparison with those reported by Baumgarten *et al.* (2003), who, working in the Lagoa dos Patos, found that ammonia concentrations ranged from 240 to 300 μg L^{-1} in areas without anthropogenic disturbance. It is of note that values as low as those observed in the present study were reported by Nunes *et al.* (2006) for the Baia dos Coqueiros, in the Pantanal region along the coast of Brazil. Those authors reported the presence of macrophytes and found that the mean 24h ammonia concentration was 33.0 μg L^{-1}, with a pH of 5.4-7.0.

The ammonium ion is recognized as a good marker of recent urban pollution, mainly from domestic sewage (Pereira & Mercante, 2005). Therefore, the low values observed in the present study could be explained by the fact that the lake evaluated is an artificial aquatic environment located within a protected area, the nitrogen content coming from rain, organic/inorganic material of allochthonous origin or fixation of molecular nitrogen within the lake itself. Because the pH of the lake is low (annual average of 6.0 ± 0.05), the ammonia formed is unstable and is converted by hydration to the ammonium ion, which becomes predominant in this

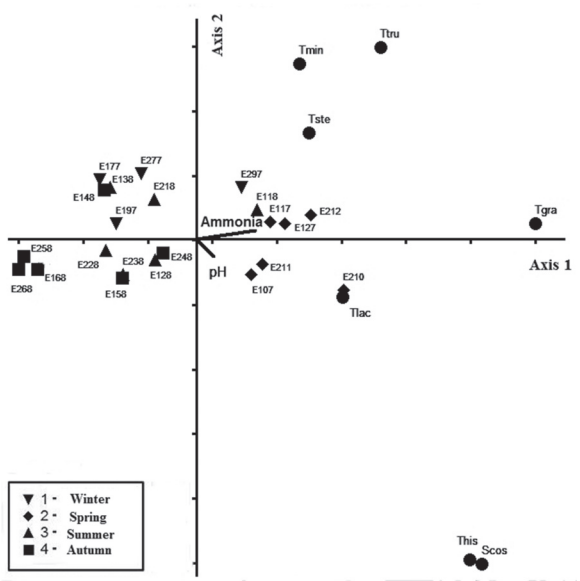


Figure 43. Scatter diagram based on canonical correspondence analysis considering indicator species and the physicochemical matrix of principal dispersion components for the Lago da Ponte, in the state of Rio Grange do Sul, Brazil, collected monthly from July 2007 to June 2008, with seasonality as the categorical variable.
Tste – *Trachelomonas armata* var. *steinii*; Tmin – *T. curta* var. *minima*; Tgra – *T. gracillima*; This – *T. hispida* var. *hispida*; Tlac – *T. lacustris*; Ttru – *T. oblonga* var. *truncata*; Scos – *Strombomonas costata*.

condition (Esteves, 1998; Pereira & Mercante, 2005). We also found that, along the ammonia gradient, there was a clear differentiation of species that comprised the Spring subcluster, which were characterized as indicator species (Fig. 42). There is therefore a high probability of there being species tolerant of low pH (acidic water, pH < 7.0), given that this condition was essential for the prevalence of the ammonium ion in the gradient detected, even at low concentrations, characterizing a natural environment. Alves-da-Silva & Avila (1995) recorded 22 taxa of *Trachelomonas* in shallow lakes of the Zoological Garden and the Botanical Garden in the city of Porto Alegre, and 17 of those taxa were also identified in the present study. Those authors stated that species richness was greatest when the pH was acidic to neutral.

Alves-da-Silva & Torres (1994b), Alves-da-Silva & Bridi (2004) and Alves-da-Silva & Bicudo, (2006) noted that genus *Strombomonas* tolerates a wide range of pH values, occurring in slightly acidic to alkaline waters. In this context, the results of the present study corroborate those obtained by other researchers: *Trachelomonas* and *Strombomonas* achieve their greatest richness in water that is slightly acidic to slightly alkaline. These data increasing the ecological knowledge of this group of algae.

Acknowledgments

This study received financial support from the Brazilian *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq, National Council for Scientific and Technological Development; *Programa Institucional de Bolsas de Iniciação Científica* [PIBIC, Institutional Program for Scientific Initiation Scholarships] Grant no. 101496/2010-9 to JCC). The authors would like to thank Manoel Luis Nunes, chemist in the Cryptogamic Botany Section, at the Museum of Natural Science of the Zoobotanical Foundation of the state of Rio Grande do Sul, for assisting in the sample collection and chemical analyses. We are also grateful to Rejane Rosa for the finished artwork.

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