Nova Hedwigia, Beiheft 136, 181–190 **Article**
Stuttgart, May 2010

Distribution of scaled chrysophytes (Chrysophyceae and Synurophyceae) from the Mesopotamia region of Argentina

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With 3 figures and 3 tables

Abstract: Next to the Amazon, the Mesopotamia region of Argentina is a component of the second largest drainage basin in South America. It is an area of high biodiversity and contains important wetlands for migratory birds. The primary purpose of this study was to expand our knowledge of the scaled chrysophyte flora of Mesopotamia and to begin to investigate whether differences exist between specific subregions. Including this study, 42 scaled chrysophyte taxa have now been documented for Mesotopamia using electron microscopy, including several with known tropical affinities. A preliminary analysis identified five groups of sites each containing discernible scaled chrysophyte flora. Some of the groups contained only sites from specific regions of Mesopotamia and may represent geographic separation of this flora. Further work is needed to fully understand the relative importance of such variables as spatial separation, water chemistry and habitat type in determining the distribution of scaled chrysophytes in this region of South America.

Key words: Mesopotamia, Argentina, scaled chrysophytes, biodiversity, biogeography

Introduction

The Mesopotamia region of Argentina is located in the northeast section of the country, bordered to the north by Paraguay and to the east by Brazil and Uruguay. The region belongs to the Paraná and Uruguay River basins, which forms the second largest drainage basin in terms of area and volume in South America, after the Amazon River basin (Bonetto & Hurtado 1998). It is composed of three political provinces, Misiones, Corrientes and Entre Ríos, bounded by the Iguazú River to the north, the Paraná River to the west and the Uruguay River to the east. The Paraná River flows south through the delta within the Río de la Plata. The Mesopotamia encompasses subtropical to temperate areas, and because the numerous wetlands form an important refuge for numerous plants and animals it is an important center of biodiversity with a high concentration of wildlife (Neiff & Malvárez 2002). Despite its importance, little is known about the algal flora.

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DOI: 10.1127/1438-9134/2010/0136-0181 1438-9134/2010/0136–0181 $ 2.50

Parts of the Mesopotamia have previously been examined for silica scaled chrysophytes (Chrysophyceae and Synurophyceae), including a northern portion of the Uruguay River region (Vigna 1990), the Paraná River region (Siver & Vigna 1996, 1997) and the Iberá region (Vigna & Siver 2003). In the present study, we continue our effort to document the diversity of scaled chrysophytes in Mesopotamia by adding sites from the median portion of the Uruguay River region, considered one of the more important wetland regions in Mesopotamia (Bonetto & Hurtado 1998). The objectives of this study are to: 1) document scaled chrysophytes found in the Uruguay River region, 2) provide an up-to-date summary of all species of scaled chrysophytes known from Mesopotamia and, 3) provide a preliminary analysis of biogeographical patterns for these organisms.

Materials and methods

Phytoplankton samples in the median Uruguay River region (URG1, Entre Ríos Province) (Fig. 1) were taken during austral spring (November 2002) using a 20 µm mesh plankton net. Half of each

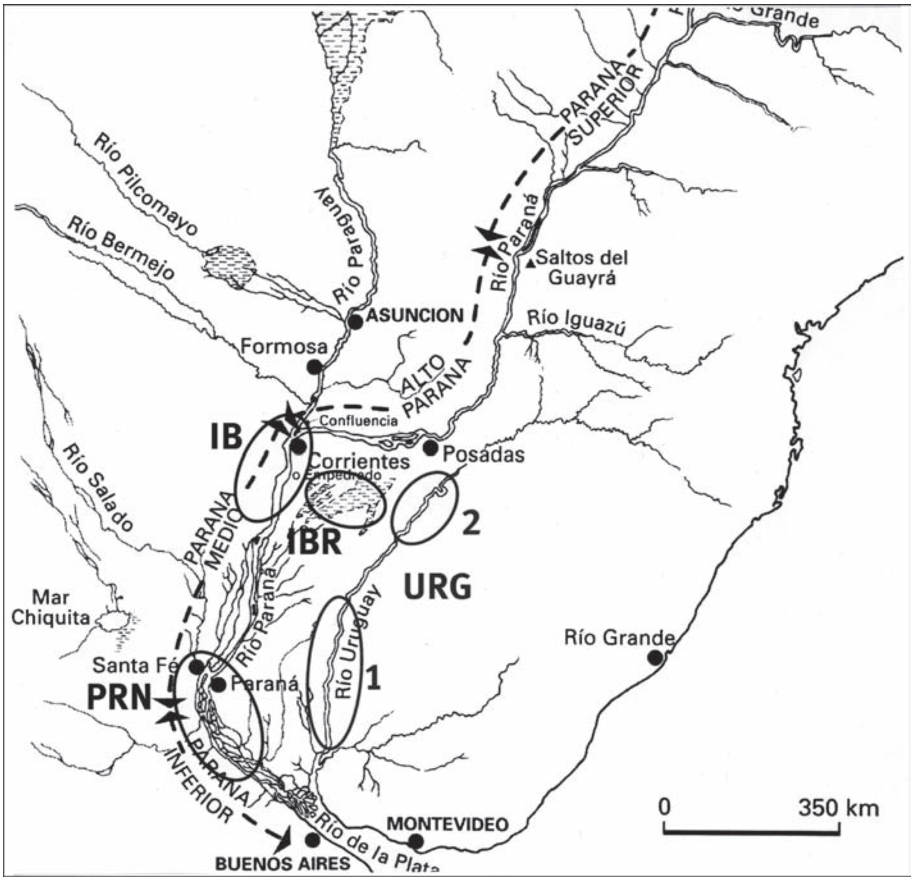


Fig. 1. Map showing locations of the sampling areas. IB and IBR represent the Iberá wetland regions, PRN the Paraná River region, URG1 the Entre Ríos Province of the Uruguay River, and URG2 the Corrientes Province of the Uruguay River.

sample was fixed with Lugol's solution and the other half kept alive for further observations with light microscopy (LM). Aliquots of each fixed sample were treated for observations with scanning and transmission electron microscopy according to the methods of Siver & Vigna (1996).

In brief, specimens were mounted on aluminum foil for observations with scanning electron microscopy (SEM) and on coated 200 mesh copper grids for observations with transmission electron microscopy (TEM). Samples were observed with a Phillips 515 SEM (Museo Argentino de Ciencias Naturales Bernardino Rivadavia, Buenos Aires) and a Jeol 1200 EXII TEM (National Institute of Agropecuary Technology, Buenos Aires). Water temperature, specific conductivity and pH were measured in the field at the time of collection with Hanna instruments.

A matrix of taxa vs. sites was developed that included results from the newly investigated sites, as well as from previous research carried on in the Paraná River area (PRN) (Siver & Vigna 1996, 1997), the Iberá wetland region (IB and IBR) (Vigna & Siver 2003), and the Uruguay River region (URG2, Corrientes Province) (Vigna 1990) (Fig. 1). The matrix contained 46 sites and 39 taxa. A cluster analysis was performed based on the presence (score = 1) or absence (score = 0) of taxa, with the aim of recognizing and defining sample groups (sites) based on taxonomic composition. For the cluster analysis Sørensen´s coefficient (Krebs 1989) and UPGMA, unweighted pair-group average (Romesburg 1984) was used. The cluster analysis was done using MVSP program version 3.1.

Results

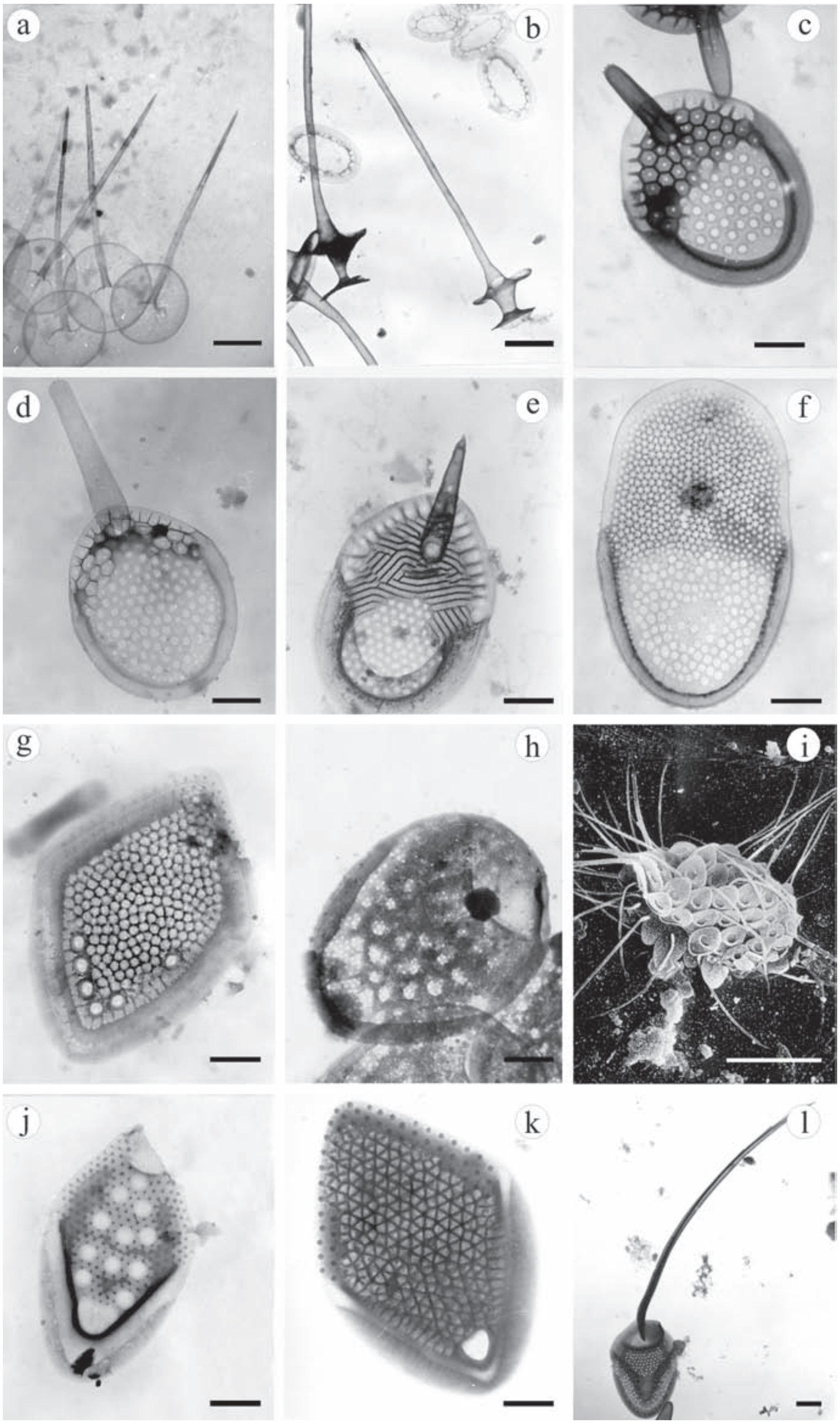
The scaled chrysophyte flora

The eight waterbodies sampled within the URG1 ranged in pH and specific conductivity from 5.5 to 7.3 and 37 to 617 µS cm $^{-1}$, respectively (Table 1).

Table 1. Physical and chemical data of the investigated localities.

Locality	Sampling Day	Temp. (°C)	pH	Conductivity (µS cm^{-1})
Perugio Verna creek	08/11/02	9,3	7,3	563
Carballo creek	08/11/02	12,7	6	420
Sarandí creek	08/11/02	21,2	6	530
Los Loros creek	09/11/02	20,7	6	290
Pozo Cantera-Palmar lagoon	09/11/02	17	6	617
Boyero lagoon	09/11/02	24	5,5	51
El Palmar creek	09/11/02	24	5,5	103
El Bañadero lagoon	10/11/02	21	5,5	37

The dominant phytoplankton species present in the eight waterbodies from the Uruguay River Region were largely representatives of the Zygnematales (Chlorophyta) and the euglenoids (Euglenophyta). The scaled chrysophytes were less important, with representatives found only in three of the sites, Perugio Verna Creek, Boyero Lagoon and El Palmar Creek. A total of 21 taxa of scaled chrysophytes representing four genera were recorded from the three waterbodies (Table 2; Fig. 2), including three new records for the Mesopotamia region, *Chrysodidymus synuroideus*, *Synura mammillosa* and *M. corymbosa* var. *corymbosa*. Boyero Lagoon had the highest number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of scaled chrysophyte taxa with 13, followed by Perugio Verna Creek and El Palmar Creek with 8 and 7 species, respectively. As is commonly observed, the most speciose genus was *Mallomonas* (Table 2).

Table 2. Scaled chrysophytes recorded from three sites from the Uruguay River Region (URG1).

Taxa	Perugio Verna	Boyero	El Palmar
Paraphysomonas vestita (Stokes) De Saedeleer		X	
Chrysodidymus synuroideus Prowse		X	
Synura curtispina f. *curtispina* (Petersen et Hansen) Asmund		X	
S. echinulata Korshikov f. *echinulata*		X	X
S. echinulata f. *leptorrhabda* Asmund		X	
S. mammillosa Takahashi		X	
S. petersenii f. *kufferathii* Petersen et Hansen		X	
S. spinosa f. *longispina* Petersen et Hansen	X		
Mallomonas akrokomos Ruttner in Pasher			X
M. caudata Ivanov emend. Krieger			X
M. corymbosa Asmund et Hillard var. *corymbosa*			X
M. cristata Dürrschmidt		X	
M. cyathellata Wujek et Asmund		X	
M. guttata Wujek	X		
M. mangofera Harris et Bradley f. *foveata* Dürrschmidt	X	X	
M. mangofera f. *reticulata* Cronberg	X	X	
M. matvienkoae (Matvienko) Asmund et Kristiansen var. *matvienkoae*	X		X
M. matvienkoae var. *grandis* Dürrschmidt et Cronberg	X	X	
M. portae-ferrae var. *reticulata* Gretz, Sommerfeld et Wujek			X
M. striata Asmund	X	X	
M. tonsurata Teiling emend. Krieger	X		X

Including results from the URG1 region, 42 taxa of scaled chrysophytes have now been documented from the Mesopotamia, including 27 from the Uruguay River region (including both the Entre Ríos Province (URG1) and the Corrientes Province (URG2)), 13 from the Iberá system (IB), 15 from the Iberá lagoon and vegetated ponds or "esteros" (IBR), and 30 from the Paraná River region (PRN) (Table 3).

Fig. 2. Chrysophyte scales of Mesopotamia region. All bars = 1 µm except fig. h where the bar = 10 µm. a) *Paraphysomonas vestita*. b) *Chrysosphaerella brevispina*. c) *Synura curtispina* f. *curtispina*. d) *Synura spinosa* f. *longispina*. e) *Synura echinulata* f. *echinulata*. f) *Mallomonas matvienkoae* var. *grandis*. g) *Mallomonas mangofera* f. *foveata*. h) *Mallomonas heterospina*. i) *Mallomonas peronoides* j) *Mallomonas guttata*. k) *Mallomonas mangofera* f. *reticulata*. l) *Mallomonas cristata*.

Table 3. A summary of the scaled chrysophyte taxa now known from the Mesopotamia region of Argentina, including the Uruguay River region (URG1 and URG2), Iberá region (IBR and IB) and Paraná River region (PRN).

Taxa	URG 1&2 (4 sites)	IBR (5 sites)	IB (4 sites)	PRN (33 sites)
CHRYSOPHYCEAE				
PARAPHYSOMONADACEAE				
Chrysosphaerella brevispina Korshikov	–	4	–	1
C. coronacircumspina Wujek et Kristiansen	–	–	–	1
Paraphysomonas undulata Presig et Hibberd	–	–	–	2
P. vestita (Stokes) De Saedeleer	2	3	2	21
Spiniferomonas spp. Takahashi	–	1	–	6
SYNUROPHYCEAE				
SYNURACEAE				
Chrysodidimus synuroides Prowse	1	–	–	–
Synura australiensis Playfair	–	–	–	2
S. curtispina (Petersen et Hansen) Asmund	2	1	2	24
S. echinulata Korshikov f. *echinulata*	3	–	4	8
S. echinulata f. *leptorrhabda* Asmund	1	–	–	5
S. mammillosa Takahashi	1	–	–	–
S. petersenii f. *kufferathii* (Korshikov) Petersen et Hansen	1	–	2	9
S. petersenii Korsikov f. *petersenii*	1	3	2	17
S. sphagnicola Korshikov	–	3	1	–
S. spinosa f. *longispina* Petersen et Hansen	1	4	2	–
S. uvella Stein emend Korshikov	1	3	1	2
MALLOMONADACEAE				
Mallomonas akrokomos Ruttner in Pasher	1	–	–	2
M. alpina Pasher et Ruttner	–	–	1	14
M. bronchartiana Compére	1	–	–	–
M. caudata Ivanov emend Krieger	2	–	–	5
M. corymbosa Asmund et Hillard var. *corymbosa*	1	–	–	–
M. crassisquama (Asmund) Fott	–	3	1	–
M. cristata Dürrschmidt	1	3	2	1
M. cyathellata Wujek et Asmund	1	–	–	6
M. elongata Reverdin	1	–	–	–
M. guttata Wujek	1	2	–	2
M. heterospina Lund	–	3	–	3
M. lelymene Harris et Bradley	1	–	–	–
M. lychenensis Conrad	–	–	–	1
M. mangofera Harris et Bradley	2	–	–	7
M. matvienkoae var. *grandis* Dürrschmidt et Cronberg	2	–	1	11
M. matvienkoae var. *matvienkoae* (Mat.) Asmund et Kristiansen	2	–	–	1
M. paludosa Fott	1	–	–	–

Taxa	URG 1&2 (4 sites)	IBR (5 sites)	IB (4 sites)	PRN (33 sites)
M. papillosa Harris et Bradley	–	–	–	1
M. peronoides (Harris) Momeu et Péterfi	–	–	–	4
M. portae-ferrae var. *portae-ferrae* Péterfi et Asmund	–	–	–	4
M. portae-ferrae var. *reticulata* Gretz, Sommerfeld et Wujek	1	–	–	2
M. pumilio Harris et Bradley emend Asmund, Cronberg et Dürrschmidt	–	–	–	3
M. punctifera var. *brasiliensis* Kristiansen et Menezes	1	5	–	–
M. striata Asmund	3	–	2	10
M. tonsurata Teiling em. Krieger	3	5	–	2
UNCERTAIN TAXONOMICAL POSITION				
Gyromitus disomatus Skuja	–	3	–	–
TOTAL NUMBER	27	15	13	30

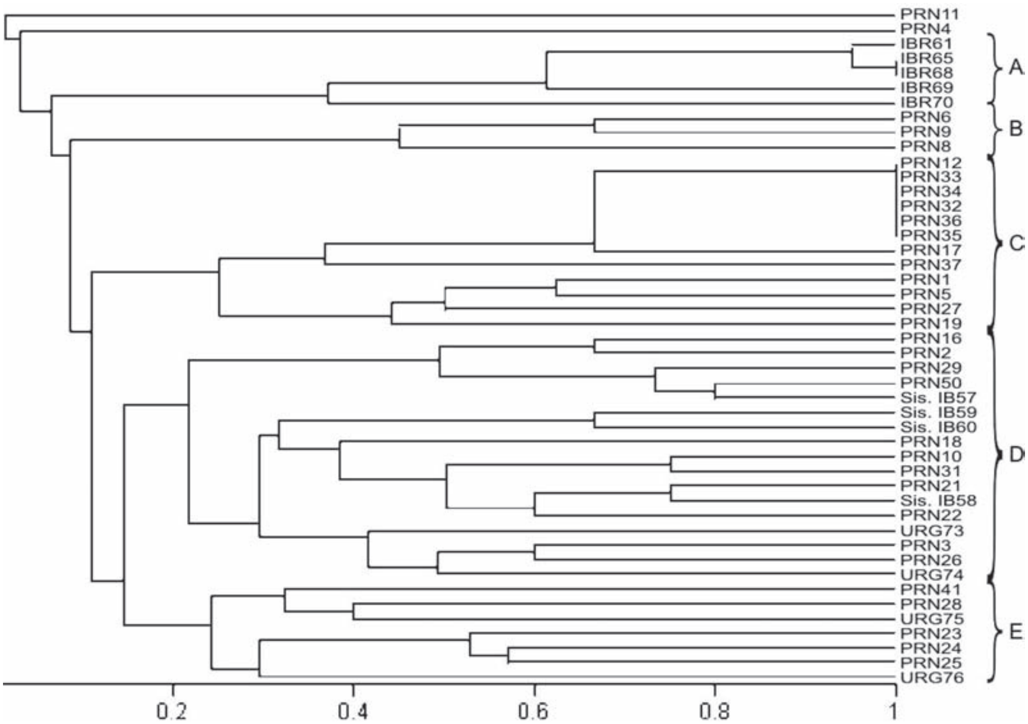

Fig. 3. Dendrogram showing clustering of sites based on species composition. Five groups of sites, A–E were detected based on 20 % similarity. See text for details.

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Paraphysomonas vestita, *Synura curtispina* and *Synura petersenii* f. *petersenii* were the most common and widespread species within the Mesopotamia region, found in all study areas and in 50 % or more of the collections (Table 3). Two additional species, *Synura uvella* and *Mallomonas cristata*, were also observed in all study regions, but in far fewer of the sites (Table 3).

Some of the species were recorded only in one area. *Chrysodidymus synuroideus, Synura mammillosa* and *M. corymbosa* var. *corymbosa* were all rare, but only found in URG1 with the first two species observed in Boyero Lagoon and *M. corymbosa* var. *corymbosa* recorded in El Palmar creek (Table 2). *Mallomonas bronchartiana, M. lelymene* and *M. paludosa* have only been recorded in the URG2 portion of the Uruguay River area (Vigna 1990). Eight species, *Chrysosphaerella coronacircumspina, Paraphysomonas undulata, Synura australiensis, Mallomonas lychenensis, M. papillosa, M. peronoides, M. portae-ferreae* and *M. pumilio*, were observed in the Paraná River region (PRN) by Siver & Vigna (1997), but were absent from the Uruguay River (Vigna 1990) and Iberá regions. Lastly, *Mallomonas crassisquama* and *Gyromitus disomatus* are only known from the Iberá region (Vigna & Siver 2003).

Preliminary analysis of the biogeography within the Mesopotamia region

As part of this study, we were interested to see if there were any distinct distributional patterns of scaled chrysophyte taxa. We used cluster analysis based on Sorensen's coefficient in an attempt to identify any potential patterns. We recognize that there are limitations with this analysis, including differences due to sample sizes, low numbers of taxa in some sites, seasonality effects, and we further understand that the use of plankton nets could bias the relative abundances of species. As a result, we used a presence/absence measure for these analyses. Even with these limitations, given the ecological importance of the Mesopotamia region, we felt a preliminary investigation of biogeographic patterns was warranted and could aid the direction of future studies of freshwater ecosystems in the region.

We performed a cluster analysis using all species, and also one where we left out the three most common and widespread taxa, *Paraphysomonas vestita*, *Synura curtispina* and *Synura petersenii* f. *petersenii*. The analysis without these three widespread species resulted in more well defined groups and is presented here (Fig. 3). At 20 % similarity, five distinct groups were identified, and are denoted here as A–E (Fig. 3). In addition, sites PRN11 and PRN4 were outliers. In general, groups A and B were more similar to each other, as were groups C, D and E. Group A includes 5 sites all from the Iberá region, with a mean of 8.3 species per site and characterized mostly by *M. tonsurata*, *M. punctifera* var. *brasiliensis*, *Chrysosphaerella brevispina*, *M. crassisquama, S. spinosa* f. *longispina*, *S. uvella*, *M. heterospina*, *S. sphagnicola*, *Gyromitus disomatus* and *M. cristata*.

Group B contains three sites all from the Paraná River region and is characterized primarily by the presence of *M. portae-ferrae* var. *portae-ferreae*. However, it should be noted that sites representing Group B had a low total number of species. Group C contains 12 sites also from the Paraná River region and all containing *M. alpina*. Six sites had very low species richness and were dominated with by *M. alpina*. The other six sites in Group C had a higher species richness and contained *M. peronoides*, *M. mangofera* and *Spiniferomonas* spp., in addition to *M. alpina*. The presence of either *M. portae-ferrae* var. *portae-ferreae* or *M. alpina* is a primary means of separating between Groups B and C.

Groups D and E contained a total of 24 sites, including the four sites from the Uruguay River region, numerous sites from the Paraná River region and the remainder of sites from the Iberá region. The average number of species in Groups D and E are 3.6 and 7.4, respectively. More specifically, Group D includes 11 sites from the Paraná River region (PRN), 4 from the Iberá System and 2 from the Uruguay River region, and is characterized largely by the presence of *M. matvienkoae* var. *grandis*, *S. petersenii* f. *kufferathii* and *M. striata*. Group E contains 5 sites from the Paraná River region and 2 from the Uruguay River region, and is characterized primarily by the presence of *M. caudata* and *M. tonsurata*. However, neither of these taxa is exclusive of this group.

Discussion

Including the new sites added in the present work, 42 taxa of scaled chrysophytes are now known from the Mesopotamia region of Argentina. The most abundant and widespread organisms include *Synura curtispina*, *Paraphysomonas vestita* and *S. petersenii* f. *petersenii*. In addition, *S. echinulata* f. *echinulata*, *M. striata*, *M. alpina* and *M. matvienkoae* var. *grandis* are also common components of the flora, each having been found in at least 14 sites. Except for *M. matvienkoae* var. *grandis*, which is known to have a distinct tropical distribution, all of these species are cosmopolitan (Kristiansen 2002). Other common elements of the Mesopotamia flora often associated with tropical regions included *M. bronchartiana*, *M. guttata*, *M. mangofera*, *M. peronoides*, *M. portae-ferrae* var. *reticulata* and *S. australiensis* (Cronberg 1989, Kristiansen & Menezes 1998, Vigna & Duque Escobar 1999).

Albeit preliminary, the cluster analysis clearly indicated associations of waterbodies harboring similar scaled chrysophyte species. Many of the sites from a given region clustered together, indicating that specific distributional patterns probably exist within the Mesopotamia region of Argentina. For example, all sites forming Group A were from the Iberá region, while those forming Groups B and C represented different areas of the Paraná River region. Sites from Group A represent lentic systems that are slightly acidic (pH 6–6.3) and very dilute with conductivity values all below 20 $\mu S\ cm^{-1}$ (Vigna & Siver 2003). On the other hand, Groups D and E combined sites from different regions and may be the result of specific chemical and physical characteristics. Further work is needed to more precisely define geographic differences in the floras between subregions of Mesopotamia and to more fully differentiate between actual geographic differences and other variables such as chemical condition and habitat type (e. g. river vs. lake vs. wetland). Our preliminary analysis should help to frame future studies of the freshwater ecosystems of the Mesopotamia.

As noted herein, the Mesopotamia region harbors some scaled chrysophytes known mostly from tropical regions. It is also interesting that Mesopotamia is a region with a great activity of aquatic migratory birds. The migratory birds could be important agents in the dispersion of chrysophyte algae (Wee et al. 1993). The wetlands of this region serve as an important component of the fly zone for aquatic birds, such as *Egretta alba*, *Amazonetta brasiliensis* and *Plegadis chichi* (Capllonch 2004), that migrate in a north to south pattern. The importance of migratory waterfowl as a vector in distributing freshwater algae remains an understudied area of inquiry.

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