

Micro-phytoplankton richness in Contas River, state of Bahia, northeastern Brazil

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ABSTRACT: Phytoplankton composition in lotic environments has received less attention than that of lentic environments. The aim of the present study was to describe the micro-phytoplankton of the Contas River, which is one of the five most important water bodies in the state of Bahia, Brazil. Collections were carried out at 28 sampling sites at three-month intervals over a three-year period between December 2007 and September 2010. The micro-phytoplankton community was represented by 198 taxa distributed among Bacillariophyceae, Coscinodiscophyceae, Cyanophyceae, Fragilariophyceae, Chlorophyceae, Euglenophyceae, Dinophyceae, Cryptophyceae, Chrysophyceae and Xantophyceae. *Geitlerinema amphibium* (C. Agardh) Anagnostidis, *Planktothrix agardhii* (Gom.) Anagnostidis and Komárek, *Pleurosira laevis* (Ehrenberg) Compère and *Ulnaria ulna* (Nitzsch) P. Compère occurred in all samples. The majority of species (n = 111; 56.06% of the taxa) were classified as rare in the Contas River, as these organisms were only recorded during one or two months.

INTRODUCTION

Rivers are complex ecosystems with characteristics that pose particular challenges to organisms, as the habitats are subject to constant change due to high current flow (Rodrigues *et al.* 2007). Phytoplankton in lotic environments has received less attention than that of lentic environments, especially in Brazil (Silva *et al.* 2001; Soares *et al.* 2007). According to Rodrigues *et al.* (2007), knowledge on the biodiversity of phytoplankton in rivers is of extreme importance for the monitoring of water quality, as these systems are increasingly affected by anthropogenic impacts, the most frequent alterations of which are changes in the shape of river channels and water flow due to the construction of dams and multiple-use reservoirs (Maddock 1999).

The study of phytoplankton composition provides information for the characterization of aquatic ecosystems (Pompêo *et al.* 1998). Phytoplankton is mostly made up of autotrophic, solitary or colonial organisms, such as cyanobacteria and a large number of eukaryotic algae. These organisms constitute the first and quantitatively most important link in the food chain, representing the main source of oxygen and energy for other trophic levels of the aquatic environment.

In order to contribute toward a better understanding of the phytoplankton structure in lotic environments, especially rivers with dams, the aim of the present study was to describe the micro-phytoplankton of the Contas River, which is one of the five most important water bodies in the state of Bahia, Brazil.

MATERIALS AND METHODS

Study area

The Contas River in the state of Bahia, Brazil, has a

hydrographic basin with an area of 53,000 km² and is just over 500 km in length. The spring of this river is located on the eastern slope of the Serra das Almas in the mountainous geological formation known as the Chapada Diamantina and the river empties into the Atlantic Ocean in the city of Itacaré (CHESF 2011) (Figure 1). The predominant climate is warm, with a mean annual temperature above 18° (SEI 1998). The rainy season is in the summer (November to January) and the dry season is in winter (June to August).

Sampling and data analysis

Collections were carried out at 28 sampling sites at three-month intervals over a three-year period from December 2007 to September 2010. Integrated samples were obtained with plankton nets (mesh: 25 µm) throughout the euphotic zone, which was determined by a digital quantameter (Licor-250). The volumes filtered were calculated by the equation $V = A \times D$, where A is the area (m²) of the mouth of the net and D is the depth (m) of the drag. The material was preserved in acetic Lugol solution (4%) and subsequently analyzed under an optical microscope and photodocumented with the aid of a microscope (Zeiss/Axioskop) equipped with a photography camera (Samsung SCC833, Japan). Image processing was performed with the Imagemlab program (Softium, Brazil). After the taxonomic analysis and photomicrographs, samples were deposited in the Herbarium Professor Vasconcelos Sobrinho, Federal Rural University of Pernambuco (PEURF 50995 to 51326).

The classification system proposed by Van den Hoek *et al.* (1997) was used for the classes Cryptophyceae, Dinophyceae, Chrysophyceae, Euglenophyceae and Chlorophyceae. The system proposed by Round *et al.* (1990) was used for Coscinodiscophyceae, Fragilariophyceae and Bacillariophyceae and the system

proposed by Komárek and Anagnostidis (2000; 2005) was used for Cyanophyceae.

The frequency of occurrence of the taxa was calculated based on the method described by Matteucci and Colma (1982), considering the number of samples in which a given taxon occurred in relation to the total number of samples collected. For this, the following categories were used: very frequent (VF) - $> 70\%$; frequent (F) - $\leq 70\% | - > 40\%$; infrequent (I) - $\leq 40\% | - > 10\%$; sporadic or rare (S) - $< 10\%$.

RESULTS AND DISCUSSION

The micro-phytoplankton of the Contas River was represented by 198 taxa: 34 Cyanophyceae, 15 Coscinodiscophyceae, 7 Fragilariophyceae, 37 Bacillariophyceae, 80 Chlorophyceae, 14 Euglenophyceae, 3 Dinophyceae, 4 Cryptophyceae, 3 Chrysophyceae and 1 Xantophyceae (Table 1). This high degree of diversity was likely due to the high degree of habitat heterogeneity in the ecosystem studied, with some regions exhibiting characteristics of lentic environments and other stretches exhibiting characteristics of lotic environments, which is common in dammed rivers. Fuentes *et al.* (2010) also reported the presence of aquatic macrophytes in some stretches as one of the factors that contribute toward the increase in diversity in the Contas River. These macrophytes provide substrate for epiphytic algae, which can move to the pelagic region of the river due to perturbation in the hydrological levels.

A large number of the taxa have also been recorded in other rivers in Brazil. In the rivers of the Upper Paraná River floodplain, Rodrigues *et al.* (2009) identified 177 taxa in the Paraná River, 288 in the Baía River and 277 in the Ivinhema River. Ferrareze and Nogueira (2006) found a total of 205 taxa in the Paranapanema River in the state of São Paulo. In these studies, the classes Bacillariophyceae and Chlorophyceae were also predominant, demonstrating

the importance of these groups in aquatic ecosystems in Brazil.

In the Boa Esperança reservoir situated between Maranhão and Piauí, Pompêo *et al.* (1998) interpreted the presence of Bacillariophyceae as being a function of the habitat. In this study, diatoms dominated sites with lotic characteristics. Chlorophytes commonly exhibit a high degree of richness in aquatic systems in Brazil, especially Zygnematales (desmids) in south and southeast (Padisák *et al.* 2000; Bittencourt-Oliveira and Moura 2001; Soares *et al.* 2007). In northeastern Brazil, Chlorococcales generally stand out in terms of floristic representativity, as reported by Bouvy *et al.* (1999; 2000) in the state of Pernambuco as well as by Barbosa and Mendes (2005) in the state of Paraíba. This order also stood out in the Contas River.

Regarding frequency of occurrence, only the species *Geitlerinema amphibium* (C. Agardh) Anagn., *Planktothrix agardhii* (Gom.) Anagn. and Komárek, *Pleurosira laevis* (Ehrenberg) Compère and *Ulnaria ulna* (Nitzsch) P. Compère occurred at all sampling sites. Another 16 species were also considered very frequent: the cyanobacteria *Cylindrospermopsis raciborskii* (Woloszynska) Seenaya and Subba Raju and *Oscillatoria* sp.; the diatoms *Aulacoseira granulata* (Ehrenberg) Simonsen, *Cyclotella meneghiniana* Kützing, *Fragilaria crotonensis* Kitton, *Melosira varians* C. Agardh and *Pinnularia* sp.; the chlorophytes *Coccoloba reticulatum* (P.A. Dangeard) Senn, *Closterium* sp., *Radiococcus planktonicus* J.W.G. Lund, *Sphaerocystis schroeteri* Chodat, *Planktosphaeria gelatinosa* G.M. Smith, *Scenedesmus quadricauda* (Turp.) Bréb. ex Ralfs and *Spirogyra* sp.; the cryptophyte *Cryptomonas ovate* Ehrenberg; and the euglenophyte *Trachelomonas volvocina* Ehrenberg. The majority of species ($n = 111$; 56.06% of the taxa) were classified as rare in the Contas River, as these organisms were only recorded during one or two months.

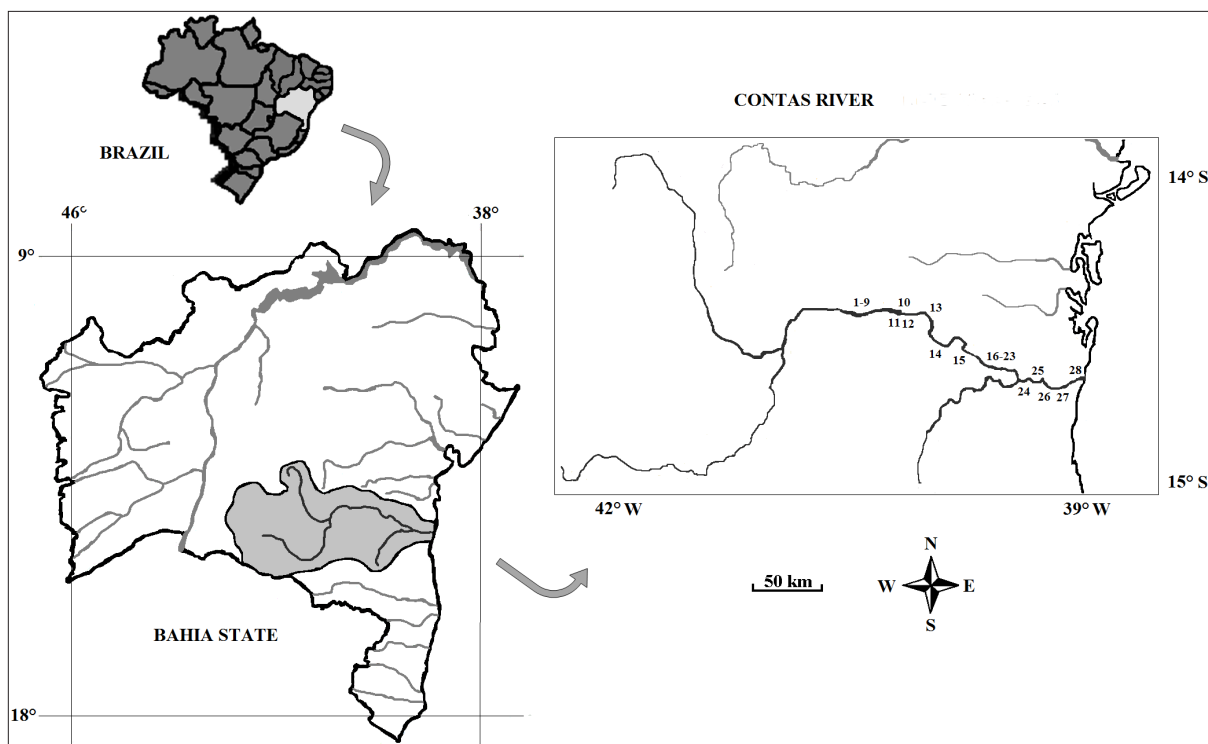


FIGURE 1. Location of Contas River and the sampling sites in the state of Bahia.

TABLE 1. Taxa identified in Contas River, Bahia, Brazil, between December 2007 and September 2010; FO = frequency of occurrence; VF = very frequent; F = frequent; I = infrequent; S = sporadic or rare.

TAXA	FO
Class Cyanophyceae	
Order Chroococcales	
Family Chroococaceae	
<i>Aphanocapsa elachista</i> W. West and G.S. West	I
<i>Aphanocapsa</i> sp.	I
<i>Aphanothece</i> sp.	S
<i>Chroococcus minutus</i> (Kützing) Nägeli	I
<i>Chroococcus turgidus</i> (Kützing) Nägeli	S
<i>Chroococcus</i> sp.	S
<i>Merismopedia glauca</i> (Ehrenberg) Kützing	S
<i>Merismopedia tenuissima</i> Lemmermann	S
<i>Microcystis aeruginosa</i> (Kützing) Kützing	I
<i>Microcystis panniformis</i> J.Komárek, J.Komárková-Legnerová, C.L.Sant'anna, M.T.P.Azevedo and P.A.C.Senna	S
<i>Microcystis wesenbergii</i> (Komárek) Komárek	I
<i>Microcystis</i> sp.	I
Order Nostocales	
Family Nostocaceae	
<i>Anabaena circinalis</i> Rabenhorst	I
<i>Anabaena constricta</i> (Szafer) Geitler	F
<i>Anabaena</i> sp.	F
<i>Aphanizomenon</i> sp.	S
<i>Cylindrospermopsis raciborskii</i> (Woloszynska) Seenaya and Subba Raju	VF
<i>Raphidiopsis mediterranea</i> Skuja	I
Order Oscillatoriales	
Family Oscillatoriaceae	
<i>Lyngbya majuscula</i> (Dillwyn) Harvey	S
<i>Lyngbya</i> sp.	F
<i>Oscillatoria limnetica</i> Lemmermann	S
<i>Oscillatoria princeps</i> Vaucher ex Gomont	I
<i>Oscillatoria sancta</i> Kützing ex Gomont	S
<i>Oscillatoria</i> sp.	VF
Family Phormidiaceae	
<i>Phormidium</i> sp.	S
<i>Planktothrix agardhii</i> (Gom.) Anagn. and Komárek	VF
Family Pseudanabaenaceae	
<i>Geitlerinema amphibium</i> (C. Agardh) Anagn.	VF
<i>Geitlerinema splendidum</i> (Greville) Anagnostidis	F
<i>Geitlerinema</i> sp.	S
<i>Pseudanabaena catenata</i> Lauterborn	I
<i>Pseudanabaena galeata</i> Böcher	S
<i>Pseudanabaena limnetica</i> (Lemm.) Komárek	F
<i>Pseudanabaena</i> sp.	I
<i>Spirulina</i> sp.	S
Class Coscinodiscophyceae	
Order Coscinodiscales	
Family Coscinodiscaceae	
<i>Coscinodiscus</i> sp.	I
Order Rhizosoleniales	
Family Rhizosoleniaceae	
<i>Urosolenia longiseta</i> (Zacharias) Bukhtiyarova	S
Order Thalassiosirales	
Family Thalassiosiraceae	
<i>Thalassiosira</i> sp.	S
Family Stephanodiscaceae	
<i>Cyclotella meneghiniana</i> Kützing	VF
<i>Cyclotella stelligera</i> Cleve and Grunow	S
Order Melosirales	
Family Melosiraceae	
<i>Melosira varians</i> C. Agardh	VF
<i>Melosira</i> sp.	I
Order Aulacoseirales	
Family Aulacoseiraceae	
<i>Aulacoseira ambigua</i> (Grunow) Simonsen	I
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen	VF
<i>Aulacoseira granulata</i> var. <i>angustissima</i> (O.F. Müller) Simonsen	I
Order Triceratiales	
Family Triceratiaceae	
<i>Pleurosira laevis</i> (Ehrenberg) Compère	VF
<i>Pleurosira</i> sp.	S
Order Biddulphiales	
Family Biddulphiaceae	
<i>Terpsinoe americana</i> (Bailey) Grunow	S
<i>Terpsinoe musica</i> Ehrenberg	F
<i>Terpsinoe</i> sp.	S
Class Fragilariophyceae	
Order Fragilariales	
Family Fragilariaceae	
<i>Asterionella</i> sp.	I
<i>Fragilaria capucina</i> Desmazières	S
<i>Fragilaria crotonensis</i> Kitton	VF
<i>Fragilaria javanica</i> F. Hustedt	S
<i>Fragilaria</i> sp.	F
<i>Synedra rumpens</i> Kützing	F
<i>Ulnaria ulna</i> (Nitzsch) P. Compère	VF
Class Bacillariophyceae	
Order Eunotiales	
Family Eunotiaceae	
<i>Eunotia flexuosa</i> (Brébisson) Kützing	S
<i>Eunotia</i> sp.	I
Order Rhopalodiales	
Family Rhopalodiaceae	
<i>Epithemia sorex</i> Kützing	I
<i>Epithemia turgida</i> (Ehrenberg) Kützing	S
<i>Epithemia</i> sp.	I
<i>Rhopalodia gibba</i> (Ehrenberg) O.F. Müller	I
Order Naviculales	
Family Diploneidaceae	
<i>Diploneis</i> sp.	I
Family Stauroneidaceae	
<i>Stauroneis phoenicenteron</i> (Nitzsch) Ehrenberg	I
<i>Stauroneis</i> sp.	S
Family Pinnulariaceae	
<i>Pinnularia gibba</i> Ehrenberg	S
<i>Pinnularia maior</i> (Kützing) Cleve	S
<i>Pinnularia</i> sp.	VF
Family Amphipleuraceae	
<i>Amphipleura pellucida</i> (Kützing) Kützing	I
<i>Frustulia rhomboides</i> (Ehrenberg) De Toni	I
Family Naviculaceae	
<i>Navicula disparalis</i> Hustedt	I
<i>Navicula</i> sp.	F
<i>Navicula</i> sp. 2	S
Family Pleurosigmaaceae	
<i>Gyrosigma spenceri</i> (W. Smith) Grif. and Henfrey	I
<i>Gyrosigma</i> sp.	F

TABLE 1. CONTINUED.

TAXA	FO		
<i>Pleurosigma</i> sp.	S		
Order Achnanthes			
Family Achnantheaceae			
<i>Achnanthes exigua</i> Grunow	S		
Family Cocconeidaceae			
<i>Cocconeis plancetula</i> Ehrenberg	F		
<i>Cocconeis</i> sp.	I		
Order Cymbellales			
Family Cymbellaceae			
<i>Achnanthes exigua</i> Grunow	S		
<i>Encyonema selesiaticum</i> (Bleisch) D.G. Mann	I		
<i>Placoneis</i> sp.	S		
Family Gomphonemataceae			
<i>Gomphonema acuminatum</i> Ehrenberg	S		
<i>Gomphonema gracile</i> Ehrenberg	I		
<i>Gomphonema parvulum</i> (Kützing) Grunow	F		
<i>Gomphonema truncatum</i> Ehrenberg	S		
Order Bacillariales			
Family Bacillariaceae			
<i>Nitzschia palea</i> (Kützing) W. Smith	I		
<i>Nitzschia</i> sp.	F		
<i>Tryblionella coarctata</i> (Grunow) D.G. Mann	S		
<i>Tryblionella victoriae</i> Grunow	I		
Order Surirellales			
Family Surirellaceae			
<i>Surirella biseriata</i> Brébisson	S		
<i>Surirella linearis</i> W. Smith	I		
<i>Surirella robusta</i> Ehrenberg	F		
<i>Surirella</i> sp.	I		
Class Chlorophyceae			
Order Chlorococcales			
Family Radiococcaceae			
<i>Radiococcus planktonicus</i> J.W.G. Lund	VF		
Family Hydrodictyaceae			
<i>Pediastrum duplex</i> Meyen	F		
<i>Pediastrum simplex</i> Meyen	I		
<i>Pediastrum tetras</i> (Ehrenberg) Ralfs	S		
Family Oocystaceae			
<i>Eremosphaera eremosphaeria</i> R.L. Smith and Bold	S		
<i>Dactylococcus infusionum</i> Nägeli	S		
<i>Oocystis elliptica</i> W. West	I		
<i>Oocystis lacustris</i> Chodat	S		
<i>Oocystis pusilla</i> Hansgirg	F		
<i>Oocystis</i> sp.	I		
<i>Oonephris obesa</i> (W. West) Fott	S		
<i>Planktosphaeria gelatinosa</i> G.M. Smith	VF		
Family Golenkiniaceae			
<i>Golenkinia paucispina</i> W. West and G.S. West	I		
<i>Golenkinia radiata</i> Chodat	I		
Family Micractiniaceae			
<i>Micractinium pusillum</i> Fresenius	S		
<i>Micractinium</i> sp.	I		
<i>Phytelios viridis</i> Frenzel	I		
Family Chlorococcaceae			
<i>Chlorococcum infusionum</i> (Schrank) Meneghini	I		
<i>Schroederia robusta</i> Korshikov	S		
<i>Schroederia setigera</i> (Schröder) Lemmermann	S		
<i>Tetraedron gracile</i> (Reinsch) Hansgirg	I		
<i>Tetraedron trigonum</i> (Nägeli) Hansgirg	S		
Family Scenedesmaceae			
<i>Crucigenia quadrata</i> Morren	I		
<i>Crucigenia tetrapedia</i> (Kirchner) West and West	S		
<i>Scenedesmus acuminatus</i> (Lagerheim) Chodat	F		
<i>Scenedesmus arcuatus</i> (Lemm.) Lemmermann	S		
<i>Scenedesmus bijugus</i> (Turpin) Kützing	VF		
<i>Scenedesmus ecornis</i> (Ehrenberg) Chodat	I		
<i>Scenedesmus incrasatulus</i> Bohlin	S		
<i>Scenedesmus quadricauda</i> (Turp.) Bréb. ex Ralfs	VF		
<i>Scenedesmus</i> sp.	S		
<i>Sorastrum spinulosum</i> Nägeli	S		
<i>Willea irregulares</i> (Wille) Schmidle	S		
Family Coelastraceae			
<i>Actinastrum gracillimum</i> Smith	F		
<i>Actinastrum hantzschii</i> Lagerheim	I		
<i>Actinastrum</i> sp.	I		
<i>Coelastrum astroideum</i> De Notaris	S		
<i>Coelastrum cambricum</i> W. Archer	S		
<i>Coelastrum microporum</i> Nägeli	I		
<i>Coelastrum reticulatum</i> (P.A. Dangeard) Senn	VF		
Family Botryococcaceae			
<i>Botryococcus braunii</i> Kützing	S		
<i>Dictyosphaerium ehrenbergianum</i> Nägeli	S		
<i>Dictyosphaerium pulchellum</i> H.C. Wood	VF		
<i>Dictyosphaerium</i> sp.	S		
Family Chlorellaceae			
<i>Ankistrodesmus fusiformis</i> Corda ex Korshikov	I		
<i>Ankistrodesmus gracilis</i> (Reinsch) Korshikov	I		
<i>Ankistrodesmus</i> sp.	S		
<i>Chlorella vulgaris</i> Beijerinck	F		
<i>Kirchneriella lunaris</i> (Kirchner) K. Möbius	F		
<i>Kirchneriella obesa</i> (G.S. West) Schmidle	I		
<i>Monoraphidium arcuatum</i> (Korshikov) Hindák	I		
<i>Monoraphidium braunii</i> (Nägeli) Kom.-Legn.	S		
<i>Monoraphidium contortum</i> (Thuret) Kom.-Legn.	F		
<i>Monoraphidium griffithii</i> (Berkeley) Kom.-Legn.	I		
<i>Monoraphidium komarkovae</i> Nygaard	S		
<i>Monoraphidium</i> sp.	I		
Order Tetrasporales			
Family Palmellaceae			
<i>Sphaerocystis schroeteri</i> Chodat	VF		
Order Zygnematales			
Family Zignemataceae			
<i>Mougeotia</i> sp.	F		
<i>Spirogyra</i> sp.	VF		
Family Closteriaceae			
<i>Closterium ehrenbergii</i> Meneghini ex Ralfs	F		
<i>Closterium moniliferum</i> Ehrenberg ex Ralfs	S		
<i>Closterium</i> sp.	VF		
Family Desmidiaceae			
<i>Cosmarium bioculatum</i> Brébisson ex Ralfs	I		
<i>Cosmarium margaritatum</i> (P. Lundell) J. Roy and Bisset	I		
<i>Cosmarium</i> sp.	F		
<i>Desmidium</i> sp.	S		
<i>Euastrum</i> sp.	S		
<i>Staurastrum gracile</i> Ralfs ex Ralfs	S		
<i>Staurastrum leptocladum</i> L.N. Johnson	F		
<i>Staurastrum rotula</i> Nordstedt	I		

TABLE 1. CONTINUED.

TAXA	FO
<i>Staurastrum tetracerum</i> Ralfs	I
<i>Staurastrum</i> sp.	F
<i>Staurodesmus</i> sp.	I
Family Peniaceae	
<i>Gonatozygon monotaenium</i> De Bary	I
<i>Gonatozygon pilosum</i> Wolle	S
<i>Gonatozygon</i> sp.	S
Order Oedogoniales	
Family Oedogoniaceae	
<i>Oedogonium</i> sp.	I
Order Volvocales	
Family Volvocaceae	
<i>Eudorina</i> sp.	I
<i>Pandorina morum</i> (O.F. Müller) Bory de Saint-Vincent	S
<i>Volvox</i> sp.	I
Class Cryptophyceae	
Order Cryptomonadales	
Family Cryptomonadaceae	VF
<i>Cryptomonas ovata</i> Ehrenberg	F
<i>Cryptomonas subovalis</i> Ehrenberg	I
<i>Cryptomonas</i> sp.	
Order Pyrenomonadales	
Family Pyrenomadaceae	I
<i>Rhodomonas</i> sp.	
Class Dinophyceae	
Order Peridinales	
Family Ceratiaceae	I
<i>Ceratium hirundinella</i> (O.F.Müller) Dujardin	S
<i>Ceratium</i> sp.	S
Family Peridiniaceae	I
<i>Peridinium cinctum</i> (O.F. Müller) Ehrenberg	I
<i>Peridinium</i> sp.	
Class Chrysophyceae	
Order Monosigales	
Family Synuraceae	
<i>Synura</i> sp.	S
Order Ochromonadales	
Family Dinobryaceae	
<i>Dinobryon sertularia</i> Ehrenberg	S
<i>Dinobryon</i> sp.	S
Class Euglenophyceae	
Order Euglenales	
Family Euglenaceae	
<i>Euglena acus</i> Ehrenberg	I
<i>Euglena oxyuris</i> Schmarda	I
<i>Euglena</i> sp.	F
<i>Lepocinclis</i> sp.	I
<i>Phacus curvicauda</i> Svirenko	S
<i>Phacus longicauda</i> (Ehrenberg) Dujardin	I
<i>Phacus pleuronectes</i> (O.F. Müller) Dujardin	S
<i>Phacus</i> sp.	I
<i>Trachelomonas acanthophora</i> Stokes	S
<i>Trachelomonas armata</i> (Ehrenberg) F. Stein	S
<i>Trachelomonas obesa</i> Ehrenberg	I
<i>Trachelomonas oblonga</i> Ehrenberg	I
<i>Trachelomonas volvocina</i> Ehrenberg	VF
<i>Trachelomonas</i> sp.	F

Class Xantophyceae	
Order Mischococcales	
Family Centritactaceae	
<i>Centritractus belenophorus</i> Lemmermann	I

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