Acta Limnologica Brasiliensia, 2014, vol. 26, no. 4, p. 347-355 http://dx.doi.org/10.1590/S2179-975X2014000400003

Epilithic diatoms in headwater areas of the hydrographical sub-basin of the Andreas Stream, RS, Brazil, and their relation with eutrophication processes

Diatomáceas epilíticas em áreas de nascentes da sub-bacia hidrográfica do Arroio Andreas, RS, Brasil, e sua relação com processos de eutrofização

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Abstract: Aim: This research aimed to study the composition of epilithic diatom flora in headwater areas of the sub-basin of the Andreas stream, RS, Brazil, and their relation with eutrophication processes. **Methods**: Quarterly excursions (March, June, September, December 2012 and Mach 2013) were performed in ten sampling points selected in the sub-basin, to collect samples for the identification and counting the organisms in the group of diatoms (Class Bacillariophyceae). **Results**: The results indicated the occurrence of 243 taxa, distributed in 53 genera. Of these, 59 were considered abundant, being distributed in 29 genera. Seven species showed elevated tolerance levels to organic pollution and eutrophication: *Adlafia drouetiana* (R. M. Patrick) Metzeltin & Lange-Bertalot, *Amphipleura lindheimeri* Grunow; *Fallacia monoculata* (Hustedt) D. G. Mann, *Navicula cryptotenella* Lange-Bertalot, *Navicula symmetrica* R. M. Patrick, *Nitzschia palea* (Kützing) W. Smith and *Sellaphora auldreekie* D. G. Mann & S. M. McDonald in Mann et al. **Conclusion**: Although this research has been conducted in headwater areas, the occurrence of these seven species could be explained by considering the use of these areas for agricultural and livestock purposes, compromising the stability of these aquatic ecosystems, due to the significant contribution of fertilizer and organic matter, a condition that characterizes a process of eutrophication.

Keywords: headwater areas, water quality, diatoms, eutrophication, sub-basin of Andreas Stream, RS.

Resumo: Objetivo: A presente pesquisa objetivou o estudo da composição da flora de diatomáceas epilíticas em áreas de nascentes da Sub-bacia Hidrográfica do Arroio Andréas, RS, Brasil, e sua relação com processos de eutrofização. **Métodos**: Excursões trimestrais (Março, Junho, Setembro, Dezembro de 2012 e Março de 2013) foram realizadas em dez pontos de coleta selecionados na sub-bacia, para coletar amostras para a identificação e contagem dos organismos do grupo das diatomáceas (Classe Bacillariophyceae). **Resultados**: Os resultados indicaram a ocorrência de 243 táxons, distribuídos em 53 gêneros. Destes, 59 foram considerados abundantes, estando distribuídos em 29 gêneros. Sete espécies apresentaram níveis de tolerância elevados à poluição orgânica e eutrofização: *Adlafia drouetiana* (R. M. Patrick) Metzeltin & Lange-Bertalot, *Amphipleura lindheimeri* Grunow; *Fallacia monoculata* (Hustedt) D. G. Mann, *Navicula cryptotenella* Lange-Bertalot, *Navicula symmetrica* R. M. Patrick, *Nitzschia palea* (Kützing) W. Smith and *Sellaphora auldreekie* D. G. Mann & S. M. McDonald in Mann et al. **Conclusão**: Embora a pesquisa tenha sida realizada em áreas de nascentes, a ocorrência destas sete espécies poderia ser explicada considerando o uso destas áreas para fins agrícolas e criação de animais, comprometendo a estabilidade destes ecossistemas aquáticos em função do aporte significativo de fertilizantes e matéria orgânica, condição que caracteriza um processo de eutrofização.

Palavras-chave: áreas de nascentes, qualidade da água, diatomáceas, eutrofização, sub-bacia do Arroio Andréas, RS.

1. Introduction

Despite the extensive hydrographic network that characterizes Brazil, divided into eight major basins (Amazon, Tocantins River, North Atlantic and Northeast, San Francisco River, eastern Atlantic, Parana River, Uruguay River and Southeast Atlantic), there are few systems of monitoring water quality that have been implemented (Moresco and Rodrigues, 2013), considering that they are essential to increase understanding of the problems related to pollution of aquatic ecosystems (Bodo, 1992; Mohlenberg et al., 2007).

Concerning the methodologies for water quality evaluation, researchers worldwide (e. g., Cairns Junior and Pratt, 1993) argue that traditional techniques based on physical, chemical and bacteriological characteristics are not enough to meet their multiple uses, since they are particularly deficient in the evaluation of aesthetics, recreation and ecological environmental conditions, being necessary therefore an integrated quality analysis, considering not only the traditional valuation methodologies, but the biological aspects of the system.

Among the bioindicator organisms of the environmental conditions of lotic systems, the use of diatoms (Bacillariophyceae) has a long history (Stevenson and Pan, 1999). They are predominantly free-living unicellular microscopic organisms, sometimes filamentous organisms gathered in colonies, surrounded by a layer of mucilage (Joly, 1979). Currently, diatoms are represented by about 100,000 species distributed in 250 genera and have a wide geographical distribution, occurring along rivers, estuaries, lakes, marine environments and a variety of substrates, natural or artificial, being observed also in humid environment, ice and hot spring waters (Hoek et al., 1995).

These organisms are one of the main dominant groups of periphytic algae in lotic systems and also efficient indicators of environmental changes, since they respond sensitively to physical and chemical changes of water (Winter and Dunthie, 2000; Lobo et al., 2002), as well as to differences in geology, climate and land use between watersheds (Stoermer and Smol, 1999). Because they have a strongly silicified cell wall, these organisms can be easily mounted in permanent microscope slides, requiring no special treatment for preservation.

However, the need for a thorough understanding of the taxonomy of diatoms has been identified as one of the major problems for using this group of algae in biological monitoring programs (Sabater et al., 1991). Although it is known that a high number of species are cosmopolitan (Kociolek and Spaulding, 2000), there is few information in the literature about the diatom flora in Latin America, a fact that significantly affect the correct identification of the species, since the base used is mainly the European bibliography (e. g., Krammer and Lange-Bertalot, 1986, 1988, 1991a, b; Lange-Bertalot, 1993). Round (1993) recommends extreme caution when identifying species found in the southern hemisphere based on studies of European flora, because, although apparently identical, the species often have subtle variations.

In this context, the present research aimed to study the composition of epilithic diatom flora in headwater areas of the sub-basin of the Andreas stream, RS, Brazil, and their relation with eutrophication processes.

2. Material and Methods

2.1. Study area

Located in the central region of Rio Grande do Sul state, the Andreas Stream Hydrographic Sub-basin is inserted in Vera Cruz city, one of the 13 municipalities that compose the Pardo River Hydrographic Basin (Figure 1). It shows a drainage area of 80.2 km^2, containing an urban population of 11,183 inhabitants and a rural population of 2,964 inhabitants. Land use is characterized by agriculture, including the presence of irrigated rice.

2.2. Data collection

Quarterly excursions (March, June, September, December 2012 and Mach 2013) were performed at ten sampling stations selected in the Andreas Stream Hydrographic Sub-basin (Figure 1), to collect samples for the identification and counting the organisms in the group of diatoms (Class Bacillariophyceae). The selection of the class Bacillariophyceae followed the recommendations of Round (1991, 1993) and Sabater et al. (1991). For qualitative and quantitative analysis, diatom samples were scrubbed off the upper surface of three to five submerged stones, 10 to 20 cm in diameter, using a toothbrush, and were fixed with formalin following the method described by Kobayasi and Mayama (1982). The samples were cleaned with sulfuric and hydrochloric acids and mounted on permanent slides with Naphrax. To estimate the relative abundance of the species, all the organisms found in random transects under light microscopy through the prepared permanent slides were

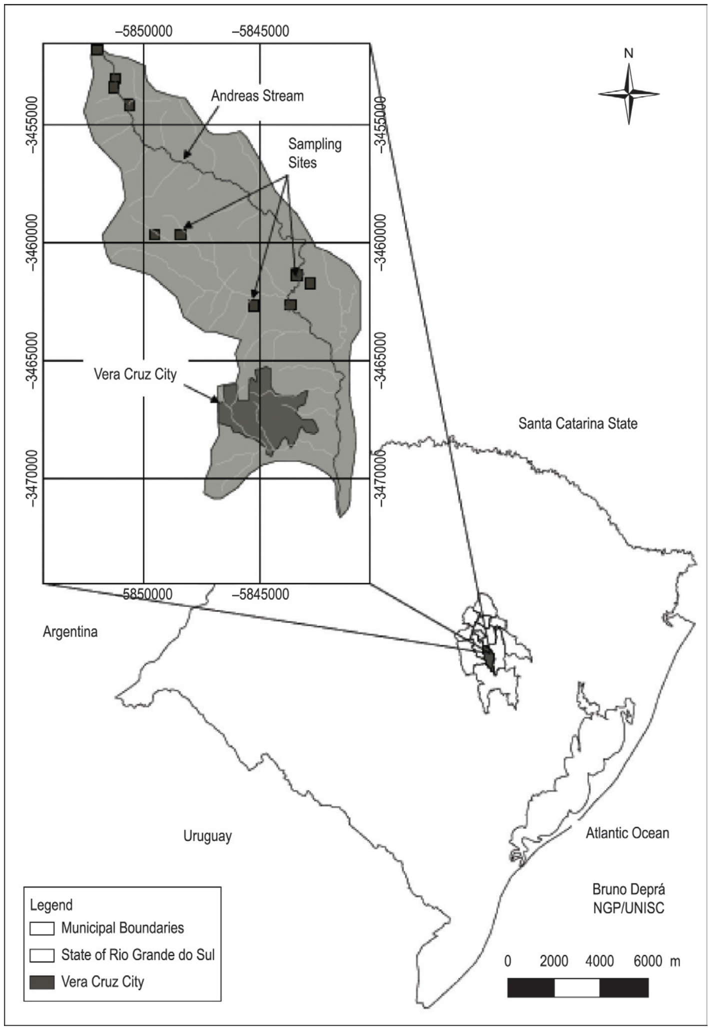


Figure 1. Map of the study area and localization of the Andreas Stream Sub-basin, in the municipality of Vera Cruz, RS, Brazil.

identified and counted up to a minimum of 600 valves using an Olympus BX-40 microscope. For the identification of species, the following taxonomic references were used: Bes et al. (2012), Metzeltin and Lange-Bertalot (1998, 2007), Rumrich et al. (2000), Metzeltin and García-Rodríguez (2003) and Metzeltin et al. (2005). Abundant species were determined according to Lobo and Leighton (1986). The permanent slides are stored in the DIAT-UNISC Herbarium at the University of Santa Cruz do Sul (RS), Brazil.

3. Results and Discussion

A total of 243 species were identified, belonging to 53 genera, 59 taxa were considered abundant, being distributed in 29 genera (Table 1). Regarding the genera level, *Navicula* Bory and *Gomphonema* Ehrenberg were the most representative, with eight and six species, respectively.

Among the abundant species, seven of them showed higher levels of tolerance to organic pollution and eutrophication (Figures 2 to 55), following the classification proposed by Lobo et al. (2004a). They are:

Adlafia drouetiana (R. M. Patrick) Metzeltin & Lange-Bertalot (Figures 33 to 43)

This species is cited as tolerant to organic pollution and eutrophication in southern Brazilian rivers (Lobo et al. 2004a, 2010).

Amphipleura lindheimeri Grunow (Figures 2 to 4)

Freshwater taxon (oligohalobous), characteristic of standing water, but may also occurs in running water (limnophilous) (Shirata, 1985). For southern Brazilian rivers, this species is cited as characteristic of α-polysaprobic pollution environments (very heavily polluted) (Lobo et al., 2002) and highly tolerant to eutrophication (Lobo et al. 2004a, 2010).

Fallacia monoculata (Hustedt) D. G. Mann (Figures 44 to 53)

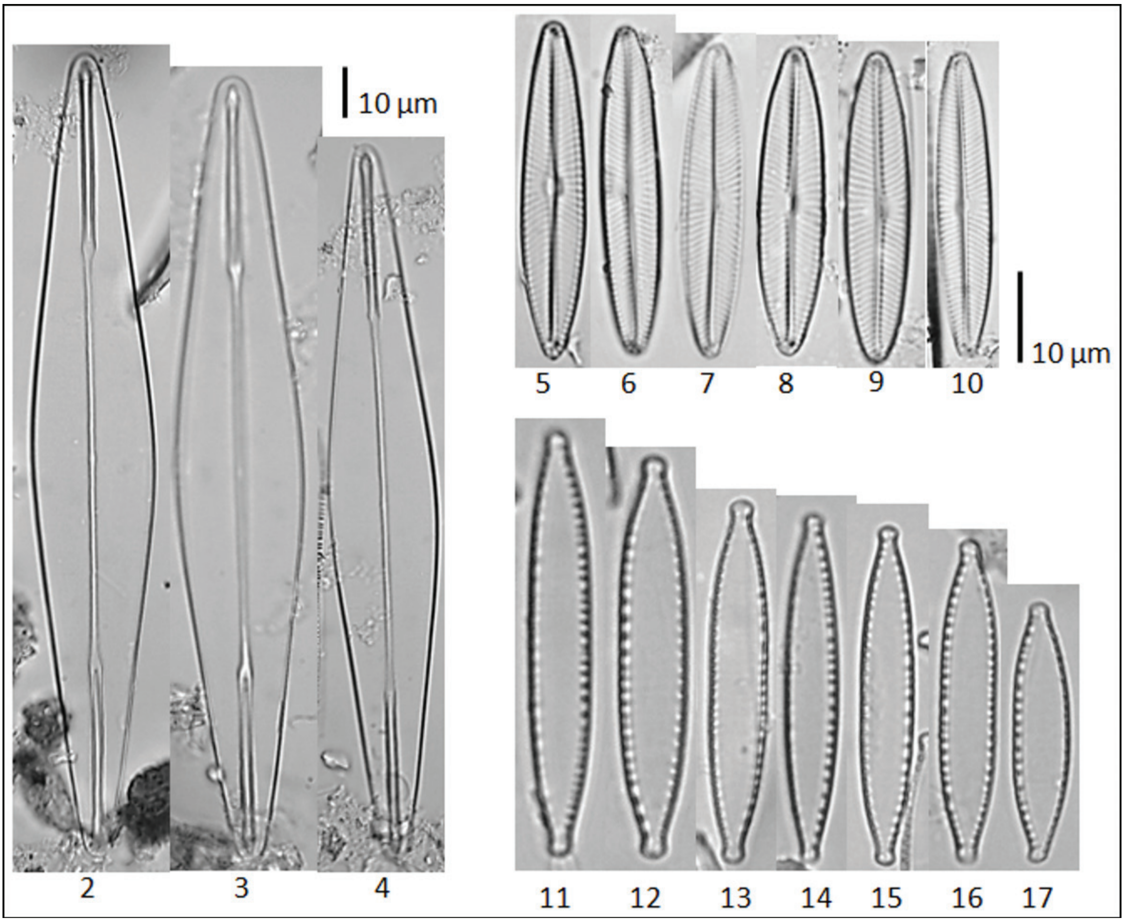
Cosmopolitan species, extremely tolerant to eutrophication and organic pollution OuvirLer foneticamente (Van Dam et al., 1994; Souza and Senna, 2009; Lobo et al., 2004a, 2010; Schuch et al., 2012).

Navicula cryptotenella Lange-Bertalot (Figures 18 to 26)

Species found in freshwater (Lange-Bertalot, 2001) and brackish (Hodgson et al., 1997). Occurring in lentic waters as well as lotic waters (Lowe, 1974), and classified as epilithic, periphytic and planktonic (Tolonen, 1978; Torgan and

Table 1. List of the abundant diatom species in the Andreas Stream Sub-basin, RS, Brazil.

Achnanthes paraexigua Metzeltin & Lange-Bertalot
Achnanthidium exiguum (Grunow) Czarnecki
Achnanthidium exiguum var. *constrictum* (Grunow) N. A. Andresen, Stoermer & Kreis
Achnanthidium minutissimum (Kützing) Czarnecki
Adlafia drouetiana (R. Patrick) Metzeltin & Lange-Bertalot
Adlafia muscora (Kociolek & Reviers) Gerd Moser, Lange-Bertalot & Metzeltin
Amphipleura lindheimeri Grunow
Brachysira neoxilis Lange-Bertalot
Caloneis hyalina Hustedt
Cocconeis lineata Ehrenberg
Cocconeis placentula var. *acuta* F. Meister
Diploneis subovalis Cleve
Eolimna minima (Grunow) Lange-Bertalot
Eolimna subminuscula (Manguin) Gerd Moser, Lange-Bertalot & Metzeltin
Eunotia kruegeri Lange-Bertalot
Eunotia veneris (Kützing) A. Berg
Fallacia meridionalis Metzeltin, Lange-Bertalot & García Rodríguez
Fallacia monoculata (Hustedt) D. G. Mann
Frustulia guayanensis ssp. *ecuadoriana* Lange-Bertalot & Rumrich
Geissleria punctifera (Hustedt) Lange-Bertalot
Gomphonema angustatum (Kützing) Rabenhorst
Gomphonema bourbonense E. Reichardt
Gomphonema brasiliense Grunow
Gomphonema brasiliensoide Metzeltin, Lange-Bertalot & García Rodríguez
Gomphonema lagenula Kützing
Gomphonema parvulum Kützing
Halamphora montana (Krasske) Levkov
Humidophila contenta (Grunow) Lowe et al.
Humidophila lacunosa (Gerd Moser, Lange-Bertalot & Metzeltin) Lowe et al.
Humidophila subtropica (Metzeltin, Lange-Bertalot & García-Rodríguez) Lowe et al.
Luticola simplex Metzeltin, Lange-Bertalot & García-Rodríguez
Mayamaea agrestis (Hustedt) Lange-Bertalot
Mayamaea permitis (Hustedt) Bruder & Medlin
Navicula capitatoradiata (Cleve) Germain
Navicula cruxmeridionalis Metzeltin, Lange-Bertalot & García-Rodríguez
Navicula cryptotenella Lange-Bertalot
Navicula germainii J. H. Wallace
Navicula gregaria Donkin
Navicula lohmanii Lange-Bertalot & Rumrich
Navicula symmetrica R. M. Patrick
Naviculadicta aff. *cosmopolitana* Lange-Bertalot in Rumrich et al.
Nitzschia amphibia Grunow
Nitzschia claussi Hantzsch
Nitzschia inconspicua Grunow
Nitzschia palea (Kützing) W. Smith
Nitzschia supralitorea Lange-Bertalot
Nupela pardinhoensis Bes, Torgan & Ector in Bes et al.
Nupela praecipua (E. Reichardt) E. Reichardt
Nupela welnerii (Lange-Bertalot) Lange-Bertalot in Rumrich et al.
Placoneis humilis Metzeltin, Lange-Bertalot & García-Rodríguez
Planothidium bagualense C. E. Wetzel & Ector
Planothidium salvadorianum (Hustedt) Lange-Bertalot
Platessa hustedtii (Krasske) Lange-Bertalot
Pleurosira laevis (Ehrenberg) Compère
Sellaphora auldreekie D. G. Mann & S. M. McDonald in Mann et al.
Sellaphora seminulum (Grunow) D. G. Mann
Simonsenia delognei (Grunow) Lange-Bertalot
Surirella bouillonii Bes, Ector & Torgan in Bes et al.
Ulnaria ulna (Nitzsch) Compère



Figures 2-17. Abundant diatom species in the Andreas Stream Sub-basin, RS, Brazil. **2-4**: *Amphipleura lindheimeri*; **5-10**: *Navicula symmetrica*; **11-17**: *Nitzschia palea*.

Biancanaro, 1991; Kuhn et al., 1981; Lowe, 1974). Characteristic of α-polysaprobic environments (very heavily polluted) according to Lobo et al., (2002) and cited as tolerant to organic pollution and highly tolerant to eutrophication (Lobo et al., 2004a, 2010). Yet, Van Dam et al. (1994) pointed out that this species has a wide tolerance to trophy, from oligotraphentic to hypereutraphentic environments.

Navicula symmetrica R. M. Patrick (Figures 5 to 10)

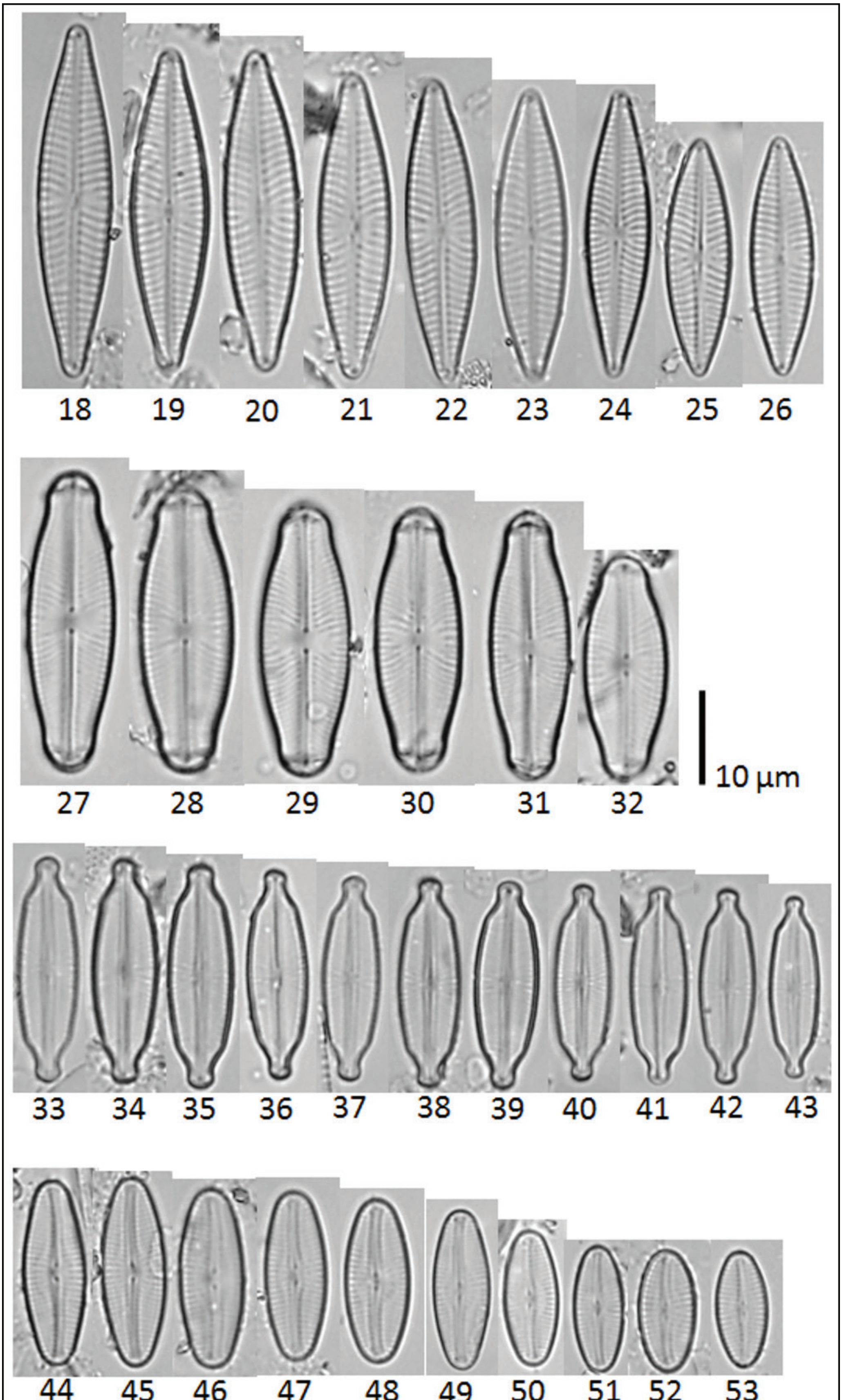
This species is characteristic of α-polisaprobic environments in southern Brazilian rivers (Lobo et al., 2002), as well as tolerant to organic pollution and highly tolerant to eutrophication (Lobo et al. 2004a, 2010).

Nitzschia palea (Kützing) W. Smith (Figures 11 to 17)

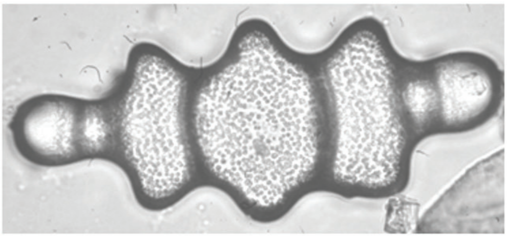
Cosmopolitan species, widely recognized as tolerant to organic pollution, according Lange-Bertalot (1979), Kobayasi and Mayama (1989) and Watanabe et al. (1988) as well as eutrophication (Lobo et al. 2004a, 2010; Schuch et al., 2012). Moreover, Van Dam et al. (1994) and Silva et al. (2010) argued that *N. palea* is a polysaprobic species, indicative of hypereutraphentic conditions. Bruno et al. (2003) confirmed *N. palea* as an indicator of high nutrient loads and Krammer and Lange-Bertalot (1988) affirm that this species has a wide range of tolerance to organic contamination, from mesosaprobic to polysaprobic environments, with an ecological optimum in highly polluted waters.

Sellaphora auldreekie D. G. Mann & S. M. McDonald in Mann et al. (Figures 27 to 32)

Cosmopolitan species, occurring in freshwater (Van Heurck, 1896) to slightly brackish (Hodgson et al., 1997). Abundant taxa in eutrophic environments with high phosphate concentrations (Lobo et al., 2004b). Still Schuch et al. (2012), studying urban streams in Santa Cruz do Sul, RS, Brazil, found the specie as highly abundant in eutrophic and organically polluted environments.



Figures 18-53. Abundant diatom species in the Andreas Stream Sub-basin, RS, Brazil. **18-26**: *Navicula cryptotenella;* **27-32**: *Sellaphora auldreekie;* **33-43**: *Adlafia drouetiana;* **44-53**: *Fallacia monoculata.*



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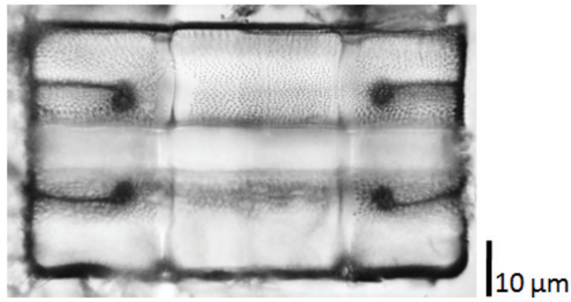

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Figures 54-55. *Terpsinoë musica*, new citation to headwater areas at Rio Grande do Sul.

Finally, we emphasize the occurrence of a new citation to headwaters in the state of Rio Grande do Sul:

Terpsinoë musica Ehrenberg (Figures 54, 55)

Among the records of this taxon realized in Brazil, we highlight the researches developed by Brassac et al. (1999), Rosa et al. (1994) and Tremarin et al. (2009). According to Round et al. (1990), this species has a large ecological distribution and can be found in brackish and freshwaters; frequently in humid rocks of tropical regions. Some studies, for example Zalocar De Domitrovic and Maidana (1997), highlight the epiphytic or epilithic habit of this taxon as well as their preference for euryhaline environments. The study also records the occurrence of this species associated with specimens of *Pleurosira laevis* and *Hydrosera whampoensis*; this species association was also verified in this present research.

4. Conclusion

The results indicate the occurrence of 243 taxa, 59 of them considered abundant species, distributed in 29 genera, characterizing the flora of epilithic diatoms in headwater areas of the Andreas Stream Sub-basin, RS, in order to provide subsidies to the correct delimitation and identification of species used in the diagnosis and characterization of aquatic environments.

Although this research has been conducted in headwater areas, the flora composition revealed seven species with high levels of tolerance to organic pollution and eutrophication, which could be explained considering the use of these areas for agricultural and livestock purposes, compromising the stability of these aquatic ecosystems due to the significant contribution of fertilizer and organic matter, condition that characterizes a eutrophication process.

Acknowledgements

The authors want to thank the Brazilian Research Council (CNPq) and the University of Santa Cruz do Sul (UNISC), by the undergraduate scholarships granted to first and second author of this scientific article, PUIC/UNISC and PIBIC/CNPq, respectively. We also thank to Dr. Carlos Wetzel and Dr. Luc Ector, from the Institute Gabriel Lippmann in Luxembourg, for their assistance in the taxonomic nomenclature procedures. Yet, we thank the CNPq by financial support of this research (Edict MCT/CNPq/Universal - nº 14/2011).

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Received: 20 January 2014
Accepted: 19 September 2014