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Epilithic diatom flora in Cali River hydrographical basin, Colombia

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Abstract

This research aimed to study the composition of epilithic diatom flora found in samples collected in Cali River hydrographical basin, Colombia. Quarterly excursions (March, June, September and December of 2012 and March of 2013) were performed in six sampling sites to collect samples for identification of diatom organisms (Class Bacillariophyceae). The results indicated the occurrence of 82 taxa distributed in 26 families and 38 genera. 32 of these are new occurrences in Colombia. The most representative families were Gomphonemataceae, Naviculaceae and Bacillariaceae. The genera richest in species were *Navicula*, *Gomphonema* and *Nitzschia*. Eight species occurred in all sampling sites: *Achnanthidium minutissimum*, *Cocconeis lineata*, *Cymbella affinis*, *Gomphonema pumilum* var. *rigidum*, *Melosira varians*, *Navicula symmetrica*, *Reimeria sinuata* and *Rhoicosphenia abbreviata*. The results indicated 13 species considered dominant and characterize the flora of epilithic diatoms in Cali River hydrographical basin, Colombia.

Key words: dominant species ecology, freshwater diatoms, new occurrences, taxonomy.

Resumo

A presente pesquisa objetivou o estudo da composição da flora de diatomáceas epilíticas encontradas em amostras coletadas na bacia hidrográfica do Rio Cali, Colômbia. Excursões trimestrais (março, junho, setembro e dezembro de 2012 e março de 2013) foram realizadas em seis sítios de amostragem para coletar amostras para a identificação dos organismos do grupo das diatomáceas (Classe Bacillariophyceae). Os resultados indicaram a ocorrência de 83 táxons, distribuídos em 26 famílias e 38 gêneros. 32 desses táxons são novas ocorrências na Colômbia. As famílias mais representativas foram Gomphonemataceae, Naviculaceae e Bacillariaceae. Os gêneros com maior riqueza de espécies foram *Navicula*, *Gomphonema* e *Nitzschia*. Oito espécies tiveram ocorrência em todos os sítios de amostragem: *Achnanthidium minutissimum*, *Cocconeis lineata*, *Cymbella affinis*, *Gomphonema pumilum* var. *rigidum*, *Melosira varians*, *Navicula symmetrica*, *Reimeria sinuata* e *Rhoicosphenia abbreviata*. Os resultados indicaram 13 espécies consideradas dominantes, e caracterizam a flora diatomológica da bacia hidrográfica do Rio Cali, Colômbia.

Palavras-chave: ecologia das espécies dominantes, diatomáceas de água doce, novas ocorrências, taxonomia.

Introduction

Diatoms are unicellular microscopic organisms that are predominantly free-living but, sometimes are filamentous and gathered in colonies, surrounded by a layer of mucilage (Joly 1979). Currently, diatoms are represented by approximately 100,000 species distributed in 250 genera and have a wide geographical distribution, occurring along rivers, estuaries, lakes, and marine environments and on a variety of substrates, including natural and artificial substrates (Hoek *et al*. 1995).

These organisms are one of the main dominant groups of periphytic algae in lotic systems and have been widely used as efficient indicators of water quality, because they respond quickly to environmental changes, especially organic pollution

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and eutrophication, with a broad spectrum of tolerances to conditions ranging, from oligotrophic to eutrophic. (Álvarez-Blanco *et al*. 2013; Lobo *et al*. 2002, 2004, 2010, 2014, 2016a, b; Hermany *et al*. 2006; Salomoni *et al*. 2006, 2011; Salomoni & Torgan 2008; Schneck *et al*. 2007). Additionally, diatoms are one of the key groups of organisms recommended by the Water Framework Directive introduced in the European Union in 2000 (European Union 2000) for the identification of ecological quality gradients in rivers.

Colombia contains the highest biological diversity in the world after Brazil (Mittermeier *et al*. 1997); however, most published diatom studies are focused on their ecologies (Martínez & Donato 2003; Díaz-Quirós & Rivera-Rondón 2004; Ramírez & Plata-Dias 2008; Montoya-Moreno *et al*. 2008; Castro-Roal & Pinilla-Agudelo 2014). Recent taxonomic studies of diatoms include the research of (Montoya-Moreno *et al*. 2012), (Vouilloud *et al*. 2013; Sala *et al.* 2013; Vouilloud *et al*. 2010), which focused mainly on specific genera; comprehensive works capable of reflecting the whole diatom community are lacking.

In this context, the present research aimed to study the composition of the epilithic diatom flora in the hydrographical basin of the Cali, Colombia, a typical river of the Colombian Andean system.

Material and Methods

Study area

The Cali River hydrographical basin is located to the northwest of the municipality of Santiago de Cali, Colombia, and extends from the Farallones de Cali National Nature Park in the western Cordillera to the mouth of the Cauca River, with a total surface area of 21, 497 hectares and with five drainage areas (CVC 2007) (Fig. 1).

Data collection

Quarterly excursions (March, June, September and December of 2012 and March of 2013) were performed in six sampling sites along the Cali River hydrographical basin, to collect samples for the identification of diatoms (class Bacillariophyceae): st.1 and st. 2 (Felidia River); st. 3 (Pichindé River); and st. 4, st. 5 and st. 6 (Cali River). For qualitative and quantitative analysis, diatom samples were scrubbed from the upper surface of three to five submerged stones with a diameter of 10 to 20 cm, using a toothbrush and were fixed with formalin following the method described by Kobayasi & Mayama (1982). The samples were cleaned with sulfuric and hydrochloric acids and mounted on permanent slides with Pleurax®. Observations, measurements and photographs were performed using an Olympus BX-40 light microscope equipped with a digital camera.

Taxa classification followed the system proposed by Round *et al*. (1990) and modified by Medlin & Kaczmarska (2004). For species identification, the following taxonomic references were used: Blanco *et al*. (2010), Hofmann *et al*. (2013), John (1983), Krammer & Lange-Bertalot (1988, 1991a,b), Metzeltin *et al*. (2005), Metzeltin & Lange-Bertalot (1998), Müller-Melchers (1957), Krammer (2000) and Rumrich *et al*. (2000). For taxonomic nomenclature, Algae Base was used (<http://www.algaebase.org>). Dominant species were determined following the criterion of Lobo and Leighton (1986). The permanent slides are stored in the DIAT-UNISC Herbarium at the University of Santa Cruz do Sul, RS, Brazil.

Results and Discussion

The epilithic diatom flora in the Cali River hydrographical basin included 82 taxa (78 to the species level and 4 to spp.) distributed among 26 families and 38 genera. The most representative families were Gomphonemataceae (13 taxa), Naviculaceae (9 taxa) and Bacillariaceae (7 taxa). The genera richest in species were *Navicula*, *Gomphonema* and *Nitzschia*. Eight species occurred in all sampling sites: *Achnanthidium minutissimum*, *Cocconeis lineata*, *Cymbella affinis*, *Gomphonema pumilum* var. *rigidum*, *Melosira varians*, *Navicula symmetrica*, *Reimeria sinuata* and *Rhoicosphenia abbreviata*. Table 1 shows the species identified highlighting in bold the 32 new occurrences for the country. Two genera are new records for Colombia, namely, *Fallacia* and *Simonsenia*. Light microscopy photographs of all species identified are shown in (Figs. 2-14).

It is important to note that one species belonging to genus *Actinocyclus* Ehrenberg was identified, *A. subtilis* (W.Gregory) Ralfs, and 4 species belonging to genus *Coscinodiscus* Ehrenberg, namely, *C. asteromphalus* Ehrenberg, *C. devius* A. Schmidt, *C. janischii* A. Schmidt and *C. kurzii* Grunow, were identified. Species belonging to these genera are normally described in floristic surveys carried out in marine environments (Lozano-Duque *et al*. 2010; Talgatti *et al*. 2010; Souza-Mosimann & Laudares-Silva 2005; Fernandes *et al*. 2001; Müller-Melchers 1957) and in estuarine zones (Procopiak *et al*. 2006; Jonh 1983).

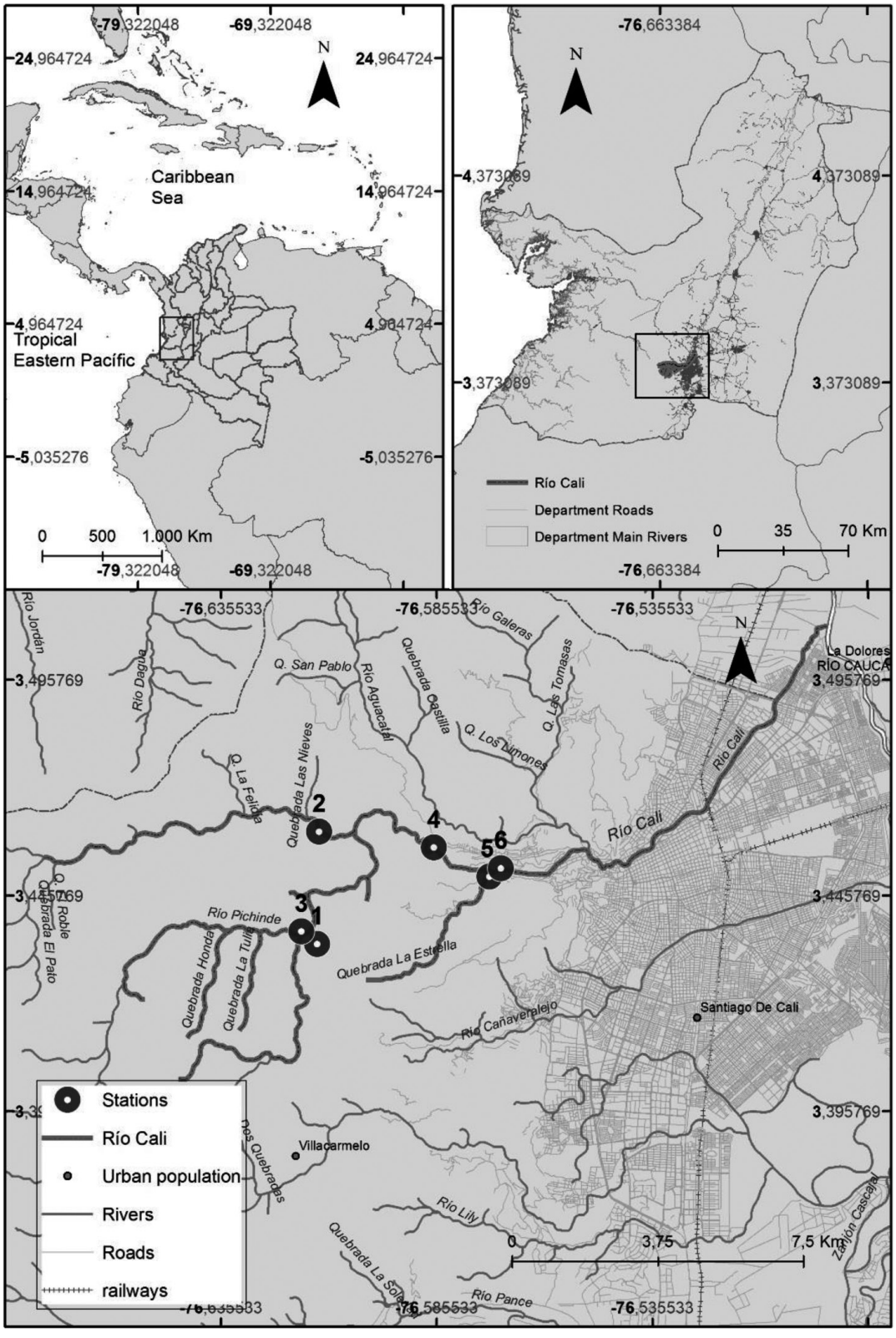


Figure 1 – Map of the study area showing the location of the Cali River hydrographical basin, Colombia, and the sampling sites (st. 1- st. 6).

Table 1 – Species identified in the Cali River basin, Colombia, highlighting in bold the 32 new occurrences for the country.

Achnanthidium minutissimum (Kützing) Czarnecki
Actinocyclus subtilis (W.Gregory) Ralfs
Adlafia bryophila (J.B. Petersen) Gerd Moser *et al*.
Adlafia minuscula (Grunow) Lange-Bertalot
Amphipleura lindheimeri Grunow
Amphora meridionalis Levkov
Aulacoseira tenella (Nygaard) Simonsen
Caloneis bacillum (Grunow) Cleve
Cocconeis lineata Ehrenberg
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow
Cocconeis pseudolineata (Geitler) Lange-Bertalot
Coscinodiscus asteromphalus Ehrenberg
Coscinodiscus devius A. Schmidt
Coscinodiscus janischii A. Schmidt
Coscinodiscus kurzii Grunow
Cymbella affinis Kützing
Cymbella sp.
Cymbella tropica Krammer
Cymbella tumida (Brébison) Van Heurck
Diadesmis arcuata Lange-Bertalot
Encyonema minutum Kützing (Hilse) D.G. Mann
Encyonema silesiacum (Bleish) D.G. Mann
Encyonema silesiacum var. *altensis* Krammer
Encyonopsis minuta Krammer & E.Reichardt
Encyonopsis subminuta Krammer & E.Reichardt
Eunotia major var. *gigantea* Frenguelli
Fallacia insociabilis (Krasske) D.G.Mann
Fragilaria arcus (Ehrenberg) Cleve
Fragilaria recapitellata Lange-Bertalot & Nergui
Fragilaria rumpens (Kützing) G.W.F. Carlson
Fragilaria vaucheriae (Kützing) J.B. Petersen
Frustulia sp.
Frustulia vulgaris (Thwaites) De Toni
Gomphonema acuminatum Ehrenberg
Gomphonema capitatum Ehrenberg
Gomphonema minutum (C. Agardh) C. Agardh
Gomphonema parvulum (Kützing) Kützing
Gomphonema pumilum var. *rigidum* E. Reichardt & Lange-Bertalot
Gomphonema subclavatum (Grunow) Grunow
Gomphonema subclavatum var. *compactum* (Grunow) Grunow

Gyrosigma obtusatum (Sullivant & Wormley) C.S. Boyer
Halamphora montana (Krasske) Levkov
Halamphora normanii (Rabenhorst) Levkov
Humidophila contenta (Grunow) R.L. Lowe *et al*.
Luticola cf. *aequatorialis* (Heiden) Lange-Bertalot & Ohtsuka
Luticola goeppertiana (Bleisch) D.G. Mann
Luticola sp.
Melosira varians C. Agardh
Navicula capitatoradiata H. Germain
Navicula cf. *notha* J.H. Wallace
Navicula cryptotenella Lange-Bertalot
Navicula gregaria Donkin
Navicula lohmanni Lange-Bertalot & U.Rumrich
Navicula rostellata Kützing
Navicula symmetrica Patrick
Navicula trivialis Lange-Bertalot
Neidium cf. *ampliatum* (Ehrenberg) Krammer
Nitzschia amphibia Grunow
Nitzschia cf. *brevissima* Grunow
Nitzschia dissipata (Kützing) Rabenhorst
Nitzschia linearis W. Smith
Nitzschia palea (Kützing) W. Smith
Nitzschia recta Hantzsch *ex* Rabenhost
Nupela cf. *lesothensis* (Schoeman) Lange-Bertalot
Nupela sp.
Orthoseira roeseana (Rabenhorst) O'Meara
Pinnularia borealis var. *sublinearis* Krammer
Pinnularia parvulissima Krammer
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot
Platessa hustedtii (Krasske) Lange-Bertalot
Reimeria sinuata (Gregory) Kociolek & Stoermer
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot
Rhopalodia cf. *operculata* (C.Agardh) Håkanasson
Rhopalodia gibba (Ehrenberg) Otto Müller
Rhopalodia gibberula Ehrenberg O. Müller
Rhopalodia parallela (Grunow) O. Müller
Sellaphora pupula (Kützing) Mereschkovsky
Simonsenia delognei (Grunow) Lange-Bertalot
Surirella angusta Kützing
Surirella cf. *angusta* Kützing
Tabellaria flocculosa (Roth) Kützing
Ulnaria ulna (Nitzsch) Compère

However, Montoya-Moreno *et al*. (2013) working with diatom flora in continental environments of Colombia, based on bibliographic searches and museum collections, cited a record of one taxon belonging to genus *Actinocyclus* (*Actinocyclus normanii* (Gregory *ex* Greville) Husted) identified in phytoplankton samples from the lagoon complex Ciénaga Grande de Santa Marta, Magdalena, and two taxa belonging to genus *Coscinodiscus*. Moreover, Wetzel (2011), working with diatom samples from the Negro River, Amazonia, Brazil, described the occurrence of species belonging to these genera, namely, *A. normanii*, *A. normanii f. subsalsa* (Juhl.-Dannf), *C. asteromphalus* Ehrenberg and *Coscinodiscus* sp.

The species *Surirella angusta* (Fig. 14e) is very similar to a new species described in Colombia by Sala *et al*. (2013), *Surirella antioquiensis* S.E. Sala, J.J. Ramírez, Plata-Díaz & Vouilloud, based on morphometric characteristics observed under light microscopy (LM), examination; however, the correct taxonomical circumscription will only be possible by using scanning electron Microscope (SEM).

For systematic classification of the species, the following abbreviations will be used: A=areolas, D=diameter, L=length, MH=mantle height, W=width, Str=striae and Fib=fibulae. Ecological data and the world distribution of the taxa considered dominant, *i.e*., those with a relative frequency of over 50% of the total samples, are included.

Bacillariophyta
Coscinodiscophytina Medlin & Kaczmarska
Coscinodiscophyceae Round & Crawford, *emend* Medlin & Kaczmarska
Aulacoseiraceae R.M. Crowford
Aulacoseira Thwaites
Aulacoseira tenella (Nygaard) Simonsen, 1979. Fig. 2a
Valve dimensions D: 6.8 mm
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 116, pl. 3, figs. 15-24.

Coscinodiscaceae Kützing
Coscinodiscus Ehrenberg
Coscinodiscus asteromphalus Ehrenberg, 1844. Fig. 2b
Valve dimensions: D: 127.4 mm; A: 4 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, EL 1617; Pichindé, 8.II.2011, EL1611.
Reference: John, Bibliotheca Phycologica. 1983. p. 218, pl. 7, fig. 2.

Coscinodiscus devius A. Schmidt, 1886. Fig. 2c
Valve dimensions: D: 70 mm; A: 3–4 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Después de Bocatoma, 8.II.2011, EL1609.
Reference: John, Bibliotheca Phycologica. 1983. p. 220, pl. 8, figs. 4,6.

Coscinodiscus janischii A. Schmidt, 1878. Fig. 2d
Valve dimensions: D: 138 mm; A: 3–4 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Después de Bocatoma, 8.II.2011, EL1609.
Reference: John, Bibliotheca Phycologica. 1983. p. 220, pl. 8, fig. 8.

Coscinodiscus kurzii Grunow, 1888. Fig. 3a
Valve dimensions: D: 124.1–147.2 mm; A: 4 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, Jardín Botánico, 8.II.2011, EL1619.
Reference: Müller-Melchers, Bol. Inst. Oceanogr. 1957. p. 128, pl. 2, fig. 7.

Actinocyclus subtilis (W.Gregory) Ralfs. Fig. 3b
Valve dimensions: D: 105–126.3 mm; A: 9 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Después de Bocatoma, 8.II.2011, EL1609, Lomas de la Cajita, 8.II.2011, EL1618.
Reference: John, Bibliotheca Phycologica. 1983. p. 224, pl. 10, figs. 2,4.

Melosiraceae Kützing
Melosira C. Agardh
Melosira varians C. Agardh, 1827. Fig. 4a
Valve dimensions: D: 12.93–21.47 mm Mantle Height: 7.2–15.11 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611; 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011, EL1626; Lomas de la Cajita, EL1614, EL1618, 8.IV.2011, EL1625; Antes de Desviación, 8.II.2011, EL1615, EL1623; Después de Bocatoma, 8.II.2011, EL1617, 8.IV.2011, EL1621; Jardín Botánico, 8.II.2011, EL1620, 8.IV.2011, EL1622.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 246, pl. 2, figs. 7-12.
Ecology and Distribution: Cosmopolitan taxon. Found in alkaline waters, with moderate oxygen saturation (>50%), α-mesosaprobic, abundant in

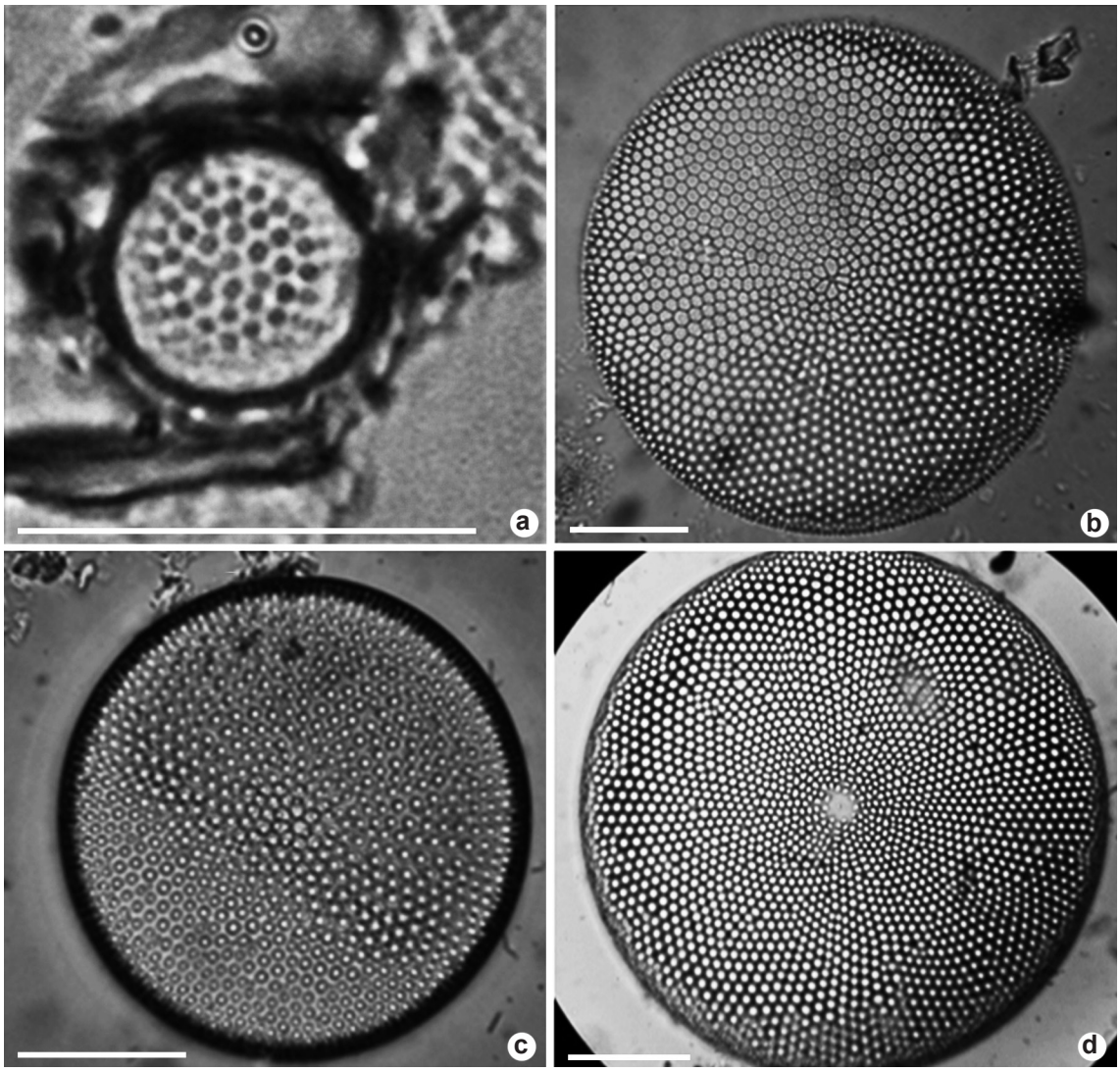
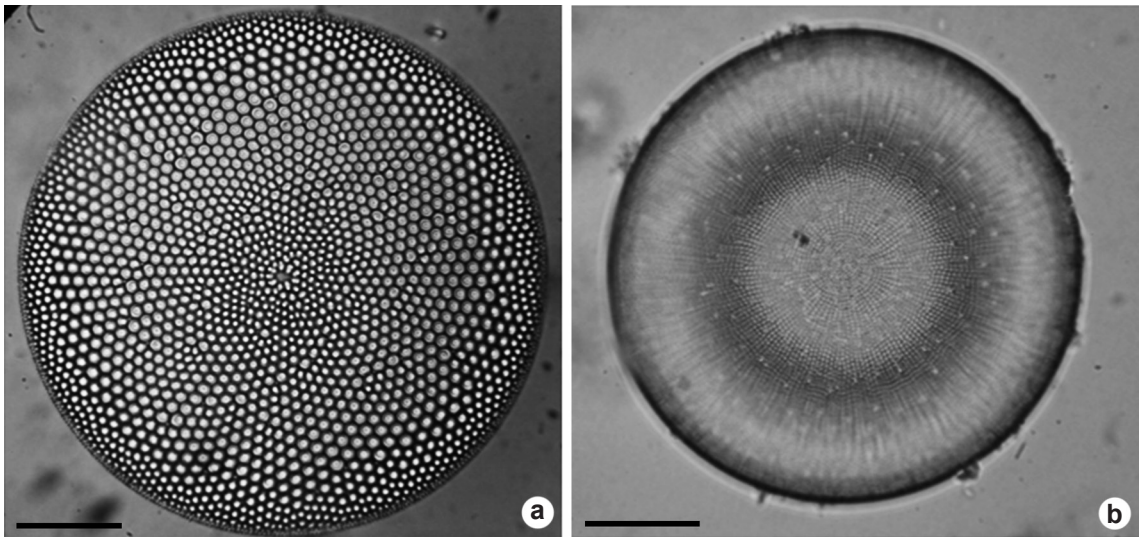


Figure 2 – a-d. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Aulacoseira tenella*; b. *Coscinodiscus asteromphalus*; c. *Coscinodiscus devius*; d. *Coscinodiscus janischii*.

eutrophic environments (Taylor *et al*. 2007; Van Dam *et al*. 1994). Lobo *et al.* (2015) cites this species with a medium tolerance to eutrophication.

Orthoseiraceae Crawford
Orthoseira Thwaites
Orthoseira roeseana (Rabenhorst) O' Meara, 1876. Fig. 4b
Valve dimensions: D: 17 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1617.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 246, pl. 2, figs. 1-4.

Bacillariophytina Medlin & Kaczmarska
Bacillariophyceae Round
Fragilariaceae Greville
Fragilaria Lyngbye
Fragilaria arcus (Ehrenberg) Cleve, 1898. Fig. 4c
Valve dimensions: L: 30.3–91 mm; W: 4.9–7.4 mm; Str: 12–14 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011, EL1614, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623; después de Bocatoma, 8.II.2011, EL1617.



Figures 3 – a-b. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Coscinodiscus kurzii*; b. *Actinocyclus subtilis*. Scales: 30 μm.

References: Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 146, pl. 18, figs. 10-16. Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 250, pl. 5, figs. 4-6.
Ecology and Distribution: Europe: Austria, Germany, Ireland, Italy, Romania, Western European mountains. North America: United States of America. Southwest Asia: Iraq. Asia: Turkey (Asia). (<http://www.algaebase.org>).

Present in alkaline waters, tolerant to small concentrations of nitrogen. It is a species that has preference for β-mesosaprobic sites, and can occur from oligotrophic to mesotrophic environments. (Van Dam *et al*. 1994).

Fragilaria recapitellata Lange-Bertalot & Nergui, 2009. Fig. 4d
Valve dimensions: L: 17–26 mm; W: 5.1–6.3 mm; Str: 11–13 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611.
Reference: Krammer & Lange-Bertalot, p. 448, pl. 109, figs. 26-28. 1991a. Reference complementary: Metzeltin *et al*. Iconogr. Diatomol.,v. 20. 2009.

Fragilaria rumpens (Kützing) G.W.F. Carlson, 1913. Fig. 4e
Valve dimensions: L: 15.6–33 mm; W: 2.4–3.7 mm; Str: 11–13 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, 8.IV.2011, EL1612; Lomas de la Cajita, 8.II.2011, EL1614, 8.IV.2011, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623; después de Bocatoma, 8.II.2011, EL1617.
Reference: Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 142, pl. 16, figs. 29-41.

Fragilaria vaucheriae (Kützing) J.B. Petersen, 1938. Fig. 5a
Valve dimensions: L: 24.5–25.6 mm; W: 3.3–3.9 mm; Str: 10–12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; antes de Desviación, 8.II.2011, EL1615, EL1623.
Reference: Krammer & Lange-Bertalot. 1991a. p. 446, pl. 108, figs. 10-15.

Ulnariaceae
Ulnaria (Kützing) Compère
Ulnaria ulna (Nitzsch) Compère, 2001. Fig. 5b
Valve dimensions: L: 138.6–198 mm; W: 6.8–7.3 mm; Str: 12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, 8.IV.2011, EL1612; antes de Desviación, 8.II.2011, EL1615, después de Bocatoma, 8.II.2011, EL1617, EL1623.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 154, pl. 22, figs. 1-7.

Eunotiaceae
Eunotia Ehrenberg
Eunotia major var. ***gigantea*** Frenguelli, 1934. Fig. 5c
Valve dimensions: L: 158 mm; W: 8 mm; Str: 19 in 10 mm.

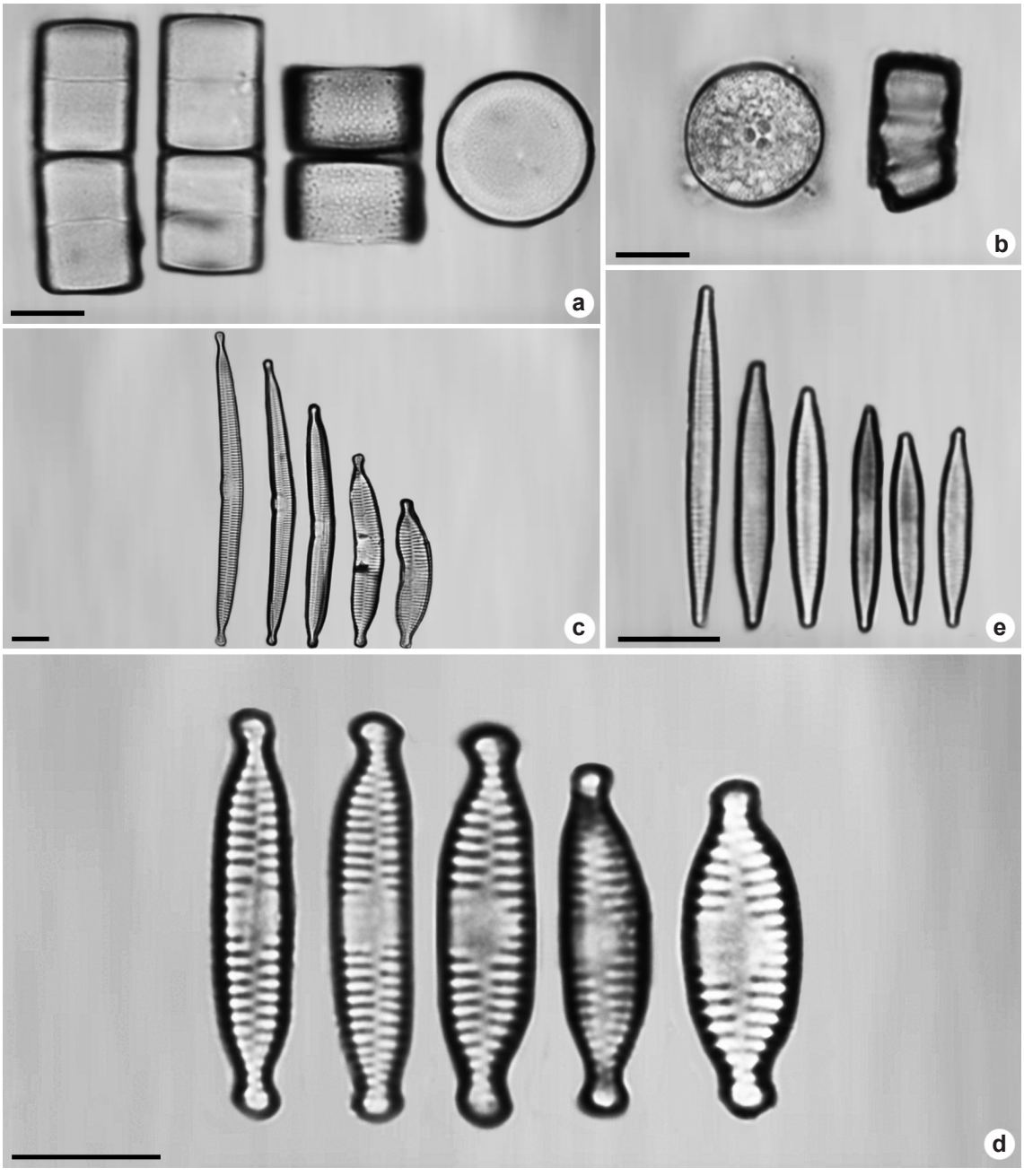


Figure 4 – a-e. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Melosira varians*; b. *Orthoseira roeseana*; c. *Fragilaria arcus*; d. *Fragilaria recapitellata*; e. *Fragilaria rumpens*. Scales: 10 µm.

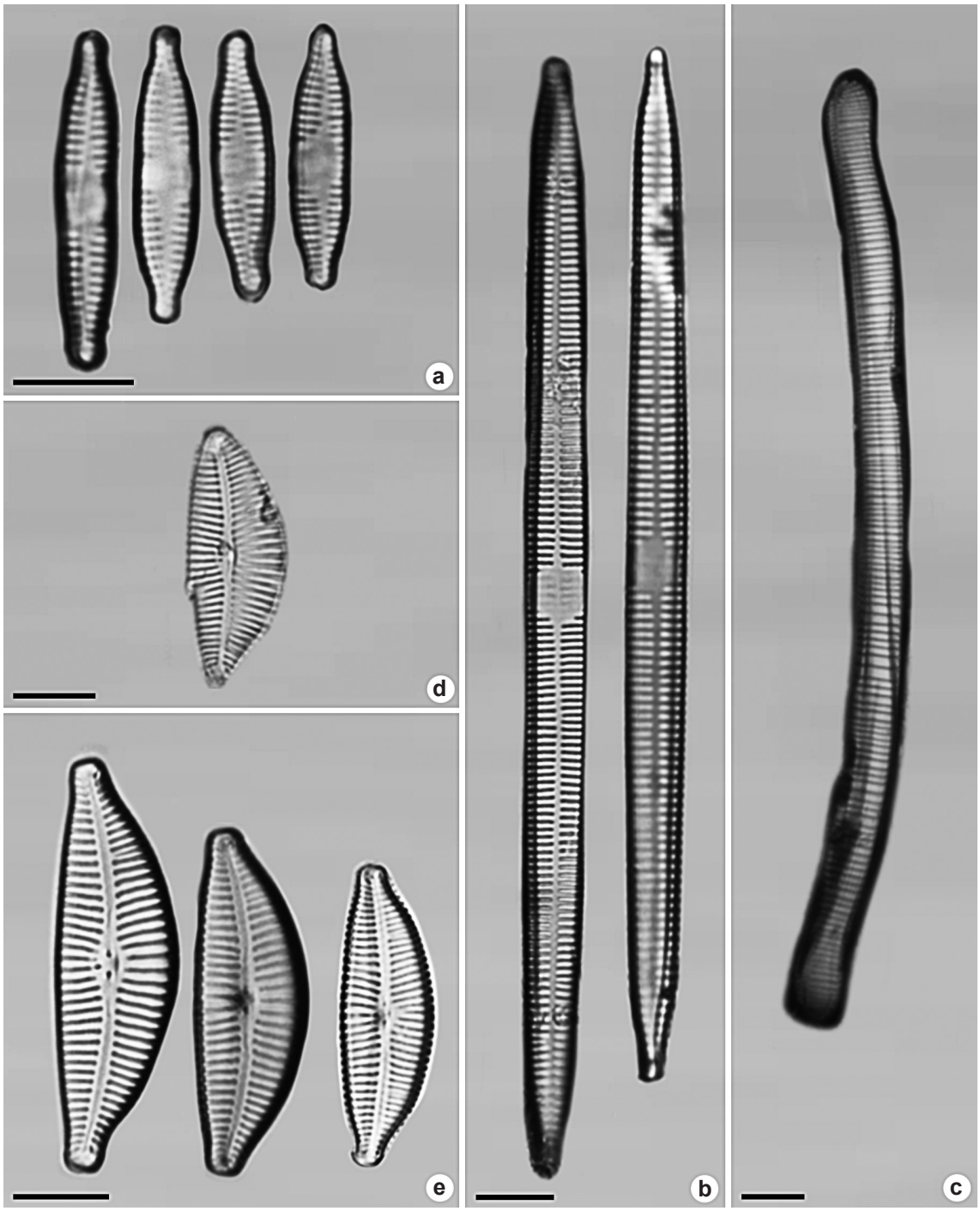


Figure 5 – a-e. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Fragilaria vaucheriae*; b. *Ulnaria ulna*; c. *Eunotia major* var. *gigantea*; d.*Cymbella* sp.; e. *Cymbella affinis*. Scales: 10 µm.

Examined material: VALLE DEL CAUCA: Cali, Lomas de la Cajita, 8.II.2011, EL1614.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 278, pl. 17, figs. 1-2.

Cymbellaceae
Cymbella C. Agardh
Cymbella sp. Fig. 5d
Valve dimensions: L: 29 mm; W: 12 mm; Str: 12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, antes de Desviación, 8.II.2011, EL1615.

Cymbella affinis Kützing 1844. Fig. 5e
Valve dimensions: L: 35.3–44.3 mm; W: 12.6–14 mm; Str: 9–10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; antes de Desviación, 8.II.2011, EL1615, EL1623; Puente de Felidia, 8.II.2011, EL1616; después de Bocatoma, 8.II.2011, EL1617, 8.IV.2011, EL1621; Lomas de la Cajita, 8.II.2011, EL1618; Jardín Botánico, 8.II.2011, EL1620, 8.IV.2011, EL1622.
Reference: Krammer, Diatoms of Europe v. 3. 2002. p. 206, pl. 8, figs. 21-25.
Ecology and Distribution: Europe: Italy, Macedonia, Poland, Romania, Spain. North America: NW USA, United States of America. Asia: China, Russia (Far East). South-west Asia: Iraq. (<http://www.algaebase.org>).

Present in alkaline waters, tolerant to small concentrations of nitrogen. It is a species that has preference for β-mesosaprobic sites, and can occur from oligotrophic to mesotrophic environments (Van Dam *et al*. 1994).

Cymbella tropica Krammer, 2002. Fig. 6a
Valve dimensions: L: 38–42 mm; W: 9–11 mm; Str: 10–12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, antes de Desviación, 8.II.2011, EL1615; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Krammer, Diatoms of Europe v. 3. 2002. p. 278, pl. 44, figs. 1-10.

Cymbella tumida (Brébison) Van Heurck, 1975. Fig. 6b
Valve dimensions: L: 46.9–76.3 mm; W: 16.1–19 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.II.2011, EL1612, antes de Desviación, 8.II.2011, EL1615, EL1623; Puente de Felidia, 8.II.2011, EL1616, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 470, pl. 115, figs. 8-10.

Gomphonemataceae
Encyonema Kützing
Encyonema minutum Kützing (Hilse) D.G. Mann, 1990. Fig. 6c
Valve dimensions: L: 16.1–19.5 mm; W: 6.1–7.3 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; antes de Desviación, 8.II.2011, EL1615; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 258, pl. 74, figs. 1- 21.

Encyonema silesiacum (Bleish) D.G. Mann, 1990. Fig. 6d
Valve dimensions: L: 33–38.2 mm; W: 9–10 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; Lomas de la Cajita, 8.II.2011, EL1614, EL1625; antes de Desviación, 8.II.2011, EL1615; después de Bocatoma, 8.II.2011, EL1617.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 498, pl. 127, figs. 7-9.

Encyonema silesiacum var. ***altensis*** Krammer, 1997. Fig. 6e
Valve dimensions: L: 20.2–25.3 mm; W: 7.8–8.3 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, Lomas de la Cajita, 8.II.2011, EL1614; antes de Desviación, 8.II.2011, EL1615; Puente de Felidia, 8.II.2011, EL1616.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 256, pl. 73, figs. 35-43.

Encyonopsis Krammer
Encyonopsis minuta Krammer & E.Reichardt, 1997. Fig. 7a
Valve dimensions: L: 15.1–17 mm; W: 4–4.1 mm; Str: 24 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611, Puente de Felidia, 8.II.2011, EL1613.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 258, pl. 74, figs. 35-64.

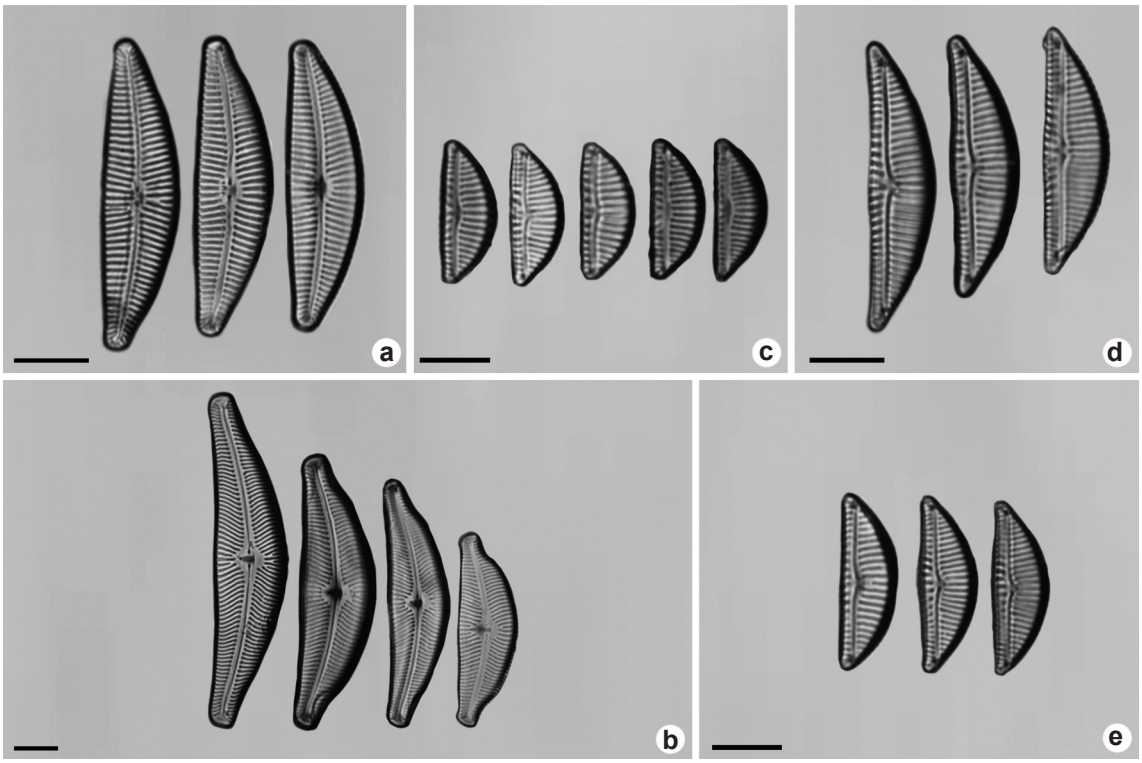


Figure 6 – a-e. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Cymbella tropica*; b. *Cymbella tumida*; c. *Encyonema minutum*; d. *Encyonema silesiacum*; e. *Encyonema silesiacum* var. *altensis*. Scales: 10 µm.

Encyonopsis subminuta Krammer & E.Reichardt, 1997. Fig. 7b
Valve dimensions: L: 21 mm; W: 5 mm; Str: 24 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 258, pl. 74, figs. 22-34.

Gomphonema Ehrenberg
Gomphonema acuminatum Ehrenberg, 1832. Fig. 7c
Valve dimensions: L: 60–66 mm; W: 11–12 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 276, pl. 83, figs. 1-5.
Reference complementary: Reichardt, E. Iconogr. Diatomol., v.8. 1999. p. 203.

Gomphonema capitatum Ehrenberg, 1838. Fig. 7d
Valve dimensions: L: 41 mm; W: 11 mm; Str: 11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 518, pl. 137, figs. 11-13.

Gomphonema minutum (C. Agardh) C. Agardh, 1831. Fig. 7e
Valve dimensions: L: 19.4–26.3 mm; W: 4.6–5.6 mm; Str: 13 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, EL1617; Pichindé, 8.II.2011, EL1610, EL1611, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011, EL1614, EL1618, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623, 8.IV.2011, EL1624.
Reference: Rumrich, Lange-Bertalot & Rumrich, Iconogr. Diatomol., v.9. 2000. p. 504, pl. 132, figs. 11-13.
Ecology and Distribution: Europe: Albania, Britain, France, Germany, Ireland, Macedonia, Poland, Romania, Spain, North America: Arkansas, NW USA, Tennessee, United States of America. South America: Colombia. Asia: Korea, Russia (Far

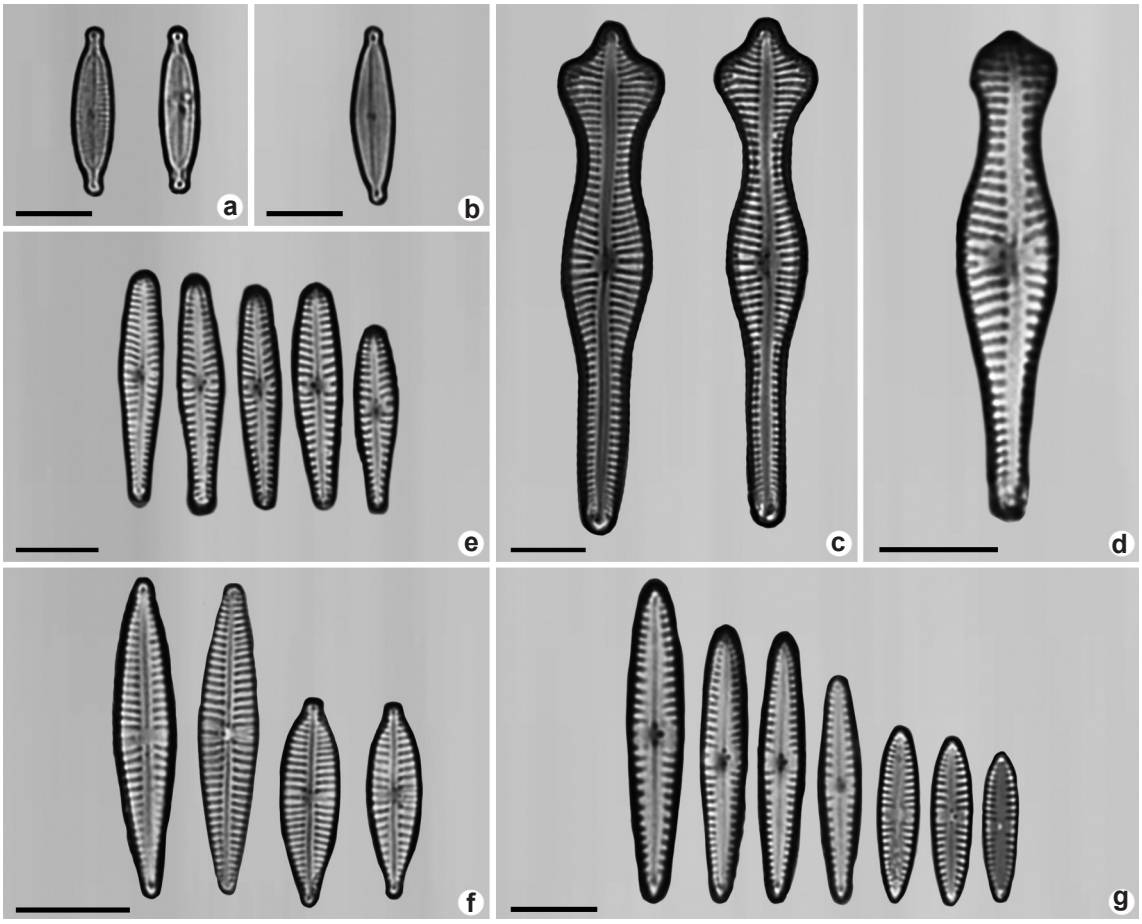


Figure 7 – a-g. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Encyonopsis minuta*; b. *Encyonopsis subminuta*; c. *Gomphonema acuminatum*; d. *Gomphonema capitatum*; e. *Gomphonema minutum*; f. *Gomphonema parvulum*; g. *Gomphonema pumilum* var. *rigidum*. Scales: 10 µm.

East), Taiwan, Turkey (Asia). Australia and New Zealand: New Zealand, Victoria (<http://www.algaebase.org>).

Present in circumneutral waters. For salinity, it is characterized as oligohalobium, fresh water with a restricted salt content less than 5 g.1-1. Occurs at pH around 7 with optimal development above 7. Found in β-mesosaprobic environments (Moro & Furstenberger 1997; Van Dam *et al*. 1994).

Gomphonema parvulum (Kützing) Kützing, 1849. Fig. 7f
Valve dimensions: L: 18.5–29 mm; W: 4.5–6.5 mm; Str: 11–14 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, EL1612; antes de Desviación, EL1615, EL1623.
References: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 528, pl. 142, figs. 9-15. Krammer & Lange-Bertalot. 1991b. p. 400, pl. 76, figs. 1-2.

Gomphonema pumilum* var. *rigidum E. Reichardt & Lange-Bertalot, 1997. Fig. 7g
Valve dimensions: L: 18.2–36.6 mm; W: 4.3–5.7 mm; Str: 12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, 8.IV.2011, EL1621; Pichindé, 8.II.2011, EL1610, EL1611, EL1612, Puente de Felidia, 8.II.2011, EL1613, 8.IV.2011, EL1626, Lomas de la Cajita, 8.II.2011, EL1614, EL1625, antes de Desviación, 8.II.2011, EL1615, EL1623; después de Bocatoma, 8.IV.2011. EL1624; 8.II.2011, EL1617, Lomas de la Cajita, 8.IV.2011, EL1618, Jardín Botánico, 8.II.2011. EL1619, EL1620, 8.IV.2011, EL1622.

Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 534, pl. 145, figs. 37- 44.
Ecology and Distribution: Cosmopolitan species. Found in mesoeutrophic to eutrophic waters with moderate electrolyte content. Not tolerant to critical levels of contamination (Taylor *et al.* 2007).

Gomphonema subclavatum (Grunow) Grunow, 1884. Fig. 8a
Valve dimensions: L: 36.8–44.4 mm; W: 7.3–8.8 mm; Str: 10–11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611, Puente de Felidia, 8.II.2011, EL1613, antes de Desviación, 8.II.2011, EL1615, Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Krammer & Lange-Bertalot, p. 414, pl. 83, figs. 9-10. 1991b.

Gomphonema subclavatum var. ***compactum*** (Grunow) Grunow, 1884. Fig. 8b
Valve dimensions: L: 28-32 mm; W: 7-8 mm; Str: 9-10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611.
Reference: Metzeltin, Lange-Bertalot, & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 544, pl. 150, figs. 5-8.

Reimeria J.P. Kociolek & Stoermer
Reimeria sinuata (Gregory) Kociolek & Stoermer, 1987. Fig. 8c
Valve dimensions: L: 14.5–18.5 mm; W: 3.9–5.4 mm; Str: 10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Después de Bocatoma, 8.II.2011, EL1609, EL1617, EL1621, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612, Puente de Felidia, 8.II.2011, EL1613, EL1616; Lomas de la Cajita, 8.II.2011, EL1614, EL1618, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623, EL1626; Jardín Botánico, 8.II.2011, EL1619, EL1620, EL1622, EL1624.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 252, pl. 71, figs. 1-12.
Ecology and Distribution: Cosmopolitan species (Taylor *et al*. 2007). Aerofitic, present in circumneutral to alkaline water, with high concentration of oxygen and preference for β-mesosaprobic sites, being able to occur from oligotrophic to mesotrophic environments. Tolerant to high levels of nitrogen (Taylor *et al*. 2007; Van Dam *et al*. 1994).

Rhoicospheniaceae
Rhoicosphenia Grunow
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot, 1980. Fig. 8d
Valve dimensions: L: 24–38.8 mm; W: 3.2–4.9 mm; Str: 10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011, EL1626, antes de Desviación, 8.II.2011, EL1615, EL1623, 8.IV.2011, EL1624, después de Bocatoma, 8.II.2011, EL1617, Lomas de la Cajita, 8.II.2011, EL1618, 8.IV.2011, EL1625; Jardín Botánico, 8.II.2011, EL1619, EL1620, EL1622; después de Bocatoma, 8.IV.2011, EL1621.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 278, pl. 84, figs. 1-21.
Ecology and Distribution: Cosmopolitan species (http://www.algaebase.org). Present in alkaline waters, with high oxygen saturation above 75%, abundant in waters with high electrolyte content. β-mesosaprobic to eutrophic, tolerant to high levels of pollution and concentrations of nitrogen (Taylor *et al*. 2007; Van Dam *et al*. 1994).

Cocconeidaceae Kützing
Cocconeis Ehrenberg
Cocconeis lineata Ehrenberg, 1843. Fig. 8e
Sin. *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, 1885.
Valve dimensions: L: 22.3–39.6 mm; W: 13–19.8 mm; Str: 13–22 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, EL1617, 8.IV.2011, EL1621; Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL 1616, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011, EL1614, EL1618, 8.IV.2011, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623; Jardín Botánico, 8.II.2011, EL1619, EL1620, 8.IV.2011, EL1622, 8.IV.2011, EL1624.
Reference: Krammer & Lange-Bertalot. 1991b. p. 352, pl. 52, figs. 1-13.
Ecology and Distribution: Cosmopolitan species (<http://www.algaebase.org>). Present in circumneutral to alkaline waters. Based on salinity, it is characterized as halophilic, preferring found in fresh water with a slight saline content. Found in oligotrophic environments with a low nutrient concentration and low mineral content, and in eutrophic environments characterized by high concentrations of nutrients, tolerant to high concentrations of nitrogen and indicating the presence of calcium in water (Moro & Furstenberger 1997; Van Dam *et al*. 1994). Lobo *et*

al. (2015) classify this species as having a moderate tolerance to eutrophication.

Cocconeis euglypta Ehrenberg, 1854. Fig. 9a
Sin. *Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow, 1884

Valve dimensions: L: 22.4–26.3 mm; W: 12.8–13.5 mm; Str: 18 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011,

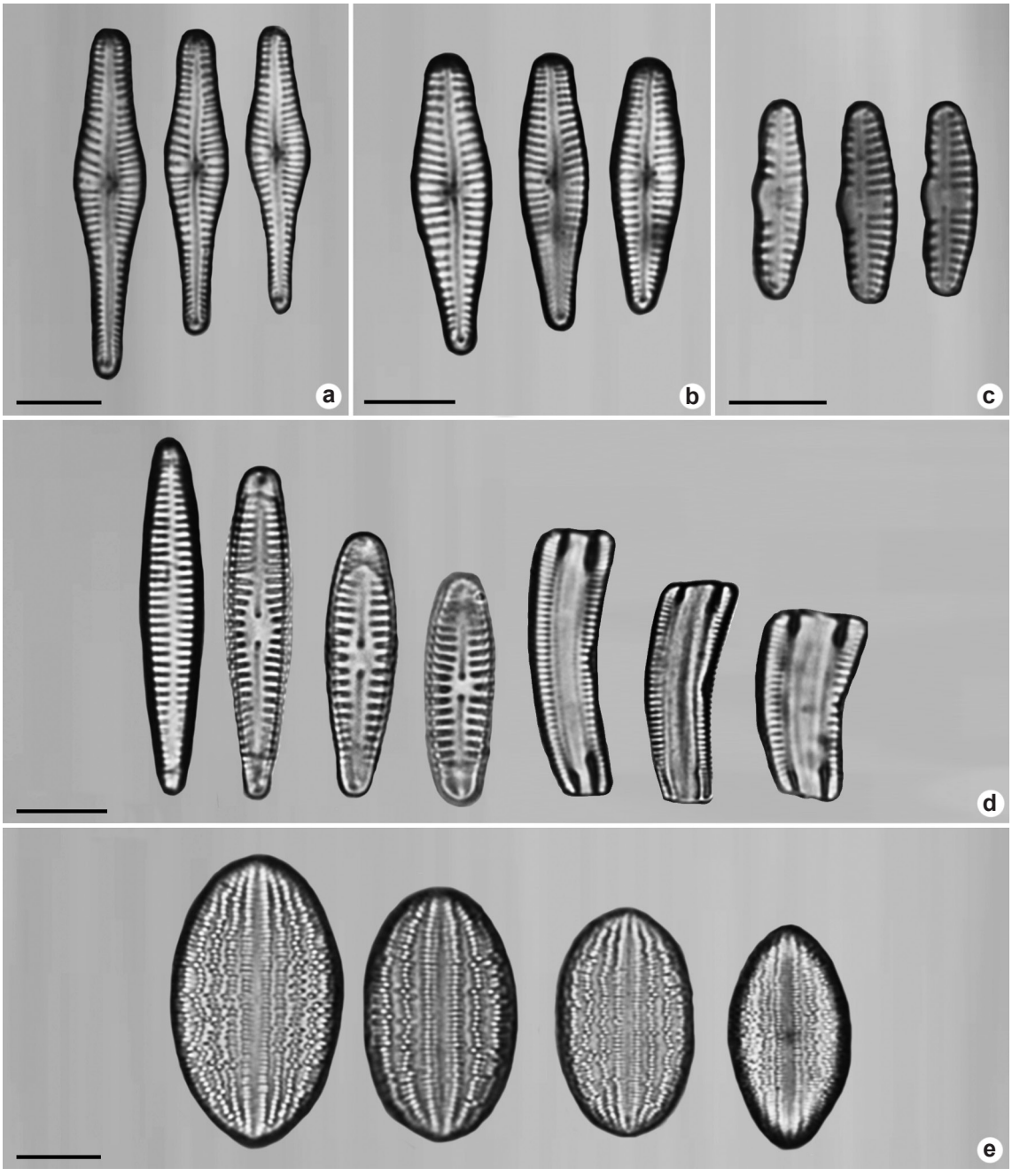


Figure 8 – a-e. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Gomphonema subclavatum*; b. *Gomphonema subclavatum* var. *compactum*; c. *Reimeria sinuata*; d. *Rhoicosphenia abbreviata*; e. *Cocconeis lineata*. Scales: 10 µm.

EL1614, 8.IV.2011, EL1625; después de Bocatoma, 8.II.2011, EL1617, EL1621; Jardín Botánico, 8.IV.2011, EL1622.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 170, pl. 30, figs. 2, 4-12.
Ecology and Distribution: Species with wide world distribution. Arctic: Ellesmere Island, Svalbard (Spitsbergen). Europe: Albania, Baltic Sea, Britain, Germany, Ireland, Italy, Macedonia, Poland, Romania, Russia (Europe), Spain, Turkey (Europe), Western European mountains. North America: Alaska, Arkansas, Canada, Great Lakes, Mexico,

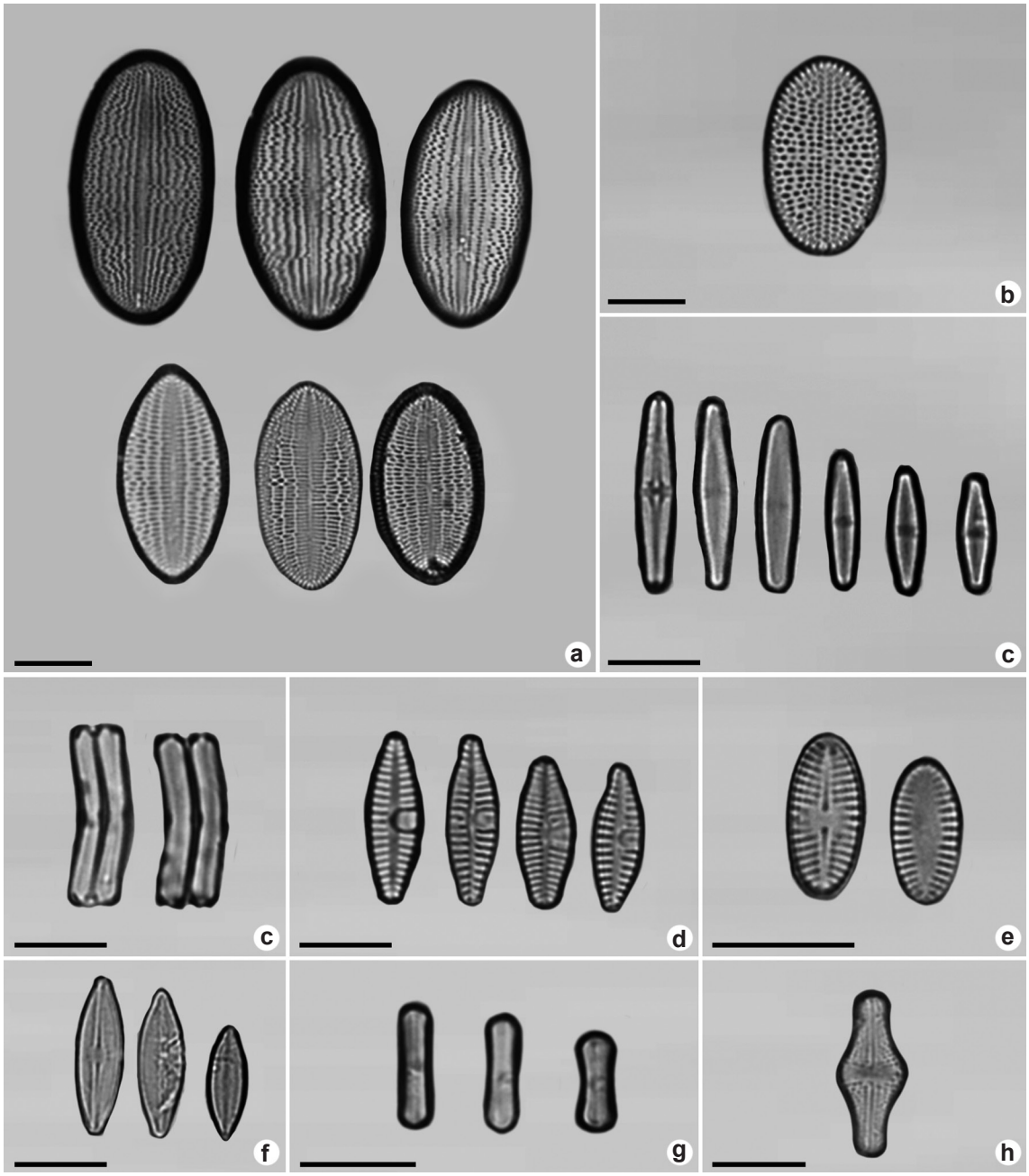


Figure 9 – a-h. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Cocconeis euglypta*; b. *Cocconeis pseudolineata*; c. *Achnanthidium minutissimum*; d. *Planothidium frequentissimum*; e. *Platessa hustedtii*; f. *Nupela* cf. *lesothensis*; g. *Humidophila contenta*; h. *Luticola aequatorialis.* Scales: 10 µm.

Mississippi, Northwest Territories, NW USA, United States of America. South America: Argentina, Brazil, Colombia. Africa: Ghana, Sudan. Southwest Asia: Iran, Iraq, Israel, Turkey (Asia). Asia: China, Korea, Mongolia, Russia (Far East), Taiwan. Southeast Asia: Singapore, Australia and New Zealand: Australia, New Zealand Pacific Islands: Hawaiian Islands (<http://www.algaebase.org>).

It presents variation in the pH scale, being able to occur in waters circumneutral with great development around 7 until alkaline. For the salinity is characterized as halophilic, fresh water with slight saline content. Found in oligotrophic environments characterized by low concentration of nutrients and low mineral content, eutrophic characterized by high concentrations of nutrients, tolerant to high variations in nutrient and mineral concentration. Indicator of the presence of calcium in water (Moro & Furstenberger 1997; Van Dam *et al*. 1994). Lobo *et al*. (2015) classifies this species as moderate tolerance to eutrophication.

Cocconeis pseudolineata (Geitler) Lange-Bertalot, 2004. Fig. 9b
Valve dimensions: L: 27 mm; W: 16 mm; Str: 11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1617.
References: Krammer & Lange-Bertalot. 1991b. p. 356, pl. 54, figs. 3-11. Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 322, pl. 39, fig. 7RL.

Achnanthidiaceae D.G. Mann
Achnanthidium Kützing
Achnanthidium minutissimum (Kützing) Czarnecki, 1994. Fig. 9c
Sin. *Achnanthes minutissima* Kützing, 1833
Valve dimensions: L: 9–21 mm; W: 2.9–3.8 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bocatoma, 8.II.2011, EL1609, EL1617, 8.IV.2011, EL1621; Pichindé, 8.11.2011, EL1610, EL1611, 8.IV.2011, EL1612, Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011, EL1626; Lomas de la Cajita, 8.II.2011, EL1614, EL1618, 8.IV.2011, EL1625; antes de Desviación, 8.II.2011, EL1615, EL1623, 8.IV.2011, EL1624; Jardín Botánico, 8.II.2011, EL1619, EL1620, 8.IV.2011, EL1622.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 184, pl. 37, figs. 1-10, 18-22.
Ecology and Distribution: Cosmopolitan taxon (Siver & Hamilton 2011). It presents a very wide ecological range, being found in water with neutral pH until slightly alkaline and slightly acidic. It is a species that has preference for β-mesosaprobic sites, and can occur from oligotrophic to eutrophic environments (Van Dam *et al*. 1994; Siver & Hamilton 2011), Lobo *et al*. (2015) classifies this species with low tolerance to eutrophication.

Planothidium Round & Bukhiyarova
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot, 1999. Fig. 9d
Valve dimensions: L: 12.9–16.2 mm; W: 4.6–5.3 mm; Str: 13–14 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 196, pl. 43, figs. 22-24, 29, 30.

Platessa Lange-Bertalot
Platessa hustedtii (Krasske) Lange-Bertalot, 2004. Fig. 9e
Sin. *Achnanthes hustedtii* (Krasske) Reimer, 1966
Valve dimensions: L: 10.9–11.8 mm; W: 6–7 mm; Str: 15–16 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.
References: Metzeltin, Lange-Bertalot, & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 312, pl. 34, fig. 18. Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 194, pl. 42, figs. 1-16.

Brachysiraceae D.G. Mann
Nupela W.Vyverman & Compère
Nupela cf. ***lesothensis*** (Schoeman) Lange-Bertalot, 1998. Fig. 9f
Valve dimensions: L: 15.2–18 mm; W: 4.5–5 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; antes de Desviación, 8.II.2011, EL1615, EL1623, 8.IV.2011, EL1624; Jardín Botánico, 8.II.2011, EL1619.
Reference: Metzeltin, Lange-Bertalot, Iconogr. Diatomol., v.5. 1998. p. 378, pl. 72, figs. 4,6.

Nupela sp.
Valve dimensions: L: 17–23 mm; W: 4 mm.
Examined material: VALLE DEL CAUCA: Lomas de la Cajita, EL1614, 8.IV.2011.

Diadesmidaceae D.G. Mann
Diadesmis Kützing
Diadesmis arcuata Lange-Bertalot, 1998.
Valve dimensions: L: 22 mm; W: 5 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.

Reference: Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 406, pl. 83, figs. 1-6.

Humidophila (Lange-Bertalot & Werum) R.L. Lowe *et al*.
Humidophila contenta (Grunow) R.L. Lowe *et al*. 2014. Fig. 9g
Sin. *Diadesmis contenta* (Grunow) Mann, 1990
Valve dimensions: L: 8.8–9.4 mm; W: 2.5–3.2 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611, Puente de Lelidia, 8.II.2011, EL1613, 8.IV.2011, EL1626; antes de Desviación, 8.II.2011, EL1615, EL1623, EL1624.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 358, pl.57, figs. 12- 20.

Luticola D.G. Mann
Luticola aequatorialis (Heiden) Lange-Bertalot & Ohtsuka, 2002. Fig. 9h
Valve dimensions: L: 17 mm; W: 7 mm; Str: 16 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.
Reference: Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 362, pl. 61, fig. 14.

Luticola goeppertiana (Bleisch) D.G. Mann, 1990. Fig. 10a
Valve dimensions: L: 22.4–34.5 mm; W: 7.5–9.7 mm; Str: 16–19 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612, Puente de Felidia, 8.II.2011, EL1613, EL1616; Lomas de la Cajita, 8.II.2011, EL1618.

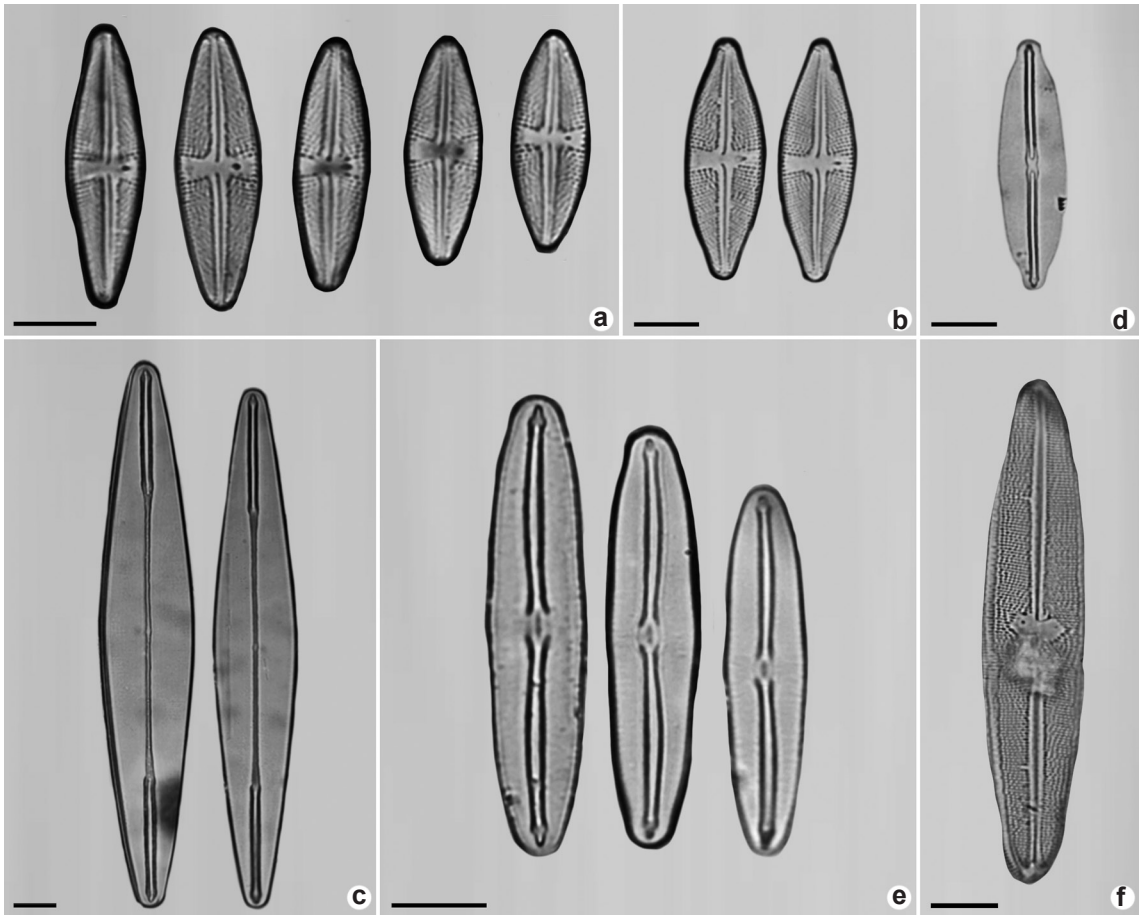


Figure 10 – a-f. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Luticola goeppertiana*; b. *Luticola* sp.; c. *Amphipleura lindheimeri*; d. *Frustulia* sp.; e. *Frustulia vulgaris*; f. *Neidium* cf. *ampliatum*. Scales: 10 µm.

Refererences: Metzeltin, Lange-Bertalot, Iconogr. Diatomol., v.5. 1998. p. 408, pl. 87, figs. 8-11. Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 212, pl. 51, figs. 1- 8.

Luticola sp. Fig. 10b
Valve dimensions: L: 27–35 mm; W: 10–10.9 mm; Str: 16–19 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.

Amphipleuraceae Grunow
Amphipleura Kützing
Amphipleura lindheimeri Grunow, 1862. Fig. 10c
Valve dimensions: L: 137.7–194 mm; W: 19.6–23.7 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611; Puente de Felidia, 8.II.2011, EL1616.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 464, pl. 110, figs. 1-2.

Frustulia sp. Fig. 10d
Valve dimensions: L: 38 mm; W: 9 mm.
Examined material: VALLE DEL CAUCA: Puente de Felidia, 8.II.2011, EL1613.

Frustulia vulgaris (Thwaites) De Toni, 1891. Fig. 10e
Valve dimensions: L: 36.2–49 mm; W: 8.8–9.7 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 460, pl. 108, figs. 2-7.

Neidiaceae Mereschkowsky
Neidium Pfitzer
Neidium cf. ***ampliatum*** (Ehrenberg) Krammer, 1985. Fig. 10f
Valve dimensions: L: 80.1 mm; W: 13 mm; Str: 20 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Lomas de la Cajita, 8.II.2011, EL1614.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 478, pl. 117, figs. 10,11.

Anomoeoneidaceae D.G. Mann
Adlafia Gerd Moser, Lange-Bertalot & Metzeltin

Adlafia bryophila (J.B. Petersen) Gerd Moser *et al*. 1998. Fig. 11a
Valve dimensions: L: 16 mm; W: 4 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613; Lomas de la Cajita, 8.II.2011, EL1614, EL1625.
Reference: Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 394, pl. 77, figs. 18-19.

Adlafia minuscula (Grunow) Lange-Bertalot, 1999. Fig. 11b
Valve dimensions: L: 16 mm; W: 4 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.
Reference: Rumrich, Lange-Bertalot & Rumrich, Iconogr. Diatomol., v.9. 2000. p. 394, pl. 77, fig. 12.

Sellaphoraceae Mereschkovsky
Fallacia Stickle & D.G.
Fallacia insociabilis (Krasske) D.G.Mann, 1990. Fig. 11c
Valve dimensions: L: 12 mm; W: 5 mm; Str: 18 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, antes de Desviación, 8.II.2011, EL1615.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 366, pl. 61, figs. 25, 26.

Sellaphora Mereschkovsky
Sellaphora pupula (Kützing) Mereschkovsky, 1902. Fig. 11d
Valve dimensions: L: 29–30 mm; W: 8 mm; Str: 25 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612; antes de Desviación, 8.II.2011, EL1615, 8.IV.2011, EL1624.
Reference: Hofmann, Werum & Lange-Bertalot, Diatomeen im Süßwasser-Benthos von Mitteleuropa. 2013. p. 684, pl. 41, fig. 14.

Pinnulariaceae D.G. Mann
Pinnularia Ehrenberg
Pinnularia borealis var. ***sublinearis*** Krammer, 2000. Fig. 11e
Valve dimensions: L: 36 mm; W: 6 mm; Str: 6 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1616.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 574, pl. 165, fig. 14.

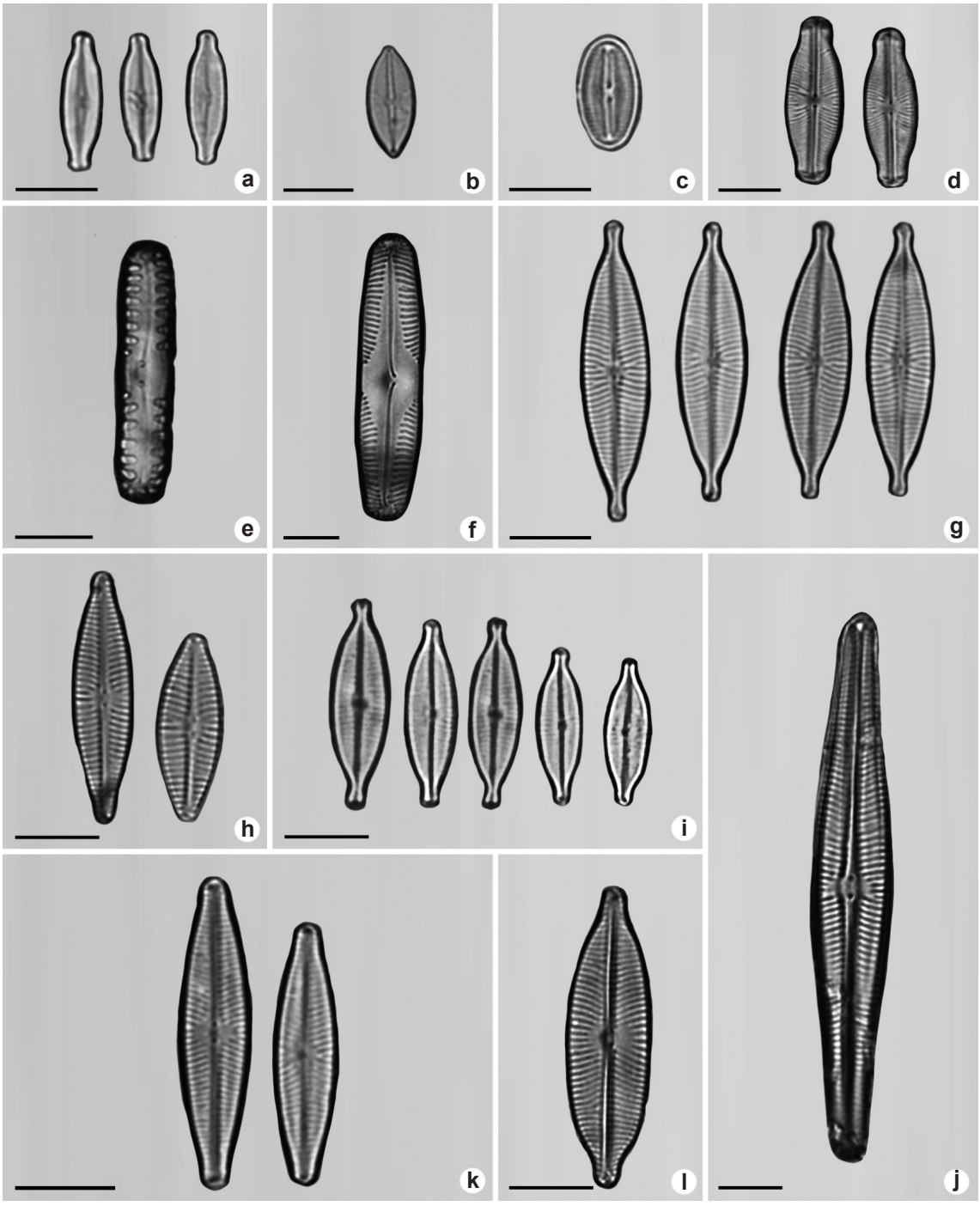


Figure 11 – a-l. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Adlafia bryophila*; b. *Adlafia minuscula*; c. *Fallacia insociabilis*; d. *Sellaphora pupula*; e. *Pinnularia borealis* var. *sublinearis*; f. *Pinnularia parvulissima*; g. *Navicula capitatoradiata*; h. *Navicula cryptotenella*; i. *Navicula gregaria*; j. *Navicula lohmannii*; k. *Navicula notha*; l. *Navicula rostellata.* Scales: 10 µm.

Pinnularia parvulissima Krammer, 2002. Fig. 11f
Valve dimensions: L: 54 mm; W: 10 mm; Str: 9 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: K. Krammer, Diatoms of Europe, v.1. 2000. p. 388, pl. 65, fig. 10.

Naviculaceae Kützing
Caloneis Cleve
Caloneis bacillum (Grunow) Cleve, 1894.
Valve dimensions: L: 19–23 mm; W: 5–6 mm; Str: 20 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611; Puente de Felidia, 8.II.2011, EL1613.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 550, pl. 153, figs. 5,10.

Navicula Bory
Navicula capitatoradiata H. Germain, 1981. Fig. 11g
Valve dimensions: L: 35.9–37.3 mm; W: 7.6–8 mm; Str: 14–15 in 10 mm.
Examined material: COLOMBIA. VALLE DEL CAUC A: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.II.IV, EL1612; Puente de Felidia, 8.II.2011, EL1613, antes de Desviación, 8.II.2011, EL1615, EL1623, 8.IV.2011, EL1624; Puente de Felidia, 8.II.2011, EL1616, 8.IV.2011, EL1626; después de Bocatoma, 8.II.2011, EL1617.
Reference: Metzeltin, Lange-Bertalot, & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 342, pl. 49, figs. 10-18.
Ecology and Distribution: Cosmopolitan species. Found in alkaline waters, high electrolyte content, with moderate oxygen saturation (>50%), α-mesosaprobic, abundant in eutrophic environments, tolerant to critical levels of contamination (Taylor *et al*. 2007; Van Dam *et al*. 1994).

Navicula cryptotenella Lange-Bertalot, 1985. Fig. 11h
Valve dimensions: L: 19.8–28.2 mm; W: 4.8–5.6 mm; Str: 12–14 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 338, pl. 47, figs. 17-20.

Navicula gregaria Donkin, 1861. Fig. 11i
Valve dimensions: L: 17.6–23.2 mm; W: 4.4–4.8 mm; Str: 15–16 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; Puente de Felidia, 8.II.2011, EL1613, 8.IV.2011, EL1626; después de Bocatoma, 8.II.2011, EL1617.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 334, pl. 45, figs. 16,17.

Navicula lohmannii Lange-Bertalot & U.Rumrich, 2000. Fig. 11j
Valve dimensions: L: 79.5 mm; W: 10.7 mm; Str: 11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: Rumrich, Lange-Bertalot & Rumrich Iconogr. Diatomol., v.9. 2000. p. 312, pl. 36, figs. 6-7.

Navicula notha J.H. Wallace, 1960. Fig. 11k
Valve dimensions: L: 27–30.8 mm; W: 5 mm; Str: 19 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610; Lomas de la Cajita, 8.II.2011, EL1618.
Reference: Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 232, pl. 61, figs. 12-23.

Navicula rostellata Kützing, 1844. Fig. 11l
Valve dimensions: L: 37.5 mm; W: 9 mm; Str: 12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 344, pl. 50, figs. 7-11.

Navicula symmetrica Patrick, 1944. Fig. 12a
Valve dimensions: L: 32.6–35.6 mm; W: 6–6.9 mm; Str: 15 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, 8.IV.2011, EL1626; antes de Desviación, 8.II.2011, EL1615, 8.IV.2011, EL1624; después de Bocatoma, 8.II.2011, EL1617, 8.IV.2011, EL1621; Lomas de la Cajita, 8.II.2011, EL1618; Jardín Botánico, 8.IV.2011, EL1622.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 340, pl. 48, figs. 6-9.
Ecology and Distribution: Europe: Germany.

North America: Arkansas, Great Lakes, NW USA, United States of America. South America: Brazil, Colombia. South-west Asia: Iraq. Asia: Taiwan. Australia and New Zealand: Australia, Victoria (<http://www.algaebase.org>).

Circumneutral taxa with optimal development around 7, found in polysaprobic environments with oxygen absent or in very low concentration to β-mesosaprobic. Oligotrophic to eutrophic, supporting large variations in nutrient and mineral concentration, present in electrolyte rich waters, tolerant to heavily polluted environments (Moro & Furstenberger 1997; Taylor *et al*. 2007). Lobo *et al*. (2015) cites this species with a medium tolerance to eutrophication.

Navicula trivialis Lange-Bertalot, 1980.

Fig. 12b

Valve dimensions: L: 41.6 mm; W: 9.6 mm; Str: 11 in 10 mm.

Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.

Reference: Saúl Blanco Lanza *et al.* Diatom atlas of the Duero basin. 2010. p. 226, pl. 58, figs. 42-43.

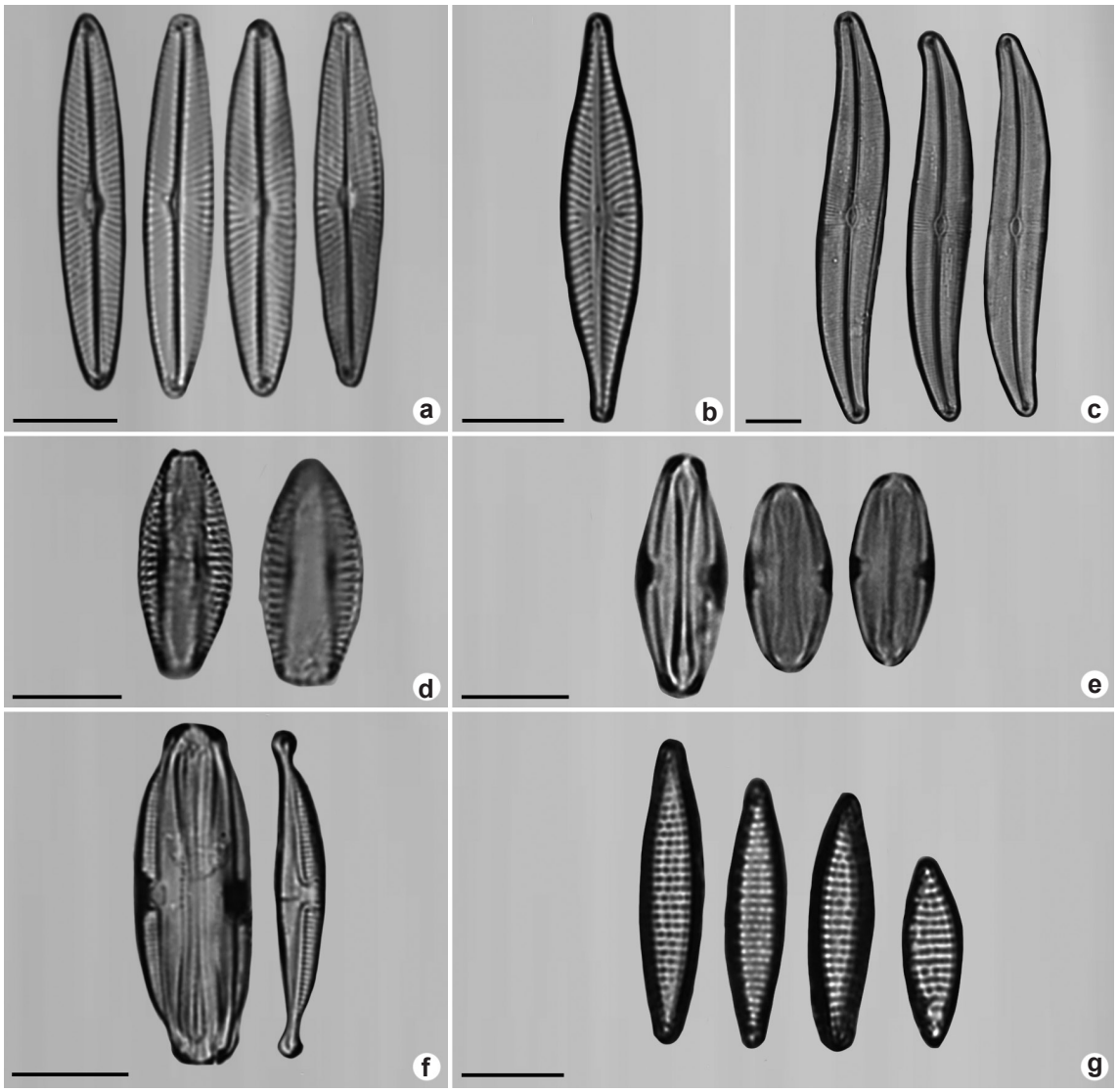


Figure 12 – a-g. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Navicula symmetrica*; b. *Navicula trivialis*; c. *Gyrosigma obtusatum*; d. *Amphora meridionalis*; e. *Halamphora montana*; f. *Halamphora normanii*; g. *Nitzschia amphibia.* Scales: 10 µm.

Pleurosigmataceae Mereschkowsky
Gyrosigma obtusatum (Sullivant & Wormley) C.S. Boyer, 1922. Fig. 12c
Valve dimensions: L: 54.2–78 mm; W: 7.2–11 mm; Str: 16 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611; Lomas de la Cajita. 8.II.2011, EL1618.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 430, pl. 93, figs. 1,2. p. 432, pl. 94, fig. 1.

Catenulaceae Mereschkowsky
Amphora Ehrenberg *ex* Kützing
Amphora meridionalis Levkov, 2009. Fig. 12d
Valve dimensions: L: 20.4–21.6 mm; W: 10.1–10.3mm; Str: 10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1612; Lomas de la Cajita, 8.II.2011, EL1614.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 240, pl. 65, figs. 15-18.

Halamphora (Cleve) Levkov
Halamphora montana (Krasske) Levkov, 2009. Fig. 12e
Valve dimensions: L: 16.9–23 mm; W: 7.1–11 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Lomas de la Cajita, 8.II.2011, EL1614, EL1618, 8.IV.2011, EL1625.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 506, pl. 131, figs. 8-13.

Halamphora normanii (Rabenhorst) Levkov, 2009. Fig. 12f
Valve dimensions: L: 27.2–31.6 mm; W: 4.2–12.5 mm; Str: 20 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610.
Reference: Hofmann, Werum & Lange-Bertalot, Diatomeen im Süßwasser-Benthos von Mitteleuropa. 2013. p. 786, pl. 92, figs. 9,10.

Bacillariaceae Ehrenberg
Nitzschia Hassal
Nitzschia amphibia Grunow, 1862. Fig. 12g
Valve dimensions: L: 18–32 mm; W: 4–5 mm; Fib: 6–7 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 658, pl. 207, figs. 20-33.

Nitzschia cf. ***brevissima*** Grunow, 1880. Fig. 13a
Valve dimensions: L: 37 mm; W: 2.6 mm; Fib: 8 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Lomas de la Cajita, 8.II.2011, EL1614.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 646, pl. 201, figs. 6-9.

Nitzschia dissipata (Kützing) Rabenhorst, 1860. Fig. 13b
Valve dimensions: L: 30.4–47 mm; W: 4–7 mm; Fib: 7–8 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, después de Bacatoma, 8.II.2011, EL1609; Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; Puente de Felidia, 8.II.2011, EL1613, EL1616, 8.IV.2011; Lomas de Cajita, 8.II.2011, EL1614, EL1618, 8.IV.2011, EL1625.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 310, pl. 100, figs. 13-30.
Ecology and Distribution: Cosmopolitan species (Taylor *et al*. 2007). Alkalophyte, high oxygen saturation above 75%, abundant in water of moderate to high electrolyte content, not present in waters with low conductivity. β-mesosaprobic, mesotrophic to eutrophic, tolerant to high nitrogen concentrations (Taylor *et al*. 2007; Van Dam *et al*. 1994).

Nitzschia linearis W. Smith, 1853. Fig. 13c
Valve dimensions: L: 72.8–126 mm; W: 4–5 mm; Fib: 11 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611, 8.IV.2011, EL1612; antes de Desviación, 8.II.2011, EL1615, 8.IV.2011, EL1624; Puente de Felidia, 8.II.2011, EL1616, 8.IV.2011, EL1626.
Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin.2010. p. 312, pl. 101, figs. 1-6.

Nitzschia palea (Kützing) W. Smith, 1856. Fig. 13d
Valve dimensions: L: 24–42 mm; W: 4–5.3 mm; Fib: 11–12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 658, pl. 207, figs. 5-7.

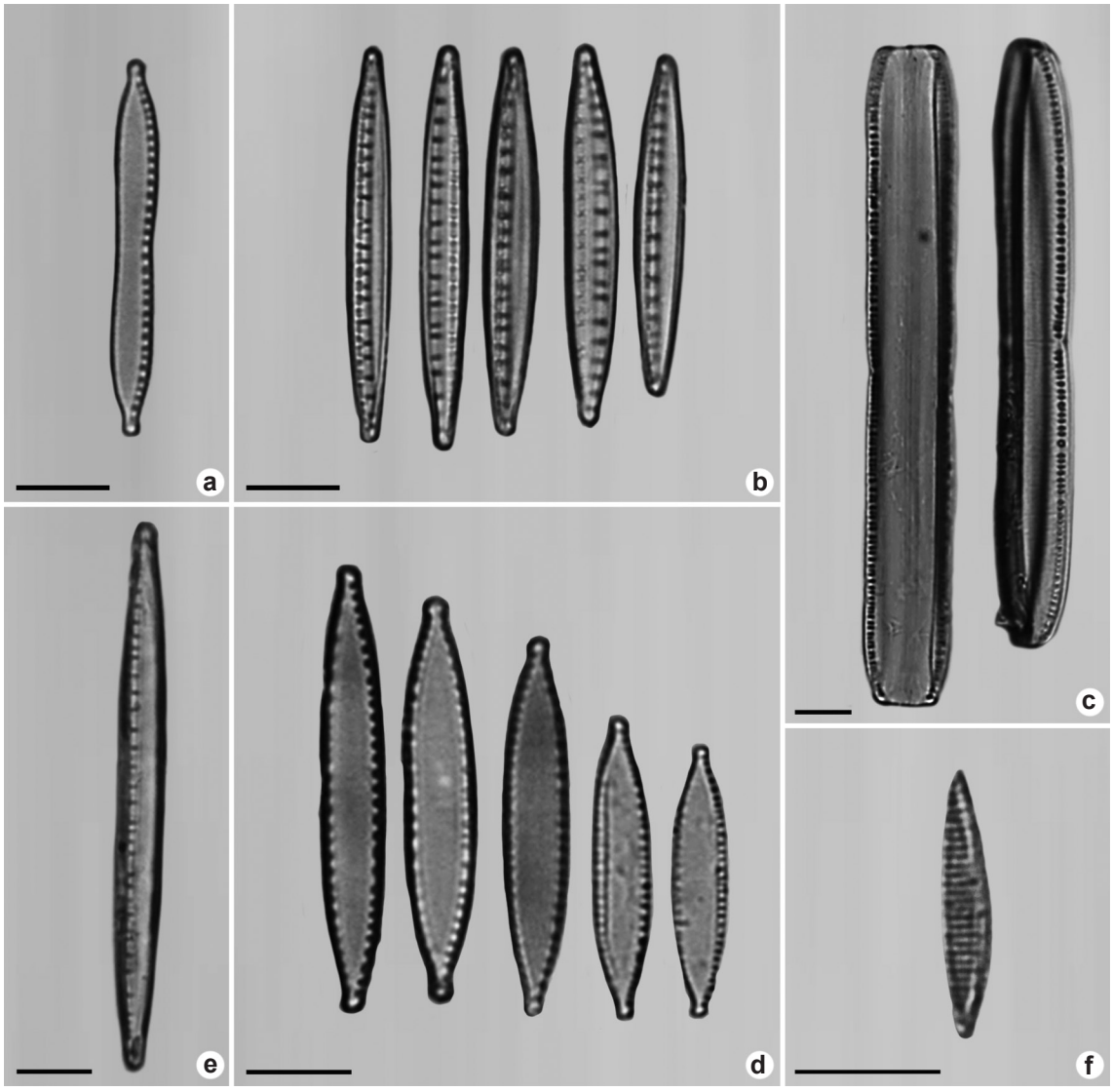


Figure 13 – a-f. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Nitzschia* cf. *brevissima*; b. *Nitzschia dissipata*; c. *Nitzschia linearis*; d. *Nitzschia palea*; e. *Nitzschia recta*; f. *Simonsenia delognei*. Scales: 10 µm.

Nitzschia palea is described as indicator species of polysaprobic or hypereutrophic environments, occurring in waters with low concentrations of dissolved oxygen, according to Van Dam *et al*. (1994), Licursi e Gómez (2002) noted that this species has no affinity for water of higher conductivity. Lobo *et al*. (2002) and Salomoni, *et al*. (2006, 2011) described this species as indicator of very polluted environments.

Nitzschia recta Hantzsch *ex* Rabenhost, 1862. Fig. 13e

Valve dimensions: L: 68 mm; W: 4 mm; Fib: 6 in 10 mm.

Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.

Reference: Saúl Blanco Lanza *et al*. Diatom atlas of the Duero basin. 2010. p. 314, pl. 102, figs. 1-8.

Simonsenia Lange-Bertalot
Simonsenia delognei (Grunow) Lange-Bertalot, 1979. Fig. 13f
Valve dimensions: L: 14 mm; W: 2.5 mm; Str: 17 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611.
Reference: Krammer & Lange-Bertalot, p. 384, pl. 84, figs. 13-17. 1988.

Rhopalodiaceae (G. Karsten)
Rhopalodia O. Müller
Rhopalodia gibba (Ehrenberg) Otto Müller, 1895. Fig. 14a
Valve dimensions: L: 68 mm; W: 23 mm; Str: 10 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 630, pl. 193, fig. 10.

Rhopalodia cf. ***operculata*** (C.Agardh) Håkanasson, 1979. Fig. 14b
Valve dimensions: L: 26.4 mm; W: 5 mm; Str: 20 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Puente de Felidia, 8.II.2011, EL1613.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 630, pl. 193, figs. 8-9.

Rhopalodia gibberula Ehrenberg O. Müller, 1895. Fig. 14c
Valve dimensions: L: 34.3 mm; W: 17.6 mm; Str: 20 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1611.
Reference: Krammer & Lange-Bertalot p. 444, pl. 113, fig. 5. 1988.

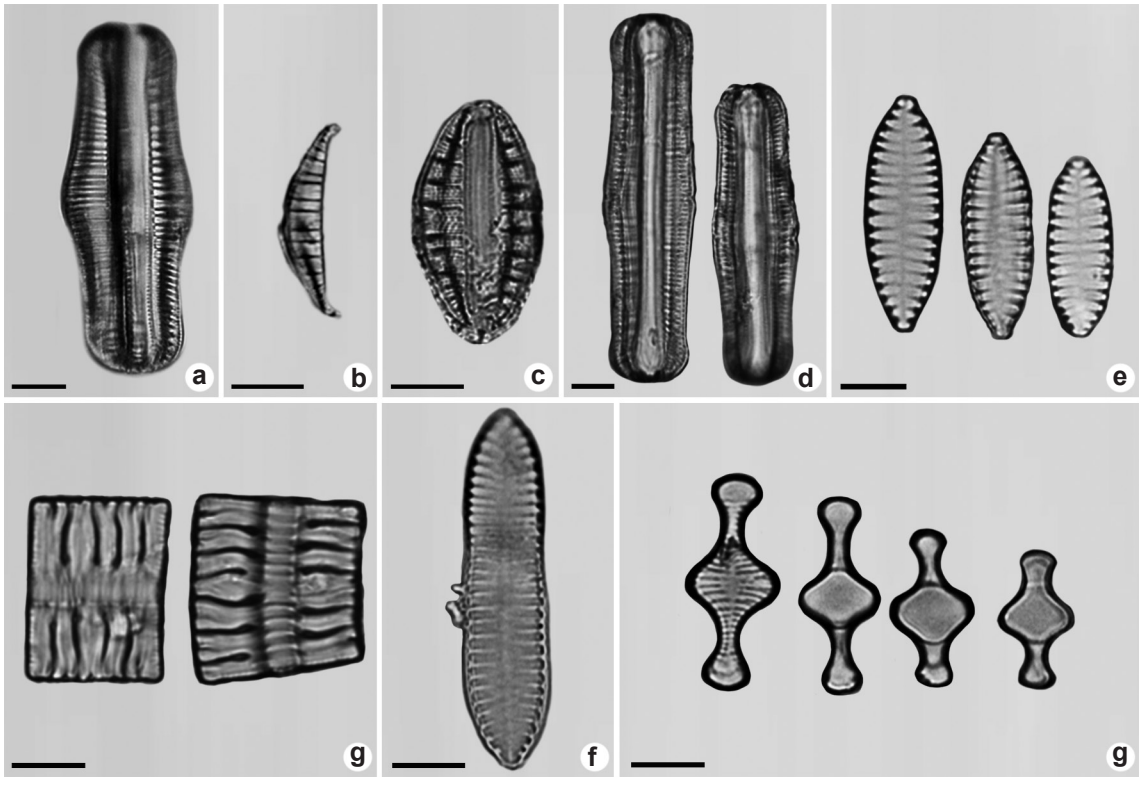


Figure 14 – a-g. Composition of the epilithic diatom flora of the Cali River basin, Colombia – a. *Rhopalodia gibba*; b. *Rhopalodia* cf. *operculata*; c. *Rhopalodia gibberula*; d. *Rhopalodia parallela*; e. *Surirella angusta*; f. *Surirella* cf. *angusta*; g. *Tabellaria flocculosa*. Scales: 10 µm.

Rhopalodia parallela (Grunow) O. Müller, 1895. Fig. 14d
Valve dimensions: L: 77.6–98.8 mm; W: 20.4–22 mm; Str: 12 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, antes de Desviación, 8.II.2011, EL1615.
Reference: Hofmann, Werum & Lange-Bertalot, Diatomeen im Süßwasser-Benthos von Mitteleuropa. 2013. p. 846, pl. 122, fig. 2.

Surirellaceae Kützing
Surirella Turpin
Surirella angusta Kützing, 1844. Fig. 14e
Valve dimensions: L: 18.1–36.8 mm; W: 7.3–9 mm; Fib: 6–8 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.II.2011, EL1610, EL1611; Lomas de Cajita, 8.II.2011, EL1618.
Reference: Metzeltin, Lange-Bertalot & García-Rodríguez, Iconogr. Diatomol., v.15. 2005. p. 686, pl. 221, figs. 1-7.
Reference complementary: Bacillaria, p. 61, est. 30, fig. 52. 1844.

Surirella cf. ***angusta*** Kützing, 1844. Fig. 14f
Valve dimensions: L: 51 mm; W: 9 mm; Fib: 6 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1612.

Tabellariaceae Kützing
Tabellaria Ehrenberg *ex* Kützing
Tabellaria flocculosa (Roth) Kützing, 1844. Fig. 14g
Valve dimensions: L: 18–27 mm; W: 7.7–8.8 mm; Str: 14 in 10 mm.
Examined material: VALLE DEL CAUCA: Cali, Pichindé, 8.IV.2011, EL1611; Puente de Felidia, 8.II.2011, EL1613; Lomas de Cajita, 8.II.2011, EL1614; Puente de Felidia, 8.II.2011, EL1616, 8.IV.2011, EL1626; Jardín Botánico, 8.II.2011, EL1619.
Reference: Krammer & Lange-Bertalot, p. 442, pl. 106, figs. 1, 9, p. 444, pl. 107, figs. 6,7. 1991a.

Conclusion

The epilithic diatom flora of the Cali River hydrographical basin included 82 taxa distributed among 26 families and 38 genera, and 32 species are new occurrences in Colombia. The most representative families were Gomphonemataceae, Naviculaceae, and Bacillariaceae. However, 13 species were considered dominant, characterizing the flora of epilithic diatoms in the Cali River hydrographical basin, Colombia.

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