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Surirella antioquiensis *sp. nov. y* S. rafaelii *sp. nov. (Bacillariophyta) de Colombia*

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Summary: This article is part of a series of studies to produce and inventory of the diatom flora of Colombia. Two *Surirella* taxa –*S. antioquiensis* S.E. Sala, J.J. Ramírez, Plata-Díaz & Vouilloud and *S. rafaelii* J.J. Ramírez & S.E. Sala– from lotic and lentic aquatic systems in the Department of Antioquia (Colombia) are proposed as new species. Both new species were analyzed with light and scanning electron microscopy. Each taxon is described and illustrated and information about environmental conditions of sampling sites is given.

Key Words: Andean region, Colombia, diatoms, lentic systems, lotic systems, *Surirella*, Tropics

Resumen: Este artículo forma parte de una serie de estudios que se llevan a cabo para realizar un inventario de la flora diatomológica de Colombia. En él se describen dos especies del género *Surirella* –*S. antioquiensis* S.E. Sala, J.J. Ramírez, Plata-Díaz & Vouilloud y *S. rafaelii* J.J. Ramírez & S.E. Sala– provenientes de sistemas lénticos y lóticos localizados en el Departamento de Antioquia, Colombia. Ambas especies fueron analizadas con microscopio de luz con contraste de fases y microscopio electrónico de barrido. Cada taxón es descrito e ilustrado y se brinda información acerca de las condiciones ambientales de los sitios en que fueron colectados.

Palabras clave: Colombia, diatomeas, región Andina, sistemas lénticos, sistemas lóticos, *Surirella*, trópicos

1 Introduction

Although it is widely assumed that microalgae are ubiquous and cosmopolitan, there are evidences that this is an erroneous assumption especially in tropical and subtropical areas. One of the most consulted diatom references around the world is the *Süßwasserflora von Mitteleuropa* [25][27][28][29], but as Metzeltin & García-Rodríguez [36] pointed out, it should be used only in Central Europe and with caution in other zones. This limitation owes to the fact that the species of Central Europe could be quite similar to those of other regions, but they are not always the same from other latitudes [1][12][13][14][34][35][39], especially those from the circumtropical areas. We are convinced that researchers of these latitudes must invest a great effort to generate their own information. The present study is part of a series of investigations carried out in order to inventory the diatom flora of Colombia.

The genus *Surirella* Turpin is the founding member of the family Surirellaceae, established by Kützing [30]. According to Fourtanier & Kociolek [20], *Surirella* comprises around 1,700 species. Peragallo & Peragallo [41], divided the genus in three subgenera groupings –Fastuosae, Robustae and Pinnatae– which differ in the morphology of the keel and associated supporting structures [6]. Ruck & Kociolek [47] held a preliminary analysis of the phylogeny of the Family Surirellaceae and found that *Surirella* is not a monophyletic group, but until more studies are held it is useful to follow the classic system of clustering.

While most representatives of the Fastuosae group live in marine and brackish habitats, have keels directly attached to the valve, opening internally through portulae, the Robustae group lives predominantly in freshwaters and the major part of the species have keels and wings connected to the valve by alar canals separated by fenestrae. The Pinnatae group can be separated into two subgroups, one comprising the big forms with morphology similar to *S. ovalis* Bréb.; and the second group –conformed around *S. minuta* Bréb. ex Kütz.– that comprises more delicate forms [26]. The species of the Pinnatae group do not have wings or alar canals, but have costate fibulae and portulae that connect the raphe canal with the inner part of the valve. The costae are transverse and the striae are generally multiseriate; both interrupted at valve centre by a hyaline area. The frustule is heavily silicified, isopolar or heteropolar, sometimes twisted. The valves are linear, elliptic or ovate, plane or concave.

Most *Surirella* species have a subcosmopolitan distribution –defined by O´Sullivan & Reynolds [40], as "species that occur throughout the world, but

always in specialized environments"– and a highest species richness in circumtropical environments. According to Karthick *et al.* [24], *Surirella* species from tropical freshwaters have received much attention due to the high percentage of endemisms reported across different continents. Many *Surirella* species from tropical regions were described during the 19th and early 20th centuries by Ehrenberg, Müller and West [12][14]. Karthick *et al.* [24] pointed out that Ehrenberg [19], reported the first *Surirella* species from the Indian subcontinent and was followed by Dickie [16], and West & West [59], among others. Cocquyt & Jahn [9][11][12][13] considered that *Surirella* species are typical components of the diatom flora of the African Great Lakes (Malawi, Nyassa, Tanganika and Victoria), with nearly 50 taxa, several of them endemic from Eastern and Central Africa. In the Malili Lakes located in the Sulawesi Island in Indonesia, Hustedt (in Huber-Pestalozzi [21]) identified 46 taxa of *Surirella*, many of them endemic, and later Bramburger *et al.* [6] studied 35 species from the same lakes, eleven of which were new to science. According to these latter authors, the high number of *Surirella* species found in the lakes of Malili put these sites at the top as the world hotspot of diversity for this genus. Cocquyt [8] found 36 *Surirella* taxa in the northern basin of Lake Tanganyika. In Papua New Guinea, Vyverman [56] registered 17 taxa and many unknown taxa. These findings place these zones as areas with a diversity comparable to that of the Malili Lakes. In the tropics of America, Krasske described *S. arctissima* var. *muscicola* Krasske from Brazil and *S. columbiensis* Krasske from Colombia and Brazil [31]. More recently, Metzeltin & Lange-Bertalot [34] reported *S. citrus* Metzeltin & Lange-Bert. from Kaiereteur Falls, Potaro River (Guyana), *S. rotti* Metzeltin & Lange-Bert. from Iguassu River (Brazil), *S. rumrichorum* Metzeltin & Lange-Bert. from Laguna Negra (Venezuela), *S. tenerisilex* Metzeltin & Lange-Bert. from Essequibo River (Guyana) and *S. susanae* Metzeltin & Lange-Bert. from Laguna Agua Azul (México). Wydrzycka & Lange-Bertalot [58] registered *S. bryophila* Lange-Bert., Wydrzycka & Metzeltin from the Agrio River in Costa Rica, while Blanco *et al.* [5] described *S. moralesii* S. Blanco, Álvarez-Blanco & Cejudo-Figueiras from Lake Honda in Bolivia.

Due to their large and heavy frustules, *Surirella* species are rarely euplanktonic and live in littoral habitats, being part of the phycoperiphyton, the metaphyton, the episammon or the epilithon [6]. Besides, *Surirella* species are sometimes common in acid waters in high-altitude lakes and peats and they develop in waters moderately rich in organic matter, but they are more common in waters with high temperatures, alkaline pH values, and relatively high conductivity [6].

In Colombia, although there are numerous records of diatoms in studies on periphyton ecology [15][18][33][38][45][60], paleoecological investigations [32], and studies on phytoplankton ecology [3][42][43][44], among other fields, the knowledge on taxonomy of freshwater algae in general –and particularly for the

diatoms– is scarce. Identifications are mostly made by ecologists, with the consequent burden of mistakes that this practice generates. In the majority of the mentioned papers, *Surirella* taxa were identified up to the genus level and the only reports at the species level are *S. columbiensis* Krasske [17] and *S. guatimalensis* Ehrenb. [37].

In a preliminary study held in lentic and lotic systems from the Antioquia Department, almost 90 diatom taxa were identified (unpublished data). Approximately 30% of them could not be assigned to recognized taxonomic entities, so they are presumably new for science. In this article, we describe two *Surirella* taxa found in this Colombian region.

2 Methodology

Samples containing the two new species described here were collected from lotic and lentic environments in the Department of Antioquia (05º 26' 20" N, 08º 52' 23" N and 73º 53' 11" W, 77º 07' 16" W), which is located in the Andean mountainous system in Colombia.

Epilithon samples from La Vega Stream (San José del Nus Municipality) were collected between August, 2001 and April, 2002 at three sampling places. The sample from El Carmen de Viboral was collected squeezing plants of *Nymphoides* sp., the dominant macrophyte of a small pond in November, 2003.

Samples were fixed with 10% Lugol or 6-8% formaline and were treated to eliminate organic matter following the method described in CENT 230 [7]. Samples for light microscopy (LM) were mounted in Naphrax ®; and for scanning electron microscopy (SEM) they were mounted on glass stubs and coated with gold-palladium in a Jeol FINE COAT ION SPUTTER JFC-1100. Observations were conducted with a Wild M20 LM and a Leica equipped with DM 2500 phase contrast for LM and a Jeol JSM-T100 for SEM at the Servicio de Microscopía Electrónica del Museo de La Plata.

The terminology used is that suggested in Anonymous [2], Barber & Harworth [4], Ross *et al.* [46] and Ruck & Kociolek [47].

Type material, holotypes and isotypes are deposited in the Herbario, Departamento Científico, Ficología, Museo de Ciencias Naturales de La Plata, Argentina (LPC). Although we analyzed several samples from Antioquia, we mention only those containing the new species:

– *LPC10003*: La Vega Stream, San José del Nus Municipality, Department of Antioquia, Colombia. April, 2002. Collector: Esnedy Hernández.

–*LPC10011*: El Carmen de Viboral Municipality, Department of Antioquia, Colombia. November, 2003. Collector: Yimmy Montoya.

3 Results and Discussion

Surirella antioquiensis **S.E. Sala, J.J. Ramírez, Plata-Díaz & Vouilloud** ***sp. nov.*** **(Figs 1-2)**

Holotype: Designated here: LPC 10011 (Slide1, Finder: P 34-2). El Carmen de Viboral Municipality, November, 2003. Collector: Yimmy Montoya. The valve representing the holotype is illustrated in Figs 1B-C.

Type locality: El Carmen de Viboral Municipality, Department of Antioquia, Colombia (6° 05' 09" N, 75° 20' 19" W).

Etymology: the specific epithet *antioquiensis* refers to the Department of Antioquia, the geographic region where the type locality is located.

Description. Light Microscope. Cells isopolar, lanceolate with cuneate poles; the longer specimens with a more or less linear outline. Valve face without concentric undulations, transapical costae strongly visible reaching the conspicuous axial area, parallel at valve center radial to the poles (Figs 1A-G).

*Scanning Electron Microscope***.** Valves slightly curved towards the girdle at the poles. Valve face in external view slightly transapically undulated due to the distinct and irregular groupings of striae and Type II costae separated by 1-2 small sunken costae that extend out to the axial area, a straight hyaline line (Figs 1H-L). Each 'group' has 3-4 uniseriate striae composed of circular areolae exceptionally transapically elongated (Fig. 1K). Striae and costae are radial towards the poles and parallel at the valve center (Figs 1H-J). The mantle is shallow with the same height alongside and the same structure of the valve face (Figs 1J, L).

In internal valve view, fibulae and portulae are evenly spaced (Figs 2A-D). Fibulae type III, reaching the sternum, are robust and broaden at the basis. The interfibular spaces present one elliptical portula. The fibulae correspond to the externally sunken costae (Figs 2C-D). Raphe canal smooth only slightly elevated above the valve surface. Raphe interrupted at both poles externally, with straight and distant ends without terminal pores (Fig. 1L).

Morphometric data (n=30): length: 14-32 μm, width: 6.4-7.6 μm, L/W: 2.7-4.5, striae: 26-27 in 10 μm: fibulae: 60-82 in 100 μm, areolae: 53-65 in 10 μm.

Ecological data: epiphythic taxon on *Nymphoides* sp. plants in a small pond located at 2,200 m a.s.l. This species is abundant and coexists with small diatoms of

the genera *Gomphonema* Ehrenb., *Achnanthidium* Kütz., *Planothidium* Round & Bukhtiyarova and *Nitzschia* Hassall.

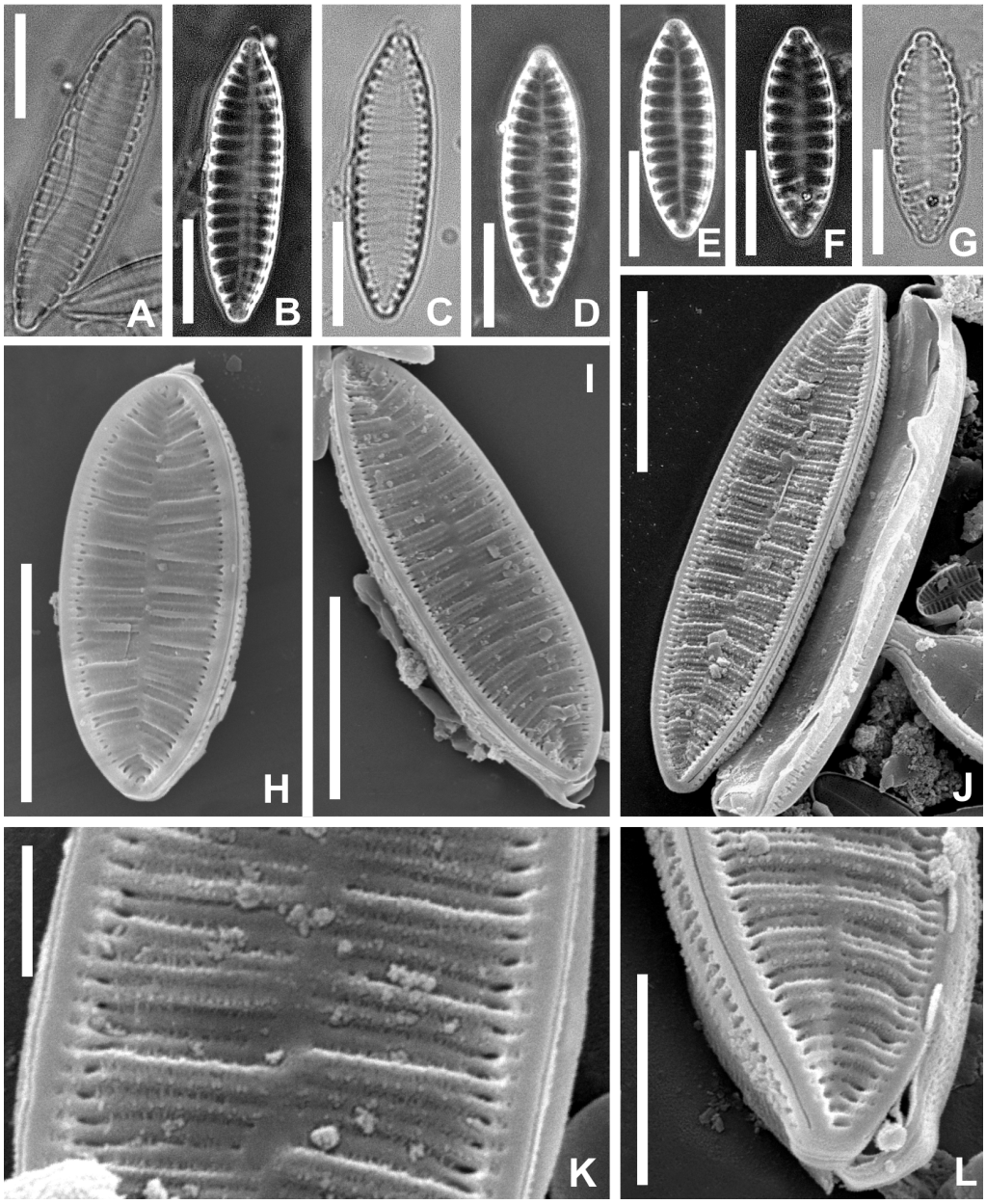

Figure 1: *Surirella antioquiensis* sp. nov. LM: **A–G.** Valves showing size range variation. SEM: **H–J.** External valve view. **K.** Detail of the valve center. **L.** Detail of the valve end. Scale bars: **A–J:** 10 μm; **L:** 5 μm; **K:** 2 μm.

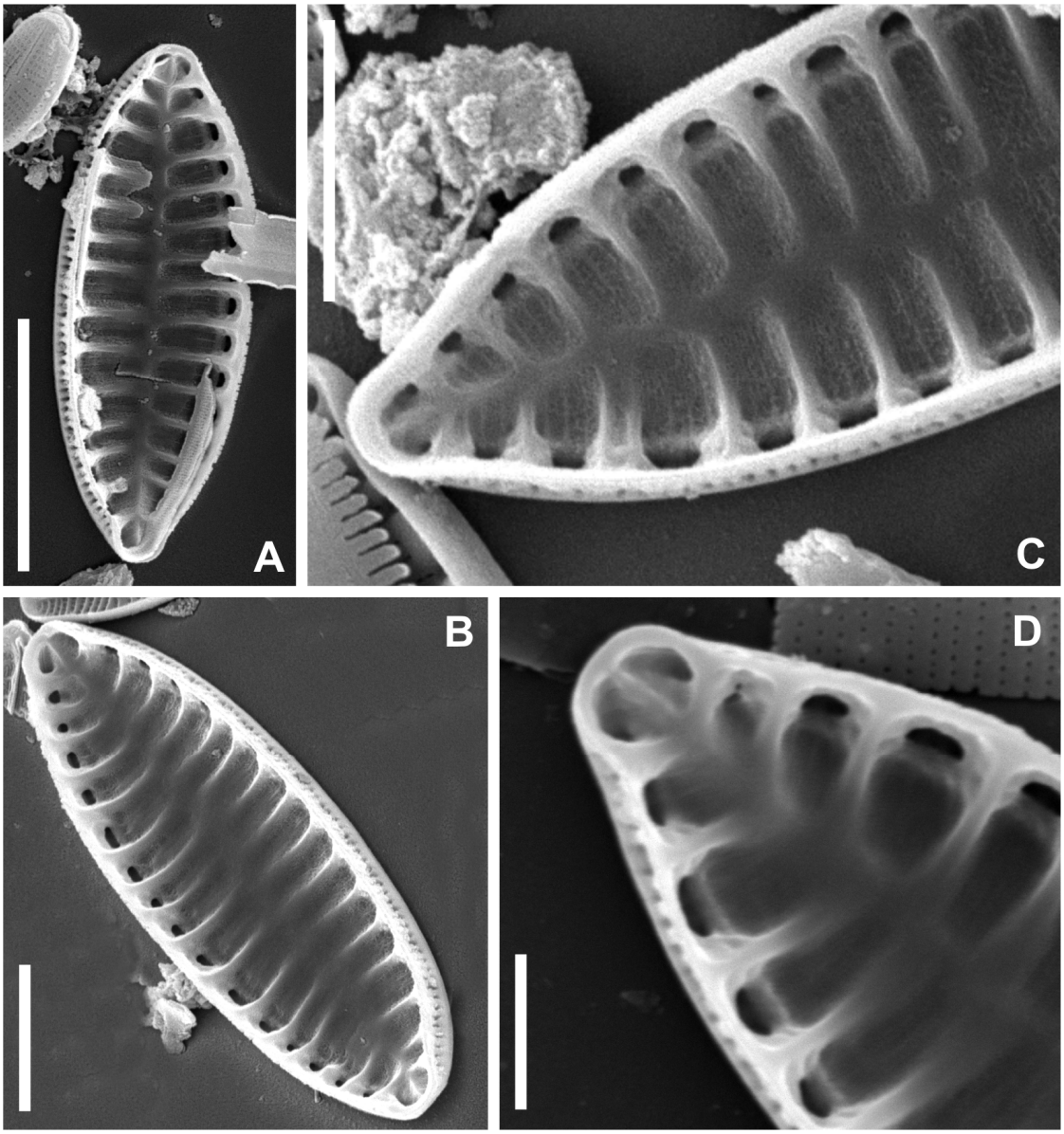

Figure 2: *Surirella antioquiensis* sp. nov. SEM: **A–D.** Internal valve view. **C–D.** Details of the valve center and end. Scale bars: A: 10 µm; B–C: 5 µm; D: 2 µm.

Distribution: This species is only known from a small pond at El Carmen de Viboral Municipality.

Remarks: the studied material belongs to the Pinnatae group; it is similar in size and structure to *S. minuta*, but clearly differs in the isopolar valve outline. *Surirella angusta* Kütz., a small isopolar species, is the closest described taxon. Information

about the valve morphology of this widely distributed species is scarce, so comparisons were done against the type material photographed with LM in Krammer & Lange-Bertalot [29]. Our material differs from *S. angusta* in its smaller size and also in valve outline, lanceolate in *S. antioquiensis* and with parallel margins in *S. angusta* (Table 1).

The studied material is also similar to materials from Crater Lake, Oregon (CAS 622015) designated as *S.* cf. *angusta* in [47]. LM photographs [47] show that this taxon has straight margins in valve view, slightly constricted at midvalve, and parallel costa alongside. Besides, under SEM, they differ in striae structure, multiseriate in *S.* cf. *angusta* and uniseriate in *S. antioquiensis*. The lower costae are connected to the grouped costa, by few and fine siliceous elements in *S. antioquiensis* (Fig. 1K), while in *S.* cf. *angusta* these elements are numerous and conspicuous [47]. The studied material differs also in valve structure with the North American valves in their wider axial area and the parallel and short costae all alongside [47]. These two taxa also differ in fibulae and areolae density (Table 1). Although, in external view these taxa can be confused, differences in internal view are conspicuous as the valves in *S.* cf. *angusta* are more robust, fibulae are short and thick and interfibular spaces are triangular.

Table 1: Comparison of *Surirella antioquiensis* with allied taxa.
(---:no data, *: measured on the illustrations)

Taxon	Bibliography	Length (µm)	Width (µm)	L/W	Fibulae in 100 µm	Striae in 10 µm	Areolae in 10 µm
S. antioquiensis (n=30)	This study	14.0-32.0	6.4-7.6	2.7-4.5	60-82	26-27	53-65
Surirella ¿nov? spec*	Metzeltin *et al.*[34]	28.0-33.5	8.0-8.7	3-4	60-75	27- 31	---
S. angusta	Krammer & Lange-Bertalot [29]	18.0-70.0	6.0-15.0	3-5	55-80	22-28	---
S. cf. *angusta*	Ross *et al*. [46]	31.0-34.0	7.0-8.0	4.5-4.3	77-80	---	140-160
S. subantarctica	Van de Vijver *et al*. [55]	36.7-63.3	11.5-13.9	2.9-4.8	40-60	22-23	120
S. heardensis	Van de Vijver *et al*. [55]	21.4-78.9	8.6-12.4	2.5-6.4	(45)50-60	22-25	120

The specimens described in [34] from Brazil, Iguazú Falls and Río Tec (Venezuela) as "*Surirella* (nov?) spec." coincide with *S. antioquiensis* in dimensions,

general LM and SEM appearance, and South American tropical distribution, but other details of this taxon are insufficient to be sure if they are conspecific (Table 1).

Other taxa with similar valve morphology are *S. subantarctica* Van de Vijver & Cocquyt and *S. heardensis* Van de Vijver & Cocquyt [55]. These taxa differ from the studied material in dimensions (Table 1), but also in the multiseriate structure of the striae, the number of portulae: a large one with two small ones on each side, among other morphological details.

***Surirella rafaelii* J.J. Ramírez & S.E. Sala *sp. nov.* (Figs 3-4)**

Holotype: Designated here: LPC 10003 (slide 1, Finder: O28-4). La Vega Stream, Municipality of San José del Nus, April, 2002. Collector: Esnedy Hernández. The valve representing the holotype is illustrated in Figs 3B-C.

*Type locality***:** Municipality of San José del Nus, Department of Antioquia, Colombia. (6° 29' 30" N, 74° 49' 30" W).

Etymology: the specific epithet *rafaelii* refers to the Zoologist Rafael Urrejola, Universidad Nacional de La Plata, Buenos Aires, Argentina.

*Description. Light Microscope***.** Frustules isopolar in valve and girdle view (Figs 3A-F, 4A). Valves parallel with a short pervalvar axis (Fig. 4A). Valves linear-lanceolate with parallel margins in the smaller specimens (Figs 3A-B) and slightly constricted at midvalve in larger specimens (Figs 3 C-F), apices bluntly cuneate. Valve face strongly transpically undulated, axial area straight slightly elevated with a conspicuous median ridge not reaching the apices (Figs 3 A-F).

Scanning Electron Microscope. Valve face regularly corrugated; axial area sligthly elevated in external view with a thin irregular ridge not reaching the valve apices (Figs 3G-H). The entire valve face is transapically striated. Striae are uniseriate with circular areolae difficult to see even with SEM (Figs 3H-J). In external view, the interstriae are covered with small granules arranged in transapical rows, more densely disposed near the central keel (Fig. 3H). Alar canals slightly wider than the fenestrae (Fig. 3G). Wings well developed (Fig. 4B), fenestrae short with 3-6 fenestral bars (Figs 3H, J, 4 B-D). Tendrils solitary or eventually grouped (2-3), ribbon-like with sharp ends placed at the base of the fenestrae (Figs 3J, 4B-D, F). Raphe canal with transversal ribs (Fig. 3H-J), raphe externally interrupted at both ends, curved towards the mantle and with terminal small pores (Figs 3 I-J, 4F). Mantle completely perforated with areolae irregularly arranged (Fig. 4E). Girdle with few broad bands, valvocopula interrupted near midvalve (Figs 4B, G). Internally, the alar canals open in simple portulae (Figs 4 E, H-I) and the mantle and the valve face have the same structure (Figs 4I).

Morphometric data (n=40): length: 56-112 μm, width: 14-19 μm, L/W: 3-7, pervalvar axis: 15.7-17.8 μm, alar canals: 21-30/100 μm, striae in 10 μm: 30-48, areolae in 10 μm: approximately 60.

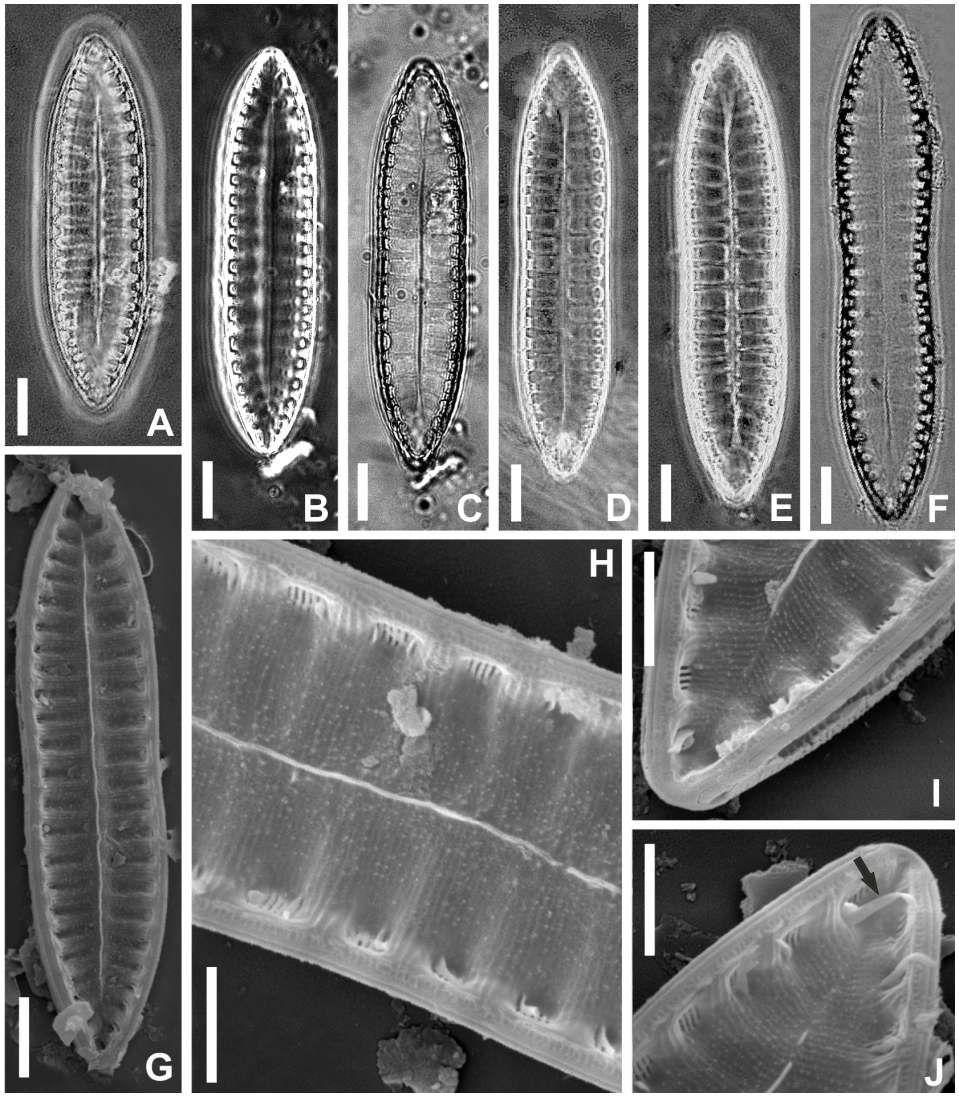

Figure 3: *Surirella rafaelii* sp. nov. LM: **A–F**. Valves showing size range variation. SEM: **G.** External valve view. **H.** Detail of the valve center. **I–J.** Details of both valve ends. Scale bars: A–G: 10 μm; H–J: 5 μm.

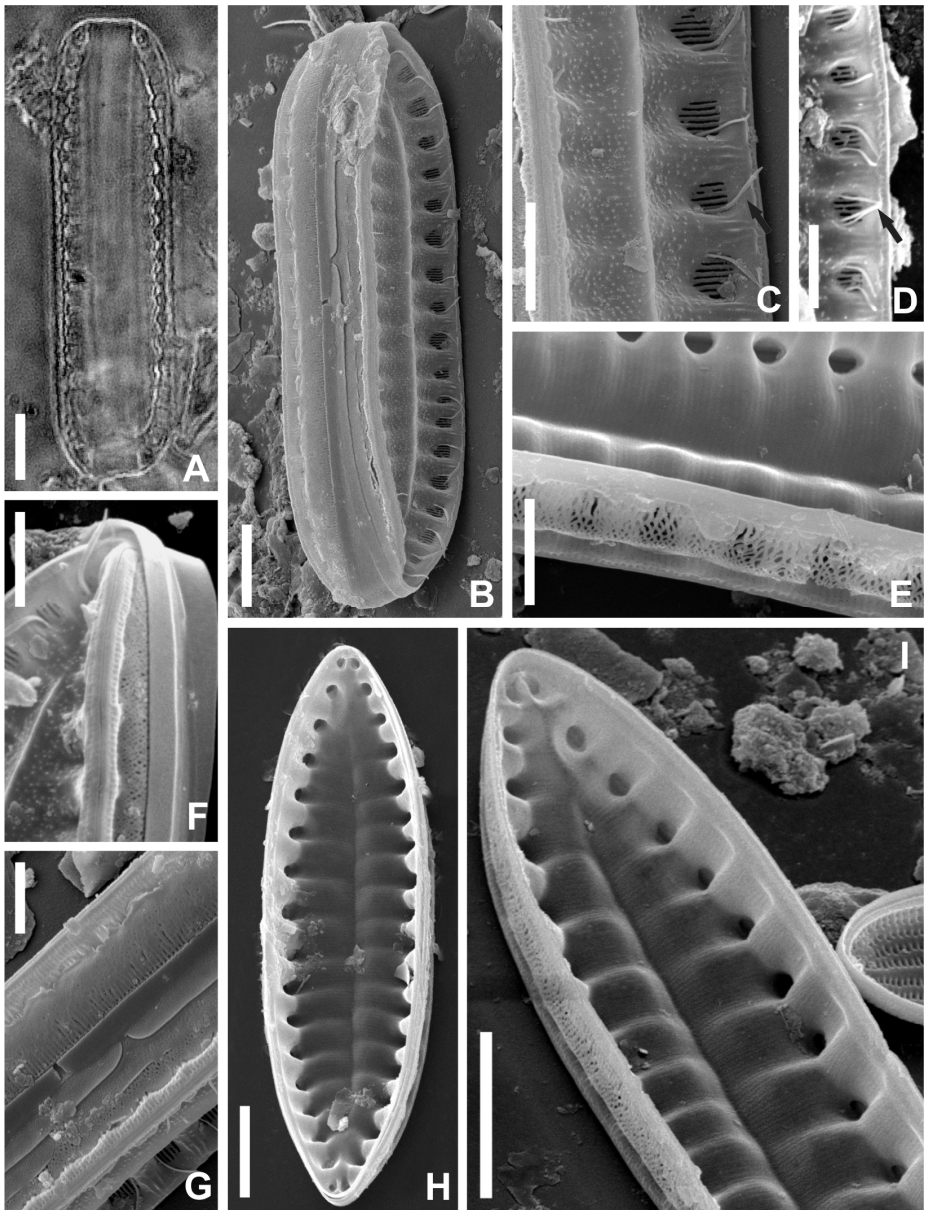

Figure 4: S*urirella rafaelii* sp. nov. LM : **A.** Frustule in girdle view. SEM: **B.** Frustule in girdle view. **C–D.** Detail of the external valve face showing the fenestrae and tendrils. **E:** Detail of valve mantle. **F:** Detail of one valve end. **G:** Detail of the girdle showing the interrupted valvocopulae. **H:** Internal valve view. **I:** Detail of the internal valve surface, portulae and mantle. Scale bars. Figs. A–B, H–L: 10 μm; C–G: 5 μm.

Ecological data: elevation: 651 m a.s.l., water temperature: 21.4-26.3º C, pH: 6.64-7.90, dissolved oxygen: 6.9-8.0 mg L^{-1}. In the study area this species is rare and coexists with diatoms of the genera *Cocconeis* Ehrenb., *Navicula* Bory and other small naviculoids.

Distribution: this species is only known from a stream at San Jose del Nus Municipality.

Remarks: this taxon belongs to the Robustae group and was compared with isopolar taxa with median ridge as *Surirella engleri* O. Müll., *S. sublinearis* Hust., *S. sublinearis* var. *suggesta* Bramburger & P.B. Hamilton, *S. angusticostata* Hust., *S. susanae* Metzeltin & Lange-Bert., *S. feuerborni* Hust., *S. biseriata* var. s*plendida* f. *constricta* Hust., *S. gradifera* Hust. and *S. acuminata* Hust. (Table 2). *Surirella engleri, S. susanae*, *S. feuerbornii*, *S. biseriata* var. s*plendida* f. *constricta* and *S. gradifera* differ from the studied material in dimensions and/or alar canal densities.

Table 2: Comparison of *Surirella rafaelii* with allied taxa (---:no data, *: measured in the illustrations)

Taxon	Bibliography	Length (µm)	Width (µm)	L/W	Fibulae in 100 µm	Striae in 10 µm
S. rafaelii (n= 40)	This study	56.0-112.0	14.0-19.0	3-7	21-30	30-48
S. sublinearis	Blanco *et al*. [5]	45.0-75.0	13.0-22.0	---	40	42
S. sublinearis var. *suggesta*	Blanco *et al*. [5]	40.0-60.0	13.0-16.0	---	30-40	30-44
S. angusticostata	Husted [22]	25.0-105.0	9.0-21.0	---	40-50	---
S. engleri O. Müll.	Cocquyt & Jahn [13]	115.0-360.0	17.2-60.0	---	13-28 (32)	---
S. susanae	Metzeltin & Lange-Bertalot [34]	110.0-175.0	29.0-31.0	4-5	22	
S. feuerbornii	Huber-Pestalozzi [21]	150-300	25-40	---	15	---
S. biseriata var. *splendida* f. *constricta*	Sala *et al*. [53] *	120-234	27-49	---	12	---
S. gradifera	Sala *et al*. [53] *	136-153	15.3	---	30.5	---
S. acuminata	Sala *et al*. [53] *	152-162	28-30	---	24	

Besides, *S. rafaelii* resembles *S. engleri* in the valve outline and the axial area, but the type material studied by Cocquyt & Jahn [13] differs from our material in the siliceous granules only distributed on the depressions of the valve face, the

elongated fenestrae, the absence of tendrils and the raphe channel with longitudinal costae. The studied material differs from *S. sublinearis* and *S. sublinearis* var. *suggesta* [6] in the numerous alar canals (see Table 2), in the absence of a silica ridge or keel along the axial area, and the long and grouped filiform tendrils. Besides, it differs from var. *suggesta* in the spinules arranged in parallel rows across the valve face becoming irregular dispersed in the central area and also in the raphe endings. All of these species were described from tropical areas, but only *S. susanae* from South America.

4 Conclusions

This study was held within the framework of a research project to produce an inventory of the Colombian diatom flora. The research is carried out in different regions of the country such as Antioquia, Santander, Chocó, Córdoba and Amazonia, as well as low and high-altitude waterbodies. While the genus *Surirella* is highly diversified in tropical zones of Africa and Asia, few species have been described from the neotropics until now. In the Colombian regions studied thus far, the genus was poorly represented both from qualitative and quantitative points of view. The species analyzed here were only found in Antioquia, a Department that belongs to the Antioquian Mountain subregion located in the Andean region. These aquatic systems are located in sites with different elevation. While La Vega stream is placed between 1,250 and 790 m a.s.l. in the subtropical level, El Carmen de Viboral is located between 3,340 and 800 m a.s.l. in the mesothermic or temperate level.

Surirella antioquiensis is close to *S. angusta* and *S.* cf. *angusta* in Ruck & Kociolek [47] and "*Surirella* (¿nov?) spec." in Meltzeltin & Lange-Bertalot [34]. The latter species, collected in Brazil and Venezuela, is similar in external valve morphology to the studied material, but data given by the authors are insufficient to establish if they are conspecific.

Surirella rafaelii, an isopolar species, was compared with related taxa with prominent median ridge that belongs to the Robustae group. Although there are several species that can be confused under LM, details of the valve morphology allow its distinction from other species. Filiform tendrils are present in other *Surirella* species [6], but ribbon like tendrils have not been described for any species in the genus up to this date.

The results of this study are consistent with those obtained in previous studies about the genera *Brachysira* Kütz., *Cyclotella* Kütz. ex Bréb., *Encyonema* Kütz., *Urosolenia* Round & R.M. Crawford, from continental water bodies of Colombia, where near one third of the taxa could not be assigned to known entities [48][49][50][51][52][53][57]. This situation allows us to conclude that Colombia has

a richer diatom flora than presumed to date, and that it is necessary to generate literature for identification of local taxa, especially if the intention is to apply this information to bioindication, paleoecology, and/or limnology.

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