Nupela species (Naviculales: Bacillariophyceae) from Colombian lowland waters including *N. acaciensis* nov. sp. and *N. catatumbensis* nov. sp.

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Abstract: The genus *Nupela* comprises *ca.* 50 species that generally have a distribution restricted by bioclimatic frontiers. As part of an integrated analysis of the diatom flora of Colombia, in this study we focused our interest on the genus *Nupela* from lowland waters. Periphyton samples were collected from 150 sites of lotic water bodies in Colombia, taking into account hidrogeomorfological variability. In each sampling station, periphyton samples were obtained by scraping, and temperature, pH, dissolved oxygen and conductivity variables were measured. Samples were processed by both light microscopy (LM; Carl Zeiss Axio Scope.A1) and scanning electron microscopy (SEM; FEI-Quanta 450 and a Jeol JSM-6360 LV). The genus *Nupela* was found in 28 sites. Five taxa were identified, described and illustrated from tropical or subtropical environments: *N. lesothensis*, *N. praecipua* y *N. subpallavicinii*; these were new records for Colombia, and *N. acaciensis* and *N. catatumbensis* two new species for science. *N. acaciensis* is characterized by raphe branches of both valves equally long combined with cymbelloid symmetry, striae built by 2 transapically elongated areolae that delimit a longitudinal line at each hemivalve. *N. catatumbensis* is characterized by the presence of a well developed raphe in both valves; valves lanceolate with subcapitated to capitated ends and cymbelloid symmetry, striae built by 3-4 transapically elongated areolae, interestriae elevated as transapical ribs and internal proximal raphe ends hook-shaped. The genus *Nupela* was widely distributed in the studied basins but showed different distribution patterns: *N. acaciensis* and *N. subpallavicini* had a restricted distribution, while *N. catatumbensis*, *N. lesothensis* and *N. praecipua* had a wider distribution, and were collected in sites with significant variations in their ecomorphology, altitude, temperature, pH and electrolyte content. Rev. Biol. Trop. 62 (1): 241-255. Epub 2014 March 01.

Key words: *Nupela, Nupela acaciensis*, *Nupela catatumbensis,* diatoms, Bacillariophyceae, neotropics, Colombia.

The genus *Nupela* was erected by Vyverman & Compère in 1991, based on materials collected in acid waters at Mont Giluwe, New Guinea. The most important character that defines the genus is the areolae structure, transapically elongated, with external big foramina and internal hymen perforated at the centre. Each stria is built by few areolae and presents a hyaline marginal area. Valves are sometimes transapically curved (cymbelloid frustules) and sometimes they are curved on the pervalvar axis combined with the presence of rudimentary or shortened raphe in one valve (achnanthoid frustules).

Although the genus was erected on the basis of *N. giluwensis* Vyverman & Compère, afterwards Lange-Bertalot (1993) and Lange-Bertalot & Moser (1994) described new species and transferred other taxa from the genera *Achnanthes, Anomoeoneis, Navicula*, *Rhoicosphenia* and *Stauroneis* to *Nupela.* Later other authors studied the genus, transfered more species and

described new taxa (Monnier, Lange-Bertalot, & Bertrand, 2003; Potapova, Ponader, Lowe, Clason, & Bahls, 2003; Siver, Hamilton, & Morales, 2007; Kulikovskiy, Lange-Bertalot, & Witkowski, 2009; Wojtal, 2009; Siver, Wolfe, & Edlund, 2010; Potapova, 2013). In the original description heterovalvar frustules are not mentioned. Lange-Bertalot & Moser (1994) and Potapova et al. (2003) described heterovalvar species, but did not redefine the genus. Monnier et al. (2003) considered that the presence of one valve with reduced raphe is a character of *Nupela* and pointed out that it is a character defined by practice.

At present, the genus *Nupela* comprises around 50 species (Wotjal, 2009; Siver et al., 2010; Fourtanier & Kociolek, 2011; Potapova, 2013). Since its initial discovery in high elevation ponds of New Guinea, *Nupela* has been reported in neutral pH, low conductivity waters across Europe, South America, North America, Asia and Africa (Spaulding & Edlund, 2008).

In Colombia, three species of the genus were mentioned (Montoya-Moreno, pers. com.): *Nupela pallavicinii* (Krasske) Lange-Bertalot in Lange-Bertalot & Moser (1994) described at El Boquerón (Bogotá); Donato (2001) mentioned *N. paludigena* Lange-Bertalot at Lago Buitrago (Cundinamarca) and Lago Santiago (Cauca) and Vélez & Hooghiemstra (2005) mentioned *N. tenuistriata* (Hustedt) Metzeltin & Lange-Bertalot at Lago Las Margaritas, Lago Carimagua (Meta).

The aim of this paper is to describe and illustrate *Nupela* species collected in lowland waters of the Eastern part of the country, as part of the study of benthic diatoms from different Colombian basins held by the Laboratorio de Biotecnología del Instituto Colombiano del Petróleo.

MATERIAL AND METHODS

Samples were collected from the sampling sites where Ecopetrol S.A. helds physical, chemical and biological assessments, according to requirements of the environmental authorities in each region. A total of 150 samples were collected from selected sites, taking into account hidrogeomorphological variability. The study area comprised the Amazon region, the interandean valleys, the Andean region, the "Llanos Orientales", high plains and the Catatumbo. These regions are contrasting in their hydrogeomorphology. The rivers in the foothills of the Andes (Magdalena Alto) have beds of blocks, stones, and gravel. The water flow is turbulent and forms cascades and rapids. In lowlands of Catatumbo and the interandean valleys (Magdalena Medio) the streams are broad and beds have soft sediments, silt and/or clay; accumulations of woody debris are frequent and the water flow is smooth. For the high plains rivers (Meta and Cravo Sur and Tomo basins), the stream bed consists of soft sediments, sand and/or fine organic matter, leaf packs are formed frequently. The streams of the Putumayo and Caquetá basins here studied are small, with rocky substrates and coverage dominated by trees, well preserved (Ovalle, Plata-Díaz, Reyes, Pimienta, & Riss, 2013).

For each site, information about water temperature, pH, conductivity and dissolved oxygen was also obtained. Phytoplankton samples were collected by brushing the surface of a variable number of substrates delimited with a 25cm^2 acrylic frame, and were preserved with 1:1 Transeau solution. Samples were treated to eliminate organic matter following the method described in CEN/TC 230 (2003). Posteriorly, they were analysed using two microscopic techniques. Samples for light microscopy (LM) were mounted in Naphrax®, and for scanning electron microscopy (SEM) on glass stubs and then coated with gold-palladium in a FEI-Quanta 450 microscope of the Laboratorio de Microscopía of Instituto Colombiano del Petróleo. Analyses were held with a LM Carl Zeiss Axio Scope.A1 and with FEI-Quanta 450 SEM and a Jeol JSM-6360 LV SEM at the Servicio de Microscopía Electrónica de la Facultad de Ciencias Naturales y Museo de La Plata.

Uncleaned and cleaned subsamples and permanent slides were deposited at the Laboratorio de Biotecnología of Instituto Colombiano del Petróleo (Piedecuesta, Colombia).

The terminology used is the one proposed by Anonymous (1975), Ross et al. (1979) and Barber & Haworth (1981).

The samples for in *Nupela* species were found are listed bellow:

200418858: Abejas Stream. 04/27/2009. Collector: Guillermo Alemán.

200420431: Bilibil Stream. 05/06/2009. Collector: Guillermo Alemán.

200527650: Bilibil Stream. 05/14/2010. Collector: Guillermo Alemán.

200468182: Bilibil Stream. 10/26/2009. Collector: Guillermo Alemán.

200423382: La Pita Stream .05/19/2009. Collector: Guillermo Alemán.

200424905: La Hormiga Stream. 05/20/2009. Collector: Guillermo Alemán.

200432427: Zancudo Stream. Upstream. 06/25/2009. Collector: Guillermo Alemán.

200432428: Zancudo Stream. Downstream. 06/25/2009. Collector: Guillermo Alemán.

200476086: Zancudo Stream. 11/25/2009. Collector: Guillermo Alemán.

200436356: Fortalecillas River. 07/08/2009. Collector: Giovani Espinel.

200436357: Fortalecillas River. Downstream. 07/08/2009. Collector: Giovani Espinel.

200436532. El Aceite Stream. 07/09/2009. Collector: Giovani Espinel.

200438022: La Azul Stream, upstream. 07/17/2009. Collector: Giovani Espinel.

200438023: La Azul Stream. downstream. 07/17/2009. Collector: Giovani Espinel.

200439228: Veradita Stream. 07/20/2009. Collector: Giovani Espinel.

200439233: El Boral Stream. 07/23/2009. Collector: Jaime Orejarena.

200440779: Agua Clara River. 07/28/2009. Collector: Giovani Espinel.

200441028: Tate River. 07/30/2009. Collector: Hernando Ovalle.

200446180: Cravo Norte River. 08/13/2009. Collector: Giovani Espinel.

200454443: La Cortezana Stream. 09/09/2009. Collector: Hernando Ovalle.

200461115: Grande Stream. 09/26/2009. Collector: Guillermo Alemán.

200476922: Grande Stream. 11/26/2009. Collector: Guillermo Alemán.

200462477: La Cira Stream. 09/29/2009. Collector: Hernando Ovalle.

200463448: El Zarzal Stream. 10/07/2009. Collector: Fredy Yepes.

200465803: Palagua Stream. 10/14/2009. Collector: Fredy Yepes.

200469503: Pamplonita Stream (San Rafael Bridge). 10/29/2009. Collector: Guillermo Alemán.

200470667: Magdalena River, downstream. 11/05/2009. Collector: Fredy Yepes.

200473754: Gavilan Stream after confluence with Negro Stream. 11/16/2009. Collector: Jaime Orejarena.

200476490: Agua Blanca Stream. 11/21/2009. Collector: Giovani Espinel.

200476494: No1 Stream. 11/21/2009. Collector: Giovani Espinel.

200484429: El Diamante Stream. 12/19/2009. Collector: Fredy Yepes.

200568525: Santa Rita Stream. 0/10/2021: Collector: Fredy Yepes.

200570641: Venado Stream. 10/11/2003. Collector: Guillermo Alemán.

200640901: Blanca stream. 11/07/2001. Collector: Giovani Espinel.

200642952: Jarama Stream 11/07/2007. Collector: Hernando Ovalle.

RESULTS

The genus *Nupela* was present at 28 sites located in streams and rivers from eight basins of different regions of the country: Magdalena Alto and Medio, Catatumbo, Cravo Sur, Putumayo, Caquetá, Tomo and Meta (Table 1). In this paper five species were described and illustrated: two of them are reported here as new species and three are new records for Colombia.

***Nupela acaciensis* nov. sp.**
Vouilloud & Sala
Figs. 1. A, B, C, D, E, F, G, H, I, J, K, L.

Description: Valves lanceolated with subrostrated to subcapitated ends, slightly asymmetric with respect to the apical axis (cymbelloid symmetry). Voigt Fault evident at the dorsal side of the valve. Striae built by two transapically elongated areolae that delimit a hyaline longitudinal line, to the ends the striae

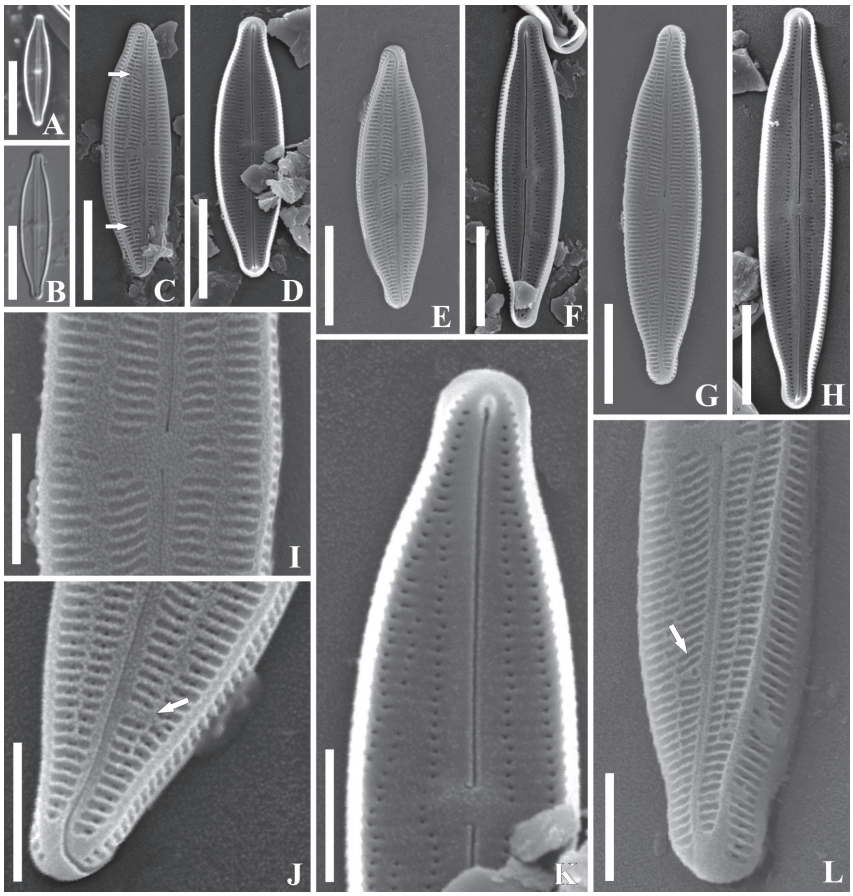

Fig. 1. (A, B, C, D, E, F, G, H, I, J, K, L). *N. acaciensis* nov. sp. (A-B. LM). General view of the valves. (C-L. SEM. C, E, G). Valves in external view; the arrows show the Voigt Fault. (D, F, H). Valves in internal view. (I). Detail of valve centre in external view, note the shape of the areolae, the central area and the proximal raphe ends. (J). Detail of an apex in external view, see the terminal raphe fissure, the arrow shows the Voigt Fault. (K). Detail of the internal valve view, note the shape of the raphe ends. (L). Tilted valve showing the areolae of the mantle, the arrow shows the Voigt Fault. (A-L) specimens of type population. (G). Holotype. Scale bars: (A-B): 10µm; (C-H): 5µm; (I-L): 2µm.

TABLE 1
Location and physicochemical characteristics of the sampling sites

Herbarium number	Coordinates		River/ Stream	Dissolved Oxygen* mg/L	Conductivity* µS/cm	pH*	Temp* °C	Altitude (m asl)	Basin
	N	W							
200418858	07° 28' 24.81" N	73° 23' 58.12" W	Abejas Stream	4.7	369.3	7.3	26.7	116	Magadalena Medio
200420431 200527650 200468182	02° 58' 1.30" N	75° 15' 15.4" W	Bilibil Stream	6.0	179	7.1	28.2	530	Magdalena Alto
200423382	08° 35' 48.67" N	73° 36' 38.17" W	La Pita Stream	6.0	163.0	7.3	28.0	116	Magdalena Medio
200424905	00° 25' 05.10'' N	76° 54' 18.4" W	La Hormiga Stream	6.8	60.7	6.9	25.7	301	Putumayo River
200432427 200432428 200476086	08° 12' 47.30'' N	72° 26' 50.1" W	Zancudo Stream	6.7	14.9	5.6	29.1	155	Catatumbo
200436356 200436357	02 °59 '41.30" N	075° 09' 57.4" W	Fortalecillas River	8.1	175.5	8.3	23.2	563	Magdalena Alto
200436532	03° 03' 42.69" N	75° 12' 46.77" W	El Aceite Stream	7.7	283	8.0	25.2	427	Magdalena Alto
200438022 200438023	00° 32' 24.20" N	74° 04' 05.40" W	La Azul Stream	8.6	13.5	6.7	25.6	542	Caquetá River
200439228	05° 20' 26.50" N	72° 51' 25.20" W	Veradita Stream	5.1	3.7	5.2	28.3	97	Meta River
200439233	05° 02' 9.00" N	70° 29' 34.30" W	El Boral Stream	5.4	3.7	5.1	28	134	Tomo River
200440779	05° 52' 44.72" N	70° 03' 53.13" W	Agua Clara River	6.5	135	6.0	29.5	95	Meta River
200441028	5° 55' 19.71" N	71° 53' 58.2421" W	Tate River	7.2	13.9	6.9	30.6	287	Meta River
200446180	06° 29' 35.03" N	71° 49' 58.15" W	Cravo Norte River	7.8	36.4	7.4	22.7	269	Meta River
200454443	05° 58' 52.63" N	71° 42' 40.73" W	La Cortezana Stream	6.3	37.1	6.67	21.1	209	Meta River
200461115 200476922	03° 51' 2.51" N	73° 39' 04.01" W	Grande Stream	6.3	11.1	6.9	26.6	396	Meta River
200462477	06° 58' 9.90" N	73° 46' 56.60" W	La Cira Stream	3.6	632	6.6	26.2	89	Magdalena Medio
200463448	07° 03' 40.80" N	73° 44' 49.80" W	El Zarzal Stream	4.8	53.94	6.2	27.6	70	Magdalena Medio
200465803	06° 04' 27.80" N	74° 33' 20.60" W	Palagua Stream	1.0	70.8	6.4	28.5	137	Magdalena Medio
200469503	07° 52' 05.92" N	72° 30' 02.95" W	Pamplonita Stream (San Rafael bridge)	7.0	302.5	8.3	28.7	329	Catatumbo

TABLE 1 (Continued)

Herbarium number	Coordinates		River/ Stream	Dissolved Oxygen* mg/L	Conductivity* µS/cm	pH*	Temp* °C	Altitude (m asl)	Basin
	N	W							
200470667	07° 04' 37.50" N	73° 53' 17.50" W	Magdalena River	5.6	205.6	7.5	30.1	69	Magdalena Medio
200473754	05° 14' 43.15" N	70° 14' 30.15" W	Gavilan Stream	6.4	3.6	5.4	26.8	105	Tomo River
200476490	00° 33' 37.60" N	74° 06' 55.00" W	Agua Blanca Stream	ND	29.6	ND	22.6	472	Caquetá River
200476494	00° 33' 2.76" N	74° 06' 10.08" W	No1 Stream	ND	23.7	ND	ND	575	Caquetá River
200484429	07° 19' 43.50" N	73° 26' 53.80" W	El Diamante Stream	6.3	31.9	6.6	27.3	129	Magdalena Medio
200568525	07° 02' 28.2" N	72° 10' 19.70" W	Santa Rita Stream	6.6	649	7.1	25.4	120	Magdalena Medio
200570641	02° 58' 07.20" N	75° 15' 30.8" W	Venado Stream	7.6	148	7.9	27.3	530	Magdalena Alto
200640901	04° 10' 57.00"N	73° 37' 31.70" W	Blanca Stream	7.4	10.3	5	21.3	370	Meta River
200642952	05° 29' 22.5" N	72° 24' 56.6" W	Jarama Stream	8.1	15.3	6.4	22.9	891	Cravo Sur River

* Average values. ND=No data.

are composed only by one areola. Striae parallel to slightly radial at valve centre, parallel to the apices. Valve mantle with a row of areolae continuous at the valve poles. Raphe well developed at both valves. External proximal raphe ends pore like, slightly expanded; terminal fissures hook-like and bent to the secondary valve side. Internal proximal raphe ends also hooked to the secondary side, central nodule notorious; distal ends straight finishing in small helictoglossae. Central area irregular, quadrangular at the primary valve side, missing the most internal areolae of the 2-3 central striae, at the secondary side more rounded due to the smaller internal areolae of the 2-3 central striae, sometimes one is missing.

Morphometric data: length: 5-12.5µm; width: 3-3.5µm; l/w: 3.9-5.6; 44-54 striae/10µm; 2 areolae/stria.

Type material: Holotype (Iconotype): specimen illustrated in Fig. 1C; Isotype: 200640901.

Type locality: 04° 10' 57.00''N-73° 37' 31.70'' W, Blanca Stream, Acacias, Meta Department, Llanos Orientales, Colombia.

Etymology: the specific epithet refers to the name of municipality of the type locality.

Distribution: only collected at the type locality.

Remaks: the closest taxon is *N. schoemaniana* Lange-Bertalot, from which it differs in having striae composed by 3-4 areolae, the shape of the central area and internal straight proximal raphe ends (Table 2). Other similar taxon is *N. florideana* Metzeltin & Lange-Bertalot that differs in striae composed by 3-4 areolae, stauroid central area and straight internal proximal raphe ends. *N. acaciensis* also resembles *N. giluwensis* Vyverman & Compére that differs in valve outline thinner with broadly capitated ends. Besides, at the dorsal side the latter has 2 hyaline longitudinal lines at valve centre that are reduced to one towards the ends and internal proximal raphe ends T-shaped.

This species was collected in samples with DO 7.4mg/L, conductivity 10.3µS/cm, pH 5, temperature 21.3ºC and altitude 370m.a.s.l.

TABLE 2
Comparison of *N. acaciensis* nov. sp. with allied taxa

Taxa	*N. acaciensis* nov. sp.	*N. giluwensis* Vyverman & Compère	*N. schoemaniana* Lange-Bertalot	*N. floridana* Metzeltin & Lange-Bertalot
Raphe developement	Equal in both valves	Equal in both valves	Equal in both valves	One valve with long raphe slits. The other valve with shorter raphe slits.
Length (µm)	12.5-20.5	13-16	13-20	20-22
Width (µm)	3-3.5	2-4.5	3.4-3.8	3.7-4.2
L/W	3.9-5.6	4.6-5.6*	4.5-5.1*	4.6-5.6*
N° striae/10µm	44-54	42	50-55	50
N° areolae/stria	2	2-4	3-4*	3-4
External proximal raphe ends	Expanded pore-shape	Slightly expanded pore-shape	Expanded pore-shape	No data
Internal proximal raphe ends	Hook-shaped	T-shaped	Straight, simple	Straight, simple
Type locality	Blanca Stream (Colombia)	Mont Giluwe, Papua (New Guinea)	Dimade River (South Africa)	Peatbog in Florida (USA)
Environmental conditions	Zone of high plains with acid pH and low conductivity.	Very shallow ponds, very low conductivity and moderately low pH	Streams of acid waters and low conductivities	No data
Bibliographic references	This study	Vyverman & Compère, 1991	Lange-Bertalot, 1993	Metzeltin & Lange- Bertalot, 2007

* measured from the illustrations of the publication.

***Nupela catatumbensis* nov. sp.**
Vouilloud & Plata-Díaz
Fig. 2. A, B, C, D, E, F, G, H, I, J, K, L.

Description: Valves lanceolate with subcapitated to capitated ends, slightly asymmetrical in relation to the apical axis (cymbelloid symmetry). Voigt Fault conspicuous, on the dorsal side of the valve. Raphe filiform straight, external proximal ends simple, terminal fissures question mark-like, curved to the dorsal side. Striae radial and parallel towards the apices. Striae uniseriate; areolae with external big foramina and internal hymen perforated at the centre, interestriae rib-like. Axial area narrow to the apices, broaden and with irregular limits to the valve centre, central area wide, irregular, more developed on the dorsal side, where the

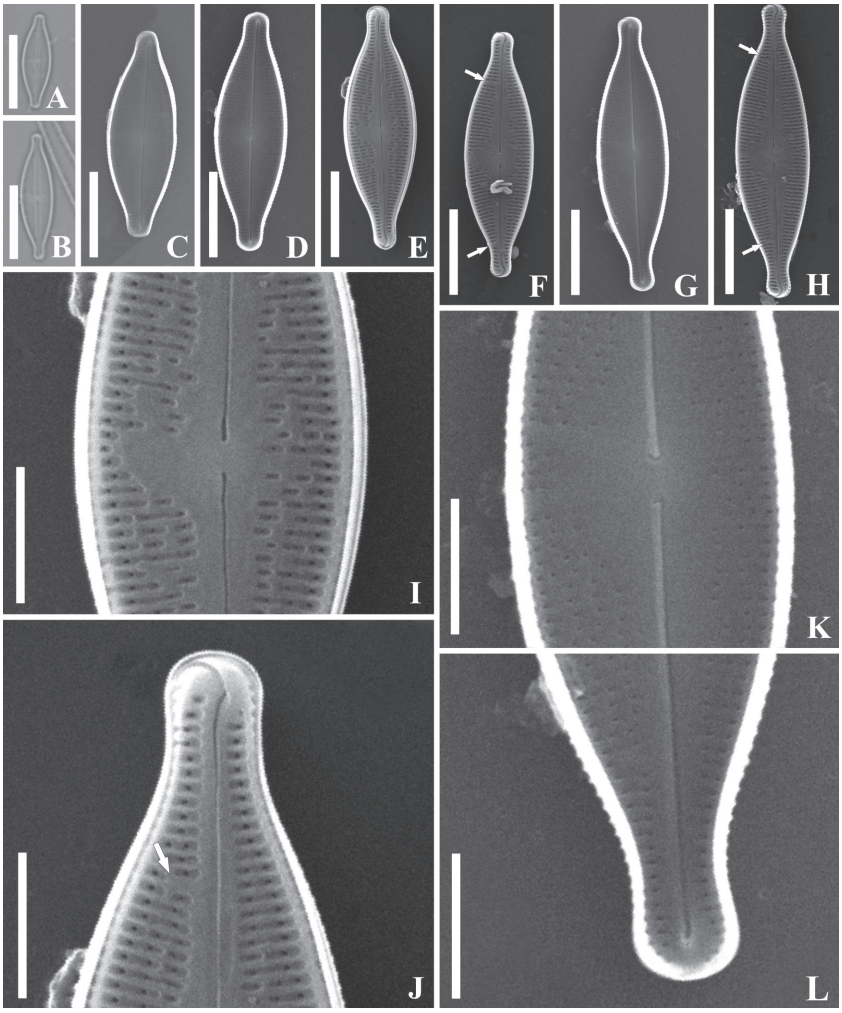

Fig. 2. (A, B, C, D, E, F, G, H, I). *N. catatumbensis* nov. sp. (A-B. LM). General view of the valves. (C-L. SEM). (C, D, G). Valves in internal view. (E, F, H). Valves in external view; the arrows show the Voigt Fault. (I). Detail of the valve centre in external view, note the shape of the areolae, the central area and the proximal raphe ends. (J). Detail of an apex in external view, see the terminal raphe fissure; the arrow shows the Voigt fault. (K). Detail of valve centre in internal view, note the shape of proximal raphe ends. (L). Detail of an apex in internal view. (A-L): specimens of type population. (H): holotype. Scale bars: (A-B), 10µm, (C-H): 5µm, (I-L): 2µm.

striae are composed of 1-2 areolae less and sometimes 1-2 striae are missing and the central area reaches the valve margin. Axial and central area more silicified. In internal view, the raphe is filiform and straight, proximal ends hook-like, curved to the dorsal side; distal ends finish in small helictoglossae. Valve mantle with a row of elongated areolae interrupted at the poles at the level of the terminal fissure.

Morphometric data: length: 12-20µm; width: 3.5-4.5µm; l/w: 3-4.6; 44-51 striae/10µm; 3-4 areolae/stria.

Type material: Holotype (Iconotype): specimen illustrated in fig. 2D. Isotype: 200432427.

Type locality: 08° 12' 47.30'' N-72° 26' 50.1'' W. Zancudo Stream, Río Zulia Basin, Catatumbo, Colombia.

Etymology: the specific epithet refers to Catatumbo, the region were the species was found.

Distribution: the species is widely distributed in the study area, at the Catatumbo, Meta River, Caquetá River, Magdalena Alto and Medio River and Tomo River basins. 200432427, 200432428, 200476086, 200570641, 200439228, 200438022, 200454443, 200476494, 200476922, 200473754, 200484429 (Table 2).

Remarks: the closest species is *Nupela encyonopsis* Metzeltin & Lange-Bertalot, both species have costa like interstriae. Nevertheless, this species differs from *N. catatumbensis* in the shape of the central and axial areas, poorly developed and with regular bounderies, in the number of areolae per striae and in the shape of the external proximal raphe ends pore-like (Table 3). Other similar species is *N. brachysiroides* Lange-Bertalot that differs in the presence of a sinuous line sunken at both sides of the central and axial areas, besides it differs in the straight external proximal raphe ends and in the lower striae density and number of areolae per striae (Table 3).

This species was collected in samples with DO 5.1-7.6mg/L, conductivity 3.6-748µS/cm, pH 5.2-7.9, temperature 21.1-29.1ºC and altitude 97-575m.a.s.l.

TABLE 3
Comparison of *N. catatumbensis* nov. sp. with allied taxa

Taxón	*N. catatumbensis* nov. sp.	*N. brachysiroides* Lange-Bertalot	*N. encyonopsis* Metzeltin et al.
Raphe development	Equal in both valves	Equal in both valves	Equal in both valves
Length (µm)	12-20	18-28	11-17
Width (µm)	3.5-4.5	4-5	2.7-3.7
L/W	3-4.6	4.8-5.6*	4.2-4.7*
N°striae/10µm	44-51	35	45-50
N° areolae/stria	3-4	4-5*	6-9*
External proximal raphe ends	Straight, slightly expanded	Straight, simple	Curved, slightly expanded pore-shape
Internal proximal raphe ends	Curved, hook-shaped	No data.	Curved, hook-shaped
Type locality	Zancudo Stream, Colombia	Borneo/Sarawak, Bako Park	River in Tepui Avayan, Venezuela
Environmental conditions	Piedmont plains. Low conductivity and pH. Prevalence of hard substrates	No data.	Black water creek
Bibliographic references	This study	Lange-Bertalot, 1993	Metzeltin & Lange-Bertalot, 1998

*measured from the illustrations of the publication.

Nupela lesothensis (Schoeman)
Lange-Bertalot in Rumrich,
Lange-Bertalot & Rumrich. 2000
Fig. 3. A, B, C, D, E, F.

Basionym: *Rhoicosphenia lesothensis* Schoeman (Schoeman & Archibald, 1976-1980).

Type locality: Spring in the Berea district of Lesotho.

Valves lanceolate with rostrate ends, slightly transapically asymmetrical. One valve has a well-developed raphe (DRV) and the other with reduced raphe branches to approximately half of its full length (VRR). Voigt Fault conspicuous. DRV: raphe filiform sligthly sinuous, internal proximal ends straight, distal ends finish in small helictoglosae. Striae radial at most of the valve extension, parallel and convergent at the ends. Axial area narrow at the ends widening to the valve centre where it merges with the wide irregular central area. VRR: it differs from the other valve in the short raphe fissures, externally it presents irregular depressions at the hyaline central area. One row of elongated areolae at valve mantle, interrupted at the apices.

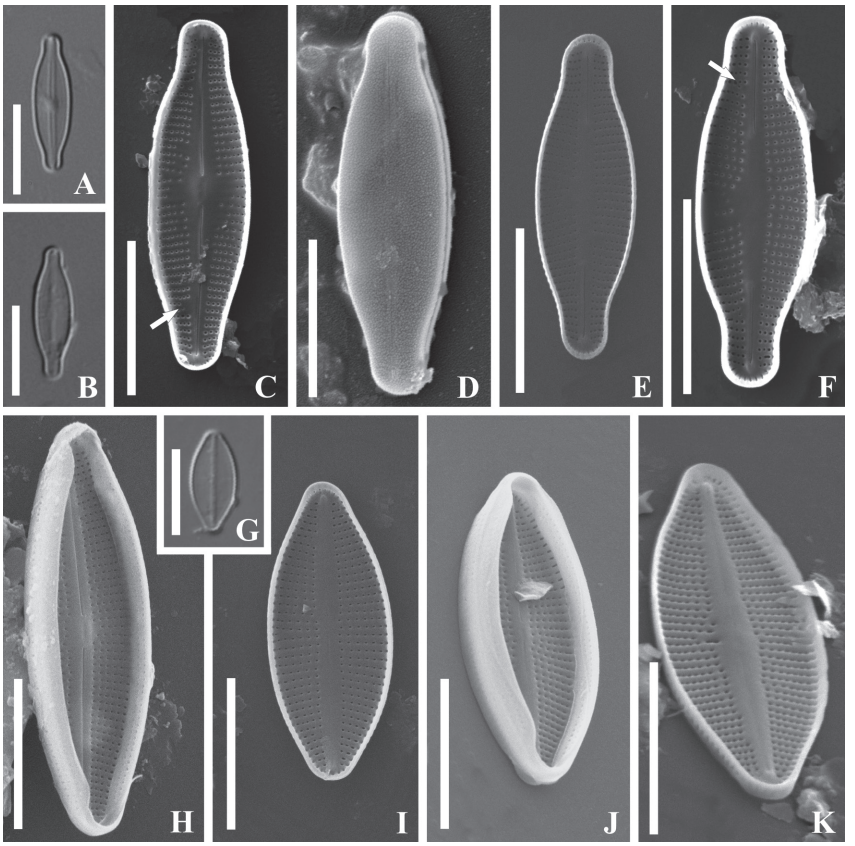

Fig. 3. (A, B, C, D, E, F). *N. lesothensis*. (A-B. LM). (A). Valve with complete raphe (DRV). (B). Valve with reduced raphe (DRR). (C-F). SEM. (C). Internal view of DRV valve, note internal proximal raphe ends and radial striae at centre; arrow shows Voigt Fault. (D). External view of DRR valve, showing irregular depressions at the hyaline central area. (E-F). Internal view of DRV valves, note the short raphe fissures and the small helictoglossae; arrow shows Voigt fault. (G-K). *Nupela praecipua.* (G. LM). Valve with reduced raphe (DRR). (H-K. SEM. H). Internal view of DRV, tilted valve. (I). Internal view of DRR valves, note internal proximal raphe ends straight and central nodule prominent, note the "ghost" full raphe, reduced to a small helictoglossa. (I, K). Tilted valves. Note the sternum and interstriae internally elevated. Scale bars: (A-B, G): 10μm; (C-F, H-K), 5 μm.

Morphometric data: length: 9-12µm; width: 3-3.5µm; l/w: 3-3.6µm; 38-46 striae/10µm; 50-74 areolae/10µm.

Distribution in Colombia: it is recorded for the first time in the country in different basins with significant variations in their ecomorphology and electrolyte content. Samples 200570641, 200527650, 200418858, 200469503, 200436532, 200438023, 200440779, 200446180, 200454443, 200465803, 200463448, 200441028 (Table 2).

Remarks: this species was collected in samples with DO 1-8.6mg/L, conductivity 13.5-302.5µS/cm, pH 6.0-8.3, temperature 21.1-30.6ºC and altitude 70-542m.a.s.l.

Nupela praecipua (Reichardt)
Reichardt in Rumrich et al. 2000
Fig. 3. G, H, I, J, K.

Basionym: *Achnanthes praecipua* Reichardt (Reichardt, 1988)

Type locality: Custepec River, México.

Valves broadly lanceolate with obtuse ends. Achnanthoid frustules, heterovalvar. A valve with complete raphe (VDR) and the other with rudimentary raphe branches (VRR). Voigt Fault inconspicuous. VDR: raphe filiform straight, internally proximal ends simple and the distal ends terminated in small helictoglossae. Axial area in internal view and central nodule prominent. Striae radial throughout the valve. Central area unmarked, wide axial area with irregular boundaries. VRR, raphe reduced to a small helictoglossa, "ghost" full raphe, sternum internally elevated. A row of elongated areolae on the mantle interrupted at the apices.

Morphometric data: length: 8-13.5µm; width: 4-5µm; l/w: 2-2.8µm; 30-39 striae/10µm; 35-43 areolas/10µm.

Distribution in Colombia: it is recorded for the first time in the country in a high variety of habitats from an ecomorphological point of view. Found in samples
200468182, 200568525, 200642952, 200424905 200527650, 200420431, 200423382, 200424905, 200436357, 200436356, 200436532, 200438023, 200438022, 200439228, 200461115, 200462477, 200476490, 200476494, 200470667, 200439233 (Table 2).

Remarks: this species was collected in samples with DO 3.6-8.6mg/L, conductivity 3.7-649µS/cm, pH 5.1-8.3, temperature 22.6-30.1ºC and altitude 69-575m.a.s.l.

Nupela subpallavicini
Metzeltin & Lange-Bertalot in
Metzeltin & Lange-Bertalot, 1998
Fig. 4. A, B, C, D, E, F, G, H.

Type locality: river of black waters in Tepui Avayan, Venezuela.

Valves broadly lanceolate with capitate ends. Both valves with developed raphe, slightly asymmetric with respect to the transapical axis, frustules curved in girdle view. Achnanthoid symmetry, one valve face concave and the other convexe. Voigt Fault sligthly conspicuous. Secondary valve margin more convex than the primary margin. Raphe filiform straight, external proximal raphe ends pore-like, slightly expanded, distal ends curved towards the secondary valve side; internally proximal raphe ends hook-shaped bent towards the secondary side of the valve and distal ends terminated in small helictoglossae. Striae radial throughout the valve. Axial area tapers towards the apex, and gently broadens towards the centre; central area asymmetric rounded at the primary side bounded by shorter striae, at the secondary side it extends up to the margin. Interstriae prominent in external view. A row of elongated areolae on the valve mantle, interrupted at the apices and at the fascia on the secondary margin.

Morphometric data: length: 10-17µm; width: 4-5.5µm; l/w: 2.5-3µm; 37-48 striae/10µm; 28-37 areolae/10µm.

Distribution in Colombia: it is recorded for the first time in the country. Found only in sample 200640901 (Table 2).

Remarks: this species was collected in samples with DO 7.4mg/L, conductivity 10.3µS/cm, pH 5, temperature 21.3ºC and altitude 370m.a.s.l.

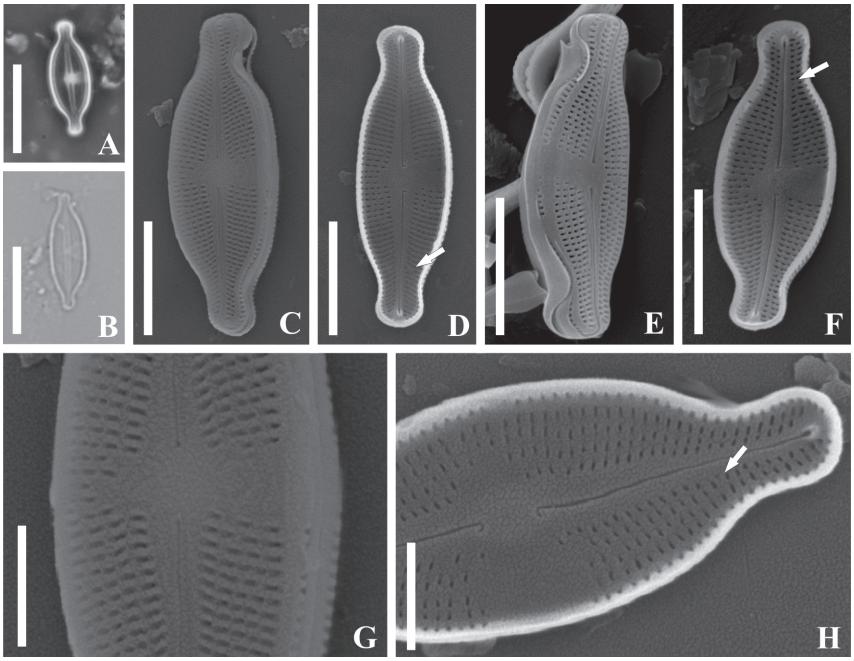

Fig. 4. (A, B, C, D, E, F, G, H). *N. subpallavicinii*. (A-B. LM). General view of the valves. (C-H. SEM. C). Frustule in valve view showing the convex valve. (D). Valve in internal view; the arrow shows the Voigt Fault. (E). Tilted frustule showing the concave valve face, mantle and cingulum. (F). Tilted valve in internal view; note the areolae at valve mantle interrupted at the apices. (G). Detail of valve centre in external view, showing the areolae; note the central area asymmetric and the mantle areolae interrupted. (H). Detail of a valve in internal view showing the proximal raphe ends hook-shaped and distal ends terminated in small helictoglossae; the arrow shows the Voigt Fault. Scale bars: (A-B): 10µm, (C-F): 5 µm; (G, H): 2µm.

DISCUSSION

Colombia is considered the second most biodiverse country in the world (Anónimo, 2010) and this may be due to its geographical location and topography. Diatom studies conducted to date, showed that this group has high diversity the same as other groups of organisms and many new taxa for science have been recently described (Vouilloud, Sala, Núñez-Avellaneda, & Duque, 2010; Montoya-Moreno, Sala, Vouilloud & Aguirre, 2012).

In the framework of a project to construct an index for water quality evaluation for Colombia and through the analyses undertaken with LM and SEM of 150 benthic diatom samples collected in lotic waterbodies from lowlands, we have identified approximatly 2 000 morphotypes. In the study area the genus *Nupela* was well represented and five species were identified: *N. acaciensis* and *N. catatumbensis* are new for science and *N. lesothensis*, *N. praecipua* and *N. subpallavicinii* are recorded for the first time in Colombia. *Nupela acaciensis* is characterized by having developed raphe in both valves, cymbelloid symmetry, striae built by two elongated areolae that delimit a longitudinal line at each hemivalve. The closest taxa are *N. schoemaniana* Lange-Bertalot (Lange-Bertalot, 1993) and *N. florideana* Metzeltin & Lange-Bertalot (Metzeltin & Lange-Bertalot, 2007) from which it differs in striae, central area and internal proximal raphe ends. *N. acaciensis* also resembles *N. giluwensis* Vyverman & Compère (Vyverman & Compère, 1991) that differs in valve outline, presence of hyaline longitudinal lines on the valve face, internal proximal raphe ends, and distribution of the mantle areolae, continuous or interrupted at valve apices. *Nupela catatumbensis*

is characterized by having developed raphe in both valves, cymbelloid symmetry, striae built by 3-4 transapically elongated areolae, interstriae elevated conforming transapical ribs and internal proximal raphe ends hook-shaped. Its closest species is *N. encyonopsis* Metzeltin & Lange-Bertalot (Metzeltin & Lange-Bertalot, 1998) which differs in the shape of the central and axial areas, in the number of areolae per striae, and in the shape of the external proximal raphe ends. Another similar species is *N. brachysiroides* Lange-Bertalot (Lange-Bertalot, 1993) that differs in the presence of a sinuous line sunken at both sides of the central and axial areas, in the external proximal raphe ends, and in striae density and number of areolae per stria.

The genus *Nupela* was originally described from high elevation ponds of Papua, New Guinea. Since its initial discovery, several species have been reported across Europe, South America, North America, Asia and Africa in neutral pH and low conductivity waters (Spaulding & Edlund, 2008). In the studied area, the genus was present in 28 sites located in 22 streams and rivers, and eight basins of different regions of the country, with low conductivity but a medium range of variation in other environmental characteristics. The Caquetá, Tomo, Cravo Sur and Meta River Basins, placed at the Eastern lowlands were characterized by waters with acid to neutral pH. On the other hand, rivers from the Putumayo River basin had neutral pH. The streams from the Upper Magdalena River Basin were characterized by high temporal variation of water flows, a high coverage of hard substrates and a relatively basic pH, while those of the Catatumbo Basin comprise mountain rivers with predominantly hard substrates (like gravel and rocks) and also lowland water bodies with soft substrates (clay); pH sligthly acid to neutral, with exception of the Pamplonita River (San Rafael Bridge) a hipereutrophic site with frequent algal blooms.

Although the genus was widely distributed in these basins, the studied species showed different distribution patterns. *N. acaciensis* and *N. subpallavicini* have a restricted distribution, while *N. catatumbensis*, *N. lesothensis* and *N. praecipua* have a wider distribution and were collected in sites with significant variations in their ecomorphology, altitude, temperature, pH and electrolyte content. *N. acaciensis* was only recorded in Meta River basin, placed at the Eastern lowlands, characterized by waters with very low electrolithic content, and acid to neutral pH. *N. subpallavicini* was originally described from a river of black waters in Tepui Avayan, Venezuela (Metzeltin & Lange-Bertalot, 1998), and in Colombia it was collected only in a site with very low conductivity and pH, and at a medium altitude. *N. catatumbensis* was found both in small rough streams (with beds of gravel and stones) with turbulent flow as well as in rivers with beds with soft sediments (silt and clay). *N. lesothensis,* originally described from South Africa (Schoeman & Archibald, 1976-1980), and *N. praecipua,* described from the Custepec River, México (Reichardt, 1988), were collected in different basins with significant variations in their ecomorphology, altitude, temperature, pH and electrolyte content.

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RESUMEN

Especies de *Nupela* (Naviculales: Bacillariophyceae) en aguas de tierras bajas de Colombia que incluyen a *N. acaciensis* nov. sp. y *N. catatumbensis* nov. sp. El género *Nupela* comprende alrededor de 50 especies que tienen en general una distribución restringida por fronteras bioclimáticas. Como parte de un estudio integral de la flora diatomológica de Colombia, en este trabajo focalizamos nuestro interés en el género *Nupela* en cuerpos de agua de tierras bajas. Muestras de perifiton fueron recolectadas en 150 sitios en cuerpos de agua lóticos seleccionados por su variabilidad hidrogeomorfológica. En cada estación de

muestreo se obtuvieron muestras por raspado de varios sustratos, y adicionalmente se registraron: temperatura, pH, oxígeno disuelto y conductividad. Las muestras fueron procesadas para su análisis con microscopio óptico (MO, Carl Zeiss Axio Scope. A1) y de barrido (MEB; FEI-Quanta 450 and a Jeol JSM-6360 LV). El género *Nupela* fue hallado en 28 sitios. Cinco especies fueron identificadas, descritas e ilustradas, tres de ellas: *N. lesothensis*, *N. praecipua* y *N. subpallavicinii* fueron descritas para ambientes tropicales y subtropicales y representan nuevas citas para Colombia. Además fueron descritas *N. acaciensis* y *N. catatumbensis*, dos especies nuevas para la ciencia. *N. acaciensis* se caracteriza por poseer rafe desarrollado en ambas valvas, simetría cymbelloide, estrías formadas por dos aréolas transapicalmente alargadas que definen una línea longitudinal en cada hemivalva. *N. catatumbensis* se caracteriza poseer rafe desarrollado en ambas valvas. Valvas lanceoladas con extremos subcapitados a capitados y simetría cymbelloide. Estrías formadas por 3-4 aréolas transapicalmente alargadas, interestrías elevadas a modo de costillas transapicales y extremos proximales internos del rafe en forma de gancho. El género *Nupela* estuvo ampliamente representado en el área de estudio, sin embargo, las especies mostraron diferentes patrones de distribución. *N. acaciensis* y *N. subpallavicini* estuvieron presentes en una única cuenca, mientras que *N. catatumbensis*, *N. lesothensis* y *N. praecipua* presentaron una distribución más amplia, y fueron recolectadas en sitios con variaciones significativas en ecomorfología, altitud, temperatura, pH y contenido electrolítico.

Palabras clave: *Nupela*, *Nupela acaciensis*, *Nupela catatumbensis,* diatomeas, Bacillariophyceae, neotropical, Colombia.

REFERENCES

Anónimo (2010). Instituto de Investigación Alexander Von Humboldt. Recuperado de http://www.humboldt.org.co/chmcolombia/ biodiversidad.htm.

Anonymous. (1975). Proposal for a standardization of diatom terminology and diagnosis. *Nova Hedwigia Beiheft, 53*, 323-354.

Barber, H. G. & Haworth, E. Y. (1981). *A guide to the morphology of the diatom frustule.* Freshwater Biological Association, Scientific Publication No 44. United Kingdom: Acanthophyllum Books.

CEN/TC 230. (2003). *Water quality-Guidance standard for the routine sampling and pretreatment of benthic diatoms from rivers*. Comité European de Normalisation, Geneva. Retrieved from www.techind.fi/standard/uusitet/tilaajat/sfs_en_12952-6.pdf

Donato, J. C. (2001). *Fitoplancton de los lagos andinos del Norte de Suramérica (Colombia): Composición y Factores de distribución*. Bogotá: Academia Colombiana de Ciencias Exactas, Físicas y Naturales. Colección Jorge Álvarez Lleras N° 19.

Fourtanier, E. & Kociolek, J. P. (2011). *Introduction and Acknowledgements to the Catalogue of Diatom Names*. Retrieved from http://researcharchive.calacademy.org/research/diatoms/names/intro.html

Kulikovskiy, M., Lange-Bertalot, H., & Witkowski, A. (2009). *Nupela matrioschka* sp. nov., *Nupela thurstonensis* comb. nov. and *Nupela neogracillima* comb. & nom. nov. (Bacillariophyceae): critical analysis of their morphology. *Polish Bototanical Journal, 54*, 13-20.

Lange-Bertalot, H. (1993). 85 neue taxa und über 100 weitere neu definierte Taxa ergänzend zur Süsswasserflora von Mitteleuropa, Vol. 2/1-4.. In J. Cramer (Ed.), *Bibliotheca Diatomologica 27*. Berlin-Stuttgart.

Lange-Bertalot, H. & Moser, G. (1994). *Brachysira*, Monographie der Gattung. *Bibliotheca Diatomologica 29*. In J. Cramer. (Ed.), Berlin-Stuttgart.

Metzeltin, D. & Lange-Bertalot, H. (1998). Tropical diatoms of South America I. In: H. Lange-Bertalot. (Ed.), *Iconographia Diatomologica* 5. Germany: Koeltz Scientific Books.

Metzeltin, D. & Lange-Bertalot, H. (2007). *Tropical diatoms of South America II*. In H. Lange-Bertalot (Ed.), *Iconographia Diatomologica 18*. A.R.G. Germany: Gantner Verlag K.G.

Monnier, O., Lange-Bertalot, H., & Bertrand, J. (2003). *Nupela exotica* species nova: une diatomée d'un aquarium tropical d'eau douce. Avec des remarques sur la biogéographie du genre. *Diatom Research*, *18*, 273-291.

Montoya-Moreno, Y., Sala, S. E., Vouilloud, A. A., & Aguirre, N. (2012). Diatomeas (Bacillariophyta) perifíticas del Complejo Cenagoso de Ayapel, Colombia. I. *Caldasia, 34*, 457-474.

Ovalle, H., Plata-Díaz, Y., Reyes, F., Pimienta, A., & Riss, H. W. (2013). Biodiversity of South American lowland streams natural scenery and anthropogenic facts. *Symposium for European Freshwater Sciences* (SEFS). Retrieved from http://www.sefs2013.de/_medien/_content/files/Abstract_Book_SEFS8_2013.pdf

Potapova, M. (2013). Transfer of *Achnanthes decipiens* to the genus *Nupela*. *Diatom Research*, *28*, 139-142.

Potapova, M. G., Ponader, K. C., Lowe, R. L., Clason, T. A., & Bahls, L. L. (2003). Small-celled *Nupela* species from North America. *Diatom Research*, *18*, 293-306.

Reichardt, E. (1988). *Achnanthes praecipua* n. sp., a new freshwater diatom from Mexico. In F. E. Round (Ed.), *Proceedings of 9th International Diatom Symposium* (391-395). Biopress Ltd, Bristol & Koeltz Scientific Books, Koeningstein.

Ross, R., Cox, E. J., Karayeva, D. G., Mann, D. G., Padock, T. B., Simonsen, R., & Sims, P. A. (1979). An emended terminology for the siliceous components of the diatom cell. *Nova Hedwigia*, *64*, 513-533.

Rumrich, U., Lange-Bertalot, H., & Rumrich, M. (2000). Diatoms of the Andes. From Venezuela to Patagonia/ Tierra del Fuego and two additional contributions. *Iconographia Diatomologica 9*. Koeltz Scientific Books.

Schoeman, F. R. & Archibald, R. E. M. (1976-1980). *The diatom flora of Southern Africa*. CISR special report-Wat 50. National Institute for Water Researchk, Council for Scientific and Industrial Research, Pretoria.

Siver, P. A., Hamilton, P. B., & Morales, E. A. (2007). Notes on the genus *Nupela* (Bacillariophyceae) including the description of a new species, *Nupela scissura* sp. nov. and an expanded description of *Nupela paludigena*. *Phycological Research, 55*, 125-134.

Siver, P. A., Wolfe, A. P., & Edlund, M. B. (2010). Taxonomic descriptions and evolutionary implications of Middle Eocene pinnate diatoms representing the extant genera *Oxyneis, Actinella* and *Nupela* (Bacillariophyceae). *Plant Ecology & Evolution*, *143,* 340-351.

Spaulding, S. & Edlund, M. B. (2008). *Nupela*. In Diatoms of the United States. Retrieved, from http://western-diatoms.colorado.edu/taxa/genus/Nupela.

Vélez, M. I. & Hooghiemstra, H. (2005). Fossil and modern diatom assemblages from the savanna lake El Piñal, Colombia: an environmental reconstruction. *Diatom Research*, *20*, 387-407.

Vouilloud, A. A., Sala, S. E., Núñez-Avellaneda, M., & Duque, S. R. (2010). Diatoms from the Colombian and Peruvian Amazon: the Genera *Encyonema*, *Encyonopsis* and *Gomphonema. Revista de Biología Tropical*, *58*, 45-62.

Vyverman, W. & Compère, P. (1991). *Nupela giluwensis* gen. & spec. nov. A new genus of naviculoid diatoms. *Diatom Research*, *6*, 175-179.

Wotjal, A. Z. (2009). *Nupela marvanii* sp. nov., and *N. lapidosa* (Krasske) Lange-Bertalot in Poland with notes on the distribution and ecology of the genus *Nupela* (Bacillariophyta). *Fottea*, *9*, 233-242.