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 hidrogeomorphological 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. subpallavicini; 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, interstriae 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-Berta- lot & 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, transferred 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 (Wojtal, 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. holds 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 inter-andean 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 25cm² 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).

200527650: Bilibil Stream. 05/14/2010. Collector: Guillermo Alemán.
200423382: La Pita Stream. 05/19/2009. Collector: Guillermo Alemán.
200568525: Santa Rita Stream. 01/10/2021: Collector: Fredy Yepes.

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

**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...
### TABLE 1
Location and physicochemical characteristics of the sampling sites

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

Remarks: the closest taxon is *N. schoemani ana* 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 21.3°C and altitude 370m.a.s.l.
<table>
<thead>
<tr>
<th>Taxa</th>
<th>( N. \text{acaciensis} ) nov. sp.</th>
<th>( N. \text{gilarwensis} ) Vyverman &amp; Compère</th>
<th>( N. \text{schoemaniana} ) Lange-Bertalot</th>
<th>( N. \text{floridana} ) Metzeltin &amp; Lange-Bertalot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raphe development</td>
<td>Equal in both valves</td>
<td>Equal in both valves</td>
<td>Equal in both valves</td>
<td>One valve with long raphe slits. The other valve with shorter raphe slits.</td>
</tr>
<tr>
<td>Length (µm)</td>
<td>12.5-20.5</td>
<td>13-16</td>
<td>13-20</td>
<td>20-22</td>
</tr>
<tr>
<td>Width (µm)</td>
<td>3-3.5</td>
<td>2-4.5</td>
<td>3.4-3.8</td>
<td>3.7-4.2</td>
</tr>
<tr>
<td>L/W</td>
<td>3.9-5.6</td>
<td>4.6-5.6*</td>
<td>4.5-5.1*</td>
<td>4.6-5.6*</td>
</tr>
<tr>
<td>Nº striae/10µm</td>
<td>44-54</td>
<td>42</td>
<td>50-55</td>
<td>50</td>
</tr>
<tr>
<td>Nº areolae/stria</td>
<td>2</td>
<td>2-4</td>
<td>3-4*</td>
<td>3-4</td>
</tr>
<tr>
<td>External proximal raphe ends</td>
<td>Expanded pore-shape</td>
<td>Slightly expanded pore-shape</td>
<td>Expanded pore-shape</td>
<td>No data</td>
</tr>
<tr>
<td>Internal proximal raphe ends</td>
<td>Hook-shaped</td>
<td>T-shaped</td>
<td>Straight, simple</td>
<td>Straight, simple</td>
</tr>
<tr>
<td>Type locality</td>
<td>Blanca Stream (Colombia)</td>
<td>Mont Giluwe, Papua (New Guinea)</td>
<td>Dimade River (South Africa)</td>
<td>Peatbog in Florida (USA)</td>
</tr>
<tr>
<td>Environmental conditions</td>
<td>Zone of high plains with acid pH and low conductivity.</td>
<td>Very shallow ponds, very low conductivity and moderately low pH</td>
<td>Streams of acid waters and low conductivities</td>
<td>No data</td>
</tr>
<tr>
<td>Bibliographic references</td>
<td>This study</td>
<td>Vyverman &amp; Compère, 1991</td>
<td>Lange-Bertalot, 1993</td>
<td>Metzeltin &amp; Lange-Bertalot, 2007</td>
</tr>
</tbody>
</table>

* 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 sub-capitlated 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 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

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![Fig. 2. A, B, C, D, E, F, G, H, I, J, K, L.](image-url)

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 boundaries, 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. brachystiroides 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.

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**TABLE 3**

Comparison of N. catatumbensis nov. sp. with allied taxa

<table>
<thead>
<tr>
<th>Taxon</th>
<th>N. catatumbensis nov. sp.</th>
<th>N. brachystiroides Lange-Bertalot</th>
<th>N. encyonopsis Metzeltin et al.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raphe development</td>
<td>Equal in both valves</td>
<td>Equal in both valves</td>
<td>Equal in both valves</td>
</tr>
<tr>
<td>Length (µm)</td>
<td>12-20</td>
<td>18-28</td>
<td>11-17</td>
</tr>
<tr>
<td>Width (µm)</td>
<td>3.5-4.5</td>
<td>4-5</td>
<td>2.7-3.7</td>
</tr>
<tr>
<td>L/W</td>
<td>3-4.6</td>
<td>4.8-5.6*</td>
<td>4.2-4.7*</td>
</tr>
<tr>
<td>N°striae/10µm</td>
<td>44-51</td>
<td>45-50</td>
<td>45-50</td>
</tr>
<tr>
<td>N° areolae/stria</td>
<td>3-4</td>
<td>4-5*</td>
<td>6-9*</td>
</tr>
<tr>
<td>External proximal raphe ends</td>
<td>Straight, slightly expanded</td>
<td>Curved, hook-shaped</td>
<td>Curved, hook-shaped</td>
</tr>
<tr>
<td>Internal proximal raphe ends</td>
<td>Curved, hook-shaped</td>
<td>No data.</td>
<td>No data.</td>
</tr>
<tr>
<td>Type locality</td>
<td>Zancudo Stream, Colombia</td>
<td>Borneo/Sarawak, Bako Park</td>
<td>Bako Park</td>
</tr>
<tr>
<td>Environmental conditions</td>
<td>Piedmont plains. Low conductivity and pH.</td>
<td>No data.</td>
<td>No data.</td>
</tr>
</tbody>
</table>

This study: Lange-Bertalot, 1993

Bibliographic references: This study, Lange-Bertalot, 1993

*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 lesothen-
sis* 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 slightly sinuous, internal proximal ends straight, distal ends finish in small helictoglossae. 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.
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, 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: 2.8µm; 30-39 striae/10µm; 35-43 areolae/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, 200438922, 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 convex. Voigt Fault slightly 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 mantle interrupted at the apices.

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.
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 approximately 2000 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. prae-cipua* and *N. subpallavicinii* are recorded for the first time in Colombia. *Nupela acaciensis* is characterized by having developed raphe in both valves, cymbeloid 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 striae, central area and internal proximal raphe ends. *N. acaciensis* is characterized by having developed raphe in both valves, cymbeloid 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, cymbellloid symmetry, striae built by 3-4 transapically elongated areolae, inter-striae 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 slightly 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 electrolytic 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 perifitón 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. subpallavicini fueron descritas para ambientes tropicales y subtropicales y representan nuevas citas para Colombia. Además fueron descritas N. acaciensis y N. thurstonsensis, dos especies nuevas para la ciencia.

N. acaciensis se caracteriza por poseer rafe desarrollado en ambas valvas, simetría cymbelloide, estrías formadas por 3-4 aréolas transapicalmente alargadas, interestrías elevadas a modo de rafe en forma de gancho. El género Nupela se caracteriza poseer rafe desarrollado en ambas valvas. Valvas lanceoladas con extremos subcapitados a capitados de ambos lados, simetría cymbelloide. Estrías formadas por 3-4 aréolas transapicalmente alargadas, interestrías elevadas a modo de costillas transapicales y extremos próximales 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 e N. subpallavicini estuvieron presentes en una única cuenca, mientras que N. lesothensis, N. lesothensis y N. praecipua presentan una distribución más amplia, y fueron recolectados en sitios con variaciones significativas en ecomorfología, altitud, temperatura, pH y contenido electrolítico.

Palabras clave: Nupela, Nupela acaciensis, Nupela catatumbensis, diatomas, Bacillariophyceae, neotropical, Colombia.

REFERENCES


