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Description of two new *Geissleria* species (Bacillariophyta) from Central and West tropical Africa

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Abstract

During a recently started-up project in the Biosphere Reserve at Yangambi, DR Congo, an unknown *Geissleria* taxon was observed in a small tributary of the Congo River. This taxon is here described as new to science based on detailed light and scanning electron microscopy observations. *Geissleria lubiluensis sp. nov.* can be distinguished by the slightly tri-undulate valve margins and the very distinct annulus located at a distance of 3 striae from the apex. The comparison of this taxon with various other *Geissleria* taxa with resembling valve outline or with resembling annulus structure, led to the description of another new species: *Geissleria fogedii sp. nov.* reported by Foged from Ghana as *Navicula paludosa*. This taxon resembles very well *Geissleria lubiluensis* but differs in the distinct annulus located closer to the apex mostly at the distance of one stria, the broader valves and the denser striation.

Keywords: diatoms, DR Congo, freshwater, Ghana, new species, taxonomy

Introduction

Based on the presence of an annulus, a circular or semi-circular hyaline area on the valve face which interrupts two or more distal striae, Lange-Bertalot & Metzeltin (1996: 63) have separated diatoms bearing this features from *Navicula* Bory (1822: 128), and have put them in the genus *Geissleria* Lange-Bertalot & Metzeltin (1996: 63). According to Guiry (in Guiry & Guiry 2019) this genus is represented by 79 species and 3 infraspecific taxa of which 43 have been flagged as accepted taxonomically. Although recently many of the *Geissleria* taxa has been transferred to *Baikalia* Bukhtiyarova & Pomazkina (Bukhtiyarova & Pomazkina 2013: 43), *Navigeia* Bukhtiyarova (Bukhtiyarova & Pomazkina 2013: 65), *Placogeia* Bukhtiyarova (Bukhtiyarova & Pomazkina 2013: 82) and *Grachevia* Bukhtiyarova (Bukhtiyarova & Pomazkina 2013: 129), we are in favor to preserve the genus *Geissleria* as defined by Lange-Bertalot & Metzeltin (1996).

During the 20th century only a couple of studies have been undertaken on algae in the present Yangambi Biosphere Reserve (Tshopo Province, part of the formerly Oriental Province, DR Congo). In 1957 Demalsy published on epiphytic diatoms on *Azolla africana* Decaisne (1827: 178), *A. nilotica* Decaisne ex Mettenius (1867: 54) and *Wolffia arrhiza* (Linnaeus) Wimmer (1857: 140). This author reported a total of 19 genera beside some other Centrales (other than *Cyclotella* (Kützing) Brébisson (1838: 19) and *Coscinodiscus* Ehrenberg (1839: 128) included in the 19 mentioned taxa) on *Azolla nilotica* with *Eunotia* Ehrenberg (1837: 44), *Cocconeis* Ehrenberg (1836: 173) and *Achnanthes* Bory (1822: 79) as dominant genera. On *Azolla africana* and *Wolffia arrhiza*, on the other hand, Demalsy (1957) observed only 9 genera each and *Eunotia* and *Navicula* were the dominant taxa. Symoens & van der Werff (1996) investigated diatoms of seven epiphytic samples collected by Jean Léonard in 1948 in three small rivers in the region of Yangambi. They reported 88 specific and infraspecific taxa, the genera *Navicula* and *Pinnularia* Ehrenberg (1843: 45) represented by 13 each, *Eunotia* by 12 and *Nitzschia* Hassall (1845: 435) by 11 species and varieties.

Diatom research from other regions in the Tshopo Province was conducted especially in and around Kisangani, the capital of the former Oriental Province and the third largest city of DR Congo (Golama Swana Kaketa 1992, 1996,

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Symoens & van der Werff 1993 and Compère 1995). These investigations led to the description of a new *Gomphonema* Ehrenberg (1832: 57) species, *G. zairense* Compère (1995: 32) which was described from the Tshopo waterfalls.

Apparently, the Boyekoli Ebale Congo 2010 Expedition initiated the (re-)start of diatom research in the Yangambi Biosphere Reserve. This interest resulted in the descriptions of new species from the Biosphere Reserve (e.g., *Cavinula lilandae* Cocquyt, de Haan & J.C. Taylor (2013: 158) and *Eunotia rudis* Cocquyt & M. de Haan (2016: 75) in Cocquyt *et al.* 2013 and 2016 respectively) and from adjacent areas such as the Lomami River, a major tributary of the Congo River (e.g., *Eunotia leonardii* J.C. Taylor & Cocquyt (2016: 295), *Gomphonema grande* B. Karthick, Kociolek, J.C. Taylor & Cocquyt (2016: 188), *Surirella ebalensis* Cocquyt & J.C. Taylor (2015: 2) and *Surirella congolensis* Cocquyt & J.C. Taylor (2015: 8) in Taylor *et al.* 2016b, Karthick *et al.* 2016 and Cocquyt & Taylor 2015 respectively). The two *Surirella* Turpin (1828: 363) species have been transferred recently to the genus *Iconella* Jurilj (1949: 184): *Iconnella ebalensis* (Cocquyt & J.C. Taylor) Cocquyt & J.C. Taylor (2017: 87) and *Iconella congolensis* (Cocquyt & J.C. Taylor) Cocquyt & J.C. Taylor (2017: 85) in Jahn et al. (2017). From the same river *Navicula nielsfogedii* J.C. Taylor & Cocquyt (2016: 202) was described, a more widespread species in tropical and sub-tropical Africa (Taylor et al. 2016a).

The present paper is dealing with the description of another new species, belonging to the genus *Geissleria* Lange-Bertalot & Metzeltin (1996: 63), which was sporadically observed in some of the rivers of the Yangambi Biosphere Reserve.

Material and Methods

Small tributaries of the Congo River in the Biosphere Reserve at Yangambi in DR Congo were sampled near their mouth during several field campaigns in the dry and wet season of 2015. Only in a restricted number of these samples an unknown *Geissleria* was observed. Most valves of this taxon were observed in the Lubilu, a rather large river compared to the other rivers flowing through the Yangambi Biosphere Reserve, located at an elevation between 400 and 460 m above sea level. The spelling of the name of this river can vary, what often occurs in African names, to Lobilo or Lubilo. Table 1 gives an overview of the samples used for the present paper, CCA numbers refer to the subsample deposited in the collection of Meise Botanic Garden (BR), LND numbers to the subsample deposited at the University of Kisangani (UNIKIS), DR Congo. Samples of 15 February 2015 were collected by C. Cocquyt and E. Lokele Njdombo while the samples of 27 December 2015 and 17 April 2015 were collected only by E. Lokele Njdombo. The river Lubilu was sampled near its mouth in the Congo River and on the right bank near the bridge on road R408 (Kisangani-Isangi) at about 1 km from its mouth into the Congo River; the river Lotuli (sometimes written as Loculi), on the left bank near the bridge on road R408 (Kisangani-Isangi), 0.61740° N and 24.71560° E; the river Lokwaje (sometimes spelled as Lokwaye), on the left bank near the bridge on road R408 (Kisangani-Isangi), 0.58400° N and 24.95680° E; the river Lokombe (sometimes referred to as Ambuku), on the left bank near the bridge on road R408 (Kisangani-Isangi), 0.71613° N and 24.60487°E; and the river Lotuli, on the left bank near the bridge on road R408 (Kisangani-Isangi), 0.61740° N and 24.71560° E. Plants sampled for the epiphytic diatoms are *Vossia cuspidata* (Roxburgh 1814:81) Griffith (1851: 153), known as 'hippo grass', for samples CCA 3567/LND 0022, CCA 3577/LND 0032, CCA 3758/LND 0076, CCA 3762/LND 0054 and CCA 4188/LND 0108, *Nymphaea lotus* Linnaeus (1753: 511) for CCA 3568/LND 0023, and green algae for CCA 3760/LND 0078.

All samples were fixed *in situ* in a 20% v/v final concentration ethanol solution (Taylor & Cocquyt 2016). Epiphytic samples were collected by scrapping material from plant stems and submerged leaves, epipsammic samples by scrapping off the sand from the bottom in the river course at shallower parts relatively close to the river bank.

A subsample of all collected material was transported to Belgium for morphologic analysis. This material was oxidized with hydrogen peroxide (30%), rinsed 5 times with distilled water and embedded in Naphrax. Light microscopy (LM) studies were carried out with an oil immersion objective (100×) using an Olympus BX 51 microscope, equipped with Nomarski differential interference contrast (DIC). Photographs were taken with an Olympus UC30 digital camera. For Scanning electron microscopy (SEM), aliquots of the oxidized material were mounted on aluminium stubs, air-dried and sputter-coated with 50 nm of gold (Balzers Union SCD 020) and studied at the Meise Botanic Garden with a Jeol JSM-7100FLV Field Emission Scanning Electron Microscope operating at 1 kV and 6.9 mm working distance. Raw materials and permanent microscopic slides are kept at the algological herbarium of the University of Kisangani; a part of the raw materials, the cleaned samples, a double of the permanent microscopic slides and SEM stubs are housed at the Meise Botanic Garden (BR).

TABLE 1. Overview of the samples collected in rivers in the Yangambi Biosphere Reserve, DR Congo, with information on the sampling day, substrate, location and some physico-chemical measurements (temperature, pH and conductivity).

Collector number	River	sample day	sample type	coordinates	temperature	pH	conductivity
CCA 3565/LND 0020	Lubilu	15 Feb. 2015	epipsammon	0.76113° N, 24.59422° E	23.0 °C	5.70	12.5 µS.cm^{-1}
CCA 3567/LND 0022	Lubilu	15 Feb. 2015	epiphyton	0.76113° N, 24.59422° E	23.0 °C	5.70	12.5 µS.cm^{-1}
CCA 3568/LND 0023	Lubilu	15 Feb. 2015	epiphyton	0.76113° N, 24.59422° E	23.0 °C	5.70	12.5 µS.cm^{-1}
CCA 3577/LND 0032	Lotuli	15 Feb. 2015	epiphyton	0.61740° N, 24.71560° E	23.0 °C	5.39	27.2 µS.cm^{-1}
CCA 3585/LND 0040	Lokwaje	15 Feb. 2015	epipsammon	0.58400° N, 24.95680° E	24.0 °C	6.46	13.4 µS.cm^{-1}
CCA 3758/LND 0076	Lubilu	27 Dec. 2015	epiphyton	0.76113° N, 24.59422° E			
CCA 3759/LND 0077	Lubilu	27 Dec. 2015	epipsammon	0.76113° N, 24.59422° E			
CCA 3760/LND 0078	Lubilu	27 Dec. 2015	epiphyton	0.76113° N, 24.59422° E			
CCA 3762/LND 0054	Lokombe	27 Dec. 2015	epiphyton	0.76113° N, 24.59422° E			
CCA 3777/LND 0053	Lokwaje	27 Dec. 2015	epipsammon	0.76113° N, 24.59422° E	24.0 °C	6.46	13.4 µS.cm^{-1}
CCA 4188/LND 0108	Lotuli	17 April 2015	epiphyton	0.61740° N, 24.71560° E	27.5 °C	6.74	30.1 µS.cm^{-1}

Physical and chemical variables (water temperature, conductivity and pH) were measured in situ just before the diatom sampling, using a multi-meter WTW 340i. Relative abundances of the diatom taxa were calculated from counts of 500 valves on each slide examined.

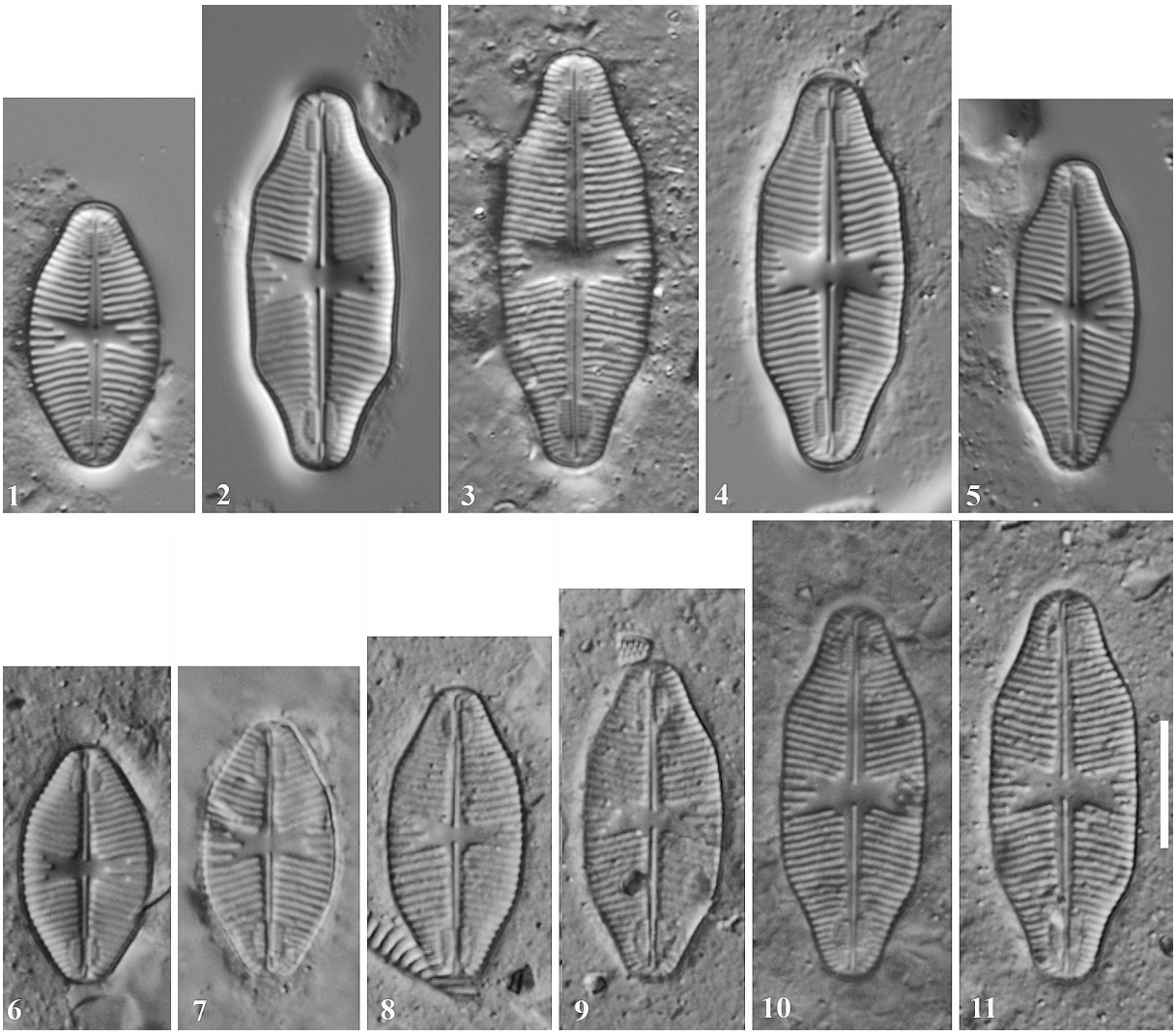
The material from Ghana, from which Foged (1966) reported *Navicula paludosa* Hustedt (1957: 286), used for the present paper is: "Locality no. 33 sampled on 13 March 1961: Suhin river, tributary to the Tain, at the village Subinso, about 20 km northwest of Wenchi; river abounding in clear, running water. Sample no. 218: scrapings from dead branches and from stones in running water in the river." This material and the original slide studied by Foged is deposited at the Museum Botanicum Hauniense (C), Natural History Museum of Denmark, University of Copenhagen. Locality 33 is located in the Guinea savannah in the central region of Ghana, on an Early Palaeozoic Voltaian formation, sandstone, shale, mudstone, conglomerates, and tillite of which form a large plateau with an average height of about 200–300 m above sea level (Foged 1966).

The genus *Geissleria* is characterized by the presence of annuli near the apices. We are given her the definition of the term annulus, as it is often incorrectly spelled (annula, plural annulae) or the structure is misinterpreted. The annulus concerns a hyaline area and not the striae (Lange-Bertalot & Metzeltin 1966) is clearly expressed in the definition given on the website of the Diatoms of North America (2019): "In the genus *Geissleria*, a circular or semi-circular hyaline area on the valve face which interrupts two or more distal striae. An annulus may be distinctive or barely discernible, depending on species. Plural form is annuli."

Results

Division **Bacillariophyta**
Class **Bacillariophyceae**
Subclass **Bacillariophycidae**
Order **Cymbellales**
Family **Gomphonemataceae**
Genus ***Geissleria***

Geissleria lubiluensis Cocquyt & Lokele *sp. nov.* (Figs 1–4, 6–17)
Valves linear with slightly triundulate margins, and protracted broadly rounded ends. Length 18.0–31.5 µm, width 9.8–11.5 µm (n = 20). Raphe filiform, straight. Axial area narrow becoming somewhat broader toward the middle of the valve. Central area large, rectangular and delimited by three to six shortened striae. Isolated areolae absent. Central raphe ending straight and slightly enlarged; terminal raphe endings deflected to opposite directions. Striae slightly radiate throughout, (13)14–15(16) striae in 10 µm, becoming denser near the apices up to 18–20 striae in 10 µm. Very distinct annuli present mostly at the distance of 3 striae from the apices; 6–9 rows of denser striae present between the annulus and the axial area, corresponding to about 6–7 striae on the opposite side of the annulus.



FIGURES 1– 4, 6–11. *Geissleria lubiluensis* Cocquyt & Lokele *spec. nov.* LM, DIC, valve views showing the size diminution series. Figs 1–4. Valves from type material CCA 3759 / LND 0077, holotype slide BR 4536, Lubilu River, DR Congo. The valve shown in Fig. 2 represents the holotype. Figs 6–11. Valves from material sampled in other small rivers in the Biosphere Reserve of Yangambi, showing the morphologic variability. Fig. 5. *Geissleria fogedii* Cocquyt *spec. nov.* valve from material CCA 3759 / LND 0077. Scale bar = 10 µm.

Type:—DEMOCRATIC REPUBLIC OF THE CONGO. Tshopo Province: river Lubilu, epipsammon, 0.76113° N, 24.59422° E, 27 December 2015*, CCA 3759 / LND 0077* (holotype BR! 4536, Meise Botanic Garden, Belgium, the valve representing the holotype is here illustrated in Fig. 2; isotype ZU! 11/21 BRM, Hustedt Diatom Collection, Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany).

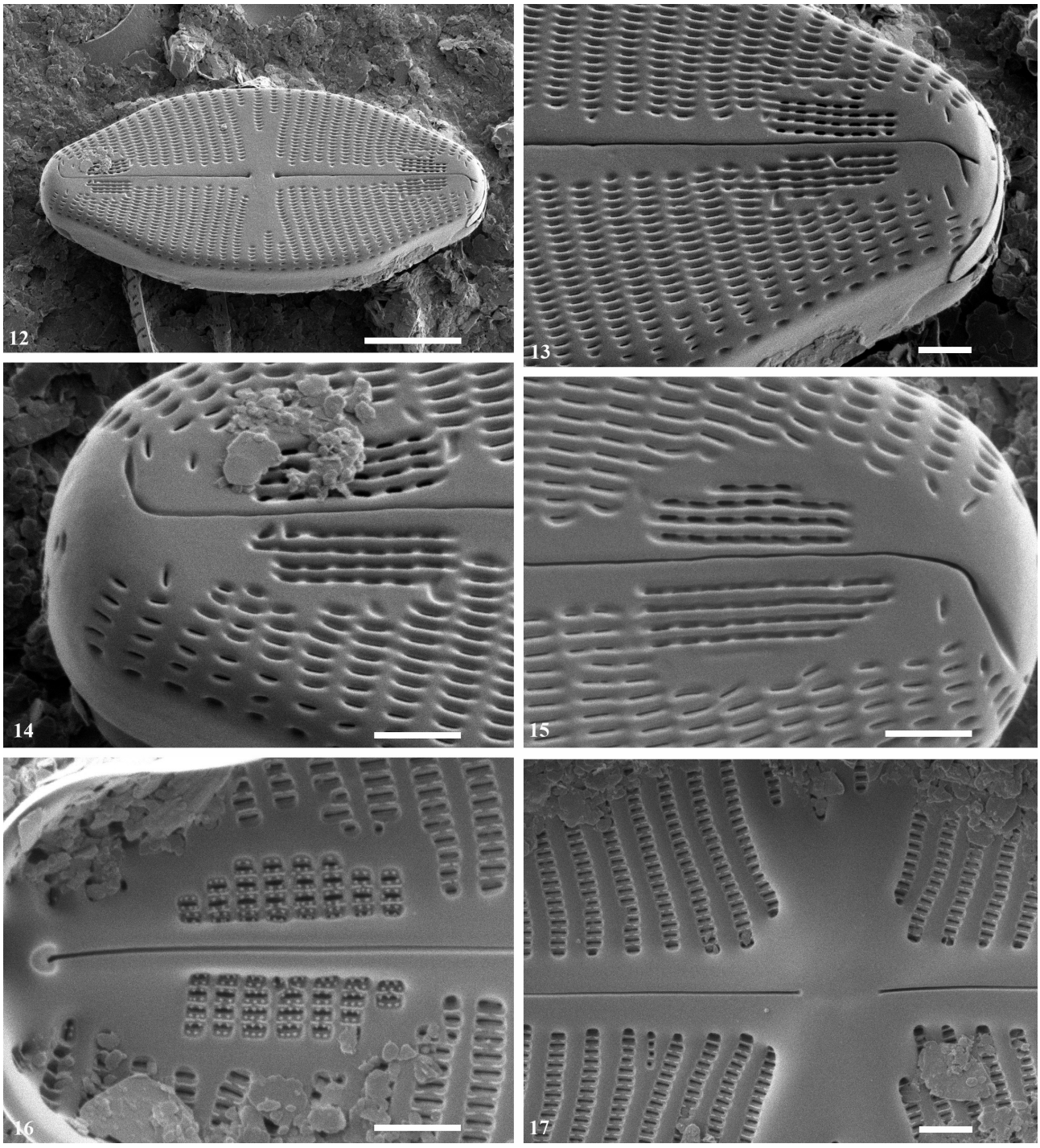
Registration: http://phycobank.org/100491

Etymology:—The specific epithet "lubiluensis" refers to the river Lubilu in which this species was first observed.

Ecology and distribution:—This taxon was found in running, acid freshwater with low conductivity in epiphytic and epipsammic samples. Up to now *Geissleria lubiluensis* was only found in some rivers in the Yangambi Biosphere Reserve e.g. Lubilu, Lokombe, Lotuli and Lukwaje, all located on the right bank of the Congo River downstream Kisangani.

SEM observations (Figs 12–17):—External view: Striae uniseriate composed of transapically elongated areolae, around 55 in 10 µm (Figs 12–15). Striae continuous on the valve mantle (Figs 12, 14). The raphe branches are straight and filiform and deflected towards opposite direction at the apices. Central raphe endings slightly roundly enlarged (Fig. 12), terminal raphe endings slightly enlarged (Fig. 14), sometimes bifurcated (Fig. 13) and sometimes continuing on the valve mantle (Fig. 15). Presence of a couple of areolae perpendicular to the raphe (Figs 13–15) in the hyaline area around the terminal raphe endings. Annuli present mostly at the distance of 3 striae from the apices (Figs 12–15); striae of the annuli slightly denser (6–9 rows) than the striae between the annulus and the junction of the valve face

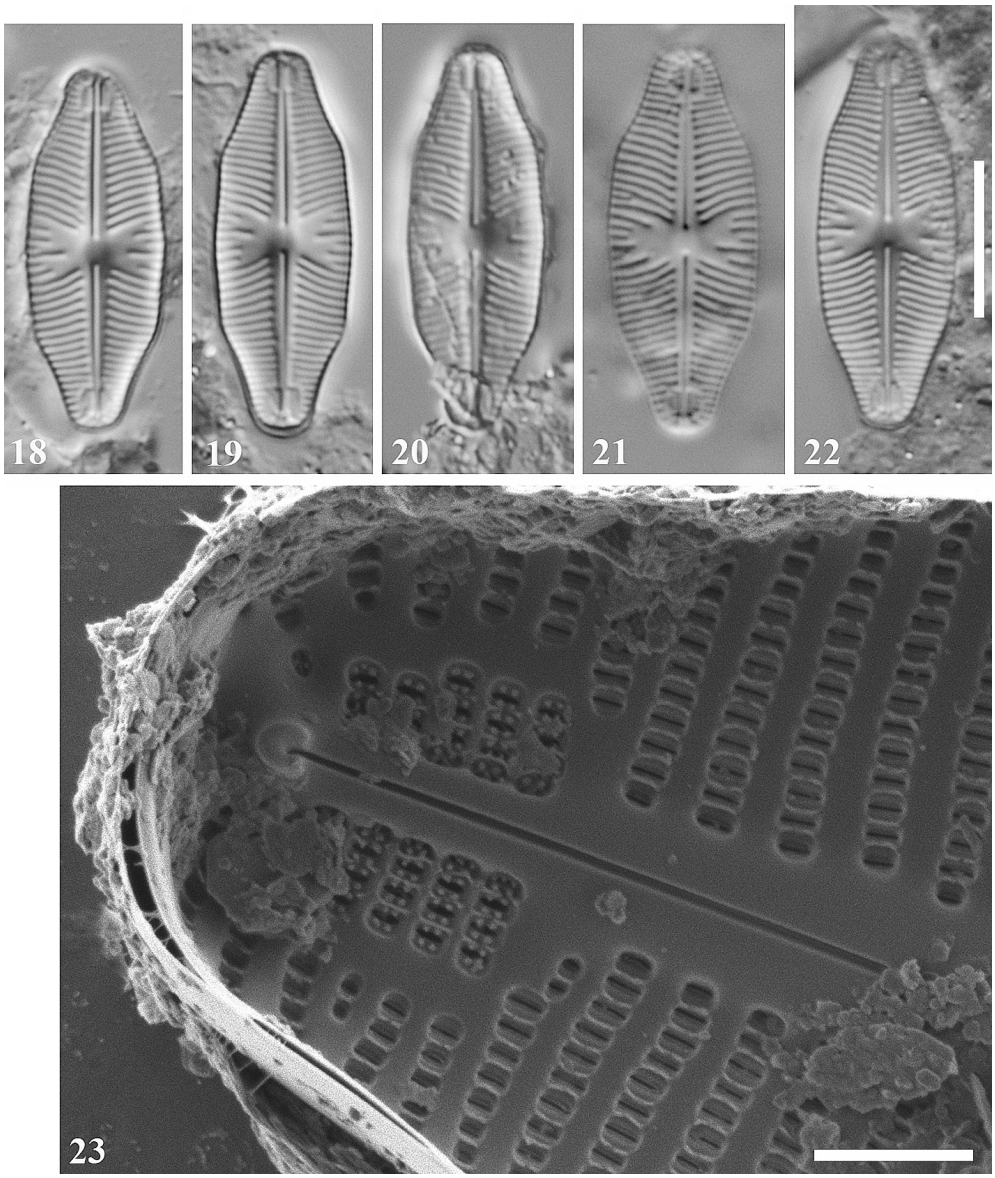
and mantle (6–7 rows). These denser striae are composed of shorter elongated areolae, around 0.2 µm compared to the other areolae of 0.3 µm, and arranged in 2 to 4, rarely 5 longitudinal narrow rows.



FIGURES 12–17. *Geissleria lubiluensis* Cocquyt & Lokele *spec. nov.* SEM, valves from type material CCA 3759 / LND 0077. Figs 12–15. External views, showing the denser striae between the annuli and axial area; note the bifurcated terminal raphe ending and an open girdle band near the apex on Fig. 13. Figs. 16–17. Internal views. Fig. 16. Detail of the annuli. Fig. 17. Detail of the straight central raphe endings. Scale bar fig. 12 = 5 µm, figs 13–17 = 1 µm.

Internally the central raphe endings are straight and not enlarged, the terminal raphe endings terminate in small helictoglossae (Fig. 16). The virgae are raised between the slightly sunken striae (Figs 13, 17); the vimines bear small silica ridges interrupted in the middle (Figs 16, 17). Presence of 2 to 3 small warts on both longest sides of the narrowly elongated areolae of the annuli (Fig. 16).

Beside the valvocopula at least one open girdle band is present (Fig. 13).



FIGURES 18–23. *Geissleria fogedii* Cocquyt *spec. nov.* Figs 18–22. LM, DIC, valve views from type material of Foged, Ghana nr 218, showing the size diminution series. The valve shown in Fig. 19 represents the holotype. Fig. 23. SEM. Inside view of valve showing the details of the striae and annuli near one pole. Scale bar figs 18–22 = 10 µm, fig. 23 = 1 µm.

Geissleria fogedii Cocquyt *sp. nov.* (Fig 18–23)

Synonym: *Geissleria paludosa* (Hustedt) Lange-Bertalot & Metzeltin sensu Foged (1966: 95, pl. 16 fig. 5).

Valves linear with slightly tri-undulate margins, and protracted broadly rounded ends. Length 21.8–23.5 µm, width 8.3–9.2 µm (n= 7). Raphe filiform, straight. Axial area narrow, becoming somewhat broader toward the middle of the valve. Central area large, rectangular and delimited by six to seven shortened striae. Isolated areolae absent. Central raphe ending straight and slightly enlarged, terminal raphe endings deflected to opposite directions. Striae radiate, 18–19 striae in 10 µm, becoming denser, up to 22.5–25 striae in 10 µm, and parallel to slightly divergent near the apices. Very distinct annuli present mostly at the distance of one stria from the apices; around 5 rows of denser striae present between the annulus and the axial area and 4–6 rows of striae between the annulus and the valve margin.

Differential diagnosis: Differs from *Geissleria lubiluensis* in the annulus which is located closer to the valve apex mostly at the distance of one stria from the apices, the smaller number of elongated areolae delimited by the annulus, and the finer striation.

Type:—GHANA. Subindo village about 20 km northwest of Wenchi: river Suhin, tributary of the Tain river, *Foged 218* (holotype C! Foged 218, Museum Botanicum Hauniense, Copenhagen, Denmark, the valve representing the holotype is here illustrated in Fig. 19; isotype BR! 4550, Meise Botanic Garden, Belgium).

Registration: http://phycobank.org/100828

TABLE 2. Overview of some morphological feature in *Geissleria lubiluensis sp. nov.*, *Geissleria fogedii* spec. nov. and other *Geissleria* taxa, according to this study and literature data

	lubiluensis	*fogedii (as Navicula pseudolagerstedtii)*		*lagerstedtii* sensu Hustedt	*pseudo–lagerstedtii*	*pseudo–lagerstedtii*	*badma*	*badarma*	*pseudobadma*	*ochigma*
valve outline	slightly triundulate	slightly triundulate	slightly triundulate	linear, triundulate	broadly lanceolate	broadly lanceolate	elliptical–lanceolate	rhombical–lanceolate	lanceolate	elliptical to linear–elliptical–lanceolate
apices	broadly rounded	broadly rounded	broadly rounded	broadly protracted	broadly protracted	broadly protracted	cuneate, bluntly rounded	bluntly rounded	cuneate, obtusely rounded	broadly rounded
length (µm)	17.7–31.4	24	21.8–23.5	15–21	13–18	8–18	16.7–20	25.3–26.7	24.7–39	23.0–46.0
width (µm)	9.8–11.5	8.8	8.3–9.2	3.5–5	6–7	4.7–6	8.0–8.6	8.0–8.7	8.7–9.3	9.0–11.3
length/width ratio	1.8–2.8		2.5–2.7				1.6–2.5		3.0–4.3	2.5–4.1
shortened striae in central area	3–6	7*	6–7	1	3	1–3*	–	–	–	–
striae in 10 µm	(13)14–15(16)	15–16	18–19	15	15	14–20	15–16	9–10	13–14	12–14 15–16 near poles
areolae in 10 µm	50		60					32–35		
striae between valve margin and annulus	6–7	3*	4–6		2	2–3				
striae in between axial area and annulus	8–9		5				5–7*		7–8*	7–8*
areolae in striae between axial area and annulus	2–4		3–4						3–4*	
literature		Foged 1966	Foged's material	Schmidt 1934	Cholnoky 1960	Carter & Denny 1982	Kulikovskiy et al. 2012	Kulikovskiy et al. 2012	Kulikovskiy et al. 2012	Kulikovskiy et al. 2012

* measured on the drawings or micrographs in the cited publication

Etymology:—The specific epithet "fogedii" is given in honour of Niels Foged who observed this taxon but considered it to belong to *Geissleria paludosa*.

Ecology and distribution:—This taxon was found in running water. Up to now *Geissleria fogedii* was reported in one river in Ghana, the Suhin river and we observed one valve in the Lubilu River (DR Congo) (Fig. 5).

SEM observations (Figs 23):—Internally the terminal raphe endings terminate in small helictoglossae. The virgae are raised between the slightly sunken striae; the vimines bear small silica ridges mostly not interrupted in the middle. Presence of two small warts on both longest sides of the narrowly elongated areolae of the annuli.

Discussion

Geissleria lubiluensis and *G. fogedii* are morphologically very similar. Both taxa have the same valve length and outline, however, the valves are broader in *G. lubiluensis* (9.8–11.5 µm) than in *G. fogedii* (8.3–9.2 µm), the striae density is coarser in *G. lubiluensis* (14–15, sporadic up to 13 or 16, striae in 10 µm) than in *G. fogedii* (18–19 striae in 10 µm). Moreover, the number of shortened striae in the central area is different (3–6 versus 6–7), and the number of striae between the annuli and axial area is larger in the Congolese (8–9) than in the Ghanaian species (5). However, in the Congolese material one valve (Fig. 5) was observed that fits the description of *Geissleria fogedii* with a valve width of 9.2 µm and up to 22 striae in 10 µm near the apices. This let us suppose that *G. fogedii* has a wider distribution in tropical West Africa and the Congo basin, and will be reported from other localities when more studies will be carried out on diatoms from small acid rivers and streams in this part of tropical Africa. As no molecular information is available of *Geissleria lubiluensis* and *G. fogedii* to support that the morphological characteristics are genetically determined, we follow the trend currently existing in the description of new diatom species based only morphological characteristics (e.g., Kociolek et al. 2015, Kulikovskiy et al. 2012, Van de Vijver 2019, Wetzel et al. 2019). The ecology of both new species is not well known as they were only observed sporadically in samples from small rivers and streams: *Geissleria lubiluensis* in the rivers Lubilu, Lokombe, Lotuli and Lukwaj in the Yangambi Biosphere Reserve, and *G. fogedii* in the river Suhin and one valve in the river Lubilu respectively. The Yangambi rivers are characterized by their low conductivity and acid pH, while no information was given on the Suhin river.

Foged (1966) reported *Navicula paludosa* from Ghana and illustrated it by a drawing. However, Foged's drawing is not fitting the original description (Hustedt 1957: 286) or the drawings given by Hustedt of *Navicula lagerstedtii* var. *palustris* Hustedt (Hustedt in Schmidt 1934: plate 400, figs 27–29), which has smaller annuli corresponding to only 2–3 striae. In 1996 *Navicula paludosa* was transferred by Lange-Bertalot & Metzeltin to *Geissleria paludosa* (Hustedt) Lange-Bertalot & Metzeltin. Later Bukhtiyarova & Pomazkina (2013: 169) transferred this taxon to the genus *Navigeia: Navigeia paludosa* (Hustedt) Bukhtiyarova. According to AlgaeBase (Guiry & Guiry 2018), *Navicula lagerstedtii* var. *palustris* Hustedt (in Schmidt 1934: plate 400, figs 27–29) is a synonym of *Geissleria paludosa*. The interpretation by Foged (1966) of the species concept of *Navicula paludosa* is another example of "species concept drift" as discussed in Taylor et al. (2016 a) for the case of *Navicula fuerbornii* f. *africana* Foged (1966: 140) from Ghana. The drawing given by Foged of *Navicula paludosa* based on material from Ghana (Foged 1966, plate 16, fig. 4) and our own observation (Figs 19–24) showed a taxon that in valve outline doesn't resemble the original concept of *Geissleria paludosa* by Hustedt but indeed resemble very well the new described slightly tri-undulate *Geissleria lubiluensis* from DR Congo. Some incongruences exist between Foged's text and drawing (Foged 1966) (Table 2): striae density of 15–16 in 10 µm mentioned in his text while on the drawing there are 18–20 striae in 10 µm close to the central nodulus. Re-examination of Foged's slide 218, showed that the striae density was indeed 18–20 in 10 µm as represented in his drawing. Comparable incongruences were also observed in other species described by Foged from Ghana (Cocquyt & Kusber 2010), e.g. number of alar canals in 10 µm in *Iconella takoradiensis* (Foged) Cocquyt & R. Jahn (in Jahn *et al.* 2017: 96) (as *Surirella takoradiensis* Foged (1966:152)): 6.0–6.5 in the text and only 4.0 on the drawing.

Morphologically *Geissleria lubiluensis* and *G. fogedii* resemble somewhat *Geissleria pseudolagerstedtii* (Cholnoky) Cocquyt & Taylor (2019: 1). This species, described from Natal, South Africa, as *Navicula pseudolagerstedtii* Cholnoky (1960: 75) has a length of 13–18 µm, a width of 6–7 µm and a central area bordered by 3 shortened striae on each side of the stauros (Cholnoky 1960) (Table 2). It was also reported from Sierra Leone by Carter & Dennis (1982). However, the two new species differ in valve outline which is tri-undulate or at least slightly tri-undulate compared to broadly lanceolate in *N. pseudolagerstedtii*, in the valve width which is somewhat broader (9–11.5 and 8.3–9.2 versus 6–7 µm) and the larger number of striae bordering the annuli (6–9 and versus 2).

Resembling annuli enclosing a large number of dense areolae are present in *G. badarma* Kulikovskiy, Metzeltin & Lange-Bertalot, *G. pseudobadma* Kulikovskiy, Metzeltin & Lange-Bertalot and *G. ochigma* Kulikovskiy, Metzeltin & Lange-Bertalot, all described from Lake Baikal (Kulikovskiy 2012, pl. 73 figs 14–20, 26–29, 32–35; pl. 74 fig. 5; pl. 75 fig. 1). However the valve outline of these three taxa as well as the coarser striation (9–10, 13–14, 12–14 striae in 10 μm respectively) are different from *G. lubiluensis* and *G. fogedii* (Table 2).

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