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Lindavia biswashanti, a new diatom species (Bacillariophyta) from Gokyo Cho, Himalayan Range, Nepal

JOSEPH MOHAN[1, 2], JEFFERY R. STONE[2], KIRSTEN NICHOLSON[3], KLAUS NEUMANN[3], CAROLYN DOWLING[3] & SUBODH SHARMA[4]

[1]*Climate Change Institute & School of Biology & Ecology, University of Maine, Orono, Maine 04469, USA*
[2]*Department of Earth & Environmental Systems, Indiana State University, Terre Haute, Indiana 47809, USA*
[3]*Department of Geological Sciences, Ball State University, Muncie, Indiana 47306, USA*
[4]*Department of Environmental Science & Engineering, Kathmandu University, Dhulikhel 45200, Nepal*
**Corresponding author (E-mail: Joseph.Mohan@Maine.edu)*

Abstract

A new species of Bacillariophyta (diatom) is described from Gokyo Cho, a lake near Mount Everest in the Himalayan Mountain Range. Water and algal samples were collected during an expedition to Sagarmatha National Park (SNP), Nepal in May 2016. Samples collected during this expedition reveal a new species of *Lindavia,* described herein with ecological information provided. The new species of *Lindavia* has three triangular undulations and depressions in the central area. This species has a likeness to the *Pantocsekiella ocellata sensu lato* group. It differs from the species in this group in undulation shape and ultrastructure numbers and distribution. Investigation into previously described *Lindavia* in the SNP region has identified a taxon, *Cyclotella antiqua* var. *minor,* which is herein transferred into *Lindavia* in order to conform to the parent taxon *Lindavia antiqua.*

Introduction

The first reports of diatoms from the Himalayan Range are likely from Dickie (1882) who notes that samples from several moraine lakes were collected during an 1881 expedition from the vicinity of Mount Kinchinjunga which lies ~123 kilometers East-Southeast of Mount Everest. Sample labels during this expedition were unfortunately destroyed so the exact location is lost (Dickie, 1882). The 1881 samples revealed 28 species in 14 genera. In 1958 the Cho Oyu Expedition-1 initially revealed 11 species of diatoms, as reported by Rao (1963). Samples from the 1958 expedition were reexamined and reported by Suxena & Venkateswarlu (1968) to contain 69 unique diatom taxa.

Samples from Gokyo Cho retrieved during the 2016 SNP expedition contain specimens of a novel diatom assigned to *Lindavia* (Schütt) De Toni & Forti (1900: 553) which bears a surficial likeness to that of *Cyclotella antiqua* var. *minor* Suxena & Venkateswarlu (1968: 6) which is transferred to *Lindavia* herein.

Materials and Methods

Site description:—The samples were collected from shoreline sediment of Gokyo Cho, the 3rd Gokyo Lake, approximately 50 centimeters above the water line on 02 May 2016. The Gokyo Lakes system is comprised of 19 lakes located on the western side of the Ngozumpa Glacier south of Mount Cho Oyu (Tartari *et al*. 1998a, Lacoul & Freedman 2006). The lakes are considered sacred to both Buddhist and Hindu religions. They are some of the world's highest elevation freshwater lake systems lying between 4,600 and 5,100 m. The lake system is comprised of six main lakes, all of which are moraine-dammed glacier lakes. The Gokyo Lakes wetland area discharges water to the Dudh Kosi, which is the main river in the SNP. In September 2007, Gokyo and associated wetlands of 7,770 ha were designated a Ramsar site (wetlands of international importance).

Gokyo Cho, also called Dudh Pokhari and 3rd lake, is the main lake with an area of 42.9 ha (106 acres), and

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the village of Gokyo lies on its eastern shore. Gokyo Cho is triangular in shape and has an asymmetrical basin with steep hills on the western and southern sides. As sources of permanent fresh water, the lake receives water from one main inflow in the north (from the higher lakes), four small inflows, and seepages from the Ngozumpa glacier, on the western side of the lake as well as several small springs on the southern slope of Gokyo Peak on the northern side of the lake.

Laboratory Methods

Samples recovered from Gokyo Cho were placed in glass scintillation vials and treated with 30% H_2O_2 for three weeks in order to remove organic material. The samples were rinsed with deionized water to remove excess H_2O_2. Diatom extracts were dried onto glass cover slips and mounted to slides with Naphrax, a high refractive index mounting media. Samples were analyzed under a Leica DM2500 light microscope. Further imaging of the specimens was conducted at the Integrated Nanosystems Development Institute at Indiana University Purdue University, Indianapolis on a JEOL 7800F field emission scanning electron microscope.

Results

Order **Thalassiosirales**

Family **Stephanodiscaceae**

Genus **Lindavia** (Schütt) De Toni & Forti (1900: 553)

***Lindavia antiqua* var. *minor* (**Suxena & Venkateswarlu) Stone & Mohan, *comb. nov.*

Basionym: *Cyclotella antiqua* var. *minor* Suxena. & Venkateswarlu in Algae of the Cho Oyu (E. Himalaya) expedition-I, Bacillariophyceae. *Hydrobiologia* 32 (1): 6, pl. 1, fig. 2. 1968.

Type:—Lower valley below Namche Bazar, Sagarmatha Zone of the Solukhumbu District, Nepal. Streams flowing into Dud Kosi river at altitudes ranging from 2900–200 m. Permanent slide No. 5: I, in Botany Department, Osmania University, Hyderabad, original drawing No. 14.

Lindavia biswashanti Mohan & Stone *spec*. *nov*. (Figs 2, 3)

Valves are discoid, 4–13 µm in diameter. Valve face is separated into a hyaline central area and a marginal area marked by radial striae. The central area exhibits radial undulation; three alternating depressed wedges are bounded by three raised wedges. Central area comprises 2/3 of the valve face area (Fig. 2). Doubly punctate fascicles are distributed 13–20 in 10 µm. Internally the fascicles perforate into alveolar chambers with a single round opening. A single fultoportula is present on the valve face near the center of the valve. Three to five mantle fultoportulae are evenly distributed around the margin. Externally the valve face and mantle fultoportulae are simple round perforations. Internally both types of fultoportulae consist of a central pore with circular raised sides. On opposite sides of the central pore exist two crescent-shaped satellite pores both with raised edges (Figs. 3, E & F). Internally the mantle fultoportulae reside on costae (Figs 3, D & F). A simple, slightly raised rimoportula is exhibited internally (Figs. 3, D & F). Externally the rimoportula is inconspicuous (Figs. 3, A & B).

Type:—NEPAL. Province No. 1 (Solukhumbu District): Sagarmatha National Park, Gokyo Cho, 4750 m, N 27.953863, E 86.692920, collected by *K. Nicholson* on 02 May 2016, General Collection no. 36357 ANSP! (**Holotype**, Fig 2, C is the encircled holotype specimen)

Etymology:—The lake from which *Lindavia biswashanti* has been recovered is considered to be sacred by Buddhists and Hindus. As such, *L. biswashanti* is named in respect for the Tengboche monks; *biswashanti* means ‘world peace’ in the Nepali language and is their message to the world.

Remarks:—*Lindavia biswashanti* differs from *Pantocsekiella hispanica* (K.T. Kiss, E. Hegewald et Ács) K.T.

Kiss *et* Ács (2016: 66) by lacking round nodes on the undulations on the central area. *P. hispanica* exhibits three areolae per fascicle whereas *L. biswashanti* has two per fascicle. *P. hispanica* also exhibits greater numbers of mantel fultoportulae than *L. biswashanti* (Table 1). *Pantocsekiella ocellata* (Pantocsek) K.T. Kiss et Ács (2016: 62) differs most notably by exhibiting papillae and orbiculi depressi in the central area. *L. biswashanti* lacks these distinct features. *P. ocellata* also show greater numbers of areolae per fascicle and greater number of mantel fultoportulae (Table 1). *Pantoscekiella tripartita* (Håkansson) K.T. Kiss *et* Ács (2016: 69) differs from *L. biswashanti* by having additional protrusions in the central area and exhibiting spinules on the interfascicles marking the interface of the valve face and mantel (Håkansson, 2002). *L. biswashanti* differs from *L. antiqua* var. *minor* by having hyaline undulations in the central area whereas *L. antiqua* var. *minor* is described as having delicately punctate depressions in the central area. Therefore, we suggest that the specimen identified by Misra *et al.* (2009) Plate 1, Fig. 1 is *L. bishwashanti* not *L. antiqua* var. *minor* because it lacks punctate depressions.

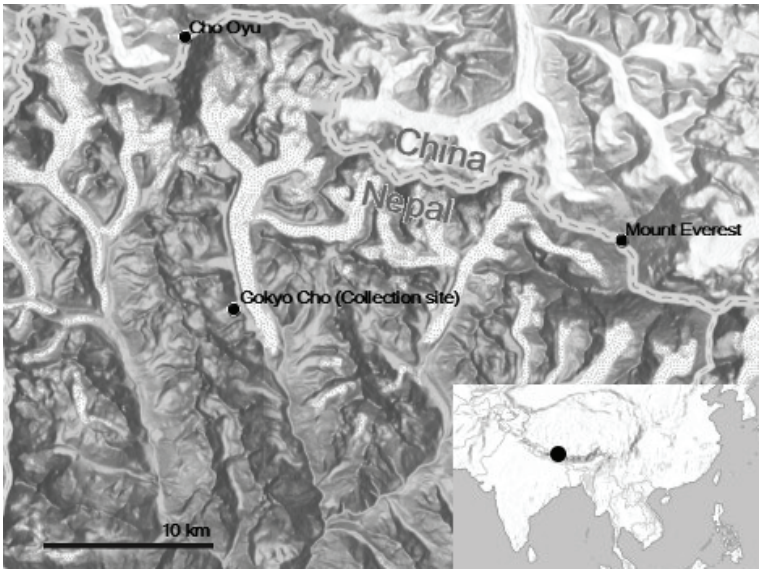

FIGURE 1: Map of the Sagarmatha National Park region, Province No. 1, Solukhumbu District, Nepal. The region is dominated by some of the tallest peaks in the world. Mount Everest (8,848 m) and Cho Oyu (8,188 m) are shown. The lakes from which samples were collected comprise some of the highest elevation lakes in the world. Gokyo Cho is the locality from which the holotype material is collected. Location of the region in the Himalayas (inset).

TABLE 1: Comparison of morphological characteristics of *L. bishwashanti* and similar taxa. Diameters are in µm. Undulations refers to raised and lowered areas within the central area. Areolae rows per fascicle is the number of areolae across each fascicle.

	L. bishwashanti (herein)	*P. hispanica* (Kiss *et al,* 2002)	*ocellata* (Burge *et al,* 2016 b)	*tripartita* (Håkansson, 2002)	*comensis* (Burge *et al,* 2016 a)
Diameter (µm)	4–13	3.5–17	4–15	2–18	5–12
Undulations	triradiate distinctly triangular	triradiate with round nodes	2–6 papillae & orbiculi depressi	triradiate with additional protrusions	Tangentially undulate
Fascicles/ 10 µm	13–20	12–20	15–30	19–22	9–12
Areolae rows per fascicle	2	3	3–5	2–3	3
No. of mantel fultoportulae	3–5	4–15	2–18	4–7	4–11
Rimoportulae	1	1	1	1	1

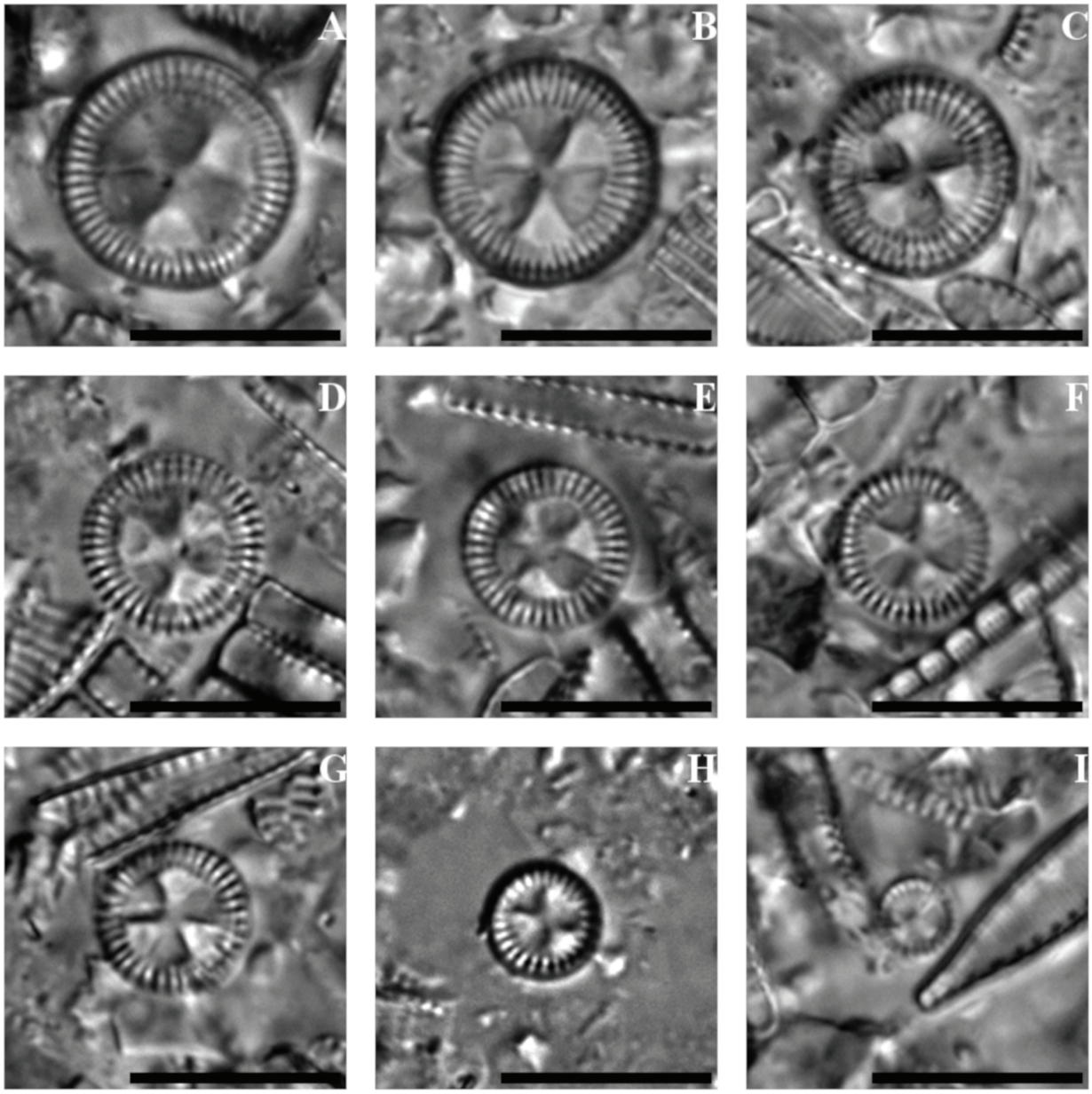

FIGURE 2: Size diminution series of *Lindavia biswashanti.* Light microscope images captured under a Leica DM2500. The holotype specimen is image C. Scale bars are all 10 µm. The central fultoportula is readily visible in larger specimens (A–F) and slightly offset from the center of the valve. Rimoportulae are indistinct in light microscope. The distinguishing features are the three triangular-shaped raised areas juxtaposed with three lowered areas to make six sectors in a superficial likeness of the nuclear fallout-shelter symbol.

Discussion

Sharma *et al*. (2010) used temperature and oxygen data to show that there is spring turn over in the lakes. The lake sediments are silty-clay in the deeper water and sandy-silt in the littoral areas (Tartari *et al*. 1998b). Sedimentation rates in Gokyo Cho are roughly 0.07 cm per annum (Sharma *et al*., 2010). The watershed contains mostly slow weathering exposed bedrock and glacier debris of gneiss and quartz-silicate rocks (Bortolami 1998). The vegetation is dominated by alpine tundra with graminoids, forbs, and shrubs such as juniper and rhododendron (Lacoul & Freedman 2006). The wetland is devoid of fish, whereas plankton and macro-invertebrates are abundant (including planariids, mites, heptagenids, baetids and simulids), particularly in the streams (Sharma *et al*., 2010). The littoral zone of Gokyo Cho includes areas of abundant aquatic vegetation and zones absent of vegetation; hence the littoral zone supports a

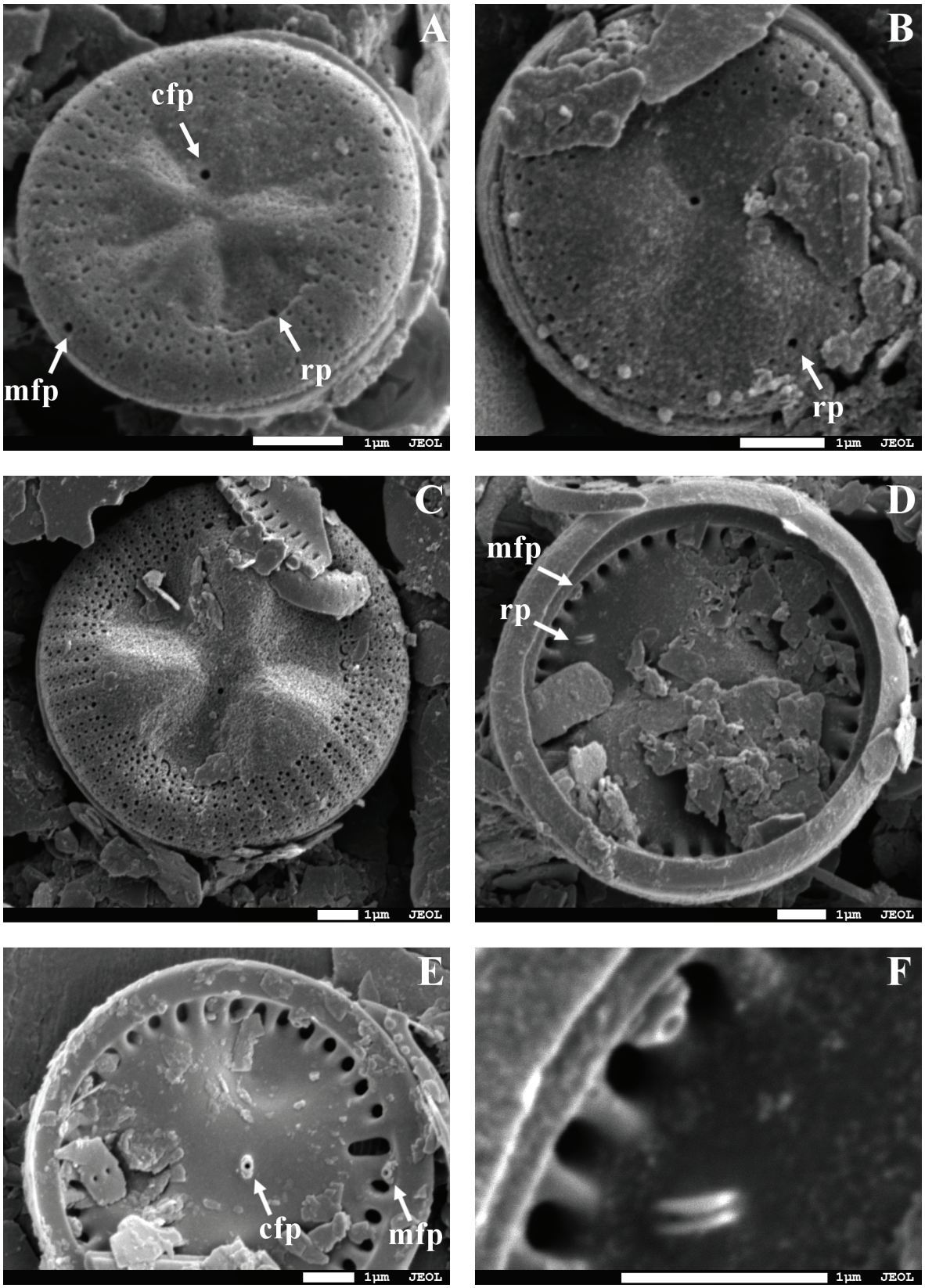

FIGURE 3: Scanning electron micrographs of *Lindavia biswashanti*. Image A exhibits the external view with central fultoportula (cfp), rimoportula (rp), and marginal fultoportulae of which one is arrowed (mfp). Image B is a small specimen that exhibits granules around the margin. Interior expressions of the central fultoportula, rimoportula, and marginal fultoportula are shown in images D & E. Image F is a close up of the rimoportula and marginal fultoportula shown in image D.

macro-invertebrates assemblage but lacks a diverse benthic community. The northern inlet to Gokyo Cho is dominated by massive growth of mosses due to Gokyo village. The deep benthos is dominated by less diverse macro-invertebrates capable of surviving in low temperature and low dissolved oxygen conditions (Sharma *et al*., 2010).

Three locations around the lake were tested and yielded an average temperature of 11.2°C, pH of 7.6, TDS of 76.9ppm, and conductivity of 154 µS. Ghimirie *et al*. (2013) conducted a three-year study of high altitude lakes in the SNP in 2008, 2009 and 2010, including the 3rd Gokyo Lake. The physical parameters from the inlet and outlet samples roughly correspond to our readings. They found Gokyo Lake inlet had an average temperature of 11.3°C, and pH of 7.8, TN-NO_3 of 0.46 mg/l, and TP-PO_4 of 0.24 mg/l, whereas the outlet had a temperature of 10.1'C, pH of 7.6, TN-NO_3 of 1.3 mg/l and TP-PO_4 of 0.30 mg/l.

It is important to note a possible rift created in taxonomic nomenclature represented by the description of *Lindavia biswashanti.* Ács *et al*. (2016) described a new genus that proposed to split *Lindavia* on the basis of genetic distance. The proposed genus *Pantocsekiella* K.T.Kiss & E.Ács, (2016: 61) is separated by genetic distance and lack of areolae in the central area. However, it lacks a complete molecular phylogeny. Current evidence that *Pantocsekiella* represents a monophyletic group is insufficient because Ács *et al*. (2016) provided genetic analysis of four *Lindavia* species and applied those results to 38 species based on morphological observations which does not preclude lack of areolae in the central area being a result of convergent evolution. This coupled with genetic distance as a dubious means of separating taxa provokes *L. biswashanti* to be placed in *Lindavia*, which we accept as a valid genus.

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