

New or otherwise interesting desmid taxa from the Bangweulu region (Zambia). 3. Genus *Cosmarium* (Desmidiales)

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Background and aims – In a third contribution to the desmid flora of the Bangweulu wetlands in Zambia a selection of species from the genus *Cosmarium* is discussed for their taxonomy and geographical distribution.

Methods – Samples were collected from Lake Bangweulu and adjacent swamps as well as from Lake Wakawaka. Collection was by squeezing submerged plant material or using a plankton net.

Key results – Eleven taxa are described as new to science: *Cosmarium bangweuluense*, *C. bidentulum*, *C. binodosum* var. *thomassonii*, *C. campanuliforme*, *C. connatoides*, *C. cunningtonii* var. *luxuriosum*, *C. lindiae*, *C. luapulaense*, *C. mitra*, *C. pseudoredimitum* and *C. subligoniforme*. Two taxa, *C. binerve* var. *elongatum* and *C. taxichondrum* var. *ambadiense*, were raised in rank and provided with new names: *C. binervoides* and *C. binodosum*, respectively.

Conclusions – All taxa discussed, except *C. binervoides*, have an exclusive African distribution. Quite a number of *Cosmarium* species encountered in the present study is marked by a cell wall sculpture consisting of prominent, scattered tubercles, those located just below the apex often being much bigger than the other ones. Possibly, this morphological feature may be considered one of the characteristics of the African *Cosmarium* flora.

Key words – Desmids, *Cosmarium*, Zambia, Bangweulu, Wakawaka, taxonomy, morphology, geographical distribution.

INTRODUCTION

In two earlier contributions to the desmid flora of the Bangweulu wetlands and the relatively nearby Lake Wakawaka (Zambia) a number of species from the genera *Micrasterias*, *Allorgeia*, *Xanthidium*, *Staurastrum* and *Staurodesmus* were discussed (Coesel & Van Geest 2014, 2016). The present contribution deals with the genus *Cosmarium*. As in the previous studies, special attention is given to taxa that are peculiar from either a morphological or biogeographical point of view.

MATERIAL AND METHODS

Samples originated from two different areas, i.e. the vast area of Lake Bangweulu, a large lake in northern Zambia, plus adjacent swamps, and Lake Wakawaka, a small, bogbordered lake located some 150 km south-east of Lake Bangweulu. Desmid samples were mostly collected by squeez-

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ing submerged water plants, preferably species of the genus *Utricularia*. For a description of the sampling areas and detailed information on the collection sites, see Coesel & Van Geest (2014).

TAXONOMIC ACCOUNT

Cosmarium bangweuluense Coesel & Van Geest, **sp. nov.** Figs 1A & B, 4S–U

Diagnosis – Cells somewhat longer than broad with a deep median constriction. Sinus widely open from a somewhat elongate isthmus. Semicells in frontal view trapeziform-hexagonal with slightly convex margins. Cell wall ornamentation in the form of stout tubercles at the angles, a semicircular series of four similar tubercles just beneath the apex and two very stout tubercles at the base on either side of the isthmus. Semicells in lateral view quadrangular with pronounced tubercles at the angles. Semicells in apical view elliptic-rhomboid, the longer sides marked by tubercles. Dimensions: cell length 36–42 μ m, cell breadth 28–34 μ m, cell thickness 20–23 μ m, isthmus 9–11 μ m.

Type – Zambia, swamp in the Chipundu region, 11°44′02″S 29°46′01″E, 25 Sept. 2012, *Hugo de Vries Lab.* 2012.04 (holo-: L), preserved as a natural sample, and illustrated in fig. 1A.

Taxonomic remarks – Cosmarium bangweuluense is a characteristic species, both in outline and cell wall ornamentation. The only taxon found to have a roughly similar appearance is *C. mediogemmatum* West & G.S.West described by West & West (1897) from Angola and never recorded again. As compared to the latter species, however, both the shape of the semicells in frontal view (hexagonal-elliptic in *C. mediogemmatum*, trapeziform-hexagonal in *C. bangweuluense*) and in lateral view (circular in *C. mediogemmatum*, quadrangular in *C. bangweuluense*) are distinctly different. In addition to that, in frontal view a different arrangement of the cell wall tubercles may be noticed: a central tubercle encircled by a series of six in *C. bangweuluense*, the marginal tubercles protruding as pronounced papillae.

Cosmarium bangweuluense was encountered in small cell numbers in samples 2012080 and 2012088 originating from the Mpanta and the Chipundu region in the Bangweulu wetlands, respectively.

Cosmarium bidentulum Coesel & Van Geest, **sp. nov.** Figs 2D & E, 3A–C

Diagnosis – Cells in frontal view somewhat longer than broad, with a deep median constriction. Sinus linear, largely closed. Semicells about trapezoid with very broadly rounded apical angles. Basal angles with thickened cell wall and furnished with a prominent, blunt dentation. Semicells in lateral view almost circular with a couple of dentations at the base, cell wall in the mid region lens-shaped thickened. Semicells in apical view lemon-shaped. Cell wall finely punctate. Basal dentations and central lens-shaped cell wall thickenings usually brownish coloured. Chloroplast with two pyrenoids. Dimensions: cell length 60–71 µm, cell breadth 52–60 µm, cell thickness 33–41 µm, breadth of isthmus 15–17 µm.

Type – Zambia, Lake Wakawaka, 12°31′14″S 30°36′12″E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.02 (holo-: L), preserved as a natural sample, and illustrated in fig. 2E.

Taxonomic remarks – At first sight, the above described taxon looks somewhat like a biradiate version of the triradiate *Staurastrum bidentulum* Grönblad as discussed in Coesel & Van Geest (2009) from the Okavango Delta and also encountered in our present samples from Lake Wakawaka. However, apart from the difference in radiation, there is an essential difference is the rough outline of the semicells, i.e. pyramidal in *Staurastrum bidentulum* versus trapezoid in *Cosmarium bidentulum*. What those two species have in common is the pair of prominent dentations at each of the basal angles, rendering them a characteristic appearance. In respect of those basal dentations and also the lens-shaped central cell wall thickenings, usually remarkably brownish colored, there is a striking resemblance with *Cosmarium*

nudum (W.B.Turner) Gutw. as depicted by Scott & Prescott (1961) from Indonesia. The semi-circular semicell outline and the open, undulate sinus of that latter species, however, make clear that quite different species are at issue. Some varieties of *C. pseudotaxichondriforme* Nordst., such as var. *simplex* Bourrelly & Couté (Bourrelly & Couté 1991) and var. *rotundatum* A.M.Scott & Grönblad (Scott & Grönblad 1957) show also bidentate basal angles but differ in cell outline, shape of the sinus and/or other cell wall ornamentations.

Cosmarium bidentulum was encountered in Lake Wakawaka where it occurred in rather low cell numbers in samples 2012072 and 2012073.

Cosmarium binervoides Coesel & Van Geest, nom. nov. & stat. nov.

Figs 1C, 3D & E

Synonym – *Cosmarium binerve* var. *elongatum* Willi Krieg. & Gerloff, Die Gattung *Cosmarium*: 258, pl. 44, fig. 2. 1969 (Krieger & Gerloff 1969).

Taxonomic remarks – Cosmarium binerve var. elongatum, originally described as a 'forma' of C. binerve P.Lundell by Krieger (1932) from Sumatra, differs from the nominate variety described by Lundell (1871) from Sweden by a longer cell length to breadth ratio associated with a hightrapezoid rather than a pyramidal outline of the semicell in frontal view. Moreover, in lateral view semicells are about rectangular (versus elliptic in the nominate variety) and in top view the apex is broadly elliptic in outline (versus circular in the nominate variety). Whereas the nominate variety is a rare taxon, only known from arctic-alpine regions in Europe, the var. *elongatum* – although but seldom recorded under that name - appears to be widely distributed in tropical regions of Asia, Australia and Africa (e.g. Krieger 1932, Scott & Prescott 1958, Grönblad et al. 1958, Scott & Prescott 1961, Rino 1971, Vyverman 1991, Bourrelly & Couté 1991). In our opinion, this difference in geographical distribution along with the above-described marked differences in cell morphology justify to raise C. binerve var. elongatum to species level. The name of C. elongatum already being applied by Raciborski (1885) for another species we had to choose another name.

Cosmarium binervoides as regularly encountered in our Wakawaka samples is marked by a slight indentation about half way the lateral sides of the semicell where that feature is not represented in pictures of *C. binerve* var. *elongatum* by the authors mentioned above. However, we think this characteristic not significant enough to consider a separate variety.

Cosmarium binodosum Coesel & Van Geest, nom. nov. & stat. nov.

Synonym – Cosmarium taxichondrum var. ambadiense Grönblad & A.M.Scott, Acta Botanica Fennica 58: 33, fig. 191–193. 1958 (Grönblad et al. 1958).

Taxonomic remarks – This taxon was originally described in Grönblad et al. (1958) as a variety of *C. taxichondrum* P.Lundell; Coesel & Van Geest (2009) argued that it better could be accommodated in *C. haynaldii* Schaarschm. On closer consideration, however, we are of the opinion that it



Figure 1 – Selected desmid taxa: A & B, *Cosmarium bangweuluense*; C, *C. binervoides*; D & E, *C. campanuliforme*; F, *C. mitra*; G & H, *C. luapulaense*; I & J, *C. subligoniforme*; K, *C. pseudotus*. Scale bar represents 25 µm.

deserves the status of a separate species. For that matter, such a raise in rank was already suggested by Thomasson (1960). As the name of *C. ambadiense* was already linked to another species (Grönblad et al. 1958) a new name had to be chosen. Consistent differentiating features, both with respect to *C. taxichondrum* and *C. haynaldii*, are the two big tubercles in the semicell centre and the widely open, undulate sinus.

So far, *C. binodosum* is only known from tropical Africa (Coesel & Van Geest 2009).

Cosmarium binodosum var. *thomassonii* Coesel & Van Geest, **var. nov.**

Figs 2I & J, 4V-Y, 5F

Diagnosis – Differs from the nominate variety by the presence of two subapical horn-like protuberances. Dimensions: cell length 29–34 μ m, cell breadth 27–31 μ m, cell thickness 18–22 μ m, breadth of isthmus 6–8 μ m.

Type – Zambia, Lake Wakawaka, 12°30'37"S 30°36'23"E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.05 (holo-: L), preserved as a natural sample, and illustrated in fig. 2J.

Taxonomic remarks – Specimens of *C. binodosum* found in our Zambia samples consistently were furnished with two prominent, horn-like protuberances just beneath the apex where the nominate variety is characterized by a transversal series of rather small granules.

Cosmarium binodosum var. *thomassonii* was occasionally encountered in samples from both Lake Wakawaka and the Bangweulu swamps. Interestingly, Thomasson (1960: 18, fig. 8: 9) in his study of the Bangweulu wetlands reports the very same algal form, there labelled *C. taxichondrum* var. *ambadiense* forma, whereas all other records of this species refer to the nominate variety. So, it seems as if we have to do with an endemic in a limited geographical region in tropical Africa.

Cosmarium campanuliforme Coesel & Van Geest, **sp. nov.** Figs 1D & E, 4N–P

Diagnosis – Cells distinctly longer than broad with a rather shallow median constriction. Sinus linear, closed for the greater part. Semicells in frontal view bell-shaped with a somewhat flattened apex showing a weak median incurvation. Semicells in lateral view oblong, in apical view elliptic with produced poles. Chloroplast with a single pyrenoid. Dimensions: cell length 26–29 μ m, cell breadth 15–17 μ m, cell thickness 10–11 μ m, isthmus 4–6 μ m.

Type – Zambia, Lake Wakawaka, 12°30′37″S 30°36′23″E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.05 (holo-: L), preserved as a natural sample, and illustrated in fig. 1D.

Taxonomic remarks – Cosmarium campanuliforme is a small-sized, smooth-walled Cosmarium the semicells of which are characterized by the shape of a bell or a high helmet. In literature, only a few taxa could be found with a more or less comparable appearance. Most resembling is C. quadratum var. africanum F.E.Fritsch (Fritsch & Stephens 1921) which, however, is much larger sized and shows indented apices. Also C. quadratulum var. latum Irénée-Marie (1956) should be compared, but this taxon is much smaller sized

with a distinctly lower cell length to breadth ratio. Also *C. loefgrenii* Borge forma, in Grönblad et al. (1968) has a lower length to breadth ratio apart from the fact that, in our opinion, it probably has nothing to do with *C. loefgrenii* as originally described by Borge (1918) from Brazil. The same comments hold for *C. trilobulatum* forma, in Schmidle (1898).

Cosmarium campanuliforme was only encountered in samples 2012073 and 2012075 originating from Lake Wakawaka, where it was not rare.

Cosmarium connatoides Coesel & Van Geest, **sp. nov.** Figs 2A, 3F–J, 5C

Diagnosis – Cells somewhat longer than broad with a shallow median constriction. Sinus widely open, at the apex about rectangular. Semicells in frontal view broadly elliptic to semicircular, the apex usually slightly flattened. Semicells in lateral view subcircular, in apical view about oblong. Isthmus in apical view oblong. Cell wall in the basal part of the semicell distinctly thickened, in frontal view provided with marked pore fields. Chloroplast with two pyrenoids. Dimensions: cell length 70–78 μ m, cell breadth 55–61 μ m, cell thickness 41–46 μ m, breadth of isthmus (in frontal view) 39–43 μ m.

Type – Zambia, small pool next to an unnamed lake, 11°26'41"S 29°33'10"E, 24 Sept. 2012, *Hugo de Vries Lab.* 2012.07 (holo-: L), preserved as a natural sample, and illustrated in fig. 2A.

Taxonomic remarks – In rough outline, our newly described species much resembles *Cosmarium connatum* Ralfs, a widely distributed taxon in both temperate and tropical climate regions. However, when comparing the morphological characteristics as specified above with those provided by Ralfs (1848) and other well-known desmid floras, such as those by West & West (1908) and Prescott et al. (1981) some striking differences come to the fore. Where those authors characterize the semicell shape in apical view as circular-broadly elliptic, the outline in our material is about oblong. Linked to that, also the outline of the isthmus in apical view distinctly differs: depicted circular in West & West (1908: pl. 67/17), perfectly oblong in our fig. 3J.

Another relevant characteristic of *C. connatoides* is the thickening of the semicell wall: confined to the sinus region when observed in frontal view (fig. 3F), extending over the entire basal half when seen in lateral view (fig. 3H). The latter thickening coincides with the cell wall zone provided with large pore fields (figs 3G & 5C). As far as could be traced, in *Cosmarium connatum* such a marked, rather sharply demarcated zone with enlarged pore fields was not described earlier in desmid literature.

Cosmarium connatoides appeared to be rather widely distributed in the Bangweulu wetlands. In sample 2012078 it was even one of the most abundant species. In view of this, it is unlikely that its occurrence would be confined to Zambia. Indeed, some of the records of *C. connatum* from Africa could refer to our newly described species. For instance, a sinus-associated thickening of the cell wall in frontal view similar to that in *C. connatoides* is depicted by Grönblad (1962) from Sudan, by Thomasson (1965) from Lake Ka-



Figure 2 – Selected desmid taxa: A, *Cosmarium connatoides*; B & C, C. *lindiae*; D & E, *C. bidentulum*; F, *C. cunningtonii* var. *cunningtonii*; G & H, *C. cunningtonii* var. *luxuriosum*; I & J, *C. binodosum* var. *thomassonii*; K & L, *C. pseudoredimitum*. Scale bar represents 25 µm.

riba in Zimbabwe and by Gerrath & John (1991) from Ghana. Those records are labelled *C. connatum* var. *africanum* F.E.Fritsch & F.Rich, but the original description of that taxon does not make mention of that feature (Fritsch & Rich 1937).

Remarkably, *C. connatoides* appeared to be widely distributed in the Bangweulu swamps but was not found in Lake Wakawaka. In that latter lake, on the other hand, 'typical' *C. connatum* was encountered in abundance, missing in our Bangweulu samples.

Cosmarium cunningtonii G.S.West Figs 2F, 4D & E

Taxonomic remarks – *Cosmarium cunningtonii* G.S.West almost certainly is identical to *C. bicorne* Borge (Coesel & Van Geest 2009). The species in question is especially notable by, in frontal view, some two big tubercles next to each other just below the apex. Both West (1907) and Borge (1928) depict a cell wall ornamentation consisting of just those two subapical tubercles (apart from papillae at the basal angles). However, Coesel & Van Geest (2009) – also de-



Figure 3 – LM pictures of selected desmid taxa: A–C, *Cosmarium bidentulum* in frontal and in lateral view; D & E, *C. binervoides* (focus-through); F–J, *C. connatoides* in frontal, lateral, apical and isthmial view; K & L, *C. subligoniforme*. Scale bar represents 25 µm.

picting just two subapical tubercles – argue that also smaller, more flattened elevations will occur that easily escape the attention. This is demonstrated in our present material from Zambia. Light microscopically, living cells with chloroplasts reveal only the subapical tubercles (fig. 2F) but in empty cell parts also additional, small inflations were observed (fig. 4D & E).

In the present investigation, the African endemic *C. cunningtonii* was encountered in small cell numbers in a number of samples from the Bangweulu swamps.

Cosmarium cunningtonii var. *luxuriosum* Coesel & Van Geest, **var. nov.**

Figs 2G & H, 4F-H

Diagnosis – Differs from the nominate variety by a somewhat larger cell size and a much more luxurious cell wall ornamentation. Cell length 51–55 μ m, cell breadth 40–45 μ m, cell thickness 24–26 μ m, isthmus 10–12 μ m.

Type – Zambia, swamp in the Chipundu region, 11°44′02″S 29°46′01″E, 25 Sept. 2012, *Hugo de Vries Lab.* 2012.04 (holo-: L), preserved as a natural sample, and illustrated in fig. 2G.

Taxonomic remarks – At first glance, the alga represented by our fig. 4F looks quite different from *Cosmarium cunningtonii* as shown in our fig. 4D. At closer examination, however, it appears to be characterized by similar morphological features. The cell outline, both in frontal, lateral and apical view, in these two taxa is essentially the same. Actually, in the var. *luxuruosum* only the cell wall ornamentation is much more pronounced. This holds both for the cell wall tubercles and the marked cell wall scrobicles that are readily to be distinguished even against the background of vital chloroplasts. As we did not find any transitional forms to the 'typical' form of *C. cunningtonii*, description as a separate variety seems to be justified.

Cosmarium cunningtonii var. *luxuriosum* was only found in small cell numbers in sample 2012088 originating from a waterway at Lake Kangwena, in the Chipundu region.

Cosmarium lindiae Coesel & Van Geest, **sp. nov.** Figs 2B & C, 4A–C

Diagnosis – Cells broader than long with a rather shallow median constriction. Sinus linear, closed for the greater part. Semicells in frontal view semicircular with broadly rounded basal angles. Cell wall beset with flattened granules rendering the semicells a slightly undulate-crenate outline. Semicells in lateral view subcircular, in apical view elliptic with produced poles. Chloroplast with two pyrenoids. Dimensions: cell length 33–37 μ m, cell breadth 39–42 μ m, cell thickness 24–27 μ m, isthmus 22–25 μ m.

Type – Zambia, swamp in the Chipundu region, 11°44′02″S 29°46′01″E, 25 Sept. 2012, *Hugo de Vries Lab.* 2012.04 (holo-: L), preserved as a natural sample, and illustrated in fig. 2B.

Taxonomic remarks – *Cosmarium lindiae* is named after Edna Lind who depicted and discussed a taxon collected in Tanzania under the name of *Cosmarium punctulatum* Bréb.

'forma' (Lind 1967: 376, pl. 5: 9, 9a, 9b). The description and illustrations of that taxon show a striking similarity with the alga represented in our fig. 2B & C. Considering the shape of this species, both in frontal and lateral view, it should be quite clear that this taxon has nothing to do with *C. punctulatum* as described by Brébisson (1856). Semicells of C. punctulatum are characterized by a truncate apex and a monocentric chloroplast (holding but a single pyrenoid) whereas our taxon under discussion is marked by a convex apex and dicentric chloroplasts. Most characteristic, however, is the outline of the semicells in apical view, i.e. elliptic with produced poles resembling the shape of a lemon. Although Lind's (1967) pictures slightly differ from ours (i.e. a relatively deeper cell sinus and a smaller cell thickness) they likely refer to the same species. Anyhow, we decided to describe our taxon as a new species.

Cosmarium lindiae was encountered in small cell numbers in samples 2012087 and 2012088 from Bangweulu swamps in the Chipundu region as well as in sample 2012078 originating from a small pool close to the proper Lake Bangweulu.

Cosmarium luapulaense Coesel & Van Geest, **sp. nov.** Figs 1G & H, 4I

Diagnosis – Cells slightly broader than long to about as broad as long with a deep median constriction. Sinus open from an acute-angled apex. Semicells in frontal view lowtrapeziform-semicircular with broadly rounded basal angles. Basal angles produced by a reinforcement of the cell wall abruptly delimiting at the distal side of the sinus. Semicells in lateral view subcircular, in apical view elliptic-rhomboid. Cell wall smooth, delicately punctate. Chloroplast with two pyrenoids. Dimensions: cell length 38–44 µm, cell breadth 42–47 µm, cell thickness 19–23 µm, isthmus 10–13 µm.

Type – Zambia, Luapula River near Mpanta,11°27'15"S 29°49'35"E, 24 Sept. 2012, *Hugo de Vries Lab.* 2012.06 (holo-: L), preserved as a natural sample, and illustrated in fig. 1G.

Taxonomic remarks – *Cosmarium luapulaense* somewhat resembles given forms of *C. lundellii* Delponte (Delponte 1877). However, our newly described species may be immediately recognized by the open sinus in combination with the sharply delimited reinforcement of the cell wall at the broadly rounded basal angles rendering those angles a produced appearance.

Cosmarium luapulaense was found in some samples from the Bangweulu swamps near Mpanta, in particular sample 2012079 originating from Luapula River.

Cosmarium mitra Coesel & Van Geest, **sp. nov.** Figs 1F, 4J–M, 5E

Diagnosis – Cells somewhat longer than broad with a deep median constriction. Sinus widely open from a somewhat elongate isthmus. Semicells in frontal view about cuneate with broadly rounded angles and slightly convex margins. Cell wall ornamentation in the form of some eight stout tubercles: four of them in a semicircular arch just beneath the apex, the other four in a horizontal series at the base where the marginal ones protrude as pronounced papillae. Semicells in lateral view including the basal and subapical tubercles about quadrangular, more or less circular when ignoring them. Semicells in apical view elliptic-rhomboid, the longer sides marked by tubercles. Dimensions: cell length $32-37 \mu m$, cell breadth $27-30 \mu m$, cell thickness $18-20 \mu m$, isthmus $9-10 \mu m$.

Type – Zambia, Lake Wakawaka, 12°30′37″S 30°36′23″E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.05 (holo-: L), preserved as a natural sample, and illustrated in fig. 1F.

Taxonomic remarks – Cosmarium mitra is a most characteristic species, the shape of its semicells reminding of a mitre in the Russian orthodox church. Just like *C. bangweuluense*, dealt with in the present paper, there is some resemblance with *C. mediogemmatum* West & G.S.West. But also in this case, both the shape of the semicells in frontal view (hexagonal-elliptic in *C. mediogemmatum*, cuneate in *C. mitra*) and the arrangement of the tubercles (a central tubercle encircled by a series of six in *C. mediogemmatum*, two horizontal series of four in *C. mitra*) are essentially different.



Figure 4 – LM pictures of selected desmid taxa: A–C, *Cosmarium lindiae* in frontal and in apical view; D & E, *C. cunningtonii* var. *cunningtonii* (focus-through); I, *C. luapulaense*; J–M, *C. mitra* in frontal, lateral and apical view; N–P, *C. campanuliforme* in frontal and in lateral view; Q & R, *C. pseudoredimitum* (focus-through); S–U, *C. bangweuluense* in frontal and in lateral view; V–Y, *C. binodosum* var. *thomassonii* in frontal, lateral and apical view. Scale bar represents 25 µm.

Cosmarium mitra was only encountered in samples 2012073 and 2012075 originating from Lake Wakawaka.

Cosmarium pseudotus Coesel & Van Geest Fig. 1K

Taxonomic remarks – Cosmarium pseudotus described by Coesel & Van Geest (2009) from the Okavango Delta differs from C. otus, a taxon widely distributed in the Indo-

Malaysian/Northern Australian region, in that (when seen in lateral or apical view) it has four series of marginal granules/ verrucae instead of two. Moreover, the extra large spines at the apical and basal angles characteristic of *C. otus* are lacking. In our Zambia sample 2012075, originating from Lake Wakawaka, cells of *C. pseudotus* were encountered showing a much more luxurious ornamentation than specimens from the Okavango Delta. Not only that the marginal, emarginate verrucae were more pronounced but instead of a slight cen-



Figure 5 – SEM pictures of selected desmid taxa: A & B, Cosmarium pseudoredimitum in frontal and lateral view, respectively; C, C. connatoides; D, C. subligoniforme; E, C. mitra; F, C. binodosum var. thomassonii. Courtesy Jan Šťastný.

tral inflation a big, clear-cut tubercle was developed (fig. 1K). Presumably, this appearance is part of the phenotypical variability, for in that same sample also cells were found meeting the original diagnosis of this species. For that reason, we desist from describing it as a separate variety as yet.

Cosmarium pseudoredimitum Coesel & Van Geest, **sp. nov.** Figs 2K & L, 4Q & R, 5A & B

Diagnosis – Cells distinctly longer than broad, with a deep median constriction, a somewhat lengthened isthmus and a widely open sinus. Semicells in frontal view circular to slightly egg-shaped, often with a flattened apex. Semicells in apical view broadly elliptic. Frontal part of the cell wall near the apices covered with tubercles surrounded with large pore fields that are arranged in hexagons. Tubercles at the apical angles usually extra pronounced. Chloroplast with two pyrenoids. Dimensions: cell length 55–64 μ m, cell breadth 23–36 μ m, cell thickness 27–29 μ m, breadth of isthmus 11–13 μ m.

Type – Zambia, Lake Wakawaka, 12°31′14″S 30°36′12″E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.02 (holo-: L), preserved as a natural sample, and illustrated in fig. 2L.

Taxonomic remarks – At first glance, this new species very much resembles Cosmarium redimitum described by Borge (1899) from Guyana and also known from a number of other South American countries. Both species are characterized by elongate cells, semicells that in frontal view show a more or less circular outline and a cell wall covered with flattened tubercles each of which is surrounded by a hexagon of distinct pore fields. However, there are a number of essential differences. First of all, in apical view, semicells of C. redimitum are perfectly circular versus broadly elliptic in C. pseudoredimitum. In connection to that, cell wall tubercles in C. redimitum are equally distributed all over the sides whereas in C. pseudoredimitum they are only found on the relatively broad frontal sides of the semicell, not on the smaller lateral sides (fig. 5B). Furthermore, the cell wall of C. redimitum is consistently described or depicted as remarkably thick (Borge 1899, Grönblad 1945, Förster 1964, 1969), a phenomenon not observed in our newly described species. Finally, the chloroplast in C. redimitum is described to consist of five parietal, longitudinal lamellae each holding a pyrenoid (Grönblad 1945, Förster 1969) where in C. pseudoredimitum an axial one holding two pyrenoids was noticed.

Cosmarium pseudoredimitum was a common species in our samples from Lake Wakawaka but lacked in the samples from the Bangweulu wetlands.

Cosmarium subligoniforme Coesel & Van Geest, **sp. nov.** Figs 1I & J, 3K & L, 5D

Diagnosis – Cells distinctly longer than broad, with a deep median constriction. Sinus linear, closed. Semicells in frontal view semi-elliptic with produced basal angles. Semicells in lateral view elliptic-oblong, in apical view oblong with mammillated poles. Chloroplast with a single pyrenoid. Cell wall finely punctate. Dimensions: cell length 52–60 μ m, cell breadth 36–43 μ m, cell thickness 21–24 μ m, breadth of isthmus 11–13 μ m.

Type – Zambia, Lake Wakawaka, 12°31′14″S 30°36′12″E, 22 Sept. 2012, *Hugo de Vries Lab.* 2012.02 (holo-: L), preserved as a natural sample, and illustrated in fig. 1I.

Taxonomic remarks – The algal form depicted in our fig. 11 & J much resembles C. ligoniforme West & G.S.West as described by West & West (1897: 115) from Angola. Most striking difference are the basal semicell angles: described as subrectangular by West & West (1897), distinctly produced in our material. Moreover, West & West characterize the cell wall in C. ligoniforme as densely punctate. Judging from their figure (West & West 1897, pl. 367: 12) likely a scrobiculate cell wall is at issue. In our material, on the contrary, the cell wall is finely punctate (fig. 5D). In respect of the abovementioned discriminating features our cells rather agree with those of C. ligoniforme var. crassum described by Förster (1972) from Florida. However, the central cell wall thickening characteristic of that latter taxon is wanting in our cells apart from a different apical and lateral cell view (broadly elliptic in C. ligoniforme var. crassum versus oblong in our *C. subligoniforme*).

Checking desmid literature, *C. subligoniforme* might also have been found in Mozambique (Rino 1971, under the name of *C. ligoniforme* var. *borgei*), Madagascar (Bourrelly & Couté 1991, under the name of *C. pseudopyramidatum* forma A) and Zambia (Thomasson 1960, also under the name of *C. pseudopyramidatum* forma). In our investigation, *C. subligoniforme* appeared a common species in samples from both Lake Wakawaka and the Bangweulu swamps.

DISCUSSION

The genus Cosmarium is considered to be the largest desmid genus worldwide (Gerrath 1993), so also in our Zambian desmid samples quite a number of Cosmarium species were to be expected. Remarkably, a large difference turned to be out between the samples from the proper Bangweulu wetlands and those from Lake Wakawaka situated some 150 km to the southeast. In the Bangweulu swamps Staurastrum and Staurodesmus were the predominating genera, in species number surpassing the genus Cosmarium with a factor of up to five. In the samples from Lake Wakawaka, on the contrary, the number of Cosmarium species exceeded that of the total of Staurastrum plus Staurodesmus species. Presumably, this marked difference in species composition is to be linked to differences in ecological conditions. Our Bangweulu samples were taken from submerged weeds in canals separating floating vegetation mats determined by high-rising helophytes such as Cyperus papyrus L. and Phragmites australis (Cav.) Steud. Samples from Lake Wakawaka, on the other hand, originated from a quaking bog zone marked by more delicate vegetation elements, such as mosses, fine grasses and sedges mixed with sundew and bladderwort species. It is a well-known fact that, among desmid species, planktic habitats such as amply encountered in the Bangweulu swamps are preferred by Staurastrum and Staurodesmus species marked by long cell processes increasing their cell surface to volume ratio, so decreasing sinking rate (Brook 1981).

An interesting morphological feature frequently observed in our Zambian *Cosmarium* species is a specific pattern of cell wall sculpturing consisting of tubercles (sometimes much flattened) each of which is surrounded by a hexagon of deep pore fields (figs 4R & 5A). Often, there is a transversal (sub-)apical series of more prominent tubercles, sometimes in combination with a similar basal series (fig. 4S–U). Usually, the two median tubercles in the apical series are bigger than the other ones (fig. 4D & G). In particular the last mentioned phenomenon, two conspicuous sub-apical protuberances, is characteristic of a number of Cosmarium species with an exclusive African distribution. See, for instance C. pseudosulcatum var. bituberculatum (F.E.Fritsch & F.Rich) Coesel, and C. permaculatum var. bituberculatum Coesel & Van Geest, described from the Okavango Delta (Coesel & Van Geest 2009) but also encountered in our present investigation of the Bangweulu swamps. Remarkably, it was already Fritsch & Rich (1937: 183) who noticed that "all the Cosmaria possessing two infra-apical papillae are confined to the southern hemisphere or occur in regions near it". So, possibly we have to do with a geographically linked morphological characteristic. As genus Cosmarium has appeared to be highly polyphyletic (Gontcharov & Melkonian 2008) one might think of convergent evolution rather than of phylogenetic relationships.

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