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Taxonomy and ecology of *Sphagnum*-associated Desmids from the New England Tablelands, New South Wales, Australia

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Abstract

Desmids associated with *Sphagnum* L. from terrestrial and aquatic habitats were investigated in the New England Tableland Bioregion. Descriptions and figures for 80 taxa are presented herein, nine of which are newly recorded for Australia, and a further seven are newly recorded for New South Wales. Two novel species of desmid, *Micrasterias bicoronata* A.Kenins and *Cosmarium phymatodeum* A.Kenins, are described. The floristic composition of desmids at Basket Swamp and Ebor Common, were compared to assess their conservation value based on an existing and modified scheme better suited to desmids from Australia. Basket Swamp received a relatively high score based on greater species richness and numerous endemics present. In contrast, Ebor Common scored lower due to less diversity and few regionally endemic species. This study also highlights that the desmid community found amongst *Sphagnum* in Australia is highly diverse (β_{SOR} = 0.82) and can differ markedly among the four assessed sites due to spatial turnover (β_{RATIO} = 0.15). While there are species in common with the much more extensively studied *Sphagnum* habitats in central and western Europe, Australia has its own distinctive desmid floral elements.

Introduction

Desmid is a colloquial term referring to microscopic, green algae capable of asexual (via cellular division) and sexual (via conjugation between two, separate cells resulting in a zygospore) reproduction that inhabit a vast array of terrestrial and aquatic freshwater environs worldwide (Brook 1981). Traditional taxonomies separate desmids into two groups; i.e., the saccoderms and placoderms. The saccoderms exhibit cylindrical or fusiform cell outlines, simple chloroplast structure and a cell wall lacking visible pores under light microscopy (Brook 1981). Placoderm desmids, Desmidiales (Gonatozygaceae, Peniaceae, Closteriaceae and Desmidiaceae), have a much more complex cell wall architecture and cellular morphology than the saccoderms. Members of the Desmidiaceae are also by far the most morphologically diverse family in the group and include most species from the Desmidiales (Brook 1981; Coesel & Meesters 2007). However, phylogenetic reconstruction of select saccoderm and placoderm taxa from the Desmidiales and Mesotaeniaceae has recovered the placoderms (Desmidiales) as monophyletic whereas saccoderms (Mesotaeniaceae) are not, with some species more closely related to uniseriate filamentous members of the Zygnematales; such as *Mougeotia* C.Agardh and *Zygnema*

C.Agardh (Gontcharov 2008). Although some representatives of the saccoderms can be no longer considered 'desmids', they do share similar habitats to desmids (acidic, humid and terrestrial), which have been largely understudied in Australia. Therefore, to exclude them on the basis of no longer being related to desmids would limit our understanding of their biodiversity in Australia. Apart from their understudied habitats, another reason for the limited knowledge of saccoderms in Australia is the requirement for living specimens to be observed with their chloroplasts well-preserved for reliable identification, since standard preservation usually denatures the chloroplast making certain identification extremely difficult (Coesel & Meesters 2007). Molecular investigations have also confirmed that the species-rich desmid genera *Cosmarium* Corda ex Ralfs, *Euastrum* Ehrenberg ex Ralfs, *Xanthidium* Ehrenberg ex Ralfs and *Staurastrum* Meyen ex Ralfs are polyphyletic (Gontcharov 2008; Gontcharov & Melkonian 2011). Yet, no new generic concept or revision of the group has been proposed, and as such we use the term 'desmid' in the traditional sense.

The majority of publications concerning desmids from New South Wales are from the early twentieth century by Playfair (1907, 1908, 1910, 1913, 1914, 1915, 1917; and see Skinner 2022) and were based on collections predominantly from the 'coastal' Lismore and Sydney districts. Since then, additional publications from this state have been sporadic, with contributions by Thomasson (1973), Skinner (1977, 1979) and Dingley (1995, 2001, 2002, 2004) that have generally been undertaken further inland. Skinner (1977, 1979) targeted areas of *Sphagnum* in the New England Tablelands bioregion; the focus of the present study.

Australian *Sphagnum* L. moss is primarily confined to montane and alpine regions, generally above 800 m elevation, in poorly drained, relatively infertile sites with water that is acidic and nutrient-poor. In contrast to European bogs, the Australian counterparts are often dominated by sclerophyllous shrubs, with *Sphagnum* not always the dominant component of the vegetation (Whinham & Chilcot 2002; Hunter & Bell 2007). *Sphagnum* communities in Australia are under threat from a range of stressors including grazing and trampling from cattle and feral animals (pigs, horses and deer), weed incursion, and anthropogenic disturbances (4WDing, skiing, moss poaching, draining, fire, drought and climate change) (Whinham & Chilcot 2002). Due to the rarity and vulnerability of Australian *Sphagnum* moss, and limited knowledge of the associated Australian desmid 'flora', it is critical to document the desmids in this threatened ecological community, not only as an inventory of biodiversity, but to also provide a tool for ecological monitoring, conservation and management of this rare and threatened ecosystem, and to facilitate broader wetland and climate change research.

The earliest Australian account concerning desmids collected from *Sphagnum* is from Playfair (1908) where species were recorded from a tract of *Sphagnum* near the coast in Coogee, Sydney (see Table 1). The species encountered were often in great abundance, forming pure gelatinous masses on the surface of the water. Of note was *Cosmarium glyptodermum* West & G.West, previously known solely from east and central Africa, but a dominant species now associated with Australian *Sphagnum* moss. This pioneering observation highlighted the difference in desmid composition from the well-studied, European counterparts. Few records have been made since, with Skinner (1979) providing additional data from a more elaborate study of the Zygnemaphyceae & Oedogoniophyceae from a range of environments from northern New South Wales. However, this study did not provide adequate sampling records to determine which species were directly collected from *Sphagnum*. The most recent study is an unpublished honours thesis by Darling (1982), who surveyed the algal epiphyton (including desmids) from *Sphagnum* hummocks growing around several ponds from Lake Mountain, Victoria. Based on these previous studies, the desmid flora from Australian *Sphagnum* appears to be rich in diversity, with species from the genera *Closterium* Nitzsch ex Ralfs and *Cosmarium* being a prominent component.

The aim of this study was to build upon previous work in Australia by surveying and recording the desmid 'flora' associated with *Sphagnum* within the New England Tablelands Bioregion and presenting the taxonomic results in the form of an illustrated synopsis. This work also explores aspects of their diversity with two of the *Sphagnum* habitats from the study area compared using a multimetric schema to assess their conservation value. Additionally, these assemblages were interpreted further by quantifying spatial patterns of beta diversity along with previous Australian studies that collected desmids from this kind of substrate. We lastly provide some context of how distinctive the Australian desmid flora is by contrasting it with their better-studied counterparts from central and western Europe.

Table 1. List of desmid taxa previously reported from *Sphagnum* in Australia with accepted taxa used for this study. Notes include the synonym/s used by the authors, objective (≡) or subjective (=). * Denotes a doubtful identification/misapplied name but with insufficient data to provide a certain, alternate identification.

Accepted name	Location	Reference	Notes
Saccoderm desmids:			
Cylindrocystis crassa	Lake Mountain	Darling (1982)	
Mesotaenium macrococcum	Lake Mountain	Darling (1982)	
Netrium digitus	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	≡ *Penium digitus*
Netrium oblongum	Lake Mountain	Darling (1982)	
Tortitaenia obscura	Coogee	Playfair (1908)	≡ *Spirotaenia obscura*
Placoderm desmids:			
Actinotaenium australe	Coogee	Playfair (1908)	≡ *Penium australe*
Actinotaenium cucurbita	Coogee	Playfair (1908)	≡ *Penium cucurbita*
Actinotaenium cf. *perminutum*	Lake Mountain	Darling (1982)	= *Cylindrocystis* cf. *minutissima*
Actinotaenium turgidum	Coogee	Playfair (1908)	≡ *Cosmarium turgidum*
Closterium acutum cf. var. *linea*			
Closterium closterioides	Coogee	Playfair (1908)	≡ *Penium libellula*
Closterium closterioides var. intermedium	Lake Mountain	Darling (1982)	Reassigned from misapplied name *Netrium* cf. *interruptum*
Closterium cynthia	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Closterium deplontei vars.	Coogee	Playfair (1908)	
Closterium dianae	Coogee	Playfair (1908)	
Closterium lunula	Coogee	Playfair (1908)	
Closterium navicula	Coogee	Playfair (1908)	≡ *Penium navicula*
Closterium nematodes & vars.	Coogee	Playfair (1908)	
Closterium rostratum	Lake Mountain	Darling (1982)	
Closterium striolatum	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Cosmarium amoenum vars.	Coogee	Playfair (1908)	
Cosmarium amplum	Coogee	Playfair (1908)	
Cosmarium boeckii vars.	Coogee	Playfair (1908)	
Cosmarium gayanum	Lake Mountain	Darling (1982)	
Cosmarium inconspicuum	Lake Mountain	Darling (1982)	
Cosmarium mesolium	Coogee	Playfair (1908)	
Cosmarium obsoletum	Lake Mountain	Darling (1982)	Reassigned from misapplied name *Cosmarium circulare*
Cosmarium orthopunctulatum	Coogee	Playfair (1908)	
Cosmarium pseudopyramidatum vars.	Coogee	Playfair (1908)	
**Cosmarium quadrifarium* var. *hexasticha*	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	≡ *Cosmarium quadrifarium* f. *hexasticha*; facial ornamentation not depicted nor described by Darling (1982)
**Cosmarium* cf. *quadrum*	Lake Mountain	Darling (1982)	Some other species of *Cosmarium* with an open sinus such as *Cosmarium reniforme* var. *compressum*
Cosmarium rectangulare	Lake Mountain	Darling (1982)	
Cosmarium reniforme var. *compressum*	Coogee	Playfair (1908)	
Cosmarium striolatum var. *nordstedtii*	Coogee	Playfair (1908)	= *Cosmarium glyptodermum sensu auctorum*
Cosmarium sp.	Lake Mountain	Darling (1982)	Similar to *Cosmarium spirale* observed in this study
Cosmarium subspeciosum	Coogee	Playfair (1908)	
Cosmarium tetragonum	Lake Mountain	Darling (1982)	
Cosmarium tinctum	Coogee	Playfair (1908)	
Cosmarium validius	Coogee	Playfair (1908)	*Nomen invalidum pro Cosmarium subspeciosum* var. *validius*

Accepted name	Location	Reference	Notes
Euastrum ansatum	Lake Mountain	Darling (1982)	
Euastrum dideltoides	Coogee	Playfair (1908)	
Euastrum insulare	Lake Mountain	Darling (1982)	
Euastrum neosinuosum vars.	Coogee	Playfair (1908)	≡ *Euastrum sinuosum* vars.
Euastrum validum	Lake Mountain	Darling (1982)	
Hyalotheca hians	Coogee	Playfair (1908)	
Micrasterias jenneri	Lake Mountain	Darling (1982)	
Micrasterias papillifera vars.	Coogee	Playfair (1908)	
Micrasterias tropica var. *indivisa*	Coogee	Playfair (1908)	≡ *Micrasterias euastroides* var. *indivisa*
Micrasterias truncata vars.	Coogee	Playfair (1908)	
Penium spirostriolatum	Coogee	Playfair (1908)	
Pleurotaenium crenulatum	Coogee	Playfair (1908)	
Pleurotaenium nodosum	Coogee	Playfair (1908)	
Pleurotaenium ovatum	Coogee	Playfair (1908)	
Staurastrum alternans	Coogee	Playfair (1908)	
**Staurastrum* cf. *chaetoceros*	Lake Mountain	Darling (1982)	Some other species of *Staurastra*; similar to *Staurastrum* cf. *hardyi* in this study.
Staurastrum inconspicuum	Lake Mountain	Darling (1982)	
Staurastrum submonticulsoum	Coogee	Playfair (1908)	
Staurodesmus connatus	Lake Mountain	Darling (1982)	
Staurodesmus triangularis	Lake Mountain	Darling (1982)	
Tetmemorus brebissonii	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Tetmemorus laevis	Lake Mountain	Darling (1982)	
Xanthidium coogeanum	Coogee	Playfair (1908)	

Materials and Methods

Study sites

Sphagnum bogs are excellent sites to sample for desmids (Entwisle et al. 1997). However, many historical sites of desmid study, e.g. “Coogee” of Playfair (1908), are vague and have been degraded or destroyed by clearing and urbanisation. Vegetation surveys by Hunter and Sheringham (2008) indicated that only a few hectares of *Sphagnum* bogs are in good condition across the New England Tablelands. In the present study, selection of sample sites was based on a review of recent literature and our knowledge of the region (Figure 1). We focused on *Sphagnum* hummocks (terrestrial or partially submerged in ditches) and tracts of *Sphagnum* (in creeks, bogs and over granite surfaces). Thus, we sampled from Ebor Common (30°24'17.8"S 152°20'58.6"E) (n = 4), Basket Swamp (28°55'13.8"S 152°08'26.0"E) (n = 8), New England National Park (30°29'47.1"S 152°23'55.4"E) (n = 7), and Oaky Creek adjacent to Cathedral Rock National Park (30°29'35.6"S 152°15'19.6"E) (n = 4).

Sampling

Samples were collected by squeezing a handful of *Sphagnum* with the thumb pointed downwards to the opening of the vial or, the *Sphagnum* moss was pressed several times with a sample lid until water pooled and then the liquid was transferred to the sample vial. Sample acidity was tested by use of a calibrated pH probe (Multi-Parameter PCSTestr™ Eutech Instruments). Separate sub-samples were preserved within 48 hrs with Lugols iodine or 4% formalin. Unpreserved samples of small fragments of *Sphagnum* with the associated water matrix were also taken and intermittently kept in a fridge and near a window away from direct sunlight over several months.

Analysis of material

For light microscopy, semi-permanent slides were prepared by adding one to two drops of sample to a glass slide and covered using a 22 × 22 mm No. 1 coverslip with the edges sealed using clear nail polish. Drawings were produced using a Nikon drawing tube attached to a Nikon Optiphot2 microscope under brightfield microscopy. Photomicrographs were taken of the sampled material using a Nikon DS-5M camera coupled with a DS-L1 monitor. Measurements of cellular dimensions (see Table 2 for definitions of symbols and abbreviations) were taken from the digital images using MICAM version 2.0 developed by Marien van

Westen (2016). Digital illustrations presented herein were produced by largely following Montesanto (2015) with GIMP 2.8 software from either the prepared drawings or by series of photomicrographs of specimens at different focal planes, which were traced into a single image.

Table 2. Symbols and abbreviations defined.

Ap. = Breadth of apices
Br. = Breadth
Br. cpr. = Breadth with processes
Br. spr. = Breadth without processes
Br. csp. = Breadth with spines
Br. ssp. = Breadth without spines
I. = Isthmus
L. = Length
L:B = Ratio of length to breadth
L. cpr. = Length with processes
L. spr. = Length without processes
L. csp. = Length with spines
L. ssp. = Length without spines
Pr. = Length of processes
Sp. = Length of spines
Th. = Thickness of cell

Specimens prepared for scanning electron microscopy (SEM) were from material preserved in either formalin or Lugols iodine and directly mounted onto ethanol washed aluminium stubs and allowed to settle for at least 1 h. The top of the drop of sample was then wicked away to reduce water and hence drying time. The stubs were then placed in a glass bell jar with silicon beads and allowed to completely dry overnight. Stubs with the dried material were then sputter coated with gold. Cells were observed using a JSM-6610 Series Scanning Electron Microscope with voltage set at 15 kV, spot size 30, and the aperture at its most closed setting.

Descriptions based on light microscopy and/or scanning electron microscopy are indicated LM: and SEM:, respectively and are used to specify which technique was used to report our observations. This distinction is important since these techniques differ in their utility. For instance, SEM is able to facilitate the observations of submicroscopic features of the cell wall but is unable to resolve intracellular features such as chloroplast configuration.

Taxonomic determinations

Whole-group treatments were consulted for identification (Brook & Williamson 2010; Coesel & Meesters 2007; Croasdale & Flint 1988, 1989; Croasdale et al. 1994; Ling & Tyler 2000). Initial identification of examined specimens was compared with illustrations and the descriptions from the available literature. Most identifications were then cross-checked by using the available dichotomous keys, and/or comparison with the original protologue of the species or taxon.

Desmid taxonomy has a notoriously troubled history of numerous infraspecific taxa and synonymy resulting from disagreement on which entities constitute species (Kouwets 2008). For this study, as many specimens as possible were observed within the representative population to understand their morphological range and variability to delimit distinct species; i.e., morphologically defined species. Some entities here have been tentatively assigned to existing species with *cf.* before the specific epithet and infer it is most likely the species designated but additional enquiry is required for confirmation. Australian distribution records by state were based on relevant sources (Day et al. 1995; Entwisle & Nairn 2021; Ling & Tyler 2000).

Comparison & assessment of sampled habitats

Nature Conservation Value (NCV) for Basket Swamp and Ebor Common was determined with the aid of the computer program DesmidValue version 1.0 (23-11-2007) in Coesel & Meesters (2007), whereby the three parameters diversity (d), rarity (r) and ecosystem maturity/sensitivity (m) are scaled in their respective transformation schemes (D, R and M) based on the acidity of the sampled habitat (see tables 3, 4, 5). These scaled data have a maximum value of three for D & R and four for M, with a possible NCV score of 10. For the diversity parameter, not all species and their infraspecific taxa encountered in our survey were available to select and enter from the list of West-European species within the program and were excluded from the analysis along with any unidentified taxa. Rarity and Maturity values associated with the desmid taxa in DesmidValue were left as default.

Table 3. Transformation scheme for Diversity scores (D) following Coesel & Meesters (2007).

Diversity			
neutral-alkaline	slightly acidic	highly acidic	
Species richness (d)	Species richness (d)	Species richness (d)	Conservation value (D)
1–5			1
6–30			2
>30			3
	1–10		1
	10–50		2
	>50		3
		1–5	1
		6–30	2
		>30	3

Table 4. Transformation scheme for Rarity scores (R) following Coesel & Meesters (2007).

Diversity			
neutral-alkaline	slightly acidic	highly acidic	
Rarity (r)	Rarity (r)	Rarity (r)	Conservation value (R)
1–2			1
3–10			2
>10			3
	1–5		1
	6–40		2
	>40		3
		1–2	1
		3–30	2
		>30	3

Table 5. Transformation scheme for Ecological maturity scores (M) following Coesel & Meesters (2007)

Ecol. maturity			
neutral-alkaline	slightly acidic	highly acidic	
Ecol. maturity (m)	Ecol. maturity (m)	Ecol. maturity (m)	Conservation value (M)
1–5			1
6–20			2
21–40			3
>40			4
	1–10		1
	11–40		2
	41–80		3
	>80		4
		1–5	1
		6–20	2
		21–40	3
		>40	4

Additionally, a customised NCV scheme was also devised to compare and note any differences from the standard scheme based on desmids from European habitats and conditions. Here, species richness (d) remained unaltered but rarity (r) values were replaced with frequency data from a comprehensive water quality study on planktic and benthic desmids collected from 150 sampling sites (reservoirs, ponds swamps and bogs) over various catchments located throughout Thailand, south-east Asia by Ngearnpat (2009). The frequency rating of the attached/benthic desmids from Table 2 in Ngearnpat (2009) were converted to the following values: very rare (+) to 3, rare (++) to 2, occasional (+++) to 1 and frequent (++++) to 0. Taxa not encountered by Ngearnpat (2009) were left blank *i.e.* not assigned any value (See table 7). As suggested by Coesel & Meesters (2007) for users from non-European continents, the ecosystem sensitivity (m) criterion above was replaced with one based on endemism (e). The endemism scheme here assigned values to species with non-cosmopolitan distributions that scaled-down if they were deemed less geographically isolated; *viz.*, values for species that are putative Australian endemics = 4, species from within a designated, single desmid bioregion (e.g. Indo-Malay and northern Australia; IMNAR; southern Australia and New Zealand; SANZ) = 3, species with apparent climatic distributions (e.g. pantropical, alpine) = 2, species with broader distributions that are not well defined but not as widespread (e.g. disjunct, southern hemisphere, or bioregions combined) = 1 and cosmopolitan species = 0 (see Table 7). The transformation schemes that generated the D, R and E values that contributed the modified NCV were the same as the original D, R, M above (*see* tables 3, 4 & 6).

Table 6. Transformation scheme for proposed Endemism scores (E) based on the Ecological maturity scheme from Coesel & Meesters (2007).

Endemism			
neutral-alkaline	slightly acidic	highly acidic	
Endemism (e)	Endemism (e)	Endemism (e)	Conservation value (E)
1–5			1
6–20			2
21–40			3
>40			4
	1–10		1
	11–40		2
	41–80		3
	>80		4
		1–5	1
		6–20	2
		21–40	3
		>40	4

The data from Basket Swamp and Ebor Common (Table 7) were combined with the species lists from Playfair (1908) and Darling (1982) (Table 1) to create a presence/absence data set of all four sites in Australia. Community composition and beta diversity partitions, including nestedness, of the combined *Sphagnum*-associated desmids listed from Australia (as presence/absence data) were assessed using R 4.1.1 (2021-08-10) -- “Kick Things” (R Core Team 2021). The “nestedtemp” function in the Vegan package (version 2.5-7) of Oksanen et al. (2020) was used to determine if the species-poor communities shared subsets with richer ones. The resultant matrix temperature is a measure between 0 and 100, where 0 is indicative of being perfectly nested whereas 100 is suggestive of a completely random species distribution pattern. Beta diversity of the above-mentioned data set was also evaluated using the “nestedbetasor” function in Vegan. Here, Sørensen dissimilarity (β_{SOR}), Simpson dissimilarity (β_{SIM}) and Nestedness-resultant dissimilarity (β_{NES}) indices as proposed by Baselga (2010) were returned. The β_{RATIO} index was obtained by dividing the resultant β_{NES} by β_{SIM} indices to determine whether beta diversity in the tested communities were dominated by species turnover (<0.5) or by nestedness (>0.5).

Results & Discussion

The results and discussion of the present study have been arranged into two sections, Ecology and Taxonomy. Section I: Ecology, deals principally with the aspects of alpha- and beta-diversity, conservation assessment and nestedness of the *Sphagnum*-associated desmids surveyed locally and abroad. Two of the study sites, Basket

Swamp and Ebor Common, were assessed for conservation value based on an existing and updated scheme. Basket Swamp received high scores due to greater diversity and the presence of numerous rare and endemic species. Ebor Common scored lower due to less species richness and fewer endemics. By combining our data set with previous surveys in Australia, we found that *Sphagnum*-associated desmid communities were highly diverse (β_{SOR} = 0.82). Despite the presence of common species at different sites, our findings suggest spatial turnover is the dominate factor in these assemblages, instead of nestedness (β_{RATIO} = 0.15). Section II: Taxonomy, is a summary and synoptic treatment of the taxonomic diversity we encountered. Of the 80 taxa recovered, 16 are new distribution records for New South Wales or Australia. Additionally, two taxonomic novelties are also described - *Micrasterias bicoronata* A.Kenins and *Cosmarium phymatodeum* A.Kenins. Aspects of biogeography and potential issues of conspecificity and crypsis have also been highlighted in this section.

Section I: Ecology

Desmids as bioindicators in Australia

Two sites, Basket Swamp (pH 4.4–5.8) and Ebor Common (pH 4.0–4.9), had the most diversity of sites surveyed in this study, and their desmid species-composition was compared (Tables 7, 8 and 9). A total of 69 desmids was recorded from Basket Swamp, with many well-known, cosmopolitan species associated with habitats rated as acidophilic and oligotrophic to oligo-mesotrophic. A small proportion of species with broader ecological tolerances was also present (Table 7). Ebor Common had fewer species of desmids (18), and were exclusively associated with acid conditions and tended to be oligo-mesotrophic (Table 7). Basket Swamp also had far greater numbers of endemic and geographically isolated taxa than Ebor Common (Table 7). Five species (*Actinotaenium cucurbitinum* (Bisset) Teiling, *Docidium baculum* Brébisson ex Ralfs, *Micrasterias jenneri* Ralfs, *Penium exiguum* West and *Staurastrum inconspicuum* Nordstedt) designated from Dutch habitats as "Red List" species were also detected from Basket Swamp, whereas none was recovered from Ebor Common.

Table 7. List of taxa found at Basket Swamp and Ebor Common with their ecological status, Rarity values based on Ngearnpat (2009) and proposed Endemism values.

Species/Taxa	Basket Swamp	Ebor Common	Ecology	Rarity value	Endemism value
Actinotaenium cucurbitinum	+		Acidophilous, oligotrophic	2	0
Actinotaenium diplosporum var. *americanum*		+	Acidophilous, meso- to oligotrophic		0
Actinotaenium cf. *phymatosporum*	+		Acidophilous, oligo-mesotrophic		
Closterium abruptum var. *brevius*	+	+	Oligotrophic, acidobiontic		0
Closterium cf. *calosporum*	+	+	Acidophilous, mesotrophic	3	0
Closterium closterioides	+		Acidobiontic, oligotrophic		0
Closterium closterioides var. *intermedium*	+	+	Acidobiontic, oligotrophic	2	0
Closterium cynthia	+		Acidophilous, oligo-mesotrophic	3	0
Closterium dianae var. *arcuatum*	+		Mesotrophic	3	0
Closterium kuetzingii var. *procerum*	+				3
Closterium lunula	+		Acidophilous	3	0
Closterium navicula	+	+	Acidophilous, oligo-mesotrophic	2	0
Closterium striolatum	+		Acidobiontic, oligo-mesotrophic	2	0
Cosmarium amplum	+				2
Cosmarium amoenum	+	+	Acidophilous, oligotrophic		0
Cosmarium annulatum	+		Acidophilous		0
Cosmarium askenasyi	+			2	2
Cosmarium contractum	+		Acidophilous-circumneutral, oligo-mesotrophic	1	0
Cosmarium cf. *difficile* var. *messikommeri*		+	Acidophilous		
Cosmarium cf. *difficillimum*	+				
Cosmarium dorsitruncatum	+			3	2
Cosmarium margaritiferum f. *regularius*	+		Acidophilous		0
Cosmarium obsoletum var. *sitvense*	+			0	1
Cosmarium phymatodeum	+				4
Cosmarium quadrifarium var. *simplex*	+	+			2

Species/Taxa	Basket Swamp	Ebor Common	Ecology	Rarity value	Endemism value
Cosmarium regnellii	+		Acidophilous-alkaliphilous, meso-eutrophic	1	0
Cosmarium cf. *reniforme var. compressum*	+		Acidophilous- alkaliphilous, meso-eutrophic		
Cosmarium spirale	+				3
Cosmarium subadoxum	+		Acidophilous, mesotrophic	3	0
Cosmarium striolatum var. *nordstedtii*	+				2
Cosmarium cf. *difficillimum*	+				
Cosmarium cf. *zonatum* var. *compressum*	+				
Cylindrocystis brebissonii var. *minor*	+		Acidophilous	3	0
Cylindrocystis crassa	+		Acidophilous, oligotrophic, (sub) atmophytic	3	0
Cylindrocystis cf. *brebissonii* var. *turgida*	+				
Cylindrocystis cushleckae	+		Acidophilous, oligotrophic, (sub) atmophytic		
Cylindrocystis gracilis	+		Acidophilous, meso-oligotrophic		
Docidium baculum	+		Acidophilous, oligotrophic		0
Euastrum ansatum	+	+	Acidophilous, meso-oligotrophic	1	0
Euastrum ansatum var. *simplex*	+	+			0
Euastrum cf. *ansatum* var. *triporum*	+				0
Euastrum denticulatum var. *quadrifarium*	+				0
Euastrum didelta var. *bengalicum*	+				2
Euastrum longicolle var. *australicum*	+				3
Euastrum cf. *longicolle* var. *australicum*	+				0
Euastrum neosinuosum var. *germanicum*	+			2	0
Groenbladia bourrellyi	+				0
Mesotaenium endlicherianum	+		Acidophilous		0
Micrasterias bicoronata	+				4
Micrasterias decemdentata	+		Acidophilous, mesotrophic		0
Micrasterias jenneri	+		Acidophilous, oligotrophic		0
Micrasterias nordstedtii f. *australiensis*	+				4
Micrasterias thomasiana var. *notata*	+		Acidophilous, oligo-mesotrophic		0
Micrasterias truncata var. *crenata*		+	Acidophilous, meso-oligotrophic		0
Netrium digitus complex	+	+	Acidophilous	1	0
Penium exiguum	+		Acidophilous, oligotrophic		0
Pleurotaenium ehrenbergii	+		Acidophilous, mesotrophic	1	0
Pleurotaenium nodosum	+			3	0
Pleurotaenium tridentulum	+		Acidophilous		0
Spirotaenia condensata		+	Acidophilous, oligo-mesotrophic	3	0
Spirotaenia sp.		+			
Staurastrum aureolatum	+			3	2
Staurastrum cf. *hardyi*	+				
Staurastrum inconspicuum	+		Acidophilous, oligotrophic		0
Staurastrum cf. *longebrachiatum*	+				
Staurastrum cf. *monticulosum*	+				
Staurastrum trihedrale		+			2
Staurodesmus cf. *cuspidicurvatus*	+				
Tetmemorus brebissonii	+		Acidophilous, oligotrophic		0
Tetmemorus granulatus	+	+	Acidophilous, meso-oligotrophic	2	0
Tetmemorus cf. *laevis*	+	+	Acidophilous, oligotrophic		
Triploceras gracile	+		Oligotrophic	1	2
Tortitaenia obscura		+	Acidophilous, oligo-mesotrophic		0
Xanthidium armatum var. *basidentatum*	+				3
Xanthidium octocorne	+		Acidophilous, oligotrophic		0
Xanthidium cf. *octonarium*	+				

The presence of some desmids deemed as acidobiontic-neutral at Basket Swamp indicated potential acidity fluctuation across the sampled habitat, so the values for both kinds of acidic conditions (slightly and highly) are reported here. The Basket Swamp survey had a NCV score of 8 from DesmidValue and 10 from the modified scheme when calculated with water type set as highly acidic and scores of 7 and 9, respectively, with a slightly acidic water type (see Tables 8 and 9). Differences between the scores from the two marking schemes were influenced by the adjusted rarity values and change from ecological maturity to endemism values. The diversity value (species richness) was unaffected (Figure 2). The modified NCV score for Basket Swamp may be conservative when considering the potentially novel/unnamed forms (e.g. *Cylindrocystis* cf. *brebissonii var. turgida* Schmidle, *Euastrum* cf. *longicolle* var. *australicum* Playfair) and tentatively identified species (e.g. *Cosmarium* cf. *neapolitanum* var. *australicum* Schmidle, *Staurastrum* cf. *hardyi* G.S.West and *S.* cf. *monticulosum* Brébisson) may increase the final mark in the endemism section.

Table 8. Calculated NCV based on the DesmidValue Version 1.0 program by Coesel & Meesters (2007) developed for European lowland areas. (HA) = highly acidic, (SA) slightly acidic conditions selected.

Site	Diversity	Rarity (R)	Maturity (M)	NCV (D+R+M)
Basket Swamp	69 species = **3** (see table 7)	**4 Very rare:** *A. cucurbitinum*, *D. baculum*, *M. jenneri*, *S. inconspicuum*; **3 Rare:** *C. closterioides* var. *closterioides*, *C. crassa*, *P. exiguum*; **9 Rather Rare:** *C. cynthia*, *C. lunula*, *C. navicula*, *C. amoenum*, *C. contractum*, *P. ehrenbergii*, *T. brebissonii*, *T. laevis*, *X. octocorne* = **27** which transforms to **2**.	**3 Most Indicative:** *D. baculum, M. jenneri, S. inconspicuum;* **11 Indicative:** *A. cucurbitinum, C. closterioides* var. *closterioides, C. cynthia, C. lunula, C. navicula*, *C. amoenum, C. contractum, P. exiguum, T. brebissonii, T. laevis, X. octocorne*; **2 Somewhat Indicative:** *E. ansatum*, *P. ehrenbergii* = **33** which transforms to **2 (SA)** or **3 (HA).**	(3)+(2)+(2 or 3) = **7 (SA) or 8 (HA)/10**, depending on acidity level selected.
Ebor Common	18 species = **2** (see table 7)	**2 Rare:** *S. condensata*, *T. obscura*; **3 Rather Rare:** *C. navicula*, *C. amoenum*, *T. laevis*, *N. digitus* = **8** which transforms to **2**	**3 Indicative:** *C. navicula*, *C. amoenum, T. laevis*; **1 Somewhat Indicative:** *E. ansatum*, = **7** which transforms to **2**	(2)+(2)+(2) = **6/10**

Table 9. Calculated NCV based on modified scheme more suited to the Australian desmid flora using modified rarity values and an endemism criterion instead of ecosystem maturity. (HA) = highly acidic, (SA) slightly acidic conditions selected.

Site	Diversity	Rarity (R)	Endemism (E)	NCV (D+R+E)
Basket Swamp	69 species = **3** (see table 7)	**10 Very rare:** *C.* cf. *calosporum*, *C. cynthia*, *C. dianae* var. *arcuatum C. lunula*, *C. dorsitruncatum*, *C. subadoxum*, *C. brebissonii* var. *minor*, *C. crassa*, *S. aureolatum*; **5 Rare:** *A. cucurbitinum*, *C. closterioides* var. *intermedium*, *C. navicula*, *C. striolatum, C. askenasyi*; **9 Occasional:** *C. contractum*, *C. regnellii*, *E. ansatum*, *E. denticulatum*, *E. neosinuosum* var. *germanicum*, *N. digitus*, *P. ehrenbergii*, *P. nodosum*, *T. granulatus, T. gracile* = **49** which transforms to **3**.	**3 Australian endemics:** *C. phymatodeum*, *M. bicoronata*, *Micrasterias nordstedtii* f. *australiensis*; **2 IMNAR:** *C. amplum*, *C. spirale*; **3 SANZ:** *C. kuetzingii* var. *procerum*, *E.* *longicolle* var. australicum, *X. armatum* var. *basidentatum*; **7 Climatic:** *C. askenasyi*, *C. dorsitruncatum, C.* *striolatum* var. *nordstedtii*, *C. quadrifarium* var. *simplex, E. didelta var. bengalicum, S. aureolatum* and *T. gracile* & **1 Broader:** *C. obsoletum* var. *sitvense* = **42** which transforms to **3 (SA)** or **4 (HA).**	(3)+(3)+(3 or 4) = **9 (SA) or 10 (HA)/10**, depending on acidity level selected.
Ebor Common	18 species = **2** (see table 7)	**2 Very rare:** *C.* cf. *calosporum*, *S. condensata*; **2 Rare:** *C. closterioides* var. *intermedium*, *C. navicula*; **2 Occasional:** *E. ansatum*, *N. digitus* = **12** which transforms to **2**	**2 Climatic:** C. *quadrifarium* var. *simplex*, *Staurastrum trihedrale* = **4** which transforms to **1**	(2)+(2)+(1) = **5/10**

Ebor Common had a lower NCV mark of 6 and 5 for both schemes (Tables 8 and 9). While there was substantial species diversity at this site, the species were relatively common, with only a few regional endemics (*Cosmarium quadrifarium* var. *simplex* Krieger, *Staurastrum trihedrale* Wolle). Rarity (R) values that formed part of the NCV from both schemes were the same despite the use of different scoring criteria for Ebor Common. However, the modified NCV scheme that used Endemism (E) values scored lower than the original

Ecological maturity (M) values for this site (compare Tables 8 & 9). This difference was due to the presence of more m-linked desmids than e-linked in the data set. It should be also noted that if *Cosmarium* cf. *difficile* var. *messikommeri* (Croasdale) Kouwets (which is encountered in artic alpine habitats) was confirmed from this site, it would raise the final mark to 6 for the modified NCV using the endemism schema. Furthermore, the presence of *Staurastrum trihedrale* is a new record for Australia and is thus far only found at this site.

Application of an NCV based on Coesel (2001) in conjunction with a modified one to better suit the Australian desmid flora resulted in some slight differences from the same data set. Basket Swamp was awarded a relatively high NCV score of 7.5 and 9.5 (averaged over slightly and highly acidic conditions) from the original and modified scheme. However, a breakdown of each criterion found a consistently lowered score for either R or M/E in the original, European-based scheme in DesmidValue (see fig. 2). These different values are likely due to many of the species encountered from Basket Swamp not present in the original species scoring list. Consequently, these species could not contribute to the overall NCV score which may suggest the original scheme has the potential to underestimate conservation value outside of western Europe if used in its original state. In contrast, Ebor Common was awarded a relatively lower score (6 from DesmidValue and 5 from modified) due to fewer species of desmids being encountered; combined with very few of these having limited geographic distributions. However, since our sampling approach focussed exclusively on *Sphagnum*, combined with particular unidentified species that may be novel and/or geographically isolated, the NCV's of both sites should be considered preliminary until a more thorough survey is undertaken. Overall similar scores from using different values is not unexpected. Fehér (2007) and Krasznai et al. (2008) used modified rarity values from Hungarian waters and found little difference in overall NCV scores when comparing the different rarity values. This insignificance in using different values may indicate a bias in this scoring system whereby high diversity (d) has a major influence upon the overall NCV score due to an increased likelihood of r- and m-linked desmids being present to contribute to R and M. Quantifying species abundance, and the use of relative rarity (average r/d) and relative maturity (average m/d) has been adopted to reduce this bias (Fehér 2007; Krasznai et al. 2008).

The devised scheme here based on Coesel (2001) in Coesel & Meesters (2007) is not restricted for the sole purpose of determining conservation value of wetlands but can also be used as a proxy to assist environmental monitoring for purposes such as remediation to observe trends over time; see Coesel (2003). The scheme has an additional advantage that it can also be calculated based on data from previous surveys of wetlands that have detailed accounts of desmids and used as part of a much larger set of data that includes a historical account (see Hansen et al. 2018 for a recent example). Limitations of the scheme include the presence of species complexes, which may result in underestimated diversity and endemism and therefore score. This, however, could hypothetically be overcome by the use of morphological disparity as an alternative, or in conjunction with, traditional measures of biodiversity (species richness) which preliminary analysis from Neustupa et al. (2009) has shown has potential in desmids. Another limitation of the modified scheme developed for Australia is that it is currently non-quantitative, however Krasznai et al. (2008) included quantification methods (enumeration) in their study of Hungarian oxbow lakes, so a similar approach could be adopted for future studies. The overall suitability of rarity values based on desmids from Thailand by Ngearnpat (2009) is unclear, but due to our incomplete knowledge of their occurrence in Australia, it was deemed the most appropriate data set to employ since it shares a similar desmid flora that is within the same biogeographic region (IMNAR). Lastly, this scheme is only truly applicable to freshwater lentic wetlands, and not fast-flowing lotic systems, or sites that frequently dry up (such as the atmophytic *Sphagnum* cushions sampled from this survey) as they have minimal desmid diversity. This last limitation is a particular issue since many Australian wetlands dry up and refill seasonally due to the water regime (Boulton et al. 2014). A remedy to this would involve sampling during "boom" rather than "bust" cycles during assessment, which was a sampling strategy employed by Casanova & Powling (2014) on temporary wetlands in western Victoria that included desmids. Ultimately, the modified scheme seems feasible but more sites from various locations from Australia need to be studied to further improve our understanding of the Australian desmid flora and its distribution, to fine-tune the proposed marking system.

Diversity of Australian Sphagnum*-associated Desmids*

The collated list of *Sphagnum*-associated desmids from Basket Swamp and Ebor Common (this study) along with the previous studies by Playfair (1908) and Darling (1982) totalled 115 different taxa, with a mean of 39 per site (see Figure 3). Some of the *Sphagnum*-associated taxa in the combined data set were grouped at the rank of species due to inconsistencies in the identification at the infraspecific level in those other studies. These were: *Netrium digitus* (Brébisson ex Ralfs) Itzigsohn & Rothe, *Cosmarium amoenum* Brébisson ex Ralfs, *Cosmarium obsoletum* (Hantzch) Reinsch, *Cosmarium quadrifarium* P.Lundell, *Euastrum ansatum* Ehrenburg ex Ralfs, *Euastrum neosinuosum* Anissimova & Guiry and *Micrasterias truncata*. Additionally, we have included '*Cosmarium validius*' (as listed in Playfair 1908), under *Cosmarium subspeciosum* var. *validius* Nordstedt since it is a *nomen nudum* that is likely to have referred to the latter name. Certain species from the previous studies were also re-identified in this study based on the figures and descriptions provided, with *Netrium cf. interruptum* (Brébisson ex Ralfs) Lütkemüller reassigned to *Closterium closterioides* var. *intermedium* (Roy & Bisset) Růžička and *Cosmarium circulare* Reinsch reassigned to *Cosmarium obsoletum* in Darling (1982). *Cosmarium glyptodermum* cited in Playfair (1908) was reassigned to *Cosmarium striolatum* var. *nordstedtii* (Möbius) Krieger as it was considered to be synonymous for the latter species in Australia.

Species richness varied, with Basket Swamp having the highest number of taxa (67) and Ebor Common the lowest (17). The coastal bog site in Coogee studied by Playfair and the Lake Mountain ponds by Darling were intermediate with 40 and 31 taxa present, respectively. The species assemblages from each site were found to be largely dissimilar ($\beta_{SOR} = 0.82$) with beta-diversity patterns being attributed mainly to species turnover ($\beta_{SIM} = 0.71$) instead of nestedness ($\beta_{NES} = 0.10$). The resultant β_{RATIO} index of 0.15, confirmed that turnover was the dominant contributor to beta diversity in these communities. Nestedness temperature analysis (Fig. 3) also indicated that nestedness was weak, with a nested temperature of 37.1 and matrix fill of 34%. Only *Netrium digitus* and *Cosmarium quadrifarium* (infraspecific taxa included) were shared between all four sites. These two taxa have broad species concepts (see taxonomic account below) and thus diversity may be underestimated, overestimating the degree of nestedness reported here. Taxa found in at least three of the four evaluated sites were: *Closterium closterioides* var. *intermedium*, *Closterium cynthia* De Notaris, *Closterium navicula* (Brébisson) Lütkemüller, *Closterium striolatum* Ehrenberg ex Ralfs, *Cosmarium amoenum* varieties, *Euastrum ansatum* varieties, *Tetmemorus brebissonii* Ralfs and *Tetmemorus* cf. *laevis* Ralfs ex Ralfs. Considering the relatively cursory sampling efforts from these studies, overall nestedness may be underestimated due to inadequate sampling. A more comprehensive sampling effort that takes microhabitat heterogeneity into account as well as temporal and seasonal factors is needed to test and verify these initial findings.

Most of the common species encountered here are found in desmid floras abroad where they are considered benthic, acidophilous and often collected from *Sphagnum* moss. Furthermore, the majority (47.5%) of the desmids identified in this study were categorised as such (see Table 7) and is probably an underestimation considering the presence of poorly-known species with unclassified ecological status. Desmids with broader ecological preferences were also encountered, suggesting migration from nearby microhabitats. It has been hypothesised that high desmid diversity found in *Sphagnum* is due to the host plants' pH reducing capabilities of the surrounding water, making conditions more favourable for desmids (Brook 1981). Mutinová et al. (2016) have reported substrate preference for *Sphagnum* in certain microalgal groups (including desmids) from a European setting and suggest they likely provide a refuge for these acid-adapted organisms. These substrate qualities may be a significant factor for why we observed the presence of different as well as some shared species assemblages between all four sites despite Ebor Common having a poorer desmid biota. Subsequently, *Sphagnum*-harbouring sites in Australia are all potential targets for conservation since rare and/or endemic species can occur in both species-rich and -poor communities due to high spatial turnover. Using the above NCV scheme may assist in determining priority over certain areas or types wetlands with *Sphagnum*, if required.

The Australian desmid flora associated with *Sphagnum* share some similarities to but also marked differences from their better-studied counterparts of western and central Europe. Species of the genera *Cylindrocystis* and *Tetmemorus* were some of the most commonly encountered desmids in this investigation, and are also commonly found amongst *Sphagnum* in central and western European wetlands (Dell'Uomo & Pellegrini 1993; Coesel & Meesters 2007). Species such as *Micrasterias jenneri* and *Tetmemorus brebissonii* are typical of oligo-dystrophic desmid communities of boggy pools with *Sphagnum* from western Europe and were also encountered in the present study. However, many other 'European' species associated with this community are yet to be encountered in Australia (e.g. *Euastrum ampullaceum* Ralfs, *Euastrum crassum* Ralfs, *Micrasterias oscitans* Ralfs *s.s.*, *Staurastrum scabrum* Brébisson, *Staurastrum hystrix* Ralfs). Instead, putative endemics and tropical species such as *Cosmarium amplum* Nordstedt, *C. striolatum* var. *nordstedtii, Euastrum neosinuosum* varieties and *Pleurotaenium nodosum* (Bailey ex Ralfs) Lundell were recovered and were also reported from the previously cited desmid surveys of Australian *Sphagnum*. Further collections from Australian *Sphagnum* would allow a more meaningful assessment of their status and could be compared to those from Europe.

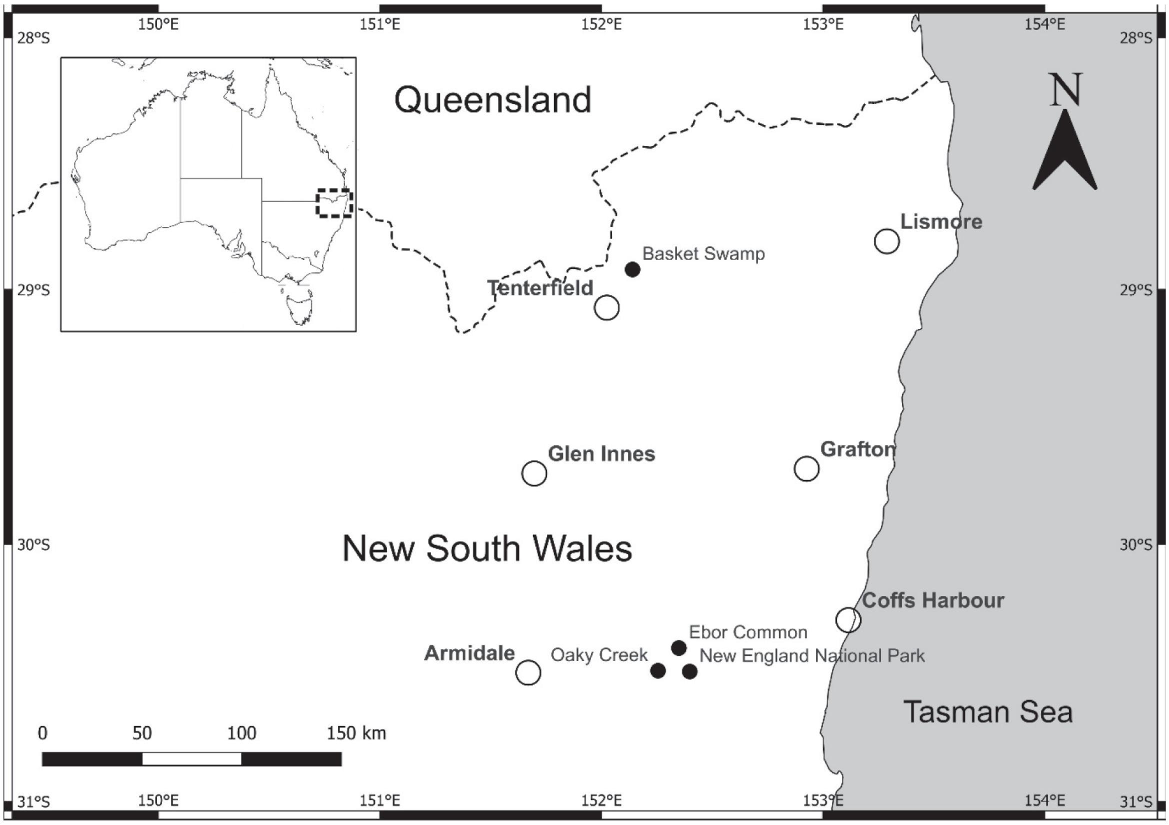

Fig. 1. Map displaying location of study sites designated with a black circle.

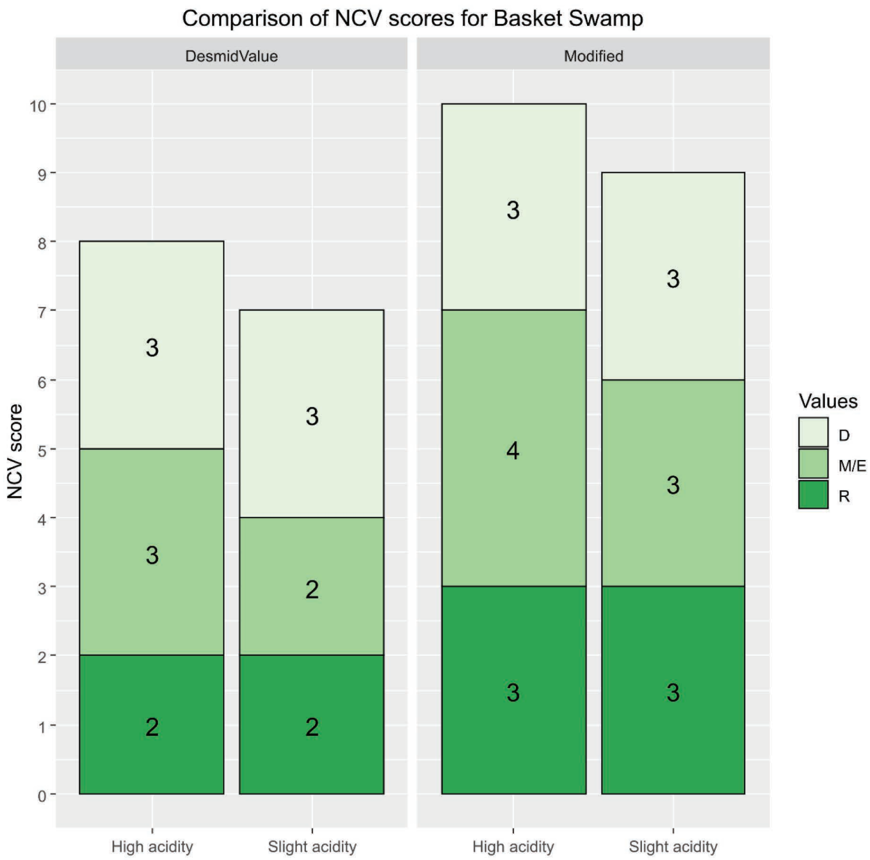

Fig. 2. Bar chart comparing the original DesmidValue scoring results versus the modified one for the Basket Swamp data at different conditions of acidity; D = Diversity value; R = Rarity value; M/E = Ecosystem maturity/Endemism value.

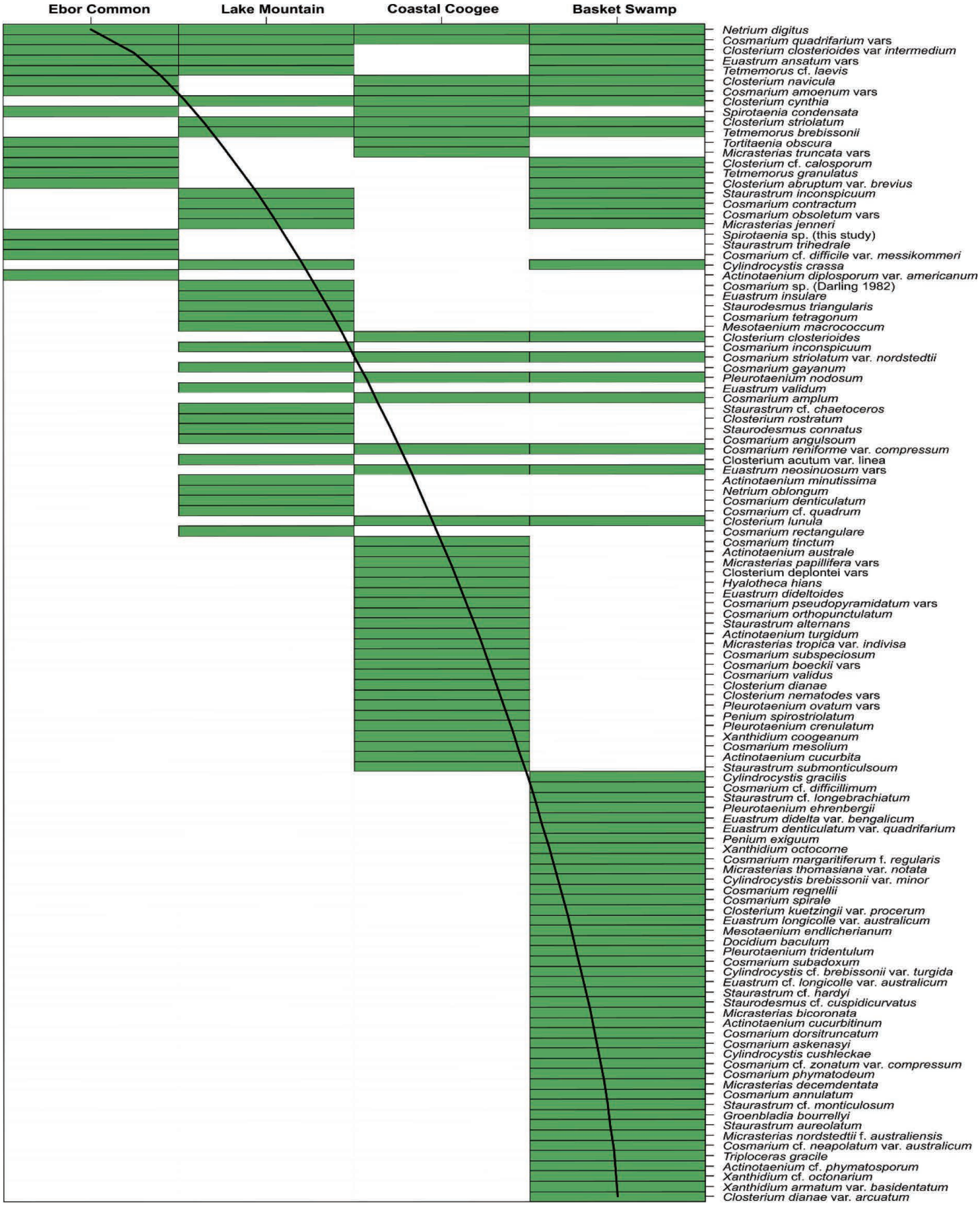

Fig. 3. Incidence matrix from tempnestedness analysis on the combined *Sphagnum*-associated desmids species list from Australia. Green bars represent taxa presence, white represents absence. Black, curved line represents isoclines of species nestedness where some species (e.g. *Netrium digitus*) are present at both lower (Ebor Common) and higher (Basket Swamp) diversity sites.

Section II: Taxonomy

Taxonomic diversity encountered

Eighty species and infraspecific taxa of desmids belonging to 19 genera were encountered. Of these, nine are newly recorded for Australia and seven are new to New South Wales; two are proposed as new species

(*Cosmarium phymatodeum* A.Kenins and *Micrasterias bicoronata* A.Kenins). Together with Skinner's (1979) publication, 125 desmids are now accounted for from this area. Some uncertain desmids that have also been described previously by Skinner (1977) from this same bioregion include *Cylindrocystis* sp. (as *C.* cf. *brebissonii var. turgida* here) and *Euastrum* sp. aff. *longicolle* (as *E.* cf. *longicolle* var. *australicum* here). A further 15 desmids have been tentatively assigned to known species in this study: *Closterium* cf. *calosporum* Wittrock, *Actinotaenium* cf. *phymatosporum* (Nordstedt) Kouwets & Coesel, *Cosmarium* cf. *difficile* var. *messikommeri*, *C.* cf. *neapolitanum* var. *australicum*, *C.* cf. *zonatum* var. *compressum* (Schmidle) Krieger & Gerloff, *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum* A.M.Scott & Prescott, *Staurastrum* cf. *avicula* Brébisson, *S.* cf. *monticulosum* and *Tetememorus* cf. *granulatus* Brébisson ex Ralfs. Additional sampling is needed to observe more of these entities in greater abundance to study their polymorphism and life cycle (e.g. sexual reproduction of zygospores) for certain identification and/or a more extensive literature survey to confirm their identities. Lastly, doubt remains concerning *Cosmarium* cf. *difficillimum* Playfair, *C.* cf. *reniforme* var. *compressum* Nordstedt, *Staurastrum* cf. *hardyi* and *Xanthidium* cf. *octonarium* Nordstedt due to their inadequate descriptions through which apparent slight differences observed here may or may not be minor for the species in question. Re-examination and comparison of any original material from Möbius's, Nordstedt's, Playfair's, Schmidle's and West's work on the Australian desmids (and other species described from overseas in general) is required to reduce these uncertainties. Many of the doubtful forms documented here may assist future efforts in better species circumscriptions, as in the case of *Micrasterias nordstedtii* f *australicum* Thomasson and *M. bicoronata* rediscovered in this survey. As emphasised above, desmid taxonomy (in Australia and abroad) is hindered by the customary approach of defining species on certain morphological features, leading to numerous infraspecific taxa and confusion as to what entities truly represent species. The unified species concept (*see* De Queiroz 2007) which promotes utilising multiple sources of evidence (morphological, molecular, ecological and biogeographical data) to determine discontinuities in species boundaries has been successfully applied on desmids in Europe by Nemjova et al. (2011), Neustupa et al. (2011) and Šťastný et al. (2013). Use of this integrated approach would greatly assist in resolving the above-mentioned taxonomic uncertainties encountered here.

Observations from the SEM component of this study match those of the same previously studied species also encountered here, finding no evidence of cryptic diversity at the ultrastructural level. One exception could be the slight and possibly insignificant differences of *C. striolatum* var. *nordstedtii* from the African and Australian continents where there is disagreement on whether they are conspecific. This study has also examined the ultrastructure of a few species (including Australian "endemics") for the first time, e.g. *Cosmarium* cf. *difficillimum*, *Euastrum longicolle* var. *australicum* Playfair, *Cosmarium quadrifarium* var. *simplex*, *C. phymatodeum* sp. nov., *Micrasterias bicoronata* sp. nov. and *Staurastrum* cf. *hardyi*. Other species with broader distributions such as *Cosmarium annulatum* (Nägeli) De Bary, *C. subadoxum* Grönblad and *Staurastrum inconspicuum* that have been examined here can serve as a baseline to compare with overseas populations.

Our understanding of the geographical distribution of desmids in Australia is inadequate due to limited sampling, focused on certain parts of the continent (Coesel & Dingley 2005). Despite this, there is recognition that some species (and infraspecific taxa) are part of a north versus south flora which are encompassed within the much larger biogeographic regions of the Indo-Malay and northern Australia (IMNAR) and southern Australia and New Zealand (SANZ) (Coesel 1996; Vyverman 1996). Possible IMNAR representatives from here are *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum, Cosmarium amplum* and *C. spirale* (Playfair) Krieger & Gerloff, in addition to three SANZ representatives here being *Closterium kuetzingii* var. *procerum* Skuja, *Euastrum longicolle* var. *australicum* and *Xanthidium armatum* var. *basidentatum* Nordstedt. The New England region appears to be within an interface of the two zones, as originally suggested by Skinner (1979). Distributions that seem to be climatically-defined, *i.e.* pantropical, are also observed in desmids (Coesel 1996), with examples of pantropical species from this survey being *Cosmarium askenasyi* Schmidle, *C. striolatum* var. *nordstedtii*, *C. quadrifarium* var. *simplex, Euastrum didelta* var. *bengalicum* Lagerheim and *Triploceras gracile* Bailey. Desmids have also been observed to have altitudinally-defined distributions where Vyverman (1992) demonstrated that northern montane taxa in Papua New Guinea were predominately confined to altitudes of 1700 to 2500 m, higher than other non-cosmopolitan species. This survey was conducted below this designated altitudinal range, and considering the aforementioned tropical desmids encountered, the flora here largely represents a (sub)tropical lowland one, with the possible exceptions of *Staurastrum* cf. *avicula* and *Cosmarium* cf. *difficile* var. *messikommeri*.

A synoptic guide of the desmids encountered during this study

Family Mesotaeniaceae Oltmanns (saccoderm desmids *sensu lato*)

Cylindrocystis Meneghini ex De Bary (1858).

Cylindrocystis brebissonii var. ***minor*** West & G.S.West

Brook and Williamson 2010, p. 30, pl. 3, figs 1–17.

Description: LM: Cells cylindrical, 36.7–47.7 µm, L × 12.7–13.5 µm Br.; chloroplast asteroid-stelloid. **Fig. 14D–F.**

Remarks: Brook and Williamson (2010) note that this species and *Cylindrocystis gracilis* I.Hirn share similar cellular dimensions but can be differentiated based on chloroplast morphology.

Location: Basket Swamp.

Australian Distribution: A new record for New South Wales, previously reported from the Northern Territory and Victoria.

Cylindrocystis cf. ***brebissonii*** var. ***turgida*** Schmidle

Brook and Williamson 2010, p. 30, pl. 4, figs 1–12.

Skinner 1977, p. 56, pl. 4, fig. 3. As *Cylindrocystis* species.

Description: LM: Cells ellipsoid, with stouter forms having one end broader than the other, 52–82 µm in L. by 38.5–47.5 µm Br.; often surrounded by a relatively thick mucilaginous envelope; chloroplasts like that of *C. crassa* de Bary, asteroid with two pyrenoids. **Fig. 15B & C.**

Notes: Skinner (1977) reports of a strikingly similar form as *Cylindrocystis* sp. with dimensions of 55–60 µm in length and 40–45 µm in width and remarks that one side appears more or less flattened in end view. The Australian, New England forms here are distinctly larger than any records of *C. crassa* and broader than any records of *C. brebissonii* var. *turgida* from this country or overseas.

Location: Basket Swamp.

Australian Distribution: Previously recorded from Queensland. A new record for New South Wales, if confirmed.

Cylindrocystis crassa de Bary

Brook and Williamson 2010, p. 31, pl. 5, figs 1–8, pl. 6, fig. 1.

Description: LM: Cell 27.7 µm L. × 20 µm Br.; chloroplast asteroid. **Fig. 15A.**

Notes: Only a few, seldom individuals were observed.

Location: Basket Swamp.

Australian Distribution: Previously reported from New South Wales and Queensland.

Cylindrocystis cushleckae A.J.Brook

Brook and Williamson 2010, p. 32, pl. 9, figs 1–15; pl. 10, figs 1–17.

Description: LM: Cells cylindrical, 7.1–8.5 µm, L × 15.4–32.4 µm Br.; chloroplast axile-stelloid type with one to two irregularly dissected longitudinal lamellae seen in face view. **Fig. 14A–C.**

Notes: This was the most commonly encountered species; it was present in almost all samples and was often the sole species collected from terrestrial cushions of *Sphagnum*.

Locations: Basket Swamp, New England National Park and Oakey Creek.

Australian Distribution: A new record for Australia.

Cylindrocystis gracilis I.Hirn

Brook and Williamson 2010, p. 34, pl. 12, figs 1–16.

Description: LM: Cells cylindrical, 29.2–31.8 µm L × 13.4–14.7 µm Br.; Chloroplast axile-stelloid with one to two longitudinal ridges in face view. **Fig. 14G.**

Locations: New England National Park and Oakey Creek.

Australian Distribution: A new record for Australia.

Mesotaenium Nägeli (1849).

Mesotaenium endlicherianum Nägeli

Brook and Williamson 2010, p. 86, pl. 39, figs 1–21.

Description: LM: Cells elliptical in outline, 14.1–34.7 µm L × 9.9–12 µm Br; L:B 1.3–2.9; chloroplast a parietal cup. **Fig. 14I.**

Location: Basket Swamp.

Australian Distribution: A new record for Australia.

Mesotaenium macrococcum (Kützing) Roy & Bisset

Brook and Williamson 2010, p. 86, pl. 37. figs 1–7; pl. 38, figs 1–8 & 11.

Description: LM: Cells oval in outline, 24.7–41 µm, L × 10.1–13.9 µm Br; L:B 2.3–3; chloroplast an axile plate with a centrally positioned *pyrenoid*. **Fig. 14H.**

Notes: Brook and Williamson (2010) note this species forming mucilaginous masses; we only encountered single cells or colonies of four.

Locations: New England National Park and Oakey Creek.

Australian Distribution: A new record for New South Wales; reported previously from Victoria.

Netrium (Nägeli) Itzigsohn & Rothe in Rabenhorst (1856).

Netrium digitus (Brébisson ex Ralfs) Itzigsohn & Rothe complex

Brook & Williamson 2010, p. 53, pl. 15, figs 1¬–4; pl. 16, figs 6–7; pl. 18 figs 1 & 3.

Description: LM: Cells relatively large, 129–227 µm L × 35.7–62 µm Br. **Fig. 15D.**

Notes: Based on a comprehensive study by Ohtani (1990), the cell size of this complex is highly variable and interlink with similar species and infraspecific taxa in this genus. *Netrium digitus* var. *lamellosum* (Brébisson ex Kützing) Grönblad was incidentally encountered with *N. digitus* var. *digitus* and have been treated here synonymously like that of Brook and Williamson (2010) and as well as Coesel & Meesters (2007). Additionally, while both Brook and Williamson (2010) and Ohtani (1990) agree that *Netrium naegelii* (Brébisson ex W.Archer) West is a distinct species from *N. digitus*, some of the cells we encountered had the chloroplast in too poor condition to confirm if this species was also present. To add further confusion, Ohtani (1990) states that *N. naegelii* possess apical vacuoles, whereas Brook and Williamson (2010) never encountered any specimens from Britain that they regarded as *N. naegelii* with this feature. We also did not encounter any individuals of *Netrium* with vacuoles.

Locations: Basket Swamp and Ebor Common.

Australian Distribution: Both *Netrium digitus* var. digitus and *Netrium digitus* var. *lamellosum* have been reported previously from the Northern Territory, Queensland and New South Wales. *Netrium digitus* has also been recorded from Victoria and Tasmania. *Netrium naegelii* has been reported from the Northern Territory and South Australia.

Spirotaenia Brébisson in Ralfs (1848).

Spirotaenia condensata Brébisson

Croasdale & Flint 1986, p. 33, pl. 1, figs 11, 12.

Description: LM: Cells cigar-shaped, 104–124 µm L. × 18.2–19.7 µm Br.; chloroplast parietal, as a broad, spiralling band. **Fig. 13 F.**

Location: Ebor common.

Australian Distribution: Previously reported from N.S.W. Also reported from the Northern Territory and Victoria.

Spirotaenia sp.

Description: LM: Cells fusiform, 35.5–36.6 µm L. × 8.2–8.4 µm Br.; chloroplast parietal, forming a spiral.

Notes: Only a pair of cells post asexual division within a mucilaginous sheath was encountered. While the cell shape and a ribbon-like chloroplast could be discerned, they had deformed from the preservation process and identification to level of species was not possible.

Location: Ebor common.

Tortitaenia Brook (1998).

Tortitaenia obscura (Ralfs) Brook

Brook & Williamson 2010, p. 111, pl. 50, figs 1–11.

Basionym: *Spirotaenia obscura* Ralfs

Synonym: *Polytaenia obscura* (Ralfs) Brook *nom. illeg.*

Description: LM: Cells fusiform to almost cigar-shaped. **Fig. 15E.**

Notes: Only two cells post asexual division encountered from live culture.

Location: Ebor Common.

Australian Distribution: Previously reported from New South Wales on numerous occasions.

Family Peniaceae Haeckel 1894 (placoderm desmids *pro parte*)

Penium Brébisson ex Ralfs (1848).

Penium exiguum W.West

Brook & Williamson 2010, p. 139, pl. 62, figs 1–7.

Description: LM: Cell cylindrical 37.2–58 µm L. × 7.4–8.5 µm Br.; Ap. 7.1–8.6 µm, slightly dilated; I. 6.4–7.7 µm. *Cell wall* granular with girdle bands. Chloroplasts axile-stelloid with longitudinal ridges. **Fig. 15F.**

Location: Basket Swamp.

Australian distribution: A new record for Australia.

Family Closteriaceae A.Pritch. (placoderm desmids *pro parte*)

Closterium Nitzsch ex Ralfs (1848).

Closterium abruptum var. ***brevius*** (West & G.S.West) West & G.S.West

West & West 1904, p. 160, pl. 20, figs 11, 12.

Description: LM: Cells curved 83–110°, 77–123 µm L. × 10.2–19.5 µm Br., with an L:B of 4.8–8.1; Ap. 4.3–5.3 µm. *Cell wall* smooth, girdle bands present. Chloroplasts axile with one to two longitudinal ridges and one to three pyrenoids. Terminal vacuole typically bearing a single crystal, but up to two observed. **Fig. 8B.**

Notes: Brook and Williamson (2010) regard *Closterium abruptum* var. *brevius* as “invalid” based on previous population studies where the varieties could not be separated into distinct morphological groups. They also note this species as an acidophile, being frequently found amongst *Sphagnum*.

Location: Basket Swamp and Ebor Common.

Australian distribution: In his census of the freshwater algae of New South Wales, Playfair (1917) recorded this species but no voucher were reported.

Closterium cf. ***calosporum*** Wittrock

Ling and Tyler 2000, p. 135, pl. 61, fig. 1.

Description: LM: Cells curved 93–113°, 75–93 µm in L. × 7.7–9.1 µm Br., with an L:B of 9.7 to 11.2; Ap. 2.3 to 2.8 µm. Chloroplasts having 3–4 pyrenoids along the centre. Apices obliquely truncate with an apical pore. **Fig. 8C.**

Notes: The curvature and dimensions match those in Ling and Tyler (2000) under this name. However, the curvature of the cells are more like *Closterium dianae* Ehrenberg ex Ralfs, which Brook and Williamson

(2010) mention can be confused with this species but the dimensions recorded here are well below for this species and any of its varieties. This species can be confused with forms of *Closterium venus* Kützing ex Ralfs and *Closterium parvulum* Nägeli whereby complete certainty can only be achieved by observations of the characteristic zygospores (Brook and Williamson 2010).

Locations: Basket Swamp, Ebor Common and New England National Park.

Australian distribution: Reported from the Northern Territory, Queensland, New South Wales, Victoria and Western Australia.

Closterium closterioides (Ralfs) A.Louis & Peeters

Basionym: *Penium closterioides* Ralfs

Synonym: *Closterium libellula* G.W.Fock ex Nordstedt

Croasdale & Flint 1986, 54, pl. 4, figs 7, 8.

Description: LM: Cells cylindrical, sides distinctly parallel to one another. Ap. 8–12.6 μm, L. 190–321 μm, Br. 29.5–32.9 μm. **Fig. 9F.**

Notes: Commonly found in *Sphagnum* pools (Croasdale & Flint 1986).

Location: Basket Swamp.

Australian distribution: Recorded from Queensland**,** New South Wales and Victoria under its various synonyms.

Closterium closterioides var. ***intermedium*** (Roy & Bisset) Růžička

Croasdale & Flint 1986, 55, pl. 4, figs 11, 12.

Description: Cells straight, broadly fusiform, 85–131 μm L. × 15.1–25.7 μm Br., with an L:B of 5.1–5.7. **Fig. 8E.**

Notes: Associated with *Sphagnum* as typical variety (Croasdale & Flint 1986).

Locations: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory and New South Wales.

Closterium cynthia De Not.

Coesel and Meesters 2007, p. 42, pl. 16, fig. 3.

Description: LM: Cells strongly curved 81–128°, with median portion often straight, 131–185 μm L. × 13.6–19.7 μm Br. with a L:Br of 8.6–10; Ap. 4.65–6 μm. Cell wall striate with girdle bands. Chloroplast with three to seven axile pyrenoids. **Fig. 8D.**

Notes: Brook and Williamson (2010) transferred this species to *Closterium jenneri* forma *cynthia*.

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, New South Wales, Victoria and Tasmania

Closterium dianae var. ***arcuatum*** (Brébisson ex Ralfs) Rabenhorst

Brook and Williamson 2010, p. 283, pl. 132, fig. 4.

Description: LM: Cells strongly curved, greater than 115°, 243–272 μm L. × 16.1–17.1 μm Br. Ap. 1.7–2.6 μm. Chloroplasts axile, with five to six pyrenoids. Terminal vacuole containing a single crystal, end pore present. **Fig. 8A.**

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, South Australia, Tasmania and New South Wales.

Closterium gracile Brébisson ex Ralfs

Brook and Williamson 2010, p. 185, pl. 75, figs 1–13.

Description: LM: Cells 182–200 μm L. × 2.97–3.95 μm Br. **Fig. 9D.**

Notes: This cosmopolitan species is essentially an acidophile and often found in abundance in *Sphagnum* bogs and peaty pools (Brook & Williamson 2010).

Location: Basket Swamp, New England National Park.

Australian distribution: Encountered previously from all Australian mainland states and territories except the Australian Capital Territory.

Closterium kuetzingii var. ***procerum*** Skuja

Croasdale & Flint 1986, p. 62, pl. 11, figs 9, 10.

Description: LM: Cell 235 µm L. × 12.9 µm Br., with an L:B of 18.2 Ap. 2.61 µm. **Fig. 9E.**

Notes: Differs from *Closterium kuetzingii* var. *kuetzingii* Brébisson in that the cells are consistently more slender and stouter (see Croasdale and Flint 1986).

Location: Basket Swamp.

Australian distribution: This species was described from New Zealand and reported for New South Wales (Playfair 1917) and for the Northern Territory from Buffalo Billabong (Thomasson 1986).

Closterium lunula Ralfs

Brook and Williamson 2010, p. 16, pl. 6, figs 1–8.

Description: LM: Cells broadly fusiform, dorsal side slightly curved, 465–550 µm L. × 59–95.2 µm Br. **Fig. 9A**.

Location: Basket Swamp and Ebor Common.

Australian distribution: Reported previously from New South Wales, Victoria and Tasmania.

Closterium navicula (Brébisson) Lütkemüller

Brook and Williamson 2010, p. 167, pl. 67, figs 1–8, 16 & 17.

Description: LM: Cells broadly fusiform, 51–65 µm L. × 14.6–15.2 µm Br., with an L:B of 3.5–4.3. **Fig. 8F.**

Location: Basket Swamp and Ebor Common.

Australian distribution: Reported from all states and territories except South Australia and Western Australia.

Closterium ralfsii var. ***hybridum*** Rabenhorst

Brook & Williamson 2010, p. 298, pl. 141, figs 2–5, 6.

Description: LM: Cell curved 34°, Ap. 5.1–5.9, 480 µm L., 30.3–30.4 µm Br. Wall finely striate, over 10 per 10 µm. **Fig. 9B.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales, seen previously in the Northern Territory.

Closterium striolatum Ehrenberg ex Ralfs

Brook & Williamson 2010, p. 227, pl. 101, figs 1–5 & pl. 102, fig. 5.

Description: LM: Cells curved 70–75°, 185–270 µm in L. × 21.9–29.4 µm Br., with an L:B of 8.4–12.3; Ap. 8–10 µm. SEM: Striae less than 2 µm apart, circa 1.5 µm; eight per 10 µm. **Fig. 9C.**

Notes: Brook and Williamson (2010) observed punctae between the striae under LM for this species, though we did not detect this feature in our material. They also note that this species is found in a range of acidic habitats, particularly *Sphagnum*.

Location: Basket Swamp.

Australian distribution: Numerous observations of this species have been reported from all the Australian states and territories except for the Australian Capital Territory and Western Australia.

Family Desmidiaceae Ralfs (placoderm desmids *pro parte*)

Actinotaenium (Nägeli) Schellenberg (1897).

Actinotaenium cucurbitinum (Bisset) Teiling

Coesel and Meesters 2007, p. 60, pl. 31, figs 9–10.

Description: Cells broadly fusiform, 56–61 µm L. × 22.8–25.2 µm Br, I. 22.4–23.8 µm. Ap. 12.6–13.7 µm; truncately rounded. Chloroplast stelloid. **Fig. 10A.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. This species has been reported from the Northern Territory and South Australia.

Actinotaenium diplosporum var. ***americanum*** (West & G.S.West) Teiling

Coesel and Meesters 2007, p. 61, pl. 30, figs 1–2.

Description: Cells cylindrical to slightly ellipsoid, 58–64 µm L. × 23.4–26.8 µm Br, with a L:B of 2.4–2.6. Sinus very small and sharp. Chloroplast asteroid. **Fig. 10B.**

Location: Ebor Common.

Australian distribution: A new varietal record for Australia. The type variety has been reported the Northern Territory and Tasmania.

Actinotaenium cf. ***phymatosporum*** (Nordstedt) Kouwets & Coesel

Coesel and Meesters 2007, p. 62, pl. 30, figs 11–12.

Description: LM: Cells, 27.7–46.5 µm L., 12.3–16.3 µm Br., with a L:B of 11.3–15.9 µm. Chloroplast lobo-stelloid. SEM: Cell wall striated by a series of fine pores parallel to one another. **Figs 19A, B & C.**

Notes: This species is asexually almost morphologically identical to *Actinotaenium spinospermum* (Joshua) Kouwets & Coesel which tends to be less than 30 µm in length. Certain identification between the two species requires confirmation of the different type of zygospores (Coesel & Meesters 2007), which were not observed in this survey.

Locations: Basket Swamp, Ebor Common and New England National Park.

Australian distribution: Reported previously from New South Wales (Skinner 1979) as *Penium phymatosporum* Nordstedt with zygospores that are depicted as globose and described as irregularly mamillated, suggesting they are more likely to be *A. spinospermum*.

Cosmarium Corda ex Ralfs (1848).

Cosmarium amoenum Ralfs

Croasdale & Flint 1988, p. 51, pl. 55, figs 4,5.

Description: LM: Cells longer than broad, 49–69.5 µm L. × 27–38 µm Br., elliptic in outline; Sinus closed, I. 10.5–18.3 µm. Th. 21.2–26 µm. Cell wall granulate except in some specimens where the central portion was smooth. Chloroplast with two pyrenoids adjacent to one another per semi-cell. SEM: Granules are surrounded by four to six (typically 5) fine pores. Specimens which lack granules from the central area of the cell face (see remarks var. *mediolaeve*) have smaller, less prominent granules; above the isthmus lies one to three rows of granules. Throughout the granule-vacant area are numerous fine pores in a scattered arrangement. **Figs 10C, 20 A–F.**

Notes: *Cosmarium amoenum* var. *mediolaeve* Nordstedt was also encountered and is very similar to the nominate, but in the former granules are smaller and absent from the central portion of the semicell, with only two horizontal rows just above the isthmus. We hypothesise that this variety may be a nascent developmental stage of the species.

Locations: Basket Swamp and Ebor Common.

Australian distribution: *Cosmarium amoenum* has been previously observed in Tasmania, Victoria and New South Wales. *Cosmarium amoenum* var. *mediolaeve* has also been reported from New South Wales and Victoria.

Cosmarium amplum Nordstedt

Croasdale & Flint 1988, p. 51, pl. 51, figs 5, 6.

Description: LM: Cells 128–136 µm L. × 90–97 µm Br, I. 35.6–.38 µm.; 66 µm Th. **Fig. 11C.**

Location: Basket Swamp.

Australian distribution: Queensland, New South Wales and Victoria.

Cosmarium annulatum (Nägeli) De Bary

Croasdale & Flint 1988, p. 53, pl. 55, figs 16–19.

Homotypic synonym: *Penium annulatum* (Nägeli) W.Archer

Description: LM: Cells cylindrical, 44.6–45.7 µm L. × 15.7–18.6 µm Br, I. 13.6–16.6 µm. Four or five transverse series of smooth nodules per semicell were observed. SEM: The nodules are oval-shaped and appear to develop from two granules opposite ends of one another and then combine when mature. The bottom of each nodule adjacent to the isthmus has a minute pore. Between all the transversely arranged nodules are three fine pores. The cell apex has concentric rings of fine pores, otherwise smooth. **Figs 21 A, B, C & D.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales as *P. annulatum* (Skinner 1977).

Cosmarium askenasyi Schmidle

Croasdale & Flint 1988, p. 53, pl. 50, figs 10–11.

Description: LM: Cell 167 µm L. × 134 µm Br, I. 62 µm. Semicells pyramidal in shape with about a dozen bluntly-pointed granules on the basal angles. **Fig. 10G.**

Location: Basket Swamp.

Australian distribution: Reported previously from New South Wales.

Cosmarium contractum Kirchner

Croasdale & Flint 1988, p. 61, pl. 33, figs 1 & 2.

Description: LM: Semicells sub-globose, 25–29.7 µm L. × 17.2–19.8 µm Br, I. 5.2–6.8 µm. Chloroplast axile with a centrally placed pyrenoid. SEM: Cell wall finely punctate. **Figs 10J and 22A & B.**

Notes: Individuals of this species with smaller cell sizes (<28 µm long) are sometimes treated as variety *minutum* (Deplonte) Coesel but Croasdale and Flint (1988) suggest such a distinction as artificial. Based on our observations, where cell sizes intergraded between both varieties, we agree that there is no merit in recognition of the variety.

Location: Basket Swamp.

Australian distribution: This species is known from the Northern Territory, New South Wales, Victoria and Tasmania.

Cosmarium cf. ***difficile*** var. ***messikommeri*** (Croasdale) Kouwets

Kouwets 1997, p. 41, figs 69–76.

Description: LM: Cells small, 13.3–17 µm in L. × 8–11 µm Br, with a L:B of 1.47–1.73. I. 2.45–3.18 µm with a Thickness of 7.5–7.7 µm. SEM: Cell wall alveolate, three transversal rows of puncta are located near the apex, centre and base of the semicell. **Figs 23C & D.**

Notes: The overall cell shape and the arrangement of the transversal pores affiliates this *Cosmarium* with the "*difficile*-gruppe" but is considerably smaller than the nominate variety and most of its other varieties or formae. Of the few subspecific forms, which have similar dimensions, such as *Cosmarium difficile* f. *rectangulum* D.B.Williamson and *Cosmarium Difficile* f. *minor* Bourelly, there are consistent differences. For *C. difficile* f. *rectangulum*, which was originally described by Williamson (1994) associated with *Sphagnum* from Britain, it has a much longer L:B ratio of two or more with the sides parallel to one another *i.e.* rectangular semicells. Specimens assigned here are also similar to *C. difficile* f. *minor*—originally described from Madagascar by Bourrelly in Bourrelly & Manguin (1949) as *C. difficile* var. *dilatatum* f. *minor*—possessing lateral margins markedly dilated with an inflated apex. The cell dimensions are also similar to a form listed as *C. difficile* forma by Grönblad et al. (1958), but more rectangular in outline with slightly indented lateral margins. Hirano (1957) describes a small *C. difficile* var. *sublaeve* Lütkemüller, which has a flattened apex and with the sides almost parallel but again is slightly larger and more rectangular than the cells observed here. *Cosmarium difficile* var. *minutissimae* (Woloszynska) Brook is possibly a synonym for *C. woloszynskae* see (Coesel and Meesters 2004), which is a larger desmid with undulating margins. The specimens observed here probably best match *C. difficle* var. *messikommeri*, however, this variety has a putative arctic-alpine distribution and the dimensions here are slightly below those previously quoted. Kouwets (1997) also notes that this species exhibits thickening of the lateral angles; this was not observed in our specimens.

Location: Ebor Common.

Australian distribution: A new record for Australia, if confirmed.

Cosmarium cf. ***difficillimum*** Playfair

Playfair 1908, p. 614, pl. 13, fig. 5.

Description: LM: Cells 33.4–35.5 µm in L. × 19.4–22.3 µm Br, with a L:B of 1.5–1.6. I. 4.8–5.5 µm with a Th. of 13.5 µm. Cell wall smooth with 3 transversal rows of pore fields. Semicells sub-quadrate with rounded angles, the apex of each bears a depression which appears to be closely arranged pores of at most 3. Chloroplast with a centrally positioned pyrenoid. **Figs 10F and 23A & B.**

Notes: This species is regarded by some as synonymous with *Cosmarium difficile* Lütkemüller but, as Playfair (1908) notes, the cell outline and pore arrangement are quite different. It is most similar to the variety *C. difficile* var. *dilatatum* Borge but that species has the lateral sides broadest near the apex whereas, in *C. difficillimum*, the lateral margins are more or less parallel to one another. In Van Westen (2015), a description of *C. pseudodifficile* M.Van Westen is also similar but that species has lateral margins that are more rounded and distinctly broadest at the centre. For cell outline and size, it is also similar to what Nordstedt (1888) described, and illustrated, as a slightly larger form ('*forma paullo majus*') of *Cosmarium exiguum* W.Archer, but his description is extremely terse, lacking any mention of additional features such as pores.

Location: Basket Swamp.

Australian distribution: Originally described by Playfair *l.c.* from New South Wales.

Cosmarium dorsitruncatum (Nordstedt) G.S. West

Croasdale & Flint 1988, p. 65, pl. 33, fig. 20.

Description: SEM: Cell broader than long with a relatively flat apex; L. 32 µm and Br. 38.7 µm. Sinus deep and closed, I. 13.7 µm. Cell wall finely punctate. **Figs 10K and 22C & D.**

Location: Basket Swamp.

Australian distribution: Recently reported from New South Wales by Dingley (2001) and reported previously from Victoria (West 1909).

Cosmarium margaritiferum f. ***regularius*** (Nordstedt) West & G.S.West

Croasdale & Flint 1988, p. 74, pl. 45, figs 13–14; pl. 46, figs 1–3.

Description: LM: Cells 47.7–54.6 µm L. × 35.5–43.2 µm Br.; L:B of 1.3, I. 12.4–15.4 µm; 26.1–26.2 µm Th. Semicells truncate-pyramidal with rounded angles and a broad flat apex. Cell wall granulate. SEM: Granules are uniform in size and are arranged over the entire surface of the cell except for the middle portion of the semicell face which has larger, more rounded granules (that increase in size towards the centre) and are surrounded by five to six scrobiculations arranged in a hexagonal pattern. **Figs 10H and 24A, B, C & D.**

Notes: *Cosmarium margaritiferum* forma *regularius* is slightly smaller, more elongate compared to the type form with many workers stating that the two forms intergrade. The typical form is commonly found amongst plants and especially *Sphagnum* (see Croasdale and Flint 1988).

Location: Basket Swamp.

Australian distribution: *Cosmarium margaritiferum* Eichwald was recently discovered by Dingley (2001) in New South Wales and has also been reported from Victoria and Tasmania. Dingley (2002) has also reported the forma *regularius* from New South Wales, however, the specimens were smaller than hitherto reported and the central granules were the same size as the rest of the cell wall granules suggesting a possible misapplication for another *Cosmarium* species. *Cosmarium margaritiferum* has been reported from the Northern Territory by Thomasson (1986).

Cosmarium obsoletum var. ***sitvense*** Gutwinski

Croasdale & Flint 1989, p. 81, pl. 29, figs 6,7.

Description: LM: Cell sub-circular, 60 µm L. × 65 µm Br, I. 34.8 µm. Semicells with pore-bearing basal angles. Chloroplast in each semicell has two pyrenoids. **Fig. 10L.**

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, Queensland, New South Wales and Victoria.

Cosmarium phymatodeum A.Kenins, *sp. nov.*

Type: NEW SOUTH WALES: Northern Tablelands: Boonoo Boonoo, Basket Swamp National Park, 8 April 2018, *A.Kenins* 5 (holo: NSW; iso: NE), deposited as permanent slides from a formalin preserved sample, the selected specimens are circled with red ink and represented by Fig. 4A.

Diagnosis: Similar to other species of *Cosmarium* that possess verrucose margins and facial ornamentation but differs from them by lacking a distinct region of smooth cell wall between the submarginal verrucae and central ornamentation; and by the arrangement and number (16–26) of the interconnected facial verrucae.

Description: Cells longer than broad, sub-pyramidal to sub-circular, L. 42.6–53.5 µm, Br. 37.3–42.3 µm, I. 13.6–14.9 µm, Th. 25 µm; cell-margin verrucose, with rows of dentate, intramarginal verrucae. Verrucae are trifid at the cell margin but decrease in size and are at most bifid when closer to the central ornament. Facial verrucae in the centre globular, ranging from 16 to 26 per semicell and interconnected by ridges. Chloroplast with two pyrenoids per semicell. Zygospore unknown.

Additional Figures and Material: Fig. 4B, Fig. 5 A, B, C & D. Other material containing this taxon has been deposited at **NE.**

Distribution and ecology: Thus far only known from Basket Swamp, New South Wales, and associated with *Sphagnum* (pH 5.60).

Etymology: The species epithet is latinised from the Greek 'phymatōdes,' meaning 'warty' or 'verrucose'.

Notes: *Cosmarium phymatodeum* shares its morphological affinities with many species of *Cosmarium* that possess verrucose margins and facial ornamentation, like, *C. quadrifarium*, *C. binum*, *C. subspeciosum*, and their subspecific forms. The lack of smooth cell wall between the marginal verrucae and the facial ornamentation, along with the overall arrangement and number of interconnected facial verrucae is unique to *C. phymatodeum* when compared with the previously mentioned species complexes.

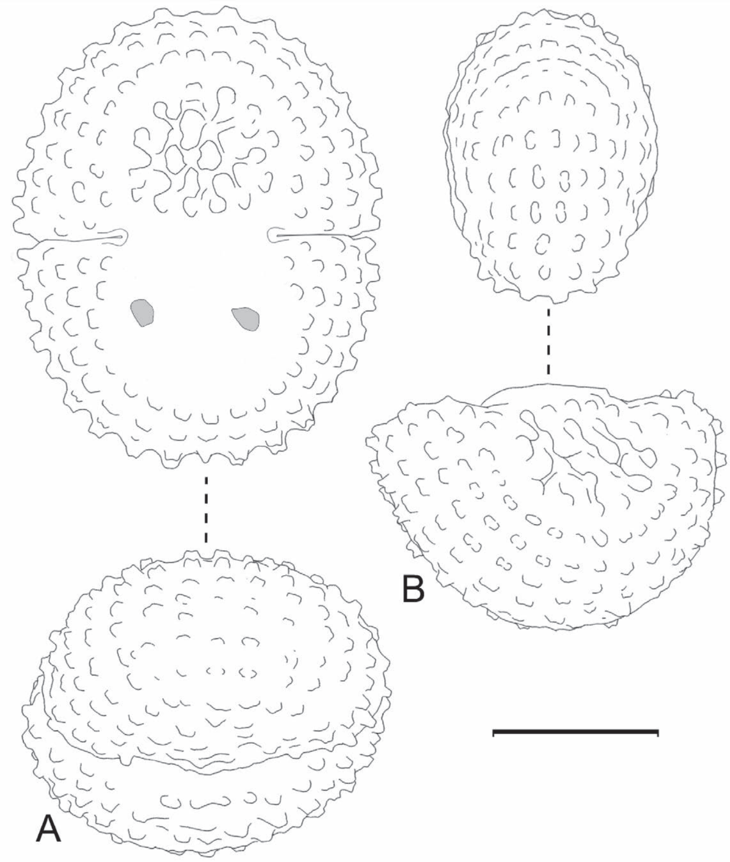

Fig. 4. Line drawing of *Cosmarium phymatodeum*, **A.** whole cell in front view (shaded regions in lower semicell indicate position of pyrenoids) and apical view, **B.** semicell in side- and slightly oblique-view. Scale bar = 20 µm.

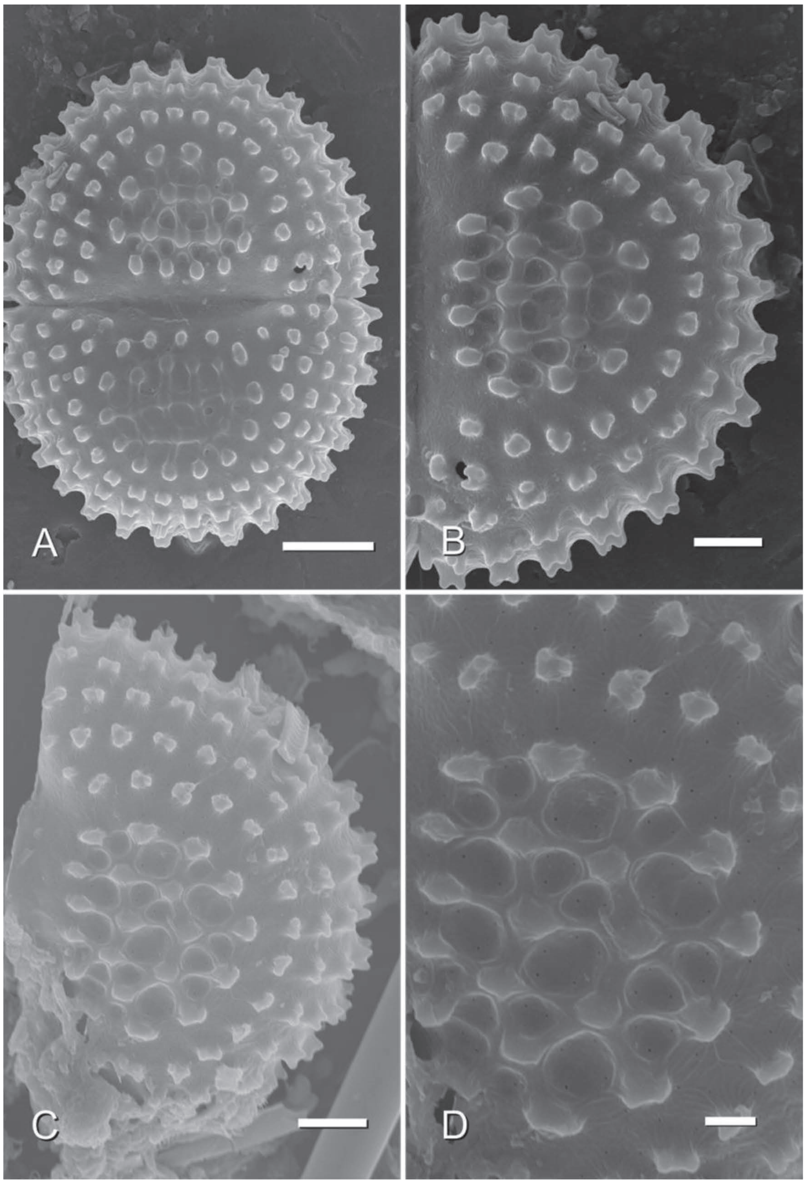

Fig. 5. Scanning electron micrographs of desmids, **A**, **B**, **C** & **D.** *Cosmarium phymatodeum* Scale bar A = 10 µm; B & C = 5 µm; D = 2 µm.

Cosmarium quadrifarium var. ***simplex*** Krieger

Krieger 1932, p. 184, pl. 12, fig. 12.

Description: Cells semicircular, 36.1–57 µm L. × 26.2–43.6 µm Br, I. 11.9–17.4 µm and Th. 18.8–26.8 µm. Margins verrucose with three rows of intramarginal verrucae. Central crown of granules ranged from five to eight. The submarginal verrucae decrease in size and complexity; the smallest are found closest to the central ornament and are at most tridentate with the verrucae not always combining which can occasionally give a false impression of an additional row of submarginal verrucae. The next row of verrucae are larger and generally quadri-dentate with some being tridentate. The final row of verrucae are the largest and quadri-dentate. The central crown of granules are rounded and arranged with five encircling the perimeter of a more or less spherical cavity that is between (5–5.5um) in diameter; each of these granules have a bridge connecting to one central granule. One specimen was observed to have six surrounding a spherical cavity 3–3.5 µm in diameter devoid of a central granule and connecting bridges. **Figs 10D and 27A, B, C, D, E, F.**

Notes: The material observed here best match that of Krieger's var. *simplex* in that they share the reduced number of central verrucae. Krieger *l.c.* states that this variety usually has three to four central verrucae per semicell but also depicts up to seven arranged elliptically. While the number of verrucae here is within this range they differ in their arrangement. Other differences such as the marginal verrucae cannot be compared since Krieger *l.c.* only states that this variety is essentially like the type in all other aspects and the illustrations provide no more detail. Bourrelly & Coute (1991) describe and depict *C. quadrifarium* var. *simplex* from

Madagascar with a more similar central ornamentation, having a crown of five or six verrucae surrounding a central one. This central ornamentation was sometimes observed to be reduced to only four verrucae from the Madagascan material; which connects it to the original description by Krieger.

Locations: Basket Swamp and Ebor Common.

Australian distribution: New varietal record for Australia.

Cosmarium regnellii Wille

Croasdale & Flint 1988, p. 98, pl. 4, figs 1–4,9.

Description: LM: Cells small, hexagonal in outline, L. 10.1–20.3 μm, Br. 10.3–19.8 μm. Sinus linear, closed I. 3.7–5.9. SEM: Cell wall composed of aveoles randomly distributed giving a reticulate appearance. Fine pores distributed about 1 μm from one another. **Figs 11B and 28A, B, C & D.**

Notes: Of the few cells observed, the size dimensions best fit with *Cosmarium regnellii* var. *minimum* Eichler & Gutwinski. Coesel and Meesters (2007) regard the morphology of this species to be highly variable and consider the several varieties of this species to have no taxonomic significance.

Location: Basket Swamp.

Australian distribution: Reported previously from New South Wales and Queensland.

Cosmarium cf. ***reniforme*** var. ***compressum*** Nordstedt

Croasdale & Flint 1989, p. 100, pl. 44, figs 6,7.

Description: LM: Cells 59–73 μm L. × 46.5–65 μm Br, I. 11.9–20 μm.; in apical view oblong, Th. 34.1–36.6 μm Semicells sub-reniforme with a flattened apex. Cell wall entirely granulate except for isthmal region. Chloroplast in each semicell has two pyrenoids, one situated near each lateral lobe. SEM: The cell wall granules are arranged in longitudinal rows (not horizontal) and are surrounded by puncta that are hexagonal in arrangement. **Figs 11A and 26A & B.**

Notes: These specimens have been tentatively designated as *C. reniforme* var. *compressum* since they are larger and have a consistently more open sinus. They should also be compared to the poorly described *Cosmarium reniforme* var. *apertum* West & G.S.West, which has a more open sinus, see West & West (1908).

Location: Basket Swamp.

Australian distribution: Reported from the Northern Territory, Queensland and New South Wales based on previous workers.

Cosmarium spirale (Playfair) Krieger & Gerloff

Playfair 1908, p. 618, pl. 13, fig. 20.

Basionym: *Cosmarium stenonotum* var. *spirale* Playfair

Homotypic Synonym: *Cosmarium pseudopyramidatum* var. *spirale* (Playfair) Playfair

Description: LM: Cells longer than broad, 57 μm L. × 30.1–34.2 μm Br. Sinus closed, linear; I. 7.6–7.9 μm. Semicells pyramidal in outline, wall coarsely scrobiculate. Torsional asymmetry at the isthmus variable. **Fig. 10I.**

Location: Basket Swamp.

Australian distribution: In Australia, only known from New South Wales, but has also been recorded from Papua New Guinea by Thomasson (1967).

Cosmarium subadoxum Grönblad

Coesel & Meesters 2007, p. 142, pl. 61, figs 35,36.

Description: Cells almost as broad as long, 7.9–8.6 μm L. × 7.7–8.4 μm Br. Sinus closed, linear; I. 1.9–2.5 μm. Th. 4.4–4.6 μm from side view (without tubercule). Apex retuse, upper lateral sides convex. Under SEM the cell wall is reticulate-foveate above and below the centrally-placed papilla, the aveoles are arranged in longitudinal rows elsewhere. **Figs 26 C & D.**

Notes: Anissimova (2015) has previously observed the alveolate disposition of the cell wall of this species from Russian material. The ultrastructural sculpturing of the cell wall is also similar to that of *Cosmarium polygonum* (Nägeli) W.Archer in Vyverman (1991) but that species is larger, and the upper portion of the lateral margins are concave.

Location: Basket Swamp.

Australian distribution: A new record for Australia.

Cosmarium striolatum var. ***nordstedtii*** (Möbius) Krieger

Claassen & Eicker 1985, p. 230, figs 29–42.

Basionym: *Pleurotaeniopsis tesselatum* f. *nordstedtii* Möbius

Heterotypic synonyms: *Cosmarium glyptodermum* West & G.S.West

Cosmarium glyptodermum var. *tuberculatum* A.M.Scott & Prescott

Description: LM: Semicells sub-globose, 88–102 µm L. × 53–62 µm Br, I. 32.3–49.9 µm and Th. 53–59 µm. Cell wall granulate, with six conspicuous pores surrounding each of these granules. Due to cell wall architecture obscuring a clear view, chloroplast morphology difficult to determine but appeared to be parietal. SEM: Granules are surrounded by six pits that from lower magnification appear smoothly triangular with a spherical base when examined closer. Each pit possesses a central pore, however, the row of pits that are directly adjacent to the isthmus sometimes had two or three pores. The apex has a region devoid of granules simply composed of pits closely arranged to one another. Both Dingley (2004) and Skinner (1977) have encountered this species in conjugation, with the resultant zygospores spherical and furnished with relatively short and stout spines. **Figs 25A, B, C & D.**

Notes: The cell wall ultrastructure of this species has been previously studied by Claassen & Eicker (1985), where they considered *C. glyptodermum* West & G.S.West and *C. glyptodermum* var. *tuberculatum* as heterotypic synonyms. Conversely, Coesel (2002) regarded *C. striolatum* var. *nordstedtii* (which was originally described from Australia) and *C. glyptodermum* (which was originally described from Africa), as separate 'species' based on morphological and geographical criteria.

The cell wall of the African specimens designated as this name by Claassen & Eicker (1985) are structurally similar to those in our material. However, they mention the cell wall granules are occasionally surrounded by five or seven pits, a feature not observed in this study. Additionally, the overall cell outline of our specimens differ by being more rounded and less conical towards the apex than theirs. Since *P. tesselatum* f. *nordstedtii* was originally described from Queensland and antedates all other supposed synonyms suggested by Claassen & Eicker (1985), we have treated all records pertaining to this taxon in Australia as conspecific. Whether the entities from Africa are indeed a separate species (*C. glyptodermum sensu stricto*) as proposed by Coesel (2002) needs further investigation.

Location: Basket Swamp.

Australian distribution: Originally described from Queensland (Möbius 1892). Playfair (1908) observed this species in great abundance from a coastal *Sphagnum* bog in Coogee, Sydney, New South Wales under the objective synonym *Cosmarium glyptodermum*. Skinner (1979) also reported this species from a swamp near Baldersleigh, New South Wales. This entity has also been recorded from the Northern Territory by Dingley (2004); Ling and Tyler (1986); Scott and Prescott (1958) if all synonyms are accepted.

Cosmarium cf. ***neapolitanum*** var. ***australicum*** Schmidle

Schmidle 1896, p. 308, pl. 9, fig. 10.

Description: SEM: Cell 41.3 µm L. × 50.6 µm Br, I. 11.6 µm. **Fig. 19D.**

Notes: Only a single, slightly distorted cell was encountered during SEM analysis; more specimens are needed to confirm its identity.

Locations: Basket Swamp

Cosmarium cf. ***zonatum*** var. ***compressum*** (Schmidle) Krieger & Gerloff

Krieger & Gerloff 1969, p. 254, pl. 43a, fig. 26.

Description: LM: Cells 27.1–36 µm L. × 15.7–20.7 µm Br, I. 3.85–5.9 µm; Th. 10.6–10.7. **Fig. 10E.**

Notes: The cell outline of our specimens are most similar to those found in the *Cosmarium* "*zonatum*-group", most notably *Cosmarium zonatum* var. *compressum* (Schmidle) Krieger & Gerloff. However, the cells here are slightly stouter compared to the original dimensions for this variety. Confirmation that the arrangement of the transverse pores match the original illustrations with the specimens here is also needed.

Location: Basket Swamp.

Docidium Brébisson ex Ralfs (1848).

Docidium baculum Ralfs

Coesel & Meesters 2007, p. 65, pl. 32, figs 3,4.

Description: LM: Cell 183 µm L, basal swelling 9.4 µm Br. Ap. 8.4 µm. Chloroplast axile. SEM: A whorl of granule-like plications of 'T' shaped folds encircle the isthmus. Cell wall finely punctate.

Notes: Cell dimensions are in the extreme lower range of this species. **Figs 29A & B.**

Location: Basket Swamp.

Australian distribution: This species has been reported from all Australian States and Territories except for Western Australia and the Australian Capital Territory.

Euastrum Ehrenberg ex Ralfs (1848).

Euastrum ansatum var. ***ansatum*** Ehrenberg ex Ralfs

Prescott et al. 2001, p. 15, pl. 58, figs 6, 6a, 7f, 8.

Description: LM: Cells 84–87 µm L by 35.8–38.3 µm Br.; I. 12.1–14.1 µm, Ap. 18.1–19.3 µm. Polar lobes slightly coarsely punctate with the remainder of cell wall smooth. **Fig. 11G.**

Notes: Compare with *Euastrum ansatum* var. *dideltiforme* F. Ducellier and *Euastrum cuneatum* var. *subansatum* R. Boldt.

Location: Ebor Common.

Australian distribution: This species has been reported in most of the Australian states and territories – Northern Territory, Queensland, New South Wales, Victoria and Tasmania.

Euastrum ansatum var. ***simplex*** Ducellier

Prescott et al. 2001, p. 19, pl. 59, figs 3, 4; pl. 60, fig. 2.

Description: LM: Cells 60–67 µm L by 29.3–32.6 µm Br., I. 8.2–10.7 µm, Ap. 16–16.7 µm. On rare occasions the swelling above the basal lobe is present. **Fig. 11H.**

Notes: These may simply be nascent forms of the *E. ansatum* encountered supra.

Location: Ebor Common.

Australian distribution: A new record for Australia.

Euastrum cf. ***ansatum*** var. ***triporum*** Krieger

Prescott et al. 2001, p. 19, pl. 59, figs 6, 7a.

Description: LM: Cells 83–89 µm L by 41.6–43.5 µm Br.; I. 10.7–12.1 µm, Ap. 20.6–22.5 µm. Polar and basal lobes coarsely punctate with the remainder of cell wall smooth. Three mucilage pores are in a triangular arrangement on the face of the semicells. SEM: Within the coarse punctae are fine pores, the remainder of the cell wall has these same pores evenly scattered. **Figs 30A, B, C & D.**

Notes: The cell outline is lacking a slight swelling above the basal lobes. This feature matches specimens under the same name recorded by Croasdale & Scott (1976) from the Northern Territory. Our specimens also lacked any discernible facial tumours that this variety reportedly has.

Location: Basket Swamp.

Australian distribution: New record for New South Wales if confirmed. Previously reported from the Northern Territory and Tasmania.

Euastrum denticulatum var. ***quadrifarium*** Krieger

Croasdale and Flint 1986, p. 89, pl. 22, fig. 15.

Description: LM: Cells 7–8 µm L by 4.7–7 µm Br.; I. 14–3.3 µm, Ap. 2 µm. Most of the cell wall coarsely punctate, up to four central mucilage pores evident. **Figs 11D and 29C & D.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. Recorded from the Northern Territory on several occasions.

Euastrum didelta var. ***bengalicum*** Lagerheim

Croasdale & Flint 1986, p. 90, pl. 18, fig. 2.

Description: Cells 165–179 µm L by 89–91 µm Br. I. 19.9–21.8 µm. Semicells possess central pores, one above the other. Slight inflation above the basal lobe sometimes present. **Fig. 11F.**

Location: Basket Swamp.

Distribution: Previously reported from north-eastern Australia – Northern territory, Queensland and New South Wales.

Euastrum longicolle var. ***australicum*** Playfair

Croasdale & Flint 1986, p. 94, pl. 20, fig. 6.

Description: LM: Cells 141–148 µm in L. 64–65 µm Br., with a L:B of 2.2–2.3; I. 15.7–16.9 µm. Semicells 'guitar-shaped' with a broad base and elongate neck extending into a dilated apex. Above the isthmus is one or two conspicuous mucilage pores surrounded by three protuberances in a triangular arrangement, another two protuberances are adjacent on either side. SEM: Cell wall for the most part homogenous/smooth with fine puncta except for the dilated apex and lateral lobes which are provided with large pore fields. The five facial protuberances can be smooth or scrobiculate. **Figs 31A, B, C & D.**

Notes: Morphologically distinct and stable from the *E. longicolle* var. *longicolle* Nordstedt to possibly warrant elevation to species status.

Location: Basket Swamp.

Australian distribution: Originally described from New South Wales by Playfair (1907) and thus far only reported from this State.

Euastrum cf. ***longicolle*** var. ***australicum*** Playfair

Euastrum longicolle var. *australicum sensu* Skinner 1977, p. 77, pl. 11, fig. 2.

Description: LM: Cell 134–148 µm in L. 66–67.1 µm Br, with a L:B of 2–2.2 I. 17.3–18.5 µm; 58 µm Th. SEM: Ultrastructure like that of *E. longicolle* var. *australicum* described above. **Fig. 32A, B, C & D.**

Notes: A stout form where the neck of the polar lobe is much shorter compared to *E. longicolle* var. *australicum* in the strict sense. Skinner *l.c.* only encountered this short morphological form which may suggest a distinct sibling species, but more specimens should be examined to confirm this since both the typical and stout forms were often encountered together in this study. It is also morphologically similar to *Euastrum bullatum* Playfair concerning the apical lobe, but that species is smaller in dimensions and has more truncated lateral lobes and less facial protuberances. The New England specimens appear to be an intermediate of *E. longicolle* var. *australicum* and *E. bullatum.*

Location: Basket Swamp.

Australian distribution: Thus far solely known from the New England region, New South Wales.

Euastrum cf. ***luetkemuelleri*** var. ***laterepunctatum*** Scott & Prescott

Scott and Prescott 1958, p. 36, fig. 6: 8.

Description: LM: Cell 22.4 µm L by 15.9 µm Br.; I. 5.5 µm, Ap. 10.2 µm; Th. 11.5 µm. In side-view a mucilage pore just below apex and the mid-region of each side of the semicell apparently thickened. **Figs 16C & D.**

Notes: Only a few cells were encountered, more specimens are needed to confirm its identity.

Location: Basket Swamp.

Australian distribution: A possible new record for New South Wales. Originally described from the Northern Territory.

Euastrum neosinuosum var. ***germanicum*** (Raciborski) O.V. Anissimova & M.D. Guiry

Croasdale and Flint 1986, p. 96, pl. 18, fig. 10.

Basionym: *E. sinuosum* f. *germanicum* Raciborski

Description: LM: Cells 77–84 µm L by 42.7–47.7 µm Br.; I. 12.4–13.3 µm, Ap. 20.6–22.5 µm. Most of cell wall coarsely punctate, with up to four central mucilage pores evident. SEM: The coarse puncta are occasionally pitted with a fine pore (rarely two pores). The central mucilage pores are also pitted with a fine pore. **Figs 11E and 33A, B, C & D.**

Notes: The arrangement and number of central mucilage pores completely match those depicted in Playfair (1907) under the basionym *E. sinuosum* f. *germanicum*. Anissimova & Guiry (2021a) have noted that *Euastrum sinuosum* Lenormand ex W.Archer is an illegitimate name and proposed the replacement *Euastrum neosinuosum* O.V.Anissimova & Guiry. Subsequently, Anissimova & Guiry (2021b) have provided the nomenclatural and/or taxonomic changes for subspecific taxa attributed with this name as well.

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales by Playfair (1907).

Groenbladia Teiling (1952).

Groenbladia bourrellyi Coesel

Coesel 1998, p. 111, figs 13–15.

Heterotypic synonym: *Hyalotheca neglecta* var. *major* Taylor

Description: LM: Cells elongate, cylindrical22.8–26.3 µm L. and 10.7–11.6 µm Br. In short filaments of two to five; L:B 2.1–2.3. Chloroplast lamelliform. **Fig. 16A.**

Notes: Coesel (1998) provides an in-depth explanation on this species often being mistakenly assigned to *Groenbladia neglecta* (Raciborski) Teiling.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales; this species has also been observed from the Northern Territory by Ling and Tyler (2000) under the misapplied name *G. neglecta*.

Micrasterias C.Agardh ex Ralfs (1848).

Micrasterias bicoronata A.Kenins, *sp. nov.*

Type: NEW SOUTH WALES: Northern Tablelands: Boonoo Boonoo, Basket Swamp National Park, 8 April 2018, *A.Kenins* 5a (holo: NSW; iso: NE), deposited as permanent slides from a formalin preserved sample, the selected specimens are circled with red ink and represented by Fig. 6A.

Micrasterias tropica var. *indivisa auctt non*. (Nordstedt) Eichler & Raciborski: Skinner in *Proceedings of the Linnean Society of New South Wales* 104: 254, fig. 10a, b (1979).

Diagnosis: Like *Micrasterias tropica* var. *indivisa*, but differs by the possession of two inflations with concentrically arranged verrucae per semicell; and by the shorter apical processes that are parallel to slightly convergent to one another.

Description: Cells 86–93 µm L. (90–120 µm in Skinner *l.c.*) by 71–85 µm Br. (80–90 µm in Skinner *l.c.*). Apex of polar lobe 46.7–54 µm wide, I. 19.3–22.4 µm; Th. Circa 39 µm. Semicells bearing two concentric series of verrucae above the isthmus; the series of verrucae adjacent to the isthmus is often larger and made up of more verrucae compared to the other and is less developed in some specimens. Processes of the apical and lateral lobes spinulate. Zygospores encountered by Skinner *l.c.* as spherical with a diameter of 65–75 µm and having a mixture of simple and bifurcate spines, being randomly distributed, mesospore brown.

Additional Figures and Material: Figs 6B and 12D. Other material containing this taxon has been deposited at **NE.**

Distribution and ecology: Thus far only known to occur in the Northern Tablelands from several sites. Skinner (1979) reported this species from collections at Baldersleigh, near Kingston (with zygospores); Round Mountain; Cooney Creek, near Hillgrove; Bullock Creek, Point Lookout; and Sandy Creek, near the dog-gate, Armidale-Dorrigo Road. Also collected from Basket Swamp (the most northern known site) associated with *Sphagnum* (this study).

Etymology: The species epithet bi – (two) and coronata (crowned) refers to the semicells of this species bearing two circular, concentric series of verrucae that appear like a crown (corona).

Notes: Skinner (1979) previously identified the species in question as *M. tropica* var. *indivisa* but noted that it differs from those described in Tyler (1970) from south-eastern Australia by the possession of not one but two concentrically arranged verrucae. The presence of these two rings of verrucae are consistent from the Northern

Tablelands specimens which differ from this variety in the strict sense occurring in Victoria, Tasmania and as well as New Zealand (from where it was originally described) as only having one. *M. bicoronata* can be further differentiated from *Micrasterias tropica* Nordstedt and the variety *indivisa* in that the apical processes are shorter and are parallel to slightly convergent to one another rather than arising divergently.

Coesel and van Geest (2014) have recently revised many varieties assigned to the *Micrasterias tropica* complex from Africa by elevating them to species status based on morphologically distinct forms with defined geographic distributions. With this in consideration and based on the previous observations by Tyler (1970) and Skinner (1979) combined with this study, this entity warrants species status.

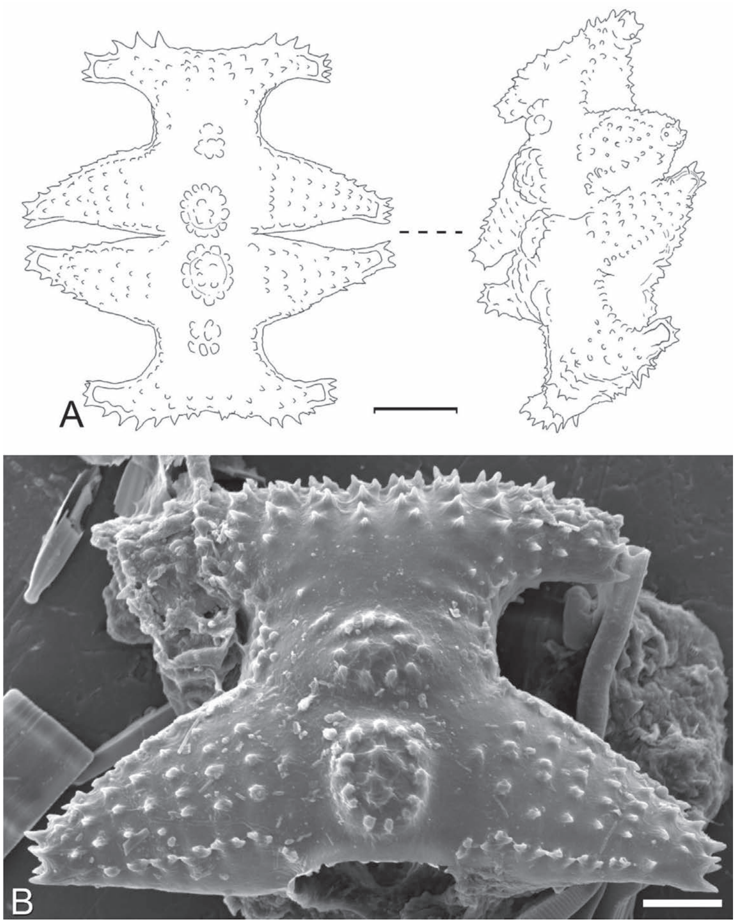

Fig. 6. Line drawings and scanning electron micrograph of *Micrasterias bicoronata*, **A**. front- and slightly oblique side-view. Scale = 20 µm. **B**. semicell. Scale bar = 10 µm.

Micrasterias decemdentata (Nägeli) Archer

Croasdale & Flint 1986, p. 104, pl. 24, figs 5, 9, 10.

Description: Cell 67 µm L. by 70 µm Br., polar lobe 55 µm µm wide, I. 13.4 µm. Lateral lobes bidentate. **Figs 12A and 16B.**

Notes: *Micrasterias zeylanica* F.E. Fritsch is morphologically similar, but that species has the lateral lobes consistently pointed downward see Croasdale and Flint (1986).

Location: Basket Swamp.

Australian distribution: Previously reported from most Australian states and territories – Northern Territory, Queensland, New, South, Wales, Victoria and Tasmania.

Micrasterias jenneri Ralfs

Coesel & Meesters 2007, p. 88, pl. 51, figs 1&2.

Description: Cell 153 µm in L. by 93 µm Br., I. 22.7 µm. **Fig. 12C.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales and Victoria.

Micrasterias nordstedtii f. ***australiensis*** Thomasson

Thomasson 1973, p. 386, fig. 1: 1.

Synonym: *Micrasterias* sp. *sensu* Dingley, *Telopea* 9: 607, fig. 6b. (2001).

Description: Cells 308–327 µm L. by 283–299 µm Br., with a L:B of 1.08–1.1. Polar lobe 54–55 µm µm wide, I. 33.5–34.1 µm. Upper and lower lateral lobes of equal size, both of which are divided to the fourth order; one to three (typically two) intramarginal spines present on the outer portion of the major incisions. Basal inflation located above the isthmus and occasionally furnished by a single spine. **Fig. 7.**

Notes: The cells observed here differ slightly from the original description by being broader, having fewer intramarginal spines and possession of a basal inflation furnished with spine positioned above the isthmus. Dingley (2001) reports a very similar specimen which was considered like *M. apiculata* var. *fimbriata* f. *fimbriata* (Ralfs) Nordstedt. All these aforementioned differences appear to be minor and part of the polymorphic variation observed in this poorly known form and have been circumscribed here as referring to the same entity.

The type forma "*nordstedtii*" is so far only known from New Zealand and differs in cell outline and polar lobe ornamentation. It follows, that the Australian records of this form and the New Zealand records of the type forma are probably separate species when considering their differences in morphology and distribution.

Location: Basket Swamp.

Australian distribution: Thomasson (1973) proposed this forma from Cataract reservoir, New South Wales. Dingley's *l.c.*"*Micrasterias* sp." was sampled from Mountain Lagoon, 14 km northeast of Bilpin, New South Wales.

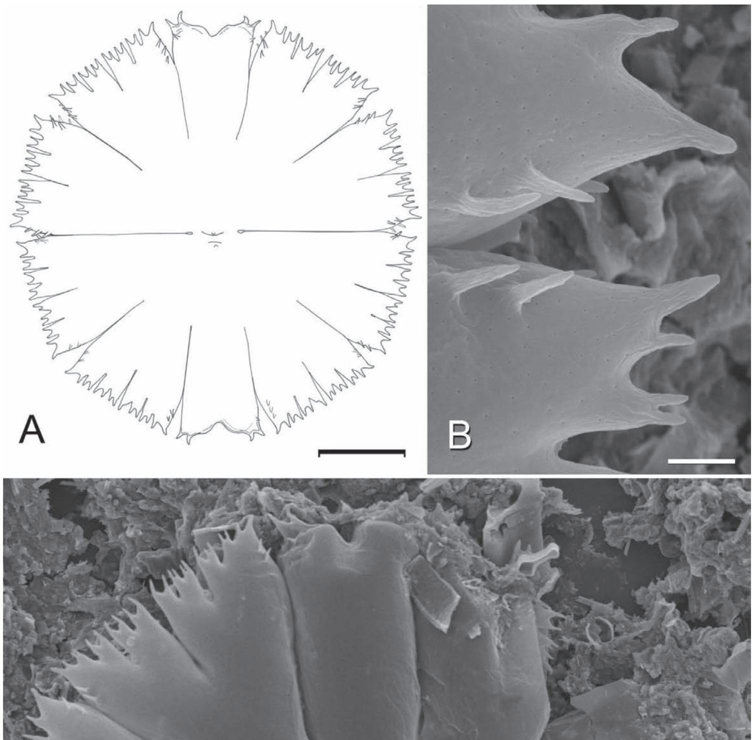

Fig. 7. Line drawing and scanning electron micrographs of *Micrasterias nordstedtii* f. *australiensis*, **A.** entire cell in front-view. Scale bar = 50 µm. **B.** close-up of intramarginal spines. Scale bar = 5 µm. **C.** semicell. Scale bar = 50 µm.

Micrasterias thomasiana var. ***notata*** (Nordstedt) Grönblad

Prescott et al. 2001, p. 191, pl. 137, figs 4–6.

Description: Cells disk-like 226 µm L. × 216 µm Br. **Fig. 12E.**

Notes: Skinner (1979) notes the New England Tableland forms of this species is without much ornamentation. However, the typical three swellings above the isthmus were encountered along with reduced forms in this survey.

Location: Basket Swamp.

Australian distribution: Reported from the Northern Territory, Queensland, New South Wales and Victoria.

Micrasterias truncata var. ***crenata*** (Brébisson) Reinsch

Prescott et al. 2001, p. 198, pl. 100, figs 2, 3.

Basionym: *Micrasterias crenata* Brébisson

Description: Cells disc-like, 72–100 µm L. by 68–90 µm; I. 15.1–23.3 µm. Lateral lobes variable, twice divided but frequently undeveloped (rounded without teeth); typical with teeth also encountered. **Figs 12B and 16E.**

Notes: Various workers have noted the highly polymorphic nature of this species with many of the named forms encountered in the same population. Thus, many of the varieties and forms are regarded as superfluous since they are based on the different stages of development of the lateral lobes. The variety *crenata* was predominant in this survey; the typical variety and the formae *reducta* Prescott were less frequent.

Location: Ebor Common, New England National Park.

Australian distribution: Previously reported from New South Wales and Victoria. *M. truncata* var. *truncata* Brébisson ex Ralfs has been reported from the Northern Territory, New South Wales, Victoria and Tasmania.

Pleurotaenium Nägeli (1849)

Pleurotaenium ehrenbergii (Brébisson) De Bary

Croasdale and Flint 1986, 71, pl. 14, figs 8,16.

Description: LM: Cells elongate, 356–432 µm L. × 26.7–28.7 µm in Br. I. 22.7–23.1 µm and an Ap. of 19.7–22.4 µm crowned with tubercules. Conspicuous basal inflation with at most one smaller swelling. Numerous ribbon-like chloroplasts possessing small pyrenoids along its length. **Figs 34A & B.**

Location: Basket Swamp.

Australian distribution: Recorded from all states except Western Australia.

Pleurotaenium nodosum (F.M.Bailey) Lundell

Croasdale & Flint 1986, p. 73, pl. 14, figs 12, 13.

Description: LM: Cells elongate, 298–311 µm L. × 45.3 µm in Br.; I. 16.8 µm and an Ap. of 26.6 µm crowned with upwardly curving spines. Semicells consisted of 4 undulations. **Figs 34C & D.**

Location: Basket Swamp.

Australian distribution: Reported from the eastern, mainland states Queensland, New South Wales and Victoria.

Pleurotaenium tridentulum (Wolle) W.West

Croasdale & Flint 1986, p. 75, pl. 16, figs 8,9.

Description: LM: Cell baculiform, 260 µm L. × 15.2 µm Br. with an L:B of 17.1; I. 12.6 µm and an Ap. 9.6 µm crowned with four small, short spines. Single undulation after the basal swelling. **Fig. 17A.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales as well as Tasmania.

Staurastrum Meyen ex Ralfs (1848).

Staurastrum aureolatum Playfair *sensu* Thomasson 1972

Thomasson 1972, p. 259, fig. 2: 1–8.

Heterotypic synonym: *Staurastrum digitatum* G.S.West

Description: LM: Cells 22.1–25.7 μm L.csp. × 21.1–26 μm Br.csp; I. 3.56–4.71 μm and often enveloped in a gelatinous sheath. *Processes* obtuse or terminating with two rounded spines. **Figs 18A & B.**

Notes: The specimens here are comparable to those observed by Thomasson (1972) from the plankton of the Rotorua lakes of New Zealand. He designated them as "*Staurastrum brachiatum*-group" and suggested a revision of this complex is needed since most of the forms he encountered intergraded between *S. brachiatum* Ralfs and *S. aureolatum*. The original iconotype of *S. aureolatum* by Playfair (1908) has somewhat dilated process, lacking any terminating spines. Thomasson and Tyler (1971) note that Playfair's illustration is of poor quality. *Staurastrum digitatum* described by West (1909) from Victoria is also considered by some as synonymous with this species see Croasdale et al. (1994).

Location: Basket Swamp.

Australian distribution: This species has been reported from New South Wales and Tasmania as well as Victoria if the synonym *S. digitatum* is also considered.

Staurastrum cf. ***avicula*** Brébisson in Ralfs

Croasdale et al. 1994, p. 84, pl. 84, figs 1–9.

Description: LM: Cell triradiate, L. 17.8 μm, Br. 23.9 μm; I. 6.6 μm. Angles terminating into to two spines. Cell wall granular. **Fig. 17B.**

Notes: A catch-all species, more specimens need to be observed to confirm its identity.

Location: New England National Park.

Australian distribution: A new record for New South Wales if confirmed. This species has been reported from the Northern Territory.

Staurastrum inconspicuum Nordstedt

Croasdale et al. 1994, p. 102, pl. 91, figs 5–9.

Description: LM: Cells relatively small, quad-radiate, L.cpr 14.2–14.9 μm & L. spr., 12.2–13.6 μm Br.cpr. 10.5–14.1; I. 6.6–6.8 μm. **Figs 35A & B.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. Previously recorded from Victoria and the Northern Territory.

Staurastrum cf. ***longebrachiatum*** (Borge) Gutwinski

Thomasson 1972, p. 265, fig 8: 10. as "*Staurastrum longebrachiatum* forma"

Description: LM: Cells bi-radiate, 28.1–30 μm L.spr; 57–60 μm Br.cpr.; I. 5.7–6 μm. Processes terminating to two rather distinct spines. Isthmal region bearing what appears to be rings of granules almost like verrucae. **Fig. 17C.**

Notes: The plants here are identical to what Thomasson (1972) designated as "*S. longebrachiatum* forma" in the broad sense, citing Krieger (1932).

Location: Basket Swamp.

Australian distribution: Possibly a new observation for Australia.

Staurastrum trihedrale Wolle

Croasdale et al. 1994, p. 144, pl. 79, figs 10–13.

Description: LM: Cells triradiate, 45.2–47.4 μm L. × 25.4–27.6 μm Br; I. 10.5 μm. Semicells triangular, cell wall punctate. Sinus closed with the rounded basal angles adjoining with the opposing semi-cell. Apex broadly rounded. In end-view, triangular with rounded angles and concave sides. **Fig. 13E**.

Location: Ebor Common.

Australian distribution: New record for Australia.

Staurastrum cf. ***hardyi*** G.S. West

West 1909, p. 71, pl. 6, figs 21–22.

Description: LM: Cells biradiate, 22.1–25.4 µm L.spr; 40.2–43.6 µm Br.cpr.; I. 4.78–5.3 µm with a ring of granules around the basal inflation. Processes terminating with four spines. SEM: Pores are situated at the base of the apical verrucae as well as scattered throughout the rest of the cell body. **Figs 17D and 36A, B, C, D, E, & F.**

Notes: This form seems to be an intermediate of *Staurastrum hardyi* and *Staurastrum longiradiatum* var. *subnudum* G.S. West; both of which were originally described by West (1909) from samples taken from Yan Yean Reservoir, Victoria. The specimens here share the same size and overall morphology of *S. hardyi* but differ in their semicell body shape. The semicell body observed here is more comparable with *S. longiradiatum* var. *subnudum*, but that species is slightly larger and apparently lacks any apical verrucae.

Location: Basket Swamp.

Staurastrum cf. ***monticulosum*** Brébisson

Vyverman 1991, p. 134, pl. 113, fig. 3.

Description: LM: Cells triradiate, 28.7–29.5 µm L.spr; 22.3–26.7 µm Br. spr.; I. 10–11.9 µm. Cell body smooth, lacking ornamentation. Chloroplast with a single pyrenoid per semicell. **Figs 18C, D, E, F, G & H.**

Notes: Only a few cells of this desmid were encountered and appear most similar to what Vyverman (1991) depicts as *S. monticulosum*. Vyverman (*l.c.*) also states his specimens closely resemble *S. monticulosum* f. *arsenii* Irénée-Marie. Further observations and additional literature reviews are needed to confirm its identity.

Location: Basket Swamp.

Staurodesmus Teiling (1948)

Staurodesmus cf. ***cuspidicurvatus*** Coesel & Meesters

Croasdale et al. 1994, p. 44, pl. 66, figs 19–22.

Basionym: *Staurastrum curvatum* W.West

Heterotypic Synonym: *Staurodesmus cuspidatus* var. *curvatus* (West) Teiling

Description: LM: Cells triradiate, 20.7–23.5 µm L.ssp × 22.3–23.1 µm Br.ssp and 26.4–37.2 µm L.csp × 24.7–25.4 µm Br.csp; I. 5.4–7.2 µm. Sp. 4.1–8.5 µm arising from apex divergently. SEM: Cell wall homogenous with evenly spaced puncta that are especially prominent on the cell apex. **Figs 13G and 35C & D.**

Notes: The plants best match those identified as *Staurastrum curvatum* West in Scott & Prescott (1958) which is now transferred to *Staurodesmus cuspidicurvatus* Coesel & Meesters. The uncertain designation here is due to the many different interpretations and depictions of this species along with morphologically similar entities such as *Staurodesmus patens* var. *inflatus* Coesel & Meesters.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales if confirmed (previously observed from the Northern Territory).

Tetmemorus Ralfs ex Ralfs (1848).

Species from this genus are largely encountered in soft waters, particularly amongst *Sphagnum* vegetation Coesel & Meesters (2007).

Tetmemorus brebissonii Ralfs

Croasdale & Flint 1986, p. 80, pl. 16, figs 10, 11.

Description: LM: Cells cylindrical 132–133 µm in L. × 23.7–28.7 µm Br; I. 20.8–26.6 µm. Cell wall with puncta arranged in vertical rows. SEM: The vertical rows of puncta are ellipsoid scrobiculations with a single fine pore located on the end facing towards the isthmus. **Figs 37A & B.**

Location: Basket Swamp.

Australian distribution: Reported from all States and Territories of Australia except Western Australia and the Australian Capital Territory.

Tetmemorus cf. ***granulatus*** (Brébisson) Ralfs

Croasdale & Flint 1986, p. 81, pl. 17, figs 1, 2.

Description: LM: Cells fusiform and only slightly tapering (no constriction below the apex), 106–127 µm in L. × 23.2–26 µm Br., with an L:B of 4.5–5.3; I. 22.9–24.8 µm. Cell wall puncta arranged irregularly, evenly spaced. **Fig. 13A.**

Notes: Cell dimensions encountered here intermeshed with those of *Tetmemorus laevis* var. *tropica* Krieger; certain distinction between the two relies on observations of the differently shaped zygospores see Croasdale and Flint (1986).

Location: Basket Swamp and Ebor Common.

Australian distribution: Previously reported from Queensland, New South Wales, Tasmania and Western Australia.

Tetmemorus laevis Ralfs

Croasdale and Flint 1986, p. 81, pl. 17, figs 3–6.

Description: LM: Cells fusiform only slightly tapering, 75–121 µm in L. × 20.5–30.3 µm Br., with an L:B of 3.5–4; I. 19.5–29.2 µm. Cell wall puncta arranged irregularly, evenly spaced. **Fig. 13B.**

Location: Ebor Common.

Australian distribution: Recorded from most Australian States and Territories except for Western Australia, Australian Capital Territory and Victoria.

Triploceras Bailey (1851).

Triploceras gracile Bailey

Croasdale and Flint 1986, p. 77, pl. 15, figs 1–3, 8.

Description: LM: Cell 195 µm L.csp. × 16.8 µm Br.csp.; I. 9.2 µm Cells ornamented with whorls of simple, single spines. **Figs 37C & D.**

Notes: Putatively a highly polymorphic taxon; probably in part due to the type description and illustration being of such poor quality (see (West 1909)) that distinction from other varieties are possibly synonymous or potentially concealing diversity. Ling and Tyler (2000) discuss this issue in greater detail. Of the few cells observed here, they best belong to the type variety.

Location: Basket Swamp.

Australian distribution: Various varieties and unnamed forms of *T. gracile* have been documented across eastern Australia – Northern Territory, Queensland, New South Wales, Victoria and Tasmania.

Xanthidium Ehrenberg ex Ralfs (1848).

Xanthidium armatum var. ***basidentatum*** Nordstedt

Croasdale & Flint 1988, p. 120, pl. 57 fig. 3.

Description: LM: Cell 85 µm L. × 68.8 µm Br. Central ornament granules arranged in a ring. **Fig. 13D.**

Notes: This is probably a distinct species rather than a mere variety since no intermediate forms of the type variety have been observed so far. It should not be confused by morphology or name with the species *Xanthidium basidentatum* (Børgesen) Coesel.

Location: Basket Swamp.

Australian distribution: Playfair (1917) cites this variety from New South Wales but no voucher were reported. Originally described from New Zealand (Nordstedt 1887).

Xanthidium octocorne Ralfs

Coesel & Meesters 2007, p. 155, pl. 85 figs 9–11.

Description: LM: Cell relatively small, each angle furnished with a simple spine. **Fig. 13C.**

Notes: The single cell observed here could be assigned to the variety *depressum* (Grönblad) Coesel which is broader than long in cell dimensions than *X. octocorne* var. *octocorne*.

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, Queensland, New South Wales and Victoria.

Xanthidium cf. ***octonarium*** Nordstedt

Nordstedt 1888, p. 42, pl. 4 fig. 22.

Croasdale & Flint 1988, p. 123, pl. 58 figs 1&2.

Description: LM: Cells 111–118 μm L.ssp × 74–80 μm Br.ssp., I. 23.2–26.4 μm with Th. of 57 μm; semicells depressed-circular with a truncated apex and rounded basal angles, margins possess nine or up to ten upwardly curving spines (5–16 μm long) arranged in pairs on either side. Central area of semicell noticeably thickened in end-view, in face-view this region has pores(?) visibly connected in a reticulate manner, cell wall punctate elsewhere. **Fig. 13H.**

Notes: Nordstedt's *l.c.* original concept was based on only a few semicells, with most having four spines on either side (totalling eight, hence the species epithet). However, he mentions one specimen having five spines on one side which seems to be an intermediate connection to the predominately five-spined (ten per semicell) forms observed in this survey. All other Australian records that describe and/or depict this entity mention the number spines being four.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales if confirmed. However, *Xanthidium octonarium* var. *coronatum*, which has in total only six spines per semicell, as described by Playfair (1908) has been reported from this State.

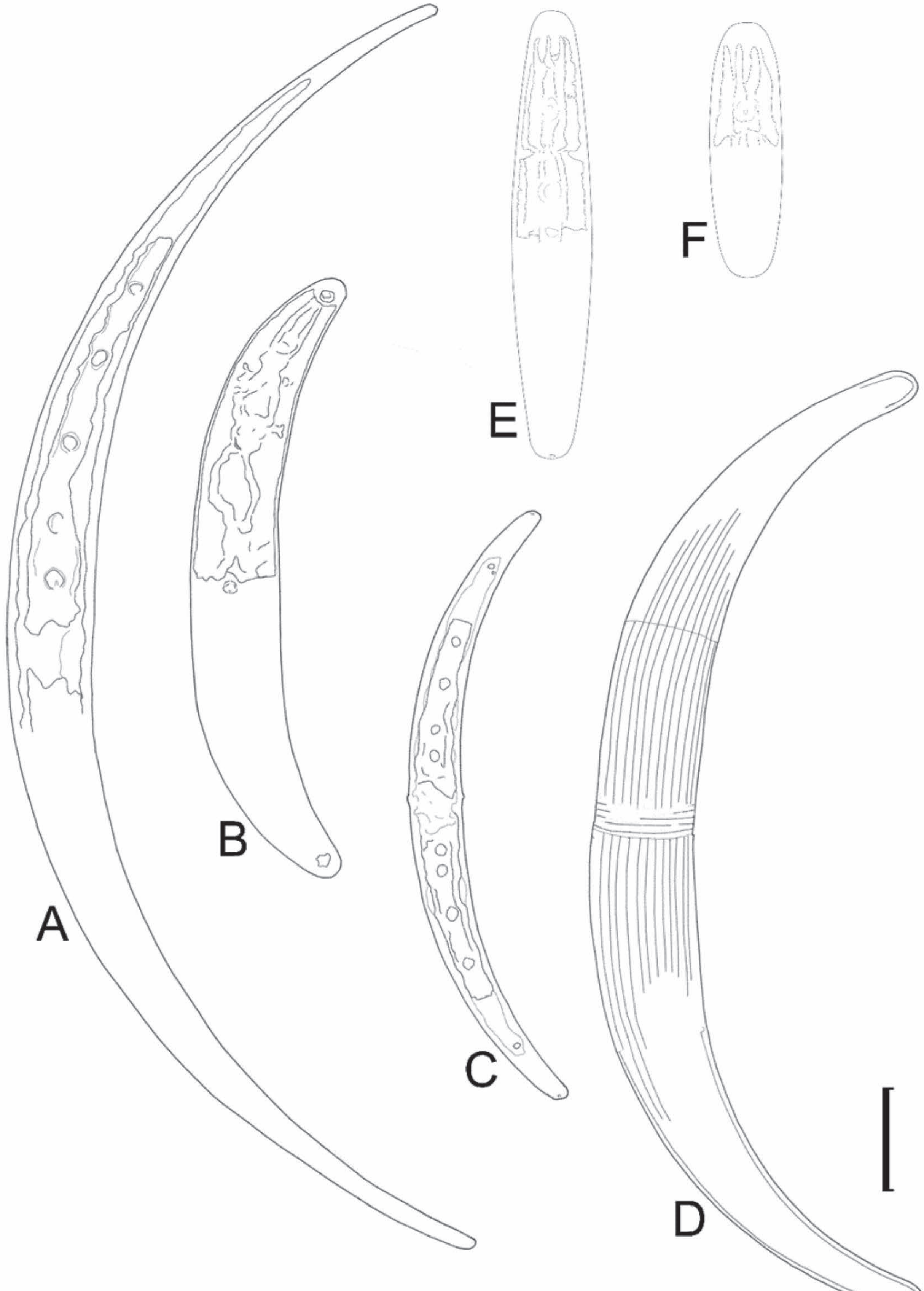

Fig. 8. Drawings of desmids based on light microscope images, **A.** *Closterium dianae* var. *arcuatum*, **B.** *C. abruptum* var. *brevius*, **C.** *C.* cf. *calosporum*, **D.** *C. Cynthia*, **E.** *C. closterioides* var. *intermedium* & **F.** *C. navicula*. Scale bar = 20 µm.

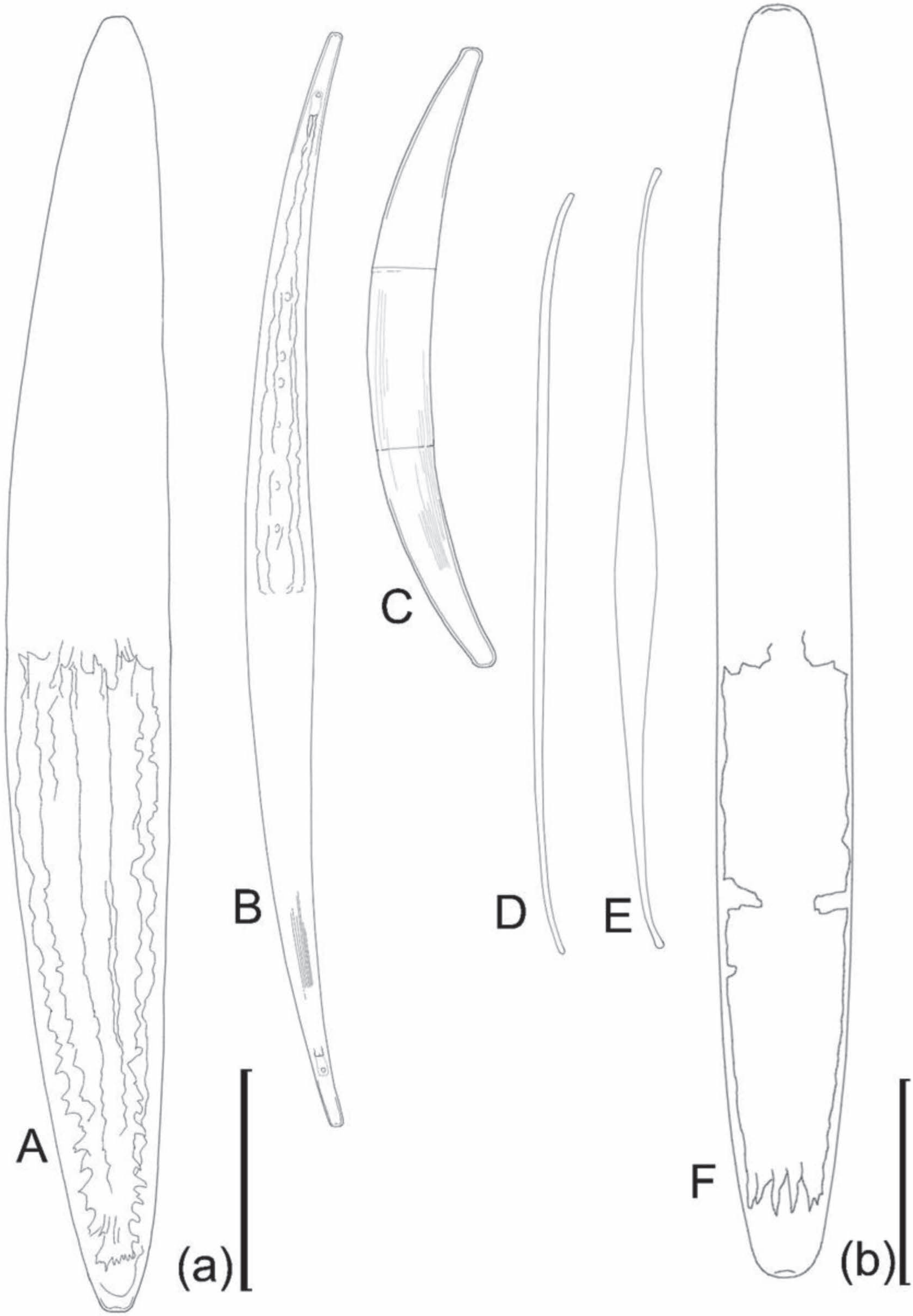

Fig. 9. Drawings of desmids based on light microscope images, **A.** *Closterium lunula*, **B.** *C. ralfsii* var. *hybridum*, **C.** *C. striolatum*, **D.** *C. gracile*, **E.** *C. kuetzingii* var. *procerum* & **F.** *C. closterioides.* Scale bar: (a) = 100 µm for A, B & C; (b) = 50 µm for D, E & F.

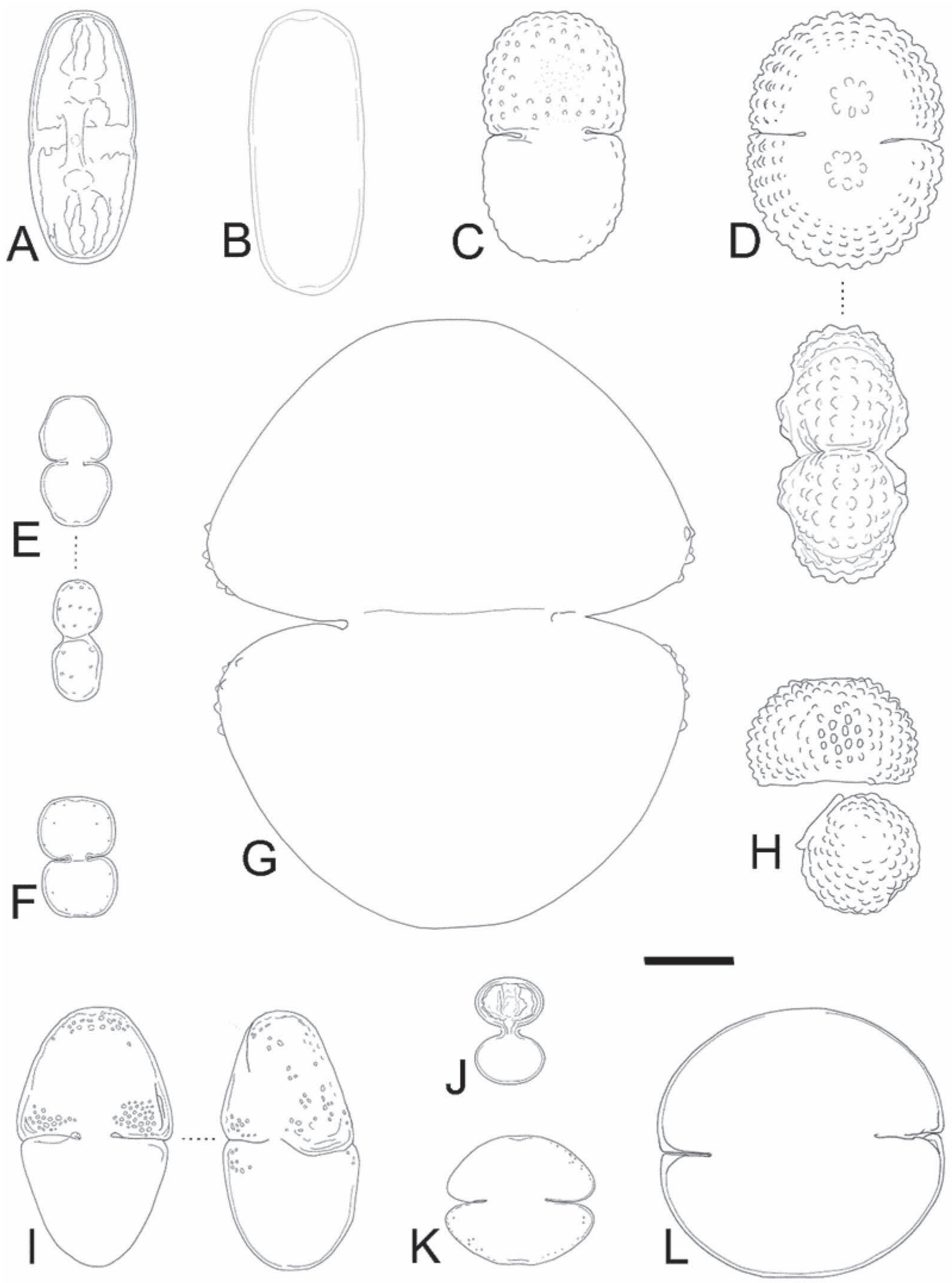

Fig. 10. Drawings of desmids based on light microscope images, **A.** *Actinotaenium cucurbitinum*, **B.** *A. diplosporum* var. *americanum*, **C.** *Cosmarium amoenum* var. *mediolaeve*, **D.** *C. quadrifarium* var. *simplex*, **E.** *C.* cf. *zonatum* var. *compressum,* **F.** *C.* cf. *difficillimum*, **G.** *C. askenasyi*, **H.** *C. margaritiferum* f. *regularius*, **I.** *C. spirale*, two specimens, **J.** *C. contractum*, **K.** *C. dorsitruncatum* & **L.** *C. obsoletum* var. *sitvense*. Scale bar = 20 µm.

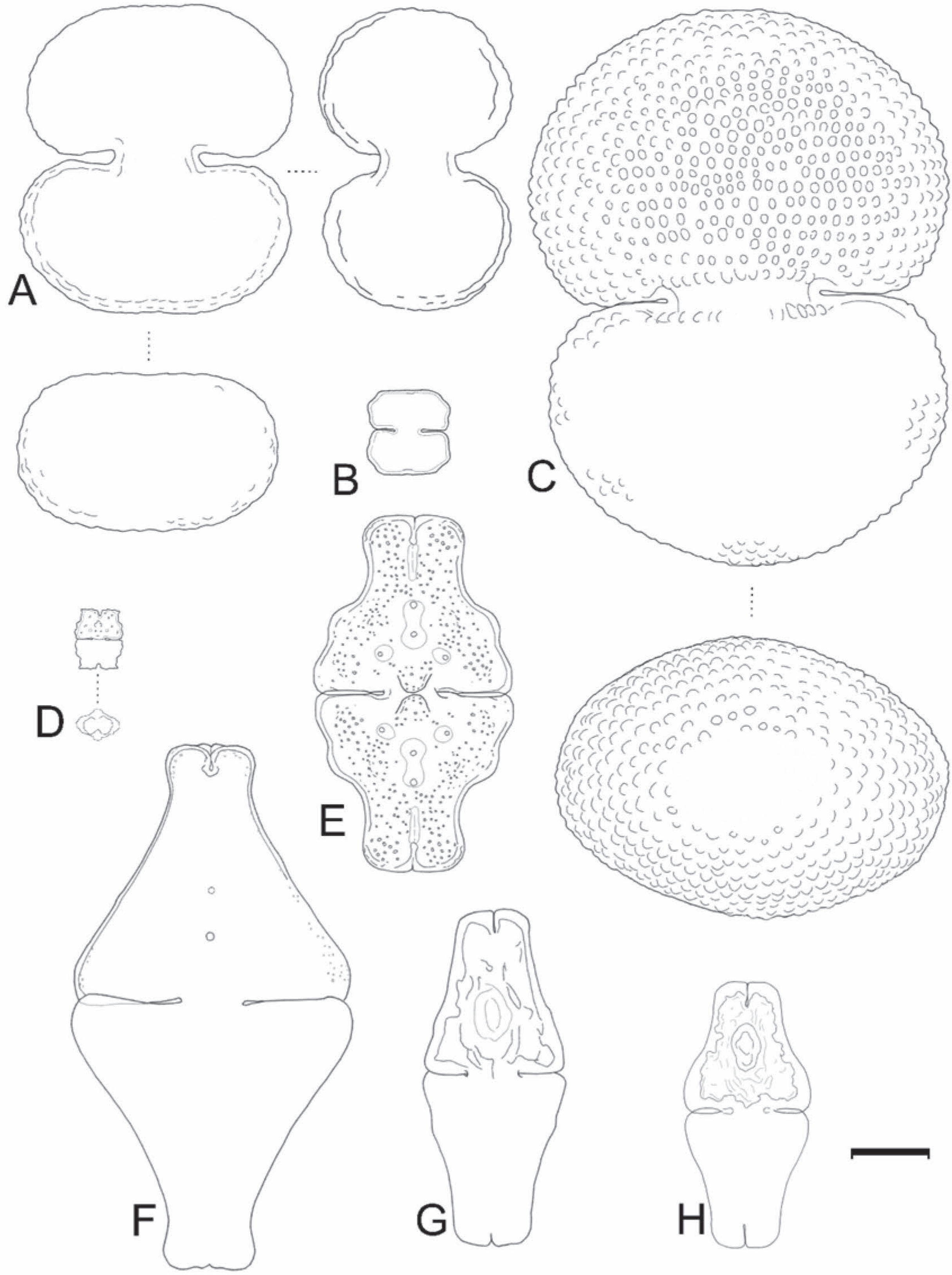

Fig. 11. Drawings of desmids based on light microscope images, **A.** *Cosmarium* cf. *reniforme* var. *compressum*, **B.** *C. regnellii*, **C.** *C. amplum*, **D.** *Euastrum denticulatum* var. *quadrifarium,* **E.** *E. sinuosum* var. *germanicum*, **F.** *E. didelta* var. *bengalicum*, **G.** *E. ansatum* & **H.** *E. ansatum* var. *simplex.* Scale bar = 20 µm.

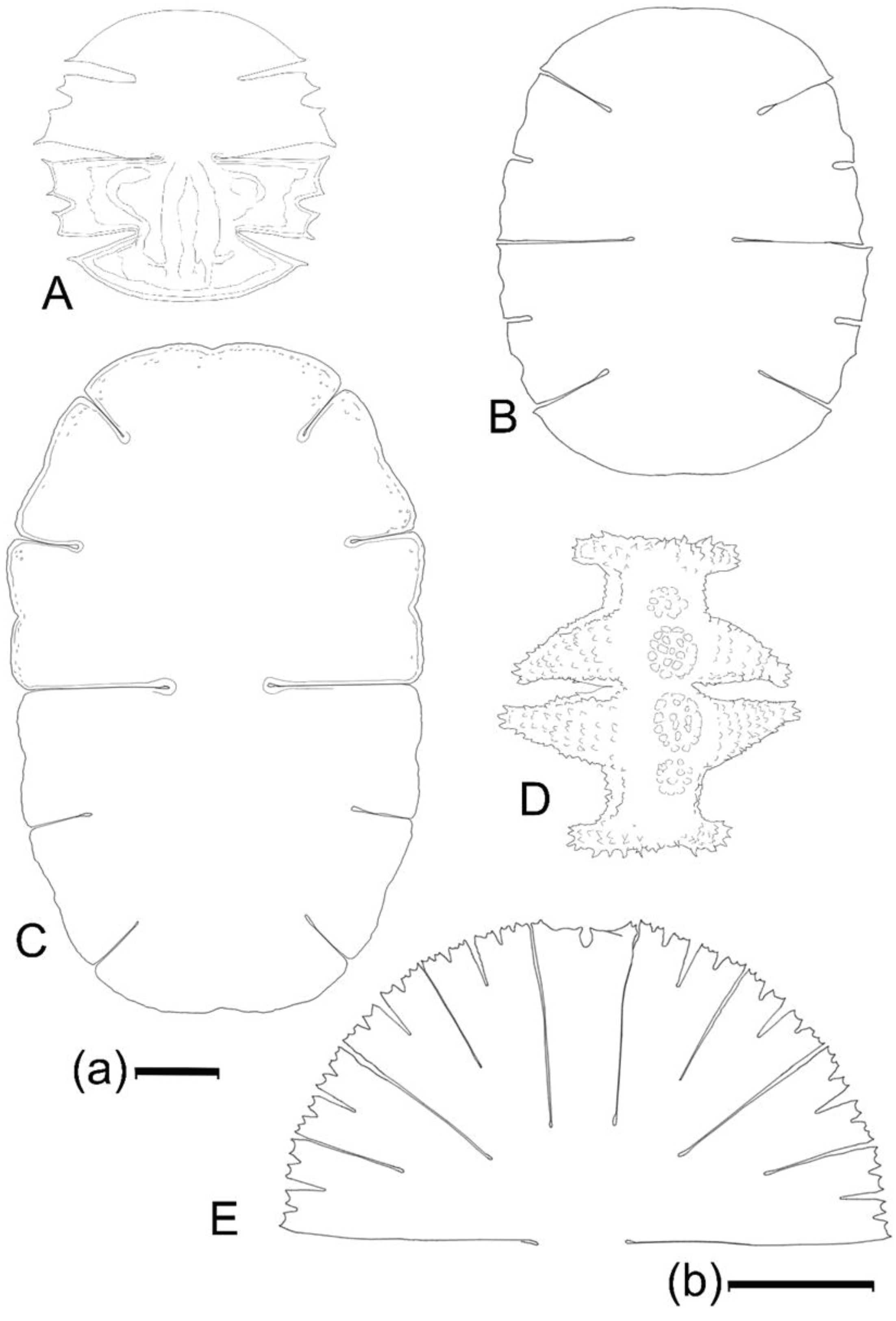

Fig. 12. Drawings of desmids based on light microscope images, **A.** *Micrasterias decemdentata,* **B.** *M. truncata* var. *crenata* **C.** *M. jenneri,* **D.** *M. bicoronata* & **E.** *M. thomasiana* var. *notata.* Scale bar: (a) = 20 µm, for A, B & C; (b) = 50 µm for D & E.

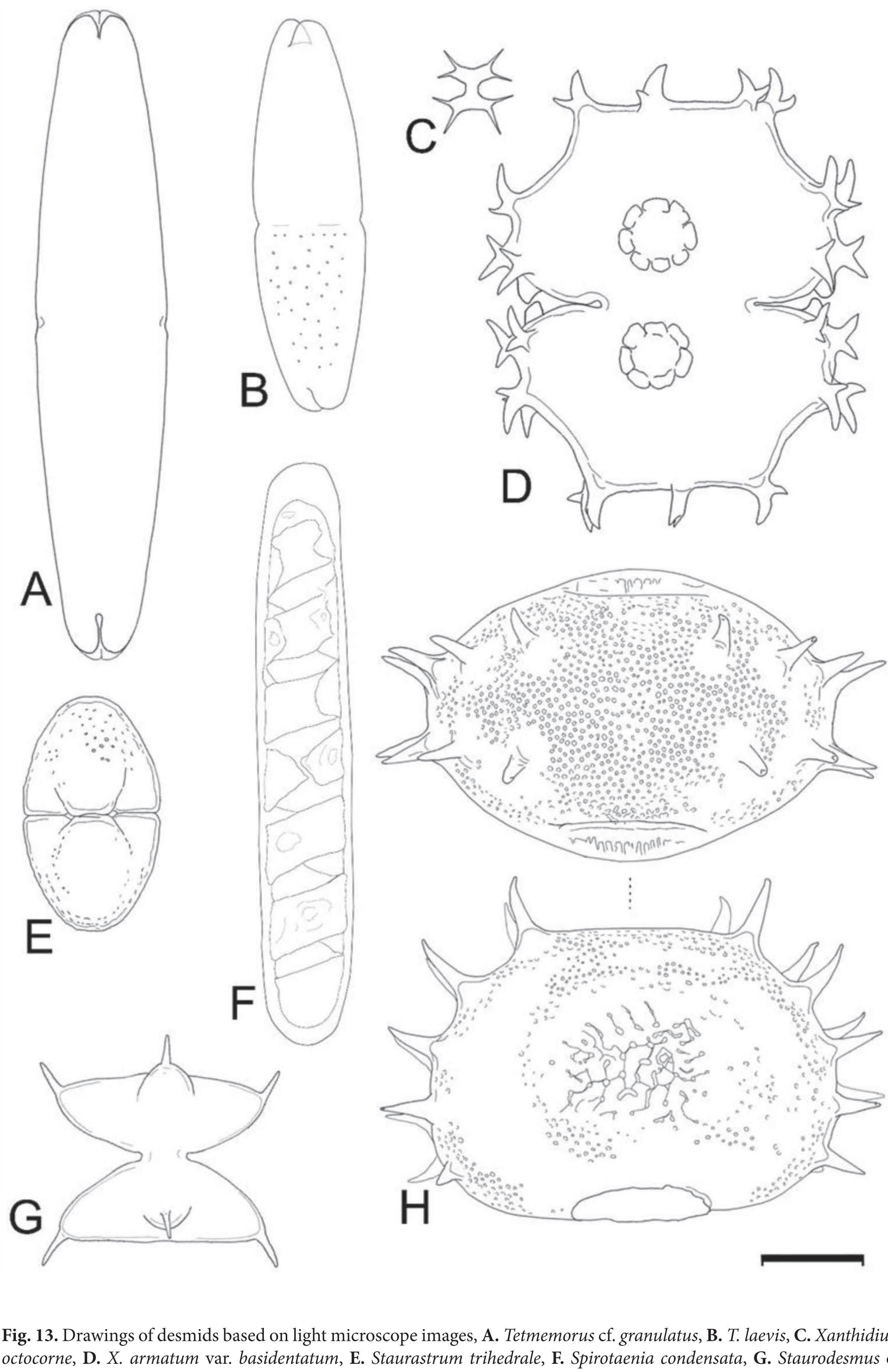

Fig. 13. Drawings of desmids based on light microscope images, **A.** *Tetmemorus* cf. *granulatus*, **B.** *T. laevis*, **C.** *Xanthidium octocorne*, **D.** *X. armatum* var. *basidentatum*, **E.** *Staurastrum trihedrale*, **F.** *Spirotaenia condensata*, **G.** *Staurodesmus* cf. *cuspidicurvatus*, **H.** *X.* cf. *octonarium*. Scale bar = 20 µm.

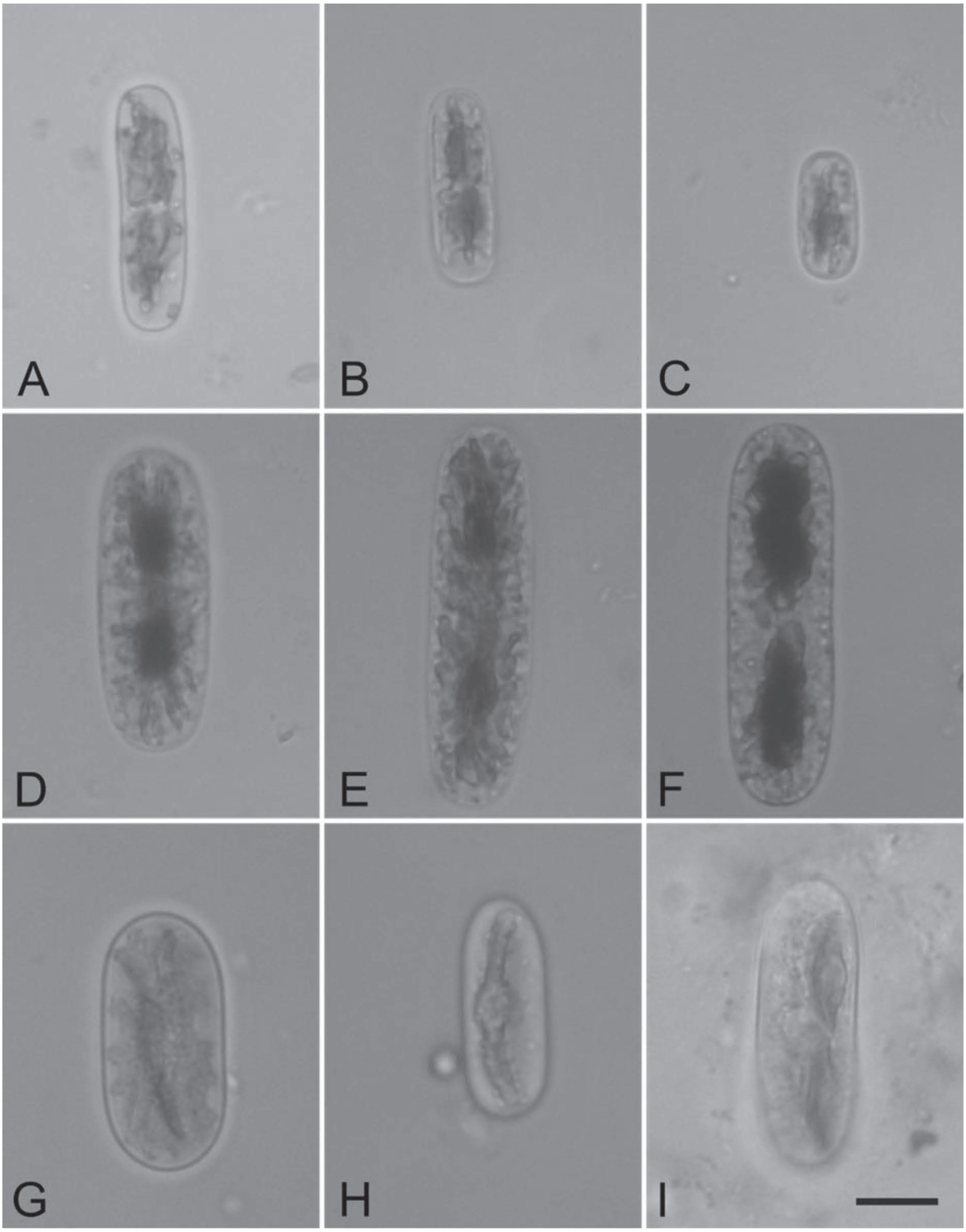

Fig. 14. Light micrographs of desmids, **A**, **B** & **C.** *Cylindrocystis cushleckae*, **D**, **E**, & **F.** *C. brebissonii var. minor*, **G.** *C. gracilis*, **H.** *Mesotaenium macrococcum*, & **I.** *M. endlicherianum*. Scale bar = 10 µm.

Fig. 15. Light micrographs of desmids, **A.** *Cylindrocystis crassa*, **B** & **C.** *C.* cf. *brebissonii* var. *turgida*, **D.** *Netrium digitus*, **E.** *Tortitaenia obscura* & **F.** *Penium exiguum*. Scale bar = 20 µm.

Fig. 16. Light micrographs of desmids, **A.** *Groenbladia bourrellyi,* **B.** *Micrasterias decemdentata*, **C.** *Euastrum cf. luetkemuelleri var. laterepunctatum,* **D.** *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum* (sideview) & **E.** *M. truncata var. crenata* Scale bar = 20 µm.

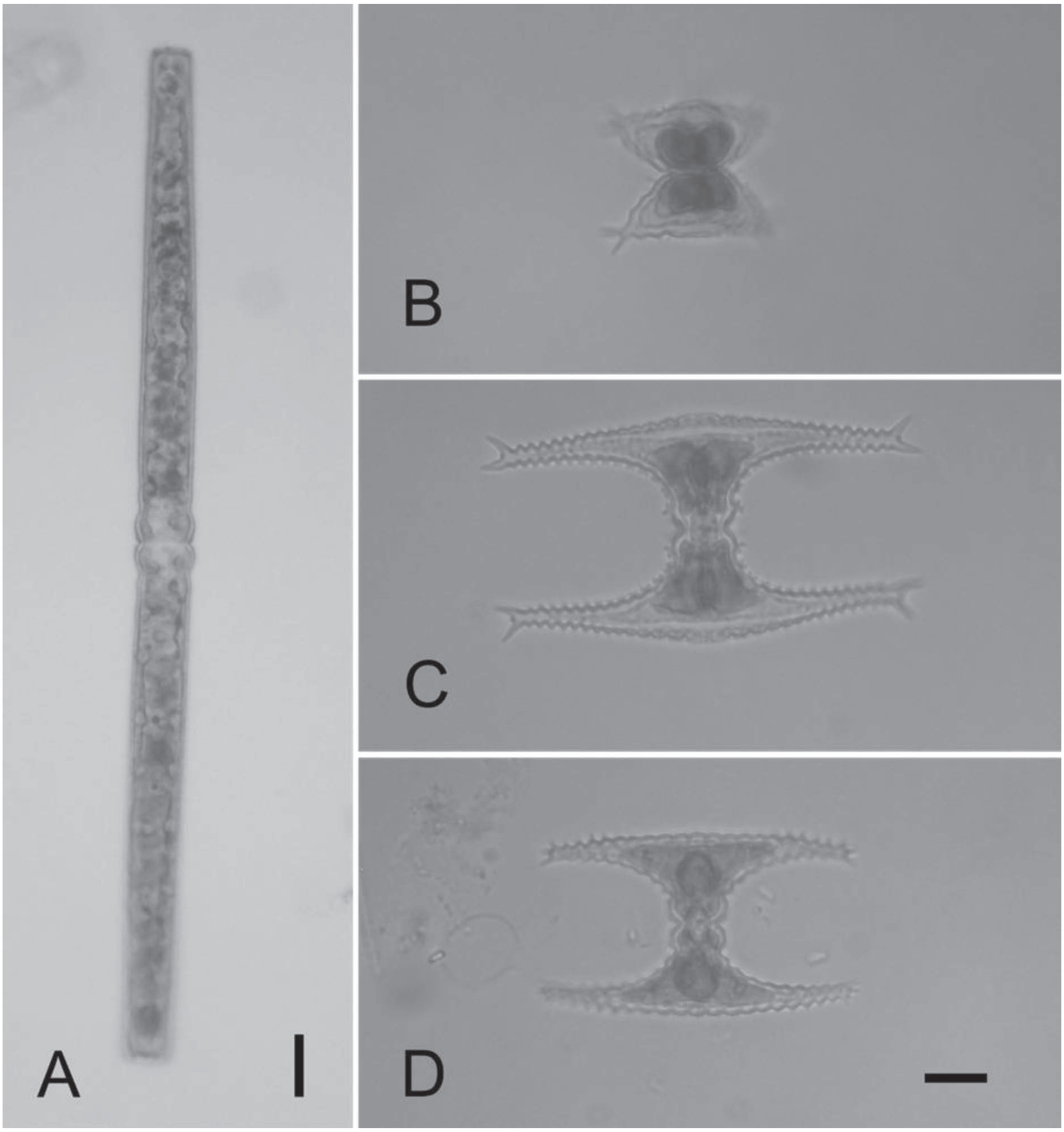

Fig. 17. Light micrographs of desmids, **A.** *Pleurotaenium tridentulum,* **B.** *Staurastrum* cf. *avicula*, **C.** *S.* cf. *longebrachiatum* & **D.** *Staurastrum* cf. *hardyi*. Scale bar A = 20 µm for A; D = 10 µm for B, C & D.

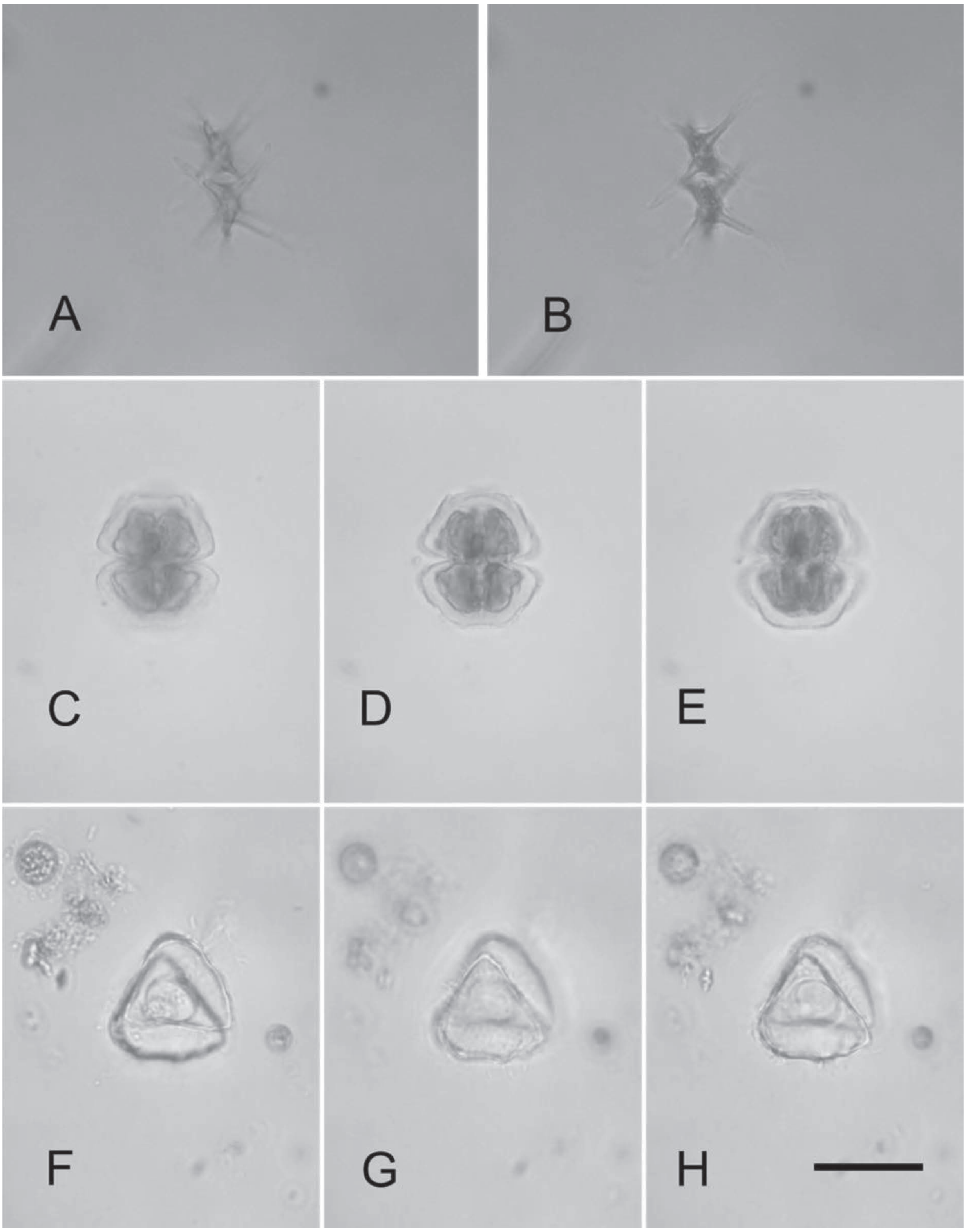

Fig. 18. Light micrographs of desmids, **A** *&* **B.** *Staurastrum aureolatum* (different focal planes), **C**, **D** & **E.** *Staurastrum* cf. *monticulosum* (different focal planes) & **F**, **G** & **H.** *Staurastrum* cf. *monticulosum* (apical view; different focal planes). Scale bar = 20 µm.

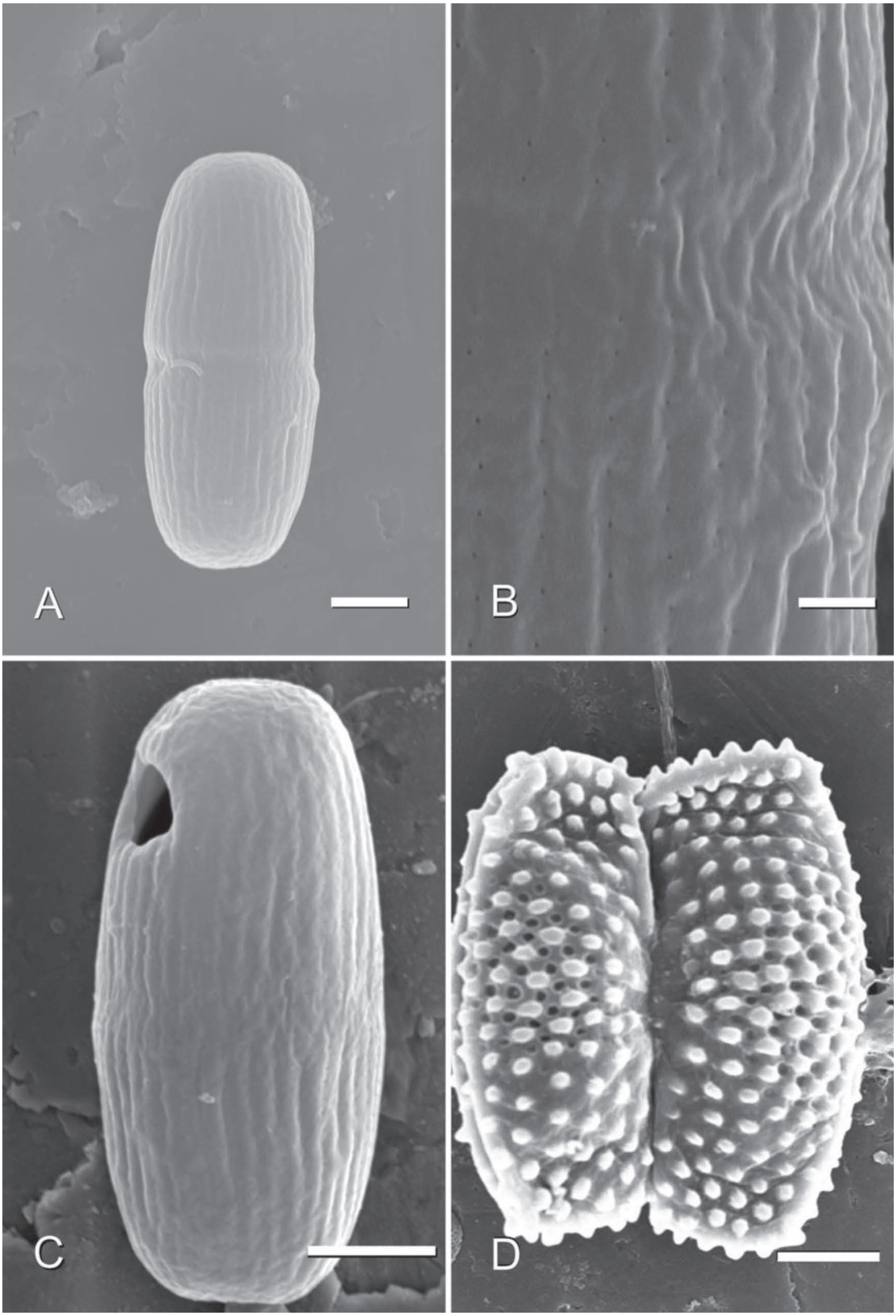

Fig. 19. Scanning electron micrographs of desmids, **A.**, **B.** & **C.** *Actinotaenium* cf. *phymatosporum*. **D.** *Cosmarium* cf. *neapolitanum* var. *australicum*. Scale bar A & C = 5 µm; B = 1 µm; D = 10 µm.

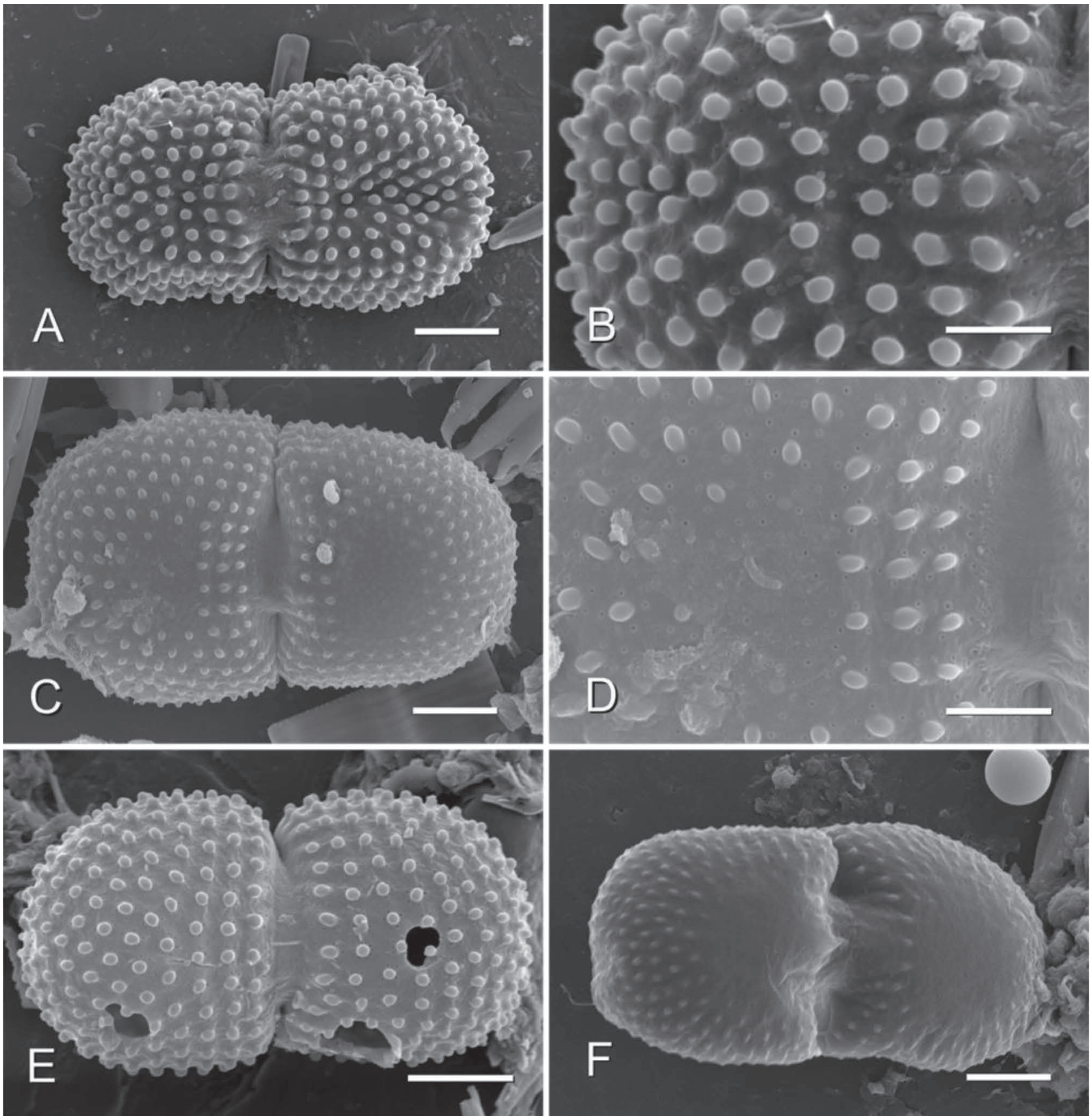

Fig. 20. Scanning electron micrographs of desmids, **A.**, **B.** & **E.** *Cosmarium amoenum.* **C.**, **D.** & **F.** *Cosmarium amoenum* var. *mediolaeve.* Scale bar A, C, E & F = 10 μm; B & D = 5 μm.

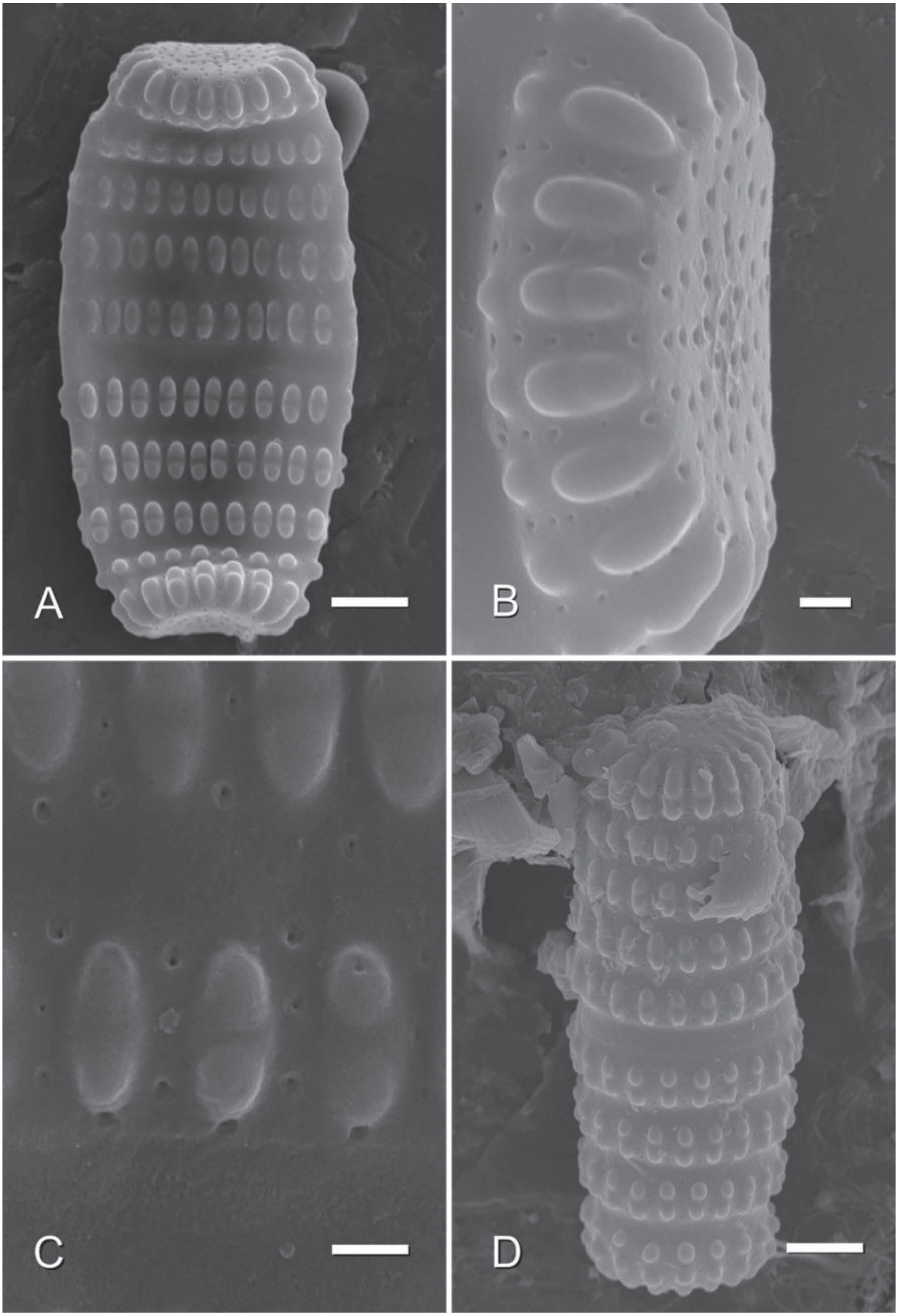

Fig. 21. Scanning electron micrographs of desmids, **A. – D.** *Cosmarium annulatum*. Scale bar A & D = 5 µm; B & C = 1 µm.

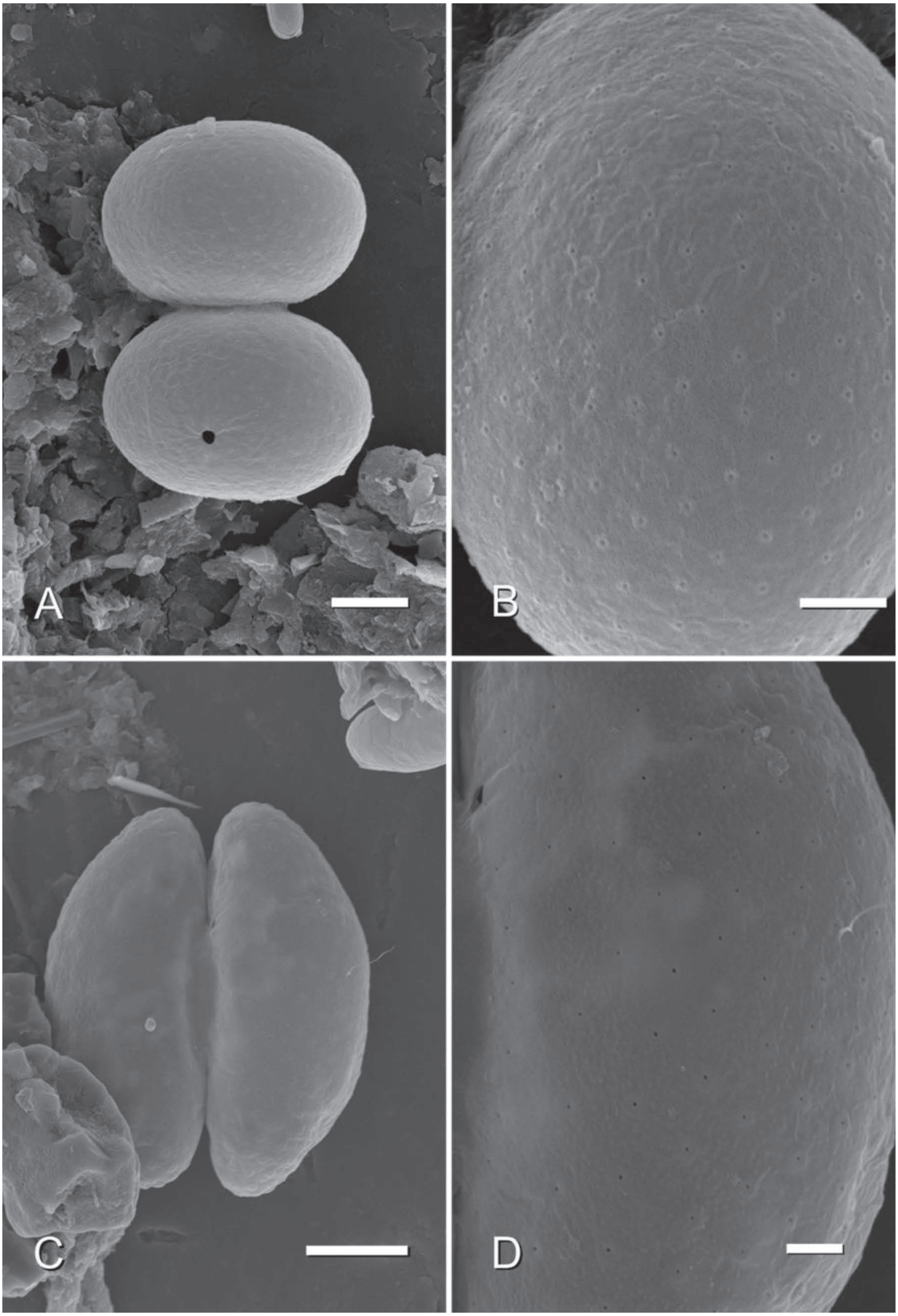

Fig. 22. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium contractum*. **C.** & **D.** *C. dorsitruncatum*. Scale bar A = 5 µm; B & D = 2 µm; C = 10 µm.

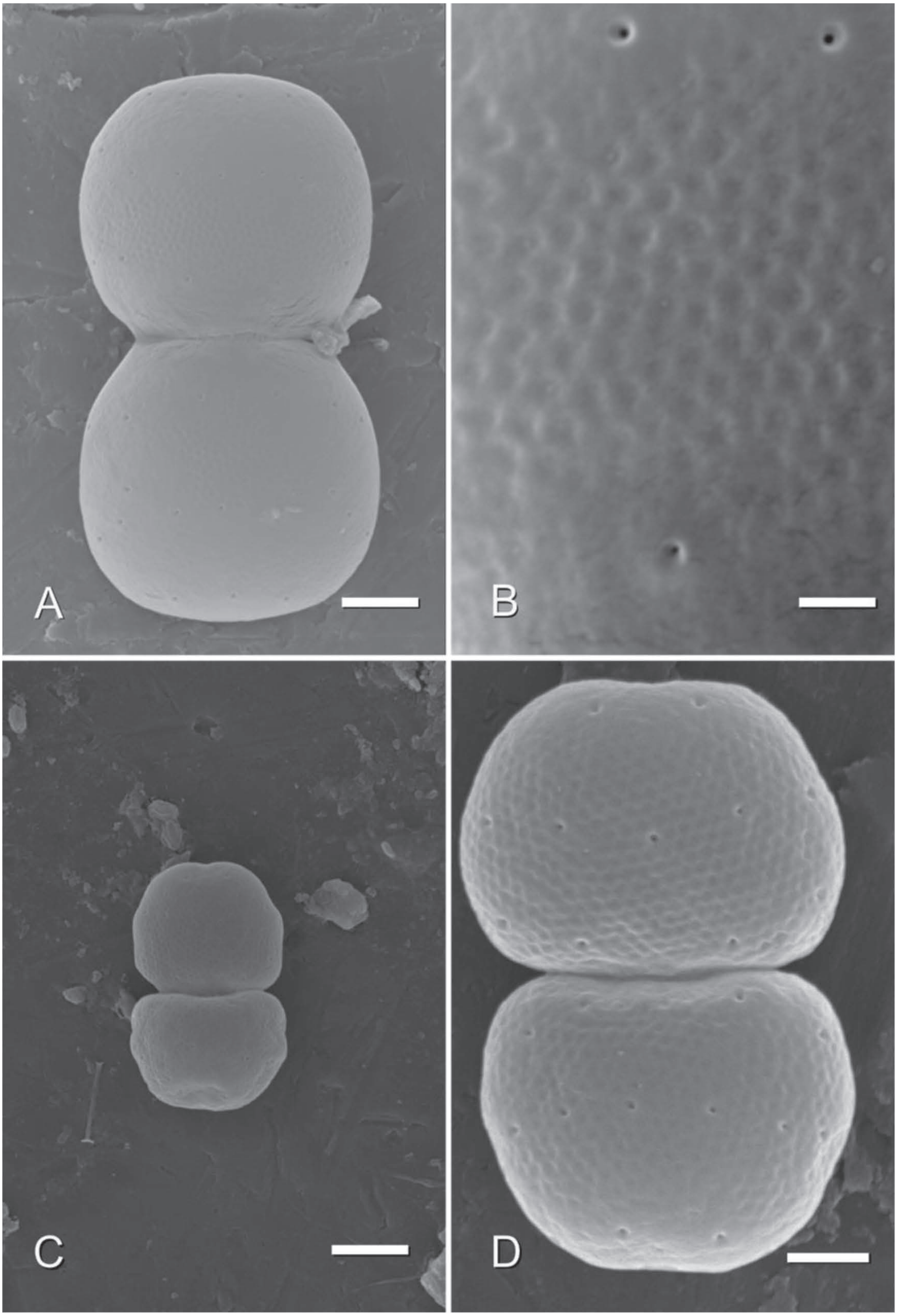

Fig. 23. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium* cf. *difficillimum*. **C.** & **D.** *C.* cf. *difficile* var. *messikommeri*. Scale bar A & D = 5 µm; B = 1 µm; C = 2 µm.

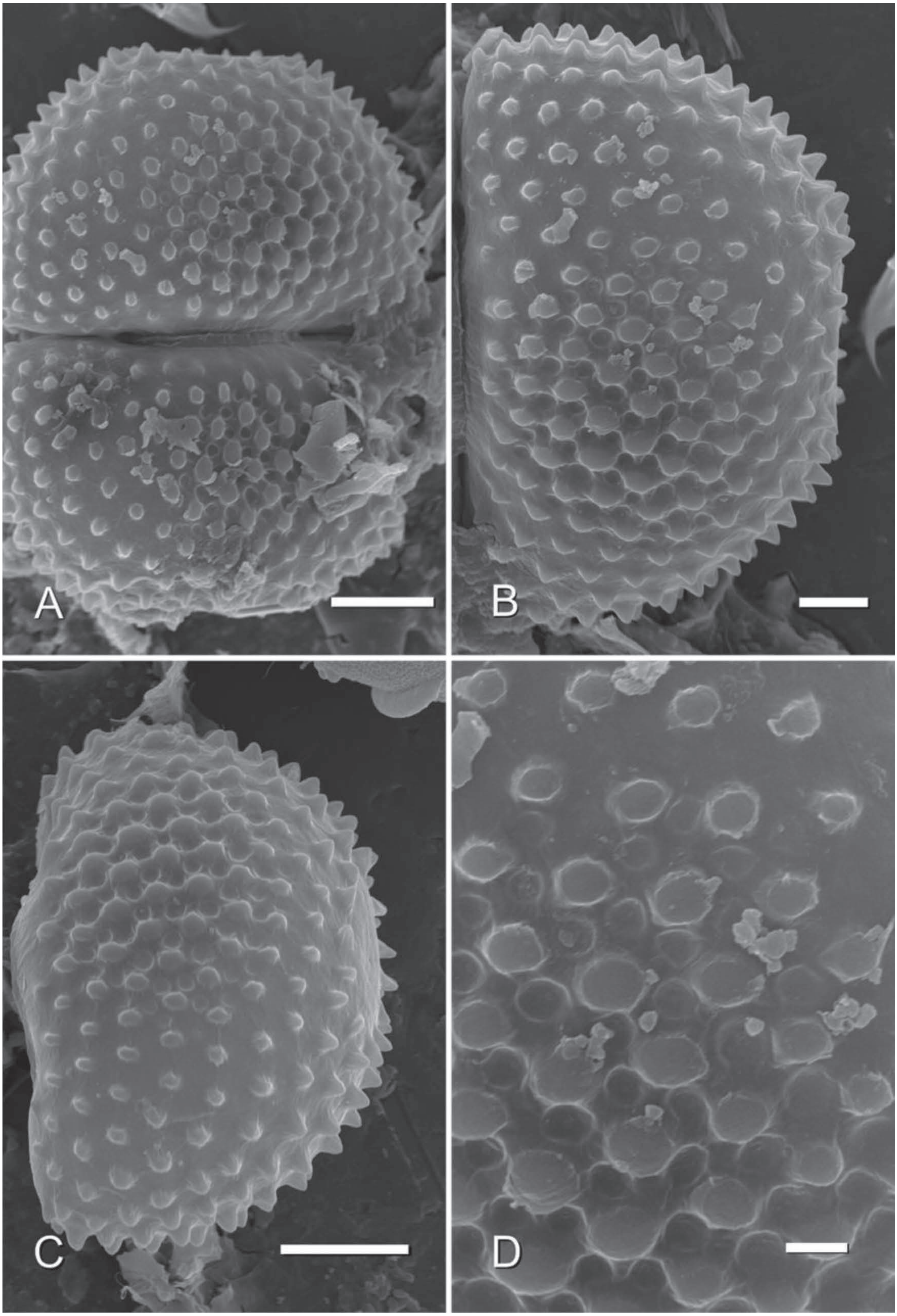

Fig. 24. Scanning electron micrographs of desmids, **A. – D.** *Cosmarium margaritiferum* f. *regularius.* Scale bar A & C = 10 µm; B = 5 µm; D = 2 µm.

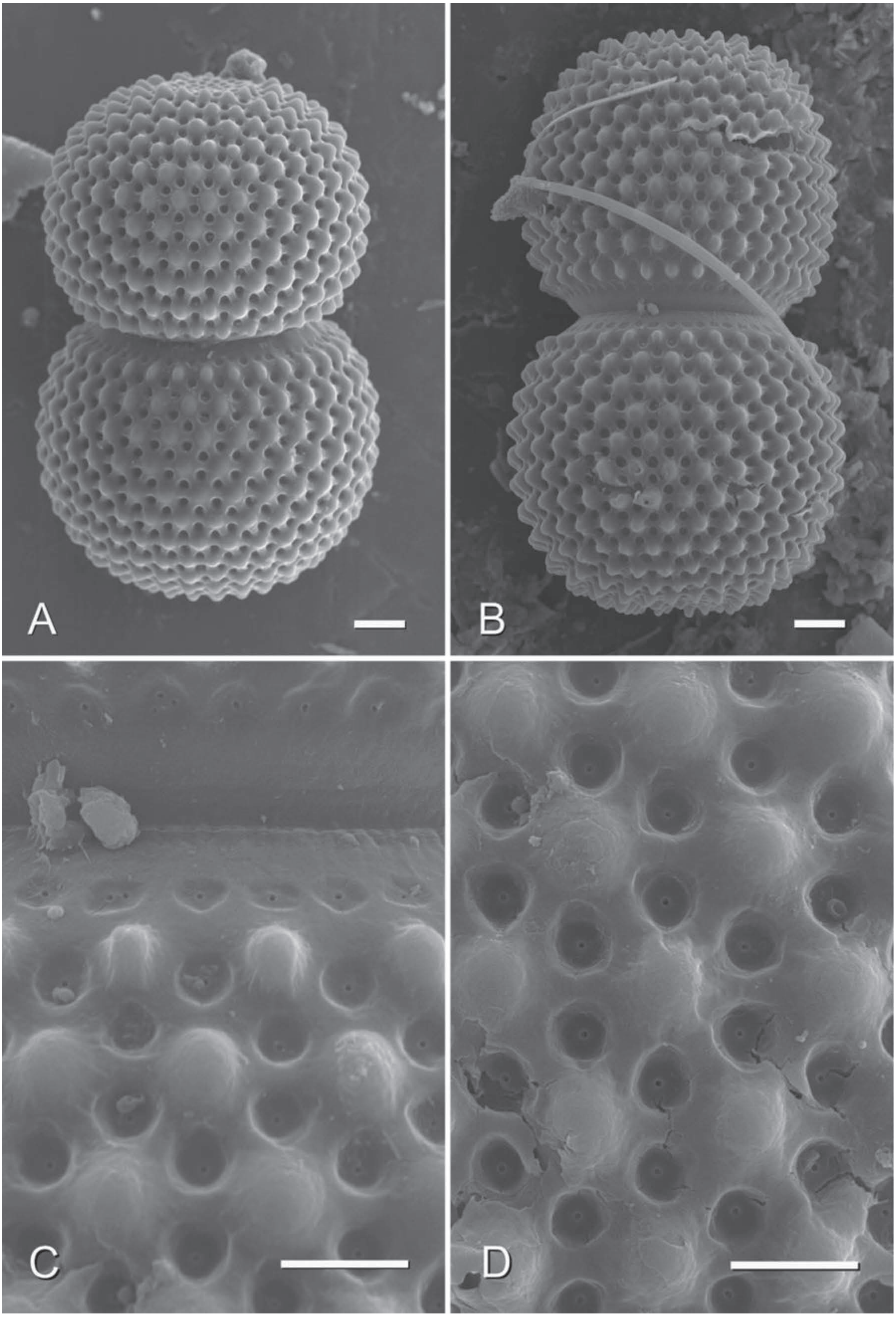

Fig. 25. Scanning electron micrographs of desmids, **A. – D.** *Cosmarium striolatum* var. *nordstedtii.* Scale bar A & B = 10 µm; C & D = 5 µm.

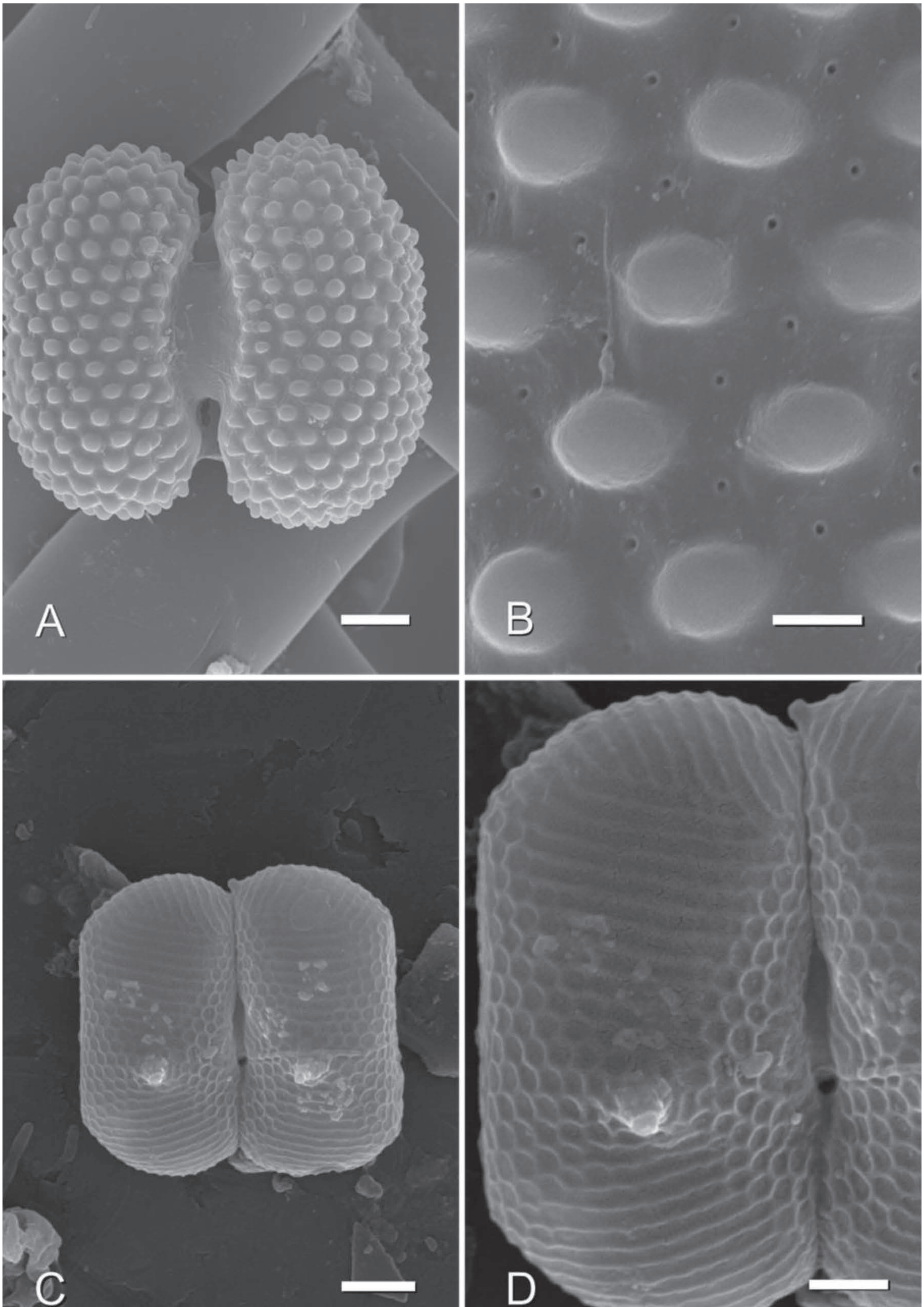

Fig. 26. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium* cf. *reniforme var. compressum*. **C.** & **D.** *C. subadoxum*. Scale bar A = 10 µm; B & C = 2 µm; D = 1 µm.

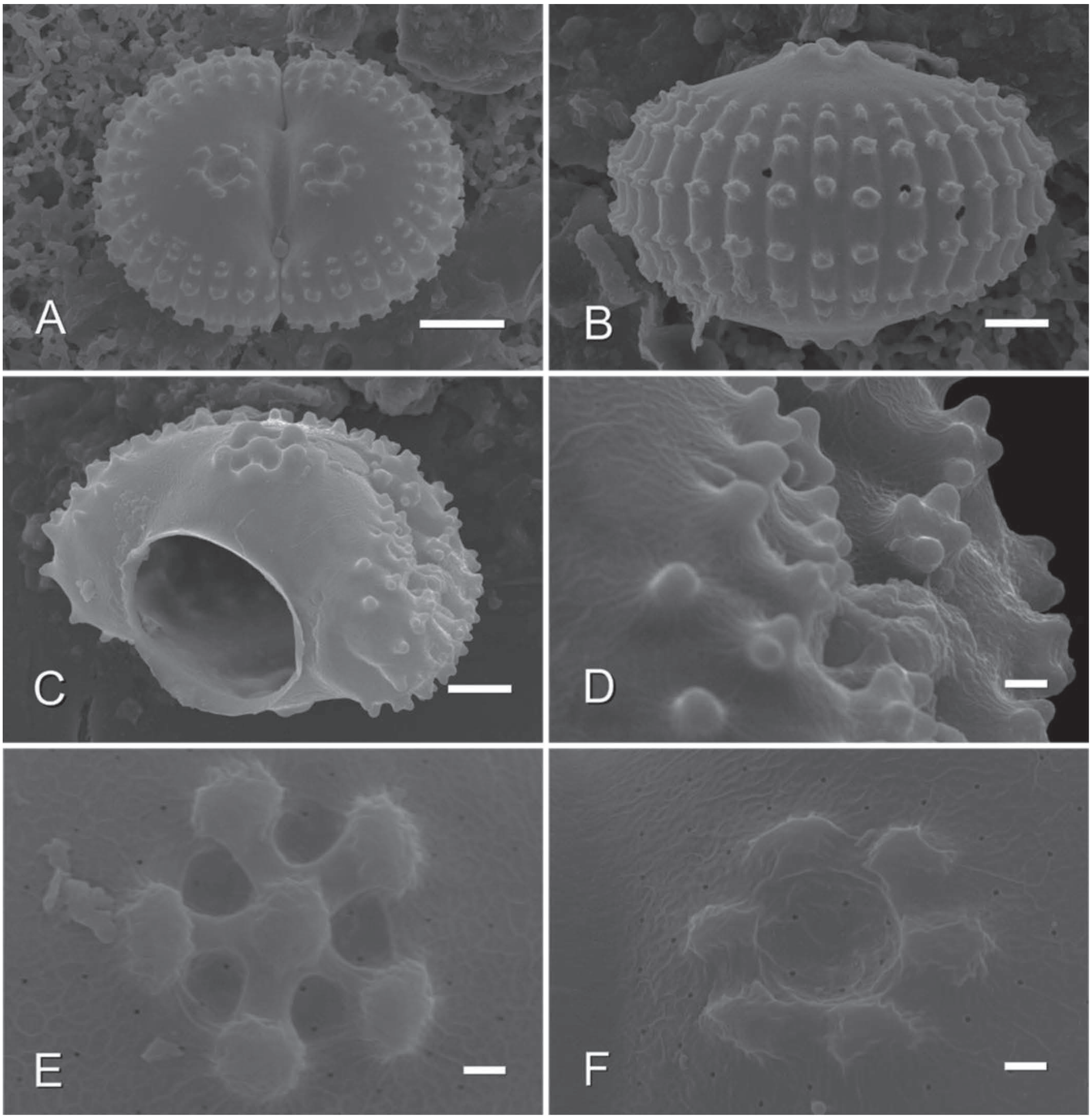

Fig. 27: Scanning electron micrographs of desmids, **A. – F.** *Cosmarium quadrifarium* var. *simplex.* Scale bar A = 10 µm; B & C = 5 µm; D, E & F = 1 µm.

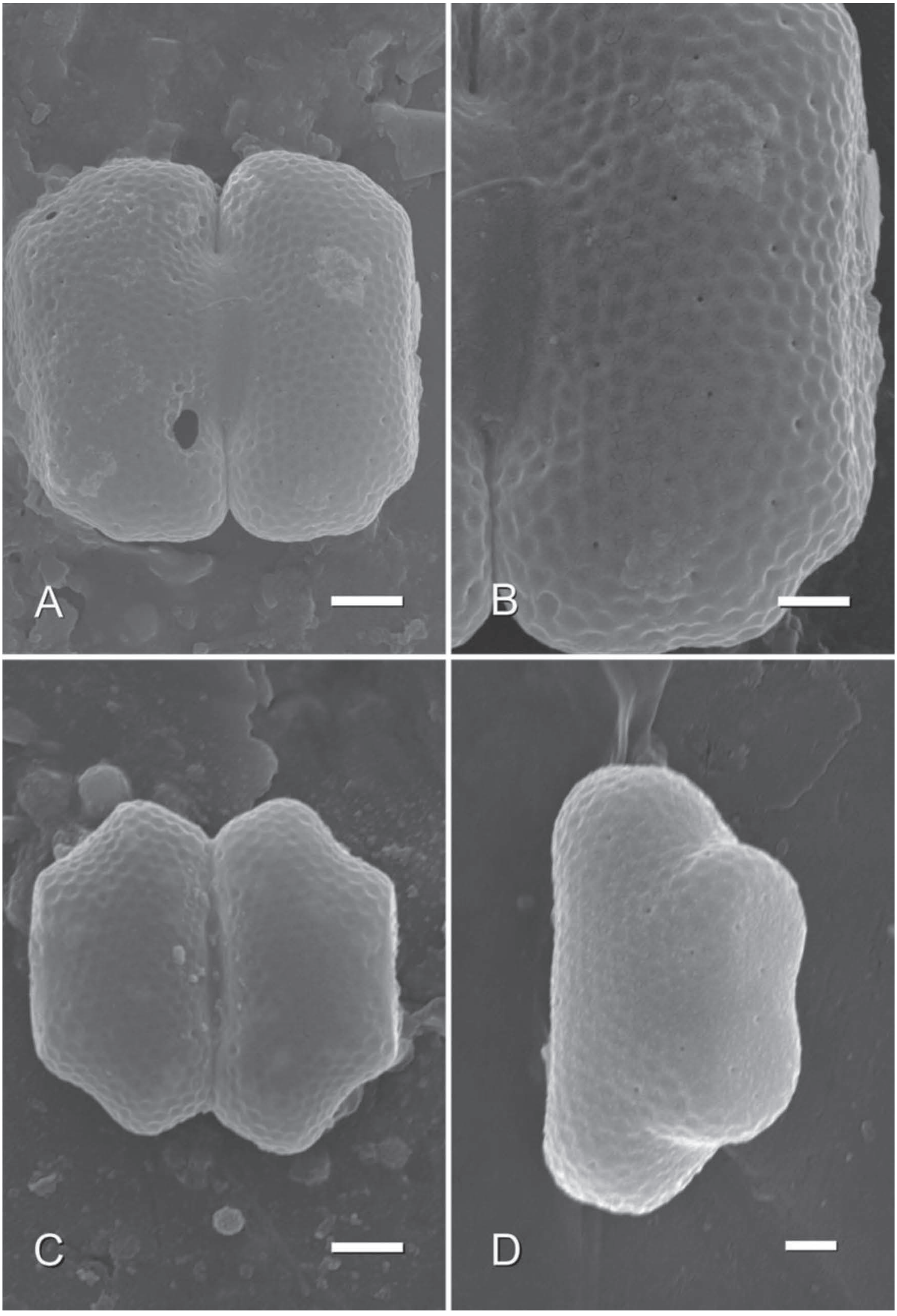

Fig. 28. Scanning electron micrographs of desmids, **A. – D.** *Cosmarium regnellii.* Scale bar A & C = 2 µm; B & D = 1 µm.

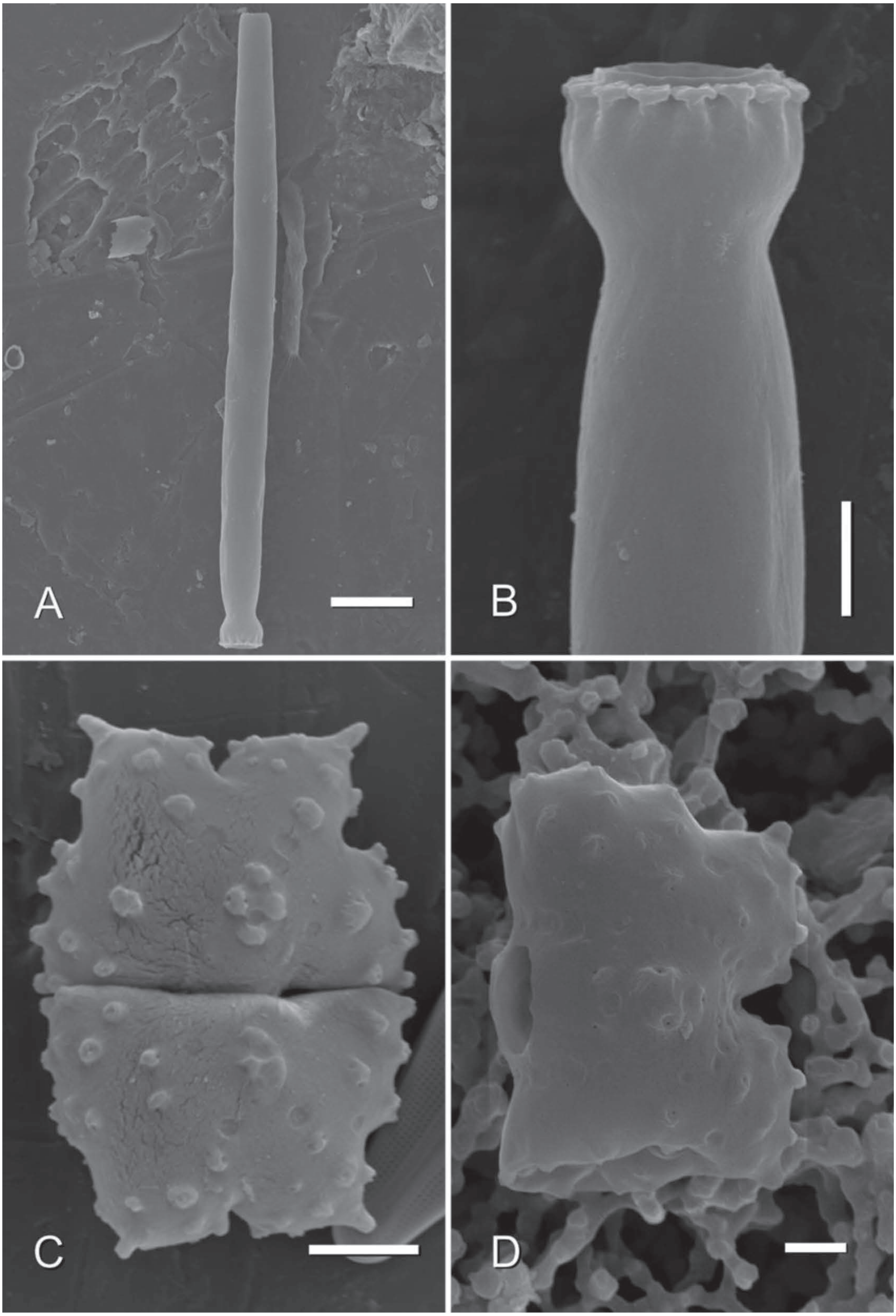

Fig. 29. Scanning electron micrographs of desmids, **A.** & **B.** *Docidium baculum*. **C.** & **D.** *Euastrum denticulatum* var. *quadrifarium*. Scale bar A = 20 µm; B & C = 5 µm; D = 2 µm.

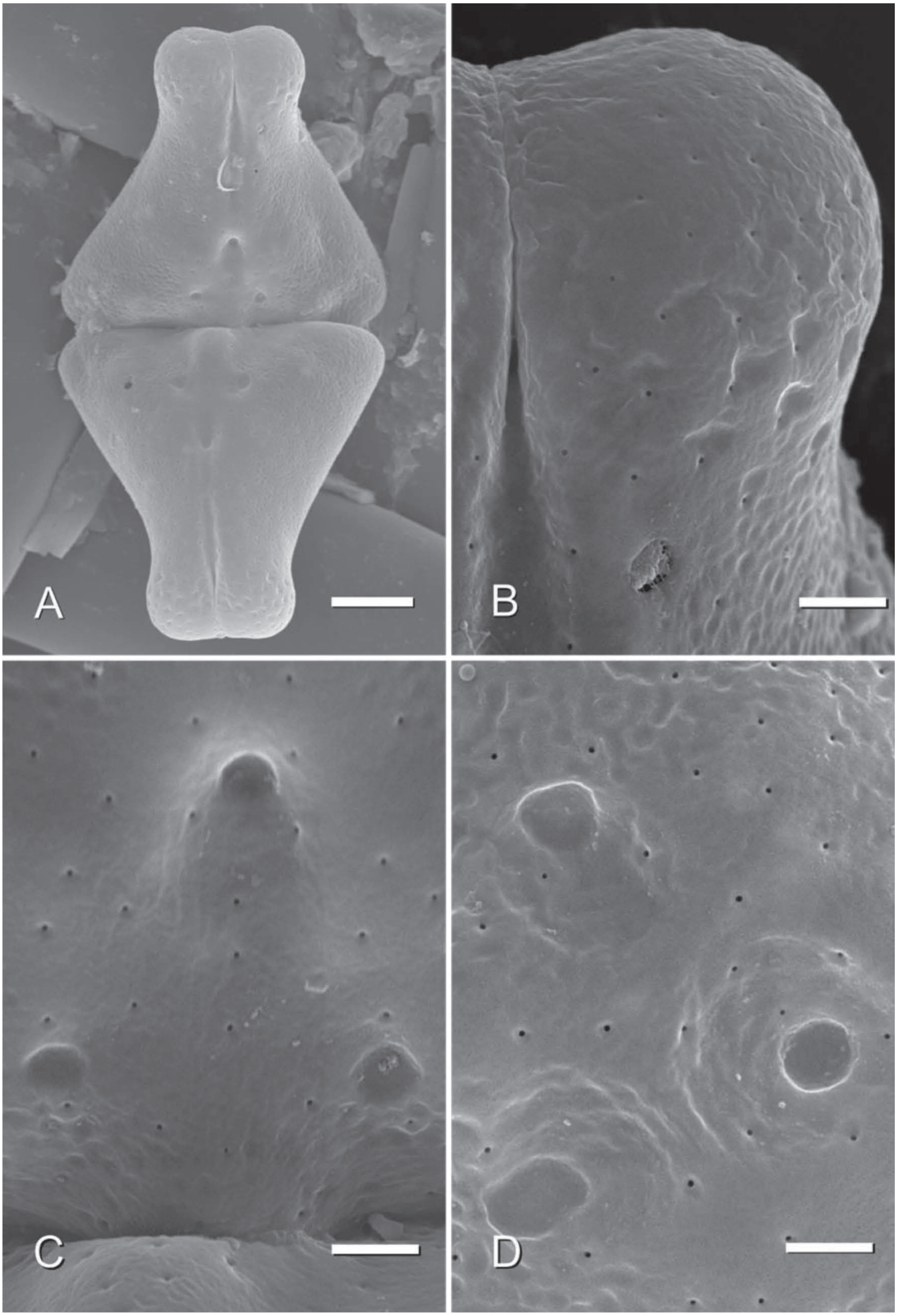

Fig. 30. Scanning electron micrographs of desmids, **A. – D.** *Euastrum* cf. *ansatum* var. *triporum.* Scale bar A = 10 µm; B, C & D = 2 µm.

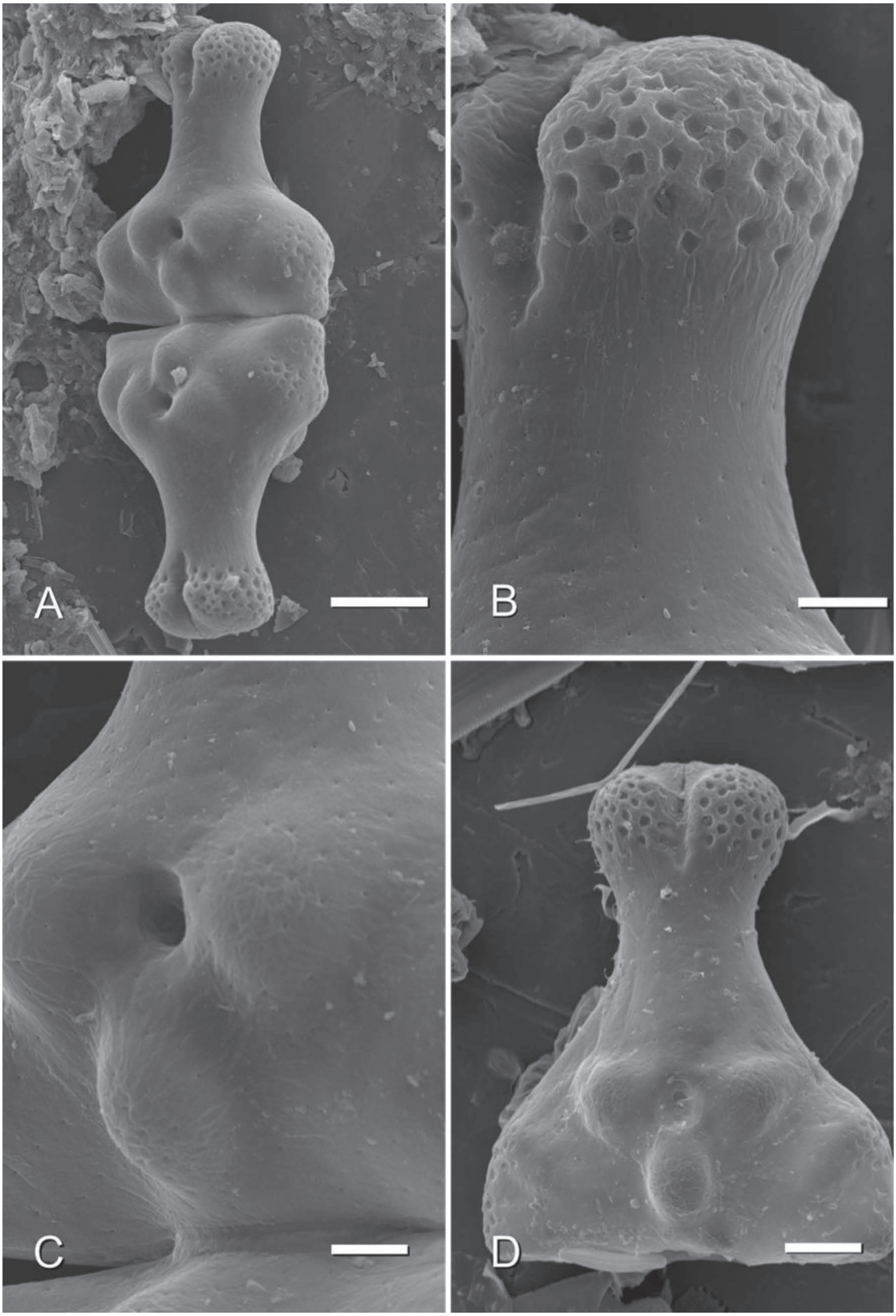

Fig. 31. Scanning electron micrographs of desmids, **A. – D.** *Euastrum longicolle* var. *australicum.* Scale bar A = 20 µm; B & C = 5 µm; D = 10 µm.

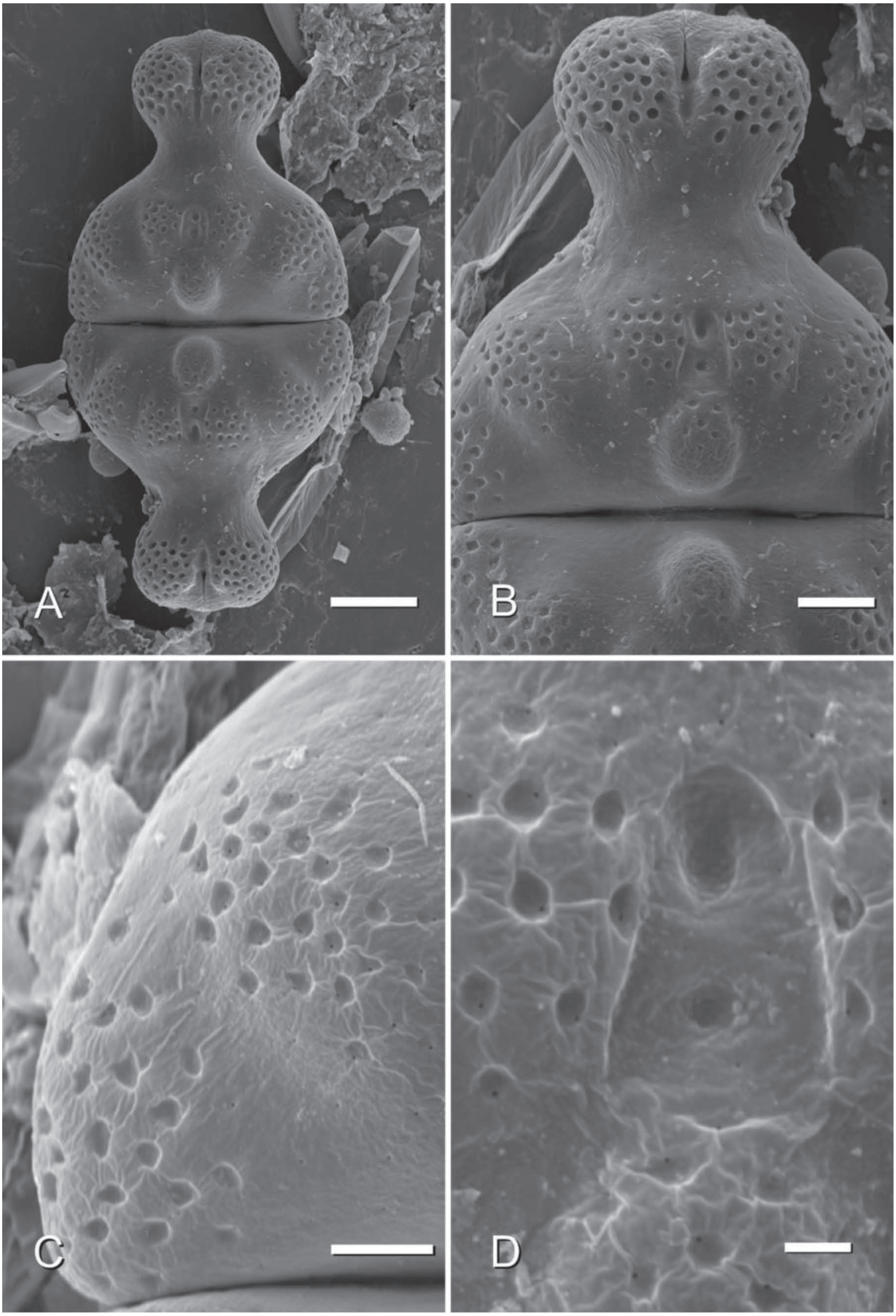

Fig. 32. Scanning electron micrographs of desmids, **A. – D.** *Euastrum* cf. *longicolle* var. *australicum*. Scale bar A = 20 µm; B = 10 µm; C = 5 µm; D = 2 µm.

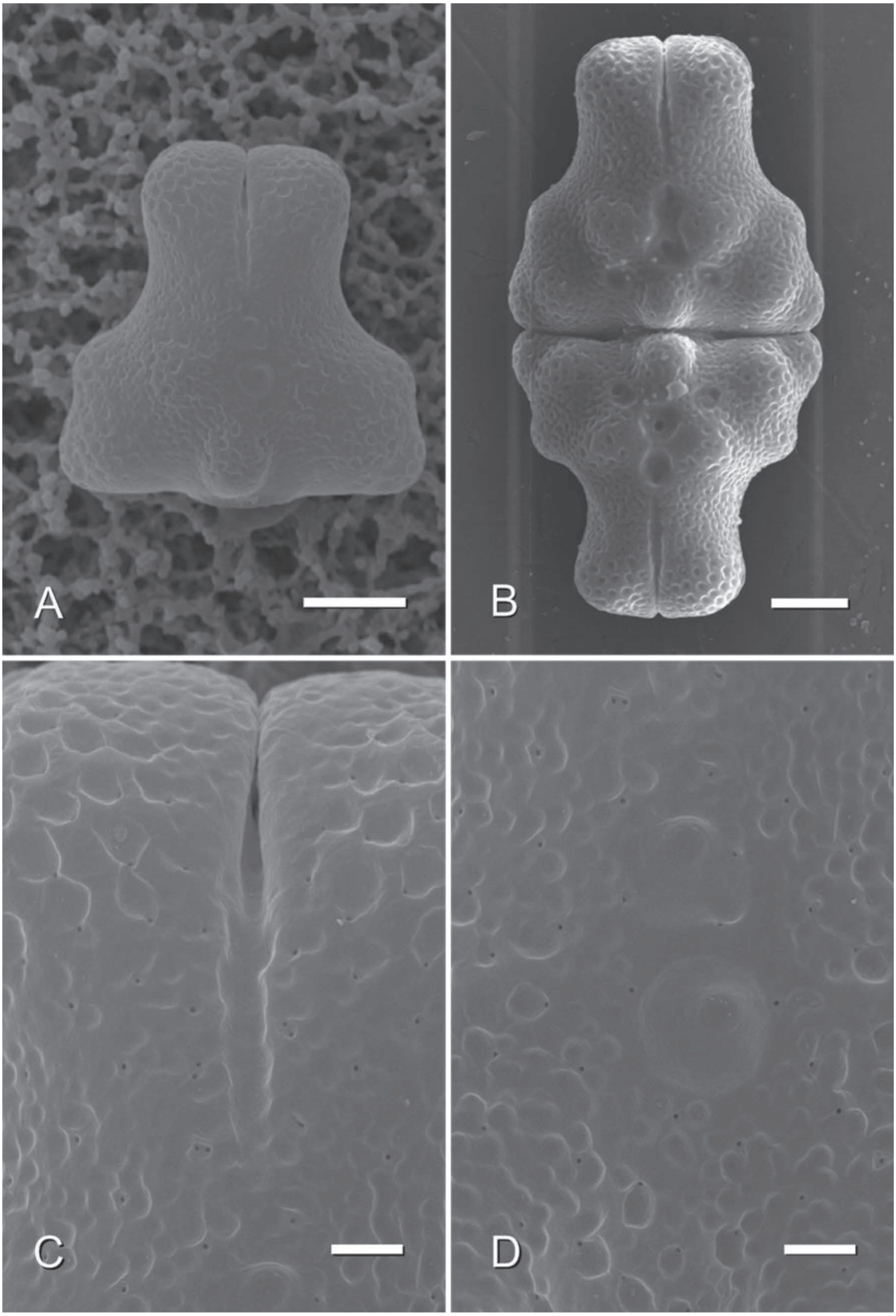

Fig. 33. Scanning electron micrographs of desmids, **A. – D.** *Euastrum sinuosum* var. *germanicum*. Scale bar A & B = 10 µm; C = 2 µm; D = 5 µm.

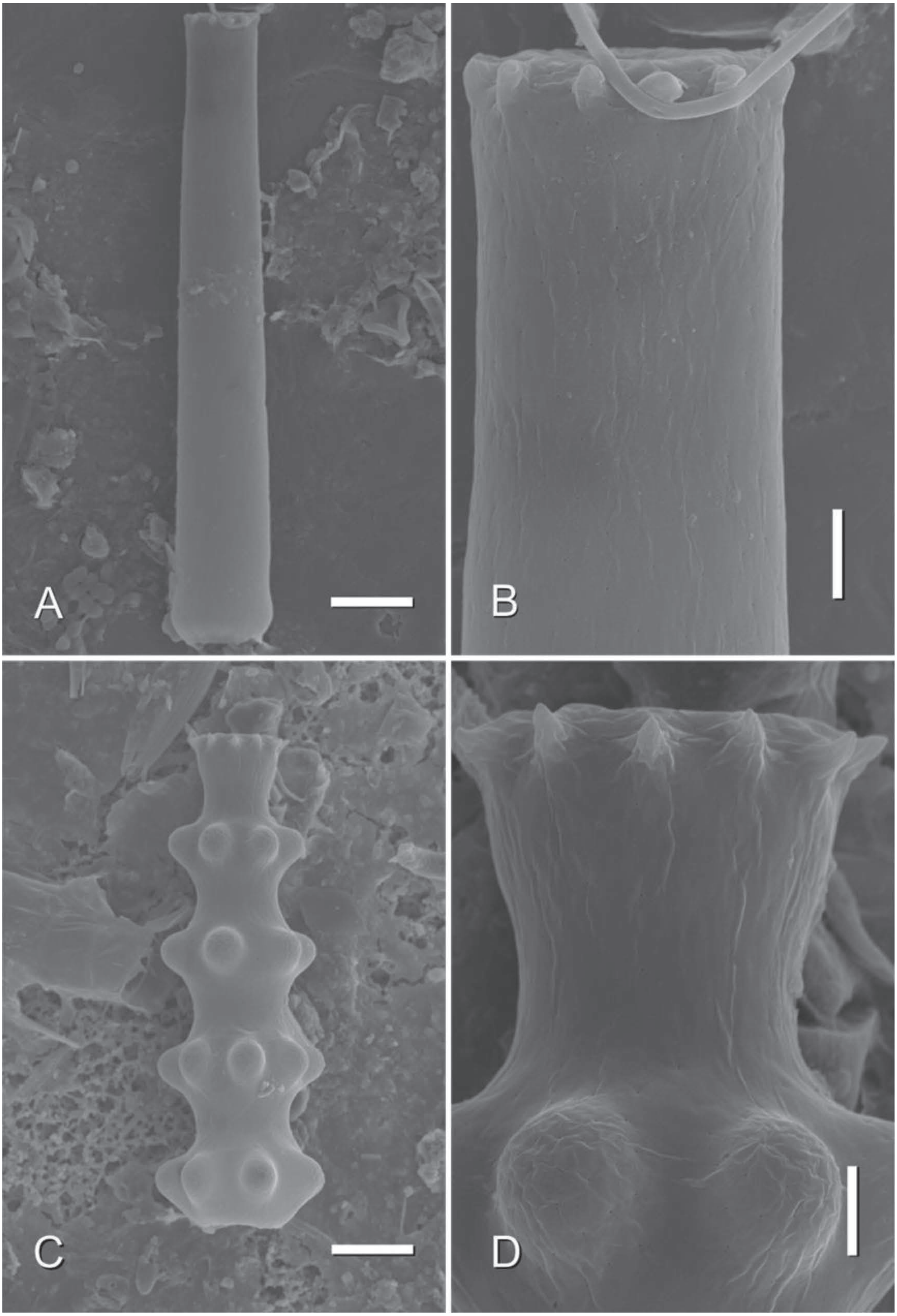

Fig. 34: Scanning electron micrographs of desmids, **A** & **B.** *Pleurotaenium ehrenbergii*. **C** & **D.** *P. nodosum.* Scale bar A & C = 20 µm; B & D = 5 µm.

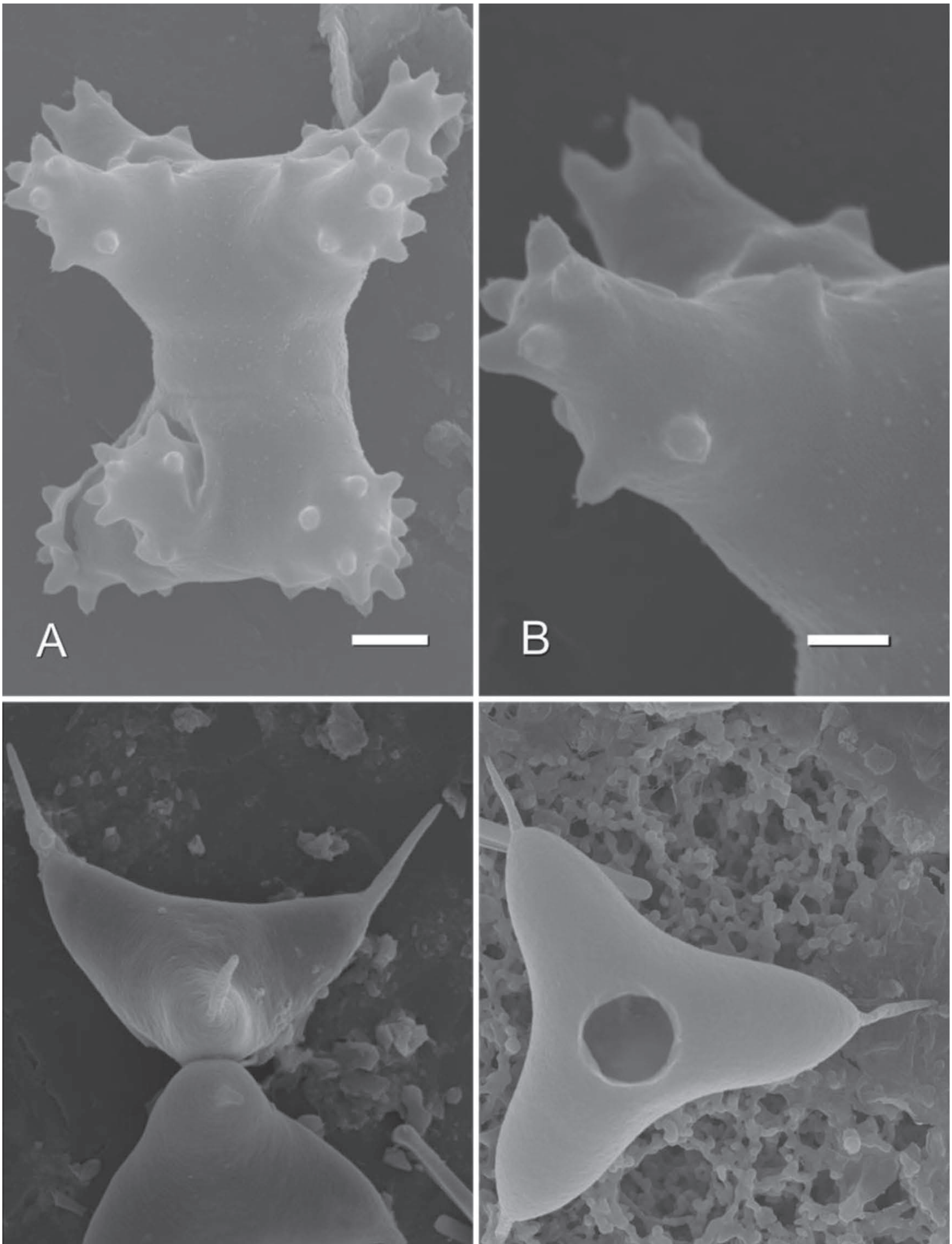

Fig. 35. Scanning electron micrographs of desmids, **A** & **B.** *Staurastrum inconspicuum*. **C.** *Staurodesmus* cf. *cuspidicurvatus* (F-stacked) & **D.** *S.* cf. *cuspidicurvatus.* Scale bar A = 2 μm; B = 1 μm; C = 5 μm; D = 10 μm.

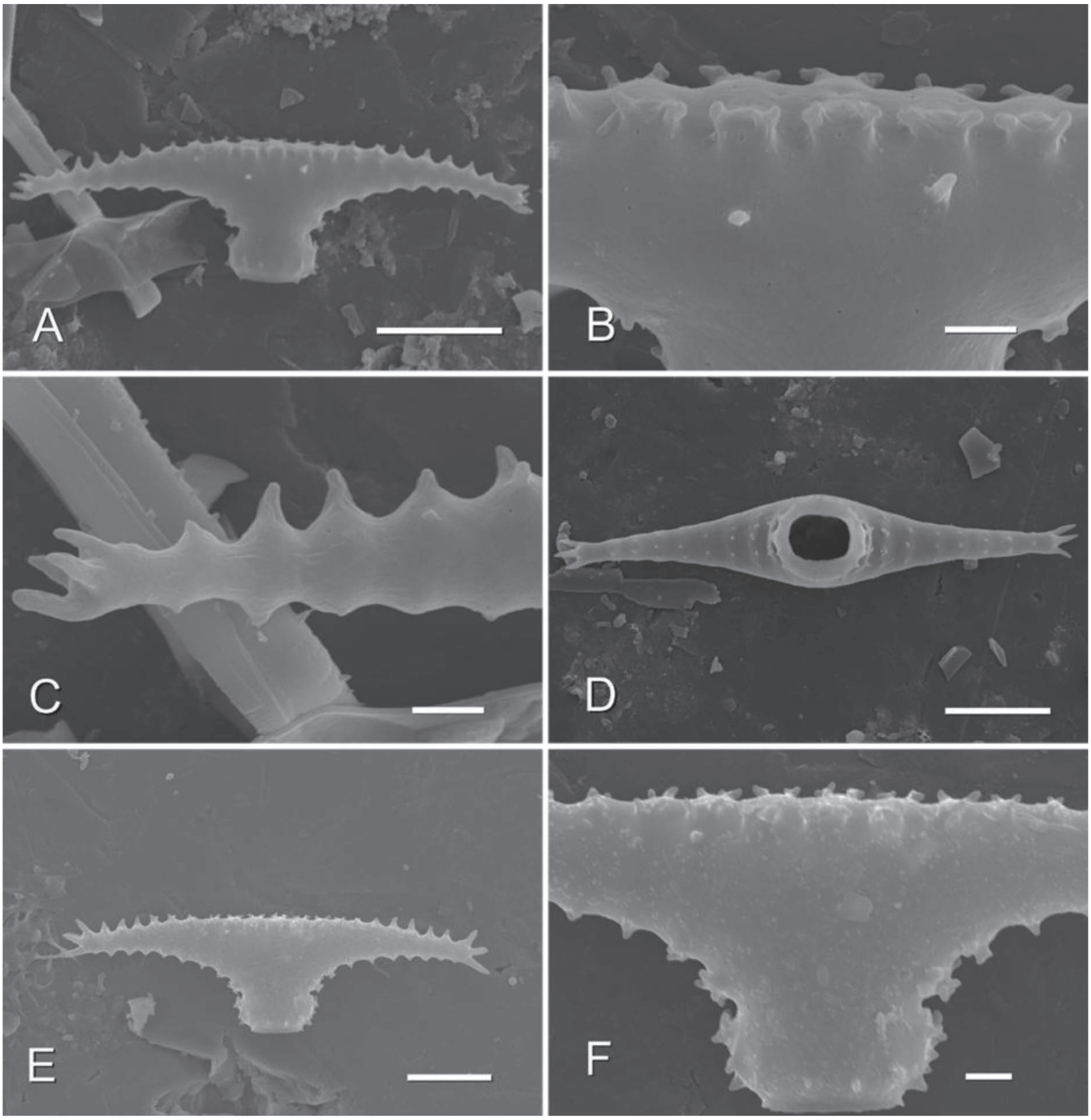

Fig. 36. Scanning electron micrographs of desmids, **A – F.** *Staurastrum* cf. *hardyi*. Scale bar A, D & E = 10 µm; B, C & F = 2 µm.

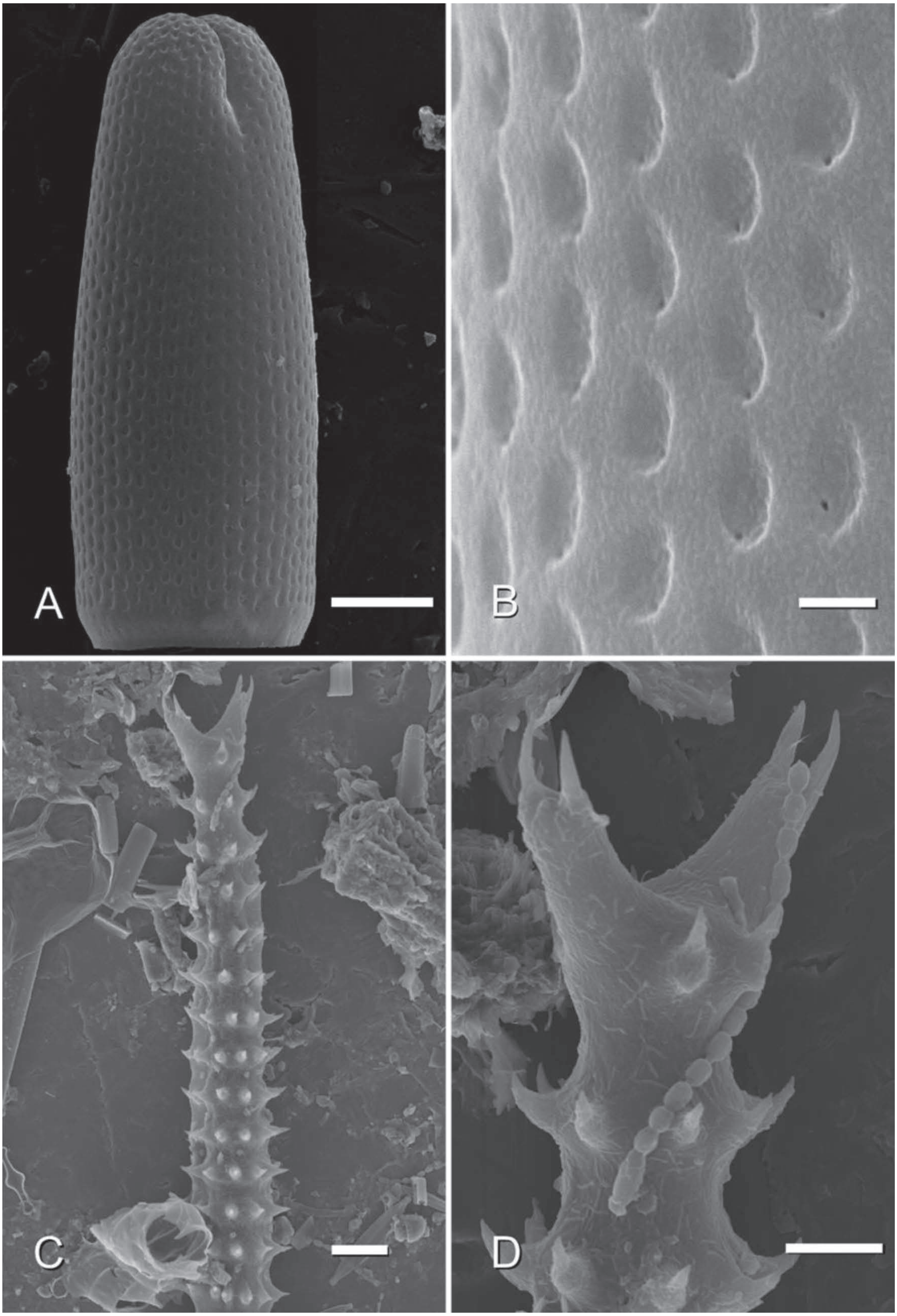

Fig. 37. Scanning electron micrographs of desmids, **A.** & **B.** *Tetmemorus brebissonii*. **C.** & **D.** *Triploceras gracile.* Scale bar A & D = 10 µm; B = 1 µm; C = 20 µm.

Conclusions

The present study recovered 80 *Sphagnum*-associated desmid taxa, which included two new species and several tentatively identified entities, highlighting the need for further taxonomic study of this group in Australia. Moreover, were the several taxa that were considered having a tenuous or dubious basis for varietal status. As alluded to previously, moving towards an integrated approach to determine species limits in Australian desmids would provide a more informed inventory of diversity.

The use of a NCV scheme allowed us to compare species diversity between Basket Swamp and Ebor Common and emphasise species of significance (bioindicators for rarity, ecosystem maturity, endemism and red list species) present at those sites. Results from the original and modified NCV were similar, suggesting their use in Australian wetland habitats is possible albeit that future work should address the limitations discussed herein.

Species associated with this substrate tended to be benthic and acidophilic, however, species with broader ecological ranges were also present, indicating migration from adjacent microhabitats had possibly occurred. Diversity between the studied sites was variable, with turnover prevailing over nestedness in terms of β-diversity patterns. Common desmid assemblages were also identified at a larger geographical scale from previous *Sphagnum* surveys from Australia and western Europe.

Additionally, local and regional endemics were recovered but require further study to confirm their ecological range like their better-known counterparts. These findings are of relevance for further biomonitoring studies concerned with the ecological status and conservation value of freshwater wetlands, especially for those habitats harbouring *Sphagnum* and its associated epiphyton.

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