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Mougeotia (Zygnemaceae, Streptophyta) in Australia

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Abstract

Fourteen taxa in the genus *Mougeotia* are described here for the Australian flora, and their distributions delineated. Many are new reports of taxa found in other parts of the world; some are reinstatements of previously reported species, like *M. nummularioides*, *M. viridis* and *M. capucina*, while there are three new varieties, *M. laetevirens* var. *trochleifera*, *M. drouetii* var. *djelkiensis* and *M. tumidula* var. *palmerstoniana*. This brings the verified species count for the continent to eighteen.

Introduction

While the relatively recent monograph of Zygnemaceae in Australia by Lewis and Entwisle (2007) recognises only four species of *Mougeotia,* six taxa are judged doubtful and thirteen names rejected because of a lack of sufficient supporting information (Lewis and Entwisle 1998 provides further analysis of older records). As is often the case with preliminary and status reviews such as that of Lewis and Entwisle (1998), enthusiasm was engendered for wider collecting and testing of the taxonomic hypotheses. Based on collections since then, particularly around Darwin and in the Pilbara, a further 13 taxa of *Mougeotia* can be added to the algal flora of Australia.

Materials and Methods

As with Lewis and Entwisle (1998), this account is based solely on morphology revealed by light microscopy, with opportunities for molecular comparison curtailed because of resourcing constraints and most of the taxa being mixed collections preserved in alcohol. However we reiterate the point made in our previous floristic papers that this documentation and alignment against existing nomenclature is a necessary precursor to a more thorough analysis of the algal flora using a combination of molecular and morphological criteria.

Collections were either adventitious or part of larger vegetation surveys of rivers in the Pilbara and Darwin regions. Water quality data taken from the Aquatic Health Unit, Water Resources Division, Northern Territory Department of Land Resource Management and the Western Australian department formerly called the Department of Conservation and Land Management.

Most specimens were preserved as (semi-)permanent slides with material mounted in Karo, some accompanied by liquid collections preserved in 70% ethanol. Collections are all held in NSW.

Specimens were examined with a Leitz Laborlux D research microscope and drawing arm.

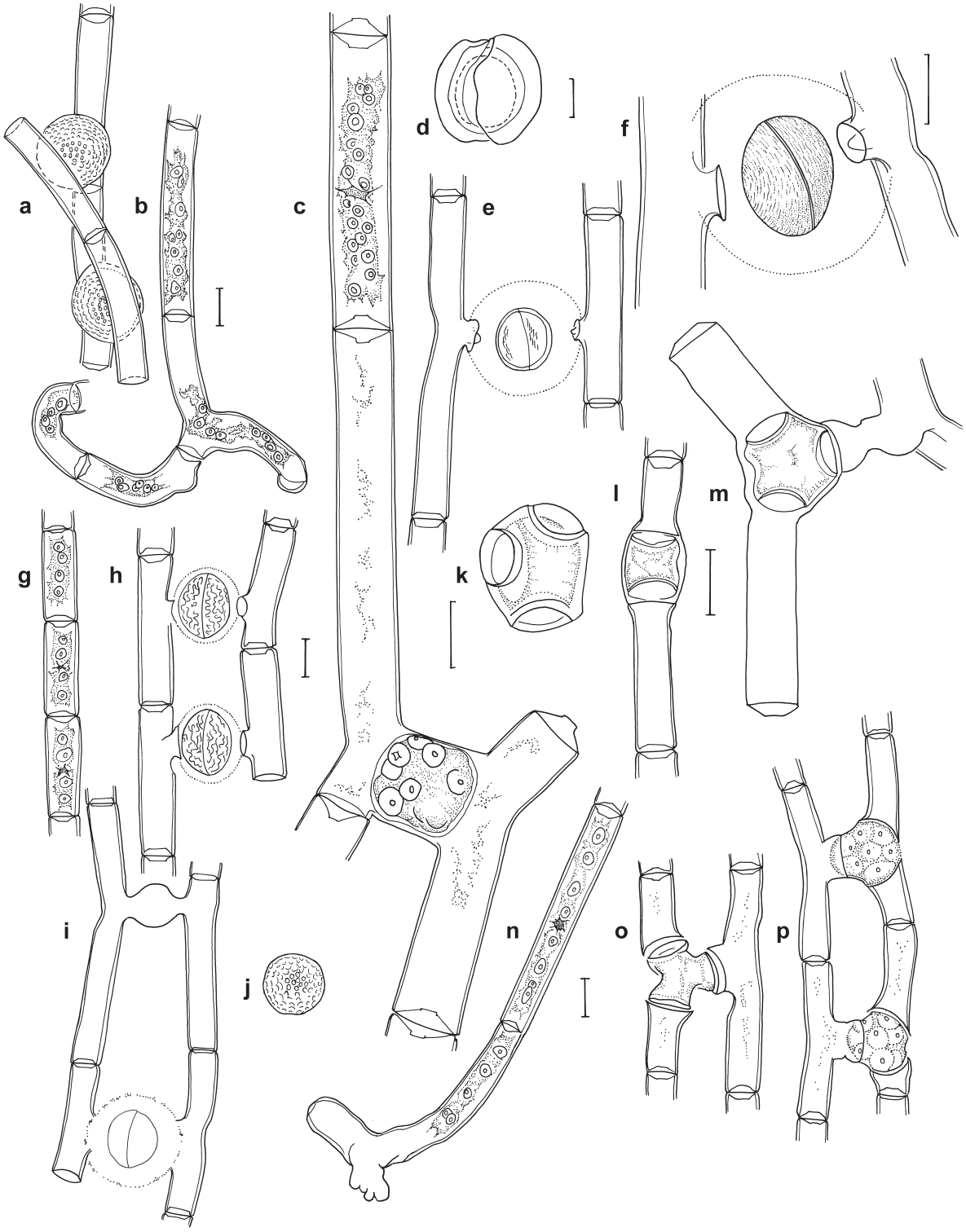

Figure 1. a, b: *Mougeotia nummuloides*, **a.**, zygospores; **b.** filament with rhizoids (Upper Snowy River, New South Wales, *Entwisle 3010*); **c, d:** *M. laetevirens*, **c.** developing zygote, **d.** free zygospore (Elizabeth River, Northern Territory, *A70*); **e, f:** *M. oedogonioides*, **e.** maturing zygospore (Quart Pot Creek, Howell, New South Wales, *Skinner 797*), **f.** mature spore, magnified (Kumina, Western Australia, *PSW580*); **g, h:** *M. viscosa*, **g.** vegetative filament, **h.** two zygospores (Mitchell Creek, Palmerston, Northern Territory, *A54*); **i, j:** *M. disjuncta*, **i.** conjugating filaments, **j.** zygospore; **k–m:** *M. transeauii*, **k.** free zygospore (Moolkin Creek, Western Australia, *P.G. Wilson s.n.*), **l.** autospore retained in cell (aquatic garden, Royal Botanic gardens, Sydney, New South Wales, *Skinner 544*), **m.** zygospore retained in conjugating cells (Moolkin Creek, Western Australia, *P.G. Wilson s.n.*); **n–p:** *M. longiarticulata,* **n.** rhizoidal base of vegetative filament, **o.** matured zygospore in conjugating filaments, **p.** maturing zygotes (Mitchell Creek, Palmerston, Northern Territory, *A54*). All scale bars 20 μm.

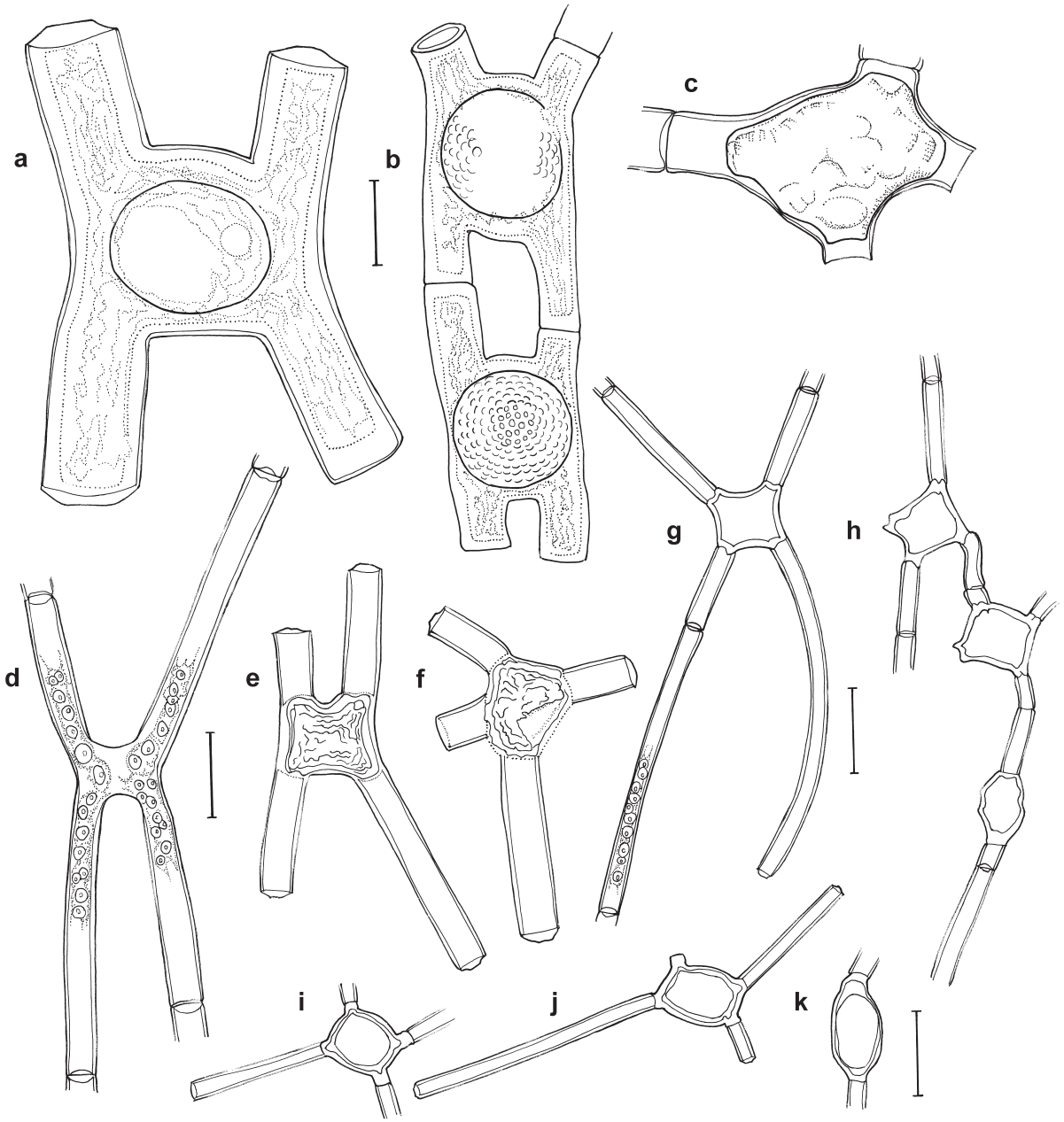

Figure 2. a. *Mougeotia sphaeocarpa*, mature zygospore (The Springs Creek, Western Australia, *PWS059c*); **b.** *M. drouetii* var. *djelkensis* two mature spores (Damidrum Billabong, Northern Territory); **c.** *M. capucina*, mature zygospore (Woronora River, Heathcote, New South Wales, *A.H.S. Lucas s.n.*); **d–f:** *M. tumidula* var. *palmerstoniana*, **d.** conjugating filament, **e,f,** zygospores (Mitchell Creek, Palmerston, Northern Territory, *A185*); **g, h:** *M. viridis*, **g.** single conjugation and vegetative cell (Bakers Creek, Inverell, New South Wales, *Skinner 790, McPherson and Towler*) **h,** zygotes in series (Douglas River, Northern Territory, *A123*); **i–k:** *M. trapaeziformis*, zygospores, (Bella Vista Waters, Baulkham Hills, New South Wales, *W.S. Rooney s.n.*).

Taxonomy

Mougeotia C.Agardh, *Systema algologia* 83 (1824) nom. cons.

Type species: *M. genuflexa* (Roth) C. Agardh

Worldwide there are 100-150 species of *Mougeotia*, although numbers remain uncertain because of uncertainty about the distinctions between species defined on morphological characteristics alone. Species complexes in *Spirogyra* are well documented (Hoshaw and McCourt, 1988) and there is a probability that they may occur in *Mougeotia*. Most Flora accounts group species into four sections based on the disposition of the zygospore or autospore at maturity (Czurda 1932; Kolkwitz & Kreiger 1941; Kadłubowska 1984). These sections have not been tested or supported by molecular analyses but continue to provide a convenient framework for the classification and identification of species in the genus.

For completeness, the four taxa documented by Lewis and Entwisle (2007) – *Mougeotia daytonae*, *M. parvula*, *M. quadrangulata* and *M. sinensis* – plus an additional species, *M. lamellosa* – added recently by Skinner (2015) are included in the key and the species list, but are not described or illustrated here, as those resources are readily avalible.

Key to Australian taxa of *Mougeotia*

1	Reproduction by autospore formation	Section **Gonatonema**
1*	Reproduction by zygospore formation through scalariform or lateral conjugation	2
2	Zygospore formed entirely in the conjugation tube (Section **Mesocarpus**)	4
2*	Zygospore formation wholly or partly involving gametangial cells	3
3	Zygospore formed in receptor gametangium and conjugation tube (Section **Plagiospermum**)	12
3*	Zygospore formed in conjugation tube and both gametangia (Section **Staurospermum**)	13
4	Zygospore retained in the conjugation tube	5
4*	Zygospore in gelatinous halo which replaces conjugation tube	10
5	Mesospore smooth	6
5*	Mesospore sculptured	7
6	Zygospore globose, 23–30µm diam.; vegetative cells 19–21µm diam.	*M. parvula*
6*	Zygospore cylindrical, spool-like, 27–50µm long, 34–45µm diam.; vegetative cells 23–30µm diam.	*M. laetevirens* var. *trochleifera*
7	Mesospore with small dimple (scrobiculate)	8
7*	Mesospore reticulate to wrinkled	9
8	Zygospore globose; exospore thin-walled; vegetative cells 10–16µm diam.	*M. nummularioides*
8*	Zygospore lozenge-shaped; exospore thick, laminated; vegetative cells 28–33µm diam.	*M. lamellose*
9	Vegetative cells 19–21µm diam.	*M. sinensis*
9*	Vegetative cells 30–37µm diam.	*M. daytonae*
10	Mesospore scrobiculate (with small dimples)	*M. disjuncta*
10*	Mesospore with reticulations or wrinkles	11
11	Specialised plates in residual end of conjugation tube; vegetative cells 16–18µm diam	*M. oedogonioides*
11*	Residual end of conjugation tube open; vegetative cells 14–18µm diam.	*M. viscosa*
12	Zygospores tricornuate; chloroplast with 8 pyrenoids	*M. transeauii*
12*	Zygospore trefoil; chloroplast with 10–14 pyrenoids	*M. longiarticulata*
13	Walls of gametangia thickened; contents becoming fibrous	14
13*	Walls of gametangia not or slightly thickened; contents not becoming fibrous	15
14	Mesospore scrobiculate; vegetative cells 12–16µm diam.	*M. drouetii* var. *djelkiensis*

14* Mesospore smooth or wrinkled; vegetative cells 18–20µm diam. ..... *M. sphaerocarpa*

15 Exospore only protruding into gametangia; mesospore smooth or finely punctate 16

15* Exospore and mesospore protrude into gametangia; mesospore lumpy or wrinkled 18

16 Mesospore smooth; vegetative cells <10µm diam..... 17

16* Mesospore finely punctate; vegetative cells 10–12µm diam. ..... *M. quadrangulata*

17 Vegetative cells 4.5–5.5µm diam.; exospore with single domes at corners ..... *M. trapiziformis*

17* Vegetative cells 6–9µm diam.; exospore with bifid corners ..... *M. viridis*

18 Buxiform zygospores with wrinkled mesospore; vegetative cells 11–14µm diam. ..... *M. tumidula* var. *palmerstoniana*

18* Irregular quadrate zygospore with lumps; vegetative cells 1416µm diam. ..... *M. capucina*

Section **Gonatonema** Wittrock

Reproducing by autospores only.

No species confirmed for Australia but see note under *Mougeotia transeauii*.

Section **Mesocarpus** (Hassall) Wittrock

Zygote formed entirely within the conjugation tube.

1. *Mougeotia parvula* Hassall, *Annals and Magazine of Natural History*, 11: 434 (1843). Lewis and Entwisle, *Zygnemaceae* 114 (2007)

2. *Mougeotia laetevirens* (A.Braun) Wittrock, in Wittrock and Nordstedt, *Algae exsiccatae*, No. 58 (1887)

Basionym: *Craterospermum laetevirens* A.Braun, *Algarum unicellularum genera nova* (1855)

2a. Mougeotia laetevirens var. trochleifera S.Skinner and Entwisle, **var. nov.**

Mougeotia laetevirens variatas laetevirens similis sed zygosporae ad trochleis nec pulvinatis necque cylindricis.

Type: Australia: Northern Territory: Elizabeth River, upstream of Stuart Highway (DW40), *Dostine, Metcalfe & Padovan A70*, 22 May 2003 (Holotype: NSW; Isotype: NT).

Vegetative cells cylindrical, 23–27(–30) µm diam. Length/Diameter (L/D) 8–12, end-walls biconvex; chloroplast broadly strap-shaped, pyrenoids large (c. 8 µm diam.) numerous, (6–)8–12 either side of pinch at nucleus in two irregular rows.

Conjugation regular scalariform; gametangia similar to vegetative cells. Conjugation tube at first cylindrical and equal from either side, becoming two wide clasps on either end of the zygospore, c. 20 µm diam., 25–30 µm long. *Zygospore* cylindrical, ends flat so appearing spool-like, occasionally somewhat crumpled across the middle, outer wall smooth, inner wall smooth, forming a thickened cylinder or disc round the spore, 27–50 µm between the two flat ends, 34–45 µm across the cylinder; walls and mesospore yellow. Fig. 1c, d

Etymology: *trochleifera*, from *trochlea*, *ae* a block or pulley.

Specimens examined: NORTHERN TERRITORY: Mitchell Creek, downstream of Lambrick Avenue (DW23), *Dostine, Metcalfe & Padovan A54*, 15 May 2003, *J. Schult* DW23-3, 24 May 2010 (NSW, NT) [pH 6.3–6.7; 72–451 µS·cm^{-1}; 1.7–8.0 NTU]; Elizabeth River, upstream of Stuart Highway (DW40), *Dostine, Metcalfe & Padovan A70*, 22 May 2003 [pH 6.8; 43 µS·cm^{-1}; 6 NTU] (NSW, NT); Amy Creek, (DW72) J. Schult DW72-2, 5 May 2010 [pH 7.6, 79 µS·cm^{-1}, 6.3NTU] (NSW, NT) Douglas River, 4.8 km upstream of Oolloo Road crossing, *Padovan & Metcalfe A 153* (NSW, NT) [pH 7.7; 41 µS·cm^{-1}; 3.2 NTU]. QUEENSLAND: Great Basalt Wall, near Burdekin River, pool, *J.W. Cribb 925,* 5 Sep 1981 (BRI).

Notes: *Mougeotia laetevirens* is the oldest described taxon within a species group of some complexity, as can be seen from the number of taxa listed in Table 1. The variety we propose here, *M. laetevirens* var *trochleifera*, has the spool-shaped spores seen in *M. opelousensis* and *M. acadiana*, although without the mesospore sculpturing. It may well, with them, turn out to be no more than a morphospecies within the complex centred on *M. laetevirens* and *M. varians* when genetic and molecular biological examinations have been completed. Other taxa also share some characteristics with the Australian collections. Indeed there are few clear disjunctions between any of these taxa so our inclination is to use the oldest available name, *M. laetevirens*, but to recognise the distinctiveness of such entities, possibly considering them of varietal status.

Although voucher specimens have not been examined, the report of *M. acadiana* from Kakadu by Ling and Tyler (1986), with vegetative cell diameter of 23–30 µm, is consistent with our new variety and that zygospore is described and illustrated with 'a circular flange on each end'. All the collections cited above show spool-like zygospores.

Table 1: Comparison of *Mougeotia* species with spool or similarly shaped zygospores

Species	Cell diam. (µm)	Pyrenoid number	Zygospore dimensions (µm)	mesospore
M. laetevirens var. ***trochleifera*** A54	23–27	c.12	30 x 34–43	smooth
M. laetevirens var. ***trochleifera*** A70	25–26	numerous	27–50 x 36–45	smooth
M. laetevirens var. ***trochleifera*** A153	25–30	12–16	48–55 x 25–30	smooth
M. laetevirens var. ***trochleifera*** Cribb 925.20 (BRI)	27–29	numerous	48–57 x 25–27	smooth
Australian material, summary	23–27(–30)	12–24, 2 rows	27–57 x 25–45	smooth
M. angolensis W & GS West	25–29	4–6, one row	19–21	smooth
M. laetevirens (A.Braun) Wittrock	(22–)34–41	numerous	36–60 x 45–75	smooth
M. varians (Wittrock) Czurda	25–27	numerous	48–60 x 64–78	smooth
M. acadiana Transeau	43–53	numerous	51–70 x 57–78	smooth
M. oblongata Transeau	19–22	6–12(–16), becoming scattered	28–36 x 47–58	exospore smooth, mesospore spotty
M. pseudo-opelousensis Gauthier-Lièvre	27–29	–	38–50 x 40–50	–
M. opelousensis Taft	25–30	6–12, one row	46–65 x 30–45	finely punctate
M. hupehensis Jao & Hu	27–30	6–12	50–57 x 54–56	–
M. guanahacabibensis Reith	26–35.5	6–25	34–54.5 x 39–78	–

Playfair (1918)'s description of *M. laetevirens* does not conform to our variety. Unfortunately Vial 158 in the Playfair collection at NSW has little recognisable algal matter, and both vial 328 and vial 332 have no preserved material of *Mougeotia* remaining, so we cannot confirm this identification. The collections by Bancroft sent to Moebius in the 1890s are now lost. Moebius (1892) gives the vegetative cell diameter as 34 µm, whereas Bailey (1893) illustrates Moebius' comments with an illustration of *M. laetevirens* var. *varians* of Wittrock and Nordstedt. The further comments in Bailey (1895) only confirm that the taxon was found at Burpengary on a second occasion. Lewis and Entwisle (1998) accept this and all other records of *M. laetevirens* from Australia. Based on the summary description in that paper we refer those records (from New South Wales and Queensland) to the type variety with caution until similar fresh material is collected.

3. *Mougeotia sinensis* L-C Li *Ohio Journal of Science*, 33: 152 (1933). Lewis and Entwisle, *Zygnemaceae*: 114 (2007)

4. *Mougeotia daytonae* Transeau, *Transactions of the American Microscipal Society*, 53: 219 (1934). Lewis and Entwisle, *Zygnemaceae*: 113 (2007).

5. *Mougeotia nummularioides* (Hassall) De Toni *Sylloge Algarum*, I:713 (1889)

Syn: *Mesocarpus nummularioides* Hassall, *A History of British Freshwater Algae*:169 (1845)

Type: Kent, England. BM?, n.v.

Illustration: *op. cit.* Pl 45, fig. 1.

Vegetative filaments narrow; cells 10–12(–16) µm diameter, L/D 3.5–7; end-wall lenticular; chloroplast ribbon-like, sometimes twisted, with 3–8 prominent pyrenoids; nucleus central but laterally disposed.

Conjugation scalariform but irregular, conjugation external; donor and receptor cells indistinguishable, kinked inwards at off-centre conjugation point; conjugation tubes short, sloping towards spore, from both cells; Zygospore depressed globose to almost thickly discoid, shortly but broadly elliptical in face view, with a thick outer wall, irregularly scrobiculate, contents golden, 27–30 µm diam., 30–36 µm long, at least 15 µm thick. Fig. 1a, b.

Specimens examined: NEW SOUTH WALES: NORTHERN TABLELANDS: Quart Pot Ck, Howell, *Skinner 0797, McPherson & Towler*, 13 Oct 2004 (NSW). SOUTHERN TABLELANDS: Upper Snowy River, *Entwisle 3010*, 17 Jan 2000 (NSW).

Notes: The scrobiculate zygospores place these collections in *M. nummularioides* rather than the otherwise similar *M. parvula*.

6. Mougeotia lamellosa Jao, *Sinensia*, 6: 557(1935). Skinner, *Telopea*, 18: 276 (2015)

7. *Mougeotia disjuncta* Transeau, *Transactions of the American Microscipal Society* 53: 222 (1934)

Type: United States of America: Fort Myers, Florida, *Tiffany* 128, (Ohio?) n.v.

Vegetative cells cylindrical, narrow, 12.5–14 µm diam., L/D 8–20; end-wall biconvex, flat across the middle third; chloroplast narrow ribbon, 2–8 pyrenoids, size variable, equal numbers on either side of middle thickening.

Conjugation scalariform, more or less regular, gametangia as vegetative cells, empty. Conjugation tube at first a pair of shallow cups around zygote, then a halo of mucilage 10–12 µm thick. *Zygospore* globose to depressed globose, 25–30 µm diam., c. 23 µm thick, outer wall smooth, with an equatorial band, inner wall finely pitted, mesospore dirty yellow to yellow-black. Fig. 1i, j.

Distribution: USA, China; a new record for Australia.

Specimens examined: NORTHERN TERRITORY: Mitchell Creek, down-stream of Lambrick Avenue (DW23), *Dostine, Metcalfe & Padovan A8*, 13 May 2002, *Dostine, Metcalfe & Padovan A52, 54*, 15 May 2003, and *Dostine, Metcalfe & Padovan A184*, *185*, *187*, 27 Apr 2004 (NSW, NT) [pH 6.3–6.7; 72–451 µS·cm^{-1}; 1.7–7.8 NTU].

Notes: the conjugation canal diffuses back to short raised rings outside the inner gametangial walls as described for *M. disjuncta* and associated taxa (*M. japonica* Yamagishi, *M. gelatinosa* Wittrock, and *M. fujianensis* Zheng & Chen). The dimensions of these collections most closely fit *M. disjuncta*, although the vegetative cell width is narrow and the spore colour may be rather darker than described in Transeau et al. (1934), and Transeau (1951).

8. *Mougeotia oedogonioides* Czurda, *Beihefte zum Botanischen Zentralblatt*, 48: 21, pl.1, fig. 3 (1931).

Type: near Aksai-Chin Lake at 5100m, Tibet, n.v.

Illustration: Czurda (1932): Fig. 65.

Vegetative cells 16–18 µm diam., L/D 8–20, chloroplast axile, serrated laminate, pyrenoids 3–8, scattered, end-wall biconvex.

Conjugation scalariform; conjugation tube ends with inner wall conical, outer wall as sheath; zygospore in gelatinous halo (c. 15 µm radius), globose to subglobose, 24–30 µm diam., mesospore thick, opaque. Fig.1e, f.

Distribution: new record for Australia; Tibet and Bangladesh.

Specimens examined: WESTERN AUSTRALIA: Kumina Creek, *Lyons s.n.*, 4 May 2005 [pH7.8–8.6; 491–658 µS·cm^{-1}; 0.4 NTU]; Innawally Pool, Jimblebar Creek, *Mickle & Dunlop s.n.*, 24 Apr 2006 [pH 8.4–8.5; 230–289 µS·cm^{-1}; 11–25 NTU]; Panorama Spring, *Mickle & Huang s.n.*, 22 May 2006 [pH 8.2–9.0; 1080–1420 µS·cm^{-1}; 0.9-4.6 NTU].

NEW SOUTH WALES: NORTHERN TABLELANDS: Quart-Pot Creek, Howell, *Skinner 797, McPherson & Towler*, 13 Oct 2004 (NSW).

Notes: The Quart-Pot Creek material produced zygospores without wrinkling of the mesospore and the dimensions are closer to those for a variety described by Islam (1972). However without further material we have referred this collection to the type variety

9. *Mougeotia viscosa* Jao & Hu, *Ocean. Limn. Sinica*, 10: 24, pl. 1. (1979)

Type: Fuzhou, Fujian Province, China. n.v.

Illustration: Jao (1988): Pl XV, fig 1.

Vegetative cells 14–18 µm diam., L/D 4–7, plane end-walls; chloroplast with 2–5 (or 6) pyrenoids, often unequally distributed relative to the central nucleus.

Conjugation scalariform; conjugation tube forms a spherical structure which later becomes a gel halo; zygospore depressed globose with equatorial ring parallel to the filament, exospore clear, smooth, mesospore wrinkled, yellow becoming translucent black, 25–27 µm diam., 23 µm long. Fig. 1g, h.

Distribution: China, reported here for Australia.

Specimen examined: NORTHERN TERRITORY: Mitchell Creek, downstream of Lambrick Avenue pumping station, Rosebury, *Dostine, Metcalfe & Padovan A54*, 15 May 2003 [pH 6.3–6.7; 72–451 μS·cm^{-1}; 1.7–7.8 NTU]

Notes: In Jao (1988) the zygospore sculpture is described as reticulate, rather than wrinkled, as described above, but otherwise the Australian material conforms closely to the protologue and subsequent descriptions by Jao. The dimensions of the Mitchell Creek collections overlap a little with *M. disjuncta*, but the spore is depressed globose, and dirty yellow-black, not chestnut brown as described in Transeau et al. (1934), and Transeau (1951).

Section **Plagiospermum** (Cleve) Wittrock

Zygospores formed in the receptor gametangium and the conjugation tube.

10a. *Mougeotia transeaui* Collins, *Tufts College Studies, Science Series* 3: 77 (1912), typical form.

M. tenuis (Cleve) Wittrock, *Bihang Til Konglinga Svenska Vetenskaps-Akademien Handlingar* 1: 39 (1872)

M. abnormis Kisselev, *Bulletin de la Section Ichthyologie applique Etudes scientifique-industriale (Universite)* 5: 301, Pl.1, fig. 6 (1927)

Basionym: *Plagiospermum tenue* Cleve, Försök till en monografi öfver de Svenska arterna af Algfamilien Zygnemaceae *Nova Acta reg Societe scientific Upsaliensis*, 3 (6): 35 (1868)

non *M. tenuis* Kützing, *Species Algarum*: 434 (1849) = *M. scalaris* Hassall, *Annals and Magazine of Natural History* 10: 45 (1842)

Type:? Sweden.

Vegetative cells 14–17 μm diam., 10 or more times longer than wide, strap chloroplast with up to 8 pyrenoids.

Conjugation mostly scalariform; donor and receptor cell as vegetative cells, conjugation tube from both gametangia, up to 20 μm long. Zygospore formed in receptor cell and receptor half of conjugation tube, tricornuate, 28–30 μm across gametangial axis, 30–31 μm along conjugation tube axis, exospore clear, with concavities set obliquely to both halves of receptor gametangium and perpendicular to conjugation tube; mesospore shortly conical-ovoid, flat end towards conjugation tube, pale golden. Fig. 1k, m.

Distribution: widespread; a new record for Australia. Lewis and Entwisle (2007) conclude that the collection of *M. tenuis* mentioned in the 1882 correspondence between von Mueller and Kützing refers to *M. scalaris* in the sense that Kützing used the name *M. tenuis*.

Specimens examined: WESTERN AUSTRALIA: Macklin Creek system, 23.3 km W of the Robe River Railway crossing on the Pannawonica road. *P.G. Wilson* s.n., 12 Jun 2006 (NSW); The Springs Creek, *Gibson s.n.*, 15 Sep 2004 [pH 8.3–8.6; 1168–1738 μS·cm^{-1}; 0.5–4.5 NTU]; Nyeetbury Pool, Jimmawurrada Creek, *Lyons & Mickle s.n.*, 14 May 2005 [pH 7.5–8.0; 824–905 μS·cm^{-1}; 0.025–0.6 NTU]; Kumina Creek, *Lyons s.n.*, 4 May 2005 [pH7.8–8.6; 491–658 μS·cm^{-1} ;0.4 NTU]; Innawally Pool, Jimblebar Creek, *Mickle & Dunlop s.n.*, 24 Apr 2006 [pH 8.4–8.5; 230–289 μS·cm^{-1} ; 11–25 NTU]; Panorama Spring, *Mickle & Huang s.n.*, 22 May 2006 [pH 8.2–9.0; 1080–1420 μS·cm^{-1} ; 0.9-4.6 NTU]; Jofie Creek, Karijini National Park, *Lyons, Mickle & Casanova s.n.*, 18 Aug 2006 [pH 6.8–7.6, 313–955 μS·cm^{-1}; 0.025–0.8 NTU].

Notes: The diameter of the vegetative cells in our specimens is large for *M. transeaui* sensu Transeau (1951), Gauthier Lièvre (1965) and Islam (1972), and there are frequently 10–14 pyrenoids present in the chloroplast. The Western Australian material matches more closely the illustrations in Islam (1972) for zygospore shape, and the range of form and dimensions described in Czurda (1932).

There has been considerable disagreement in the literature as to the valid name for this taxon. Czurda (1932) used *M. tenuis*. Transeau in Transeau et al. (1934) noted that *M. tenuis* and *M. transeaui* were synonyms, and described three similar taxa, *M. reinschii* for forms with cell diameter 9–13 μm, *M. floridiana* for forms with cell diameter 14–20 μm, and *M. poinciana*, with cell diameter 21–25 μm. Kolkwitz and Kreiger (1941) using the name *M. abnormis* Kisselev, provided a detailed synonymy, and dismissed the Collins name and description as incomplete (Kolkwitz and Kreiger 1941, page 195) and included *M. floridiana* in *M. abnormalis*. Jao (1988) follows suit. Transeau (1951), Randawa (1959), Gauthier Lièvre (1965) and Kadłubowska (1984) all use *M. transeaui*. As this is the Type for the Section *Plagiospermum* it is notable that there is no mention of nomenclatural difficulties with this species in Kadłubowska (1983).

10b. *Mougeotia transeaui*, aplanosporic form. Transeau, *Zygnemataceae* : 104 (1951)

M. tenuis, 'azygoten' Czurda, *Zygnemales*: 81, fig. 66b, c (1932).

Vegetative cells narrow, regular cylindrical, with diamond shaped lenticular end-walls, 10–12 µm diam., (75–)80–120(–130) µm long, chloroplast of two equal, slightly undulate, laminar axial plates, 4 pyrenoids (3–6 µm diam.) in each half.

Reproduction by aplanospores (or parthenospores); most, but not all, contents of each cell in a filament individually aggregate in the central region, which becomes inflated and forms a capsule about 20 µm across and 24–28 µm long; *spore* like an imploded barrel, exospore clear, mesospore golden-green to gold, 18–23(–27) µm long, 16–17 µm diam. Figure 1, l.

Specimen examined: NEW SOUTH WALES: Central Coast: water-gardens beside the nursery, Royal Botanic Gardens, Sydney, *Skinner 544*, 18 Feb 2002 (NSW); Lake Nadungamba, Australian Botanic Gardens, Mount Annan, *J. Ling s.n.*, 22 Oct 2001 (NSW).

Notes: The shape of the aplanospore resembles a cylindrical version of the tricornuate zygospores of *M. transeaui*, but also has similarities to the zygospores of *M. boodlei* (W.West & G.S.West) Collins and *M. ventricosum* (Wittrock) Collins. We have decided to include these collections in *M. transeauii* as they fit the description in Transeau (1951) and the illustrations in Czurda (1932).

Kennedy and Hoshaw (1975) provide a detailed study into the life history of this interesting species, with reference to its anisogamy and the conditions that induce both sexual and asexual spore formation.

11. *Mougeotia longiarticulata* Islam, *Nova Hedwigia* 24: 656 (1972).

Type: Bangladesh, shallow pond filled with aquatic grasses and paddy, Nayarhat, Dacca district, *A.K.M.N. Islam 44*, 27 Dec 1964: Botany Department, University of Dacca.

Illustration: op cit: Plate 6, figs 43–46, 48.

Vegetative cells cylindrical, 11–16 µm diam., 90–180 µm long, end-wall plane; chloroplast single, entire, strap-like, (6–)10–14 pyrenoids (c. 9 µm diam., incl. starch halo) in a row.

Conjugation regular scalariform, fragmentary after maturity. Conjugation tube cylindrical c. 15 µm diam., c. 30 µm long. *Zygospore* truncated triangular (trefoil) extending into conjugation tube 0.3–0.5 tube length, pale golden, 17–30 µm long, 23–30 µm diam. Fig 1n–p.

Distribution: in Australia, the Northern Territory; Bangladesh & China.

Specimens examined: NORTHERN TERRITORY: Mitchell Creek, down-stream of Lambrick Ave, (DW23), *Dostine, Metcalfe & Padovan s.n.*, 13 May 2002; *Dostine, Metcalfe & Padvan A54*, 15 May 2003 (NSW, NT) [pH 6.3–6.7; 72–451 µS·cm^{-1}; 1.7–7.8 NTU]; Berry Creek, upstream of gauging station. (DW31), *Dostine, Metcalfe & Padovan A77*, 23 May 2003 [pH 7.2; 238 µS·cm^{-1}; 3 NTU] (NSW, NT).

Notes: The zygospores in the Australian material may be turgid or somewhat shrivelled probably indicating different levels of maturation at the time of fixing. The photomicrograph Islam (1972) Pl. 13, fig. 68 shows the distinctive spore of *M. longiarticulata* well. Material from Mitchell Creek and Berry Creek fits well with *M. longiarticulata* although not showing the pronounced donor conjugation tube as Islam (1972) described for his type variety, but nearer fa. *brevis* Islam described below it. Jao and Hu (1979) give the range of pyrenoids for Chinese material *of M. longiarticulata* as 4–10, while some Northern Territory specimens showed as many as 14. The range in number of pyrenoids may be rather plastic in this taxon.

This is probably the same taxon referred to *M. poinciana* Transeau by Ling and Tyler (1986), a determination rejected by Lewis and Entwisle (1998) on several grounds including the cellular and reproductive dimensions. The description in Transeau et al. (1934) for *M. poinciana* is illustrated with zygospores having six sides. The illustration of the Ling and Tyler indicates three sides to the zygospore, while the material is slightly larger in dimensions to other northern Australian collections, here referred to *M. longiarticulata*.

Section **Staurospermum** (Hassall) Wittrock

Zygospore formed in the conjugation tube and both gametangia.

12. *Mougeotia sphaerocarpa* Wolle, *Freshwater Algae of the United States*, 227, Plate 146, figs 1 & 2 (1887)

Mougeotia sestertisignifera S.Skinner (1983) *Transactions of the Royal Society of South Australia*, 107: 225, Figure 2A–C.

Type: not specified.

Vegetative cells, 18–20(–26) µm diam., L/D 6–10 or more, end-walls biconvex; chloroplast broad, strap-like, with 4–10 pyrenoids, scattered, and a distinct median notch for the nucleus.

Conjugation scalariform; conjugation tube persistent, inflated, mature zygospore including all arms of the gametangia, with spherical to depressed globose mesospore filling the conjugation tube and reaching the outer lateral walls of the gametangia. Walls of gametangia thickened, contents replaced with dark, fibrous material; mesospore smooth, pearly, 45-49 μm diam. Fig 2a.

Distribution: South America, central Asia and Australia.

Specimens examined: WESTERN AUSTRALIA: Palm Spring, on the line of Cave Creek, *Lyons, Mickle & Casanova s.n.,* 21 Aug 2006 [pH 7.9–8.4; 3270–3380 μS·cm^{-1}; 0.2–1.4 NTU]; creek pool near Mt Amy, *Gibson & Mickle s.n.*, 16 Sep 2004 [pH 8.0–8.4; 4140–6010 μS·cm^{-1}; 1.0–1.6 NTU]; Erawallana Spring, *Gibson & Mickle*, 30 Sept 2004; The Springs Creek, *Gibson s.n.*, 15 Sep 2004 [pH 8.3–8.6; 1168–1738 μS·cm^{-1}; 0.5–4.5 NTU]; Panorama Spring, *Mickle & Huang s.n.*, 22 May 2006 [pH 8.2–9.0; 1080–1420 μS·cm^{-1}; 0.9-4.6 NTU]. SOUTH AUSTRALIA: Ibis Rookery, Bool Lagoon, *Roberts & Preece s.n.*, 5 Nov 1982 (AD). NEW SOUTH WALES: South West Slopes: Lake Wyangan, W of Griffith, *Skinner 361, Arnold & Towler*, 23 Sep 2001 (NSW).

The vegetative cell dimensions in Australian material cover broader forms of *M. drouetii* as well as *M. sphaerocarpa*. Wolle (1887) does not mention fibrous inclusions in the gametangia. Randhawa (1959, Fig. 21c) illustrates some inclusions in the arms of the gametangia for *M. sphaerocarpa.* Jao (1988) describes and illustrates *M. sphaerocarpa* with fibrous material retained in the gametangia, and his taxon has dimensions similar to our collections.

13. *Mougeotia drouetii* Transeau, *American Journal of Botany*, 25: 524, Fig. 1. (1938)

Type: pond near Porangaba, Caera, Fortaleza, Brazil, *F. Drouet 1463*, 14 Oct 1935 (US)

13a *Mougeotai drouetii* var. *djelkiensis* S.Skinner and Entwisle, **var. nov.**

Mougeotia drouetii variatas drouetii similis sed angustiorae cellulae diametri 12–15 μm mesosporaeque vardosae scrobiculatae.

Type: Damdam Billabong, Djelk Indigenous Protected Area North-Central Arnhem Land, *G.M. Towler 600,* 7 Oct 2009 (NSW).

Vegetative filaments narrow; cells 12–13.5(–15) μm diam., L/D 5–10, end-wall biconvex; chloroplast ribbon-like, with 4 pyrenoids in a row; nucleus central but laterally disposed.

Conjugation scalariform in groups of less than 10; conjugation tube persistent, mature zygospore includes all four arms of the gametangia. Contents of the arms replaced by tan coloured fibrous material; mesospore spherical to depressed globose, finely covered with shallow, small scrobiculate, 28–29 μm x 23–27 μm diam., c. 32 μm thick. Fig. 2b.

Distribution: Northern Territory, known only from the Type locality.

Etymology: *djelkiensis* from Djelk Indigenous Protected Area, as a compliment to the local people who asked for the algal vegetation of the area to be collected and identified.

Specimen examined: only known from the Type collection.

Notes: This taxon differs from both *M. sphaerocarpa* (vegetative cells 17–28 μm diam.) and *M. drouetii* Transeau (vegetative cells 15–18 μm diam.) in vegetative cell diameter and also in having a finely dimpled mesospore. Like *M. drouetii* it has thickened gametangial arms so we have described it as a new variety of that species.

There are several taxa described from various parts of the planet in the *M. sphaerocarpa* group, as was noted by Transeau (1938) in his protologue for *M. drouetii*. Given the general similarity in vegetative characters, both *M. drouetii* and *M. drouetii* var. *djelkiensis* may form a species complex around *M. spherocarpa*. The scrobiculate sculpturing of *M. drouetii* var. *djelkiensis* is quite distinctive, but it obviously sits in this complex, next to the nominate variety. *Mougeotia sestertisignifera* is clearly based on immature material and so is relegated to synonomy with *M. sphaerocarpa*.

14. *Mougeotia quadrangulata* Hassall, *Annals and Magazine of Natural History*, 12: 434 (1843). Lewis and Entwisle *Zygnemaceae*: 114, fig. 33A (2007).

15. *Mougeotia trapaeziformis* Iyengar, *Phykos*, 2: 57 (1963)

Type: Quarry pool, Bangalore, Mysore State, India (Iyengar collection) n.v.

Illustration: op. cit., Fig. 137.

Vegetative cells narrow, 4.5–5.5 µm diam., L/D > 10 (41–68 µm long); chloroplast strap-like, 2–4 pyrenoids.

Conjugation scalariform; conjugation in tube and immediate gametangia. Exospore clear to pearly, ovoid to buxiform, with four short projections into gametangia, transverse axis 26–29(–31) µm diam., by 24–26 µm long, by c. 21 µm thick; mesospore smooth, layered, ovoid (ellipsoid in side view) with rounded projections into exospore arms, outer layer brown, inner layers yellow. Fig. 2i–k.

Distribution: India, newly reported from Australia.

Specimen examined: NEW SOUTH WALES: Central Coast: head of Strangers Creek, Bella Vista Waters (Baulkham Hills), *W.S. Rooney s.n.,* 2 Jul 2004 (NSW).

Notes: Although the zygote in this species is encased in a pectin exospore, the gametangial arms are hollow with occasional residues, characteristic of *Mougeotia* rather than *Debarya*.

Although the vegetative material fits published descriptions of *M. trapaeziformis*; zygospores produced in material from New South Wales are large, but similar in form to those described by Iyengar (1963). They are also larger than described for the similar species *M. corniculata* Hansgirg in Kolkwitz and Kreiger (1941).

16. *Mougeotia viridis* (Kütz.) Wittrock, *Bihqng til Konglinga Svensk Vetenskaps-Akademiens Handlinger* 1: 39 (1872)

Staurospermum viride Kützing, *Phycologia Generalis*: 278 (1845)

Type: not specified?

Vegetative cells very narrow cylindrical, 6–9 µm diam., L/D 8–11, endwall plane; chloroplast strap-like, 3–6 pyrenoids either side of central pinch for nucleus.

Conjugation irregular scalariform; gametangia similar to vegetative cells, separated into four short empty chambers as conjugation tube forms a rectangular biconvex chamber between filaments. Zygospore quadrate in face view, more or less lozenge shaped in side view, 20–29 µm long, 18–24 µm diam., 18–23 µm thick, exospore smooth, clear, sometimes slightly horned; mesospore brown, often with two- to three-cornered concave projections. Fig. 2g, h.

Distribution: in Australia, Northern Territory, Victoria and New South Wales; Europe, Asia, North Africa and North America commonly in moorland.

Specimens examined: NORTHERN TERRITORY: Douglas River, upstream of Douglas Hot Springs, *Padovan & Metcalfe A123*, 20 Aug 2003 [pH 6.7; 30 µS·cm^{-1}; 3.7 NTU] (NSW).

NEW SOUTH WALES: Northern Tablelands: Bakers Creek, near Bundarra, *Skinner 790, McPherson & Towler*, 13 Oct 2004 (NSW).

Notes: Although *Mougeotia viridis* has been reported previously from Victoria (West 1909) and New South Wales (May 1972, Noble and Happy-Wood 1987) no voucher material was located at MEL or NSW. According to Czurda (1932), *Mougeotia virescens* (Hassall) Borge differs from this species in having rounded horns on the mesospore and slightly broader vegetative cells (8–9 µm). We can find no report of the number of pyrenoids for *M. virescens*, but *M. viridis* has 4(–8) pyrenoids. The Bakers Creek material shows 10–12 pyrenoids per chloroplast, and cell widths of 7–9 µm.

17. *Mougeotia tumidula* Transeau, *American Journal of Bot*any 1: 297 (1914)

Type: Embarras River, Wheeler, Illinois, USA, Sep 1911; *ENT No. 744*.

Illustration: op. cit. Pl. XXVIII, fig. 4.

17a. *Mougeotia tumidula* var. ***palmerstoniana*** S.Skinner and Entwisle, **var. nov.**

Type: Northern Territory: Mitchell Creek, *Dostine, Metcalfe & Padovan A187*, 27 Apr 2004 (holotype: NSW, isotype: NT).

Ad Mougeotia tumidula var. tumidula similis sed cellulis 11–14 µm diametricis multis cum pyrenoidibus atque tota in cubiculum zygospora mesosporaque corrugata.

Vegetative cells cylindrical, L/D +10, 11–14 µm diam., chloroplast strap-like, irregular double row of 14–20 variable pyrenoids (3–7 µm diam.); rhizoidal cell with curved end and short processes.

Conjugation scalariform, twisted; gametangia similar to vegetative cells, separated into four chambers by zygote. Conjugation tube forming a slightly opaque box around zygote, extending into both gametangia, 23–25 µm diam., c. 27–30 µm long. *Zygospore* rectangular cuboid, mesospore, and sometimes exospore corrigated, often with pointed corners, mesospore pale yellow to golden, 20–23 µm diam., 27 µm long, c. 7–8 µm thick, released at maturity. Fig. 2d–f.

Distribution: Australia, the Northern Territory.

Etymology: Mitchell Creek is a prominent waterway in the district of Palmerston in Darwin, capital of the Northern Territory.

Specimen examined: NORTHERN TERRITORY: Mitchell Creek, downstream of Lambrick Avenue (DW23), *Dostine, Metcalfe & Padovan A8* , 13 May 2002, *Dostine, Metcalfe & Padovan A52*, *55*, 15 May 2003, *Dostine, Metcalfe & Padovan A184, 185, 187*, 27 Apr 2004 [pH 6.3–6.7; 72–451 µS·cm^{-1}; 1.7–7.8 NTU] (NSW, NT).

Notes: The mesospore in these specimens is coloured but often faintly so. However, Transeau (1951) notes *M. tumidula* and *M. punctata* mesospore walls are colourless and Jao (1988) describes his *M. subpunctata* as having a colourless mesospore wall. While similar in form to both *M. punctata* Wittrock sensu Kolkwitz and Krieger (1941) and *M. tumidula*, the vegetative cells are wider and contain chloroplasts with many more pyrenoids than described for either of those taxa. There are no distinct punctae on the mesospore, and the conjugation tube forms a distinct capsule round both the mesospore and the exospore.

Kadłubowska (1984) separates *M. tumidula* from *M. punctata* by its distinct punctae on the mesospore, while *M. punctata* has small scrobiculae, referring to Krieger's illustration from Kolkwitz and Krieger (1941). It may well be that Kolkwitz and Krieger (1941) are correct in making these two taxa conspecific, but it would require examination of Type material. Note also the distinction made by Jao (1947) between these two taxa and *M. subpunctata* Jao, where the Chinese taxon was smaller in general than either of the others, and the zygospore was concave, rather than tumid to convex.

Table 2. Some taxa in the *Mugeotia punctata* complex.

Name	Diameter of vegetative cells (µm)	Zygospore description
M. punctata	8–12	Small dimples; bifid horns
M. tumidula	6–9	Large spots; bifid horns
M. producta G.S.West	7–8	Finely spotted but smooth; short flat topped horns
M. subpunctata	5–6.5	Minutely punctate; bifid horns

Mougeotia tumidula var. *palmerstoniana* appears, without molecular biological and genetic examination, to be a distinct entity within the *M. tumidula–M. punctata–M. producta* group. In the Floras there is much disagreement as to the actual limits of these three taxa, and their various subspecific forms.

18. *Mougeotia capucina* (Bory) C. Agardh, *Systema Algarum*: 84 (1824)

Basionym: *Leda capucina* Bory, in Mougeot and Nestler, *Stirpes cryptogamae vogeso-rhenanae*, No. 793 (1824)

Type: France, PC., exsiccata widely distributed. n.v.

Vegetative cells L/D 5–10, 18–23 µm diam.; end-walls plane; chloroplast ribbon with 6–8 pyrenoids in a row.

Conjugation scalariform, involving one or two pairs of cells, not long ladders. Zygospore squatly cruciate or irregular cuboid, with terminal concavities on some arms, 50–68 x 89–93 µm; exospore clear, mesospore irregularly undulate, rose-pink. Fig. 2c.

Distribution: Europe, the Americas and Africa as well as some Pacific islands, in Australia only reported from New South Wales (Lucas in Maiden 1915).

Specimens examined: NEW SOUTH WALES: Central Coast: Creek, Woronora River, Heathcote, *A.A. Hamilton s.n.*, 4 Oct 1915 (NSW); Creek, Heathcote, running water, attached at base, *A.H.S. Lucas s.n.*, 9 Oct 1915 (NSW).

Notes: The Australian collections are relatively well preserved, and although chloroplast morphology is lost and many cells are split lengthwise, the spores are squatly cruciate, making Lucas' determination reasonable when compared with *M. capucina* in Kadłubowska (1984). Lewis and Entwisle (1998) failed to find spores in the material they examined.

Discussion

Repeated surveys of the same waterways across a number of years in the Pilbara (Western Australia) and the 'Top End' (Northern Territory) have provided ten of the 13 new records. Not only have these taxa been located in a fertile state, but almost all of them have been found at more than one location and in successive seasons. It is to be hoped that similar surveying will occur throughout the continent in coming years. As the occasional tentative assignment indicates, there are likely to be more representatives of *Mougeotia* in Australia even within the collections already to hand. With further collecting, perhaps inspired by this paper as we and others were by Lewis and Entwisle (2007), there are almost certainly undiscovered taxa to find. A molecular study of the Australian 'silkweeds' (*Mougeotia* and its relatives in the family Zygnemaceae) would most likely reveal more taxa but also perhaps demonstrate some synonymy among those here delineated.

As a parting remark, fate can be kind. The badly muddled description in Skinner (1978) of a single *Mougeotia* species from Quart-Pot Creek, Howell in New South Wales, can now be corrected. Material from the same locality, collected as part of the Border Rivers survey in 2004, demonstrate there are two taxa in that pristine creek (*Mougeotia nummularioides* and *M. oedogonioides),* each fitting part of the muddled description.

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References:

Bailey FM (1893) Contributions to the Queensland Flora. Botany Bulletin No. VI Department of Agriculture, Brisbane

Bailey FM (1895) Contributions to the Queensland Flora Botany Bulletin No. XI, Department of Agriculture, Brisbane

Borge O (1913) Zygnemales in Pascher, A. *Dei Susswasser-flora Deutschlands, Osterreichs und der Schweiz.* Verlag von Gustav Fischer, Jena

Czurda V (1932) Zygnemales in Pascher, A. *Dei Susswasser-flora Mitteleuropas* Verlag von Gustav Fischer, Jena

Gauthier-Lièvre L (1965) *Zygnemacees Africaines* Beihefte Nova Hedwigia, 20: 1–210

Hoshaw RW, McCourt RM (1988) The Zygnemataceae (Chlorophyta): a twenty-year update of research *Phycologia*, 27: 511–548 http://dx.doi.org/10.2216/i0031-8884-27-4-511.1

Islam AKM (1972) New and rare species of some green algae from Bangladesh *Nova Hedwigia,* 24: 655–678

Iyengar MOP (1963) Latin Diagnoses of New Taxa of Zygnemales Phykos, 2: 54–62

Jao C-C (1947) Studies on Freshwater Algae of China. XV Oedogoniaceae and Zygnemataceae from Kwangsi. *Botanical Bulletin of Academia Sinica*, 1: 81–102

Jao C-C (1988) Zygnemataceae in Jao, C-C *Flora Algarum Sinicarum Aquae Dulcis* Science Press, Beijing

Jao C-C, Hu H (1979) Studies on the Zygnemataceae of China, II *Oceanologia et Limnologia Sinica*, 10: 24–27

Kadłubowska T (1983) On changes in the nomenclature of some taxa of Zygnemaceae. *Acta Societatis Botanicorum Poloniae*, 52: 315–320 http://dx.doi.org/10.5586/asbp.1983.035

Kadłubowska T (1984) Conjugatophyceae 1 in Ettl, H, Gerloff, J, Heynig, H, Mollenhauer, D. *Susswasserflora von Mitteleuropa* Gustav Fischer Verlag, Jena

Kennedy FGR, Hoshaw RW (1978)Culture studies of reproductive cycles and systematics in *Mougeotia transeauii* (Chlorophyta). *Journal of Phycology*, 14: 445–450 http://dx.doi.org/10.1111/j.1529-8817.1978.tb02466.x

Kolkwitz R and Krieger H (1941) Zygnemales in *Rabenhorst's Kryptogamenflora von Deutschland und der Schweiz*. Akademische Verlagsgesellschaft Becker and Erler, Leipzig

Lewis SH, Entwisle TJ (1998) Zygnemataceae (Chlorophyta)in Australia: a reassessment of records and a key to accepted taxa. *Muelleria*, 11: 51–93

Lewis SH, Entwisle TJ (2007) Zygnemaceae, *Algae of Australia: Batrachospermales, Thoreales, Oedogoniales and Zygnemaceae*, 112–155

Ling H, Tyler PA (1986) *A limnological survey of the Alligator Rivers Region* Part II: freshwater algae exclusive of diatoms. Research Report 3 Australian Government Publishing Services, Canberra

Maiden JH (1915) *Annual Report for The Botanic Gardens*. 1915 Government Printer, Sydney

May V (1972) Blue-green algal blooms at Braidwood, New South Wales, Australia *Science Bulletin (New South Wales Department of Agriculture)* 82: 1–45

Moebius MA (1892) Australische Susswasseralgen *Flora oder Allgemeine botanische zeitung,* Jena 75: 421–450

Noble R and Happy-Wood C (1987) Some aspects of the ecology of algal communities in ricefields and rice irrigation systems of southern New South Wales *Journal of the Institute of Agricultural Science*, 53: 170–284

Playfair GI (1918) New and rare freshwater algae *Proceedings of the Linnaean Society of New South Wales*, 43: 497–543

Randhawa MS (1959) *Zygnemaceae* Indian Council of agricultural research Monographs on Algae, New Delhi

Skinner S (1978) *The Zygnemataphyceae of the New England Region* Master of Science thesis, Department of Botany University of New England (unpublished)

Skinner S. (2015) Some silkweeds (Zygnemataceae, Zygnemales, Charophyceae) from the Upper Murrumbidgee River catchment. *Telopea*, 18: 273–295 http://dx.doi.org/10.7751/telopea8752

Transeau EN (1938) Notes on Zygnemataceae *American Journal of Botany*, 25: 524–528

Transeau EN (1951) *The Zygnemataceae* Ohio State University Press, Columbus

Transeau EN, Tiffany LH, Taft, CE, Li, L-C (1934) New species of Zygnemataceae. *Transactions of the American Microscopical Society*, 53: 208–230 http://dx.doi.org/10.2307/3222098

West GS (1909) The algae of Yan Yean Reservoir, Victoria: a biological and ecological study Journal of the Linnaean Society, Botany, 39: 1–88

Wolle F (1887) *Freshwater Algae of the United States (exclusive of the Diatomaceae)* Comenius Press, Bethlehem, Pennsylvania

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