

Non-marine algae of Australia: 6. Cladophoraceae (Chlorophyta)

Stephen Skinner and Timothy J. Entwisle

Abstract

Skinner, S. and Entwisle, T.J. (Royal Botanic Gardens and Domain Trust, Mrs Macquaries Road, Sydney NSW 2000, Australia. email: tim.entwisle@rbgsyd.nsw.gov.au) 2004. *Non-marine algae of Australia: 6. Cladophoraceae (Chlorophyta)*. *Telopea* 10(3): 731–748. Five species of *Cladophora* and one each of *Rhizoclonium*, *Pithophora* and *Wittrockiella* are reported for freshwater habitats in Australia. *Rhizoclonium riparium* (= *R. heiroglyphicum*) is shown to be widespread in coastal and near coastal areas of eastern Australia, while the range of *Pithophora oedogonia* is extended and a new variety, var. **calcarata** is described. *Cladophora globulina* and *C. kosteræ* are reported for the first time from Australia, and the presence of *C. glomerata*, *C. aegagropila* and *C. fracta* is confirmed and their distribution extended. *Wittrockiella salina* var. **kraftii** is newly described from freshwater habitats on Lord Howe Island.

Introduction

Despite Martin Möbius' (1895) comment that *Cladophora*, common in European freshwater, was relatively rare in the samples sent to him from Australia, records suggest that taxa in the Cladophorales, particularly *Cladophora* species, are both widespread and common in freshwater habitats in all States and Territories. Members of the group tend to prefer mineral-rich waters with pH values greater than seven, but may also be found in neutral and slightly acid waters, especially where there are elevated levels of dissolved salts. It is likely that increased eutrophication of Australia's inland waterways over the last century has actually favoured the spread of this genus.

The Cladophorales is one of the very few groups of macro-green algae that flourish in both marine and freshwater habitats, and its members have structural and phenological characteristics which suit both milieux. The cell walls are strongly reinforced; the cell structure is siphonous, each cell containing two to dozens or hundreds of nuclei and an open peripheral reticulum of chloroplasts associated with numerous pyrenoids. Individuals in general are perennial, their reproduction variously involving fragmentation of the thallus, the formation of thick-walled akinetes, or the release of sexual or asexual zooids.

Many freshwater representatives of the order are considered nuisance algae or weeds. In garden or other artificial water features, *Cladophora* — and more rarely *Rhizoclonium*

This research was funded through the NSW Biodiversity Strategy



or *Pithophora* – may be the first macroscopic organism to thrive in pioneer conditions. Physical removal of plants that leads to a subsequent increase in vegetation complexity is the main element of human control that usually keeps such populations in check. Both *Cladophora* and *Pithophora* can become weedy in irrigation channels, drains and flood mitigation schemes, as well as river systems where control measures may involve management of nutrient input from catchment groundwater.

Methods

Where specimens have been collected by the authors or have been sent by others in recent years to the Royal Botanic Gardens and Domain Trust for classification, spirit collections have first been fixed in 10% formalin and afterward preserved in 70% ethanol with 5% glycerol. Specimens have been mounted in 40% Karo after staining in aniline blue (0.5 g water soluble aniline blue in 100 ml distilled water and 5 ml conc. acetic acid) for general staining, Lugol's Iodine for chloroplasts and pyrenoids, or safranin for walls and mucilage. Specimens held at NSW have provided the main sources of distributional and biogeographical data, but some specimens from other collections in Australia have also been examined and cited. Where possible, we have compared our material with authenticated Exsiccatae. No attempt has been made to view type material, however, for, as was noted in Skinner & Entwisle (2001), types are either mostly lost, unobtainable, or in poor condition and are there instances where a type and/or a type locality may never have been designated.

As authorities for identification of Australian species, the monographs or substantial genus revisions of Nienhuis (1975) have been followed for *Rhizoclonium*, van den Hoek (1963) for *Cladophora* (both marine and freshwater species), and Pankow & Täuscher (1980) for *Pithophora*.

Key to the genera in Cladophoraceae from non-marine habitats in Australia

- | | |
|---|-------------------------|
| 1. Filaments unbranched, or with rhizoidal branching only | 2 |
| 1. Filaments variously branched | 3 |
| 2. Cells less than 70 μ m diameter; marine or freshwater | 1. Rhizoclonium |
| 2. Cells greater than 70 μ m diameter; marine only | Chaetomorpha* |
| 3. Branching opposite and often perpendicular to bearing axes, akinetes alternating with vegetative cells | 2. Pithophora |
| 3. Branching alternate or dichotomous at acute angles?, akinetes in segments of filaments or absent | 4 |
| 4. Cells more-or-less uniform in diameter | 3. Cladophora |
| 4. Cells variable in diameter | 4. Wittrockiella |

* no species described, see note under *Rhizoclonium riparium*, below.

1. *Rhizoclonium* Kützing

This is a genus of unbranched filamentous algae growing attached or floating in marine, estuarine and freshwater habitats. Unicellular or short multicellular rhizoids arise (often very infrequently) both from the base and in intercalary positions on or as extensions of conspicuously bent cells ('knees'). Cell diameter does not exceed 70 μ m, and the number or nuclei per cell is usually <10, these being the characters which distinguish *Rhizoclonium* from the more usually marine genus *Chaetomorpha*, in which

rhizoids are absent, nuclei are usually many more than 10 per cell, and the only modified cell in the filament (in attached species) is the basal holdfast cell.

One widespread species in Australia (see below).

Rhizoclonium riparium (Roth) Harvey, *Phycologia britannica* IV: Pl. 138 (1846) emend. Nienhuis, *Biosys. Ecol. Rhizo.* 63 (1975)

Rhizoclonium hieroglyphicum (C. Ag.) Kütz., *Tab. phyc.* 206 (1845)

Thallus a long unbranched filament, with or without a basal rhizoid and/or intercalary one- or two-celled rhizoids, the filaments becoming detached and either free-floating or entangled with age. Cells cylindrical L/D (0.75–)1–6(–10), (14–)20–32(–46) μm diam., nuclei two to four per cell, chloroplast a reticulum of interconnected strands, pyrenoids frequent, the cell wall lamellate and often moderately thick. Reproduction by fragmentation, akinetes (often occurring in short terminal or intercalary series), or by zooids discharged through pores at the upper ends of sporangia or gametangia of cells. Figs 1a–h.

Distribution and habitat: cosmopolitan in fresh, brackish or marine habitats. Reported from all Australian states and territories. New South Wales records are predominantly coastal and frequently from sites in close proximity to salt water, as are those presented here for Victoria and South Australia. This is similar to the pattern of distribution in the Netherlands as reported by Koster (1955) and Nienhuis (1975). Plants are usually encountered as green to yellowish-green rafts, often mixed with other filamentous algae (Zygnematales and Oedogoniales commonly) among aquatic vegetation or occurring as 'curls', thick mats in which the surface has an undulating form like wet curly hair, at the margins of shallow water bodies. Some collections showed concretions of lime.

Notes: Entwisle & Nairn (1999) listed seven species of unbranched Cladophoraceae as occurring in Australia, although there were no records for New South Wales at that time. *Rhizoclonium capillare* Kütz., *R. fontanum* Kütz. and *R. hookeri* Kütz. were names applied by Cribb (1965) or McLeod (1975) to material from Queensland localities, the vouchers for these records, held in BRI, not having been examined in the present study. Although not included by Koster (1955) in her revision of Dutch taxa, *R. capillare* and *R. fontanum* appear to be synonymous with *R. riparium* (sensu Nienhuis 1975), whereas *R. hookeri* may be conspecific with *R. africanum* Kütz., which Kraft (2000) records from the mouth of Soldiers Creek on Lord Howe Island.

Nienhuis (1975) redefined *R. riparium* to include all specimens from both estuarine and freshwater habitats with filaments 8–43 μm in diameter and L/D 1–11. Within it he included *R. implexum* (Dillw.) Kütz., which Koster (1955) had maintained for narrow (8–15 μm diameter) specimens, and *R. hieroglyphicum*, to which most freshwater collections have usually been referred. Kraft (2000) attributed a somewhat coarser (filaments 44–48 μm thick) but otherwise similar taxon from a euryhaline habitat on Lord Howe Island to *R. africanum* Kütz., a species and range of filament diameters not otherwise recorded in Australia. The two recent collections from Lord Howe Island cited here have cells less than 44 μm diameter. Wide variation in diameter has been observed in collections listed below, and we prefer to follow Nienhuis (1975) in placing them all in *R. riparium*.

Parodi & Cáceres (1993) preferred to continue to employ the name *R. hieroglyphicum* for freshwater specimens from Argentina and, by implication, Europe, emphasising the number of nuclei at 2(–4) as a reliable character, claiming the taxon was clearly defined, without making a clear distinction between *R. hieroglyphicum* and *R. riparium* other than to separate them on habitat choice. The name *R. hieroglyphicum* is also retained in recent freshwater floral treatments (John et al. 2002, Wehr & Sheath 2003)

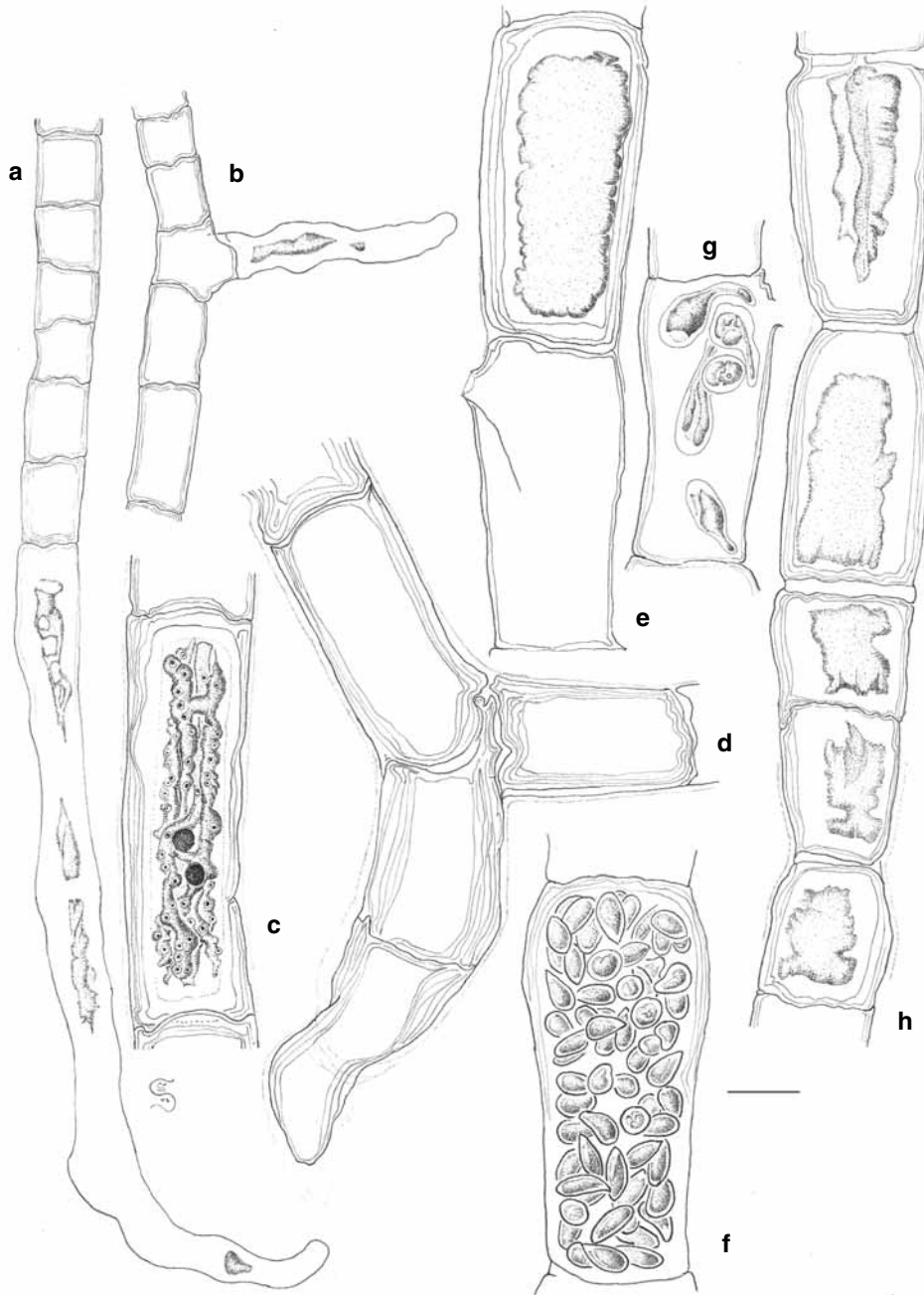


Fig. 1. *Rhizoclonium riparium* **a, b**, basal and lateral rhizoids (Skinner 0348); **c**, mature cell, after staining, showing two nuclei and pyrenoids (Skinner 0452); **d**, rhizoidal branch (Conn 4360, & Brown); **e, f, g**, immature, ripe and discharging sporangia (premature germination among zooids late to leave sporangium in g) (Hacking, sample C); **h**, akinetes (Skinner 0452, Arnold & Towler). (Scale = 20 μ m)

from the northern hemisphere. Rather than use three names, two freshwater (*R. implexum* and *R. hieroglyphicum*) and one marine and estuarine (*R. riparium*), all morphologically intergrading, it appears preferable to follow Nieuhuis (1975) and call all similar collections *R. riparium*.

Selected specimens examined: New South Wales: North Coast: Deep Ck, Valla Beach, *Hacking, sample C*, – Jan 2001 (NSW). Central Coast: Lotus pond, Royal Botanic Gardens, Sydney, *Skinner 0017*, 26 Jun 2000 (NSW); quarry, Clovelly Bowling Club, Shark Point, *Skinner 0062, & Entwisle*, 12 May 2000 (NSW); McKell Park, Darling Point, *Skinner 0316*, 18 Apr 2001 (NSW); Cadigal Reserve, Hawthorne Canal, Summer Hill, *Skinner 0348*, 12 Aug 2001 (NSW). Central Tablelands: road gutter, Bowral, *Small s.n.* Apr 2002 (NSW). South Coast: Congo Ck, *K.L. Wilson 10030*, 20 Dec 2001 (NSW); culvert, Long Point St., Potato Point, *Skinner 0494*, 27 Dec 2001 (NSW); Dry R., Quaama, *Skinner 0526*, 2 Jan 2002 (NSW). Southern Tablelands: Queanbeyan R., Queanbeyan, *Skinner 0510*, 28 Dec 2001 (NSW).

Lord Howe Island: NW of Kim's Lookout, *Conn 4268, Brown, Downs, & Hutton*, 9 Nov 2000 (NSW); small freshwater creek, Boat Harbour, *Conn 4360, & Brown*; 16 Nov 2000 (NSW). Victoria: Barwon Valley Park, Belmont Common, *Skinner 0012*, 1 Feb 1986 (NSW); Wagon Bay, Tower Hill, *Skinner 0429, Arnold & Towler*, 30 Sep 2001 (NSW); east main lake, Tower Hill, *Skinner 0430, Arnold & Towler*, 30 Sep 2001 (NSW).

South Australia: 'Heatherdale', Sellicks Hill, *Skinner 0557, & Thomas*, 12 Nov 1976 (NSW); fly-ash lagoons, Port Augusta, *Kokkim s.n.*, – Nov 1982 (NSW); Mrs Cuttings Lake, Allandale East, *Skinner 0450, 0452, Arnold & Towler*, 1 Oct 2001 (NSW).

Chaetomorpha linum (O. Müll.) Kütz. has been collected (and confirmed in this study) in coastal areas of western Victoria and adjacent South Australia (for example *Thurgate 10*), in what was reported as fresh water, but recent collections from the area (for example *Skinner 0430, 0450, Arnold & Towler*) have only revealed *Rhizoclonium riparium*. The *Thurgate 10* specimen is indeed *C. linum*, but it may have been blown/washed into the ponds during very rough weather as the outlet is onto the beach through a low sandhill.

Specimen examined: South Australia: Piccaninnie Ponds, *Thurgate 10*, Feb 1993 (MEL 2034318).

2. *Pithophora* Wittrock

A genus of vigorously growing, much branched, multinucleate multicellular filaments that favour still or slow-flowing waterbodies and are highly tolerant of eutrophication. A single cosmopolitan species has been reported previously for Australia (Entwisle & Nairn 1999).

Pithophora oedogonia (Montagne) Wittrock, *Nova acta Regiae Soc. Sci. Upsal.* 3: 55 (1877) var. ***oedogonia***

Thallus a tangle of uniseriate branching filaments forming anchored by akinete wall and rhizoids or free-floating rafts of a few to 20 or more cm across, the mats yellow- to dark green in colour. Main filaments cylindrical (50–)60–100(–120) µm diameter, cells L/D > 20; chloroplast an open to compact peripheral reticulum with numerous pyrenoids; branching opposite or irregular, arising distally on and forming nearly right angles to their bearing cells; terminal cells of main and lateral axes tapering gradually to an obtuse point. Akinetes intercalary or terminal, when intercalary solitary, in pairs or threes, cylindrical, barrel-shaped or inflated on one side, 200–300 µm long, 70–125 µm diam.; terminal akinetes solitary or, more rarely, in short series, hastate to piliate (with a short or long point), 125–300 µm long, 55–80 µm diam. Rhizoids and haptera rare, basal; helicoid structures at branches not observed in Australian material. Figs – see Entwisle & Price (1993) Fig. 1a.

Distribution and habitat: This species has been reported from throughout the Australian continent (Entwisle & Nairn 1999). Entwisle & Price (1993) particularly noted its high tolerance for warm, shallow, alkaline water that is rich in nitrogen and phosphorus at Queensland sites. The most recent collections also come from such habitats, one a transient stream in an urban area, others being shallow riverine lagoons within canefields. Western Australian and New South Wales collections are from artificial ponds or the streams feeding them that are similar to Queensland sites in physical and chemical characteristics.

Notes: terminal akinetes in our collections are usually hastate and obtuse rather than pointed, whereas intercalary akinetes are usually solitary, never in groups of more than three. Our specimens thus conform well to both van den Hoek's (1959) and Pankow & Täuscher's (1980) circumscriptions of *P. oedogonia*. Pankow & Täuscher (1980) recognise two broadly defined taxa and have suggested synonymy or doubtful status for many if not most of the previously described fifteen species. They defined *Pithophora roettleri* (Roth) Witttr. as having rows of variously shaped intercalary akinetes (up to seven/row) and rounded terminal akinetes, whereas in their opinion *P. oedogonia* has one or two [3–7 in var *polyspora* (Rendle & West) Pankow & Täuscher] barrel-shaped to cylindrical intercalary akinetes and pointed terminal akinetes. Van den Hoek (1959) had earlier separated four Caribbean taxa on the basis of akinete shapes and main-filament diameters, but Pankow & Täuscher (1980) included all of van den Hoek's taxa in one or other of the two species that they recognised.

Fresh specimens may have a distinct smell of cats' urine.

Specimens examined: Queensland: Anderson Park, Townsville, *Price s.n.*, 9 Aug 1990 (JCT); James Cook University Campus Ck, Townsville, *Dell s.n.*, 11 Nov 2002 (NSW); Castanelli's Lagoon, near Burdekin R., *Reid s.n.*, 14 Nov 2002 (NSW); Healeys lagoon system, off Woodstock Rd, *Reid 270103.10*, 27 Jan 2003 (NSW).

New South Wales: Central Coast: Mullet Ck, North Narrabeen, *Entwisle 2920* (NSW); Fairlight, *McCune s.n.*, 4 Apr 2003 (NSW).

Western Australia: Berkerley R., *Kenneally 11878*, 13 Jun 2003 (NSW); Broome airport, *Kenneally 11900, 11901*, 21 Jun 2003 (NSW).

***Pithophora oedogonia* var. *calcarata* Skinner and Entwisle var. nov.**

Akineta intercalaria terminaliaque frequenter calcar breviore vel exteioriore extrudete a latere.

Intercalary and terminal akinetes frequently with a short to extended spur projecting from the side; otherwise morphology as for var. *oedogonia*. Fig. 2.

Type: type locality: as turf in concrete drain, Pieter van Hasselt Park, Shalvey, 33°43'S; 150°48'E, N.S.W. *Coveny 18551 & Sherring*, 24 April 2000 (NSW).

Etymology: *calcar* (latin) is a spur, so *calcaratus*, *a*, *um* meaning spurred.

Distribution & habitat: coastal hinterland of New South Wales, in sluggish, often warm, shallow freshwater disturbed by storm-water or agricultural runoff.

Notes: there is much variation in the form of the akinetes, both intercalary and terminal, in *Coveny 18550*, including some with lateral spurs, but most intercalary akinetes fit the 'meist tonnenförmig, selter zylindrisch bis subzylindrisch' specifications of *P. oedogonia* (Pankow & Täuscher 1980). As well, there are plenty of the short hastate terminal akinetes that are characteristic of that species. The spurs that confer the varietal name are pronounced and more uniform than the irregular lateral projections in *O. aequalis* Witttr. (as illustrated by van den Hoek 1959), which we consider synonymous with *P. oedogonia*.

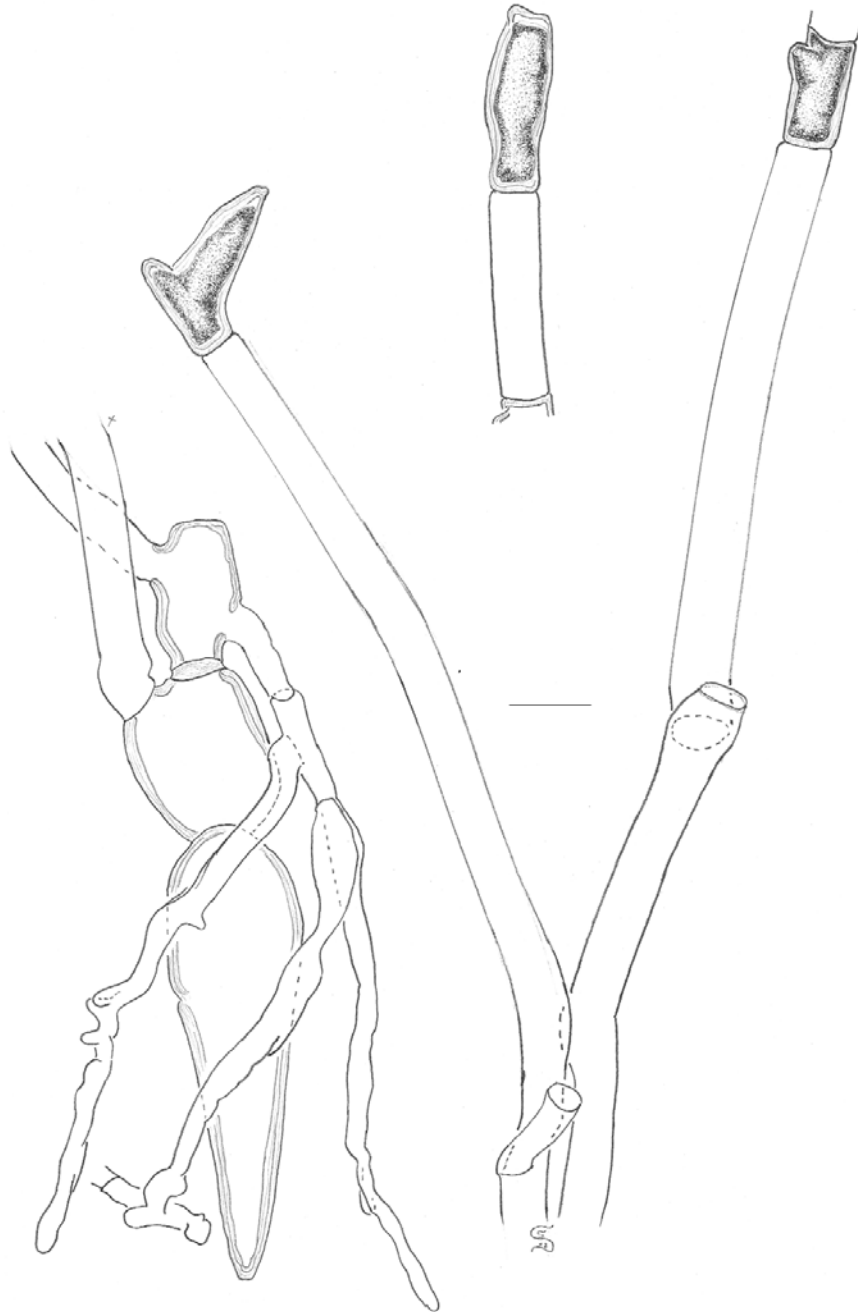


Fig. 2. *Pithophora oedogonia* var. *calcarata*: germinating akinete series, with intercalary and apical spurred akinetes in germling (Coveny 18551 & Sherring). (Scale = 100 μ m)

Short series of akinetes, including the hastate terminal one, have been found in *Coveny 18551* showing production of both new axes and tendril-like haptera. It would appear that the empty akinete chambers, with their thick walls, act as an anchor for the new thallus.

Specimens examined: New South Wales: North Coast: Nahiack, *Skinner 0352*, 28 Aug 2001 (NSW). Central Coast: Pieter van Hasselt Park, Shalvey, *Coveny 18550, 18551 & Sherring*, 24 Apr 2000 (NSW); Bells Ck, Oakhurst, *Coveny 18963*, 14 Oct 2001 (NSW).

3. *Cladophora* Kützing

A large genus of branching, filamentous algae, with multinucleate cells with reticulate parietal chloroplasts, numerous pyrenoids, and frequently thickened walls. Although most species-rich and morphologically diverse in marine habitats, at least nine members are credited by van den Hoek (1963) to euryhaline or freshwater habitats in Europe, of which three or four have been reported in Australian inland aquatic systems. There are nine names used in Entwisle & Nairn (1999), many are synonyms for the five species documented below, which probably represent the full range of morphological variation in Australia.

Key to freshwater *Cladophora* in Australia

1. Basal system prostrate and extensive; secondary laterals making acute angles (<45°) with main axes **3a. *C. kosterae***
1. Basal system, where present, rhizoidal; secondary (and higher order) laterals with wide (>45°) adaxial angles
2. Lateral filaments laterally inserted subapically; rhizoids, if present, arising adventitiously; cells large, with thickened walls **3b. *C. aegagropila***
2. Lateral filaments inserted at apical ends of bearing cells; rhizoids confined to basal areas; cells sizes variable, with or without thickened walls 3
3. Thalli sparsely branched and finely constructed, with even gradations from main axes to higher orders of branching **3c. *C. globulina***
3. Thalli repeatedly branched and often coarse, with distinct size differences between diameters of main axes and ultimate branch orders
4. Thalli attached, or facultatively free-floating; apical cells 20–90 µm diam., main axes often more than 100 µm diam. **3d. *C. glomerata***
4. Thalli usually free floating, apical cells 16–27 µm diam., main axes less than 85 µm diam. **3e. *C. fracta***

3a. *Cladophora kosterae* van den Hoek, *Revision of the European species of Cladophora*: 37 (1963)

Erect axes arise from an extensive prostrate base and give rise to opposite or alternate laterally inserted secondary axes. Main axes are often very long, sometimes with pairs of parallel, tangentially inserted cells, often subtending branching, L/D 3–10, 47–72 µm diam. Secondary branches inserted below end-walls at acute adaxial angles, such that secondary branches often appear to lie parallel to main axis, at least for the first cell in a branch, 50–54 µm diam. Apical cells tapering, tip more-or-less blunt, 25–29 µm diam. Groups of intercalary or subterminal swollen sporangia 65–72 (–90) µm long, 58–65 µm diam. opening by a suprmedian lateral pore. Fig. 3 a–c.

Distribution and habitat: van den Hoek (1963) reports this species from France and the Netherlands. In Australia it has only been collected in the South Creek catchment of the Cumberland Plain, west of Sydney, always from sluggish, weed-infested waterbodies in suburban developments.

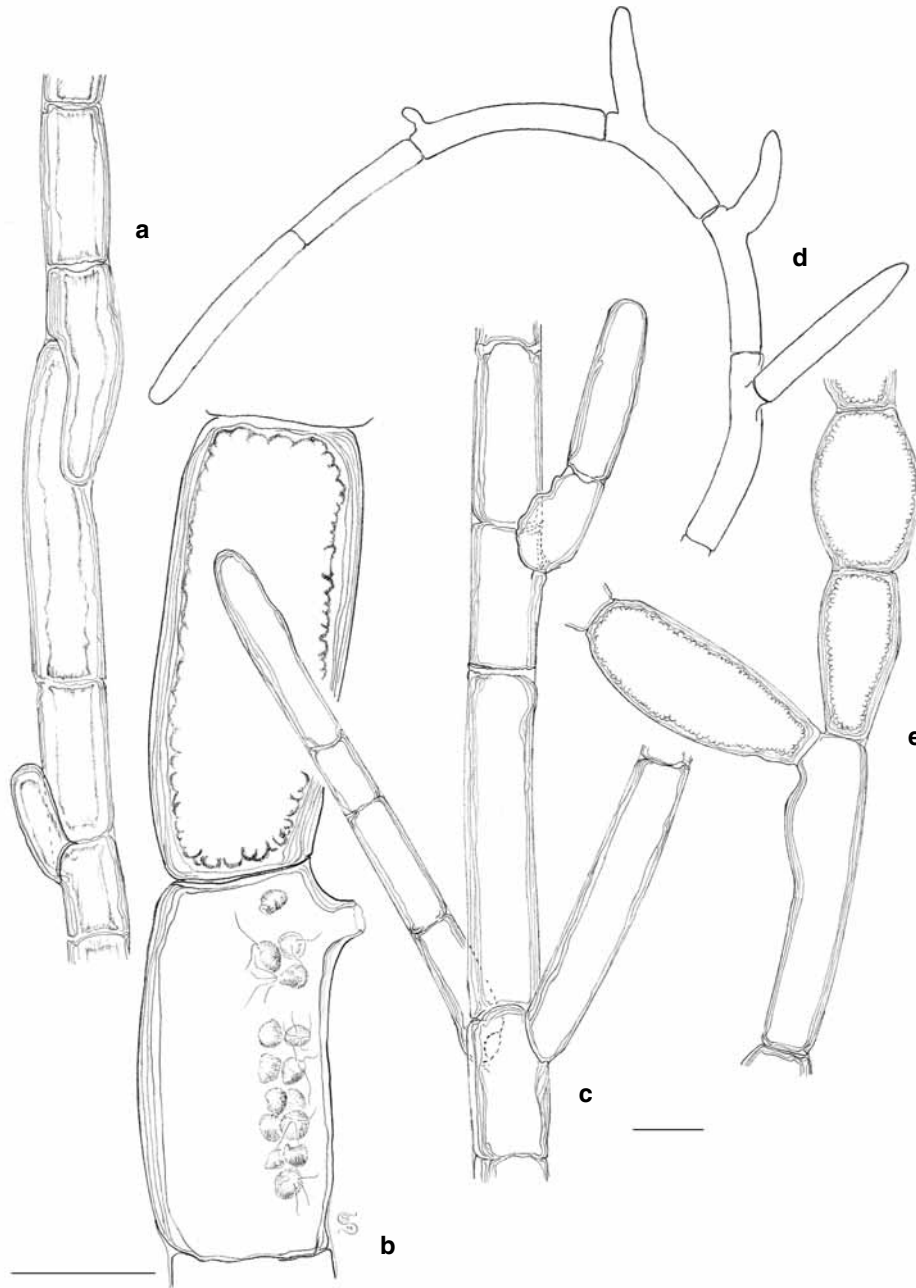


Fig. 3. *Cladophora kosteriae*: **a**, primary filament with tangentially disposed cells (Coveny 18546); **b**, sporangia, the lower one with mature zooids (Coveny 18550); **c**, filament with opposite and alternate laterals, showing narrow adaxial angle (Coveny 18550); *C. aegagropila*: **d**, growing tip with maturing laterals (Skinner 0371); **e**, akinetes (Reid 270103.5). (Scale a,c-e = 20 μ m at 250 \times ; b = 20 μ m at 400 \times)

Notes: Although the extensive basal mat described by Hoek for *C. kosterae* has not been seen in Australian specimens, the reproductive structures fit its description well. The almost parallel secondary branches are distinctive, and the occasional oblique septation of cells, described by van den Hoek as being particularly numerous in parts of the prostrate system, are also present.

Ducker (1958) described as *Basicladia ramulosa* Ducker populations from Victoria and Queensland that appear similar to *C. kosterae*, the plants growing obligately on the carapaces of the freshwater turtle *Chelodina longicollis* (Shaw). We do not have any specimens to hand of turtle carapaces with epizoic Cladophoraceae and thus cannot reassess the position of Ducker's taxon. Van den Hoek (1963) considered both the obligate epizoic taxa and the similar *Cladophora kosterae* and *C. okamurai* (Ueda) Hoek, to belong to section *Basicladia* of the genus *Cladophora*.

Specimens examined: New South Wales: Central Coast: Bells Ck, Oakhurst, *Coveny* 18963, 14 Oct 2001 (NSW); Peter van Hasselt Pk, Shalvey, *Coveny* 18550; Emerton, *Coveny* 18546, 9 Apr 2000 (NSW).

3b. *Cladophora aegagropila* (L.) Rabenh., *Flora europaea algarum aquae dulcis et submarinae* III 343–344. (1868)

Conferva aegagropila Linnaeus, *Sp. pl.* II 1167–1168. (1753)

Cladophora parvula Möbius, *Abh. seneckenberg. naturf. Ges.* 18: 328 (1895).

Thallus attached or, commonly, free floating, yellowish to dark green. Apical cells L/D 5–24, 30–70 µm diam.; ultimate branch cells L/D 3–15; 30–100 µm diam.; main axes L/D 1.5–15, 125–200 µm diam.; wall 2.5–8 µm thick at tip, 20 µm in main axes. Lateral branches inserted laterally and a little below upper end-wall of axis cell, retaining this position with maturity. Rhizoids may sprout from most parts of thallus. Reproduction only by fragmentation or akinete formation. Akinetes in series, ovoid to elliptical, 100–190 µm long, 70–80 µm diam. with strongly lamellate walls. Fig. 3 d,e, 4. a–c.

Distribution and habitat: cosmopolitan. Collection localities in Australia are often alkaline streams with at least moderate flow rates, often in association with improved pasture.

Notes: there are two distinct groups of specimens: those that conform to the 'European' *C. aegagropila*, and those that have a similar branching pattern but narrower apical cells and generally less robust form throughout, thus fitting the description of Möbius (1895) for *C. parvula*. *Cladophora parvula*, from Warwick, Queensland, is described by Möbius (1895) as less than 8 mm long. Without culture and field work it would be decidedly premature to describe a variety or, alternatively, to resurrect the ill-defined epithet *parvula*, but it may be beneficial for future workers if the collections to hand are filed separately.

Entwisle 1507 was previously reported (Entwisle 1994) as *Chaetomorpha linum*, as the filaments are very rarely branched and the cells are broad, moderately short (L/D 2.5–3.5) and thick-walled. Comparison with perennial fragments in other collections (*Skinner 0041*, *Thurgate 21*) and the occasional subterminal branch initial or scar suggest that it may be better referred to *Cladophora aegagropila*.

Specimens examined: Queensland: Burdekin R., Hwy crossing, *Reid 270103.05*, 27 Jan 2003 (NSW).

New South Wales: Northern Tablelands: MacDonald R., Bendemeer, *Skinner 0074*, & *Cherry*, 21 May 2000 (NSW); Falconers Ck, Backwater Rd, near Guyra, *Skinner NED027*, Dec 1974 (NE); Apsley R., Walcha, *Skinner 0201* & *Cherry*, 25 May 2000 (NSW); Apsley R., Apsley Falls, *Skinner 0203b* & *Cherry*, 25 May 2000 (NSW); Tia R., Tia Falls, *Skinner 0214* & *Cherry*, 25 May 2000 (NSW). Central Coast: McKell Park, Darling Point, Port Jackson, *Skinner 0314*, 18 Apr 2001 (NSW); Yarramundi Bridge, Nepean R., *Skinner 0334* & *McPhearson*, 9 Aug 2001 (NSW). Central Tablelands: Wingecarribee R., Berrima, *Skinner 0317*, 25 Apr 2001 (NSW). Central Western Plains: Arnolds bridge, Page R.,

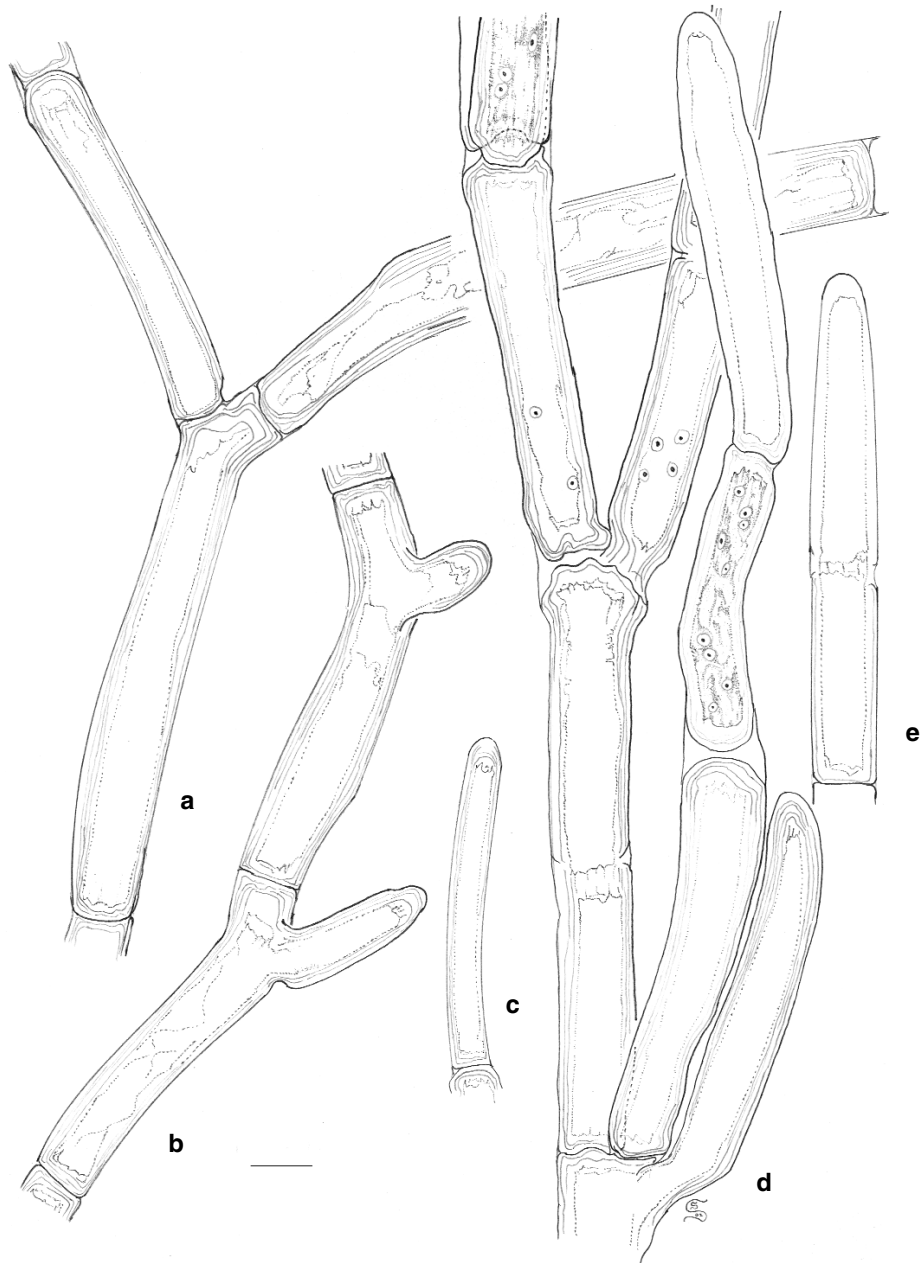


Fig. 4. *Cladophora aegagropila*: **a, b**, lateral branching ; **c**, apical cell (Skinner 0317); *C. glomerata*: **d**, pseudodichotomous branching; **e**, apical tip (Skinner 0408, Arnold & Towler). (Scale = 20 μ m)

Murrurundi, *Skinner 0021*, 11 Dec 1999 (NSW); Lake Cargelligo, *Skinner 0476*, Arnold & Towler, 4 Oct 2001 (NSW).

Victoria: Barwon R., Barwon Valley Park, Belmont, *Skinner 0012*, 1 Feb 1986 (NSW); Lake Cooper, near Shepparton, *Gar?ia AG 30.09.01.1A1*, 30 Sept 2001 (NSW); Korkuperrimul Ck, Bacchus Marsh, *Entwisle 1507*, 14 Jul 1988 (MEL).

South Australia: 'Heatherdale', Sellicks Hill, *Skinner 0557*, & *Thomas*, 12 Nov 1976 (NSW, AD); Torrens R., River Torrens Linear Park, Paradise, *Skinner 0276*, 24 Dec 2000 (NSW); Torrens R., RTLP, Highbury, *Skinner 0278*, 24 Dec 2000 (NSW); Eight Mile Ck, *Skinner 0041*, 6 Dec 1989 (NSW); Ewans Ponds, *Thurgate 21*, –Feb 1992 (MEL); Goulden Hole *Thurgate 12*, – Feb 1992 (MEL); Piccaninnie Ponds, *Skinner 0032*, 00033, 15 Nov 1989 (NSW); main pond, Piccaninnie Ponds, *Skinner 0445*, *Arnold & Towler*, 1 Oct 2001 (NSW); Piccaninnie Ponds, *Thurgate (Entwisle 1540)*, –Oct 1988 (MEL).

Doubtful determinations: New South Wales: Eastern Ck, *Coveny 18856*, 16 Apr 2001 (NSW); Macdonald R., Bendemeer, *Skinner 0071*, 0072 & *Cherry*, 21 May 2000 (NSW); RBG Mt Annan, *Coveny 18890*, 22 Nov 2001 (NSW) may all be referable to *C. parvula*, but are much, much bigger plants than the Type (as described in Möbius 1895).

3c. *Cladophora globulina* (Kütz.) Kütz., *Phyc. germ.* 219 (1845).

Conferva globulina Kütz., *Alg. aq. dulc. germ.*, no. 20 (1833).

Filaments are long and delicate, with almost no branching; apical cells tapering sharply to a bluntly rounded end, L/D 7–10, 17–20 µm diam., cells of filaments thin walled, L/D 10–12, to 35 µm diam.; insertion of branches rare, at first lateral but becoming sub-dichotomous with age in lower parts of axes. Reproduction by fragmentation or akinetes, as well as zoids. Fig. 5 a–d.

Distribution and habitat: Continental Europe; newly recorded for Australia from central and south coast of New South Wales, where it is found in artificial ponds and a sluggish, seasonally shallow to dry river.

Notes: The Quaama and Camperdown specimens conform well vegetatively to the description in van den Hoek (1963), the Camperdown collection being additionally actively reproductive, releasing large numbers of zoids. Van den Hoek (1963) comments on the 'thorn-like' appearance of young branch initials and the swelling of the cell ends in older parts of the filaments, both of which features can be seen in Australian material. Confusion with *Rhizoclonium* can be largely avoided in fresh material by looking for nuclei, as most cells have four, six or even ten as opposed to 2–4, in *Rhizoclonium riparium*.

Specimens examined: New South Wales: Central Coast; Victoria Park, Camperdown, *Skinner 0554*, 24 Mar 2002 (NSW); garden pond, Penrith, *Cammack s.n.*, 17 Jan 2000 (NSW); Lake Nadungamba in Mount Annan Botanic Garden, *Coveny 18980*, 22 Nov 2001 (NSW). South Coast: Dry R., Quaama, *Skinner 0524*, 0526, 2 Jan 2002 (NSW).

3d. *Cladophora glomerata* (L.) Kütz., *Phyc. gen.* 226 (1843).

Conferva glomerata Linnaeus, *Sp. pl.* II:1167 (1753)

Cladophora chartacea Grunow, *Reise...Novara*, vol.I, *Sporenpflanzen. Heft I Algae 1* (1867)

Rhizoids basal, often grouped into a fascicular holdfast. Axes repeatedly branched, insertion either terminal or lateral but at the apical ends of cells, becoming co-terminal and so forming pseudo di- or trichotomies; growth intercalary to acropetal; main axes 100–275 µm diam., L/D (7–12)–(1.5–5), ultimate branch cells (22–34)–(68–100) µm diam., L/D (5–10)–(1.5–3.5), apical cells (21–31)–(58–91) µm diam., L/D (6–13)–(1.5–5). Reproduction by fragmentation, by intercalary akinetes, and zoids formed in terminal and sub-terminal cells of upper lateral branches, opening by sub-terminal or terminal pore. Figs 4 d,e, 5 e,f.

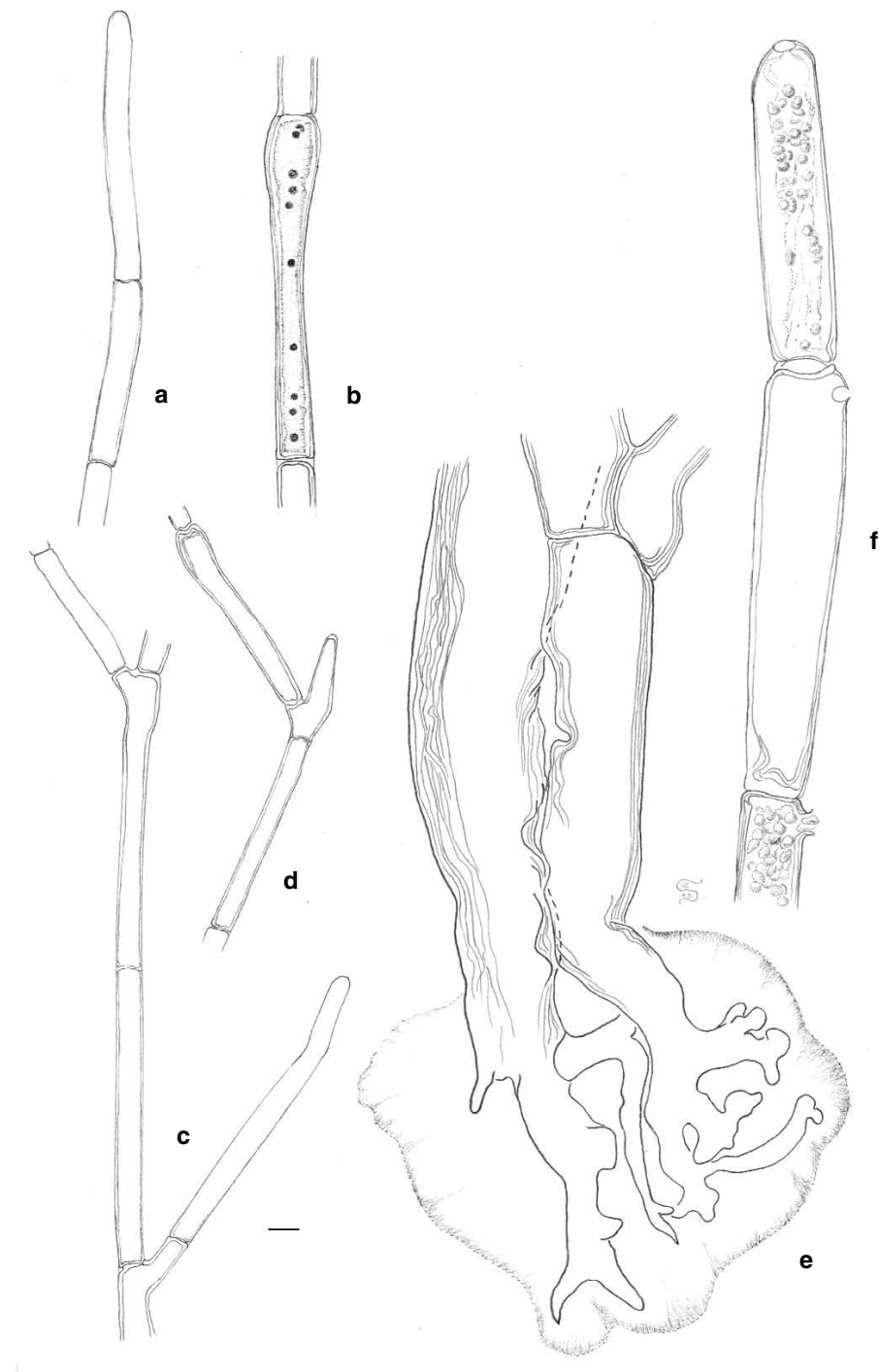


Fig. 5. *Cladophora globulina*: **a**, apical tip; **b**, terminally thickened cell, showing distribution of nuclei; **c**, branching pattern; **d**, thorn-like branch initial (Skinner 0554); *C. glomerata*: **e**, rhizoidal system; (Woods s.n.) **f**, series of sporangia (Skinner 014). (Scale = 20 μ m)

Distribution and habitat: cosmopolitan, reported from freshwater and saline habitats in all states and territories of Australia. Widely distributed in New South Wales, where it favours neutral to alkaline, often weedy waterways, but can also be found in seepages and other almost aerophylic conditions. A similar distribution is to be expected in other States, as is indicated by the South Australian collections examined.

Notes: This is a very variable and frequently perennial species, so that some specimens may have much variation in dimensions between old and new growth that probably reflect responses to changes in environmental conditions.

Cladophora chartacea Grunow (1867), based on a collection by Frauenfeld at Naraby (most likely an orthographic error for Narrabeen) Lagoon, Port Jackson, is a good example of the blanket-weed form of *C. glomerata*. The dried material does show the alternating imploded cells of Grunow's figure, but on regaining turgidity it displays the expected form of the species. When growing rapidly, specimens often show a predominance of conspicuously shortish cells in the new-growth parts.

Specimens examined: New South Wales: North Coast: Wrights Ck, Port Macquarie, *Skinner 0014*, 1999 (NSW). Northern Tableland: Wollomombi R., Waterfall Way bridge, *Skinner 0190 & Cherry*, 24 May 2000 (NSW). North West Slopes: Chaffy Dam, Peel R., near Nundle, *May s.n.* 14 Feb 1978 (NSW). Central Coast: BB Ck, Manly Dam, no collector name 22 Sep 2000 (NSW); Middle Harbour Ck, St Ives, *Entwisle 2962*, 20 Mar 1999 (NSW); Panania, *Pinner s.n.*, 2 Jul 2000 (NSW); Tropical House pond, RBG Sydney, *Skinner 0228a*, 21 Jun 2000 (NSW); stairs between Lower Fort St & Hickson Rd, Dawes Point, Sydney, *P.G. Wilson 1578*, 20 Feb 2003 (NSW); West Wollongong, *Garcia s.n.* 14 Mar 2002 (NSW); Nor-West Business Park, Baulkham Hills, *Rooney s.n.*, 10 Jul 2003 (NSW); Lake Nadungamba in Mt Annan Botanic Garden, *Ling, J. s.n.*, 22 Oct 2001 (NSW). Central Western Plains: Lake Cargelligo, *Skinner 0477, Arnold & Towler*, 4 Oct 2001 (NSW). South Coast: Narira Ck, Cobargo, *Skinner 0233*, 13 Jul 2000 (NSW); Jemersons Beach, Potato Point, *Skinner 0496*, 27 Dec 2001 (NSW). South West Slopes: Botanic Gardens, Wagga Wagga, *Skinner 0378, Arnold & Towler*, 26 Sep 2001 (NSW). South West Plains: Yenda, *Skinner 0359, Arnold & Towler*, 24 Sep 2001 (NSW); Box Ck channel, Blighty, *Skinner 0408, Arnold & Towler*, 27 Sep 2001 (NSW).

Also: Naraby Lagoon, Port Jackson, *Frauenfeld 884*, 1858? (NSW) = Coll. Grunow 15411, 32416, 32417, 32418. (WEIN).

Victoria: Lake Cooper, Shepparton, *Garcia AG 30-09-01-1 A1*, 30 Sep 2001 (NSW).

South Australia: Inman R., billabong, Encounter Bay, *Skinner 0005*, Oct 1978 (NSW); Brownhill Ck, Fullerton Rd., *Woods s.n.*, 18 Jun 1978 (NSW); Torrens R., Reeds Rd ford, Highbury, *Skinner 0004*, 4 Feb 1986 (NSW); Bool Lagoon site 1, *Lloyd s.n.*, 5 Nov 1982 (NSW).

Northern Territory: Roper R. at Moraok Station, *Townsend A1, A2*, 12 Sept 2000 (NSW).

Western Australia: Swan R., Wanganga NP, *Entwisle 2994*; Loch Ness, Yanchep Inn area, *Entwisle 3000*.

3e. *Cladophora fracta* (Müll. ex Vahl) Kütz., *Phyc. gen.* 263–264 (1843)

Conferva fracta Müller ex Vahl, *Flora danica* 16: 946 (1787)

Basal rhizoids often present, although plants not usually attached; branching frequent, insertion terminal; vegetative cell walls usually not heavily lamellated, growth mostly acropetal. Apical cells L/D 3.5–25, 14–27 µm diam.; ultimate branch cells L/D 3–17, 17.5–38 µm diam.; main axes L/D 1.5–14, 45–85 µm diam. Reproduction asexual. Sporangia in laterals, tumid, L/D 5–8; 29–36 µm diam. opening by terminal pore. Akinetes not seen. Fig. 6 a,b.

Distribution and habitat: world-wide but apparently uncommon, rare or under-collected in Australia. Favours coastal localities with fluctuating balance of salt and fresh water such as estuaries and sand dune marshes.

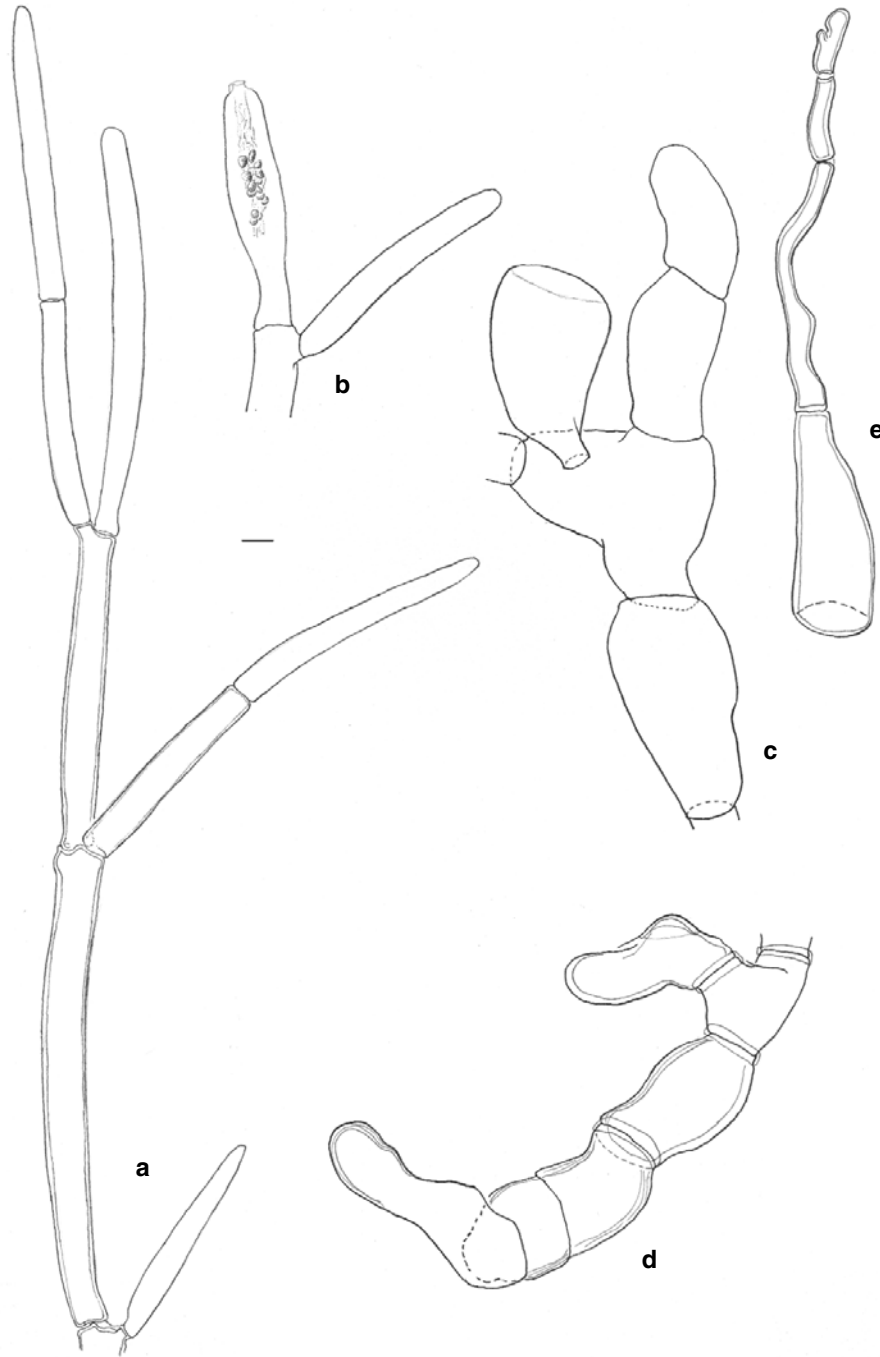


Fig. 6. *Cladophora fracta*: **a**, branching filament, including immature sporangium (third branch); **b**, discharging sporangium (Skinner 0512); *Wittrockiella salina* var. *kraftii*: **c**, **d**, prostrate system; **e**, erect filament (Brown 2000/157 et al.). (Scale a, b = 20 μ m, c-e = 50 μ m)

Notes: both specimens of the NSW collections are from the same estuarine system from sites where the water was only slightly salty to taste and direct communication to the sea only intermittent during spring tides.

Specimens examined: New South Wales: South Coast: estuary between Lake Brunderee and Potato Point beach, *Skinner 0512*, 29 Dec 2001 (NSW); Lake Brunderee, *Skinner 0515*, 31 Dec 2001 (NSW).

4. *Wittrockiella* Wille

A small genus of a few species that are most often encountered in specialised coastal and estuarine habitats. The prostrate and erect systems are photosynthetic, and there is little uniformity in cell shape, rather a fitting to spaces between surrounding cells. Most previous records in Australia and from overseas are from saline habitats or the brackish-water interfaces between fresh and salt water in coastal rivers.

Wittrockiella salina Chapman, *Farlowia* 3: 495 (1949) var. ***kraftii*** Skinner & Entwistle var. nov.

Filamentibus prostratis ad varietati implicitae aestuarii mentiens sed in aquam dulcem processibusque erectis intricatis sinuatis sineque pilis.

Type: New South Wales: Lord Howe Island, Dinner Run, at base of lowest falls, *Brown 2000/157*, Conn, Downs & Hutton, 11 Nov 2000 (holo: NSW).

Thallus a mat of entangled, freely branching prostrate filaments (with some suggestion of anastomoses) and erect processes rhizoid-like in appearance. Prostrate filaments of short broad, cylindrical to irregular cells, L/D 1–2.5(–3), 200–260 µm diam.; terminal cells broadly obtuse and short, 100–150 µm diam. Erect processes arising laterally or sub-apically, erect, sinuous, narrow, much longer than broad, 25–90 µm diam. Reproduction unknown. Fig. 6c–e.

Etymology: named in honour of Dr G. T. Kraft who has contributed much to the study of marine and freshwater Cladophorales in Australia, and has a continuing special interest in the algal flora of Lord Howe Island.

Notes: var. *kraftii* does not show either the regular erect processes in *W. salina* or the hairs, especially when compared to the ball form from the Lake Brunderee estuary near the Tuross River delta. It has more elongate erect processes and, at least in its Type collection, a contrasting habitat preference. *W. salina* var. *kraftii* does not compare well with the description and illustration in Harvey (1855) for *W. lyallii* (as *Cladophora lyallii* Harvey) from New Zealand, but has some similarity to the figures of *W. lyallii* (Harvey) van den Hoek, Ducker & Womersley that are given in van den Hoek et al. (1984). *W. lyallii* has apical cells 250–510 µm diam. and intercalary cells 250–450 µm diam. (van den Hoek et al 1984), however, which are much larger dimensions than those of *W. salina* var. *kraftii*, and in addition form as a turf at high water or form floating 'moss' balls.

The type variety is an estuarine populant of south eastern Australia and New Zealand. As noted by van den Hoek et al. (1984), it is often found in lower salinities than marine habitats. *Skinner 0514*, from the estuarine creek flowing out of the almost freshwater Lake Brunderee, is the 'moss-ball' form. The creek mouth was closed to all but spring tides in summer 2001–2002, but the water tasted salty at the place, close to the road to the mouth of the Tuross, where the moss balls formed a carpet on top of the water. Other records from the south coast of New South Wales (*Verdon 1091*, *1097*) are of the turf form from margins of coastal waterways.

***Wittrockiella salina* var. *salina* examined:** New South Wales: South Coast: estuarine creek into Lake Brunderee, Potato Point, N.S.W., *Skinner 0514*, 30 Dec 2001 (NSW), Little Malua Bay Beach, Malua Bay, *Verdon 1091*, 10 Apr 1975 (CANB); Lilli Pilli Beach, 8 km S of Batemans Bay, *Verdon 1097*, 10 Apr 1975 (CANB).

There are a number of other infrequently encountered freshwater genera in Cladophoraceae, including *Cladophorella* Fritsch, *Cladostroma* Skuja, *Arnoldiella* Miller and *Chaetonella* Schmidle and more (Bourrelly 1966,1988). *Arnoldiella* and *Cladostroma* are taxa with compact thalli, whereas *Cladophorella* has some morphological similarities to *Wittrockiella*, but is distinct in forming terminal akinetes, and having its erect processes composed of regular cylindrical cells like those of short filaments in *Cladophora*. None of these mostly middle-European taxa have yet been reported from Australia.

Acknowledgments

Thanks are also due to many of our colleagues here in Sydney (especially the Lord Howe Island team led by Dr Elizabeth Brown) and in other states and territories (especially Dr Kevin Kenneally, Dr Simon Townsend, and David Reid) for many of the collections. We also thank the National Herbarium of Victoria for the loan of numerous specimens and Dr G.T. Kraft for discussions of various taxa, and especially the loan of references on *Rhizoclonium*. This research was funded through the *NSW Biodiversity Strategy*.

References

- Bourrelly, P. (1966) *Les Algues D'eau Douce I Les Algues Vertes*. (Éditions N. Boubée & Cie: Paris).
- Bourrelly, P. (1988) *Compléments Les Algues D'eau Douce*. (Société Nouvelle Des Éditions Boubée: Paris).
- Cribb, A.B. (1965) An ecological and taxonomic account of the algae of a semi-marine cavern, Paradise Cave, Queensland. *Pap. Dept. Bot. Queensland* 4: 259–282.
- Ducker, S.C. (1958) A new species of Basidiadia on Australian freshwater turtles. *Hydrobiologia* 29: 157–174.
- Entwisle, T.J. (1989) Macroalgae in the Yarra River Basin: Flora and Distribution. *Proc. R. Soc. Vic.* 101: 1–76.
- Entwisle, T.J. (1994) Macroalgae. in Entwisle, T.J. *Aquatic Cryptogams of Australia: a Guide to the Macroalgae, Larger Fungi, Lichens and Bryophytes of Australian Inland Waters*. (Australian Society for Limnology: Melbourne).
- Entwisle, T.J. and Nairn, L. (1999) Freshwater Algae — Census of Freshwater Algae in Australia . <http://plantnet.rbgsyd.gov.au/PlantNet/fwalgae.htm>
- Entwisle, T.J. & Price, I.R. (1993) New records of two potential weed species of freshwater macroalgae from Queensland. *Proc. R. Soc. Qld* 102: 57–63.
- Grunow, A. (1867) Algae. In *Reise der Österreichischen Fregatte Novara um die Erde in der Jahren 1857,1858, 1859: Botanischer Theil, Erstr Band: Sporenpflanzen*. 1–104, pl. I–IX (K.K. Hof & Staatsdruckerie: Vienna).
- Harvey, W.H. (1855) Algae. in Hooker, J.D. (ed.) *The Botany of the Antarctic Voyage*. Part II *Flora Novae Zealandiae* Vol. 2: 211–266 (Pl. 107–121).
- Hoek, C. van den (1959). Caribbean fresh and brackish water Chlorophyta. *Blumea* 9: 590–625.
- Hoek, C. van den (1963) *Revision of the European species of Cladophora*. (E.J. Brill: Leiden).
- Hoek, C. van den, Ducker, S.C. and Womersley, H.B.S. (1984) *Wittrockiella salina* Chapman (Cladophorales, Chlorophyceae), a mat and ball forming alga. *Phycologia* 23: 39–46.
- John, D.M., Whitton, B.A. and Brook, A.J. (2002) *The Freshwater Algal Flora of the British Isles*. (University Press: Cambridge).
- Koster, J.T. (1955) The genus *Rhizoclonium* Kütz. in the Netherlands. *Pubblazioni della Stazione Zoologica di Napoli* 27: 335–357.
- Kraft, G.T. (2000) Marine and estuarine benthic green macroalgae (Chlorophyta) of Lord Howe Island, south west Pacific. *Aust. Sys. Bot.* 13: 509–648.
- McLeod, J.A. (1975) *The Freshwater Algae of Southern Queensland*. unpublished Ph.D. Thesis, University of Queensland.
- Möbius, M.A. (1895) Australische Süßwasseralgen II. *Abh. Senckenberg. Naturf. Ges.* 18: 310–350.

- Nienhuis, P.H. (1975) *Biosystematics and Ecology of Rhizoclonium riparium (Roth) Harv. (Chlorophyceae: Chlorophyta) in the estuarine area of the rivers Rhine, Meuse and Scheldt.* (Rotterdam).
- Pankow, H. & Täuscher, L. (1980) Über eine *Pithophora*-Art aus den Gewächshäusern des Botanischen Gartens in Rostock. *Nova Hedw.* 33: 465–474.
- Parodi, E.R. and Cáceres, E. J. (1993) Life history of freshwater populations of *Rhizoclonium hieroglyphicum* (Cladophorales, Chlorophyta) *Eur. J. Phycol.* 28: 69–74.
- Skinner, S. & Entwisle, T.J. (2001) Non-marine algae of Australia: 1. Survey of colonial gelatinous blue-green macroalgae (Cyanobacteria) *Telopea* 9: 573–599.
- Wehr, J.D and Sheath, R.G. (2003) *Freshwater Algae of North America. Ecology and Classification.* (Academic Press: Boston).

Manuscript received 15 October 2003
Manuscript accepted 10 February 2004