Mangrove-associated macroalgae and cyanobacteria in Shark Bay, Western Australia

J M HUISMAN 1,2, A J KENDRICK 3 & M J RULE 3

1 Western Australian Herbarium, Department of Parks and Wildlife, Locked Bag 104, Bentley Delivery Centre, WA 6983, Australia
2 School of Veterinary and Life Sciences, Murdoch University, Murdoch, WA 6150, Australia
3 Marine Science Program, Department of Parks and Wildlife, Kensington, WA 6151, Australia

INTRODUCTION

Shark Bay is a large marine embayment located in Western Australia’s semi-arid mid-west. The bay is geologically recent and is separated from the Indian Ocean on its western side by a ridge of Pleistocene Tamala limestone that forms the Zuytdorp Cliffs, Steep Point and the western side of Dirk Hartog Island (Playford 1990). The underlying geology of the region is largely covered by Pleistocene and Holocene sediments that now dominate marine and terrestrial habitats across much of the bay. Shark Bay’s typically shallow marine environment comprises western and eastern gulfs separated by the Peron Peninsula. The complex bathymetry formed by channels, banks and sills constrains circulation and contributes to the persistence of hypersaline conditions in the south-eastern reaches at L’Haridon Bight and Hamelin Pool. These features are markedly different to the adjacent high-energy oceanic environment and the bay is recognized as being biogeographically unique in the region (DEH 2006).

The distinctive physical and biological features of Shark Bay have led to the region’s inclusion on the World Heritage List (whc.unesco.org), and the WA Government manages the bay’s world heritage values under an agreement with the Australian Government. Conservation values are also managed by inclusion of marine and terrestrial areas in WA’s reserve system, including the Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve which were created in 1990 and comprise ca. 750 000 ha (CALM 1996).

Seagrasses and soft sediments form the major marine benthic habitats in Shark Bay, along with smaller areas of sponge-dominated habitat, corals and mangrove. The limited presence of marine rocky substrata means that macroalgal communities are not a prominent benthic feature as they are along the adjacent coast. Macroalgae occur on limited areas of rocky reef and pavement at mostly western locations in the bay, as epiphytes on seagrasses and mangroves, and where they have colonized artificial structures like jetties and piers. A review by Huisman et al. (1990) documented 153 species of marine algae from Shark Bay.

A sole mangrove species, the Western white mangrove Avicennia marina var. marina (Fig. 2a, b), inhabits Shark Bay, which is the southern-most location where it forms extensive growth in WA. A general account of A. marina in Shark Bay is given in Kendrick et al. (2009). About 1,500 ha of A. marina exists in dense but often isolated stands around the bay, most of which are less than 10 ha in size and few of which exceed 100 ha (DPaW data). Notably, these trees and their pneumatophores can form a significant source of intertidal hard substratum across large parts of this sand-dominated bay where rocky substrata are scarce.

The suite of algal epiphytes associated with mangrove pneumatophores typically includes species associations that are rarely found in other habitats. Genera commonly found on (but not exclusive to) mangroves include the red algae Bostrychia and Caloglossa, plus a selection of generalist epiphytes such as Spyridia filamentosa, Anotrichium tenue and Sphecocladia rigida. As part of a study of A. marina in the Shark Bay Marine Park, we undertook a taxonomic survey of the associated epiphytes, primarily to document their presence but also to examine whether species or species associations were unique to particular sites within the bay.

MATERIALS AND METHODS

Field work was undertaken during June 2009 and 13 sites of relatively dense mangrove growth were selected at spatially dispersed locations across Shark Bay (Fig. 1). At each site the occurrence of epiphytes was noted and where possible photographed in-situ. Representative samples of epiphyte-bearing pneumatophores were collected and preserved in a 5% Formalin/seawater solution. In the laboratory, larger epiphytes were pressed...
onto herbarium sheets, while smaller specimens were mounted whole on microscope slides. Where necessary for microscopic examination, specimens were hand-sectioned, stained in aniline blue, and mounted in a solution of 50% Karo syrup and freshwater. Microscope preparations were examined and photographed using either a Nikon SMZ800 stereo microscope or a Nikon Eclipse 80i compound microscope, in both cases with a Nikon DS Fi1 digital camera. All herbarium sheets and microscopic preparations have been lodged in the Western Australian Herbarium (PERTH). The distribution of species at the various sites (Table 1) is based on presence as observed during the survey, and on subsequent laboratory examination of smaller species.

Only species intimately associated with pneumatophores were recorded. These were growing either directly on the pneumatophores (primary epiphytes) or attached to these primary epiphytes (secondary epiphytes). Some taxa (such as *Chaetomorpha*) were mostly unattached and entangled amongst the pneumatophores.

Taxa were identified based on morphology and agree with previously published accounts of the relevant species. In several cases, particularly in the Cyanobacteria, the identifications are tentative and confirmation by molecular analyses is highly desirable.

**Arrangement of the taxonomic account**

Taxonomic results are grouped into Cyanobacteria (= blue-green algae), Phaeophyceae (= brown algae), Chlorophyta (= green algae), and Rhodophyta (= red algae), with constituent species listed alphabetically. This arrangement generally follows that of Huisman *et al.* (2011). For each species, the name, authority, and date and page of publication are given (the place of publication listed in the references), with author names abbreviated according to Brummitt & Powell (1992). Species newly recorded for Shark Bay are marked with an asterisk (*). The PERTH voucher is cited, followed by a comments section. Descriptions of specimens are based on the Shark Bay material. Unless otherwise indicated by ‘epiphytic on...’, the algae were growing directly on the *Avicennia marina* pneumatophores.

**PREVIOUS RECORDS**

The diversity of mangrove-associated algae in Shark Bay has not been studied intensively, but several species from the bay have been recorded in monographs and other studies. King & Puttock (1994a, b) surveyed Australian mangrove-associated red algae and recorded *Bostrychia moritziana*, *B. radicans*, *Caloglossa leprieurii*, *Polysiphonia scopulorum*, *Caulacanthus indicus* and *Gelidium* spp. for the region extending from Cape Cuvier to Cape Naturaliste, but no records specifically attributed to Shark Bay were included. Two species of *Bostrychia* often found on mangrove pneumatophores, *B. radicans* and *B. moritziana*, were recorded from Steep Point, Shark Bay, by King & Puttock (1989), although specific habitat details were not given. The collector of these specimens was Fred Wells, at the time with the Western Australian Museum, who
Figure 2. Habitat views and in-situ specimens. a. The mangrove *Avicennia marina* growing on the coast near Uendoo Creek. A dense stand of pneumatophores can be seen in the foreground. b. Pneumatophores from the Herald Bight stand, with no epiphyte growth. c. *Acetabularia peniculus* on pneumatophores at Wooramel Central. d. *Ulva flexuosa* on pneumatophores at the seaward edge of Big Lagoon. e. The leafy green *Gayralia oxy sperma* on pneumatophores at the same site. f. A dense band of *Caloglossa leprieuri* on pneumatophores at Uendoo Creek. g. Close view of *Bostrychia flagellifera*. 
<table>
<thead>
<tr>
<th>Table 1. Algae and cyanobacteria epiphytic on <em>Avicennia marina</em>, Shark Bay, June 2009.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Acetabularia peniculus</td>
</tr>
<tr>
<td>Aghoathamnion cordatum</td>
</tr>
<tr>
<td>Anotrichium tenue</td>
</tr>
<tr>
<td>Blastophysea rhizogus</td>
</tr>
<tr>
<td>Boodleopsis siphonacea</td>
</tr>
<tr>
<td>Bostrychia flagellifera</td>
</tr>
<tr>
<td>Bostrychia moritziana</td>
</tr>
<tr>
<td>Bostrychia radicans</td>
</tr>
<tr>
<td>Bostrychia tenella</td>
</tr>
<tr>
<td>Bostrychioclax australis</td>
</tr>
<tr>
<td>Caloglossa aeruginea</td>
</tr>
<tr>
<td>Catenella nipae</td>
</tr>
<tr>
<td>Cenotoceras sp.</td>
</tr>
<tr>
<td>Chaetomorpha ligustica</td>
</tr>
<tr>
<td>Cladonia succulenta</td>
</tr>
<tr>
<td>Cladophora patensiramea</td>
</tr>
<tr>
<td>Cladophora rupestris</td>
</tr>
<tr>
<td>Cladophora vagabunda</td>
</tr>
<tr>
<td>Crouania sp.</td>
</tr>
<tr>
<td>Cenophasciculites chthonoplastes</td>
</tr>
<tr>
<td>Dasya kristenii</td>
</tr>
<tr>
<td>Dichothrix utahensis</td>
</tr>
<tr>
<td>Dictyota furcellata</td>
</tr>
<tr>
<td>Erythromitrha carnea</td>
</tr>
<tr>
<td>Gaylussia fimbriata</td>
</tr>
<tr>
<td>Gelidium minisculum</td>
</tr>
<tr>
<td>Griffithsia heteromorpha</td>
</tr>
<tr>
<td>Herposiphonia pacifica</td>
</tr>
<tr>
<td>Herposiphonia tenella</td>
</tr>
<tr>
<td>Laurencia sp.</td>
</tr>
<tr>
<td>Lyngbya semiplena</td>
</tr>
<tr>
<td>Myrionema sp.</td>
</tr>
<tr>
<td>Myxohyella papuana</td>
</tr>
<tr>
<td>Polysiphonia infestans</td>
</tr>
<tr>
<td>Polysiphonia scopularum</td>
</tr>
<tr>
<td>Polysiphonia teges</td>
</tr>
<tr>
<td>Polysiphonia sp.</td>
</tr>
<tr>
<td>Rhizoclonium riparium</td>
</tr>
<tr>
<td>Rivularia atria</td>
</tr>
<tr>
<td>Scytonea crisppum</td>
</tr>
<tr>
<td>Sphaelaria rigidula</td>
</tr>
<tr>
<td>Spyridia filamentosa</td>
</tr>
<tr>
<td>Stylophora alsidii</td>
</tr>
<tr>
<td>Ulva flexuosa</td>
</tr>
<tr>
<td>Ulva paradoxa</td>
</tr>
<tr>
<td>Ulvella leptochoae</td>
</tr>
<tr>
<td>Ulvella viridis</td>
</tr>
<tr>
<td>Uronema marinum</td>
</tr>
</tbody>
</table>

X: Present

Uendoo Creek
Wooramel Central
Wooramel South
Little Lagoon
Big Lagoon
Cape Leveque
Dubuat Creek
Herald Bight
Saure North East
Saure South
Blind Inlet West
Blind Inlet East
Long Tom Bay

48
recalled (pers. comm., 1 Mar. 2012) that the specimens were indeed epiphytic on mangroves.

Kendrick et al. (1990: 48) noted that collections of epiphytes were made from the pneumatophores of the mangrove Avicennia marina in Shark Bay during 1986. They listed Ulvaria oxysperma [= Gayralia oxysperma], Caloglossa leprieurii, Spyridia filamentosa, Bostrychia moritziana, B. radicans and B. tenella ssp. flagellifera [= Bostrychia flagellifera], but no collection data were given. These records were provided by Robert King, who identified the specimens (Kendrick et al. 1990: 53). Huisman et al. (1990) collated new and published records of macroalgae from Shark Bay, but did not include the mangrove epiphytes mentioned by Kendrick et al. (1990).

Kamiya et al. (1997) described the new species Caloglossa monosticha, with the type locality of Derby, Western Australia. They also cited a specimen from ‘Small’ [presumably Little] Lagoon, Denham, collected in 1991. The specific habitat of this Shark Bay specimen was not stated, but the species was described as “often epiphytic on mangroves” (p. 104).

Finally, the molecular phylogenetic analysis of Caloglossa species by West et al. (2001: 187, Table 2) included C. leprieurii from Shark Bay (specific location not given) and C. monosticha from Monkey Mia, Shark Bay.

RESULTS

Key to the major groups of mangrove-associated macroalgae and cyanobacteria at Shark Bay

1 Thallus blue-green to dark green, forming unbranched or falsely branched filaments, in some with heterocytes; cells prokaryotic, lacking organelles, but occasionally granular in appearance

Cyanobacteria

1 Thallus various shades of green, red or brown, with simple or complex construction, without heterocytes; cells eukaryotic, with organelles

Chlorophyta

2 Thallus grass green

Chlorophyta

3 Thallus brown

Phaeophyceae

3 Thallus red

Rhodophyta

Cyanobacteria (blue-green algae)

Numerous unicellular and filamentous cyanobacteria were present on the Avicennia pneumatophores. The present treatment only deals with the conspicuous taxa.

Key to the mangrove-associated Cyanobacteria at Shark Bay

1 Trichomes aggregated in a mucilage

2: Trichomes not aggregated

4: Trichomes without heterocytes

5 Heterocytes intercalary, filaments with occasional false branching

6 Heterocytes basal, filaments unbranched

5:  Trichomes aggregated in a mucilage hummock

6:  Trichomes with heterocytes

7:  Trichomes without heterocytes

8:  Heterocytes intercalary, filaments with occasional false branching

9:  Heterocytes basal, filaments unbranched

1. Calothrix aeruginea

Thallus blue-green, with several trichomes united in a common sheath. Trichomes unbranched, slightly constricted at the cross walls, 5–9 µm diam. Cells L:B ±1.5–2, not tapering, apical cell with rounded apex, noncalyptrate (Fig. 3b).

Specimen: Herald Bight, seaward side, on basal region of Gayralia oxysperma, 8 June 2009, J.M.Huisman (PERTH 08578699).

The present specimen agrees morphologically with the description of this apparently widespread species by Siegsmund et al. (2008), but the identification should be confirmed by molecular analyses.

2. Coleofasciculus chthonoplastes


Thallus blue-green, with several trichomes united in a common sheath. Trichomes unbranched, slightly constricted at the cross walls, 5–9 µm diam. Cells L:B ±1.5–2, not tapering, apical cell with rounded apex, noncalyptrate (Fig. 3b).

Specimen: Long Tom Bay, South Passage, 11 June 2009, J.M.Huisman (PERTH 08578796).

The present specimen agrees morphologically with the description of this apparently widespread species by Siegsmund et al. (2008), but the identification should be confirmed by molecular analyses.

3. Dichothrix utahensis

Tilden 1898 [1894–1909]: 288.

Thallus forming upright tufts of one to numerous trichomes in a common branched sheath, the basal segment comprised of a single trichome, more distal segments with progressively increasing numbers of trichomes due to addition by false branching. Trichomes 2–7 µm diam., tapering to pointed apices that emerge from the sheath, cells L:B 0.2–10 (shortest near apices). Heterocytes basal on false branches, unipolar, dome-shaped, 5–12 µm diam., L:B 0.5–1, or intercalary and bipolar, to 20 µm long and 7 µm diam. (Figs 3c, d).

Specimens: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578702).

The specimens agree with the description of this species from the Caribbean by Littler & Littler (2000), which was also of thalli growing on mangrove prop roots. Amongst the species they recorded, D. utahensis was characterized by its narrow heterocytes (10–16 µm diam.) and the presence of intercalary as well as basal heterocytes.
both features of the Shark Bay material. The species was subsequently recorded from Wake Atoll in the central Pacific by Tsuda et al. (2010).


Forming tangled mats. Filaments straight or occasionally coiled, unbranched, 7–12 µm diam., sheath inconspicuous. Cells discoid, L:B 0.2–0.3, with or without a terminal callytra. Necrida common (Fig. 3c).

Specimen: Cape Lesueur, 7 June 2009, J.M.Huisman (PERTH 08578680).

This is a seemingly cosmopolitan species, found in coastal regions worldwide


Thallus blue-green, minute, 50–100 µm broad, prostrate and partly endophytic on *Bostrychia tenella*, with branched pseudofilaments. Central region of angular to rounded, mostly equisimensional cells, 3–5 µm diam. Peripheral cells elongate, L:B 2–7, often irregularly shaped and following the contours of the host cells (Fig. 3f).

Specimen: South Passage, epiphytic on *Bostrychia tenella*, 11 June 2009, J.M.Huisman (PERTH 08578757).

This small epiphyte was described from Papua New Guinea, based in part on a specimen 'endophytic in a red alga growing on the roots of mangrove trees in the intertidal zone'.


Colonies forming hemispherical hummocks, to 2 mm diam., formed by aggregated *Calothrix*-like filaments. Trichomes 150–400 µm long, with a dome-shaped basal heterocyte, ± 5 µm diam., then cells of similar diameter, L:B 0.5–1, gradually tapering to a hair-like apex (Fig. 3g).

Specimen: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578710).

*Rivularia* is a colonial organism formed of *Calothrix*-like trichomes embedded in mucilage.


Thallus tufted, to a few mm tall, often accumulating mud and other debris. Filaments mostly tortuous, occasionally straight, rarely with false branching, 25–35 (–50) µm diam., of fairly uniform width. Trichome blue-green, often filling sheath, especially near apices, to 15–25 µm diam., cells L:B 0.1–0.3, often considerably more slender in lower portions, to 3–7 µm diam., L:B up to 2, and occupying ± 15% of the sheath. Apices rounded or tapering, often with a cap-like apical cell. Heterocytes conspicuous, intercalary, with diameter similar to that of adjacent cells, L:B 0.5–2 (Figs 3h, i).

Specimen: Dubaut Creek, 8 June 2009, J.M.Huisman (PERTH 08578451).

This species forms dense tufts on the pneumatophore surface. The false branching and presence of heterocytes places it in the genus *Scytonema*, but most species in the genus have considerably more slender filaments. The specimens agree well with the description in Whitton (2011), although he recorded only freshwater habitat and the determination is therefore tentative. King & Wheeler (1985) recorded *Scytonema crisum* (C. Agardh) Bornet occurring as dense tufts on pneumatophores at Stuarts Point, N.S.W. An invalidly described species, *Scytonema hamelinii* Gebelein (in Logan, Hoffman, & Gebelein, 1974: 146, 194) was recorded from Hamelin Pool, Shark Bay. This species was presumably not a mangrove epiphyte and we are unaware of any extant material.

Chlorophyta

*Key to the mangrove-associated Chlorophyta at Shark Bay*

1. Thallus microscopic, single-celled, endophytic or epiphytic on larger algae .............. 9. *Blastosphaea rhizopus*

2. Thallus microscopic .......................... 2

3. Thallus with upright unbranched filaments ................................................................. 21. *Uronema marina*

4. Filaments closely arranged; cells with hairlike extensions ........................... 19. *Ulvella leptochaete*

5. Thallus radially symmetrical, with a central stalk and apical crown of gametangial rays.......................... 8. *Acetabularia peniculus*

6. Thallus with discrete cells .................. 7

7. Thallus filamentous, branched, or of other structure ............................................ 9

8. Cells 70–100 µm in diameter ............................... 11. *Chaetomorpha ligula*

9. Thallus filamentous, branched, never multisieriate, .10

10. Thallus forming decumbent clumps, with arching filaments.................................... 13. *Cladophora patentirea*

11. Thallus with percurrent primary axis and often opposite lateral branches; not falcate near apices.................................................. 14. *Cladophora rupestris*

12. Thallus membranous .................. 15. *Gayralia oxyperma*

13. Thallus lacking uniseriate branches .. 17. *Ulva flexuosa*

14. Thallus with uniseriate branches near apices.................................................. 18. *Ulva paradoxa*

51
8. *Acetabularia peniculus* (R.Brown ex Turner) Solms-Laubach 1895: 27. Thallus generally with several upright axes in a cluster, pale green or whitish from calcification, to 10 cm tall, with several whorls of colourless branched hairs and an apical whorl of 10–18 green gametangial rays, these basally attached but not laterally joined. Gametangial rays clavate, 2–5 mm long and 0.5–3.0 mm broad, when fertile with numerous spherical gametangial cysts 240–270 µm diam. (Fig. 2c).


*Acetabularia peniculus* is a common species that is often found growing in clusters on old bivalve shells on sandy substrata. This represents the first record of this species from South Australia. The dimensions of these specimens fall within *Cladophora dalmatica* Kütz., a species now provisionally treated as a small form of *C. vagabunda* (e.g. Kraft 2007: 81), although molecular analyses will likely result in further revision. Previously recorded for Shark Bay by Huisman *et al.* (1990).


Individual, irregularly shaped, green cells, 35–50 µm broad, epiphytic on *Bostrychia tenella*.


This is a small epi/endophyte that is often associated with larger red algae.

10. *Boodleopsis siphonacea* A.Gepp & E.Gepp 1911: 64.*

Thallus tufted, dark green, to 5 mm tall, with prostrate and irregularly constricted siphons 50–75 µm diam., attached by tapering rhizoids 8–20 µm diam.; erect siphons terete, 17–25 µm diam. Branches 50–900 µm long, more elongate distally, evenly constricted at branch bases and often with slight constrictions elsewhere (Figs 4a, b).


This species is apparently known only from the type collection, but other species recorded from elsewhere might be synonymous. Species of *Boodleopsis* are distinguished by features such as habit, density of branching, and frequency of constrictions, which appear to overlap in many cases. Skelton & South (2002) described similar specimens from mangroves in Samoa, which they ascribed to *B. carolinensis* Trono, a species separated from *B. siphonacea* largely by its more densely branched habit (Trono 1971).

11. *Chaetomorpha ligustica* (Kutz.) Kütz. 1849: 376.* Thallus grass green, generally entangled amongst other algae or cyanobacteria, composed of unbranched filaments. Cells 70–100 µm diam., L:B 1–3, intercalary divisions common and forming pairs of daughter cells. Parietal reticulate plastids with numerous pyrenoids. Rarely with attachment rhizoids (Fig. 3d) similar to those found in *Rhizochlorion* (Figs 4c, d).


These specimens agree with Womersley’s (1984) concept of *Chaetomorpha capillaris* (Kutz.) Borgesen, a species now regarded as a taxonomic synonym of *Chaetomorpha ligustica* (see Leliaert & Boedeker 2007: 142); Cribb (1965) treats this species as the basionym *Rhizochlorion capillare*, based on the presence of attachment rhizoids similar to those found in the present material, but Womersley (1984) doubted the specific identity of Cribb’s material. Beanland & Woelkerling (1982: 94) recorded this species (as *C. capillaris*) on *Avicennia* pneumatophores in South Australia.

There is considerable uncertainty regarding specific identities of *Chaetomorpha* and *Rhizochlorion* species, and it is likely that several cryptic species are involved. Thus application of this name must be regarded as tentative in the absence of DNA sequence analyses.


13. *Cladophora rupestris* (L.) Kütz. 1843: 270.* Thallus dark green, attached by digitate processes arising from the basal cell. Primary axis percurrent, with cells 70–100 µm diam., L:B 1–4, each generally with (1-) 2 (-3) opposite lateral branches, occasionally naked (Fig. 4e).


This distinctive species has dark green percurrent primary axes from which lateral branches arise in opposite pairs.


Thallus upright, grass green, filamentous, generally branched every 1–2 cells but often with intercalated unbranched cells. Branching falcate near apices. Cells 70–80 µm diam. near base, tapering to 20–25 µm diam.

Specimen: Faure I., 10 June 2009, *J.M.Huisman* (PERTH 08578443).

The dimensions of these specimens fall within *Cladophora dalmatica* Kütz., a species now provisionally treated as a small form of *C. vagabunda* (e.g. Kraft 2007: 81), although molecular analyses will likely result in further revision. Previously recorded for Shark Bay by Huisman *et al.* (1990).


Thallus grass green, membranous, leafy, to 3 cm tall and equally as broad. Blade one cell thick, in surface view the cells often in packets. Lower cells with basally directed, elongate tails (Figs 2e, 4f).
Figure 4. Chlorophyta (green algae). a, b. Boodleopsis siphonacea. a. view of upper thallus. b. detail of branching with slight constrictions. c. Chaetomorpha ligustica (broad, lower filaments) and Rhizoclonium riparium (narrow, upper filaments), often found growing together. d. Chaetomorpha ligustica, with attachment rhizoid. e. Cladophora rupestris, with branched filaments. f. Surface view of Gayralia oxysperma, at the transition to the basal region and showing cells with elongate tails. g, h. Ulva flexuosa. g. thallus habit. h. closer view of branch with cells in vague longitudinal rows. Several pyrenoids can be seen in each cell. i. Ulva paradoxa, thallus habit, showing numerous uniseriate branches characteristic of this species. j. Uronema marinum, simple filaments typical of this species.
Specimen: Big Lagoon, 7 June 2009, J.M.Huisman (PERTH 08578427).

The membranous green thallus of *Gygaria oxysperma* superficially resembles that of some leafy species of *Ulva* (see Kendrick *et al.* 2009: unnumbered fig. on p. 55), but it can be readily identified by its blades composed of only a single cell layer, whereas those of *Ulva* have two layers.

16. *Rhizoclonium riparium* (Roth) Harv. 1849: pl. CCXXXVIII.*

Slender unbranched filaments, growing indeterminately (vouchers to 5 mm long), sporadically attached to the pneumatophores by rhizoidal outgrowths from distal ends of cells, these causing the filament to kink. Filaments 15–35 µm diameter, cells L:B 1–3, intercalary divisions common and distinct pairs of daughter cells. Parietal plastids somewhat rod-shaped, with numerous pyrenoids (Fig. 4c).

Specimens: Uendoo Creek, 4 June 2006, J.M.Huisman (PERTH 08578672); Faure I., 10 June 2009, 10.17 a.m. J.M.Huisman (PERTH); Long Tom, South Passage, 11 June 2009, J.M.Huisman (PERTH).

17. *Ulva flexuosa* Wulfen 1803: 1.*

Thallus erect, to 7–8 cm tall, grass-green, attached by a rhizoidal base. Branching primarily from near the base; branches proximally narrow and broadening distally. Structure with cells mostly in longitudinal rows, occasionally also in transverse rows, the alignment of cells more regular near the base and becoming irregular above. Cells in surface view square to rectangular, 10–20 µm wide, each with a parietal chloroplast and 2–4 pyrenoids each 5–6 µm diam. (Figs 4g, h).

Specimen: Big Lagoon, Shark Bay, ocean side, on *Aricennia marina* pneumatophores, 7 June 2009, J.M.Huisman (PERTH 08578664).

*Ulva flexuosa* and *U. paradoxa* were previously included in the now subsumed genus *Enteromorpha*, a genus wherein the thallus was tubular in form rather than sheet-like as in typical *Ulva*. Thalli of *Ulva flexuosa* have tubular branches in which the cells are arranged in longitudinal and often transverse series. Adventitious uniseriate branches arise occasionally to profusely from the tubular branches. Each cell has 2–3 pyrenoids. *Ulva paradoxa* was once regarded as a form of *U. flexuosa*. It differs in the regular occurrence of uniseriate branches, these near apices often with opposite lateral branches.

18. *Ulva paradoxa* C.Agardh 1817: xxii.*

Thallus erect, to 5 cm tall, olive-green to grass-green, tufted, with a rhizoidal base. Primary axes 30–60 µm diam. Branching irregular, most axes with uniseriate lateral branches, these alternate or often opposite, 15–20 µm diam. Cells transversely and longitudinally aligned throughout, although often displaced, 10–35 µm diam. in surface view, each with 2–10 pyrenoids (Fig. 4i).

Specimen: Cape Lesueur, 7 June 2009, J.M.Huisman (PERTH 08578273).


Thallus microscopic, prostrate on *Acetabularia peniculus*, composed of branched filaments that generally coalesce to form a partly complete cover. Cells irregularly shaped, 20–35 µm diam., many with hairlike extensions.


Thallus microscopic, bright green, endophytic in walls of *Polysiphonia teges*, of irregularly branched prostrate filaments to 200 µm long. Filaments generally remaining free, rarely forming a loose pseudoparenchyma. Cells mostly subsisdiametric, squarish to rectangular in outline, mostly 10–15 µm diam., but some cells in actively growing regions more slender (c. 5 µm diam.). Cells with a parietal chloroplast and 1 or 2 pyrenoids. Hairs not observed.

Specimen: Little Lagoon, on *Polysiphonia teges*, 6 June 2009, J.M.Huisman (PERTH 08578583).


Thallus grass green, with simple filaments to 400 µm tall, 7–17 µm diam., attached basally by a small digitate holdfast. Cells L:B 1.5–4, with one central nucleus and several pyrenoids (Fig. 3j).

Specimen: Faure I., epiphytic on *Bostrychia tenella*, 10 June 2009, J.M.Huisman (PERTH 08578761).

**Phaeophyceae**

The diversity of brown algae was very low, with only *Dictyota furcellata*, *Sphacelaria rigidula* and the small encrusting *Myrionema* sp. encountered.

**Key to the mangrove-associated Phaeophyceae at Shark Bay**

1. Thallus forming discoid crusts, less than 1 mm diam. ..........................23. *Myrionema* sp.

2: Thallus upright, not small crusts ........................................2

2. Thallus dichotomously branched, with flat axes ..........................22. *Dictyota furcellata*

2: Thallus tufted, wiry, irregularly branched, with terete axes .................24. *Sphacelaria rigidula*


Thallus to 8 cm tall, entangled, dichotomously divided every 5–10 mm. Axes flattened, to 1 mm broad below, tapering to 200 µm near apices. Apices pointed, with a prominent apical cell. Hair tufts common. Tetrasporangia scattered or in small groups on surface of thallus, spherical, 75–110 µm diam. (Fig. 5b).


Shark Bay is the type locality of this narrow species of *Dictyota*.
23. *Myrionema* sp.*

Thallus epiphytic, discoid, to 350 µm diam., with a monostromatic basal layer of regularly or irregularly radiating filaments, these when mature bearing short upright filaments, phaeophycean hairs, or asccysts. Basal filaments laterally coherent, except at margins where some are free, with cells quadrate or irregular in shape, 8–10 µm broad, L:B ±1. Phaeophycean hairs to 400 µm long, simple, with a basal meristem subtending hyaline cells 7–10 µm diam., L:B to 10.


This is a small discoid epiphyte found on a variety of other algae. The specimens are not adequate for species determination.


Thallus to 10 mm tall, forming dense dark brown wiry tufts attached by rhizoidal filaments arising from lower axes. Erect axes mostly of similar height; apical cells 25–50 µm diam.; lower segments undergoing several longitudinal divisions, but maintaining a similar diameter throughout the plant, in lateral view showing 1–3 (–4) cells. Lateral branches common, arising at shallow angles and slightly narrowed at the base. Elongate hairs forming laterally near apices of erect axes, 20–25 µm diam., with a basal meristem. Propagules with a primary axis c. 250 µm long, bearing 2 elongate arms and a small dome-shaped cell at the apex (Fig. 5a).

Specimen: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578494).

**Rhodophyta**

*Key to the mangrove-associated Rhodophyta at Shark Bay*

1 Thallus filamentous, structurally without pericentral cells, pseudoparenchyma or cortication of any form ..........................2

1: Thallus structurally with pericentral cells, pseudoparenchyma or cortication of any form ..........................7

2 Filaments without pit-connections between cells .................................................3

2: Filaments with pit-connections between cells.................................................4

3 Thallus unbranched ........................................39. *Erythrotrichia carnea*

3: Thallus branched ......................................51. *Stylonema alsidii*

4 Axial cells each with 3 whorl branches ...............................................................37. *Crownia sp.*

4: Axial cells with fewer than 3 branches ............................................................5

5 Thallus alternately branched with a single lateral branch per axial cell, without trichoblasts ..................................................25. *Aglaotheramnion cordatum*

5: Thallus sparsely branched, with trichoblasts (colourless hairs) .................................................6

6 Cells mostly of similar form; trichoblasts numerous, very conspicuous .................................................................26. *Anoctrichium tenue*

6: Cells cylindrical in lower thallus, barrel-shaped to spherical in upper thallus; trichoblasts rudimentary ..................................42. *Griffithsia heteromorpha*

7 Thallus cartilaginous, wiry, structurally with longitudinal medullary filaments and a pseudoparenchymatous cortex .........................................................................8

7: Thallus not as above .........................................................9

8 Thallus segmented, without rhizines .................................................................34. *Catenella nipae*

8: Thallus not segmented, with rhizines (thick walled internal filaments) .................................................................41. *Gelidium minisculum*

9 Thallus leafy, with a midrib and lateral wings .........................................................10 (Caloglossa)

9: Thallus not leafy .................................11

10 Attachment rhizoids forming a stipe; basal axial cell of lateral branches lacking an adaxial pericentral cell ..........32. *Caloglossa leprieurii*

10: Attachment rhizoids not forming a stipe; basal axial cell of lateral branches with an adaxial pericentral cell ..........33. *Caloglossa monosticha*

11 Forming parasitic pustules on *Bostrychia* .........................................................31. *Bostrychiocolax australis*

11: Not parasitic ........................................................................................................12

12 Branches with pericentral cells (longitudinally oriented cells cut off from the primary axial cells) ..................................................13

12: Branches without pericentral cells .................................................................25

13 Pericentral cells divided transversely ...14 (Bostrychia)

13: Pericentral cells not divided transversely .........................................................17

14 Thallus with main axes corticate .........................................................15

14: Thallus ecorticate throughout .................................................................16

15 Lateral branches arising from every axial cell on the indeterminate axes .................................................................30. *Bostrychia tenella*

15: Lateral branches arising from every 2–4(-5) axial cells on the indeterminate axes .................................................................27. *Bostrychia flagellifera*

16 All branches polysiphonous ..............................................................................29. *Bostrychia radicans*

16: Main branches polysiphonous; ultimate vegetative branches monosiphonous ...................................................28. *Bostrychia moritziana*

17 Thallus with distinct prostrate axes from which arise upright branches in a regular pattern of determinate and indeterminate branches .............................................................18 (Herposiphonia)

17: Thallus erect, or if prostrate without a regular pattern of branches .................................................................................................19

18 Lateral branches in the repeating pattern: 3 determinate/1 determinate .............................................................................44. *Herposiphonia tenella*

18: Lateral branches in the repeating pattern: 1 determinate/1 determinate/1–2 naked segments ..................................................................43. *Herposiphonia pacifica*

19 Thallus with pigmented monosiphonous filaments .................................................................38. *Dasya kristeniae*

19: Thallus with unpigmented monosiphonous filaments (= trichoblasts) ..................................................................................20

20 Thallus with secondary cortication obscuring the pericentral cells ..................................................21

20: Thallus without secondary cortication, with visible pericentral cells ..................................22 (Polysiphonia)
Figure 5. Phaeophyceae (a, b) and Rhodophyta (c–f). a. *Sphacelaria rigidula*, thallus habit with propagules (arrows). b. *Dictyota furcellata*, branch apices with surface hair clusters. c. *Anotrichium tenue*, branch apex showing whorled trichoblasts (colourless hairs). d. *Bostrychia flagellifera*, thallus habit with corticated primary axes tapering to uniseriate filaments. e, f. *Bostrychia moritziana*. e. thallus habit. f. detail showing uncorticated axes.
21. Thallus prostrate with dense lateral branches, robust, mat-forming, dull purple to deep red. Primary axes 150–230 µm diam., bearing alternate lateral branches every 2–3 axial cells. Lateral branches polysiphonous proximally, 70–100 µm diam., bearing ultimate uniseriate branches 15–30 µm diam., these tapering distally with cells L:B 1–1.5 (Figs 2g, 5d).

Specimen: Blind Inlet, South Passage, 11 June 2009, J.M.Huisman (PERTH 08578303)

This species, described originally from the Paramatta River in New South Wales, is also known from New Zealand and Japan (Post 1961). King & Puttock (in King et al. 1988) treat it as a subspecies of Bostrychia tenella, and a previous Shark Bay record was under that name (Kendrick et al. 1990). Recognition at species level was recommended by Zuccarello & West (2006) based on molecular analyses that showed B. flagellifera did not group with B. tenella, and the taxon displays a diagnostic synapomorphy (branching interval).

28. Bostrychia moritziana (Sond. ex Kütz.) J.Agardh 1863: 862

Thallus prostrate, mat-forming, purple to brown; main axes indeterminate, 20–40 (–60) mm long, bearing determinate lateral branches 2–3 mm long, with 1–3 orders of alternate branching; 2 tiers of pericentral cells per axial cell with 4–5 (–8) pericentral cells per tier around the main axes and primary lateral branches; ectocortex throughout; polysiphonous except for monosiphonous ultimate and penultimate determinate branches. Indeterminate axes 60–100 µm diam.; branches arising subdichotomously at intervals of more than 10 axial cells; determinate branches arising laterally at intervals of 2–5 (–8) axial cells. (Figs 5e, f).

Specimen: Long Tom Bay, South Passage, 11 June 2009, J.M.Huisman (PERTH 08578435)

Recorded from Steep Point, Shark Bay (26°08'S., 113°10'E., iii.1986, Wells UNSW 16271) by King & Puttock (1989: 32)

29. Bostrychia radicans (Mont.) Mont. 1842: 661

Thallus prostrate with suberect branches, robust, turf-forming, purple to brown; main axes indeterminate, 10–15 (–20) mm long, bearing determinate lateral branches 2–3 mm long, with 1–2 (–3) orders of alternate branching; 2 tiers of pericentral cells per axial cell, with (5)–7–8 pericentral cells per tier around the main axes and lateral branches, ectocortex and polysiphonous throughout; attached to the substratum by cladhophyta. Indeterminate axes 120–200 µm diam.; branches arising subdichotomously at intervals of more than 10 axial cells; determinate branches arising laterally at intervals (2–)4–6 axial cells (Fig. 6a).

Specimen: Uendoo Creek, 4 June 2009, J.M.Huisman (PERTH 08578516); also recorded from Steep Point, Shark Bay (26°08'S., 113°10'E., iii.1986, Wells UNSW 16269) by King & Puttock (1989: 32)

30. Bostrychia tenella (J.V .Lamour.) J.Agardh 1863: 869

Thallus prostrate with dense lateral branches, robust,
mat-forming, dull purple, violet to brown; main axes indeterminate, 20–50 mm long, bearing determinate branches 2–3 mm long, with 1–3 (–4) orders of alternate branching; 2 tiers of 5–7 (–8) pericentral cells per axial cell; indeterminate axes and first-order lateral branches corticate; polysiphonous except for wholly or partially monosiphonous ultimate branches. Indeterminate axes 80–500 µm diam.; branches arising subdichotomously or laterally at intervals of 1 (–4) axial cells. Determinate branches arising at intervals of 1 (–2) axial cells. Tetrasporangial stichidia on ultimate lateral branches (Fig. 6b).

Specimen: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578249).


Thalli forming colourless irregularly shaped to hemispherical pustules laterally on host leaves, to 600 µm tall and 900 µm broad. Structure filamentous, multiaxial, with darkly staining large internal cells bearing numerous radiating branches. Tetrasporangia terminal on filaments, ellipsoidal to obovoid, 20–30 µm long, 12–17 µm diam., tetrahedrally divided (Fig. 6c).

Specimen: Uendoo Creek, on Bostrychia radicans epiphytic on Avicennia marina pneumatophores, 4 June 2009, J.M.Huisman (PERTH 08578508).

This species is a parasitic red alga seemingly restricted to the host Bostrychia radicans. Two specimens were collected from the Uendoo Creek site, one male gametophyte and one tetrasporophyte. This represents a new generic record for Western Australia, the genus previously known only from Queensland (Zuccarello & West 1994: 138).


Thalli forming low mats composed of arching leaf-like blades, pale brown to reddish brown, epiphytic and epilithic, loosely attached to the substratum at intervals by clusters of coalescent rhizoids arising from cortical pads produced by pericentral cells at the nodes; mature blades linear to suborbicular, (0.35–) 0.6–2.1 (–3.5) mm wide, with (0.8–) 3.1–6.2 (–7.5) mm between weakly to strongly constricted nodes, occasionally arising as stipitate rosettes; endogenous branches produced by an axial cell above the nodes; adventitious branches absent. Reproductive structures not observed (Fig. 6d).

Specimen: Uendoo Creek, 4 June 2009, J.M.Huisman (PERTH 08578524); Faure I., 10 June 2009, J.M.Huisman (PERTH); also recorded from Shark Bay by West et al. 2001


Thalli forming low mats composed of arching blades, pale brown to olive-green, epiphytic, subdichotomously branched, loosely attached to the substratum at intervals by clusters of divergent rhizoids arising directly from nodal pericentral cells; mature blades linear to narrowly elliptical, 0.3–1.4 mm wide with 1.3–5.8 mm between slightly constricted nodes; stipes absent. Nodes on main axes with all second- and third-order cell rows on the adjacent and opposite sides reaching the blade margin. Rhizoids arising from first and second adjacent and adaxial lateral pericentral (second-order) cells above the node, 6–10 cells and 0.6–1.5 mm long, 25–45 µm diam. Reproductive structures not observed (Fig. 6e).

Specimen: Dubaut Creek, 8 June 2009, J.M.Huisman (PERTH 08578354); also recorded from Monkey Mia, Shark Bay, by West et al. (2001: 192).

Caloglossa monosticha can be distinguished from C. leprieurii by the attachment rhizoids remaining free and not forming a stipe. This feature is best observed in well-developed specimens, as rhizoids in young branches of C. leprieurii are also free. A further distinction can be seen in the cell arrangement at nodes. In C. leprieurii the basal axial cell of the lateral branch lacks an adaxial pericentral cell, whereas these are present in C. monosticha. Wynne & De Clerck (1999) proposed that C. monosticha was conspecific with the earlier described C. saigonensis Tak.Tanaka & P.H.Hô, but this was rejected by Kamiya et al. (2003) based on molecular and culture studies.

34. Catenella nipae Zanardini 1872: 143.

Thalli dark red to brown, to 4 cm tall, tufted or tangled, with sprawling terete stolons to 0.5 mm wide, attached at several points. Erect axes richly branched, segmented; segments elongate-ovoid, 3–5 mm long, 0.5–1.0 mm wide. Structure with a prominent apical cell but usually lacking a single distinct axial filament; centre of the medulla occupied by several longitudinal filaments, each with a single lateral filament, these forming a reticulate medulla of regularly spaced branched filaments 10–25 µm diam., often with stellate cells. Secondary connections between medullary filaments common. Cortex of 2 cell layers; inner layer of clavate to spherical cells; outer layer of ellipsoidal to elongate cells 3.5–7.0 µm diam., forming a palisade. Spermatangia in sori on thallus surface. Other reproduction not observed (Figs 7a, b).

Specimen: Uendoo Creek, 4 June 2009, J.M.Huisman (PERTH 08578532).

The present specimens agree in most respects with the description by Min-Thein & Womersley (1976), excluding the presence of two periaxial cells per axial cell, a feature regarded as characteristic for the genus (Guiry & Guiry, 2014). Later, however, Womersley (1994), described only one periaxial cell per axial cell. The primary axial filament in the Shark Bay specimens was often conspicuous, particularly so in material stained with aniline blue, this also differing from Womersley’s description who suggested that the axial filament was inconspicuous. The persistent visibility of the axial filament is a feature of the closely related Caulacanthus ustulatus, but that species is not constricted. One of the specimens was male, with spermatangia produced in sori on the thallus surface.

35. Centroceras sp.*

Thalli with prostrate and assurgent axes, light red, to 3.5 mm tall, sparsely subdichotomously branched every c. 8 cells, but often with long unbranched axes. Prostrate axes attached by multicellular rhizoids arising 1–3 per
node from periaxial cells, basally as an extension of the periaxial cell and the first cross wall external to the node. Upright axes with foricate apices. Segments 70–90 μm diam. [L:B < 1 near apices, to 5 in mature segments]. Periaxial cells 8–11 per node, each bearing 2 acropetal and 1 basipetal initials. First acropetal initial bearing either a spine or a gland cell, and 1 or 2 conical to elongate cells, these often forming elongate hairs. Second acropetal initial bearing 1 acropetal conical to elongate cell and a basipetal cortical filament. Basipetal initial bearing 1 basipetal cortical filament. Spines 2-celled (not including acropetal initial), in whorls of 4–6 per node. Gland cells ellipsoidal, 10–12 μm long, 7–10 μm diam. Basipetal cortical filaments 10–12 cells long, completely covering the axial cells, with cells of varying lengths, these often becoming transversely aligned towards the proximal portion of each segment (Fig. 6g).


This is a new species, known also from Barrow Island, the Rowley Shoals, and Scott Reef, which is being formally described elsewhere (Huisman, in prep.).


Thallus with several simple to 1–3 times branched axes arising from a common holdfast, to 6 mm tall. Axes terete, 0.25–0.6 mm diam., with blunt to sunken apices with emergent filaments. Epidermal cells elongate to ellipsoidal, 17–20 μm diam. L:B to 7. Tetrasporangia near apices, spherical, 50–75 μm diam., tetrahedrally divided. Spermatangia in discoid plates, to 450 μm broad, with a single row of sterile marginal cells (Fig. 6f).


Although of only a small stature, both male and tetrasporic specimens were collected. These agree for the most part with the description by Gordon-Mills & Womersley (534–537), differing only in the smaller size of the thallus and tetrasporangia. In both cases this is probably due to the plant maturity.

37. *Crouania* sp.

Thallus filamentous, uncorticated, with prostrate and erect branches. Erect branches c. 750 μm tall, with axial cells 10–15 μm diam., L:B 1.5–2, each axial cell bearing a whorl of 3 branches, these 2–3 cells long and dichotomously branched (in one instance trichotomous). Reproductive structures not observed.

Specimen: Wooramel South, epiphytic on *Bostrychia tenella*, 5 June 2009, J.M.Huisman (PERTH 08578389; PERTH 08578613).

These are immature specimens that cannot be identified to species.


Thallus red, 9 mm tall, attached by clumped pigmented cells arising from the basal region. Primary axis polysiphonous, terete, basally to 200 μm diam., tapering to 50 μm diam. near apices, with sympodial apical growth and pericentral cells developing spirally. Primary axial cells each with 5 pericentral cells and a branched, pigmented monosiphonous lateral arising in a 2/5 spiral. Segments of primary axis elongate, L:B 2–4. Monosiphonous laterals to 1.5 mm long, monopodial, dichotomously branched every 1–2 cells, with elongate cells 10–20 μm diam., L:B 5–7. Reproductive structures not observed (Figs 6h, i).


This small species is attributed to *Dasya* based on the production of five pericentral cells, sympodial growth of primary axes, and branched, monosiphonous pigmented laterals arising on every segment in a 2/5 spiral. Unlike most species of the genus, however, the pigmented lateral branches divide monopodially, and thus do not have dichotomies wherein the two distal cells have a confluent lateral face (the ‘inverse Y junction’ described by Parsons 1975: 562). Although this was not described by Abbott (1998, 1999), her figures of *Dasya kristeniae* appear to show a similar arrangement. Abbott (1998) described *D. kristeniae* as having only four pericentral cells, but also as having monosiphonous laterals arising in a 2/5 spiral, which is incompatible with four pericentral cells. Coppejans & Millar (2000: 329) attributed completely ecorticate (except for small rhizoids at the very base) plants from Papua New Guinea to *D. kristeniae*, although they did not comment on the number of pericentral cells.


Thallus red to purple-red, with erect filaments to 3 mm tall, attached by a single basal cell that can be lobed. Filaments mostly simple, 15–20 μm diam. (including a thick gelatinous wall); cells 12–14 μm long [L:B 0.7–1]. Monosporangia subspherical, cut off by a curved wall.

Specimen: Cape Lesueur, epiphytic on *Gayliella fimbriata*, 7 June 2009, J.M.Huisman (PERTH 08578605).

*E. carnea* forms small, unbranched, uniseriate filaments, epiphytic on a variety of algae. It is a common and widespread species.


Thallus red to purple-red, with prostrate and erect axes to 7.5 mm long, attached by rhizoids arising from periaxial cells of lower axes. Erect axes subalternately branched every 4 or 5 cells in the primary axes and every 5–7 cells in lateral axes. Apices straight to curved, not cincinate. Periaxial cells 6, each producing basipetally a transversely aligned cell that subsequently cuts off 1 or 2 cells by oblique divisions from the lower corners, and acropetally a pair of cells that divide several times. Cortical cell development more extensive in older nodes. Distal cells of nodes commonly with elongate or clavate gland cells. Reproductive structures not observed (Fig. 7c).

Specimen: Cape Lesueur, 7 June 2009, J.M.Huisman (PERTH 08578362).

The genus *Gayliella* was erected by Cho et al (2008) for several species previously placed in *Ceramium*, but which
Figure 7. Rhodophyta. a, b. *Catenella nipae*. a. habit showing characteristic segmented thallus. b. showing obvious central axis. c. *Gayliella fimbriata*, detail of thallus showing filamentous construction with nodal cortication. d–f. *Gelidium minusculum*. d. Plant habit showing prostrate axis and simple upright axes. e. Transverse section of thallus showing rhizines at the medulla/cortex interface (arrow). f. Closer view of thallus showing pointed apex with a single apical cell. g. *Griffithsia heteromorpha*, habit. Note trichoblasts on upper cells (arrow). h. *Herposiphonia pacifica*, habit, showing prostrate axis with a simple determinate branch proximal to an indeterminate branch. i. *Herposiphonia tenella*, habit, showing regular pattern of three determinate branches and one indeterminate branch.
resolved in a segregate clade in molecular analyses and differed in having transversely aligned basipetal cortical cells. Prior to this, Gayliella fimбриata (as Ceramium) was one of several species thought to belong to a widespread, morphologically variable species Ceramium fладicium (now Gayliella flaccida) (Womersley 1978). Thus many records of the latter, including those from Shark Bay (Huisman et al. 1990: 96; Kendrick et al. 1990: 51) are possibly incorrect and should be re-assessed.

Thallus forming creeping prostrate axes attached by clustered rhizoids, bearing sparse, perpendiculär erect axes approximately every 500–700 µm, although these often more frequent or absent for long distances. Prostrate axes terete, to 150 µm diam. Upright axes terete, to 1–4 mm tall, 80–100 µm diam., mostly simple, with pointed apices. Structure uniaxial, when mature with a medulla of longitudinal filaments, these cross-linked by pit-connections, and a cortex of 2–4 layers of smaller pigmented cells. Outer cells rounded to transversely elongate in surface view, 12–18 µm long, 5–8 µm broad, in vague, meandering longitudinal lines. Rhizines inconspicuous, in small bundles at the medulla/cortex interface. Reproductive structures not observed (Figs 7d–f).

Specimen: Uendoor Creek, epiphytic on Avicennia marina pneumatophores, 4 June 2009, J.M. Huisman (PERTH 08578656).

This small, wiry species with cylindrical branches was originally described (but not illustrated) based on specimens from Indonesia (Weber-van Bosse 1921: 226, as Gelidium pusillum var. minuscula). Hatta & Prud’homme van Reine (367, fig. 9A) illustrated a plant that was collected as a mangrove epiphyte from Sumba, Indonesia. The taxon was subsequently recorded from South Africa and raised to species level by Norris (1992), who regarded G. pusillum (sensu stricto) to be considerably more restricted in distribution than previously believed. A subsequent study by Millar & Freshwater (2005) supported this view of G. pusillum, but referred the South African taxon to Gelidium isabelae Taylor. The Shark Bay specimens have uniformly terete branches that are never flattened, similar to the mangrove epiphyte described by Hatta & Prud’homme van Reine (1991: 368, table 3), but differing from the lagoonal plants with spathulate upright branched described by those authors. Flattening of branches in Gelidium often occurs when they become reproductive, however, and the Shark Bay specimens were vegetative only.

42. Griffithsia heteromorpha Kütz. 1863: 2, pl. 3, figs a, b.

Thallus red, filamentous, 3.5 mm tall, attached by rhizoids and cells arising from lower cells. Lower cells cylindrical to clavate, 100–200 µm diam., L:B 4±, grading to upper barrel-shaped to spherical cells 200–250 µm diam., L:B ±1, then tapering to apical cells. Upper cells each with 2–3 distal trichoblasts. Reproductive structures not observed (Fig. 7g).


Griffithsia heteromorpha is similar in form to other species of the genus and is distinguished by its tetratsporangia lacking an involucre (protective branches). The present specimen is immature and lacks this feature, but morphologically accords with this common species.

43. Herposiphonia pacifica Hollenb. 1968b: 549.

Thallus red, attached by unbranched unicellular rhizoids, with digitate tips arising from the distal end of ventral pericentral cells. Indeterminate prostrate axes with circinate apices, with indeterminate axes arising laterally on alternate sides every 3 or 4 segments. Determine lateral branches arising dorsally every 3 segments, 1 segment proximal to the indeterminate lateral branch. Prostrate axes terete, 130–145 µm diam. [segment L:B c. 1], with 8–11 pericentral cells. Determine branches initially curved but becoming straight, unbranched, to 35 segments long when mature, terete, 80–100 µm diam. [segment L:B mostly 1–1.5], with 8–11 pericentral cells. Determine axes with well-developed apical trichoblasts to 1.6 mm long, dichotomously divided to 7 times. (Fig. 7h).

Specimen: Uendoor Creek, 4 June 2009, J.M. Huisman (PERTH 08578540).

44. Herposiphonia tenella (C.Agardh) Ambronz 1880: 197.

Thallus red, with prostrate indeterminate and erect determinate axes, attached by unbranched unicellular rhizoids arising from the distal end of ventral pericentral cells. Indeterminate prostrate axes with circinate apices, with a regular sequence of 3 determinate and 1 indeterminate lateral branches; determinate axes arising dorsally or dorso-laterally, but erect; indeterminate axes ventro-lateral and prostrate. Prostrate axes terete, 100–110 µm diam. [segment L:B c. 1], with 9 or 10 pericentral cells. Determine branches initially curved but straightening, unbranched, 1.5–2.5 mm long, with 9–11 segments when mature, terete, 60–75 µm diam. [segment L:B mostly 1–4], with 6–9 pericentral cells. All axes with terminal trichoblasts, these dichotomously divided, with tapering unpigmented cells. Cells with numerous spherical plastids, these often pectinate (Fig. 7i).

Specimen: Cape Lesueur, 7 June 2009, J.M. Huisman (PERTH 08578788).

This species, the generitype, is often treated as a form of Herposiphonia secunda (C.Agardh) Ambronz (see Wynne 1985), but recent studies have regarded it as a distinct species (Schneider & Searles, 1997; Masuda & Kogame 2000). It is characterized by the regular sequence of determinate and indeterminate branches.

45. Laurencia sp.

Thallus with several simple to once-branched axes arising from a common holdfast, to 8 mm tall. Axes terete, 0.25–0.5 mm diam., with blunt apices and an apical pit with emergent filaments. Epidermal cells with longitudinal pit connections, in surface view rounded to ellipsoidal, 20–50 µm diam. Tetratsporangia with parallel arrangement near apices, spherical, 100–130 µm diam., tetrads half-divided (Fig. 8a).
Figure 8. Rhodophyta. a. Laurencia sp., branch apex with tetrasporangia (arrow). b. Polysiphonia infestans, branch apex showing trichoblasts and (at right) a portion of an older branch, showing considerable variation in branch width. c, d. Polysiphonia scopulorum. c. Thallus habit, with prostrate axes and simple upright branches. d. Detail of attachment rhizoids in open connection with bearing cell (arrow). e. Polysiphonia sp., branch apices showing origin of lateral branches in axils of trichoblasts (arrows). f. Spyridia filamentosa, thallus habit, with fully corticated primary axis bearing lateral filaments corticated only at nodes.
Specimen: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578265).

These plants are reproductively mature but show few diagnostic features. They agree with Laurencia intricata J.V.Lamour as described by Price & Scott (1992), but we defer specific placement until more luxuriant specimens are available.

46. Polysiphonia infestans Harv. 1855: 539.
Thallus red, primarily erect, to 16 mm tall, or with limited prostrate axes, attached to the substratum by unicellular digitate rhizoids arising from basal cells of primary axes. Erect axes subdichotomously branched every 5–10 segments. Axes with 4 pericentral cells and a trichoblast/scar cell on each segment in a spiral pattern with a 1/4 divergence between successive segments. Lower segments 390–430 µm diam. (including wall to 100 µm thick) [L:B 0.4–0.5 (c. 1 if the wall is excluded)]; mid-thallus segments 100–170 µm diam. [L:B 1–1.3 (~3)], tapering gradually to upper segments 40–75 µm diam. [L:B 1–1.2]. Lateral branches replacing trichoblasts. Spermangia in cylindrical to lanceolate heads forming as one branch of a basal dichotomy of trichoblasts, 170–290 µm long, 40–45 µm diam., without a sterile apical cell (Fig. 8b).

Specimen: Wooramel South, 5 June 2009, J.M.Huisman (PERTH); Faure I., 10 June 2009, J.M.Huisman (PERTH 08578311).

47. Polysiphonia scopulorum Harv. 1855: 540.
Thallus with well-developed prostrate axes, 80–100 µm diam., attached by unicellular rhizoids in open connection with bearing cell. Upright axes to 3 mm tall, often arising from segments adjacent to rhizoids, 50–100 µm diam., simple to sparsely branched, trichoblasts rudimentary at apices, soon deciduous. All axes with 4 pericentral cells. Scar cells occasionally present. Pericentral cells equidimensional near apices, forming segments L:B 0.3–0.5; lower segments L:B 0.8–1. Reproductive structures not observed (Figs 8c, d).


The extensive prostrate axes, 4 pericentral cells per axial cell, and attachment rhizoids in open connection to the parent cell are characteristic of this species (Womersley 1979: 467–469). It is similar to Polysiphonia teges (see below), but that species has 6 pericentral cells.

48. Polysiphonia teges Womersley 1979: 494, fig. 10A–C.*
Thallus with prostrate axes, 90–100 µm diam., attached by unicellular rhizoids in open connection with bearing cell. Upright axes to 9 mm tall, 75–100 µm diam., sparsely branched, trichoblasts rudimentary at apices, soon deciduous. All axes with 6 pericentral cells, these generally slightly rounded. Scar cells occasionally present. Segment L:B generally ≤ 1, rarely longer. Reproductive structures not observed.

Specimen: Little Lagoon, 6 June 2009, J.M.Huisman (PERTH 08578621).

49. Polysiphonia sp.*
Thallus 32 mm tall, mostly upright, attached by thin rhizoids arising from pericentral cells near base. Axes 300–350 µm diam. near base, segment L:B ±0.6, tapering gradually to mid thallus 150 µm diam., L:B ±1, then to upper branches 50 µm diam., L:B 2–2.5. Axes with 6 pericentral cells in primary axes, 5 pericentral cells in lateral branches and minor axes. Trichoblasts present near apices, 300–600 µm long, 2–3 times subdichotomously divided, with hyaline cells. Lateral branches arising every 7–15 segments, initially in axis of trichoblasts, slightly narrowed at branch base. Scar cells at intervals of 2–6 segments, occasionally at regular intervals of 3 or 4. Reproductive structures not observed (Fig. 8e).


This specimen possibly represents a new species. The combination of 5–6 pericentral cells, lateral branches arising in association with trichoblasts, and the irregular occurrence of scar cells does not appear to have been described previously, certainly not for any species recorded for Australia (Cribb 1983; Price & Scott 1992; Womersley 1979). It appears to be similar to Polysiphonia homoia, a species described originally from Isla Guadalupe, Mexico (Setchell & Gardner 1930), but since recorded from several other tropical locations in the Pacific (Hollenberg 1968a, Abbott 1999, N’Yeurt & Pavri 2010). Hollenberg commented on some important differences between his material and the type, which suggests that more than one taxon might be involved. Setchell & Gardner (1930: 162) stated that P. homoia was ‘constantly 5-siphonous’ (i.e. with 5 pericentral cells), which differs from the Shark Bay specimen which had 6 pericentral cells in major axes. Unfortunately reproductive specimens were not collected and we defer any taxonomic decisions until additional material is available.

50. Spyridia filamentosa (Wulfen) Harv. 1833: 337.
Thallus to 10 cm tall. Growth from a prominent apical cell, producing a series of short cells before initiation of nodal cortication. Determine or indeterminate lateral branches arising singly from each axial cell in a spiral pattern, or adventitiously from cortical cells. Primary axes with a ring of 10–14 cells at the nodes, these dividing basipetally to form a ring of longitudinally elongate cells covering the internodal region. Primary axes thus with alternating bands of broad and narrow cells, later mixed with corticating rhizoids. Determine laterals 20–25 cells long, initially with short cells and attaining full cell number before producing nodal cortication, often with a terminal spinous cell but this generally lost. Mature determinate branches 1.5–2.0 mm long, with cells 30–55 µm wide [L:B to 4–5], and nodal cortication of 6–8 cells, these dividing to form a band of 1 or 2 (rarely 3) layers. Tetrasperangia arising singly or in sequentially maturing pairs on the adaxial surface of determinate branch nodal cells, sessile, pyriform when young but becoming spherical, 60–72 µm diam. (including wall 10–12 µm thick), tetrahedrally divided. Other reproductive structures not observed (Fig. 8f).

Specimen: Faure I., 10 June 2009, J.M.Huisman (PERTH 08578281).
Thallus erect, usually epiphytic, inconspicuous, to 500 μm tall, pseudofilamentous, branched, uniseriate. Cells within a conspicuous mucilaginous sheath, 15–25 μm diam., this often not obvious near the apices but conspicuous near the base and 2–3 times the diameter of the cells; cells 7–10 μm diam. [L:B 0.5–2.0], mostly cylindrical, but basal cells of branches tapering proximally.
A small, uniseriate epiphyte, possibly more widespread than the present records indicate.

DISCUSSION
The present account records 51 species of marine algae and cyanobacteria from the pneumatophores of the mangrove Avicennia marina in Shark Bay, Western Australia. Of these, the vast majority (31) represent new records for the bay, with three species also newly recorded for Western Australia. These observations most likely reflect the relative paucity of collections from the region, and are not indicative of newly introduced species. The macroalgae of Shark Bay are represented in the Western Australian Herbarium (PERTH) by only 212 specimens, mostly collected by JMH or Gary Kendrick and Diana Walker as part of the University of Western Australia’s research program in the 1980s. None of these specimens are mangrove epiphytes, and the group was similarly overlooked in the collation of records presented in Huisman et al. (1990). Thus the surfeit of new records presented here is to be expected following the initiation of interest in the region’s mangrove-associated flora.

The range of taxa recorded is remarkably similar to that reported from mangals elsewhere in Australia (e.g. Saenger et al. 1977, Davey & Woelkerling 1980; Beanland & Woelkerling 1982; King & Wheeler 1985) and worldwide (e.g. Lambert et al. 1987; West 1991; Skelton & South 2002; West et al. 2013). The flora includes species of Bostrychia, Caloglossa, and Catenella, which, while none are obligate, are almost universally recorded as part of mangrove floras (King 1981). Other genera recorded for Shark Bay that were also recorded for N.S.W. mangroves by King & Wheeler (1985) include Erythrotrichia, Polysiphonia, Spyridia, Sphacelaria, Chaetomorpha, Cladophora, Ulva, Rhizoclonium, and Gauralia (as Ulvaria). These taxa, however, are commonly found as epiphytes on a range of seagrasses and larger macroalgae and are best considered as generalists.

Mangrove habitats are typically regarded as having a low diversity of epiphytes, and this was commented on by King (1981: 322), who suggested that these habitats are unfavourable due to a lack of stable substratum (excluding the mangroves), mud in suspension, and the physiological stress placed on algae in a situation of fluctuating salinity. King (1981: 322) also suggested that the “algal flora of marshes and mangals is depauperate and dull”, resulting in little incentive for floristic studies. Despite this, King himself devoted much of his life to studying the mangrove algal flora, and phycologists such as John West (University of Melbourne) and Joe Zuccarello (Victoria University of Wellington) have used molecular and culture studies to tease out the minutiae of the biology of mangrove epiphytes such as Bostrychia and Caloglossa, resulting in several landmark studies (e.g., Zuccarello & West 2006). Despite (or perhaps because of) the limited diversity of mangrove-associated algae, the group has been the subject of considerable interest and provided model organisms for life history and taxonomic studies.

The presence of 51 species at Shark Bay is comparable to the 32 recorded for N.S.W. by King & Wheeler (1985, not including cyanobacteria), 49 for South Australia by Beanland & Woelkerling (1982), and 22 species by Davey & Woelkerling (1980) for Victoria. While those diversity estimates might seem small in comparison to the corresponding local floras, the marine benthic flora of Shark Bay was given at only 153 species by Huisman et al. (1990), the low number undoubtedly an underestimate but also a clear reflection of the lack of hard substrata in the bay. Thus the mangrove community, with almost a quarter of the now known Shark Bay flora, represents a significant contributor to the bay’s macroalgal diversity.

While this study aimed to document this algal community, we did notice marked differences in the diversity of algal flora at some sites, including some where the pneumatophores were essentially devoid of algae. The occurrence of species did not exhibit any consistent broad scale patterns across the study sites, and such differences may relate to site-specific factors like tree size and canopy density. As this study was essentially a qualitative snapshot of this community based on sampling over several days, it would be beneficial if further ecological research was undertaken to examine factors that influence the composition and distribution of this poorly known community.

ACKNOWLEDGEMENTS
We thank the marine staff of Parks & Wildlife’s Shark Bay District (particularly Dave Holley, Ross Mack and Wayne Moroney) for their assistance at Shark Bay. JMH thanks the Australian Biological Resources Study for support.

REFERENCES
Agardh C A 1817. Synopsis algarum Scandinaviae, adjecta dispositione universal algarum. Ex officina Berlingiana, Lundae [Lund].


BRUMMITT R K & POWELL C E 1992. Authors of Plant Names. A list of authors of scientific names of plants, with recommended standard forms of these names including abbreviations. Royal Botanic Gardens, Kew.


HARVEY W H 1849. Phycologia britannica, or, a history of British sea-weeds: containing coloured figures, generic and specific characters, synonyms, and descriptions of all the species of algae inhabiting the shores of the British Islands. Reeve & Benham, London.

HARVEY W H 1855. Some account of the marine botany of the colony of western Australia. Transactions of the Royal Irish Academy 22, 525–566.


*Manuscript accepted October, 2014*