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BY
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AN ECOLOGICAL AND TAXONOMIC ACCOUNT OF THE ALGAE OF A SEMI-MARINE CAVERN, PARADISE CAVE, QUEENSLAND*

Summary

Paradise Cave is a semi-marine cavern approximately 140 ft long, penetrated by the sea only during rough weather, and its algal vegetation is largely dependent on the occurrence of freshwater seepage from roof and walls. The distribution of the species is described and the following species, most of which are newly reported for Queensland, are discussed: *Plectonema purpureum* Gom., *Rhizoclonium capillare* Kuetz., *R. implexum* (Dillw.) Kuetz., *Cladophorella calcicola* Fritsch, *Pseudendoclonium submarinum* Wille, ***Gongrosira cavernicola*** sp. nov., *Cyanidium caldarium* (Tilden) Geitler, *Waerniella lucifuga* (Kuck.) Kylin var. ***australis*** var. nov., *Audouinella eugenea* (Skuja) Jao, *Hildenbrandtia* sp., ***Caulacanthus salifugus*** sp. nov., *Bostrychia binderi* Harv.. *Rhizoclonium capillare* Kuetz., of which *R. hookeri* Kuetz. is possibly a synonym, is returned from *Chaetomorpha* to *Rhizoclonium.*

The algal vegetation of marine caves has been investigated in various parts of the world, e.g. see Dellow & Cassie (1955), Grubb & Martin (1937), Lami (1940), but nothing has hitherto been published on the flora of such caves in Australia.

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*Manuscript submitted 8/iv/1964.

Paradise Cave, situated in the southernmost of the exposed headlands of the Noosa Heads area, at approximately lat. 26° 23′ S., is a semi-marine cavern hollowed out of well-jointed Mesozoic sandstone. At least two other caves occur in cliffs in the vicinity but these are accessible only under exceptionally calm weather conditions and have not been investigated. The entrance to Paradise Cave is divided by an irregular pillar into two very unequal mouths, the larger approximately 50 ft wide and high, and the smaller approximately 30 ft wide and 17 ft high. From this point the cave penetrates in a WNW. direction for approximately 140 ft, the roof, walls, and floor converging irregularly so that at the rear end the width is reduced to about 8 ft, and the roof and floor meet in an angle at a point about 20 ft above the level of the floor at the entrance. At high water of spring tides during calm weather waves surge gently to just within the cave entrance, their force largely broken by the irregular rocky shore beyond the mouth, but during very heavy seas they may reach to the rear end. The frequency with which the sea penetrates to this extent is not known, but it probably occurs on several occasions each year. The presence of a large portion of a *Pandanus* trunk wedged in the rearmost part of the cave is indicative of the force of the waves at times reaching this point.

Marine algae and animals occur at and just within the cave entrance, both on the walls and in pools, but there are no pools well within the cave, and the furthest penetrating of the clearly marine algae is *Bostrychia simpliciuscula* Harv. ex J.Ag. which, on the more shaded northern wall, forms brown-black mat-like colonies extending up to approximately 6 ft above high water spring tides of calm weather, in crevices sometimes mingling with *Hildenbrandtia prototypus* and a marine *Caulacanthus* sp. commonly found in shaded positions on southern Queensland shores. The most deeply penetrating of all the typically marine species is the littorinid *Nodilittorina pyramidalis* Quoy & Gaimard which extends on the northern wall up to approx. 60 ft from the mouth.

A few welcome swallows, *Hirundo neoxena* Gould, nest in the roof in the rear half of the cave, and an occasional hornet's mud nest has been seen also on the roof. Isopods are fairly common, one frog has been noted, and on occasions spider webs have been found in the rearmost part of the cave roof.

Although under some marine influence, much of the vegetation of the cave is dependent upon the occurrence of freshwater seepage from various points in roof and walls, and during periods of prolonged drought, when many of these soaks diminish or disappear, the algal vegetation may become much reduced.

On the southern side of the cave, starting about 45 ft from the entrance, is a fairly smooth rock shelf approximately 36 ft long and up to approximately 13 ft wide at its widest part, sloping from the cave wall down to the floor at an angle of approximately 30°, and also sloping inwards and downwards. Freshwater, seeping from walls and roof, trickles over or drips upon part of this shelf, the area so irrigated varying with the season. Most of this shelf appears to be bathed by salt water only during very rough seas and can probably be regarded as essentially a freshwater habitat, although subject frequently to a light salt-laden misty spray which drifts past the mouth for much of the time.

At most points upon which water drips for long periods there is a fine, soft, slippery algal fur of varying colour, mostly dark brown through purple-brown to dull pink. In the positions of most vigorous irrigation, often where water pours in a thin stream, the alga usually forming the fur is *Audouinella eugenea* Skuja. Immediately surrounding these colonies, and often in the path of the run-off, is commonly a dull, purple-brown, relatively coarse carpet of another red alga, *Caulacanthus salifugus* sp. n., amongst which are numerous diatoms and over which in a few places sometimes lie the green sterile filaments of a species of *Oedogonium*. The moss, *Rhynchostegium tenuifolium* (Hedw.) Jaeg. also may occur in these very well-irrigated positions, in some cases partly overgrowing the *Caulacanthus* or hanging in dripping festoons from the overarching wall above.

In other positions subject to less vigorous dripping or run-off the algal fur is commonly composed of the blue-green alga *Plectonema purpureum* Gom., superficially often not readily distinguishable from *Audouinella* except by its thinner stratum. Less commonly the phaeophyte *Waerniella lucifuga* (Kuck.) Kylin var. *australis* var. nov. forms a more distinctly brown fur, and the chlorophyte *Rhizoclonium implexum* (Dillw.) Kuetz. a distinctly green fur.

Another common, though often inconspicuous, alga of this slope is the green crustose *Gongrosira cavernicola* sp.n. which occurs among and often partly obscured by the above species as well as in positions where the irroration is not sufficient to support the fur-forming plants. It may be accompanied by inconspicuous black colonies of the lichen *Verrucaria* sp., by depauperate filaments of *Rhizoclonium capillare* Kuetz. and occasionally of *Cladophorella calcicola* Fritsch; colonies of *Hildenbrandtia* sp. occur rarely, and in the more poorly irrigated parts *Pseudendoclonium submarinum* Wille may mingle with the superficially similar green colonies of *Gongrosira*.

From about half way along this shelf a second ledge of similar slope about 3 ft higher runs gradually upwards towards the entrance where it reaches a point approximately halfway up the wall. This is, in the main, better illuminated and drier, and less subject to saline influence than the slope noted above. At seepages it supports *Lobelia anceps* Thunb., species of moss and leafy liverwort, and various typically freshwater green and blue-green algae. Of the species found on the lower shelf, *Rhizoclonium capillare* and *Cladophorella calcicola*, both in small quantity, are found amongst the *Lobelia* and moss, while poorly developed *Caulacanthus salifugus* is found on the lower, inner, and better-irrigated part only.

In several places where adequate freshwater seepage occurs, the walls, and sometimes immovable rocks on the floor, support thin, dull-red crusts of *Hildenbrandtia* sp. *Bostrychia binderi* Harv. f. *terrestris* (J.Ag.) Post occupies similar and often drier habitats along the walls, extending from above the irrigated slope to the innermost extremity where it is very well developed on the roof. This alga forms usually purplish, sometimes fawn mats, cushions, or occasionally short festoons, and is often accompanied by mosses, usually *Bryum* sp. in the drier parts and *Rhynchostegium tenuifolium* in the wetter. In many places the mats or rock surfaces beside the mats support olive or light olive-brown, sticky-gelatinous patches of mainly unicellular algae in which *Anacystis montana* (Lightf.) Dr. & Daily, *Coccochloris peniocystis* (Kuetz.) Dr. & Daily, and *Coccomyxa* sp. are common constituents. Bright green, crimped fleeces of *Rhizoclonium capillare* are found on the walls at a few points towards the rear of the cave, growing either over the rock surfaces or over *Bostrychia*. Although the roof of the cave is inaccessible over most of its length, as far as can be seen the *Bostrychia* and moss extend along the roof to near the entrance whenever adequate seepage occurs, and for approximately the outer two-thirds of the roof are accompanied by the fern *Asplenium obtusatum* Forst. var. *difforme* (R.Br.) Benth..

Towards the rear end of the cave some of the rock surfaces, particularly those of a softer nature, are prominently stained green by *Chlorococcum* sp. or blue-green by *Cyanidium caldarium* (Tilden) Geitler. Elsewhere, on relatively dry parts of the wall or floor, the slight green staining which is sometimes present is generally caused by *Pseudendoclonium submarinum*. Also in the rear part of the cave there are in places on the roof, and to a less extent on the walls, numerous stalactitic outgrowths of opaline silica up to approximately 1 in long; these are sometimes stained green or blue-green by various small algae, amongst which the most common are usually *Coccochloris peniocystis*, *Cyanidium caldarium*, and *Gongrosira cavernicola*.

Further notes on some species from the cave

PLECTONEMA PURPUREUM Gomont

Plectonema purpureum Gomont, 1892, p. 101, pl. 1, figs. 7–8; Geitler, 1925a, p. 249, fig. 297; Prescott, 1951, p. 540, pl. 126, fig. 8.

Forming a more or less velvety, dull purple-black to red-black layer; part of each filament shortly decumbent, often with both ends erect and straight to somewhat flexuose, up to 450μ high; parts of trichome on or near substratum (1.5) 2–3 (3.5)μ diam., with cells mostly 1/3–1 diam. long, often strongly constricted at the cross walls; upper parts of trichomes not tapering, mostly $1\frac{1}{2}$–2μ diam., with constriction between cells slight to marked, but nearly always less distinct than in lower parts; cells in upper parts mostly about $\frac{3}{4}$–1 diam. long; apical cell rounded; false branching very sparse, the branches arising singly or less commonly in pairs.

The impression of *Plectonema purpureum* given by the descriptions of Gomont (1892) and of Geitler (1925a) is of a plant in which the filaments are more entangled and the stratum less velvet-like than in the Queensland specimen. Also, these authors report false branching to be common, while in the Queensland plant it is rare. However the extent of the false branching may well be a variable character, and where such branching is common the filaments are more likely to appear flexuose and entangled. In size, cell-form, and colour the cave plant appears to show good agreement with these earlier descriptions of *Plectonema purpureum* and it seems reasonable to refer the specimen to this species.

Extra-Austr. distr.: Europe, North America.

RHIZOCLONIUM CAPILLARE Kuetzing

Rhizoclonium capillare Kuetzing, 1847, p. 166; Bornet, 1892, p. 205.
Chaetomorpha capillaris (Kuetz.) Boergesen, 1925, p. 45, fig. 13; Feldmann, 1937, p. 208, fig. 17; Chapman, 1939, p. 23; Womersley, 1956, p. 356.
Lola capillaris (Kuetz.) Hamel, 1931, p. 25; Chapman, 1956, p. 464; 1961, p. 73, fig. 78.
Rhizoclonium hookeri sensu Cribb, 1954, p. 18, pl. 1, fig. 4.

Forming fleeces of entangled filaments; cells mostly cylindrical, occasionally slightly barrel-shaped in lower parts, (20) 30–70 (96)μ diam., (1) $1\frac{1}{2}$–3 (5) diam. long, the walls 3–12μ thick; filaments often with a basal rhizoidal attaching cell, commonly poorly developed, and in the lower parts with a few non-septate or septate lateral rhizoidal branches, occasionally growing out into a branch resembling the main filament and then usually displacing it so that the lower part of the main filament appears as a lateral branch growing out at right angles; nuclei 1–30 per cell.

The above description is derived from consideration of plants growing towards the rear of the cave. This material shows considerable resemblance to, and is considered to be conspecific with, several other collections from south-eastern Queensland. These other collections came from seepage amongst moss and *Lobelia anceps* Thunb. about halfway up the wall of the cave just within the entrance, from amongst *Sporobolus virginicus* (L.) Kunth, *Juncus maritimus* Lam., and *Salicornia australis* Sol. on salt flats landwards of mangrove communities, from the upper littoral and supralittoral fringe under mangroves along river banks, and from the ground beneath *Pandanus pedunculatus* R.Br. on the Paradise Cave headland.

In all these collections the plant forms a fleecy to woolly tangled layer; the filaments commonly possess an often rather poorly developed basal rhizoidal cell, and show branching similar to that in the cave plant. All differ from the cave plant mainly in their greater uniformity of cell size and proportion and generally shorter cells. In the case of the collection from beneath *Pandanus* the cells are 30–45 (55)μ diam. and ($\frac{1}{2}$) 1–2 (3) diam. long, with very dense contents. In a collection from the Pine River the filaments are relatively uniform and robust, the cells being (45) 65–80 (90)μ diam. and ($\frac{1}{2}$) 1–2 (3) diam. long. The number of nuclei in cells in the cave material is 1–30; the number, in general, depends on the size of the cell, the uninucleate condition occurring only in a few of the narrowest cells, while the larger numbers are found only in the largest cells. In collections from outside the cave which lack the very slender filaments sometimes found in the cave, the number is generally greater, being mostly 8–30 or more. The general appearance of all the collections is fairly similar, and there are some which are more or less intermediate between the collections with consistently robust filaments and those from the cave with a great range of filament diameter. It seems reasonable to suppose that the reduced light intensity in the inner parts of the cave might induce the formation of narrow elongate cells, and that drier conditions and higher light intensities might lead to the production of shorter cells.

Some support for this view has been obtained by growing plants from various localities on the surface of soil saturated with fresh water and kept in a saturated atmosphere away from direct sunlight in the laboratory. In both the Pine River collection and the collection from beneath *Pandanus*, growth under these conditions for 8 weeks resulted in an approximate doubling of the average cell length with some cells reaching 4 diam. in length, although there was little change in cell diameter. A collection from amongst mangroves along the Brisbane River grew vigorously in fresh water in the laboratory with an approximate doubling of cell length after 8 weeks and without the production of any rhizoidal branches.

The unsatisfactory nature of the distinction between *Rhizoclonium* and *Chaetomorpha* is well known. In general, *Rhizoclonium* is distinguished by the presence of rhizoidal branches, by a relatively small number of nuclei per cell, (1) 2–4 (8) and by cylindric rather than swollen cells. In *Chaetomorpha* the cells are sometimes much swollen and there are usually no rhizoidal branches, although some may be present in *C. capillaris*. However, some collections of *Rhizoclonium* are without rhizoidal branches, and the examination of the Paradise Cave material seems to show that the number of nuclei per cell is an unsatisfactory taxonomic character. Cell form is also an unreliable character. Hamel (1931) and Chapman (1956) place specimens in which the filaments do not usually exceed 100μ diam., are free living or occasionally attached, have few or no lateral rhizoids, and 5–20 (50) nuclei per cell, in the genus *Lola* A. & G. Hamel, which is claimed to be intermediate between *Rhizoclonium* and *Chaetomorpha*. However, the rather variable nature of the characters on which the distinction from these two genera is made makes it difficult to maintain *Lola*.

However, before Boergesen (1925) transferred *R. capillare* Kuetz. to *Chaetomorpha* because of the number of nuclei (30–50) per cell, the latter genus seems to have been recognized as being always without rhizoidal branches, the capacity to produce this type of branch being characteristic of *Rhizoclonium*. Since the generic distinction based on the number of nuclei per cell appears to be unsatisfactory, it would probably be desirable to remove *Rhizoclonium capillare* from this genus, in which case the capacity to produce rhizoidal branches will remain as a distinguishing character of *Rhizoclonium* although the character is not always expressed in every collection. *Chaetomorpha capillaris* is therefore here regarded as a species of *Rhizoclonium* as was done originally by Kuetzing.

Rhizoclonium capillare Kuetz. and *R. hookeri* Kuetz. do not appear to be clearly distinguished in the literature. *R. hookeri* was originally described from Kerguelen, with cells reported as 1/40–1/35 line wide and 1–2 diam. long, although Kuetzing (1853) later figured filaments in which the cells are approximately 1–4 diam. long. Subsequent reports of the species have extended its geographical range to South Africa, New Zealand, Malaysia, Japan, West Indies, and Azores, its habitat to salt water, fresh water, and caves, and its filament diameter to 28–120μ. Lateral rhizoidal branches are often reported as rare. (See Kuetzing, 1849, p. 383; 1853, p. 21, pl. 67, fig. III; p. 21, pl. 67, fig. II (as *R. africanum*); Collins & Hervey, 1917, p. 43; Howe, 1920, p. 600; Weber-van Bosse, 1926, p. 79; Taylor, 1928, p. 66, pl. 3, fig. 7, pl. 4, fig. 18; 1960, p. 77, pl. 2, fig. 5; Okamura, 1929, p. 16, pl. 260, figs. 9–11; Schmidt, 1929, p. 102; Levring, 1938, p. 8, fig. 4, C–F; 1945, p. 5; Prescott, 1951, p. 143, pl. 23, figs. 4–7; Chapman, 1956, p. 468, fig. 126a; 1961, p. 74, fig. 80.)

Rhizoclonium capillare was originally described with filaments 1/45 line diam. and cells 1–2 diam. long. By subsequent reports its range of filament diameter has been increased to 40–150μ and its cell length to 1–3 diam. long. Lateral rhizoidal branches are reported as rare or absent. The reported geographical range includes Mediterranean, Atlantic, South Australia, New Zealand, Japan, and Pacific North America.

Thus on reported morphological and distributional grounds there appears little on which the two species may be distinguished.

Boergesen (1925) gives the number of nuclei per cell in *Rhizoclonium capillare* (as *Chaetomorpha capillaris*) as 30–50, while in the Queensland material of this species it is 1–40+. There seems to be no record of the number occurring in *Rhizoclonium hookeri*.

On the evidence available it seems likely that *Rhizoclonium capillare* and *R. hookeri* are conspecific, although in the absence of further evidence and a comparison of the type specimens, *R. hookeri* is not at this stage reduced to synonymy.

There has been considerable confusion between *Rhizoclonium tortuosum* (Dillw.) Kuetz. (1845) (syn. *Conferva tortuosa* Dillwyn, *Chaetomorpha tortuosa* (Dillw.) Kleen) and *Chaetomorpha tortuosa* "(Dillw.) Kuetz.", the latter based on a specimen reported by J. Agardh (1842) as *Conferva tortuosa* but, according to Boergesen (1925) and Chapman (1939), not the same as *Conferva tortuosa* Dillw. The confusion has been partly sorted out by Boergesen (1925), Chapman (1939), and Womersley (1956). *Rhizoclonium tortuosum* (Dillw.) Kg. has recently been recombined as *Lola tortuosa* (Dillw.) Chapman (1956) and recorded from New Zealand, being distinguished from *Rhizoclonium capillare* (syn. *Lola capillaris* (Kg.) Hamel), at least for New Zealand material, on its smaller size and greater range of cell length, although the dimensions given by Chapman, 30–36μ diam. and 1–6 diam. long, are not strikingly different from dimensions in the Queensland cave plant referred to *Rhizoclonium capillare*. Chapman in his paper lists *Rhizoclonium tortuosum* sensu Setchell & Gardner (1920) under *Lola tortuosa*, although in 1939 he listed this plant under the different species *Chaetomorpha capillaris*. More recently Lund (1959) has referred *Chaetomorpha tortuosa* (Dillw.) Kleen as a synonym of *C. melagonium* (Web. & Mohr) Kuetz.

Extra-Austr. distr.: Very widely distributed.

RHIZOCLONIUM IMPLEXUM (Dillwyn) Kuetzing
(Plate 1, Figs. 1–8)

Rhizoclonium implexum (Dillw.) Kuetzing, 1845, p. 206; 1853, p. 23, pl. 73, fig. III; Koster, 1955, p. 343, fig. 2.
Conferva implexa Dillwyn, 1809, p. 46.
Conferva implexa Lyngbye, 1819, p. 144, T.49B.
Rhizoclonium kochianum Kuetzing, 1845, p. 206; 1853, p. 23, pl. 75, fig. III; Vickers, 1908, p. 18, pl. 11, figs. 1–4; Boergesen, 1913, p. 19, fig. 7; 1920, p. 427, fig. 406; 1935, p. 14, fig. 4; 1948, p. 5; Hamel, 1931, p. 21, fig. 36, b–e; Newton, 1931, p. 93; Feldmann, 1937, p. 213, fig. 20, F–H; Levring, 1940, p. 11; Nasr, 1947, p. 37; Kylin, 1949, p. 50.
Rhizoclonium kochianum var. *ragusanum* Kuetzing, 1849, p. 387; 1853, p. 23, pl. 75, fig. IV.
Rhizoclonium kerneri Stockmayer, 1890, p. 582; Boergesen, 1913, p. 20, fig. 8; 1920, p. 427, fig. 407; 1939, p. 63; Collins & Hervey, 1917, p. 43; Setchell & Gardner, 1920, p. 185; Feldmann, 1937, p. 213, fig. 20 A–E; Dawson, 1954, p. 386, fig. 7 a–c; Chapman, 1956, p. 468; Taylor, 1957, p. 81; 1960, p. 75; Funk, 1961, p. 173.
R. lacustre Kuetzing, 1849, p. 385; 1853, p. 22, pl. 72, fig. IV.
R. biforme Kuetzing, 1849, p. 384; 1853, p. 21, pl. 69, fig. I (in part).
(Non *R. riparium* var. *implexum* (Dillw.) Rosenvinge, 1893, p. 915, fig. 34. Non *R. implexum* sensu Setchell & Gardner, 1920, p. 183; Newton, 1931, p. 93; Chapman, 1939, p. 25; Smith, 1943, p. 62, pl. 8, fig. 3. Non *Lola implexa* (Dillw.) Hamel, 1931, p. 25; Chapman, 1956, p. 463; 1961, p. 73, fig. 77.)

Forming a soft, dense, green fur; filaments flaccid, straight, up to 3 mm long, unbranched or very exceptionally with a single branch resembling the main filament produced from near the base, or with a rhizoidal branch; filaments (9) 11–14 (20)μ diam., (2) 4–10 (15) diam. long, not constricted at the septa, always basally attached, the basal rhizoidal cell erect, decumbent, or partly decumbent, mostly 50–400μ long, tapered downwards sometimes to 3.5μ in the more slender and elongate cells, either simple or lobed at its basal end; 1–4 nuclei per cell.

Koster (1955) has removed much of the confusion surrounding the slender

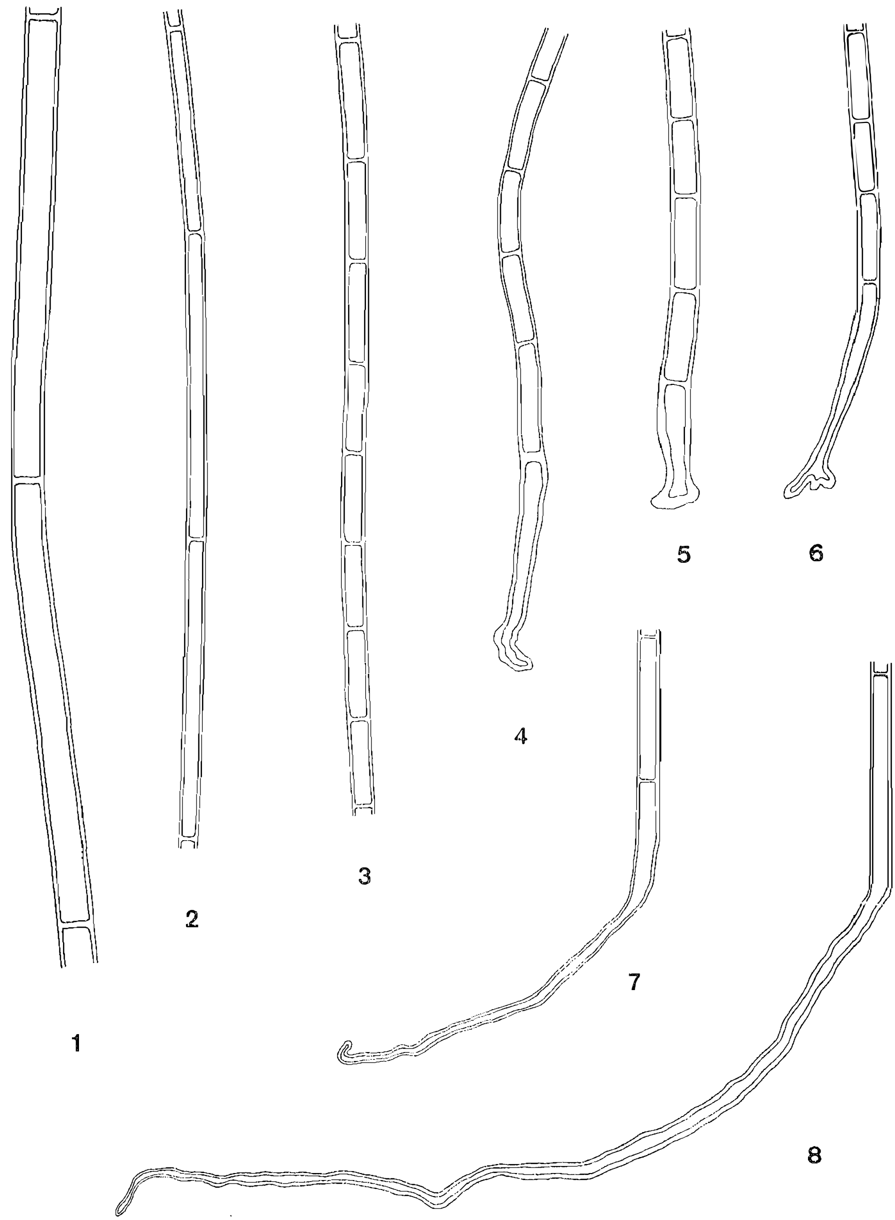

PLATE 1.—Figs. 1–8. *Rhizoclonium capillare*, Paradise Cave, X 257 approx.

marine and brackish Rhizocloniums and has shown that the names *R. implexum* and *R. riparium* var. *implexum* have commonly been misapplied to a rhizoidless form of *R. riparium*, and that *R. implexum* (Dillw.) Kuetz., with which *R. kochianum* Kuetz. and *R. kerneri* Stockm. are conspecific, is to be distinguished from *R. riparium* by its "cells 10–21 (mostly 14–18)μ broad and 1–8½ (mostly 2–3) × as long", those of *R. riparium* being "18–48μ broad and ½–4½ (mostly 1–2) × as long".

R. implexum is reported to be a marine and brackish species while *R. hieroglyphicum* (Ag.) Kuetz. is generally regarded as a freshwater species. There is little information available on the possibility of the one species occupying both marine and freshwater habitats, although *R. implexum* has been found to occupy a fairly wide range of salinities, and *R. hieroglyphicum* is reported by Collins & Hervey (1917) from slightly brackish water. Koster (1955) has examined authentic material of *R. hieroglyphicum* and reports cells 18–25μ broad and 1–3½ diam. long; she also found that in the dry state *R. hieroglyphicum* is not to be distinguished from *R. riparium*. The ranges of filament diameter reported by various authors for other specimens which have been assigned to the typical form of *R. hieroglyphicum* commonly fall within the range 10–37μ, although some report higher upper-limits, with the cells reported as up to 10 diam. long. Whether or not all these fresh water plants are correctly assigned to *R. hieroglyphicum*, and whether or not some or all are conspecific with either *R. riparium* or *R. implexum*, is not known.

The cells of the cave plant reach lengths apparently not reported previously for either *R. implexum* or *R. hieroglyphicum*, although the specimen of *R. implexum* recorded by Funk (1961) (as *R. kerneri*) with cells 8–16μ diam. and 5–10 diam. long is probably very close to the cave plant. In cell diameter this Queensland plant is in good agreement with Koster's concept of *R. implexum* and is considerably narrower than at least the authentic material of *R. hieroglyphicum*. It is also subject to some marine influence, and it therefore seems reasonable to refer it to *R. implexum*.

Another plant which is to be assigned to *R. implexum*, but which differs in some respects from the cave plant, is found in other habitats in south-eastern Queensland. It is common on wood and on *Avicennia* trunks and pneumatophores in the upper littoral region of the Brisbane River in the Brisbane district, where the water is decidedly brackish, and also on the ground beneath *Sporobolus virginicus* (L.) Kunth and *Juncus maritimus* Lam., on the salt flats which extend landwards from the mangrove communities and which are only rarely inundated by salt or brackish water. This plant is attached or sometimes eventually unattached, and differs from the cave plant mainly in its much shorter cells, mostly 1–3 diam. long.

Extra-Austr. distr.: Very widely distributed.

CLADOPHORELLA CALCICOLA Fritsch
(Plate 2, Figs. 1–16)

Cladophorella calcicola Fritsch, 1944a, p. 157, figs. 1–4; 1944b, p. 620.

The specimens from Paradise Cave are poorly developed plants with hardly any erect branches, and the following description has been derived from consideration of both these plants and those from other habitats.

Plant sometimes of sparsely branched prostrate filaments without erect branches, but mostly with a much branched prostrate system with many of the cells producing erect, suberect, or arched filaments, simple or branched, and commonly densely crowded and intricate to form a dense mat up to 1.5 mm thick, the filaments of which are readily teased apart; filaments occasionally penetrating much decayed roots and stems; septum between mother cell and erect branch often slightly to prominently displaced upwards; where erect branches produced, cells of the prostrate filaments often colourless or almost so; plant attached by rhizoids produced one per cell from some cells of the prostrate or subprostrate filaments, commonly from near one end of the cell, or sometimes from the end of the terminal cell of a prostrate filament, more commonly from the more or less cylindrical cells than from the broadly ellipsoid or globose cells; rhizoids usually not cut off from the parent cell by a septum, usually non-septate and unbranched, colourless or brownish, tapering, up to 4 mm long, mostly 7–25μ diam.; cells of the filaments (17) 30–90 (120)μ diam., mostly 1–10 diam. long, occasionally more slender, very variable in form, cylindric, ellipsoid, ovoid, globose, or irregular, sometimes with one cell form more or less predominating, sometimes with cell forms more or less indiscriminately mixed; filaments tending to

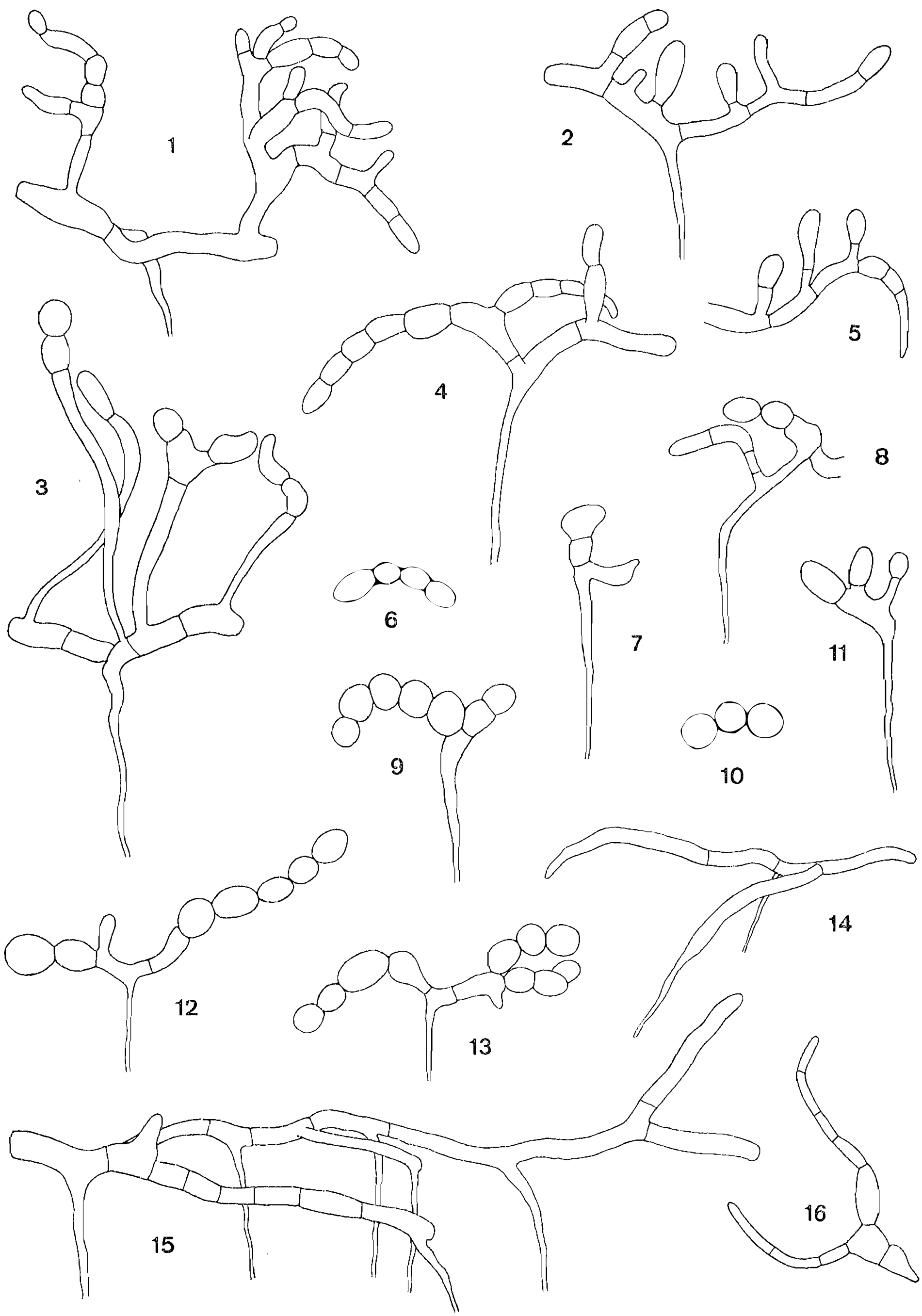

PLATE 2.—Figs. 1–16. *Cladophorella calcicola*, X 65 approx. Figs. 1–15, Brisbane R., Indooroopilly; Fig. 16, prostrate filament, L. Weyba.

fragment rather readily, particularly when composed of broadly ellipsoid to globose cells, the plant sometimes consisting of groups of crowded, rounded to ellipsoid cells dissociating very readily into individual cells so that the filamentous nature may not be readily apparent; sometimes with terminal, or less commonly intercalary cells developing darker contents and often thicker walls than adjacent cells, and probably functioning as akinetes; chloroplast parietal and reticulate.

Several collections were brought into the laboratory and kept under natural light of low intensity, sufficient tap water being added to keep the mud saturated but not submerged. After approximately three weeks nearly every cell from the surface of the colonies had produced a slender, erect, unbranched, positively phototropic filament up to 1 mm high and consisting of cylindrical or somewhat undulate cells 14–25μ diam. and 4–50 diam. long. Plants grown in the same container but kept only moist rather than saturated produced only occasional and much shorter erect branches with shorter cells.

This species was found in Queensland first on the surface of an unglazed earthenware pan containing plants of *Selaginella kraussiana* in the glasshouse of the University of Queensland, Brisbane (November 1954). The plant shows excellent agreement with the figures and description given by Fritsch (1944a) for *Cladophorella calcicola* Fritsch, which he described from oolitic limestone in the damper hothouses of the Cambridge Botanic Gardens and which he suggested might not be indigenous to England.

Subsequent south Queensland collections from Paradise Cave, from the supra-littoral fringe on brackish *Sporobolus virginicus* (L.) Kunth flats and brackish river banks, show a great deal of variation but nevertheless, in general, are in good agreement with the glasshouse material, except that in some cases the distinction between prostrate and erect filaments is less clear, possibly due to the fact that the plants are subject to covering by tide-carried sediment. In Fritsch's specimen the tufts reached up to 5 mm in height, but in the Queensland glasshouse material the height did not exceed 1.5 mm, while in the other collections it was rarely above 1 mm.

The other described species of the genus is *Cladophorella marina* Chapman (1956) from New Zealand. Unfortunately, Chapman, in his brief description, does not record the nature of the habitat, other than in the phrase "attached to the ground", nor does he record the dimensions and forms of the cells. However, from his figure, the cells appear to show much less variation in form than in the Queensland plant, being mostly cylindric to cylindro-ellipsoid or sometimes irregular, with none broadly ellipsoid to globose; the range of cell diameter appears, from the figures, to be approximately (30) 80–200 (300)μ, the cells being thus, in general, much more robust than in the Queensland plant.

Gomontia lignicola Moore (1918), a wood-penetrating species from fresh water, is described as possessing a reticulate chloroplast and 1–6 nuclei. It probably shows some resemblance to the penetrating specimens of *Cladophorella calcicola*, but observations by Moore over several years did not reveal the typically superficial growth, commonly with erect branches, which characterizes *C. calcicola*. Moreover, in *Gomontia lignicola* zoospores are very commonly produced, while none have been seen in *Cladophorella*.

Extra-Austr. distr.: England.

PSEUDENDOCLONIUM SUBMARINUM Wille

Pseudendoclonium submarinum Wille, 1901, p. 29, pl. 3, figs. 101–134; 1910, p. 282, pl. 1, figs. 1–9; Hamel, 1930, p. 42, fig. 15 A–C; Kylin, 1949, p. 33, fig. 34; Waern, 1952, p. 49; Taylor, 1957, p. 55; Lund, 1959, p. 26.

Forming green, irregular, crustose, often confluent, more or less pseudoparenchymatous colonies composed of a prostrate system of irregularly arranged cells from which usually arise erect, or suberect, mostly irregularly arranged filaments generally not exceeding eight cells in height; cells rounded to angular, mostly 2–8μ diam. and ½–2 diam. long, with a parietal plate-like chloroplast with a single pyrenoid; in surface view of the colony, cells irregularly rounded to angular.

The colonies vary greatly in thickness, those parts occupying minute depressions being usually much thicker than those on convexities of the substratum.

The species is common also in the supralittoral fringe on the stems of the salt-water couch, *Sporobolus virginicus* (L.) Kunth and on pneumatophores and stems of the mangrove *Avicennia marina* (Forsk.) Vierh. var. *resinifera* (Forst.) Bakh. growing along the Brisbane River in the Brisbane district, and over salt flats adjoining Lake Weyba at Noosa Heads. On *Avicennia* the crust is sometimes less compact than it is on rocks, possibly due to the rather spongy nature of the substratum which undergoes contraction and expansion with changes in water content. On this substratum too there is sometimes slight penetration of the *Avicennia* tissue by filaments of the alga.

Aleem and Schulz (1952) adopt the name *Pseudendoclonium marinum* (Reinke) Aleem & Schulz for this.

GONGROSIRA CAVERNICOLA sp.n.
(Plate 3, Figs. 1–22)

Thallus incrustatus, sine calce, pseudoparenchymatus, usque ad 160μ crassus; cellulae plerumque fusoideo-ellipsoideae vel irregulariter ellipsoideae, aliquando globosae, cylindricae vel irregulares, (2) 6–25 (36)μ diam., (½) 1–6 (20) diam. longae; ab *Gongrosiris* ceteris in cellulis plerumque fusoideo-ellipsoideis differt. TYPE: in rupibus irroratis, Paradise Cave, Queensland, 14. ix. 1962.

Forming green, irregular, crustose colonies often about 1 mm diam., but commonly larger or smaller, up to 160μ thick, without lime encrustation; with a basal prostrate system of irregularly branched, closely associated filaments from which arise erect or suberect branched filaments usually arranged without apparent order or sometimes in part with the filaments more or less parallel; filaments closely associated to form a more or less pseudoparenchymatous tissue, the filaments of which separate in part under firm pressure beneath a coverglass; cells very variable in form and size, commonly fusoid-ellipsoid to irregularly ellipsoid, sometimes with the ends of the cells much attenuate, sometimes globose, cylindrical, or irregular, (2) 6–25 (36)μ diam., (5) 7–36 (50)μ long, (½) 1–6 (20) diam. long; some cells, occurring in any part of the thallus, commonly the larger globose or subglobose cells, developing walls up to 5μ thick, sometimes accumulating oil globules, and possibly acting as resting cells, but not sharply differentiated from other cells of the thallus; cells with a single parietal, plate-like chloroplast, often with the margins very deeply lobed, lining most of the cell wall, with 1–2 pyrenoids; 1–6 nuclei per cell.

Hab.: On rock slope irrigated by dripping and trickling fresh water.

From previously described non-calcified species of *Gongrosira* this plant appears to differ in the fusoid-ellipsoid form of many of the cells.

Gongrosira differs from the related *Pseudendoclonium* in having 2- rather than 4-flagellate zoospores, and the finding of zoospores in the above species will be necessary to determine its generic position with certainty.

Gongrosira is reported by Printz (1927) to be uninucleate, but it is doubtful whether the occurrence of more than one nucleus in some cells of the plant necessarily excludes it from this genus. In the closely related genus *Gomontia* there are 1–several nuclei per cell, but this is a genus of penetrating algae, although it is conceivable that an alga might be either penetrating or superficial depending on the nature of the substratum. *Gomontia aegagropilae* Acton (1916) appears to show some resemblance in cell form to *Gongrosira cavernicola*, but Acton apparently found no evidence that her plant formed a superficial multi-layered thallus on either the hard or soft substrata present in her culture.

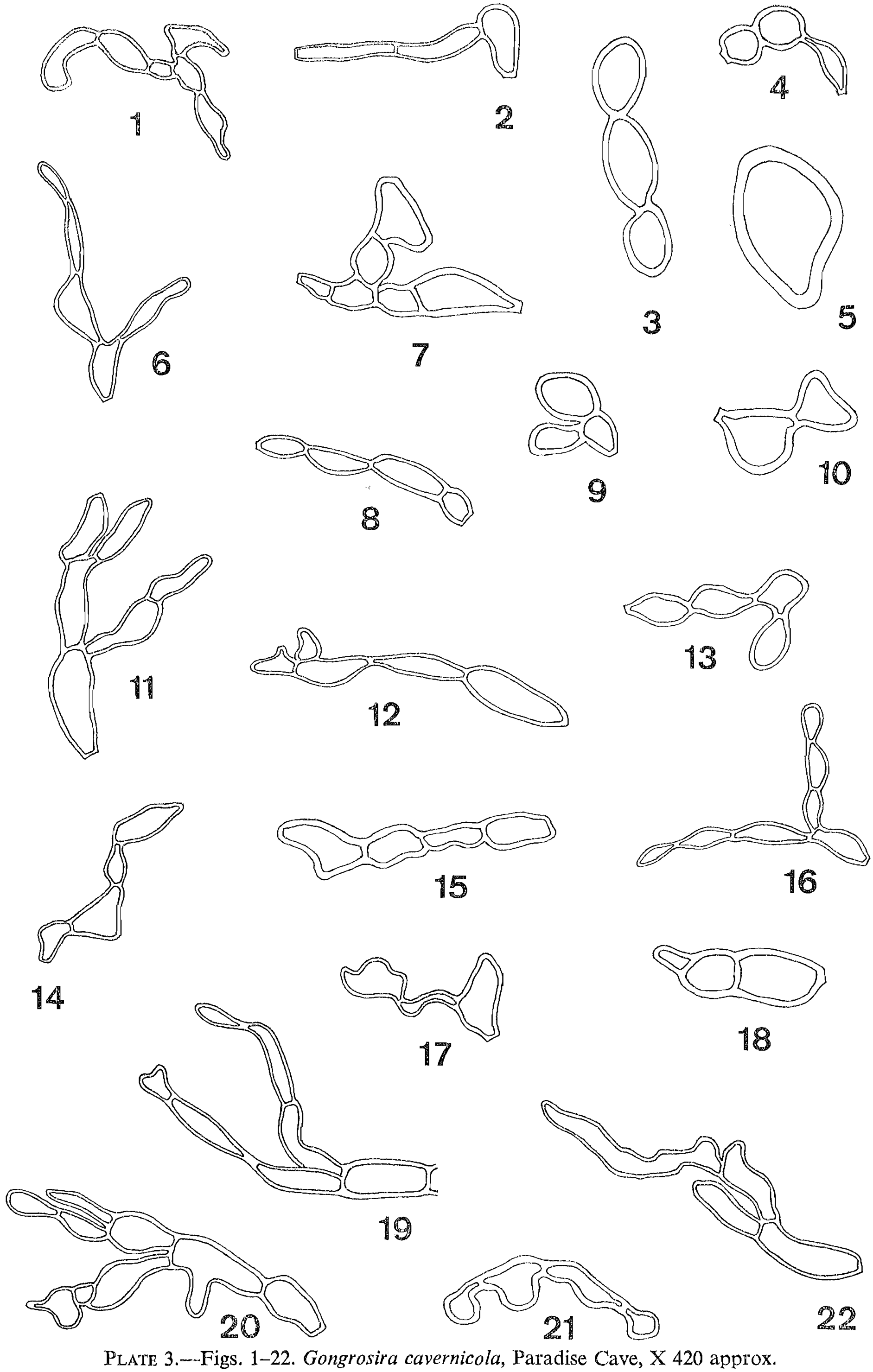

PLATE 3.—Figs. 1–22. *Gongrosira cavernicola*, Paradise Cave, X 420 approx.

CYANIDIUM CALDARIUM (Tilden) Geitler

Cyanidium caldarium (Tilden) Geitler, 1933, p. 624; 1958, p. 172; Hirose, 1950, p. 107; Drouet & Daily, 1956, p. 161; Lewin, 1961, p. 6; Dougherty & Allen, 1956, p. 11; Allen, 1959, p. 270; Silva, 1962, p. 835.
Protococcus botryoides f. *caldarius* Tilden, 1898, p. 94, pl. 8, fig. 18.
Pleurocapsa caldaria (Tilden) Setchell, 1901, *in* Collins, Holden & Setchell, Phyc. Bor.—Amer., Fasc. 18, no. 851.
Palmellococcus thermalis West, 1904, p. 287, pl. 464, fig. 21.
Chroococcopsis caldaria (Tilden) Geitler, 1925b, p. 241.
Dermocarpa caldaria (Tilden) Drouet, 1943, p. 672.
Pluto caldarius (Tilden) Copeland ex Drouet, 1943, p. 672; Copeland, 1936, p. 72, fig. 33; Smith, 1950, p. 571, fig. 482.
Chlorella caldaria (Tilden) Hirose, 1950, p. 107.
Chlorella caldaria (Tilden) Allen, 1954, p. 42.
Rhodococcus caldarius (Tilden) Hirose, 1958, p. 347.

Forming a blue-green stratum up to several cells thick; cells globose, rarely ellipsoid or oval, (2) 3–6 (7)μ diam., never forming colonial aggregates; cells with a single, parietal, plate-like, blue-green chloroplast, without pyrenoid, lining usually about half the cell wall; multiplication by tetrahedral division to form 4 autospores which appear to escape early from the thin mother cell wall.

The fairly dry wall of a cave is a strikingly different habitat from the acid hot springs in which this species has hitherto been reported. Copeland (1936) reports it from a temperature range of 34°–80.2°C, in one locality intermittently bathed in water at 90°C, while he found the pH range to be 2.6–5.4. However, Allen (1954) has found that a plant isolated from a spring with pH of 1 and a temperature of 70°C grew in culture at temperatures ranging from room temperature to 50°C, and at a pH of 7. The alga thus appears to have considerable potential for adaptation to differing environments, and since there seems to be no morphological character on which the Queensland and exotic plants can be separated they are regarded as conspecific.

Cyanidium caldarium has had a chequered taxonomic history having been referred to nine different genera, while its relationship has been suggested as being with Chlorophyta, Cyanophyta, Rhodophyta, and recently the Cryptophyta.

Extra-Austr. distr.: Acid hot springs throughout the world.

WAERNIELLA LUCIFUGA (Kuckuck) Kylin

Waerniella lucifuga (Kuck.) Kylin, 1947, p. 26, fig. 23; Waern, 1952, p. 118, fig. 52; Blackler, 1956, p. 52.
Leptonema lucifugum Kuckuck, 1897, p. 38, pl. 12, figs. 20–24; Batters, 1906, p. 2; Skuja, 1928, p. 39, pl. 1; Hamel & Lami, 1931, p. 18; Hamel, 1935, p. 128, fig. 29e; Rosenvinge, 1935, p. 40, figs. 40–41; Rosenvinge & Lund, 1943, p. 7; Waern, 1936, p. 329; 1940, p. 4; Lami, 1940, p. 61; Levring, 1940, p. 47.
Leptonematella lucifuga (Kuck.) Silva, 1959, p. 63.

var. AUSTRALIS var.nov.
(Plate 4, Figs. 1–14)

Ab *W. lucifuga* (Kuck.) Kylin var. *lucifuga* in cellulis decumbentibus longioribus, in sporangiis plurilocularibus septas longitudinales raras formantibus, in habitatione irrorata differt. TYPE: Paradise Cave, Noosa Heads, 10.vii.1963.

Filaments forming a soft, dark brown, somewhat velvet-like layer, or less commonly small irregular colonies; prostrate filaments closely and irregularly arranged, readily separable, with cells mostly irregularly cylindrical, sometimes irregularly torulose, often sinuate, 5–12μ diam., 1–3 diam. long; erect filaments free from one another, .5–2 mm high, with cells (5) 7–10 (12)μ diam. and (1) 1½–2 (4) diam. long, cylindrical to occasionally slightly constricted at the septa, from untapered and with the apical cell dome-shaped and proportionally no longer than other cells of the

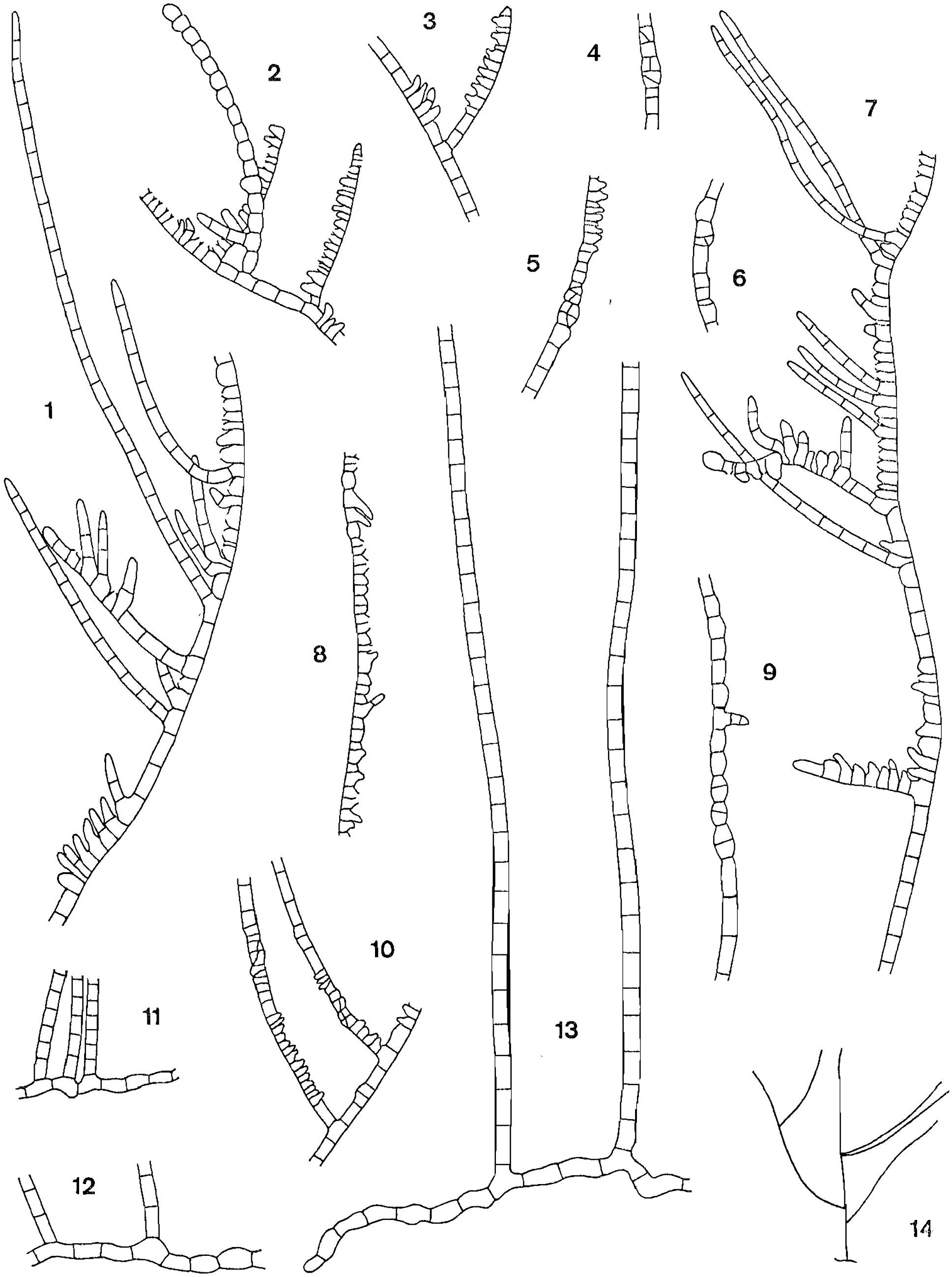

PLATE 4.—Figs. 1–14. *Waerniella lucifuga* var. *australis*, Paradise Cave. Figs. 1–10, filaments with plurilocular sporangia, X 230 approx.; Figs. 11–13, basal and portion of erect filaments, X 230 approx.; Fig. 14, branched erect filament, X 20 approx.

filament to gradually tapered with the terminal cell down to ½ diam. of cells in the lower part of the filament and proportionally considerably longer; erect filaments mostly simple or sparsely branched except sometimes in the sporangial region;

chromatophore usually 1, rarely 2 per cell, parietal, very deeply multilobed; presumed plurilocular sporangia arising through the transformation of intercalary or occasionally terminal rows of 1–30 approx. cells which usually become somewhat inflated and divided by 1–3 transverse walls, very exceptionally also by longitudinal walls, the cells so formed being usually $\frac{1}{4}$–1 diam. long and mostly unilaterally protuberant; the contents of some of these cells apparently escaping but of others apparently germinating in situ and growing out occasionally irregularly, but usually unilaterally, to form a series of often closely but irregularly spaced branches of often uneven length, some of which may eventually behave in a similar way; unilocular sporangia not seen.

Collections were made from two localities in the cave, namely from one of the points on which water dripped very rapidly on the well-irrigated slope described above, and also from close to the rear end of the cave on a boulder which was kept wet by only a very slow dripping from the roof. The latter collection differs from the other in having filaments, in general, with slightly shorter cells and without plurilocular sporangia, although the presence of a few rows of inflated cells suggests incipient sporangium formation.

Waerniella lucifuga is an alga which has hitherto been reported only from maritime caves and shaded crevices high on the shore in Europe, and it was not expected that this species would be found in subtropical Australia. Waern (1952) reports that in Sweden the species "does not colonize trickle water surfaces". In Paradise Cave, the plant grows vigorously in this type of habitat and has not been found on surfaces which are not obviously wet.

Apart from this difference in habitat, the only apparent differences between the plants from the two hemispheres concern the prostrate filaments and the sporangia. In the northern plant the cells of the prostrate filaments appear to be torulose and about as long as broad; such cells occur also in the Queensland plant but the majority are subcylindric and at least $1\frac{1}{2}$ diam. long. Also, in the European plant longitudinal walls are commonly formed during the production of plurilocular sporangia. In the Queensland plant longitudinal and oblique walls are found only exceptionally amongst the rows of very short and commonly empty cells which are assumed to constitute the plurilocular sporangia.

Whether or not these morphological differences justify taxonomic distinction for the Queensland plant is open to question, but, when considered with the difference in habitat and the markedly discontinuous distribution, it seems advisable, at least for the present, to distinguish the southern plant as a variety of the northern.

AUDOUINELLA EUGENEA (Skuja) Jao
(Plate 5, Figs. 1–13; Plate 6, Figs. 1–4)

Audouinella eugenea (Skuja) Jao, 1940, p. 243; Papenfuss, 1945, p. 325; 1947, p. 438.
A. eugenea var. *secundata* Jao, 1941, p. 254, pl. 4, figs. 21–22.
Chantransia eugenea Skuja, 1935, p. 179, pl. 1, figs. 3–5.

Caespitose, forming a dull red-brown to purple-brown, soft, velvety carpet; prostrate filaments of irregularly cylindrical to irregularly torulose cells, closely associated and approximating to a pseudoparenchyma; erect filaments to 4 mm high, sometimes unbranched, sometimes with branching mainly restricted to lower parts with upper parts simple or almost so, or sometimes the upper parts with close irregularly secund to alternate branching; branches untapered or tapered very gradually towards the apices, the end cells obtuse and never hair-like; cells (5) 7–14 (17)μ diam., (2) 3–5 (7) diam. long, cylindrical or occasionally slightly inflated in the lower parts; cells with 3–5 chromatophores, broadly band-shaped, often irregularly lobed, and more or less spirally arranged; monosporangia obovate to subpyriform, 12–17 $\times$ 8–11μ, sessile, or pedicellate, with 1–3 sporangia on a usually unicellular pedicel; sporangia sometimes scattered sparsely and irregularly along main branches, but usually with several or numerous sporangia arising in close proximity and arranged

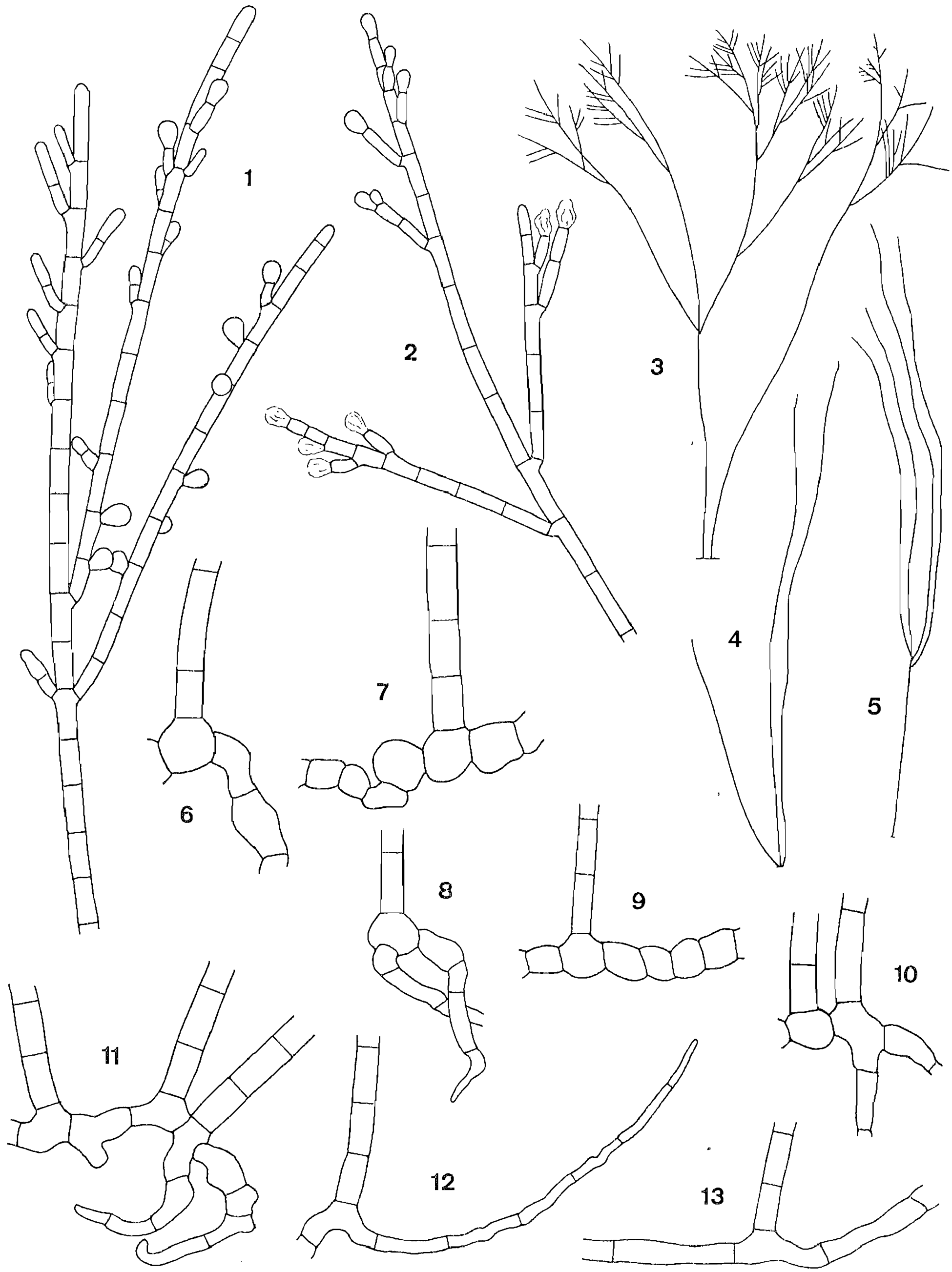

PLATE 5.—Figs. 1–13. *Audouinella eugenea*, Paradise Cave. Figs. 1–2, branches with monosporangia, X 230 approx.; Figs. 3–5, erect filaments, X 20 approx.; Figs. 6–13, prostrate filaments, X 230 approx.

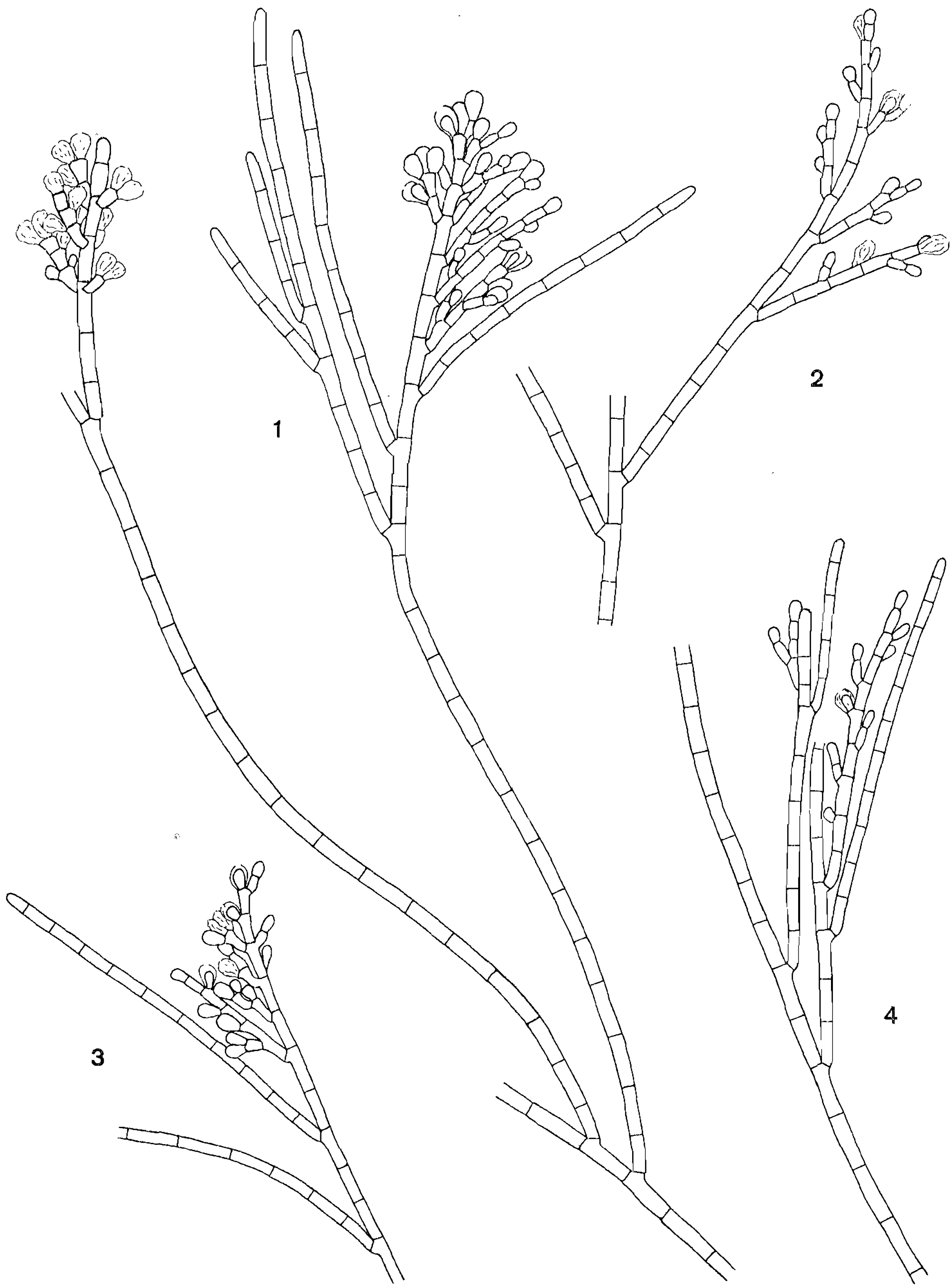

PLATE 6.—Figs. 1–4. *Audouinella eugenea*, erect branches with monosporangia, Paradise Cave, X 230 approx.

alternately, secundly, or less commonly oppositely on short branches which may themselves be closely grouped and similarly arranged.

Of the described species of *Audouinella* the cave plant appears to be closest to *A. sinensis* Jao (1940), reported so far only from China, and to *A. eugenea* (Skuja) Jao, described from India and subsequently reported in the variety *secundata* Jao from China.

The filament diameter reported for each of these species is similar, although *A. eugenea* has, in general, proportionally longer cells, 4–8 diam. long, those of *A. sinensis* being 2–4 diam. long. Monosporangia in each may be sessile or stalked, and either opposite or secund, the opposite condition strongly predominating in *A. sinensis*, while in *A. eugenea* both arrangements seem to be common, with possibly the secund condition the more frequent. Fertile branches seem to show less tendency towards being determinate in *A. eugenea* than they do in *A. sinensis* where they are mostly only 3–4 cells long, while the tendency for fruiting branches to occur in close proximity along the main branches seems, from the published figures, to be more pronounced in *A. eugenea* than in *A. sinensis*. The nature of the apparent differences between these two species leaves some doubt as to the justification for their separation, and an examination of a wider range of specimens of each is desirable.

The cave plant has a filament diameter in general similar to that of both the above species, although the diameter of the broadest filaments near their base considerably exceeds that recorded for either of those species; the cell proportions are somewhat intermediate between the two. Monosporangia also are more or less intermediate in size between the two, and, although the arrangement of the monosporangia may be alternate, secund, or opposite, the common grouping of the fertile branches in close proximity suggests *A. eugenea* rather than *A. sinensis*.

Although not in complete agreement with the published description and figures of *A. eugenea*, the apparent differences do not seem to be of sufficient magnitude to justify taxonomic distinction and the Queensland plant is therefore assigned to this species.

Extra-Aust. distr.: India, China.

HILDENBRANDTIA sp.

Hildenbrandtia prototypus Nardo and *H. rivularis* (Liebm.) J.Ag. are both widely distributed species distinguished by their habitat and the nature of the tetrasporangia. *H. prototypus* is marine, with mostly ellipsoid, ovoid, or obovoid tetrasporangia obliquely and often rather irregularly divided, and contained in a conceptacle (see Rosenvinge, 1917). *H. rivularis* is a freshwater species and according to Flint (1955) has fusoid tetrasporangia regularly zonately divided and borne in a conceptacle, although in a few cases tetrasporangia are embedded in the thallus and not in a conceptacle; Palik (1957) reports tetrasporangia in this species without the formation of specialized conceptacles (this paper is known to me only through the review in *Rev. algol. N.S.*, **4** (2), p. 142).

H. prototypus is a common species along marine shores in southern Queensland, and a freshwater species, probably *H. rivularis*, but so far found only in the sterile condition, is common in some swiftly running streams. Vegetatively these two Queensland populations are not readily distinguishable. No tetrasporangia have been found in the cave material, so it is not possible to make a determination of the species.

CAULACANTHUS SALIFUGUS n. sp.
(Plate 7, Figs. 1–7)

Rami teretes, 55–165μ diam., alterni vel unilaterales; cellulae superficiales plerumque irregulariter dispositae, 5–12 (16)μ diam., saepe a latere elongatae; rhizoidei ab apicibus ramorum producti; ab *Caulacanthis* ceteris in aqua dulci

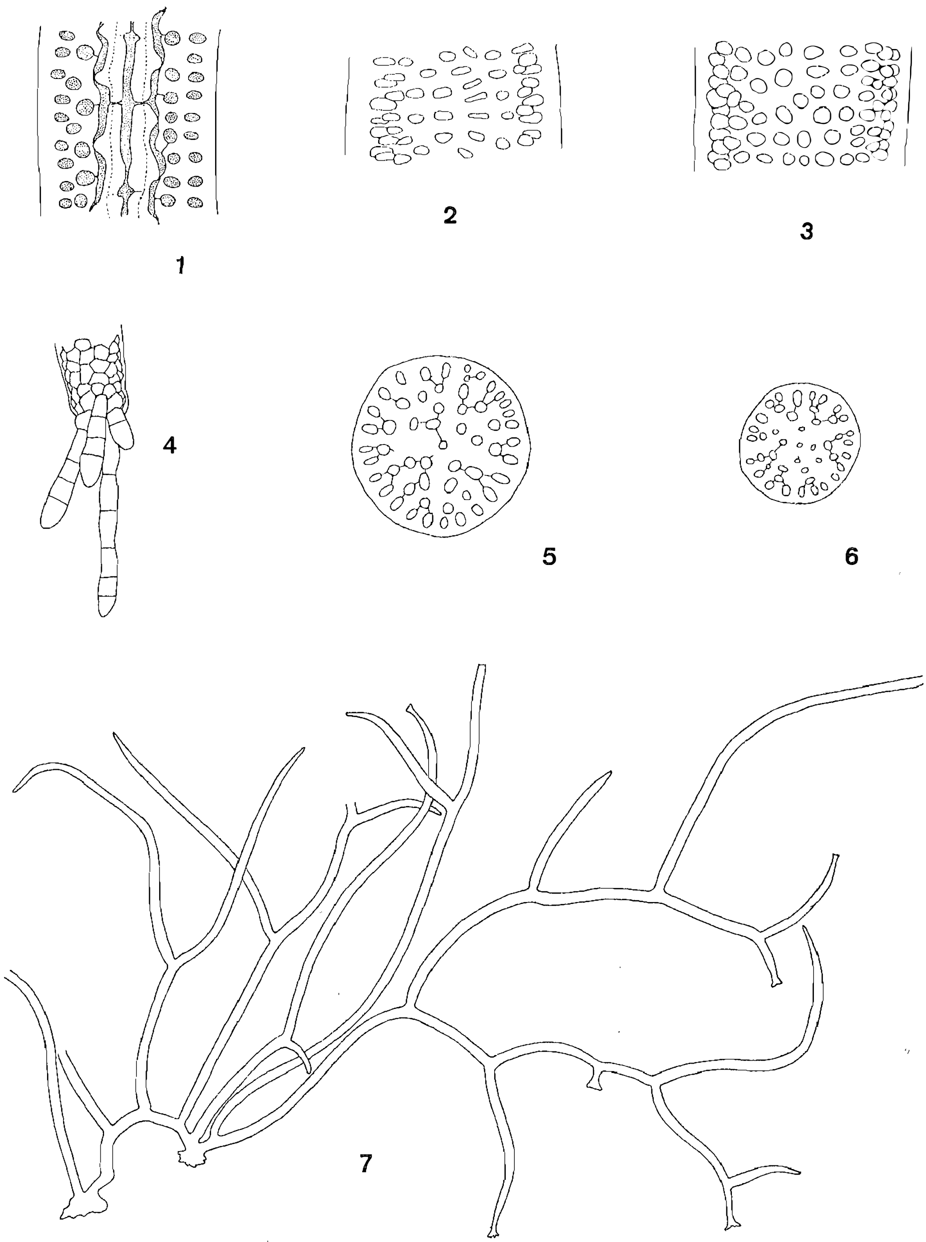

PLATE 7.—Figs. 1–7. *Caulacanthus salifugus*, Paradise Cave. Fig. 1, longitudinal section, X 280 approx.; Figs. 2–3, surface view of preserved specimen, X 280 approx.; Fig. 4, branch apex with rhizoids, X 230 approx.; Figs. 5–6, transverse section, X 280 approx.; Fig. 7, whole plant, X 13 approx.

habitanda differt. TYPE: in rupibus irroratis, Paradise Cave, Queensland, 10. vii. 1963.

Forming a dull, dark purple-brown carpet of lax, loosely entangled branches up to approx. 15 mm high; branching irregularly alternate or unilateral, the branches

PLATE 8.—Entrance to Paradise Cave. A few trees of *Pandanus* may be seen above the entrance.

PLATE 9.—Part of Paradise Cave showing, in the middle foreground, the well-irrigated slope much darkened in its mid part by the algal mat.

often somewhat curved, sometimes slightly constricted at their insertion; apices subulate, with a single apical cell dividing obliquely; branches terete, 55–165μ diam.; many of the branch tips producing groups of rhizoids which become attached to the substratum but not to other branches, and which coalesce to form a discoid holdfast from which eventually numerous branches may arise; branch tissue compact, with an axial row of elongate cells, mostly 35–60μ long, surrounded by 4 rows of elongate cells $\frac{1}{2}$–1/3 as long as the central row, followed by a layer 1–3 cells thick of more or less rounded cells, and finally by an epidermal layer of mostly somewhat radially elongate cells; in surface view epidermal cells not distinctly arranged in regular rows, rounded to elliptical or somewhat angular, mostly 5–12 (16)μ diam., in some places mostly somewhat horizontally elongate and 1–3 times as broad as high.

No reproductive bodies have been found amongst the several collections made, and the species can be only tentatively assigned to *Caulacanthus*.

The plant occurs only where vigorously irrigated by fresh water and sometimes mingles with *Oedogonium* sp. and the moss *Rhynchostegium tenuifolium*. A species of *Caulacanthus* occurs fairly commonly in shaded crevices mainly on the mid and lower littoral along the shores of south-eastern Queensland, but this species differs in a number of respects from the cave material and appears to be a different species.

All other species of *Caulacanthus* appear to be distinctly marine.

BOSTRYCHIA BINDERI Harvey

Bostrychia binderi Harvey, 1847, p. 68, pl. 28; J. Agardh, 1863, p. 873; Falkenberg, 1901, p. 521; Post, 1936, p. 28; Taylor, 1942, p. 140; 1960, p. 598; Tseng, 1943, p. 177, pl. 1, figs. 7–8; Joly, 1954, p. 61, pl. 2; 1957, p. 168, pl. 7, fig. 7, pl. 11, fig. 13, pl. 13, fig. 7, pl. 14, figs. 6, 6a, 6b.
B. tenella var. *terrestris* J. Agardh, 1863, p. 869.
B. vieillardii Kuetzing, 1865, p. 10, pl. 26, figs. a–e.
B. vieillardii var. *pectinata* Kuetzing, 1865, p. 10, pl. 26, figs. f–h.
Amphibia pectinata (Kuetz.) Howe, 1920, p. 573; Taylor, 1928, p. 166.

The production of lateral branches is sparse and irregular, although there is considerable variation in the degree of branching; some axes are almost without branches with monosiphonous tips, while on others they are fairly common, although produced rather irregularly. The population belongs to the f. *terrestris* (J.Ag.) Post (1936).

Extra-Austr. distr.: Widely distributed in warm seas.

Acknowledgments

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