

## *Ballia prieurii* KUETZING and the related species (Ceramiaceae, Rhodophyta)

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*Ballia prieurii* KUETZING and two related freshwater species, *B. pygmoea* MONTAGNE and *B. pinnulata* KUMANO, can be distinguished from the type species of the genus, *B. callitricha* (AGARDH) MONTAGNE, mainly in the organization and size of thallus, the reproductive organs and the geographical distributions of species. Re-examinations of the taxonomic criteria, especially of reproductive organs, are strongly desired.

**Key Index Words:** *Ballia callitricha*—*Ballia pinnulata*—*Ballia prieurii*—*Ballia pygmoea*—freshwater Rhodophyta—mode of ramification—monosporangia—saddle-shaped joints.

*Sphacelaria callitricha* was described as a new species by C. A. AGARDH (1824). MONTAGNE (1839) reported this species with figures based on the Patagonian specimens. Based on the Australian specimens collected by R. BROWN, HARVEY (1840) established the genus *Ballia* and described *Ballia brunonia* as a new species. HARVEY (1840) presumed that *Sphacelaria callitricha* might be *Ballia brunonia* only in a battered and faded state. *Sphacelaria callitricha* was transferred from the genus *Sphacelaria* to the genus *Ballia* as *Ballia callitricha* (AG.) MONTAGNE (1841–1845), and it has been regarded as the type species of the genus *Ballia*.

On the other hand, three freshwater species of the genus *Ballia* have been described, although DE TONI (1903) kept them aside as species inquirendae, because he regarded *Ballia prieurii* as merely an underdeveloped form of *Ballia callitricha*. *B. prieurii* was described by KUETZING (1847) based on the specimen collected from Rivulet les Gemeaux in Mahuri Mountains, Cayenne in French Guiana. *B. pygmoea* was described by MONTAGNE (1850) based on the specimen epiphytic on *Batrachospermum equisetifolium* MONTAGNE collected from Crique Gravier in Kaw Mountains in French Guiana. *B. pinnulata* was described by KUMANO (1978) based on the

specimen collected from Sungai Gombak, Selangor, in Peninsular Malaysia.

This paper deals with the differences between the type species of the genus *Ballia*, *B. callitricha*, and three freshwater species of the genus, based on the type specimens and the allied specimens of each species.

### Specimens examined in the present study

The following specimens are examined.

#### 1. *Ballia prieurii* KUETZING

1) Three Malaysian collections of *B. prieurii*: the specimen (No. 105) from Sungai Sempanong, Johore, Peninsular Malaysia (S. M. PHANG, 28/09/1985); the specimen (No. 236) from Sungai Jasin, Johore, Peninsular Malaysia (S. M. Phang, 23/01/1986); the specimen (No. 266) from Sungai Pelawar, Johore, Peninsular Malaysia (S. M. PHANG, 23/01/1986), deposited in the herbarium of the Faculty of Science, Kobe University, Japan.

2) The specimen (Leiden No. 938, 92–104) of *B. prieurii*, collected from Rivulet Gemeaux in Mahuri Mountains in French Guiana by M. LEPRIEUR (no. 832), with Kuetzing's note "bei *Ballia prieurii* KUETZING" in pencil and Taylor's note "this is tagged the type specimen and probably so", deposited in the

Rijksherbarium in the Netherlands.

### 2. *Ballia pygmoea* MONTAGNE

The type specimen of *B. pygmoea*, epiphytic on *Batrachospermum equisetifolium*, collected from Creek Gravier in Kau Mountains in French Guiana by M. LEPRIEUR (no. 1109) and deposited in the herbarium of Muséum National d'Histoire Naturelle in France.

### 3. *Ballia pinnulata* KUMANO

The type specimen of *B. pinnulata*, collected from Sungai Gombak, Selangor in Peninsular Malaysia by S. KUMANO, on May 30, 1971, deposited in the herbarium of Faculty of Science, Kobe University, Japan.

### 4. *Ballia callitricha* (AGARDH) MONTAGNE

1) The specimen reported by MONTAGNE (1939) as *Sphaclaria callitricha* AGARDH in the herbarium de C. Montagne, collected from Iles Malouines and deposited in the herbarium of Muséum National d'Histoire Naturelle in France.

2) The specimen of *B. callitricha*, collected from Queenscliff, Victoria in Australia by T. YOSHIDA, on August 20, 1988 and deposited in the herbarium of Faculty of Science, Hokkaido University, Japan.

## Observations

### 1. *Ballia prieurii* KUETZING

1) The Malaysian specimens of *B. prieurii* (Figs. 1-10): The thallus of the Malaysian specimens is 3-5 mm high, heterotrichous, attached to substratum with the prostrate system which is composed of two kinds of cells, round (Fig. 1, p) and filamentous cells (Fig. 1, p').

The erect system (Fig. 1, e) is fastigiate, with twiggy, long, slender, streaked and rod-like branches, all of which reach nearly the same height. The axes of the erect system are noncorticated, consisting of barrel-shaped and subhexagonal cells, and terminating in a round tip (Fig. 2).

There is a pit connection at each joint of the axial cells of the erect system, however, the knob-like stoppers and the saddle-shaped joints of axial cells are not observed.

The primary branchlets are placed on the

opposite side of the axis on the same plane; the primary branchlets are unilaterally branched and bear the secondary branchlets composed of 2-6 cells, gradually tapering toward the apex where terminal hairs (Fig. 1, h) are occasionally observed. The basal cell of the primary branchlet elongates downwards along the axial cells and divides to produce the rhizoidal filament, which is composed of elongated cells (Figs. 3, 4 and 9, r). The lower part of the axes of the erect system is occasionally covered by the rhizoidal filaments.

Monosporangia (Figs. 6-8 and 10, m) are spherical, 30-50  $\mu\text{m}$  in diameter, mostly lateral, sometimes subterminal (Figs. 6-8 and 10), rarely terminal (Fig. 5, m') on the primary branchlets. No sexual reproductive organs are observed for the Malaysian specimens of *B. prieurii*.

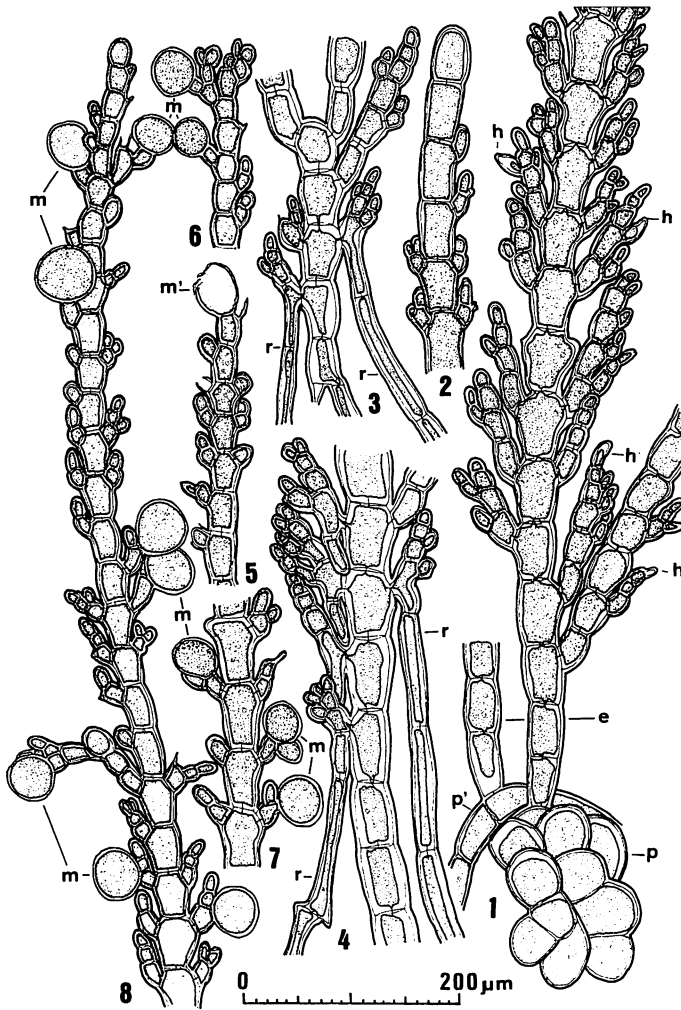
2) Type specimen of *B. prieurii* KUETZING (Figs. 11-12): The thallus of the type specimen is 20-25 mm high. There is a pit connection at each joint of axial cells of the erect system, however, the knob-like stoppers and the saddle-shaped joints of axial cells are not observed (Fig. 12).

The primary branchlets (Fig. 11) are placed on the opposite side of the axis on the same plane, irregularly tapered toward the apex and are unilaterally branched bearing the secondary branchlets. The basal cell of the primary branchlet becomes elongated downwards along the axial cells to produce the rhizoidal filaments (Fig. 12, r). The lower part of the axis of the erect system is sometimes covered by rhizoidal filaments.

The asexual and sexual reproductive organs are not observed in the type specimen of *B. prieurii*.

### 2. *Ballia pygmoea* MONTAGNE (Figs. 13-14)

The thallus of the type specimen is 1-2 mm high, heterotrichous, epiphytic, and attached to the cortical filaments of the thallus of *Batrachospermum equisetifolium* by the prostrate system, which is composed of two kinds of cells, namely, round cells and filamentous cells.



Figs. 1–8. Malaysian specimen of *Ballia prieurii* KUETZING.

1. Heterotrichous thallus consisting of prostrate and erect systems. 2. Terminal portion of erect system. 3, 4. Rhizoidal filaments arising from basal cells of the primary branchlets. 5. Terminal portion of erect system showing empty monosporangia. 6–8. Monosporangia, mostly lateral, sometimes subterminal and rarely terminal on the lateral branchlets.

e, erect system; h, terminal hair; m, monosporangia; m', empty monosporangia; p, prostrate system composed of round cells; p', prostrate system composed of filamentous cells; r, rhizoidal filament.

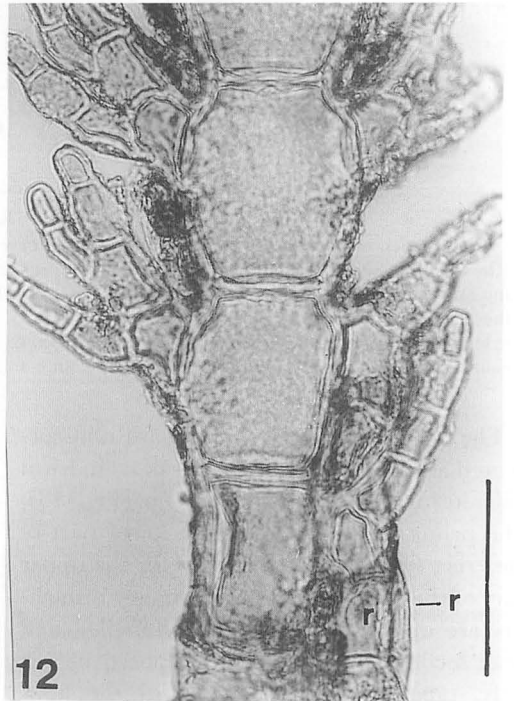
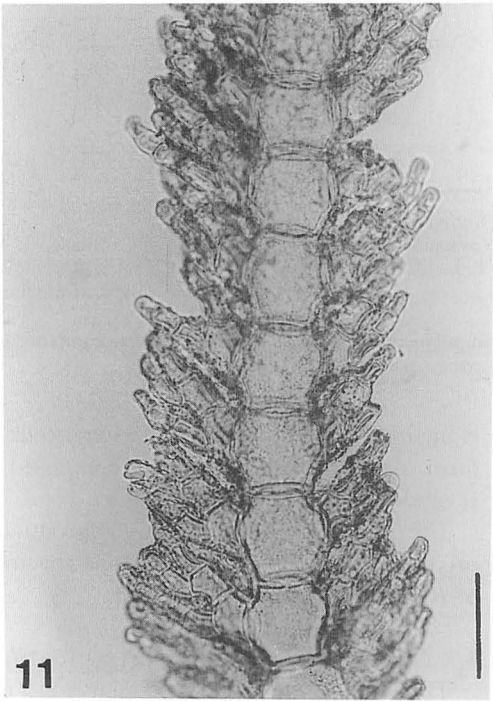
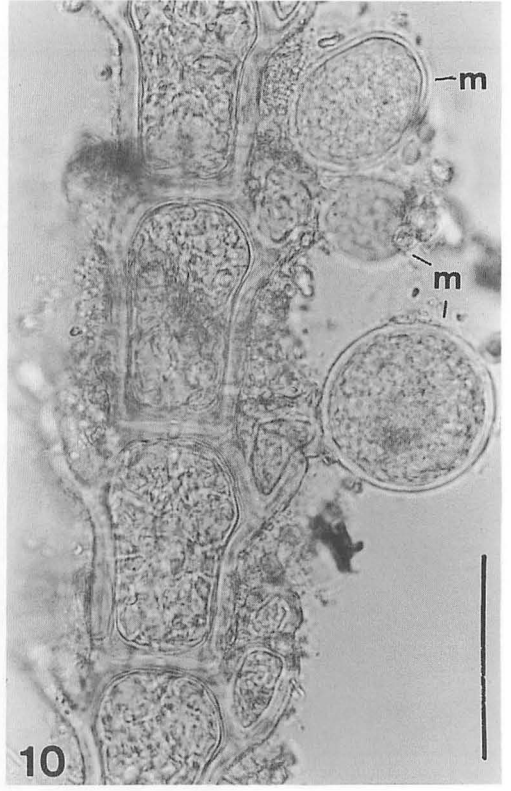
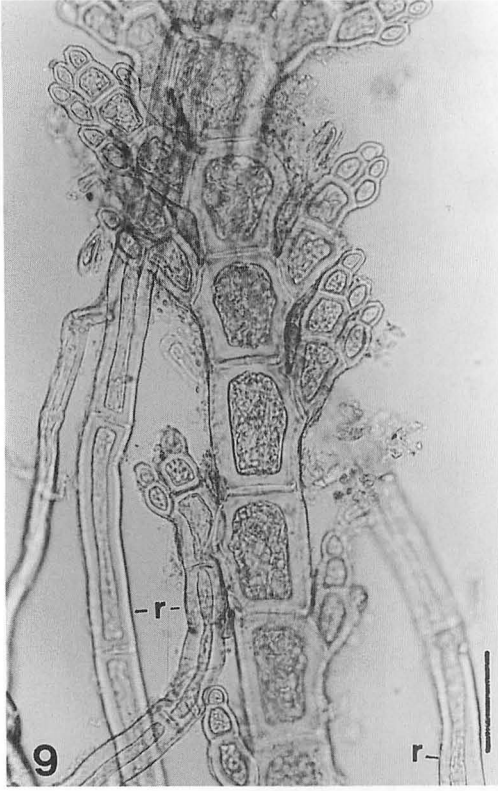
The axes of the erect system are non-corticated and composed of a series of cylindrical cells, terminating in a round tip (Fig. 13). The primary branchlets in the lower part of the erect system are alternate. In the upper part of the erect system, the primary branchlets are opposite, unilaterally branched and bear secondary branchlets composed of 3–5 cells, tapering gradually towards the apex (Fig. 13). In the lower part of the erect system, the basal cell of the primary branchlet

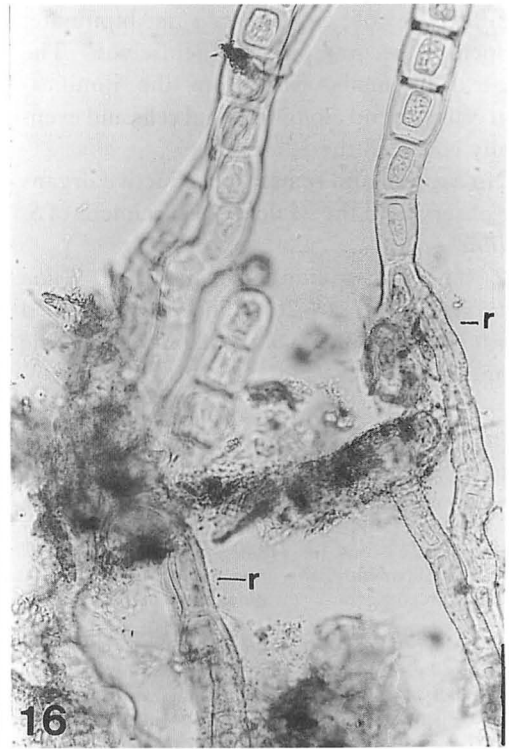
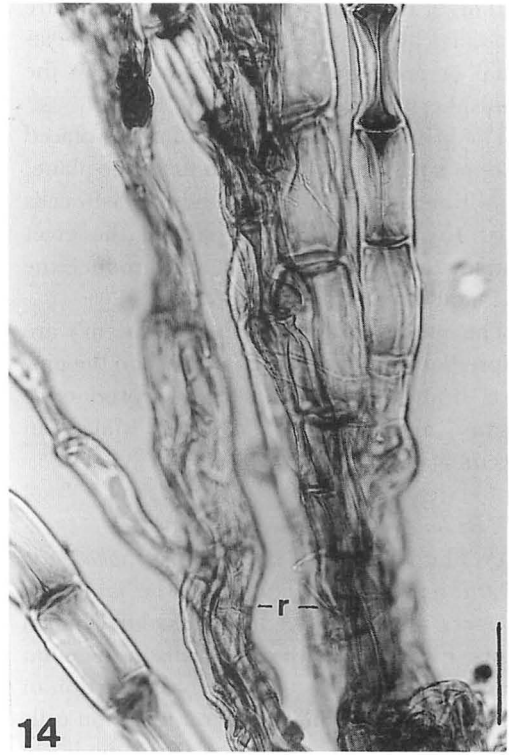
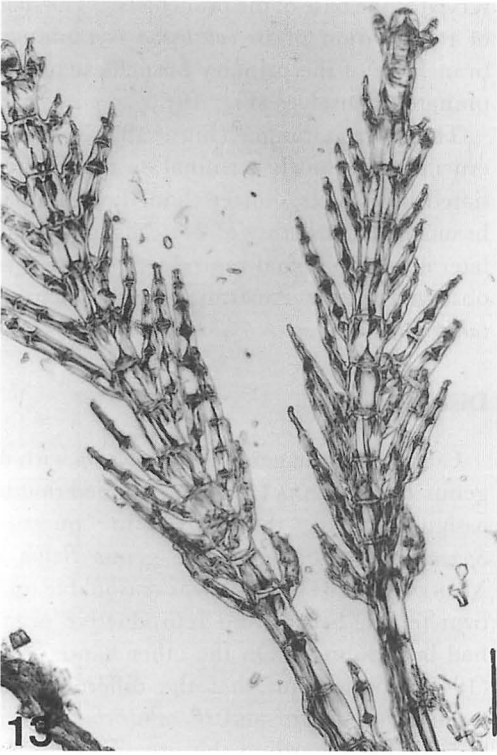
elongates downwards along the axial cells, to form the rhizoidal filament, composed of several elongated cells (Fig. 14, r).

The asexual and sexual reproductive organs are not observed in the type specimen of *B. pygmoea*.

### 3. *Ballia pinnulata* KUMANO (Figs. 15–16)

The thallus of the type specimen is 2–3 mm high, heterotrichous and attached to the substratum with the filamentous prostrate





system. The axes of the erect system are non-corticated and composed of subhexagonal or octagonal cells, terminating in the hemispherical tip.

The primary branchlets are pinnate, placed on opposite side of the axis on the same plane, non-branched, and composed of 3–9 cells (Fig. 15). In the lower part of the erect system, the axial cells grow and produce the rhizoidal filaments (Fig. 16, r).

The monosporangia (Fig. 15, m, m') are ellipsoidal or ovoidal, and terminal on the pinnate branchlets. No sexual reproductive organs are observed in the Malaysian specimens of *B. pinnulata*.

#### 4. *Ballia callitricha* (AG.) MONTAGNE

1) The Malouines specimen of *Sphacelaria callitricha* (Fig. 17): There are the knob-like stoppers (Fig. 17, k) at the saddle-shaped joints (Fig. 17, s) of the axial cells in the main stem and branchlets. In the basal portion of the primary branchlets, the ramification cells (Fig. 17, ra) are found. The mode of ramification of *S. callitricha* is bipinnate; branchlets become pinnate themselves. The cortical filaments arise from the ramification cells, extend along the axial cells and eventually cover all the axis.

No asexual and sexual reproductive organs are observed in the Malouines specimens of *S. callitricha*.

2) The Australian specimen of *Ballia callitricha* (Figs. 18–20): The saddle-shaped joints (Figs. 18, 20, s) of the axial cells and the ramification cells (Figs. 18, 20, ra) are ob-

served at the base of the branchlets. The mode of ramification of *B. callitricha* is bipinnate; branchlets of the primary branchlets become pinnate themselves (Fig. 19).

The tetrasporangia (Figs. 19, 20, t) are cruciate and mostly terminal on the differentiated branchlets shorter than the secondary branchlets, consisting of 2–4 cells and arising laterally. No sexual reproductive organs are observed in the Australian specimen of *B. callitricha*.

### Discussions

Comparing the genus *Ptilothamnion* with the genus *Ballia*, SKUJA (1944) mentioned that the assignment of the algae in question, *Sphacelaria callitricha*, to the genus *Ballia* by MONTAGNE (1841–1845) was reasonable on its own terms, because no reproductive organs had been found. On the other hand, SKUJA (1944) pointed out that the differences between *Ballia prieurii* and *B. callitricha* are very remarkable regarding the organizations and size of thalli and the geographical distributions of the taxa.

#### 1. Organizations of thalli

Concerning the organization of thalli of the type species, *B. callitricha*, many authors such as HARVEY (1840), ARCHER (1876) and SKUJA (1944), and the present study have observed the knob-like stoppers (Figs. 17, 18, k) at the saddle-shaped joints of the axial cells (Figs. 17, 18, 20, s). Moreover, for this species, the mode of ramification is bipinnate and the ramification cells (Figs. 17, 18, 20, ra) of

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Figs. 9 and 10. Malaysian specimen of *Ballia prieurii* KUETZING.

9. Rhizoidal filaments arising from basal cells of the primary branchlets. 10. Monosporangia terminal or subterminal on the primary branchlets.

Figs. 11 and 12. Type specimen of *Ballia prieurii* KUETZING.

11. Axial cells and the primary branchlets unilaterally branched. 12. Lower part of the thallus, showing the rhizoidal filament arising from the basal cell of the primary branchlet. m, monosporangia; r, rhizoidal filament. Scale 50  $\mu\text{m}$  for Figs. 9–12.

Figs. 13 and 14. Type specimen of *Ballia pygmoea* MONTAGNE.

13. Axial cells and the opposite branchlets. 14. Lower part of the thallus, showing rhizoidal filaments arising from the basal cell of the primary branchlet.

Figs. 15 and 16. Type specimen of *Ballia pinnulata* KUMANO.

15. Upper part of the thallus, showing axial cells and monosporangia terminal on the pinnate primary branchlets. 16. Lower part of the thallus, showing the rhizoidal filament or prostrate system. m, monosporangia; m', liberated monosporangia; r, rhizoidal filament. Scale: 100  $\mu\text{m}$  for Fig. 13, 50  $\mu\text{m}$  for Figs. 14–16.

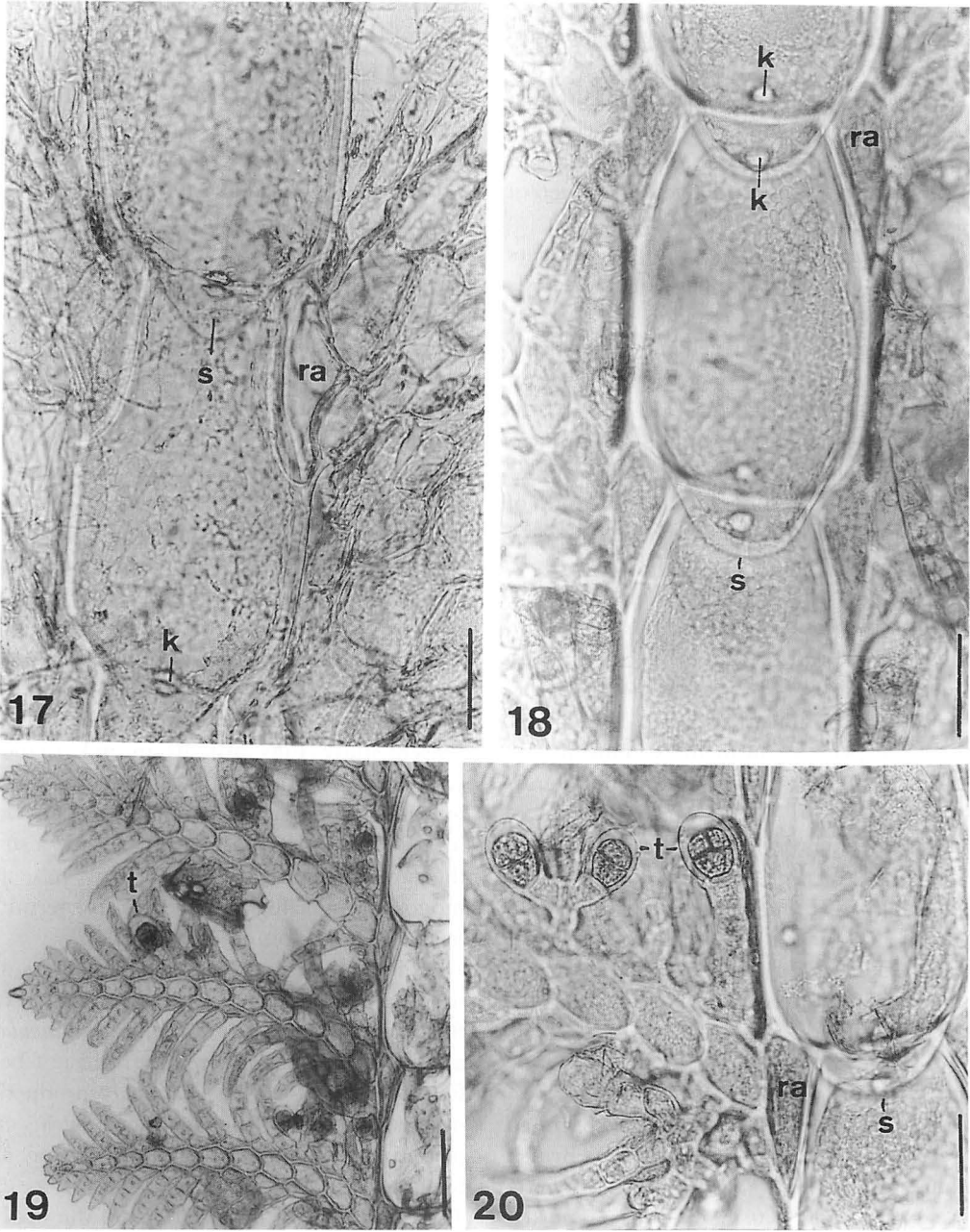


Fig. 17. Specimen of *Sphacelaria callitricha* Agardh. The saddle-shaped joints of axial cells with the knob-like stoppers and the ramification cells.

Figs. 18–20. Australian specimen of *Ballia callitricha* (Agardh) Montagne.

18. The saddle-shaped joints of axial cells with the knob-like stoppers and the ramification cells. 19–20. Cruciate tetrasporangia on differentiated branchlets shorter than the secondary branchlets.

k, knob-like stopper; ra, ramification cell; s, saddle-shaped joint of axial cell; t, tetrasporangia. Scale: 50  $\mu\text{m}$  for Figs. 17, 18, 20, and 100  $\mu\text{m}$  for Fig. 19.

branchlets are observed.

In the case of *B. prieurii*, the present study confirmed the observations made by KUETZING (1862) on the specimens from French Guiana, by SKUJA (1944) on the specimens from River Essequibo in British Guiana and by BOURRELLY (1970) on the type specimen of *B. prieurii*.

On the other hand, no knob-like stoppers and no saddle-shaped joints of the axial cells are observed in this species (Figs. 9–12). It is observed that the basal cell of the primary branchlet of *B. prieurii* is not the remification cell reported by ARCHER (1876) for *B. callitricha*. Moreover, the mode of ramification of *B. prieurii* is not bipinnate; the primary branchlets are placed on the opposite side of the axis and unilaterally branched.

In the case of the type specimen of *B. pygmoea* (Figs. 13, 14), the same facts are observed as those of *B. prieurii*, i.e. no saddle-shaped joints of the axial cells and no ramification cells are present. Moreover, the mode of ramification is not bipinnate, namely the primary branchlets being placed on the opposite side of the axis and unilaterally branched.

The above-mentioned facts were observed in the case of the type specimen of *B. pinnulata* (Figs. 15, 16), i.e. no saddle-shaped joints of the axial cells and no ramification cells are present. The mode of ramification is not bipinnate but pinnate.

## 2. Size of thalli

The thallus is 20–25 mm high in the type specimen of *B. prieurii* examined in the present study, and 5–10 mm high in the specimen collected from River Essequibo in British Guiana reported by SKUJA (1944). RATNASABAPATHY and KUMANO (1982) reported that thalli of the Malaysian specimens of *B. prieurii* collected from Pulau Tioman are 5–7 mm high, and those of the Malaysian specimens examined in the present study are 3–5 mm high. As shown in the present study, the thallus of the type specimen of *B. pygmoea* is 1–2 mm high, and that of *B. pinnulata* is 2–3 mm high.

As mentioned above, the thalli of the

freshwater species are microscopic, from several to several tens millimeters high. On the other hand, the thalli of *B. callitricha* are macroscopic, from several to several tens centimeters high.

## 3. Reproductive organs

Cruciate divided tetrasporangia are found in some of the more primitive genera of the Ceramiaceae, Ceramiales, but most of the genera have tetrahedrally divided tetrasporangia (GUIRY 1978).

As shown in the present study (Figs. 19, 20, t), the tetrasporangia are cruciate and mostly terminal on the differentiated branchlets which are shorter than the secondary branchlets in the Australian specimen of *B. callitricha*.

Monosporangia are very rarely found in the taxa of the family Ceramiaceae; for example, monosporangia have been reported in a species of *Antithamnion* by JAASUND (1965). But nothing is known about the phase of the spores. The monosporangia for the Malaysian specimen of *B. prieurii* examined in the present study (Figs. 5–8, 10, m, m') are mostly lateral, sometimes subterminal and rarely terminal on the primary branchlets. According to KUMANO (1978) and as shown also in the present study (Fig. 15, m, m'), the monosporangia for *B. pinnulata* are terminal on the primary pinnate branchlets.

As for the asexual reproductive organs, the monosporangia have been observed in two freshwater species, *B. prieurii* and *B. pinnulata*, although those for *B. pygmoea* have not been found yet. Moreover, sexual reproductive organs, namely spermatangia and carpogonia, have not been reported for any freshwater species of the genus *Ballia*.

## 4. Geographical distributions of the taxa

The marine species, *B. callitricha*, has been reported from Bass's Strait, Auckland Islands and Kerguelen's Land in the southern regions of Australia, and Fego Island and Falkland Islands of the southern regions of South America. As SKUJA (1944) mentioned, these localities, where the marine species of the genus *Ballia* were distributed, are in the Antarctic Ocean and the cool temperate regions



along the coasts of Atlantic or in South Pacific Ocean.

On the other hand, the freshwater species of the genus *Ballia* have been reported from the freshwater rivers and streams in French Guiana and British Guiana in the northern tropical regions of South America, and tropical Malaysia in Southeast Asia.

As mentioned previously, the type locality of *B. prieurii* is Rivulet les Gemeaux in Mahuri Mountains in French Guiana (KUETZING 1847), then, this species was reported by SKUJA (1944) from the first waterfalls of River Essequibo in British Guiana, both in the northern tropical regions in South America. In Southeast Asia, *B. prieurii* was reported also from Sungai Ayer Besar in Pulau Tioman, tropical Malaysia, by RATNASABAPATHY and KUMANO (1982), and from Sungai Sempanong, Sungai Jasin and Sungai Pelawar in Johor in tropical Malaysia in the present study. Recently, THÉRÉZIEN (1985) reported *B. prieurii* from Creek Balate and Creek Awahakiki along the tributary of River Maroni in French Guiana in the northern tropical regions of South America.

The type locality of *B. pygmoea* is Creek Gravier in Kau Mountains in French Guiana in the northern tropical region of South America (MONTAGNE 1850), and that of *B. pinnulata* is Sungai Gombak in tropical Malaysia of Southeast Asia (KUMANO 1978).

The above-mentioned rivers and creeks, where the freshwater species of the genus *Ballia* are distributed, are situated around at latitude 5 degrees north in the northern tropical regions of South America, and also around at 5 degrees north in tropical Malaysia of Southeast Asia.

The type species (marine species) and the freshwater species have been assigned to the same genus, *Ballia*, because of the scanty information concerning the sexual reproductive organs such as spermatangia and carpogonia for freshwater species. However, *B. prieurii* and two related freshwater species, *B. pygmoea* and *B. pinnulata*, are distinguished from the type species, *B. callitricha*, mainly in the organization and size of thallus, the reproduc-

tive organs and the geographical distributions.

Re-examination of the taxonomic criteria, especially of reproductive organs is strongly desired for further rearrangement of the two groups; the *B. callitricha* group and the freshwater species group (*B. prieurii* group).

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熊野 茂\*・S. M. PHANG\*\* : 紅藻イギス科の *Ballia prieurii* KUETZING 及び関連種について

*Ballia prieurii* KUETZING と関連種のタイプ標本又はそれに準ずる標本を調査した。淡水種の *Ballia prieurii* KUETZING, *B. pygmoea* MONTAGNE 及び *B. pinnulata* KUMANO は、バリア属のタイプ種 *B. callitricha* (AG.) MONTAGNE とは藻体の構造と大きさ, 生殖器官, 地理的分布などの諸形質が異なることを確かめた。バリア属を, *B. callitricha* などの海産種と *B. prieurii* などの淡水産種との2つのグループに分かつことの可否を決定するためには, 更に各種の生殖器官を精査する必要がある。(\*657 神戸市灘区六甲台町 神戸大学理学部生物学教室, \*\*Institute of Advanced Studies, University of Malaya, 59100, Kuala Lumpur, Malaysia)