# TAXONOMY OF ECONOMIC SEAWEEDS

## With reference to some Pacific species

## Volume VII

Isabella A. Abbott, Editor

A Publication of the
California Sea Grant College System

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Results of an international workshop sponsored by the California Sea Grant College System in cooperation with the University of Hawaii and hosted by Kasetsart University, Bangkok, Thailand, May 1997.

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# Preface

James J. Sullivan
Director, California Sea Grant College System

The original rationale behind this series of workshops was that progress in seaweed aquaculture and marine natural products chemistry would require that we better understand the taxonomy of commercially interesting species. Though this remains our primary goal, we have also come to appreciate that one of the most serious consequences of habitat destruction around the globe is loss of species diversity, including that of marine algae.

Biodiversity has been defined as the collection of species (or distinct genetic entities), communities, and ecosystems occurring in a geographically defined region. But describing changes in diversity over time, whether resulting from human activities or natural processes, requires historical information based on rigorous species identification.

Dr. Abbott, editor of this series, had the wisdom to recognize that many eminent algal specialists around the Pacific Rim were not being succeeded by younger generations. Her vision throughout has been to bring together these leading taxonomists and to direct their collective energies toward the enormous ignorance that prevails about warm-water Pacific algae.

The progress made at these workshops has been considerable, and we and our colleagues in the other Pacific Sea Grant Colleges are proud to have played some small part in this endeavor.

# Introduction

Isabella A. Abbott, Workshop Convener and Editor

In the workshop held in Kuala Lumpur in 1995, we had a new-to-the-workshop taxon introduced, the genus *Hypnea,* with studies of the species led by Professor Masuda of Hokkaido University. The research by Y. Yamagishi and Dr. Masuda on *Hypnea* formed the centerpiece for other papers on the genus, making those studies with a relatively large geographic base important for future workers. In the past, *Hypnea* had the reputation of being a taxon with good-quality carrageenan, and this characteristic was the reason *H. musciformis* was brought to Hawaii about 1975 by persons with commercial interests and no sense of ecological balance or invasion (and without permission of the Department of Agriculture). Since then, *Hypnea* has spread to nearly all of the Hawaiian islands and was one of the chief weedy components of a "bloom" that persisted for about 3 years on the island of Maui. Anyone who knew the most elementary biology about seaweeds would have known that any plant (seaweed or not) that has thick hooked ends to its branches could easily attach to other plants and spread in that way. We do not need to have intruders like these added to any marine flora. Similarly, the earlier introduced *Eucheuma,* now known as *Kappaphycus alvarezii,* brought to Hawaii under permit to experimentally test for growth rates, is still present in the bay to which it was introduced by Dr. M. S. Doty. A paper presented at the International Seaweed Symposium in Cebu, Philippines, in April 1998, reported that *Eucheuma* planted at Fanning Island many years ago, and thought not to have established itself, is now doing very well.

This volume of the series on the taxonomy of economic seaweeds includes chapters on another new-to-the-workshop taxon, *Halymenia,* and may also serve as an important starting point for further taxonomic studies. The careful study of *Halymenia dilatata* by Dr. Kawaguchi should be the impetus for bringing other widely distributed and poorly known *Halymenia* species under scrutiny. Speaking from experience, I know that most phycologists who have reported *Halymenia* species from various places did not section or compare the specimens with type or other "authentic" specimens. Consequently, this genus has an enormous number of names, many of which may be redundant.

Because carefully dried species of *Halymenia,* including *H. dilatata,* are sold to be rehydrated and added to fresh salads, the temptation may be great to grow the plants in places where the species do not naturally occur. As practicing phycologists, we should be exceedingly careful about giving advice to potential growers who have a poor record of introducing weedy species and then abandoning the site when things go "wrong." *Hypnea musciformis* is an example of this problem in Hawaii. Controlling the spread of the plant has cost the U.S. government and the state of Hawaii many hundreds of thousands of dollars, putting the burden of cleanup and control on local taxpayers and phycologists who were not responsible for the introduction to begin with.

On the other hand, the taxonomic contributions of the Sea Grant workshops have put pressure on phycologists to determine WHAT IS *Gracilaria verrucosa*? After several of us examined specimens of this species obtained from its alleged British type locality, we concluded that it was not like any of the plants that we were working with (in California, China, Japan, Australia, and other western Pacific places) under that name. *Gracilaria verrucosa* is no longer found in any of the places where workshop workers live.

We have not participated in broad-range investigations of some other species, but Professor Yamamoto apparently has inspired his own students and those of Dr. Ohno to work on certain "parasites" of *Gracilaria,* and the only thing left to do is to study the type specimens from the Leiden Herbarium. On the basis of the vegetative and reproductive structures in this group of plants, perhaps 3, but at least 2, species exist. The problem is, what name should be used for which taxa?

Less progress has been made in *Sargassum* but, after all, it is a genus with far more species than all other taxa put together that we have examined. I still have hope that some solution to the grouping of taxa can be found in order to reduce the total number of species so that the plants will be easier to "handle," that is, identify, than they are now. One thing has been accomplished, nevertheless; more people than ever before know the common species of *Sargassum* in the western Pacific. And we have produced written records showing how we came to recognize these common species.

Another problem has been solved in the *Gelidiales.* Santelices and Hommersand (1997) showed that *Pterocladiella,* with *P. capillacea* as the type species, has a very different structure with respect to the central axis than does *Pterocladia,* with *P. lucida* as the type species. The structure of the cystocarps also is different in the 2 genera, and different from that of the bilocular *Gelidium.* In examining the articles of Dr. Santelices on *Pterocladia* vs. *Gelidium* during the past 12 workshop years, we have been treated to dogged examination, first one way, then another. Consequently, the short article announcing these results culminates a long-time interest in the morphology of these important industrial genera. It is fitting that the Sea Grant workshops contributed to these results.

## Literature Cited

Santelices, B. and Hommersand, M. 1997. *Pterocladiella*, a new genus in the Gelidiaceae (Gelidiales, Rhodophyta). Phycologia 36:114–119.

# Acknowledgments

Twelve years ago when the Sea Grant workshops on taxonomy of economic seaweeds began, I never dreamed that I would travel to so many interesting places, of which Thailand must be one of the most fascinating. Bangkok and its temples are certainly architecturally dazzling; I hope everyone stopped to see some of these interesting monuments to Buddha on their way to or from Phuket. I thought that the choice of holding the meetings in Phuket—although trying and worrisome to our Thai hosts—was excellent. To be "in the country," but having so many tasty restaurants about, was most satisfying. Professor Lewmanomont, who wore herself out being the perfect hostess, showed excellent judgment in choosing the lodgings and the workplace above the Phuket Aquarium.

On behalf of the participants of the 7th workshop, I thank Professor Lewmanomont for the warm Thai hospitality and her gracious attention to the many small details that made our stay so comfortable—even if she had to stay in the hospital overnight because of exhaustion. Small details included fresh fruit that many of us had never seen before (e.g., rambutan) and Thai cakes and candies, so that we had a sense of what Thai people snack on. I thank her husband, too, for his help and support that made events run more smoothly. It was not all that easy to have a meeting in Phuket, which we all enjoyed so much, many miles away from the home campus of Kasetsart University in Bangkok.

I also thank the director of the Phuket Aquarium for welcoming us and providing us the use of the air-conditioned upstairs rooms. And although we did not buy a single Nikon microscope "gadget," we very much enjoyed using brand-new, first-rate microscopes, including a model that could show on a television monitor what we were supposed to (or could) see. I am not sure that I would be a better phycologist, but a lot of people might think that I was really a professional scientist if I had equipment like that. Because of this equipment, some of us could make slides and talk to others about structures we were looking at, such as the "rabbit ear" cortical cells of *Halymenia maculata*. (A picture is worth 1000 words.) Khan, please express our thanks to the Nikon Corporation in Bangkok for these loans to us.

So thank you, Khan, and Anong, and all of your Thai students.

Isabella A. Abbott

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# Notes

About Chinese Names

In accordance with the national change made in China in 1987, Chinese names are listed with surname first, *no comma*, and given name last. A good example of old style and new style is Chang, C. F. (old) vs. Zhang Junfu (new). For another example, Lu Baoren's *first name* is Baoren.

Listing Species Names

In accordance with the practices of the international journal *Taxon* and the adoption of this practice in volume 4 of the workshop series, reference to *place* of publication follows author name(s) for nomenclature of species, basionyms, synonyms, types, and so forth and is *not* listed in the Literature Cited sections (references). On the other hand, if the species and author(s) are listed in the *text*, for example, in the discussion, this citation is listed in Literature Cited. An example is as follows:

*Sargassum ilicifolium* (Turner) C. Agardh, Sp. algarum, p. 11, 1820.
Basionym: *Fucus ilicifolius* Turner, Fuci ..., vol. 1, p. 113, pl. 51, 1808.

The order is species name, author name, *place of publication* (i.e., name of either book or journal), volume number, page number(s), plate or figure number(s), and date. If this style is followed, no one will ever create an illegitimate name, many of which occur because an author did not provide the *exact reference* in which the species are described. Article 33.2 of the International Code of Botanical Nomenclature states: "A new combination ... for a previously and validly published name is not validly published unless its basionym ... is clearly indicated and a *full and direct reference given to its author and place of valid publication with page or plate reference and date.*"

**Literature Cited**

In this volume, all references to volumes (1–6) from the first six workshops are listed in nomenclature setups and in Literature Cited as "Tax. Econ. Seaweeds 1 (or 2, 3, 4, 5, 6)," followed by page and figure numbers, instead of giving the whole citation including editor, place of publication, and so forth. Inasmuch as the entire citation for each volume takes five lines of type, it will save a lot of ink and paper if we shorten the references within the volume. The entire citations are given here for reference:

*Taxonomy of economic seaweeds: with reference to some Pacific and Caribbean species*, vol. 1. I.A. Abbott and J.N. Norris, eds. [i–ii] + iii–xv + 1–167, 1985. California Sea Grant College, University of California, La Jolla, Calif. Report No. T-CSGCP-011.

*Taxonomy of economic seaweeds: with reference to some Pacific and Caribbean species*, vol. 2. I.A. Abbott, ed. [i–ii] + iii–xv, + 1–265, 1988. California Sea Grant College, University of California, La Jolla, Calif. Report No. T-CSGCP-018.

*Taxonomy of economic seaweeds: with reference to some Pacific and Western Atlantic species*, vol. 3. I.A. Abbott, ed. [i–ii] + iii–xiv + 1–241, 1992. California Sea Grant College, University of California, La Jolla, Calif. Report No. T-CSGCP-023.

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*Taxonomy of economic seaweeds: with reference to some Pacific species*, vol. 6. I.A. Abbott, ed. [i–ii] + iii–xviii + 1–212, 1997. California Sea Grant College System, University of California, La Jolla, Calif. Report No. T-040;
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# Section I. *Sargassum* Species

## INTRODUCTION

Isabella A. Abbott

Unlike previous volumes of the Sea Grant workshop studies on *Sargassum*, this volume has the smallest number of contributions, but from what I have heard or know, the next volume will have many articles on this species. The reason for the expected increase is that the Joint Japan-Malaysia Agreement on marine algae is in its 2nd year, and masses of collections have been accumulated of Malaysian algae in both Kuala Lumpur and in various places in Japan. I am hopeful that many of the Siboga Expedition species will be made available for study to some scientists who did not go on the collecting trips. You get free, expert identifications.

I was responsible for sending to Dr. Ajisaka a relatively large collection of *Sargassum* specimens from the central and southwestern Pacific on loan from the University of California, Berkeley, and from the Bishop Museum, Honolulu. Material from the museum included numerous specimens from Malaysia, including Borneo, that the late Maxwell Doty collected a decade or more ago. Dr. Ajisaka and his colleagues may not be able to study all of these in addition to their new Malaysian collections for the next volume, as there is no shortage of specimens in their hands at this time, but I am expecting some exciting results nevertheless.

# STUDIES ON THE BISERRULIC *SARGASSUM* OF CHINA:
# II. THE SERIES *CORIILFOLIAE* J.G. AGARDH

C.K. Tseng and Lu Baoren

## Abstract

Nine Chinese species of the series *Coriifoliae* of biserrulic *Sargassum* were studied. The series *Coriifoliae* is characterized by spinous androgynous receptacles, flattened to cylindrical primary branches, and lanceolate to linear leaves with mostly unequal basal parts. Three new species are described here: *S. beihaiense* Tseng et Lu, sp. nov., *S. taiwanicum* Tseng et Lu, sp. nov., and *S. silvai* Tseng et Lu, sp. nov. The remaining 6 species, namely, *S. amabile* Yamada, *S. odontocarpum* Sonder (=*S. coriifolium* J. G. Agardh), *S. spinifex* C. A. Agardh, *S. turbinatifolium* Tseng et Lu, *S. wangii* Tseng et Lu, and *S. xishaense* Tseng et Lu, were previously reported.

## Introduction

In part I of this series of chapters on the biserrulic *Sargassum* of China (Tseng et Lu 1997), we discussed the taxonomy of the subsection *Biserrulae* and promoted the groups Ilicifolia, Coriifolia, and Parvifolia, to series rank, eliminating the Dentifolia group. At that time, we were not sure whether the androgynous condition is more primitive or more advanced. For the time being, we consider the *Coriifoliae* as the most advanced of the 3 series. Some time ago, we discovered a plant (AST 87-13356) that for a long time was identified as *S. coriifolium* (=*S. odontocarpum*), but the receptacles were surprisingly glabrous and had exceptionally few spines. This finding shows that the species was evolved from an ancestor with glabrous receptacles. It also means that, at least in *Sargassum*, androgyny is more primitive than is dioecism.

## Key to the Chinese Species of the Series *Coriifoliae*

1. Receptacles with very few spines ........................................ *S. beihaiense*
1. Receptacles with numerous spines ........................................ 2
    2. Primary branches flattened ........................................ 3
    2. Primary branches subcylindrical or cylindrical ........................................ 4
3. Receptacles flattened, leaves acute, serrate at margin with raised cryptostomata, globular vesicles, and small, conical holdfast ........ *S. xishaense*
3. Receptacles compressed to triquetrous, leaves blunt, wavy or irregularly shallowly toothed, with ovate vesicles and scutellate holdfast ............ *S. wangii*
    4. Apices of leaves commonly with cup-shaped depression ............................ 5
    4. Apices of leaves without cup-shaped depression ........................................ 6
5. Leaves turbinate ........................................ *S. turbinatifolium*
5. Leaves elliptical ........................................ *S. taiwanicum*

  6. Leaves obovate or elongated ovate, serrate ........................................... 7
  6. Leaves elongate-lanceolate, not serrate ................................................. 8
7. Leaves obovate, usually conduplicate at the apices ............................. *S. silvai*
7. Leaves elongately ovate ........................................................................ *S. spinifex*
  8. Leaves elongately lanceolate, with blunt tips ..................... *S. odontocarpum*
  8. Leaves lanceolate with acute tips ..................................................... *S. amabile*

## Description of the Species

*Sargassum amabile* Yamada, J. Jpn. Bot. 18:515, figs. 16–17,1942.

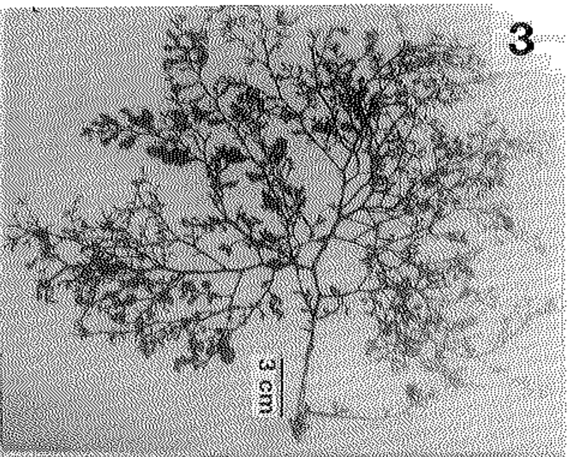
Frond up to 50 cm tall, arising from a small conical discoid holdfast. Main stem short, less than 1 cm long, cylindrical, 1–2 mm in diameter, with smooth or somewhat warty surface. Primary branches cylindrical, about 1 mm in diameter, glabrous. Secondary branches issued spirally at about 3-cm intervals, up to 15 cm long, rarely with cryptostomata. Leaves on the lower part of main branch linear-lanceolate, 4–7 cm long and 6–8 mm wide, cuneate at base, acute at apex, margin toothed with teeth pointing upward from a widened base or teeth with a narrow base, widening slightly upward, cryptostomata few, scattered over the surface, midrib percurrent. Leaves on the upper part of the plant smaller and narrower. Larger vesicles spherical, becoming obovate or elliptical nearer the plant apices, and fusiform in most distal areas, with short cylindrical stipe; receptacles androgynous, 5–10 mm long, simple or furcate, 2-edged to triquetrous, spiny to dentate at margin and racemosely arranged.

Distribution: Endemic to Taiwan and China.

Remarks: *Sargassum amabile* is known only from the type collection, and this short description was based on information published by Yamada (1942, 1944) and Yoshida (1988).

*Sargassum beihaiense* Tseng et Lu, sp. nov.
(Figs. 1 and 9)

Frons luteus brunneus, 46 cm alta, haptero disciformi, circa 1 cm in diametro. Axe principalis cylindricis, brevi, circa 5 mm longis. Ramis primariis cylindricis vel subcylindricis, laevibus, ad 45.5 cm longis, 2 mm in diametro; ramis secundaris cylindricis, aliquot non elevatis glandibus, 4–6 cm longis, 1–1.5 mm in diametro; ramulis brevibus, cylindricis, 2 cm longis, 1 mm in diametro, non elevatis glandibus. Foliis lanceolatis, multis acutis, aliis obtusis ad extremum; costis percurrentibus vel infra apices evanida, asymmetricis, obliquis ad basim, dentatibus ad margines; cryptostomatibus conspicuis, irregularis, dispersis ad utrique costalis; foliis in ramis primariis, circa 3–4 cm longis, 5–8 mm latis; foliis in ramis secundariis et ramulis, 2.5–3 cm longis, 3–4 mm latis. Vesiculis sphaericis vel subsphaericis, interdum oblongis, 4–6 cm in diametro, vulgo acutis vel parvis foliis in apicibus, pedicellis foliosis; costis conspicuis, aliquot conspicuis cryptostomatibus.



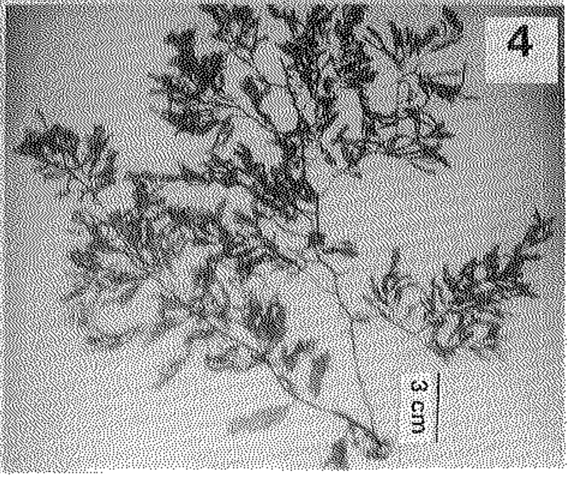


**Fig. 1.** ***Sargassum beihaiense*** **Tseng et Lu.**
**Fig. 2.** ***Sargassum odontocarpum*** **Sonder.**
**Fig. 3.** ***Sargassum silvai*** **Tseng et Lu.**
**Fig. 4.** ***Sargassum spinifex*** **C. A. Agardh.**

Planta androgyna. Receptaculis compressis, aliquot spinis in apicibus, sinuatis lateribus, non spinis, 4–6 mm longis, 1 mm latis, racemosis.

Frond yellowish brown, up to 46 cm tall. Holdfast discoid, about 1 cm in diameter. Main axis cylindrical, about 5 mm tall. Primary branches cylindrical or subcylindrical, smooth, up to 45.5 cm long and 2 mm in diameter. Secondary branches from leaf axils, cylindrical, with some glandular dots, about 4–6 cm long and 1–1.5 mm in diameter, generally at intervals of 3–4 cm between the branches, larger on lower part of branches and smaller on upper part of branches. Ultimate branchlets very short, cylindrical, generally about 2 cm long and less than 1 mm in diameter, with abundant glandular dots, crowded with leaves, vesicles, and receptacles. Leaves lanceolate, about 3–4 cm long and 5–8 mm wide in the primary branches and 2.5–3 cm long and 3–4 mm wide in the secondary branches and branchlets, mostly acute and sometimes obtuse at the apices, slightly unequal at the base, usually larger outside and smaller inside, with distinct midribs, percurrent or disappearing below the apices, serrate at the margins, and with conspicuous cryptostomata on both sides of the midribs. Vesicles spherical, subspherical, or oblong, usually with small sharp points or small leaves at the apices, mostly surrounded by leafy envelopes, with rather long leafy stipes, generally 2–3 cm long and 3–4 mm wide, provided with conspicuous midribs, entire or serrate at the margins, with cryptostomata on the surface.

Plants androgynous. Receptacles compressed, racemosely arranged, with a few spines at the upper parts and glabrous below, about 4–6 mm long and 1 mm wide.

Holotype: AST 87-1335. Collected by Lu Baoren and Dong Meiling from Weizhou Island, Beihai City, Guangxi Province, April 23, 1987.

Other Materials Examined: AST 87-1180, 87-1336, 96-0007, 96-0058, 96-0061, and 96-0114. All collected from Weizhou Island, Beihai City, Guangxi Province, in April to May.

Etymology: Named for its type locality, Beihai City.

Habitat: Growing on subtidal rocks.

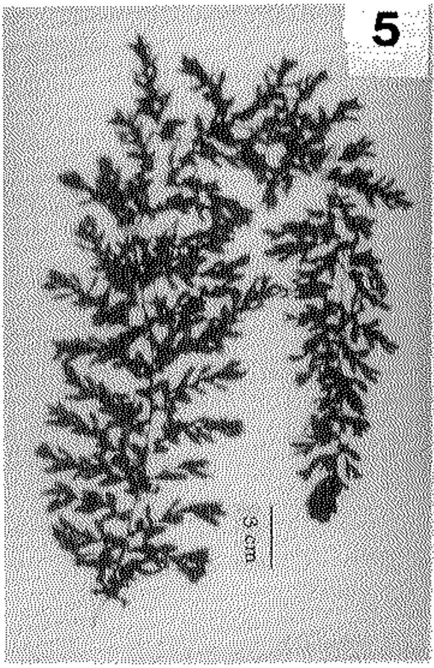
Distribution: Endemic in southern China.

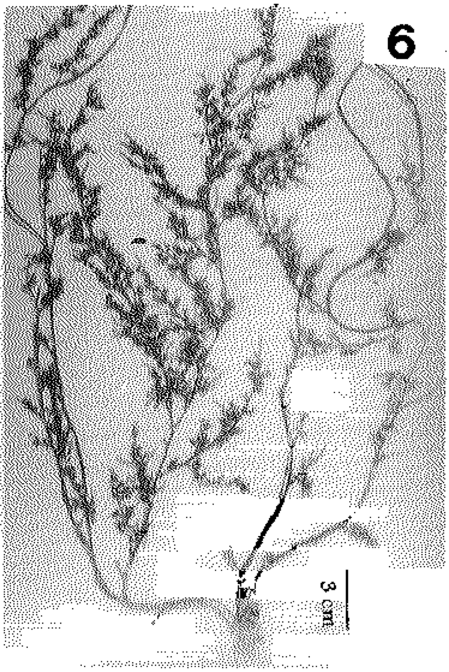
Remarks: *Sargassum beihaiense* is characterized by flattened receptacles with only a few spines at the apices and by spherical or subspherical vesicles, enclosed to various degrees by an envelope, supported by an elongated leafy stipe, 5 times or more longer than the width of the vesicles. The primary and secondary branches are cylindrical or subcylindrical, and the lanceolate leaves have a slightly oblique base.

*Sargassum taiwanicum* Tseng et Lu, sp. nov.

(Figs. 5, 13, 14)

Frons atrofuscus, circa 68 cm altus, hapteron rhizoidea formans discoidea, ramis principalis cylindricis. Foliis primariis ellipsoidia, 1.8 cm longis, 10 mm latis, apicibus rotundis, vulgo duplicatis. Foliis secundaris ellipsoideis, vulgo apicibus





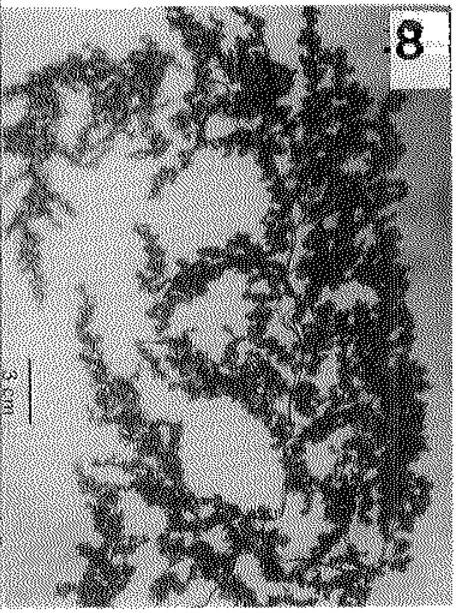


Fig. 5. *Sargassum taiwanicum* Tseng et Lu.
Fig. 6. *Sargassum wangii* Tseng et Lu.
Fig. 7. *Sargassum xishaense* Tseng et Lu.
Fig. 8. *Sargassum turbinatifolium* Tseng et Lu.

obtusis, interdum apicibus acutis, 1.5–2.5 cm longis, 8–9 mm latis, symmetrici ad basim, costa non percurrens, cryptostomatibus conspicuis, dentatis ad marginem, vulgo duplicato-serratis ad extremum. Foliis ramulis parvis, ellipsoideis, non duplicatis ad extremum, 1–1.5 cm longis, 3–5 mm latis. Vesiculis ellipsoideis vel obovatis, 6 mm longis, 4 mm latis, roundatis ad extremum, auritis aliis in vesiculis utroque parvis.

Planta androgyna. Receptaculis compressis, aliquot spinis, furcatis, 3 mm longis, 1 mm latis, confertis in racemis.

Frond yellowish brown, up to 68 cm tall. Holdfast scutellate with rhizoids radiating and fusing with each other forming a disc up to 2 cm in diameter. Main axis cylindrical, glabrous, up to 5 mm tall and 2 mm wide. Primary branches cylindrical, up to 67.5 cm long, 1.5 mm in diameter. Secondary branches alternate, cylindrical, up to 17 cm long, 1 mm in diameter, about 2–3 cm from each other. Ultimate branches short, only 2 cm long, and less than 1 mm in diameter, densely grown with leaves, vesicles, and receptacles. Leaves of primary branches coriaceous, elliptical, rounded at tip, euneate at base, toothed at the margins, quite a few duplicate at the apices, up to about 1.8 cm long and 1 cm wide, with conspicuous midrib vanishing below the apices and cryptostomata scattered on both sides of the midrib. Leaves on secondary branches and ultimate branchlets similar to those on primary branches but smaller. Vesicles elliptical or obovate, up to 6 mm long and 4 mm wide, with winglike appendages, cryptostomata, and flat or compressed stipes provided with cryptostomata and midribs, about 3–4 mm long and 1 mm wide.

Plants androgynous. Compressed receptacles, closely and racemosely arranged, with spinous tips and upper parts, up to 3 mm long and 1 mm wide. Branches once or twice divided.

Holotype: SAP 026449. Collected by Y. Yamada in 1941 in Ryukyusho, Taiwan Province (as *S. coriifolium*).

Etymology: The specific epithet *taiwanicum* means “belonging to Taiwan.”

Remarks: We are indebted to Professor Tadao Yoshida, who loaned us 3 specimens (SAP 026448, SAP 026449, and SAP 061203) collected and identified by Dr. Y. Yamada from Ryukyusho, Taiwan, in 1941 as *S. coriifolium* J. G. Agardh. These specimens have duplicate leaves, scutellate holdfasts, and other characteristics like those described for *S. taiwanicum* here. *Sargassum odontocarpum* (*S. coriifolium*) has a platelike discoid holdfast and nonduplicate leaves. Therefore, we venture to name the Yamada plants as a new species. The new species may be the same as *S. coriifolium* J. Agardh var. *duplicatum* Yamada (1950), but the characteristics of the leaves differ somewhat. Our decision can be confirmed only by a comparison with the type specimen. In making a transfer of taxa from *S. coriifolium* to *S. odontocarpum*, Silva et al. (1996 ) overlooked this Yamada variety. We do not make a change now because we are uncertain of the status of the variety.

*Sargassum odontocarpum* Sonder, Abhandl. Naturwissensch. Verein Hamburg 5(2), p. 43, 6 pls., 1871.

(Figs. 2 and 10)

Synonyms: *Sargassum echinocarpum* Greville, Ann. Mag. Nat. Hist. (Ser. 2) 2:274–275, pl. 5, 1848; *Sargassum cinctum* J. G. Agardh var. *echinocarpum* Grunow in Askenasy, Forschung. S.M.S. "Gazelle." IV. Theil Botanik. 58 pp., 1888; *Sargassum coriifolium* var. *echinocarpum* (Grunow) Grunow, Verhandl. K.-K. Zool.-Bot. Gessellsch. Wien 65:436, 1915; *Sargassum lanceolatum* Greville, Ann. Mag. Nat. Hist. (Ser. 2) 2:431–432, pl. XIII, figs. 1–5, 1848; *Sargassum coriifolium* var. *lanceolatum* (Grunow) Grunow, Verhandl. K.-K. Zool.-Bot. Gesellsch. Wien 65:436, 1915. *Sargassum odontocarpum* Sonder var. *lanceolatum* (Grunow) P. C. Silva, in Silva et al., Catalogue of the Benthic Marine Algae of the Indian Ocean, p. 690, 1996. *Sargassum coriifolium* J. G. Agardh, Kgl. Svenska Vet.-Akad. Handl. (Ser. 4) 23(3):96–97, 1889 (nomen illeg., a later homonym of *S. odontocarpum* Sonder 1871).

Frond yellowish brown, reaching a height of 70 cm, with discoid holdfast, 1 cm in diameter. Main axis cylindrical, glabrous, about 2 mm in diameter, with 2–3 primary branches arising from the upper part. Primary branches subcylindrical and glabrous, up to 25 cm long and 2 mm in diameter, with several secondary branches arising from the leaf axils. Ultimate branchlets cylindrical, up to about 4 cm long and 1.5 mm in diameter. Leaves on primary branches somewhat thick, oblong-lanceolate, or elliptical, up to about 5 cm long and 8 mm wide, mostly obtuse at apices, occasionally somewhat acute, slightly oblique at the base, toothed at the margin in the upper parts, but wavy lower, with conspicuous midrib vanishing at the apices and conspicuous cryptostomata irregularly scattered on both sides of the midrib. Leaves on secondary branches and ultimate branchlets similar in shape to, but somewhat smaller than, those on primary branches. Vesicles spherical, subspherical, or ellipsoidal, up to 10 mm long and 8 mm in diameter, with numerous cryptostomata on the surfaces, acute or with leaflets at the tips, and elongated stipes, generally flat and leaflike, up to 15 mm long and 5 mm wide, with midribs and 2 rows of cryptostomata.

Plants androgynous. Receptacles somewhat elongate, subcylindrical below and compressed above, up to 4 mm long and 1.5 mm wide, spiny apically and laterally, closely racemosely arranged.

Habitat: Growing on sublittoral reef about 1 m deep. AST 96-0006, 96-0062, and 96-0111 collected from Shilou Village, Zhuzailing, Weizhou Island, Guangxi Province, May 17–26, 1996.

Distribution: India, Solomon Islands, and China (Taiwan and Guangxi provinces).

Remarks: Greville (1848) published 2 species of *Sargassum* collected from India, *S. echinocarpum* and *S. lanceolatum*, that differ from each other in the leaves. The leaves of *S. echinocarpum* are oblong-lanceolate and obtuse, whereas those of *S. lanceolatum* are lanceolate and somewhat acute. J. G.

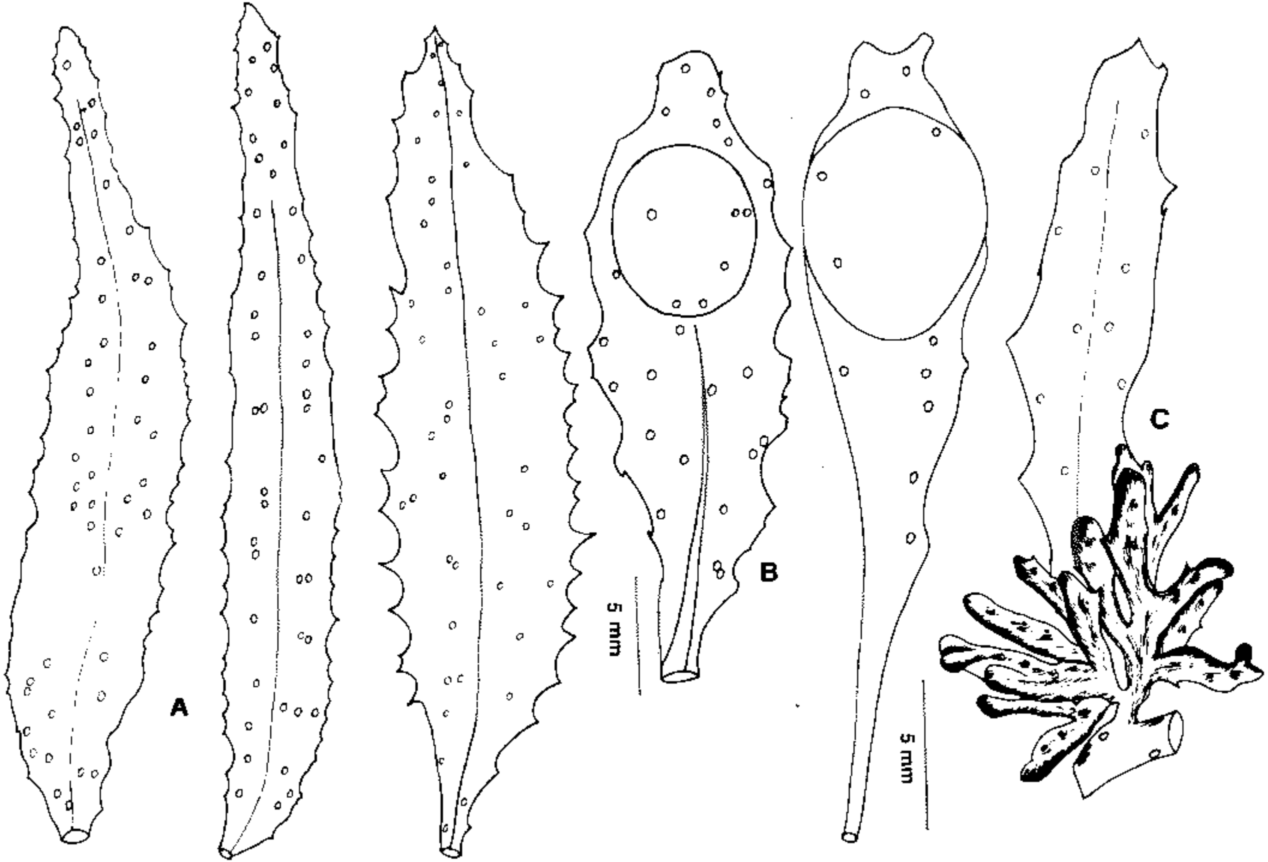


Fig. 9. *Sargassum beihaiense* Tseng et Lu. A, Three lanceolate leaves. B, Two vesicles. C, A branchlet with a receptacular branch.

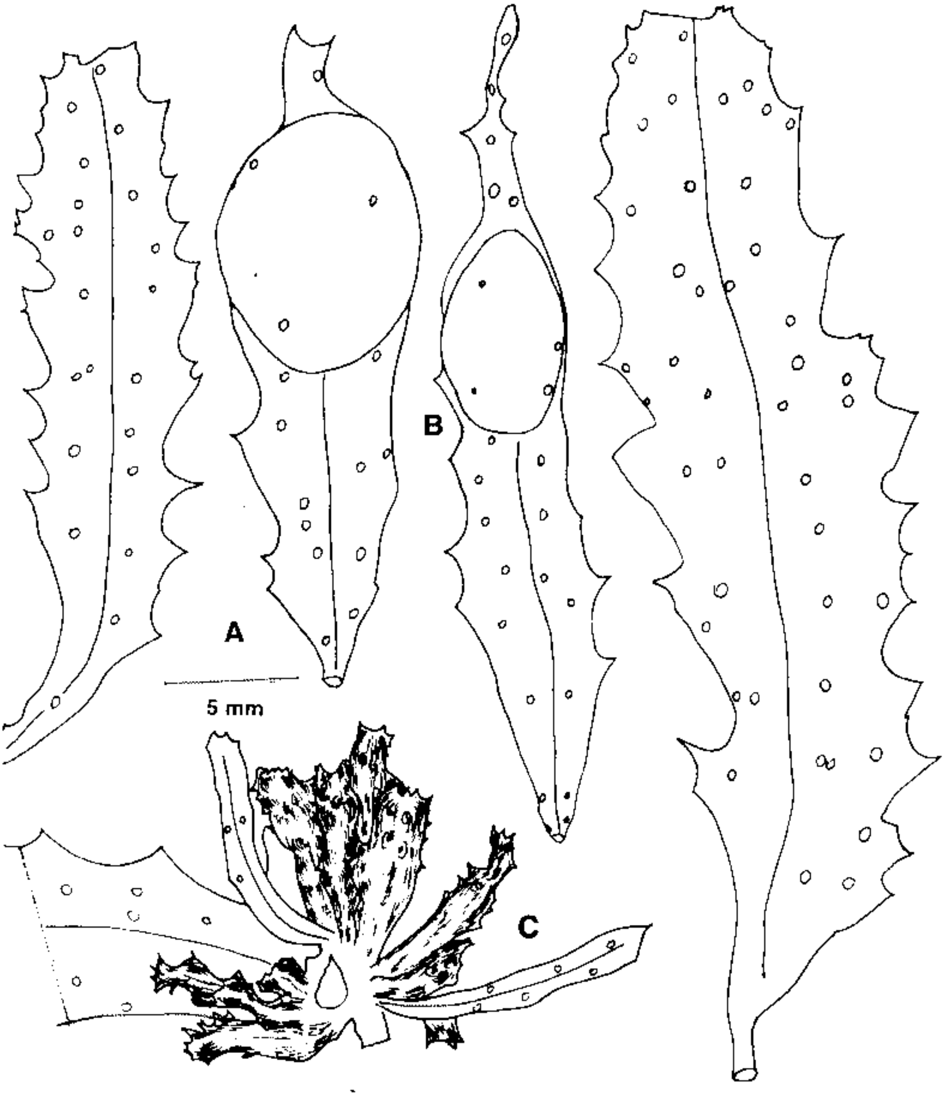


Fig. 10. *Sargassum odontocarpum* Sonder. A, Leaves. B, Two vesicles. C, A branchlet with leaves and receptacles.

Agardh (1848) had used these 2 specific epithets for 2 different species (*S. echinocarpum* J. Agardh from Hawaii and *S. lanceolatum* J. Agardh from Australia), published in 1848, a few months earlier than those of Greville. Combining the 2 Greville species, J. G. Agardh published a new name for them: *S. coriifolium* J. Agardh (1889). However, according to Silva et al. (1996), Sonder, working on material from Queensland (Australia) and Singapore, thought that his plants (Sonder's) were conspecific with Greville's *S. echinocarpum* and proposed the substitute name *S. odontocarpum* Sonder (1871). Thus, when J. G. Agardh (1889, p. 96) merged the 2 Greville species under the name *S. coriifolium*, he created a superfluous (and illegitimate) name. In recognizing 2 varieties of *S. coriifolium*, Grunow (1915) in effect was placing more emphasis on their differences than on their similarities, whereas in merging the 2 species of Greville, J. G. Agardh was recognizing similarities. In our opinion, the variations shown in the morphology of the leaves are so great that to recognize varieties in this species is futile, an opinion shared by Womersley and Bailey (1970). Other differences in morphology may merit variety status, but gross leaf morphology is not among them.

*Sargassum odontocarpum* (as *S. coriifolium*) has been studied by Womersley and Bailey (1970, p. 295, fig. 6) and by Yoshida (1988, p. 10, fig. 5).

*Sargassum silvai* Tseng et Lu, sp. nov.

(Figs. 3, 11, 12)

Frons luteus brunneus, 26 cm alta, haptero disciformi, 1 cm in diametro. Axe principalis cylindricis, brevi, circa 5 mm longis, 2 mm in diametro, ramis primariis subcylindricis, laevibus, ad 25.5 cm longis, 1.5 mm in diametro; ramis secundariis cylindricis aliquot elevatis glandibus, 17 cm longis, 1.2–1.5 mm in diametro; ramulis cylindricis elevatis glandibus 11 cm longis, 1 mm in diametro. Foliis in ramis primariis et secundariis obovatis vel ellipticis, 1.5–2.0 cm longis, 1.0–1.2 cm latis, rotundis ad truncatis apicibus acutis duplico-dentatibus ad margines, vulgo conduplicatibus, duplicato-marginemibus, asymmetricis, obliquis ad basim; costis conspicuis, non percurrentibus, mediis evanida, elevatis cryptostomatibus, irregularis, dispersis ad utrique costalis, foliis in ramulis parvis, 8–10 mm longis, 4–6 mm latis, vulgo obliquis cuneatis ad basim. Vesiculis sphaericis vel obovatis, 4–6 mm in diametro; rotundis, practer apicem.

Planta androgyna. Receptaculis subsphaericis ingra, compressis supra, 2.5–3.5 mm longis, 2 mm latis, spinis, racemosis.

Frond yellow-brown, up to about 26 cm tall, arising from a discoid holdfast, about 1 cm in diameter. Main axis cylindrical, glabrous, up to 5 mm tall and 2 mm in diameter, 2–3 primary branches arising from upper part of the main axis, subcylindrical to slightly compressed, glabrous, up to 25.5 cm long, 1.5 mm in diameter. Secondary branches cylindrical with raised glands, up to 17 cm long, 1.2–11 cm long, 1 mm in diameter, with raised glands. Ultimate branches cylindrical, up to 11 cm long, 1 mm diameter, with raised glands, crowded with leaves,

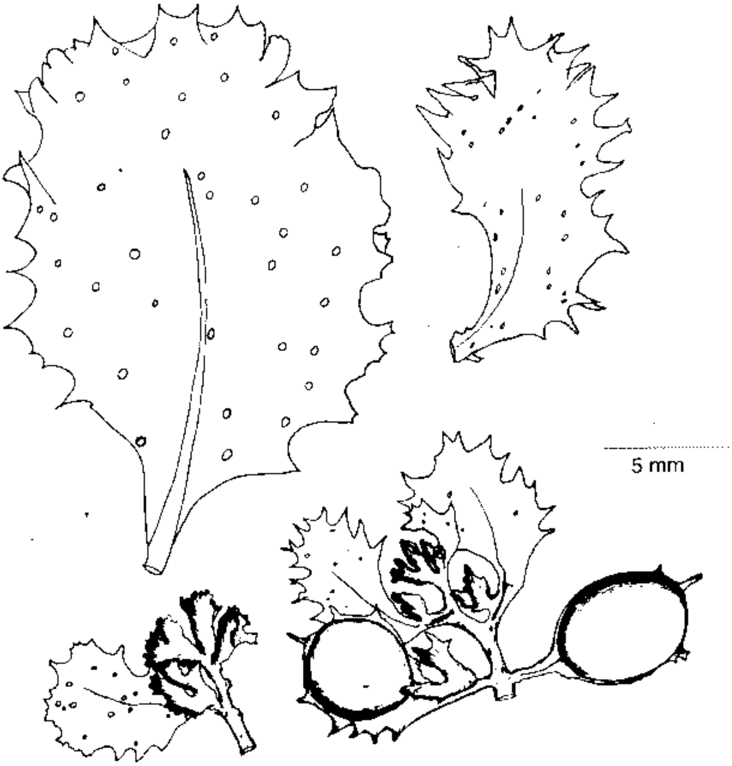


**Fig. 11.** ***Sargassum silvai*** **Tseng et Lu. Three leaves showing duplicate terminal margins; leaf at lower right is simple (not duplicate).**

vesicles, and receptacles. Leaves on primary and secondary branches obovate to elliptical, up to 1.5 cm long and 1.2 cm wide, rounded prominent midribs vanishing below the middle parts of the leaves; cryptostomata somewhat raised, irregularly scattered on both sides of the midrib, very sharp, doubly dentate at the margins, sometimes conduplicate, double-margined, and sharply dentate at the apices, not forming a cuplike structure; leaves on the ultimate branchlets smaller than but similar to those of primary and secondary branches, about 8–10 mm long, 4–6 mm wide, obliquely cuneate at base, with indistinct midribs and conspicuously raised cryptostomata. Vesicles globular or obovate, about 4–6 mm in diameter, varying in size, rounded, acute or with a small foliar top at the apex, usually with earlike appendages on both sides or very narrow spiny fringes surrounding lower parts of the margins, with short cylindrical, slightly compressed pedicels, about 2 mm long, less than 1 mm wide.

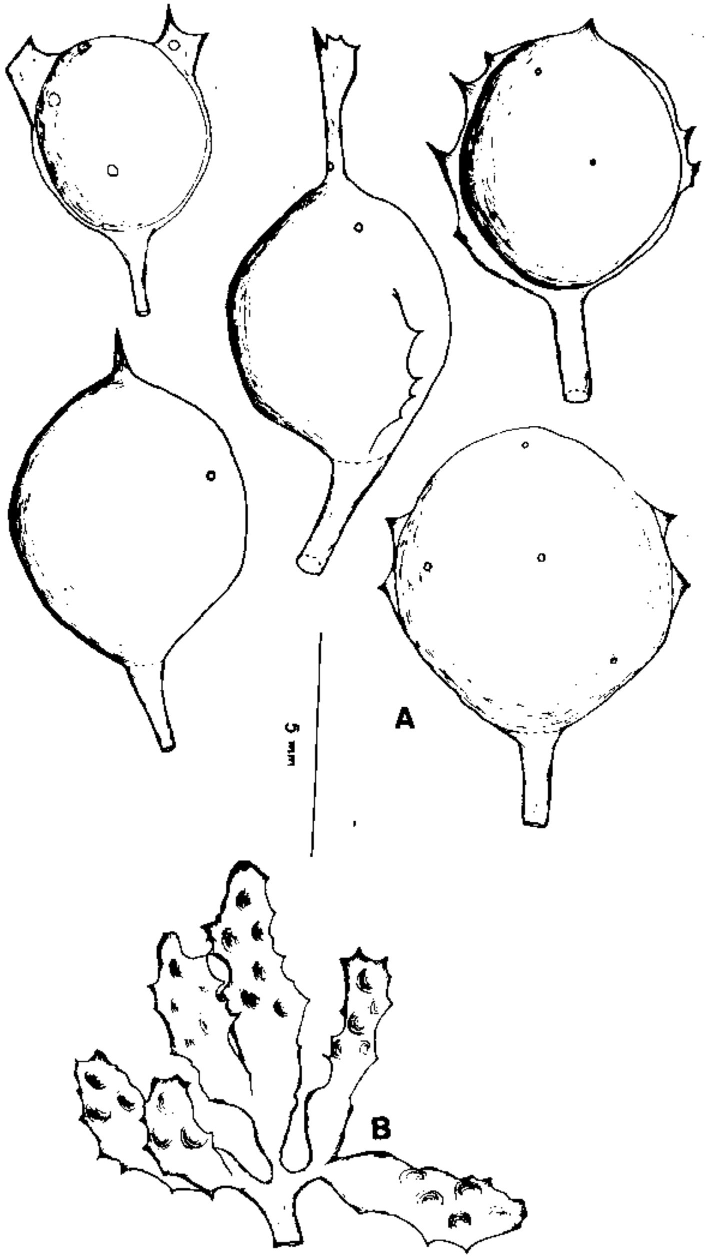


Fig. 12. *Sargassum silvai* Tseng et Lu. A, Five vesicles. B, A receptacular branch.

Plants androgynous. Receptacles cylindrical below and slightly compressed above, divided, with spines up to about 2.5–3.5 mm long and 2 mm wide, with long stipes, about 1–2 mm long, 0.3–0.4 mm wide, usually about 3–5 receptacles racemosely arranged in fertile branchlets.

Holotype: AST 58-5041. Collected by Xia Enzhan and Xia Bangmei from Sanya City, Hainan Province, March 20, 1958.

Etymology: Named for Dr. Paul C. Silva, Herbarium, University of California, Berkeley, whose help to us and others on nomenclature has been outstanding.

Other Materials Examined: AST 92-0225 and 92-0232. Collected from Dadonghai, Sanya City, Hainan Province, March 31, 1992.

Habitat: Growing on lower littoral rocks exposed to strong waves, Sanya City, Hainan Province.

Distribution: Endemic in China.

Remarks: *Sargassum silvai* Tseng et Lu is characterized by branchlets with raised glands and short leaves that do not form cuplike structures; with vesicles spherical to obovate, varying in size, usually rounded, sometimes with apex acute or with a small foliar expansion at the apex, or with earlike appendages on both sides or very narrow fringes on the lower parts; and with receptacles that are subcylindrical below and slightly compressed above, with rather long spines, racemosely arranged in fertile branchlets.

*Sargassum spinifex* C. A. Agardh, Syst. algarum, p. 304, 1824.
(Fig. 4)

Frond yellow-brown, about 25 cm tall, arising from an irregular discoid holdfast, about 1 cm in diameter. Main axis cylindrical, glabrous, about 6 mm tall, 2.5 mm in diameter, with 2–3 primary branches arising from the upper part. Primary branches cylindrical, up to 25 cm long, 2 mm in diameter. Secondary branches shorter, also cylindrical, up to 12 cm long, 1–1.5 mm wide, 0.6–1.5 mm apart from each other. Ultimate branchlets cylindrical, only about 4 cm long, less than 1 mm in diameter, crowded with leaves, vesicles, and receptacles. Basal leaves somewhat smaller than other leaves, lanceolate, acute at tip, oblique at base, with percurrent midrib and slightly raised cryptostomata irregularly scattered on both sides of the midrib; basal leaves 1.5 cm long, 4 mm wide, stipitate, the margins finely serrate. Leaves on primary branches elliptical, obovate, or spatulate, wider in upper parts of the leaves, obtuse or roundish at the apices, and asymmetrical at the base, with short midrib vanishing in the middle part of the leaf, and margins with irregular coarse teeth, about 2.5–3 cm long, 6–12 mm wide. Leaves on secondary branches similar to those of the primary branches, but smaller, with inconspicuous or no midribs, 1.2–1.5 cm long and 5–6 mm wide. Leaves of ultimate branchlets even smaller than those on secondary branches, the vesicles 1.5–2 mm in diameter, globular or ovate, roundish at tips, with raised up cryptostomata and cylindrical stipe, about 3 mm long.

Habitat: Growing on lower littoral rocks. AST 56-1516, 56-1517, 60-4110, and

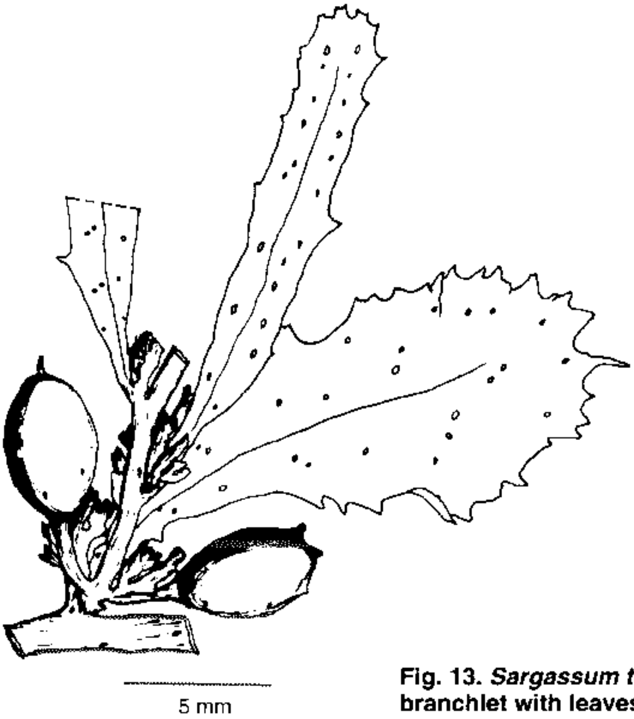


**Fig. 13. *Sargassum taiwanicum* Tseng et Lu. A branchlet with leaves, vesicles, and receptacles.**

60-4117. Collected in January to February from Xinying, Chengmai District, Hainan Province.

Distribution: Sri Lanka, Australia, and China.

Remarks: The specimens collected in January and February were immature with very young receptacles. The leaves, however, match well the description of the species. *Sargassum spinifex* was placed in the group Ilicifolia by Grunow, who emphasized the characteristics of the leaves. However, we think that the receptacles are more important phylogenetically. The receptacles of this species are androgynous, and we have moved the species from the group Ilicifolia to the series *Coriifoliae*. *Sargassum spinifex* C. A. Agardh has been previously studied by J. G. Agardh (1848, p. 312; 1889, p. 92, pl. 27, fig. 1) and Grunow (1915, p. 400).

*Sargassum turbinatifolium* Tseng et Lu, Stud. Mar. Sinica 15:9, fig. 6, pl. 7, 1979.
(Figs. 8 and 15)

Frond medium sized, 35–40 cm tall, arising from a small discoid holdfast, about 1 cm in diameter. Main axis cylindrical, glabrous, about 3 mm long and 2 mm in diameter. Primary branches subcylindrical, 4–5 cm from the apex of the main axis, 30–40 cm long, 1.5–2 mm in diameter, with small amounts of brownish-black cryptostomata. Secondary branches 15–20 cm long and 1 mm in diameter,

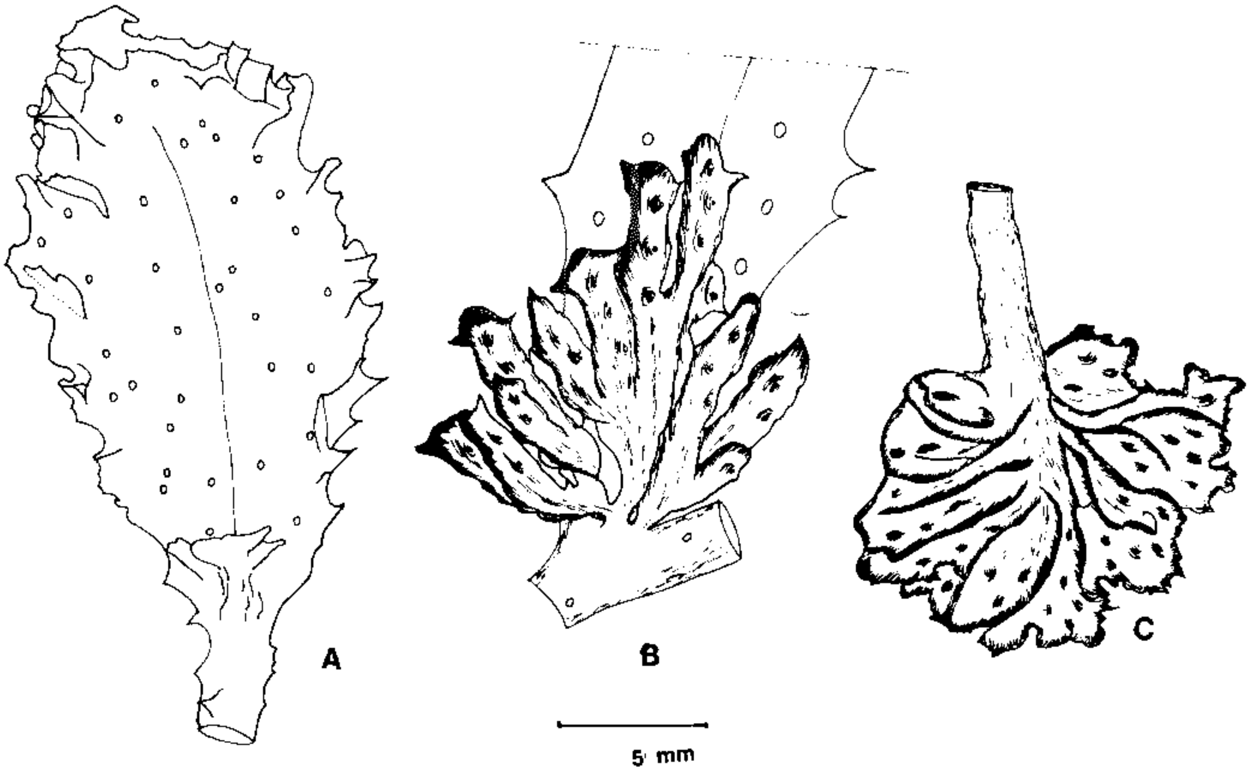


Fig. 14. *Sargassum taiwanicum* Tseng et Lu. A, A leaf with terminal duplicate margins. B, Receptacular branches. C, Holdfast.

with raised cryptostomata, alternate, 2.5–4 cm apart. Ultimate branchlets cylindrical, crowded with leaves, vesicles, and receptacles, with raised cryptostomata. Leaves lanceolate, 1.8 cm long, 8 mm wide, rigid and turbinate, strongly conduplicate on both sides of the midrib. Vesicles globular, 4–5 mm in diameter, with earlike winged appendages and numerous cryptostomata.

Plants androgynous. Oogonia and antheridia in different conceptacles but in the same receptacles. Ancipital receptacles toothed and racemosely arranged.

Habitat: Growing on coral reefs in the lower littoral regions. AST 76-1305, 76-1549, 76-1569, and 76-1594.

Distribution: China and the Philippines. The type locality is the Xisha Islands, Hainan Province.

Remarks: *Sargassum turbinatifolium* is easily recognized on the basis of its small but rigid turbinately duplicate leaves and ancipital toothed receptacles, racemosely arranged. It has been previously studied by Ajisaka et al. (1997).

*Sargassum wangii* Tseng et Lu, Stud. Mar. Fauna Flora Biog. Nansha Islands Neighbouring Waters, 3, p. 10, pl. 2:4, fig. 6, 1998.

(Figs. 6 and 16)

Fronds yellowish black, reaching a height of about 40 cm, arising from a scutellate discoid holdfast about 1.5 cm in diameter. Main axis cylindrical, about 5 mm tall and 6 mm in diameter. Primary or main branch arising from the top of the main axis, flattened, rather glabrous, up to about 39 cm long and 4 mm wide. Secondary branches glabrous and flattened, up to 15–23 cm long and 3–4 mm wide. Ultimate branchlets cylindrical to subcylindrical, 6–18 cm long and about 2 mm in diameter, crowded with leaves, vesicles, and receptacles. Leaves of primary branches mostly fallen away and remaining leaves rather wide, about 4–5 cm long and 5–7 mm wide, somewhat blunt at the apices, rather symmetrical and cuneate at the base, with wavy margin, midribs percurrent or nearly to the tips, with slightly protruding cryptostomata, irregularly scattered on both sides of the midrib. Leaves on secondary branches slightly thicker than, and somewhat smaller but longer than, those on primary branches, oblong-lanceolate, to 4–5 cm long and 4–5 mm wide, acute at the apices, rather symmetrical at the base, midrib percurrent or nearly to the tips, cryptostomata slightly raised, arranged in 2 rows on both sides of the midrib, the leaf margin wavy in the lower parts of leaves and with some shallow teeth in the upper parts. Leaves in ultimate branchlets similar to the other leaves in shape but smaller, up to 1.5 cm long and 2 mm wide. Vesicles ovate, the larger ones 8 mm long and 6 mm in diameter, the smaller ones only 3 mm long and 2.5 mm in diameter, with 2–3 slightly raised cryptostomata and mostly cylindrical stipes, 4–5 mm long and 2–2.5 mm wide, or some leaflike appendages with midrib.

Plants androgynous; receptacles racemosely arranged, flattened or triquetrous, spinous apically and laterally with oogonia concentrated in the upper parts of the receptacles and the antheridia in the lower parts.

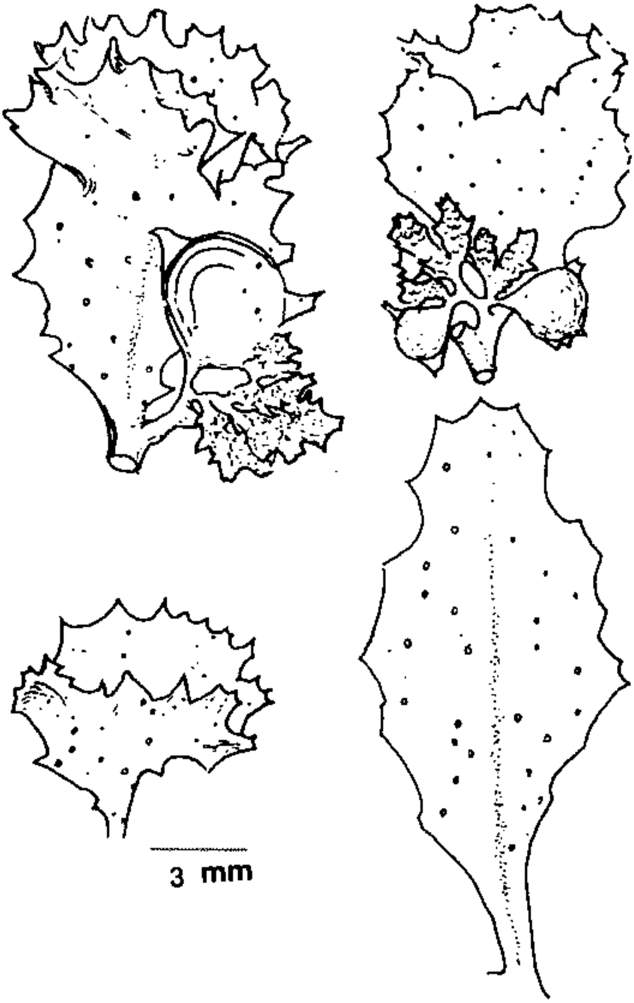


**Fig. 15.** ***Sargassum turbinatifolium*** **Tseng et Lu. Top figures showing two leaves with duplicated margins; 2 lower figures showing branchlets with simple leaves, receptacles and vesicles.**

Habitat: Drifted ashore. AST 94-0100, 94-0101.

Distribution: Endemic in China. The type locality is Panyueiiao, Nansha Islands, Hainan Province.

Remarks: *Sargassum wangii* Tseng et Lu is 1 of the 2 species with flattened or compressed primary and secondary branches in this series. This characteristic is more primitive than the characteristic of cylindrical stems. Leaves with shallow teeth at the margin and slightly raised cryptostomata and compressed to triquetrous receptacles differentiate *S. wangii* from the closely related *S. xishaense,* which has leaves with deeply doubly serrate margins and conspicuous, raised cryptostomata and flattened receptacles. *Sargassum wangii* also is similar to *S. swartzii* C. A. Agardh, but unlike *S. swartzii*, it has androgynous racemose receptacles.

*Sargassum xishaense* Tseng et Lu, Stud. Mar. Sinica 15:4, fig. 5, pl. 4, fig. 2, pl. 6, 1979.

(Figs. 7 and 17)

Frond elegant, reaching a height of 60 cm, with a conical holdfast about 1 cm in diameter. Main axis glabrous, cylindrical, 2–3 mm tall, 1–2 mm in diameter. Primary or main branches about 30–60 cm long, flattened, 2–3 mm wide, with greatly raised cryptostomata. Secondary branches flattened, 1–2 mm wide, alternate, 6–10 cm long, 2–4 cm between the branches, also with numerous greatly raised cryptostomata. Ultimate branchlets about 1–2 cm long, with leaves, vesicles, and receptacles. Leaves lanceolate, 3–5 cm long and 6 mm wide, with numerous conspicuous open-mouth–type cryptostomata on both sides of the prominent midribs. Vesicles with raised cryptostomata, globular, 5–9 mm in diameter, with mostly flattened, leaflike stipes provided with midribs, 5 mm long.

Plants androgynous. Oogonia and antheridia in different conceptacles on the same receptacle, with oogonial conceptacles distal and antheridial conceptacles proximal. Flattened to compressed receptacles thicker in the center and thinner at the edges, 11.5 cm long and 1–1.5 mm wide, irregularly spinous, stipulate, racemosely arranged. In the Xisha region, the receptacles appear in March and mature in May.

Habitat: Growing on lower littoral to sublittoral coral reefs. AST 57-5481, 58-4156, 76-0849, 76-1062, and 76-1802.

Distribution: Endemic in China. The type locality is Yongxing and Guangjin islands, the Xisha Islands, Hainan Province.

Etymology: Named for the Xisha Islands, a location where many Chinese phycologists have collected and studied marine algae.

Remarks: *Sargassum xishaense* is 1 of the 2 members of the series *Coriifoliae* with flattened primary and secondary branches. It is further characterized by prominent, greatly raised open-mouth–type cryptostomata, lanceolate leaves with doubly serrate margins, and globular vesicles, commonly with leaflike stipes.

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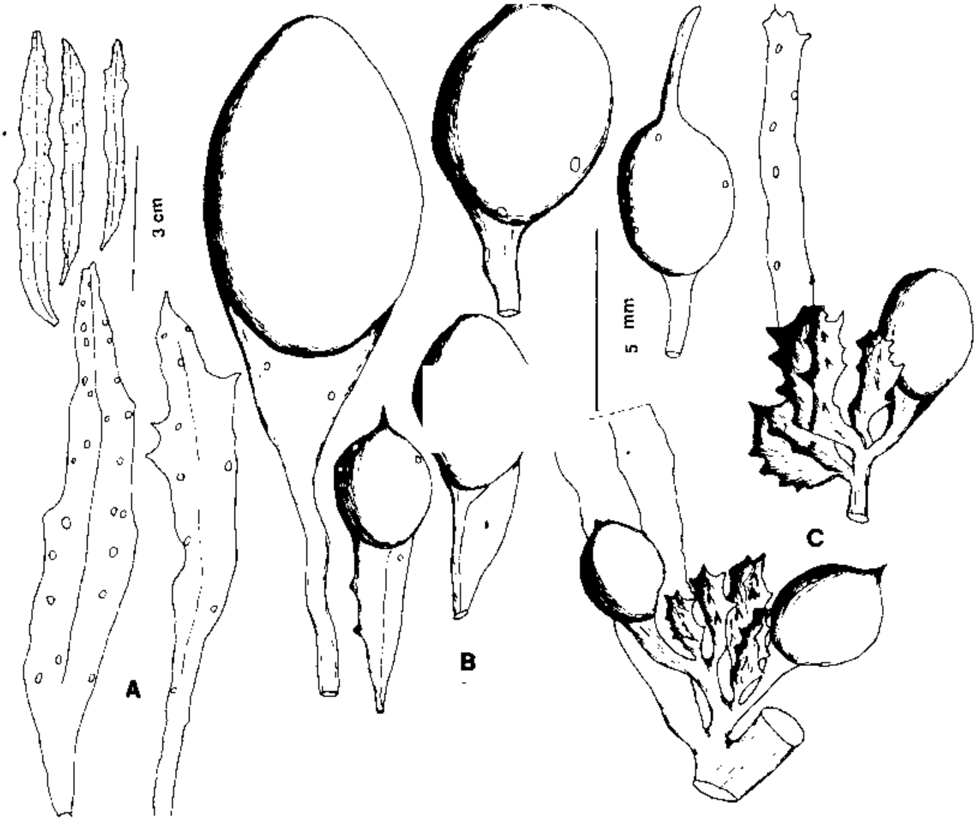

Fig. 16. *Sargassum wangii* Tseng et Lu. A, Lanceolate leaves. B, Vesicles. C, branchlets with leaves, vesicles, and receptacles.

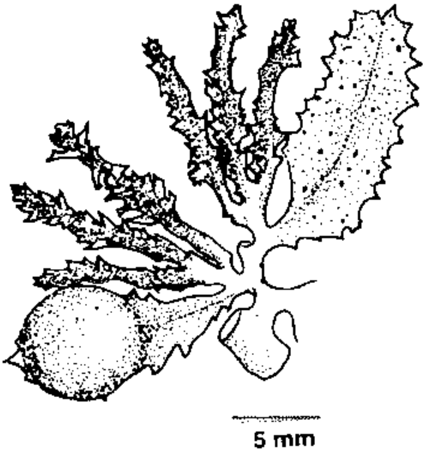

Fig.17. *Sargassum xishaense* Tseng et Lu. A branchlet with leaf, vesicle, and receptacles.

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# PRELIMINARY REPORT OF *SARGASSUM* SPECIES COLLECTED FROM MALAYSIAN COASTS

Tetsuro Ajisaka, Phang Siew Moi, and Tadao Yoshida

## Abstract

Eight species of *Sargassum* from several coasts of Malaysia were identified. Six species were from the western coasts of the Malay Peninsula, 1 from the eastern coast of the Malay Peninsula, and 3 from the coasts of Sabah (Borneo). Descriptions of 6 species are given in detail, and a key to 8 species is presented. *Sargassum baccularia* J. G. Agardh and *S. oligocystum* Montagne are both reported for the first time from Malaysian coasts. *Sargassum oligocystum, S. polycystum* C. A. Agardh, and *S. siliquosum* J. G. Agardh were commonly found along both coasts of the Malay Peninsula and Sabah and are widely distributed in this area.

## Introduction

On the basis of bibliographical studies, Phang and Wee (1991) listed a total of 18 species of *Sargassum* in the marine flora of Malaysia and Singapore: 9 species from Singapore, 11 from the western coasts of the Malay Peninsula, 5 from the eastern coasts of the Malay Peninsula, and 6 from the coasts of Sabah (Borneo). Ismail and Go (1994) reported 5 species of *Sargassum* from Tioman Island off the eastern coast of the Malay Peninsula. However, in those lists, we found some names of *Sargassum* species that grow in the Atlantic Ocean, the Red Sea, and the Mediterranean Sea.

In the text figures of *Seaweeds of Singapore* (Teo and Wee 1983), we found several misidentifications of *Sargassum*, for example, fig. 77 (*S. duplicatum* is actually *S. siliquosum*), fig. 80 (*S. spathulaefolium* is actually *S. polycystum*), fig. 82 (*S. asperifolium* is actually *S. baccularia*), fig. 83 (*Sargassum* sp. 1 is actually *S. oligocystum*), and so on.

Clarification of the taxonomy of *Sargassum* in Malaysia is important. Species of this genus are used as sources of alginic acid and are important in maintaining algal beds to ensure a sustainable coastal environment. In a cooperative research effort between Japan and Malaysia (a governmental project of the ministries of education of both countries), we are reviewing specimens of *Sargassum* from the coasts of Malaysia, including Sabah and Sarawak (Borneo). We made 2 field trips, in 1995 and 1996, to make preliminary collections at the locations shown in Figure 1.

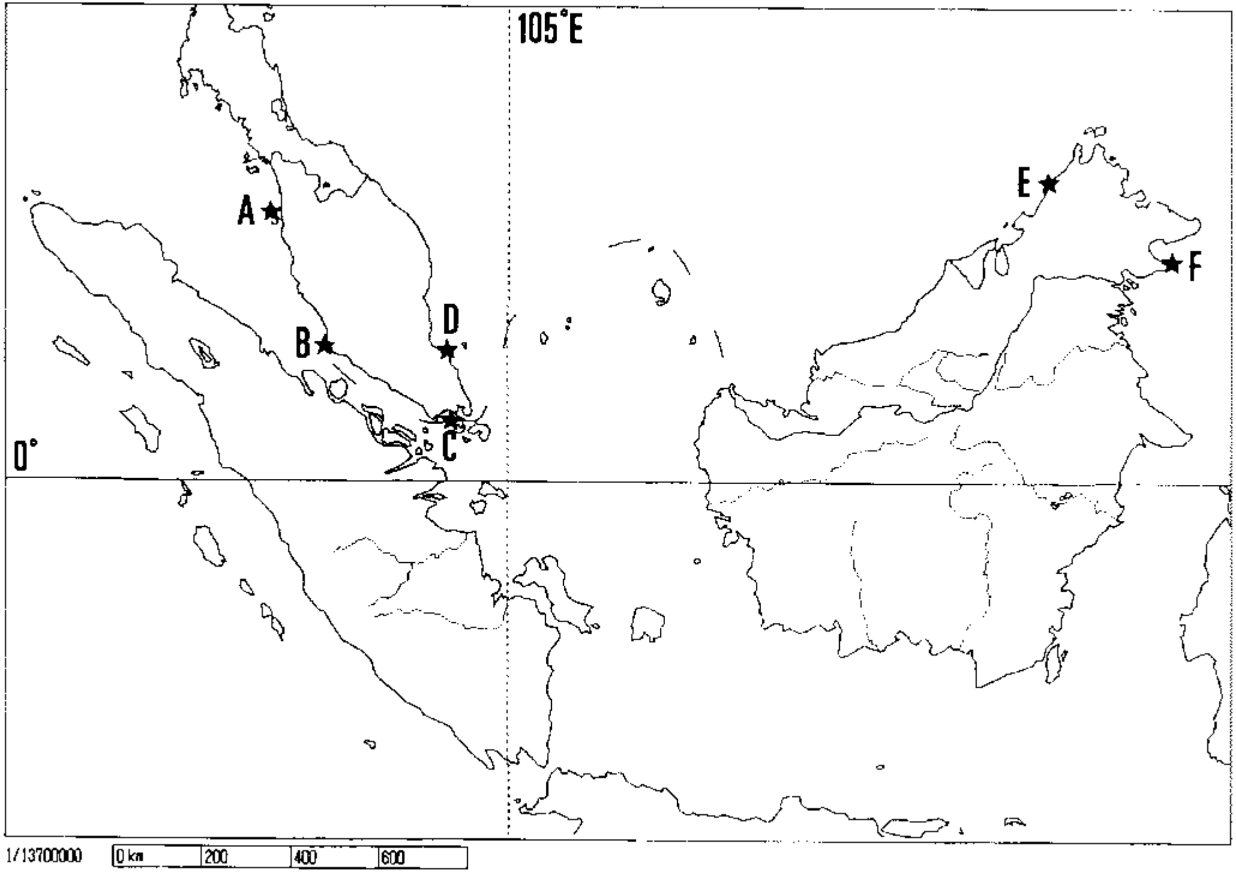

Fig. 1. Sites of collection in Malaysia. A, Penang Island. B, Port Dickson. C, Singapore. D, Mersing. E, Kota Kinabalu. F, Tawau.

In this chapter, we describe 6 species of *Sargassum* included in these collections. Two species, *S. siliquosum* J. G. Agardh and *S. stolonifolium* Phang et Yoshida, have been described in detail in previous reports (Phang et al. 1995, Phang and Yoshida 1997). We also present a key to 8 species of *Sargassum* identified from Malaysia.

### Key to the Malaysian Species of *Sargassum*

1. Secondary holdfasts transformed from cauline leaves .............. *S. stolonifolium*
1. Holdfast not transformed from cauline leaf .............. 2
    2. Main branch with many spines .............. 3
    2. Main branch smooth .............. 4
3. Secondary holdfast transformed from stolons .............. *S. polycystum*
3. Secondary holdfast lacking .............. *S. myriocystum*
    4. Main branch terete .............. 5
    4. Main branch flattened .............. 7
5. Leaves of young plant large (up to 8 cm) .............. *S. siliquosum*
5. Leaves small (less than 4 cm) .............. 6
    6. Leaves ashy-gray .............. *S. cinereum*
    6. Leaves dark-brown .............. *S. baccularia*
7. Receptacles flattened, often twisted, with dentate margins .............. *S. binderi*
7. Receptacles compressed, not twisted, with apical spines .............. *S. oligocystum*

All specimens used in this work are deposited at the herbarium in the Division of Applied Bio-Science, Graduate School of Kyoto University, Japan.

### Description of the Species

*Sargassum baccularia* (Mertens) C. A. Agardh, Syst. algarum, p. 304, 1824.
(Figs. 2 and 7a–7d )

Misidentification: *S. asperifolium* of Teo and Wee, Seaweeds of Singapore, 1983.

Holdfast discoid to conical, up to 1 cm in diameter. Stem terete, warty, up to 1 cm or 2.5 cm long. Primary branches terete, up to 50 cm long, up to 1.5 mm in diameter, sometimes with spines at the margin or smooth, producing spirally arranged secondary branches. Lower leaves large lanceolate, simple, up to 3.5 cm long, up to 8 mm wide, with rounded apices, margin entire or dentate with small teeth, midrib distinct and evanescent, small cryptostomata scattered. Upper leaves on the secondary branches and branchlets slender, lanceolate to linear,

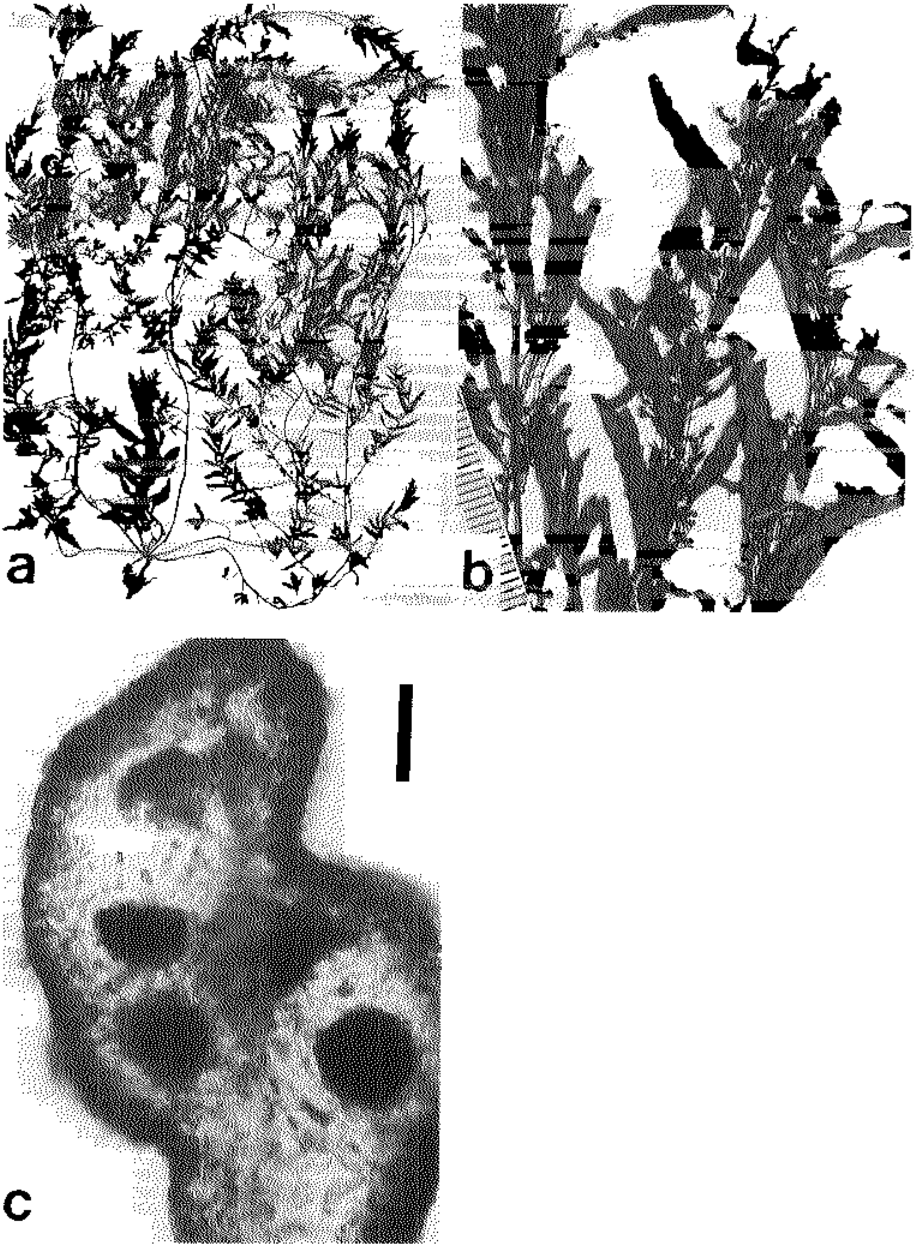

Fig. 2. *Sargassum baccularia* (Mertens) C. A. Agardh from Malaysia. a–c, Female plant. Scale bar = 100 μm (c).

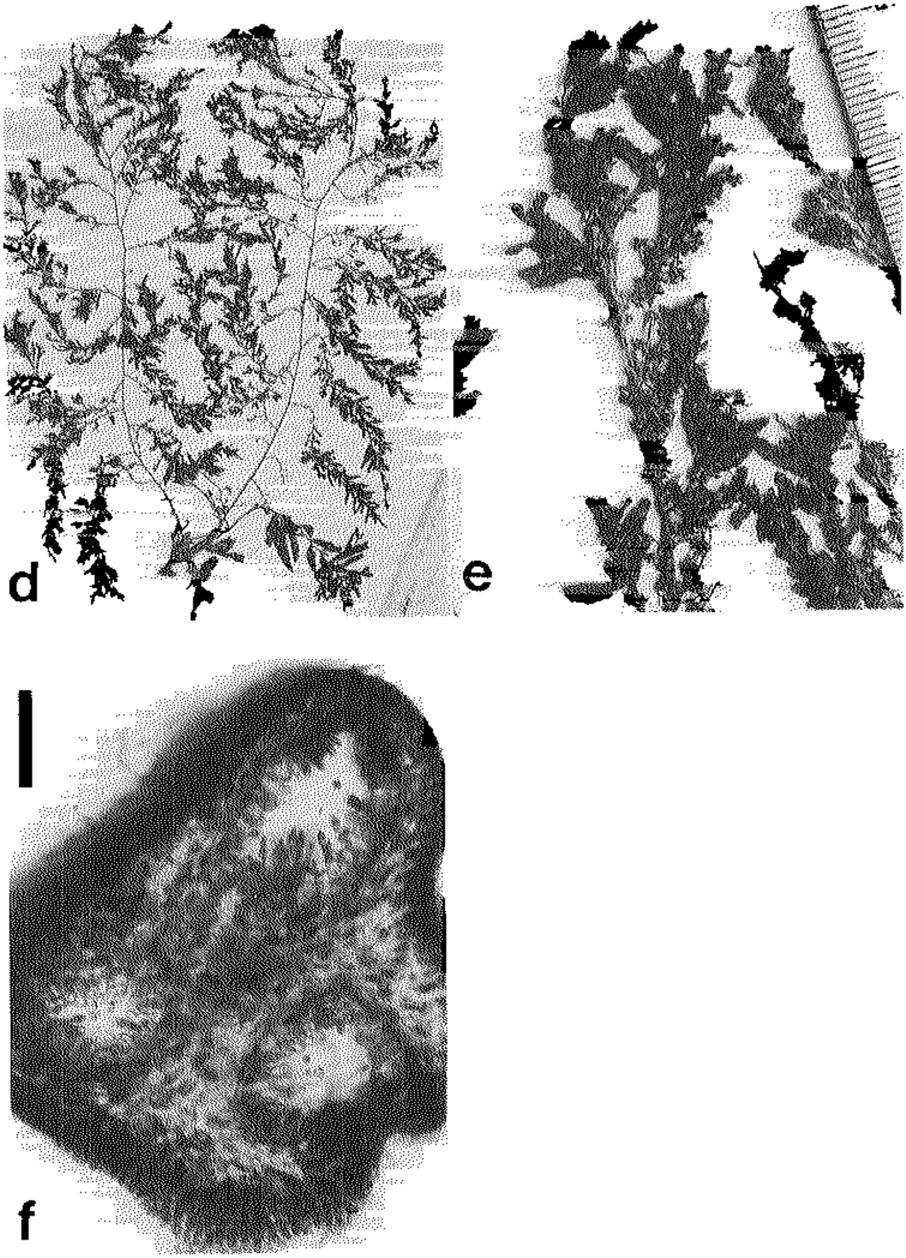

Fig. 2. *Sargassum baccularia* (Mertens) C. A. Agardh from Malaysia. d–f, Male plant. Scale bar = 100 μm (f).

simple, up to 1.5 cm long, up to 4 mm wide, with sharp apices, margin dentate with small teeth, midrib distinct and evanescent, cryptostomata arranged in rows on both sides of the midrib. Vesicles small spherical, up to 1–2 mm in diameter, clustered or paired at the upper branches and branchlets, entire at the apices; stalks terete, usually shorter than the vesicles themselves.

Plants dioecious. Male receptacles long, terete, up to 3 mm long, up to 1 mm wide, with smooth surface, simple to furcate once or twice, pseudozygocarpic with vesicles. Female receptacles short conical, up to 2 mm long, up to 1.5 mm wide, with warty surface, sometimes bearing spines near the apex, simple to furcate once or twice, pseudozygocarpic with vesicles.

Habitat: Growing on lower tidal rocks, Port Dickson, western coast of Malay Peninsula, Malaysia.

Remarks: *Sargassum baccularia* has no secondary holdfast and sometimes has a few spines or otherwise smooth branches.This species was easily distinguished from *S. polycystum,* which has secondary holdfasts transformed from stolons and is heavily muricate on main branches. This record is the first from Malaysia.

*Sargassum binderi* Sonder ex J. G. Agardh, Sp. gen. ordines algarum, vol. 1, p. 328, 1848.

(Figs. 3a–3c and 7e–7g)

Holdfast discoid, about 1 cm in diameter. Stem terete, warty, up to 1 cm long. Primary branches flattened or compressed, up to 50 cm long, up to 3 mm wide, smooth, producing distichously arranged secondary branches. Lower leaves large lanceolate, simple, up to 3 cm long, up to 9 mm wide, with rounded apices, margin entire to dentate with small teeth, midrib indistinct, vanishing below upper parts of the leaves or otherwise completely evanescent, small cryptostomata scattered. Upper leaves on secondary branches and branchlets slender lanceolate, simple, up to 1.7 cm long, up to 5 mm wide, with sharp apices, margin dentate with sharp teeth, midrib vanishing near apices, small cryptostomata scattered. Vesicles spherical to elliptical, up to 8 mm long, often mucronate at the apex; stalks flattened, usually longer than the vesicles.

Plants monoecious. Receptacles androgynous, flattened, often twisted, up to 5 mm long, sharply dentate at the margin, simple to furcate once, racemosely arranged, clustered.

Habitat: Growing on lower tidal rocks, Port Dickson, western coast of Malay Peninsula, Malaysia.

Remarks: This species belongs to a group with flattened main branches. The identification of the species in this group is somewhat confused. *Sargassum binderi* was characterized by its sharply dentate receptacles in the original description (J. G. Agardh 1848) and in the descriptions of Chinese specimens (Tseng et Lu 1995b). *Sargassum swartzii* (Turner) C. A. Agardh has spines only at the tips of receptacles (J. G. Agardh 1848). Noro et al. (1994) reported that

*S. oligocystum* Montagne has receptacles with apical spines and that *S. swartzii* has receptacles without spines. Tseng et Lu (1995a, 1995b) reported that *S. swartzii* has receptacles with small apical spines, but they did not include any information on receptacles in Chinese specimens of *S. oligocystum*. Womersley and Bailey (1970) suggested that *S. binderi* is a synonym of *S. oligocystum*. However, we retain *S. binderi* on the basis of the characteristics of receptacles in Malaysian specimens.

*Sargassum cinereum* J. G. Agardh, Sp. gen. ordines algarum, vol. 1, p. 305, 1848.

(Figs. 4 and 7h–7m)

Holdfast and stem unknown (drifted specimens). Primary branches terete, up to 60 cm long, up to 1 mm in diameter, slender and smooth, producing secondary branches spirally. Lower leaves slender lanceolate to linear, up to 3 cm long, up to 5 mm wide. Upper leaves more slender lanceolate to linear, up to 3 cm long, up to 2 mm wide. Leaves ashy gray, simple, membranous, with an asymmetrical to cuneate base, with sharp apices, margin dentate with small teeth, midrib distinct, vanishing below upper part of the leaves, small cryptostomata arranged in rows on both sides of midrib. Vesicles spherical to elliptical or obovoid, up to 5 mm long, up to 3 mm wide, entire at apices; stalks terete or sometimes cuneate, nearly the same length as vesicles.

Plants dioecious. Male receptacles long, terete, up to 15 mm long, up to 1.0 mm wide, simple or once furcate, pseudozygocarpic with vesicles and small leaves. Female receptacles compressed and triquetrous at the apices, with dentate margin, up to 4 mm long, up to 1.5 mm wide, simple or once furcate, pseudozygocarpic with vesicles and small leaves.

Habitat: Drifted on the shore, Mersing, eastern coast of Malay Peninsula, Malaysia.

Remarks: On the basis of the pseudozygocarpic dioecious receptacles (male receptacles are terete and smooth; female receptacles are compressed to triquetrous with spines), this species should be included in the species group *Cinerea* Setchell in subsection *Pseudozygocarpicae* Setchell (see Ajisaka et al. 1995). Only 2 species are described in this species group: *S. glaucescens* J. G. Agardh and *S. cinereum* J. G. Agardh. *Sargassum cinereum* is distinguished from *S. glaucescens* by the membranous leaves and longer (up to 15 mm) male receptacles of the former. The morphological characters of leaves, vesicles, and receptacles of Malaysian specimens of *S. cinereum* differ only slightly from those of Chinese specimens (Tseng and Lu 1988, pp. 33–35), and we conclude that this species is stable with small variations.

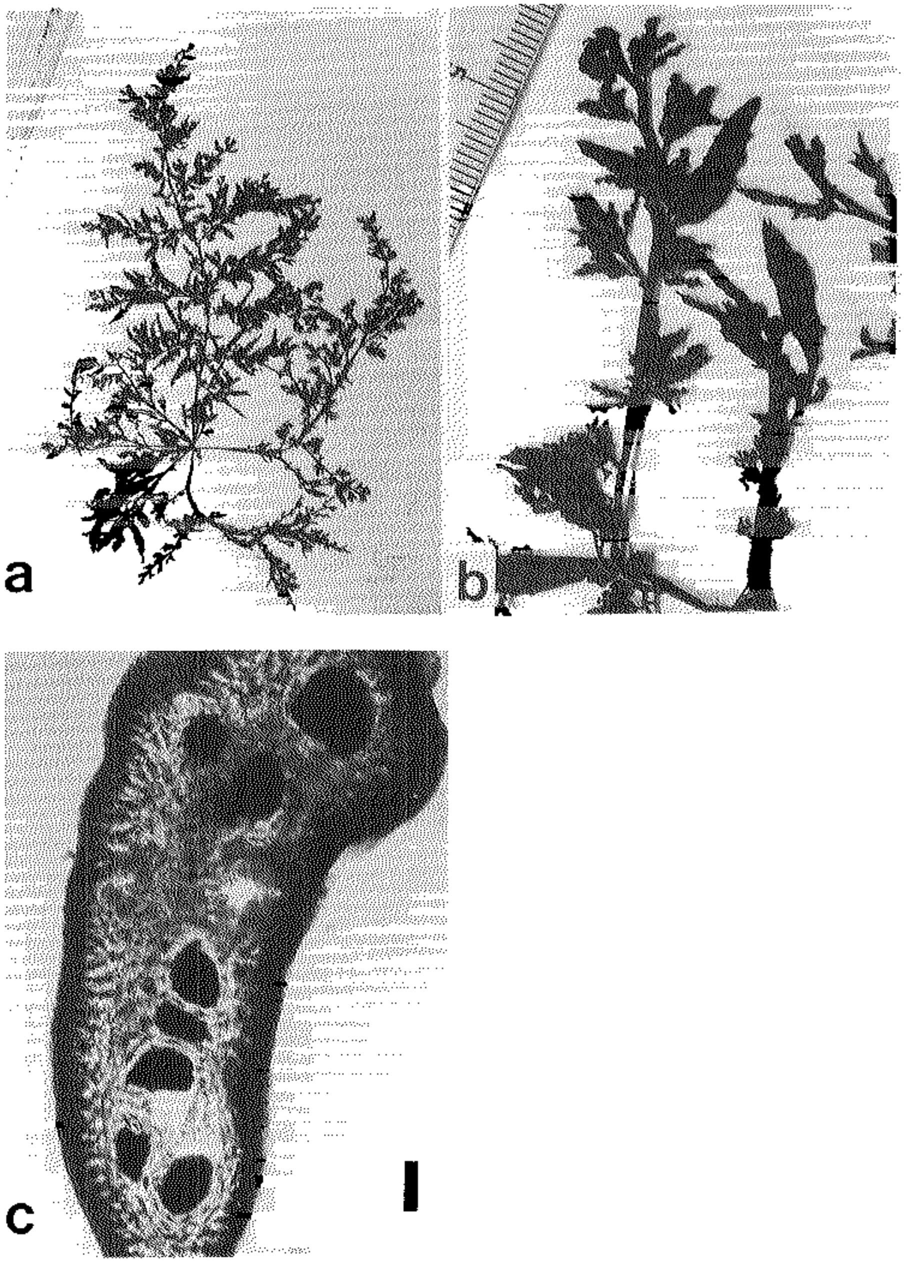

Fig. 3. *Sargassum binderi* Sonder (a–c) from Malaysia. Species has monoecious and androgynous receptacles. Scale bar = 100 μm (c).

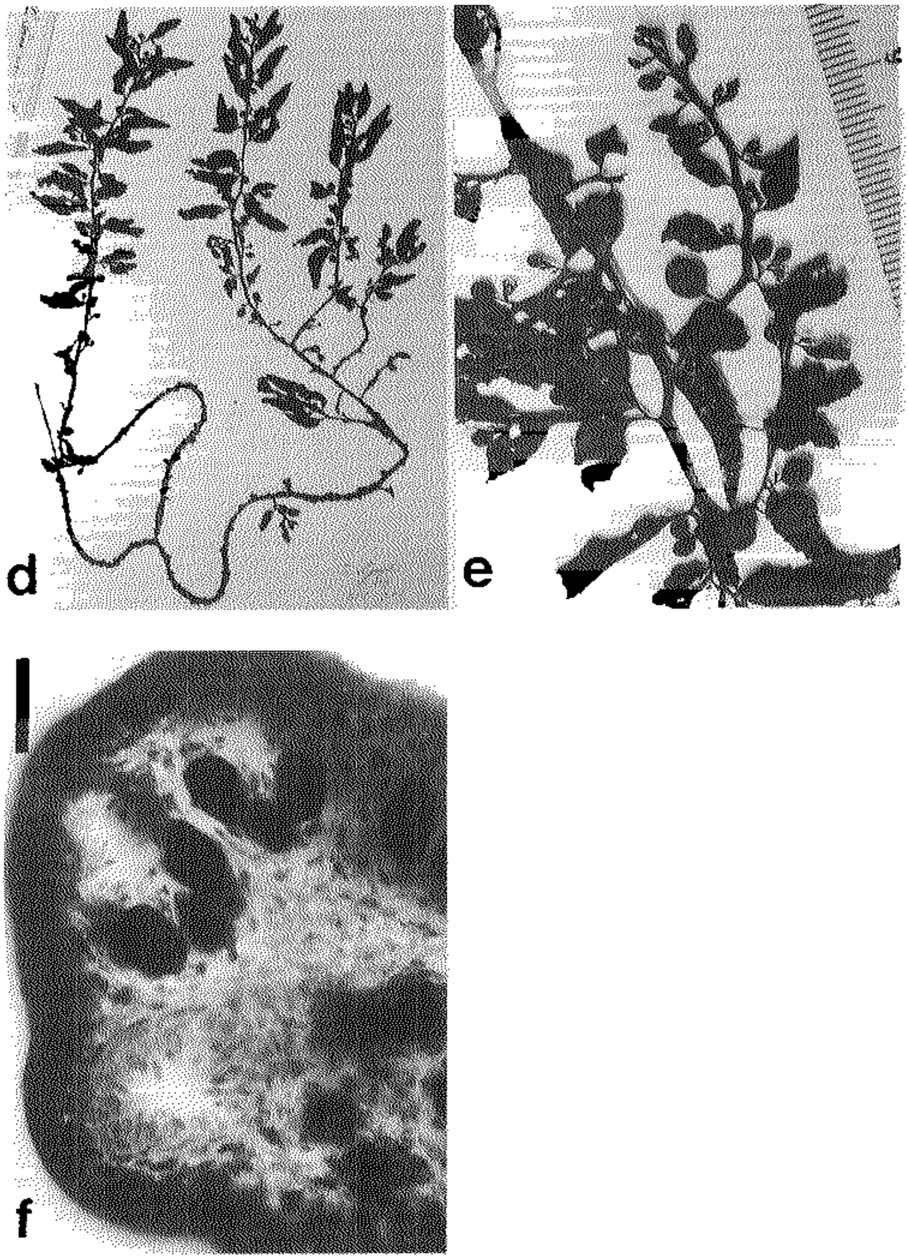

Fig. 3. *Sargassum oligocystum* Montagne (d–f) from Malaysia. Species has monoecious and androgynous receptacles. Scale bar = 100 μm (f).

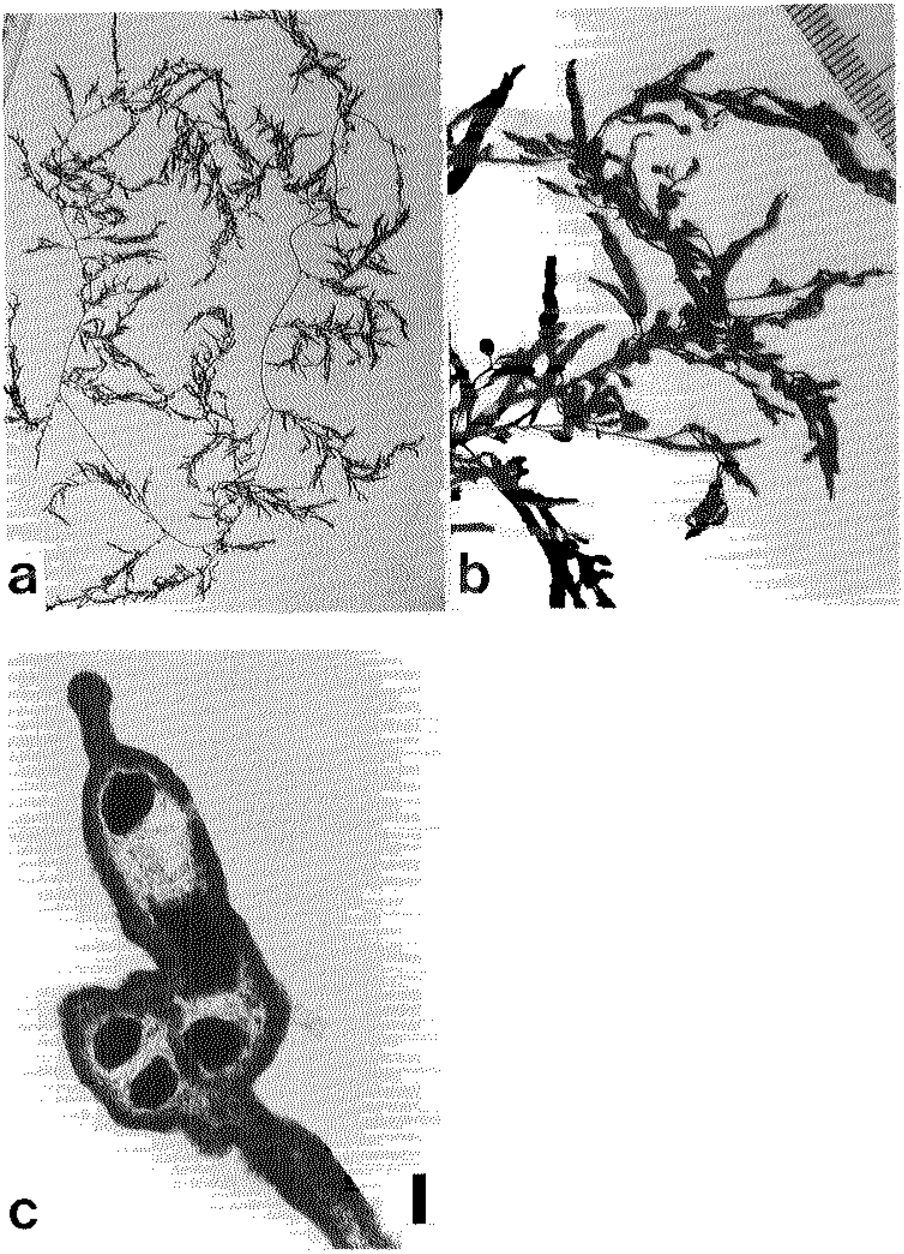

Fig. 4. *Sargassum cinereum* J. G. Agardh from Malaysia. a–c, Female plant. Scale bar = 100 μm (c).

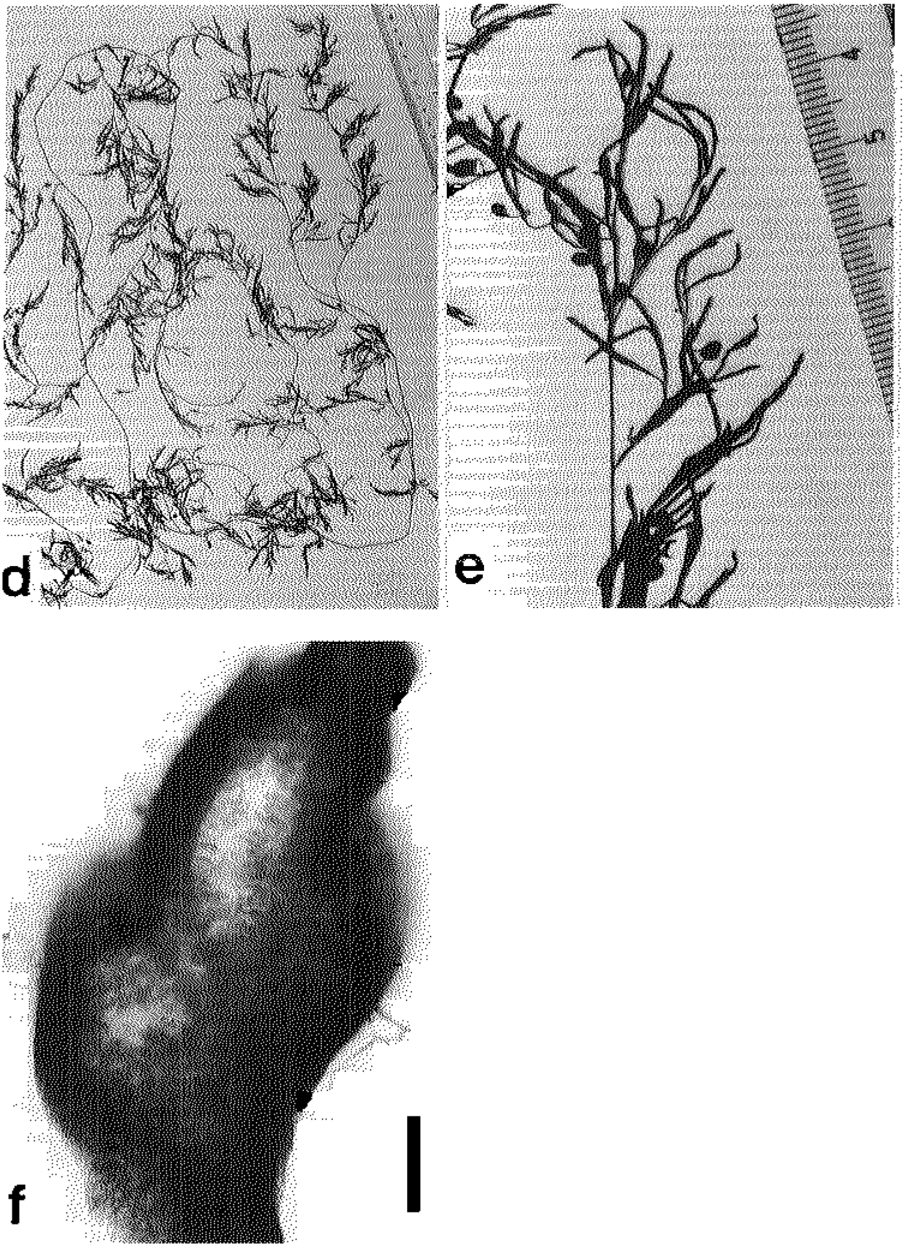

**Fig. 4.** ***Sargassum cinereum*** **J. G. Agardh from Malaysia. d–f, Male plant. Scale bar = 100 μm (f).**

*Sargassum myriocystum* J. G. Agardh, Sp. gen. ordines algarum, vol. 1, p. 314, 1848.

(Figs. 5 and 8a–8f)

Synonym: *Sargassum opacum* J. G. Agardh, Kgl. Svenska. Vet.-Akad. Handl. 23:98, pl. 28, fig. 4, 1889.

Holdfast discoid, up to 1.2 cm in diameter. Stem terete, up to 9 mm tall, up to 1.5 mm in diameter, with a smooth surface, bearing up to 6 primary branches. Primary branches up to 25 cm long, terete, up to 1 mm in diameter, usually muricate with crowded spines, producing spirally arranged secondary branches. Leaves spatulate to ovoid, simple, with an asymmetrical to cuneate base, up to 22 mm long, up to 7 mm wide, with rounded apices, margin dentate with coarse teeth or entire, midrib indistinct, vanishing below the middle part of the leaves, cryptostomata scattered or arranged in rows on both sides of the midrib. Vesicles of primary and secondary branches sparse (most had already dropped off). Vesicles on branchlets spherical to elliptical, up to 1 mm in diameter, with earlike wings on both sides of the vesicles or entire; stalks terete, shorter than vesicles themselves.

Plants dioecious. Female receptacles compressed, 1–1.5 mm long, about 0.5 mm wide, margin slightly dentate, simple to once furcate, sometimes pseudozygocarpic with vesicles. Male receptacles cylindrical, up to 5 mm long, about 0.5 mm in diameter, entire, warty, furcate 2 or 3 times.

Habitat: Growing on lower tidal rocks, Port Dickson, western coast of Malay Peninsula, Malaysia.

Remarks: Although this species is heavily muricate on the main branches, it was easily distinguished from *S. polycystum* C. A. Agardh, which also has muricate branching but in addition has a secondary holdfast transformed from stolons. *Sargassum myriocystum* has a small discoid holdfast and develops into a small plant. In Japanese specimens of this species, the shapes of male and female receptacles were widely variable (Ajisaka et al. 1995). In the Malaysian specimens, the shapes of the receptacles were more uniform.

*Sargassum oligocystum* Montagne, Voy. Pol. Sud. Bot. 1:67, 1845.

(Figs. 3e–3f and 8g)

Holdfast discoid, up to 10 mm in diameter. Stem terete, up to 1.5 cm tall, with a warty surface, bearing up to 8 primary branches. Primary branches up to 80 cm long, distinctly compressed, 6 mm wide, 1.5 mm thick, with a smooth surface, producing distichously arranged secondary branches. Leaves linear-lanceolate to lanceolate or spatulate, simple, 40 mm long, 15 mm wide, with an acute apex, margin dentate with teeth or entire, midrib distinct, reaching nearly to apex, cryptostomata scattered or arranged in rows on both sides of midrib. Vesicles spherical or elliptical, up to 8 mm long, entire at apex; cryptostomata scattered; stalk terete, up to 3 mm long, shorter than the vesicles themselves.

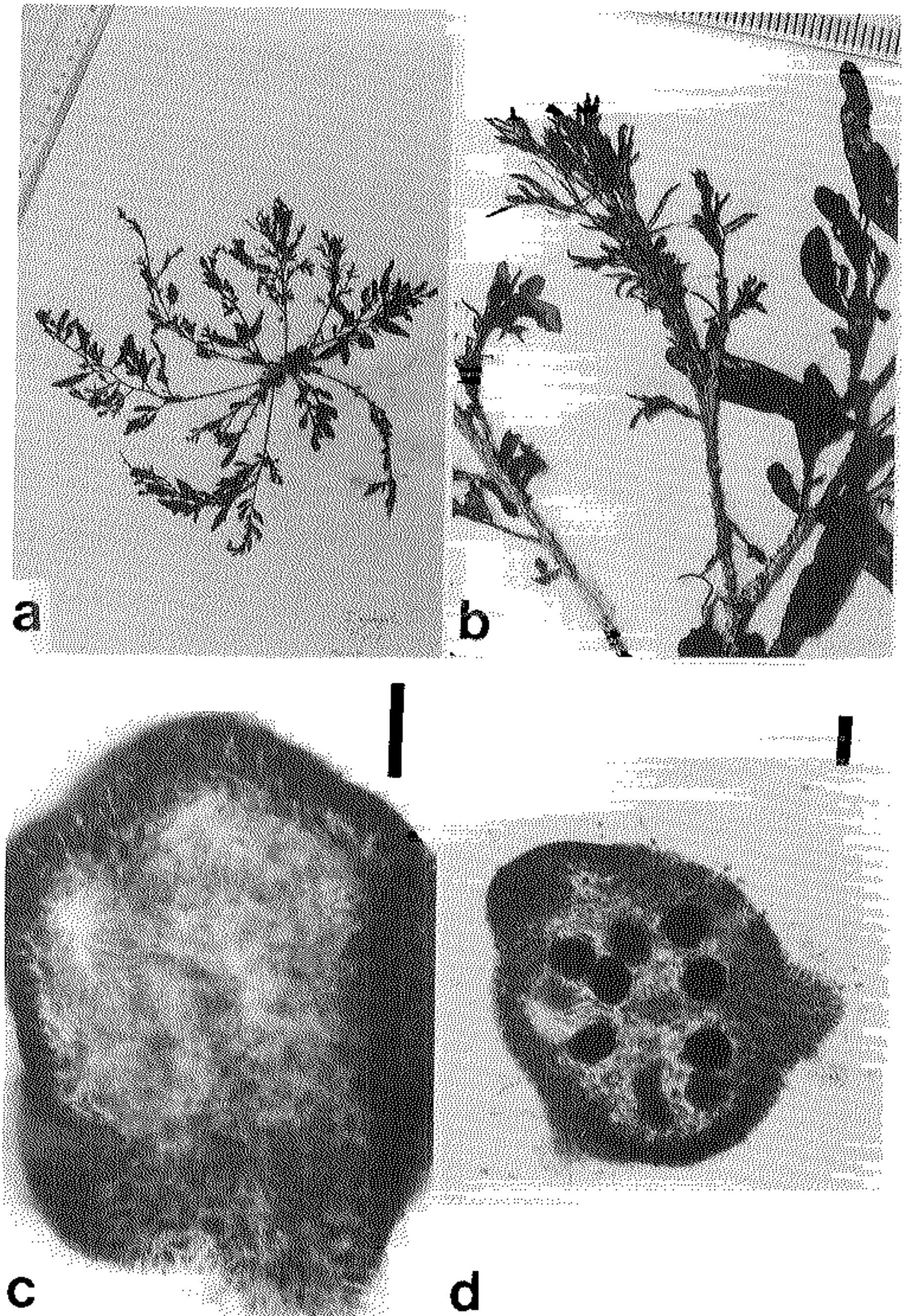

Fig. 5. *Sargassum myriocystum* J. G. Agardh from Malaysia. a–c, Male plant. d, Transverse section of female receptacle. Scale bars = 100 μm (c and d).

Plants monoecious. Receptacles androgynous, terete to slightly compressed at upper part, up to 4 mm long, up to 1 mm in diameter, warty, without spines or with a few spines, simple to furcate 2 or 3 times, usually pseudozygocarpic with vesicles.

Habitat: Growing on lower tidal rocks, Tawau and Kota Kinabalu, Sabah (Borneo), Malaysia.

Remarks: This species is separated from *S. binderi* Sonder on the basis of the receptacles. *Sargassum oligocystum* has flattened receptacles, often twisted, and with dentate margins, whereas *S. binderi* has compressed receptacles, not twisted, and with apical spines instead of dentate margins, as is emphasized in the key. This record is the first from Malaysia. Text figure 83 of *Sargassum* sp. 1 of Teo and Wee (1983) should be identified as *S. oligocystum*, drifted on the coast of Singapore.

*Sargassum polycystum* C. A. Agardh, Syst. algarum, p. 304, 1824.
(Figs. 6a and 6b)

Misidentification: *Sargassum spathulaefolium* of Teo and Wee, Seaweeds of Singapore, 1983.

Holdfast small, discoid, up to 7 mm in diameter. Stem terete to slightly compressed, up to 15 mm tall, up to 2 mm in diameter, with a warty surface, bearing up to 3 stolons and up to 4 primary branches. Stolons terete or slightly compressed at their proximal parts, irregularly alternately branched, up to 10 cm long, up to 2 mm in diameter, muricate with spines; primary branches usually muricate with highly branched spines, up to 50 cm or more long, terete, up to 1.5 mm in diameter, giving rise to spirally arranged secondary branches; spines up to 1 mm tall, sometimes forked in Y-shape at apical part; secondary branches up to 15 cm long, terete, crowded with spines. Leaves elliptical to lanceolate, simple, with an asymmetrical to cuneate base, up to 3 cm long, up to 10 mm wide, with rounded apices, margin dentate with coarse teeth, midrib distinct, vanishing near the apex, cryptostomata distinct, scattered. Vesicles spherical, up to 3 mm in diameter, with earlike wings on both sides of the vesicles or entire, cryptostomata scattered; stalks terete, shorter than vesicles themselves. No receptacles observed.

Habitat: Growing on lower tidal rocks, Port Dickson, western coast of Malay Peninsula, and Tawau and Kota Kinabalu, Sabah (Borneo), Malaysia.

Remarks: This description should be referred to the descriptions of Chiang et al. (1992) and Ajisaka et al. (1995). Wide variations were reported in this species. *Sargassum polycystum* is characterized by the secondary holdfast transformed from stolons (modified primary branches) and heavily muricate primary branches. It is easily distinguished from other Malaysian species of *Sargassum*.

For descriptions of *S. siliquosum* and *S. stolonifolium*, see Phang et al. (1995) and Phang and Yoshida (1997), respectively. Because these authors treated the Malaysian specimens in detail, descriptions of these species are omitted here, and only photographs are shown.

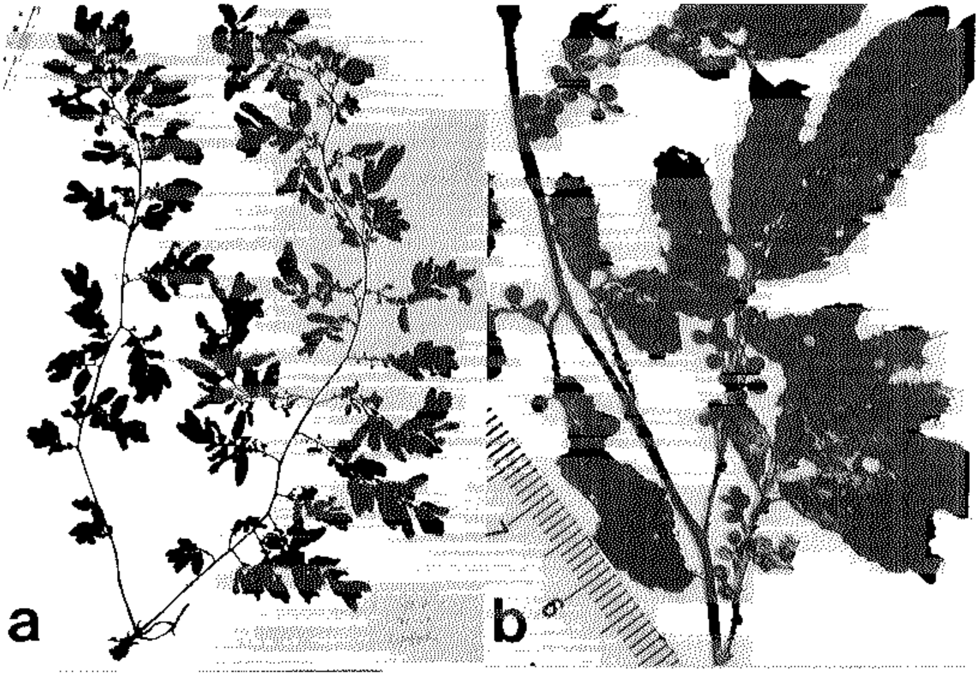

**Fig. 6.** ***Sargassum polycystum*** **C. A. Agardh (a, b).**

*Sargassum siliquosum* J. G. Agardh, Sp. gen. ordines algarum, vol. 1, p. 316, 1848.

(Figs. 6c and 6d)

Misidentification: *Sargassum duplicatum* J. G. Agardh, Teo and Wee, Seaweeds of Singapore, 1983.

For description of this species, see Phang et al. (1995).

Habitat: Growing on lower tidal rocks, Port Dickson, western coast of Malay Peninsula, and Tawau and Kota Kinabalu, Sabah (Borneo), Malaysia.

*Sargassum stolonifolium* Phang et Yoshida, In: Tax. Econ. Seaweeds 6, p. 63, figs. 2–9, 1997.

(Figs. 6e and 6f)

For description of this species, see Phang and Yoshida (1997).

Habitat: Growing on lower tidal rocks, Penang Island, Malaysia.

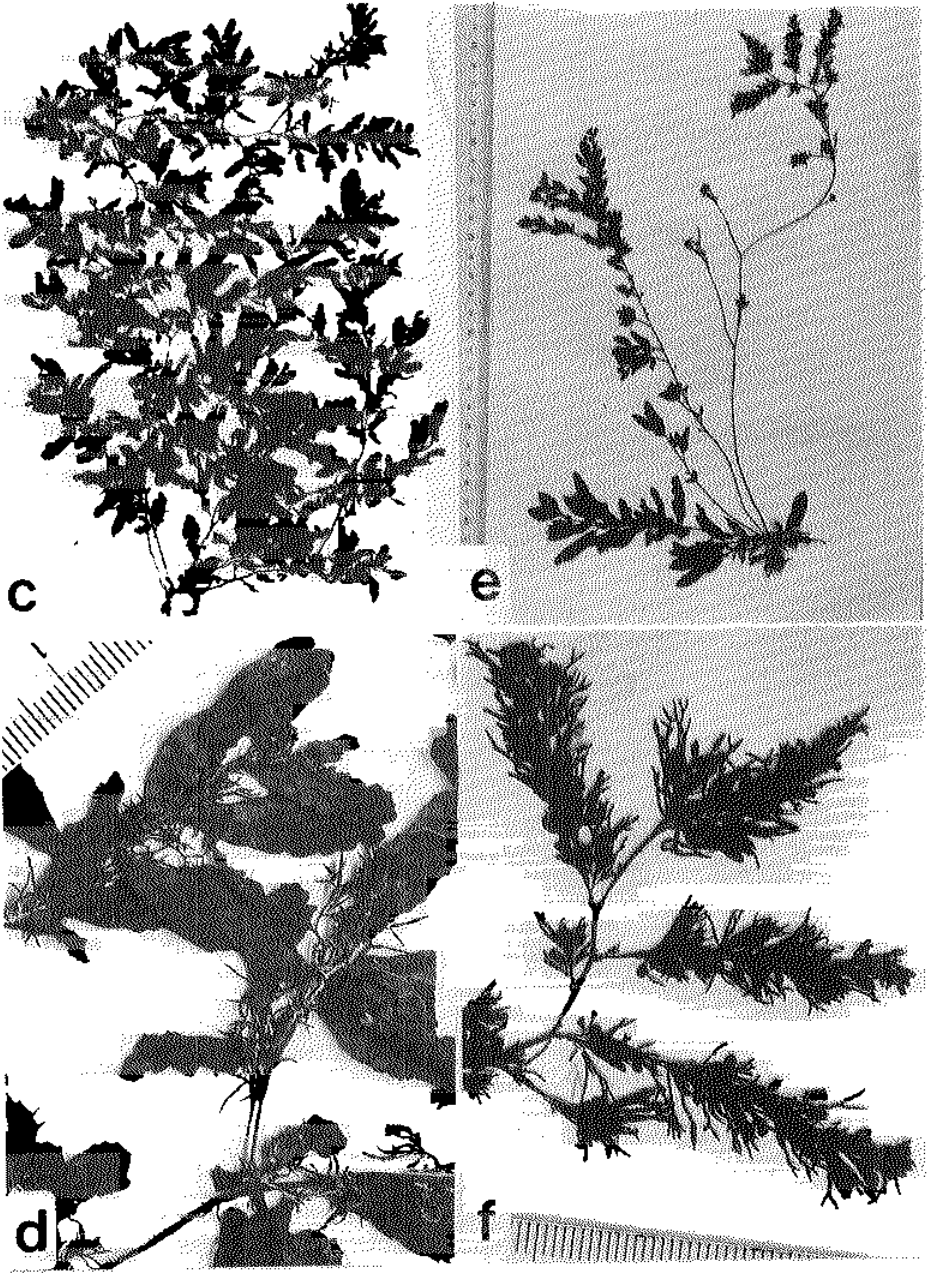

Fig. 6. *Sargassum siliquosum* J. G. Agardh (c, d), and *Sargassum stolonifolium* Phang et Yoshida (e, f) from Malaysia.

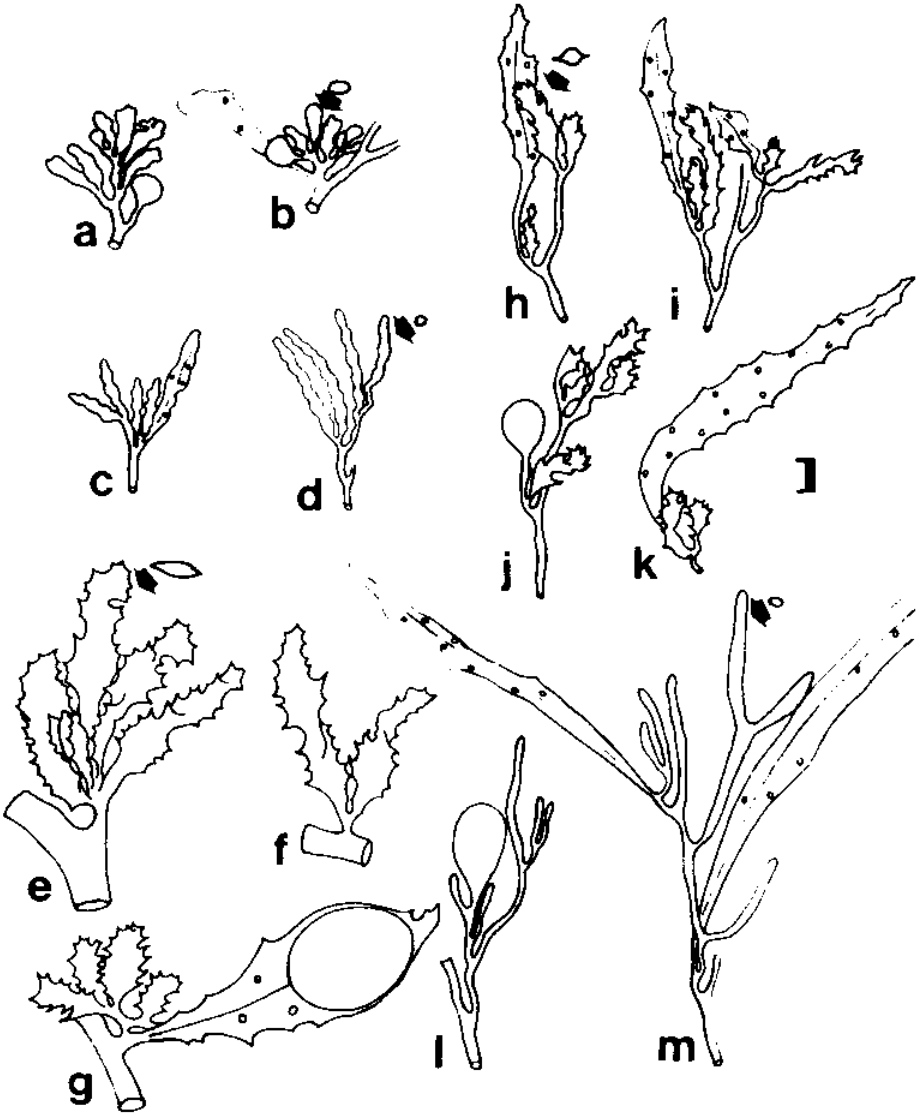

Fig. 7. Receptacle branches of *Sargassum* from Malaysia. Female (a, b) and male (c, d) plants of *Sargassum baccularia* (Mertens) C. A. Agardh; *Sargassum binderi* Sonder (e–g); and female (h–k) and male (l, m) plants of *Sargassum cinereum* J. G. Agardh.

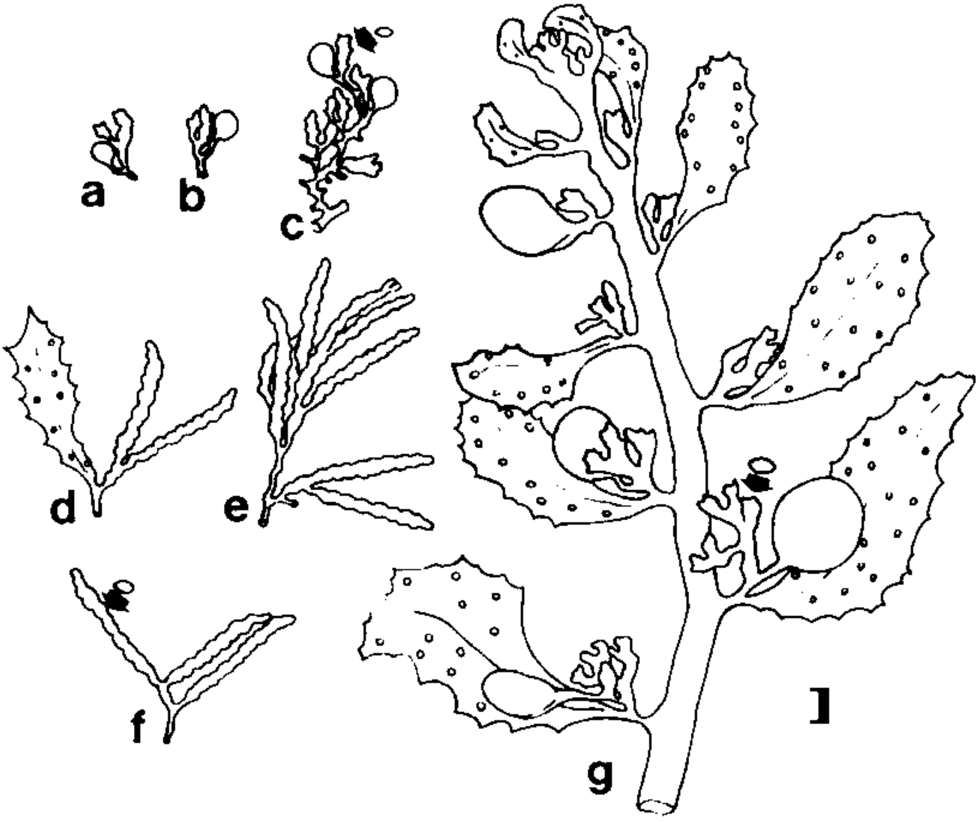

**Fig. 8. Receptacle branches of *Sargassum* from Malaysia. Female (a–c) and male (d–f) plants of *Sargassum myriocystum* J. G. Agardh and *Sargassum oligocystum* Montagne (g). Arrowheads show male receptacles (f) in section as nearly spherical, and females (c, g) as compressed.**

## Acknowledgments

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Tseng, C. K., and Lu Baoren. 1995a. Studies on the glomerulate *Sargassum* of China: II. The species group *Swartzia*. In: Tax. Econ. Seaweeds 5, pp. 75–92.

Tseng, C. K., and Lu Baoren. 1995b. Studies on the glomerulate *Sargassum* of China: III. The species group *Binderia*. In: Tax. Econ. Seaweeds 5, 93–106.

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# SOME NEW TAXA OF *SARGASSUM* (PHAEOPHYTA) FROM VIETNAM

Nguyen Huu Dinh and Huynh Quang Nang

## Abstract

A new species, *Sargassum cornutifructum* H. D. Nguyen et Q. N. Huynh, and a new variety, *S. carpophyllum* var. *honomense* H. D. Nguyen et Q. N. Huynh, from Vietnam are described. The new species can be distinguished from other species of *Sargassum* on the basis of its attachment via small discoid haptera with many filamentous rhizoids from which erect stems arise. The new variety is characterized by flattened, foliaceous primary branches that are pinnately divided. It differs from *S. carpophyllum* var. *carpophyllum* and *S. carpophyllum* var. *nhatrangense* in these features.

## Introduction

*Sargassum carpophyllum* J. G. Agardh was first validly reported for Vietnam in volume 6 of *Taxonomy of Economic Seaweeds* (Ajisaka et al. 1997), although it had been previously mistakenly identified by Pham (1967), according to Tseng and Lu (1988, p. 33). Ajisaka et al. (1997) recognized the species with a transfer of variety *nhatrangense* Pham (1967) from *S. piluliferum* (Turner) C. A. Agardh to *S. carpophyllum* var. *nhatrangense* (Pham) Ajisaka (1997). Monographs on Chinese (Tseng and Lu 1988, pp. 30–33, figs. 4, 19–20) and Japanese (Ajisaka et al. 1995, pp. 13–16, figs. 2 and 3) species have been published. In this chapter, we add another variety, *S. carpophyllum* var. *honomense*, an addition that calls attention to some of the different aspects of the species across its geographic range from the Indian Ocean (Ceylon) type locality to various areas in the warm western Pacific. This variety differs principally from *S. carpophyllum* var. *nhatrangense* in the primary branches, which are flattened, foliaceous, and pinnately divided in *S. carpophyllum* var. *honomense*.

We also describe a new species, *S. cornutifructum*, on the basis of 2 characteristics: (1) the presence of hornlike protuberances on receptacles and (2) a newly described kind of basal part in which a membranous disc bears rhizoids from which erect stems are formed. These taxa are found in central and southern Vietnam (Fig. 1).

## Descriptions of the New Taxa

*Sargassum cornutifructum* H. D. Nguyen et Q. N. Huynh, sp. nov.
(Figs. 2–9)

Planta laete fusca, usque ad 50–70 cm alta. Hapteron tenuiter discoideum, 5–7 mm in diametro. Rhizomata filamentosa 1 mm diametro e margine enascentes. Surculi novi e rhizomatibus crescentes. Caulis teres, brevis, 3–4 mm

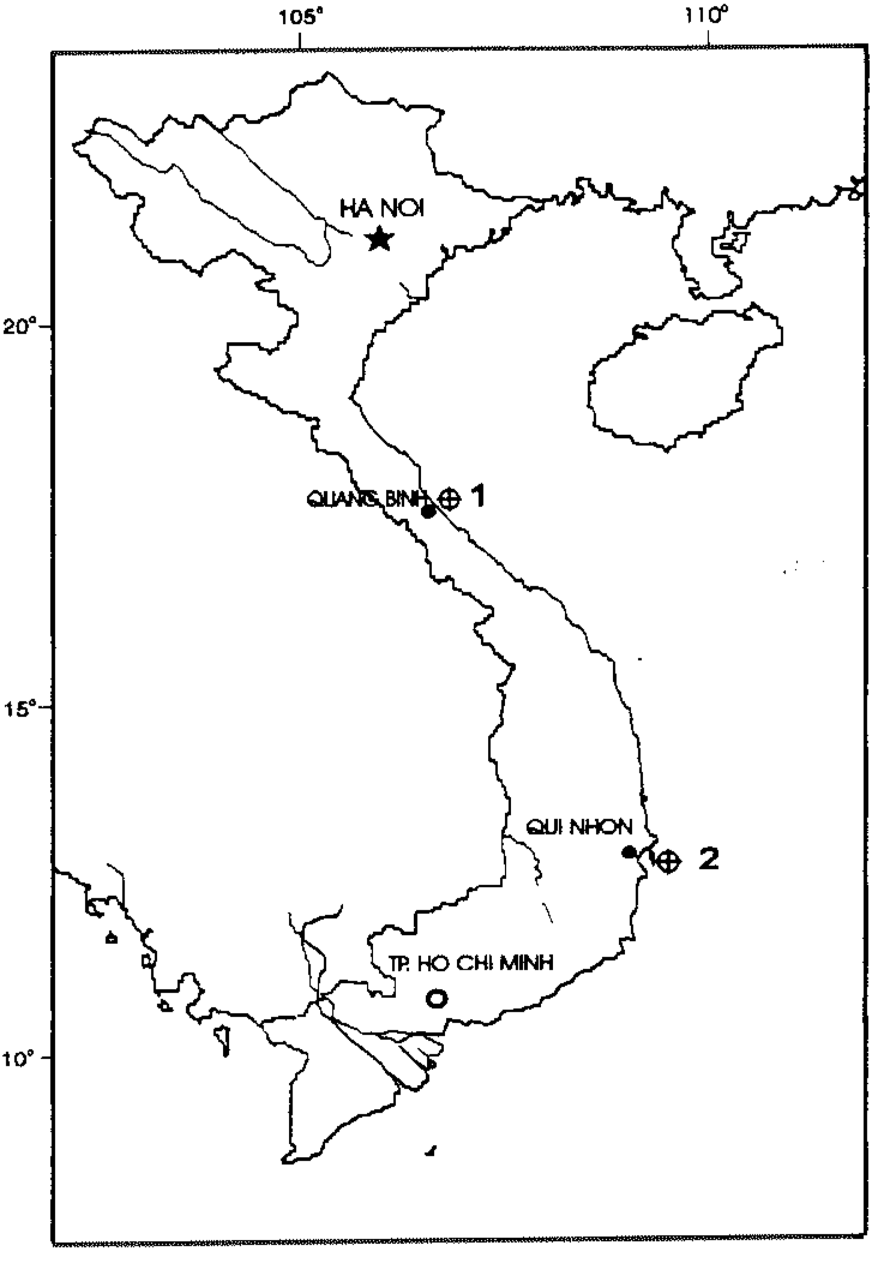


Fig. 1. Map of collection sites in Vietnam on the South China Sea. 1, Nom Island, Quang Binh Province, site of collection of *Sargassum carpophyllum* var. *honomense*. 2, Phong Mai Peninsula, Binh Dinh Province, site of collection of the new species, *Sargassum cornutifructum.*

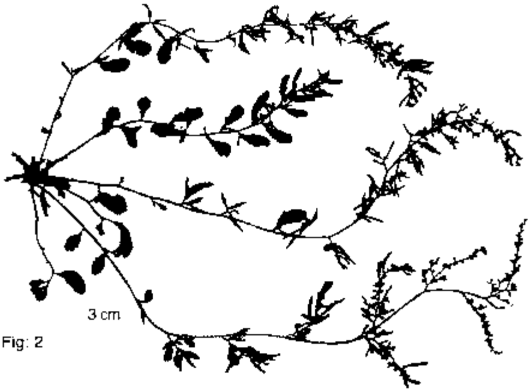


Fig: 2

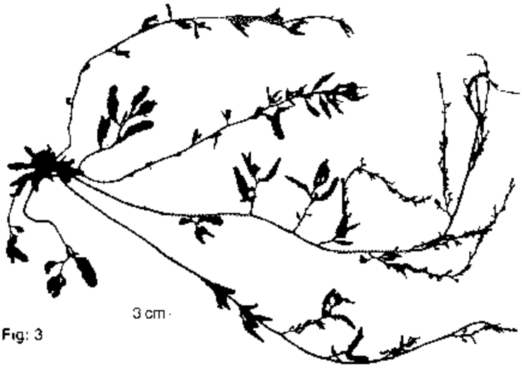


Fig: 3

**Figs. 2–9.** ***Sargassum cornutifructum*** **H. D. Nguyen et Q. N. Huynh, sp. nov. Fig. 2, Holotype specimen. Female plant with receptacles. Fig. 3, Holotype specimen. Male plant with receptacles.**

altus, 1.5–2 mm in diametro. Rami principali teretes usque ad 30–50 cm longi, 1–1.5 mm in diametro. Rami secundarii teretes, 3–8 cm longi, 0.7–1.2 mm in diametro. Folia in parte inferiore ellipsoidea vel obovata, apice obtusis et saepe duplicato-serratis, 2–3 cm longis, 8–13 mm latis, costa evanescenti in medio foliis. Cryptostomata in 2–3 seriatim utroque costae latere. Folia in parte superiore linearibus, 10–12 mm longi, 1–3 mm lati, margine acute denticulatis, costa evanescenti sub apices, cryptostomatibus seriatim utroque costae latere. Vesiculae sphaericae vel subsphaericae vel obovatae, apice mucronatae, stipitate teretes vel compressis, breviore quam vesiculis.

Planta dioica. Receptacula masculina cylindrica, saepe furcata, sine spina. Receptacula feminina variabila, cornuta, floscula vel triquetra.

Holotype: FMQ-96, deposited in the herbarium of Nha Trang Institute of Material Science, Nha Trang, Vietnam.

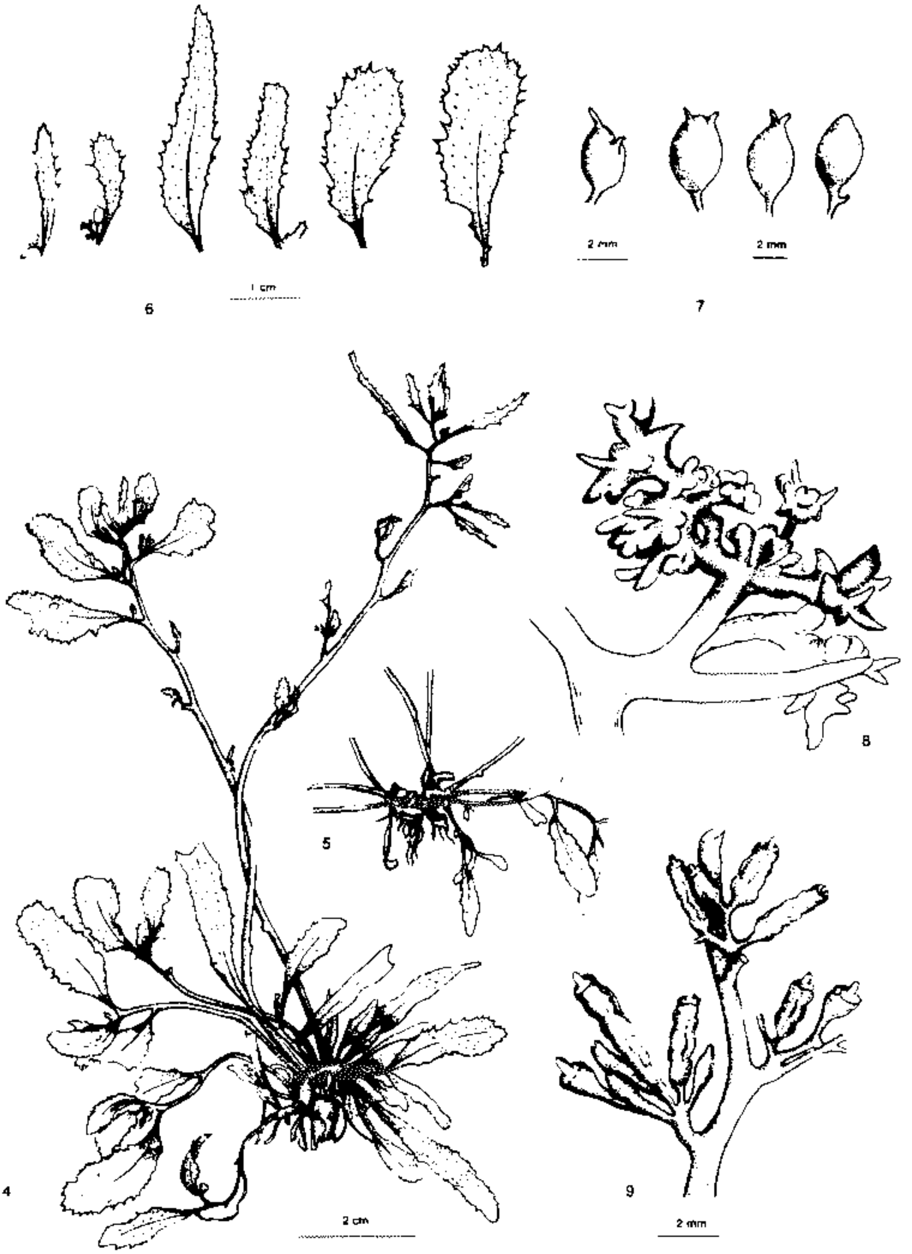


Fig. 4, Lower part of plant with holdfast. Fig. 5, Detail of holdfast with erect axes arising from near margins of disc (same scale as in Fig. 4). Fig. 6, Leaf shapes, sizes, toothed margins, and midrib characteristics. Fig. 7, Ornamentation of vesicles. Fig. 8, Female receptacle with hornlike projections. Fig. 9, Male receptacles with no hornlike ornamentation. Scale is the same for Figs. 8 and 9.

Habitat: Growing on subtidal rocks at a depth of 0.7 to 1 m, Phuong Mai Peninsula, Binh Dinh Province, central Vietnam. Not collected elsewhere.

Etymology: Named for the numerous hornlike protuberances on the female receptacles.

Plant light brown, up to 50–70 cm tall (Figs. 2 and 3); holdfast a membranous disc, 5–7 mm in diameter, margins provided by creeping filamentous rhizoids (Figs. 4 and 5), 1 mm in diameter, bearing several erect, slender stems (Fig. 5), only 3–4 mm long, 1.5–2 mm thick, from which several cylindrical primary branches are formed, 30–50 cm long, 1–1.5 mm in diameter. Secondary branches cylindrical, 3–8 cm long, 0.7–1.2 mm in diameter. Leaves in lower parts of the plant (Fig. 6) ellipsoidal-obovate, apex blunt and often double-toothed near the top, 2–3 cm long by 8–13 mm wide, midrib vanishing at the middle; cryptostomata in 2–3 rows on both sides of midrib. Leaves on upper parts of plant linear, 10–12 mm long, 1–3 mm wide, with sharp teeth at the margins, midrib vanishing below the apices; cryptostomata in 1 row on each side of midrib. Vesicles spherical to subspherical to obovate with 1 or 2 mucronate spines at the top (Fig. 7); stipe terete or slightly compressed, shorter than vesicles.

Plant dioecious. Male receptacles cylindrical (Fig. 9), sometimes forked at top, without spines; female receptacles with a variety of forms (Fig. 8), mostly with many hornlike (cornute) protuberances, or triquetrous.

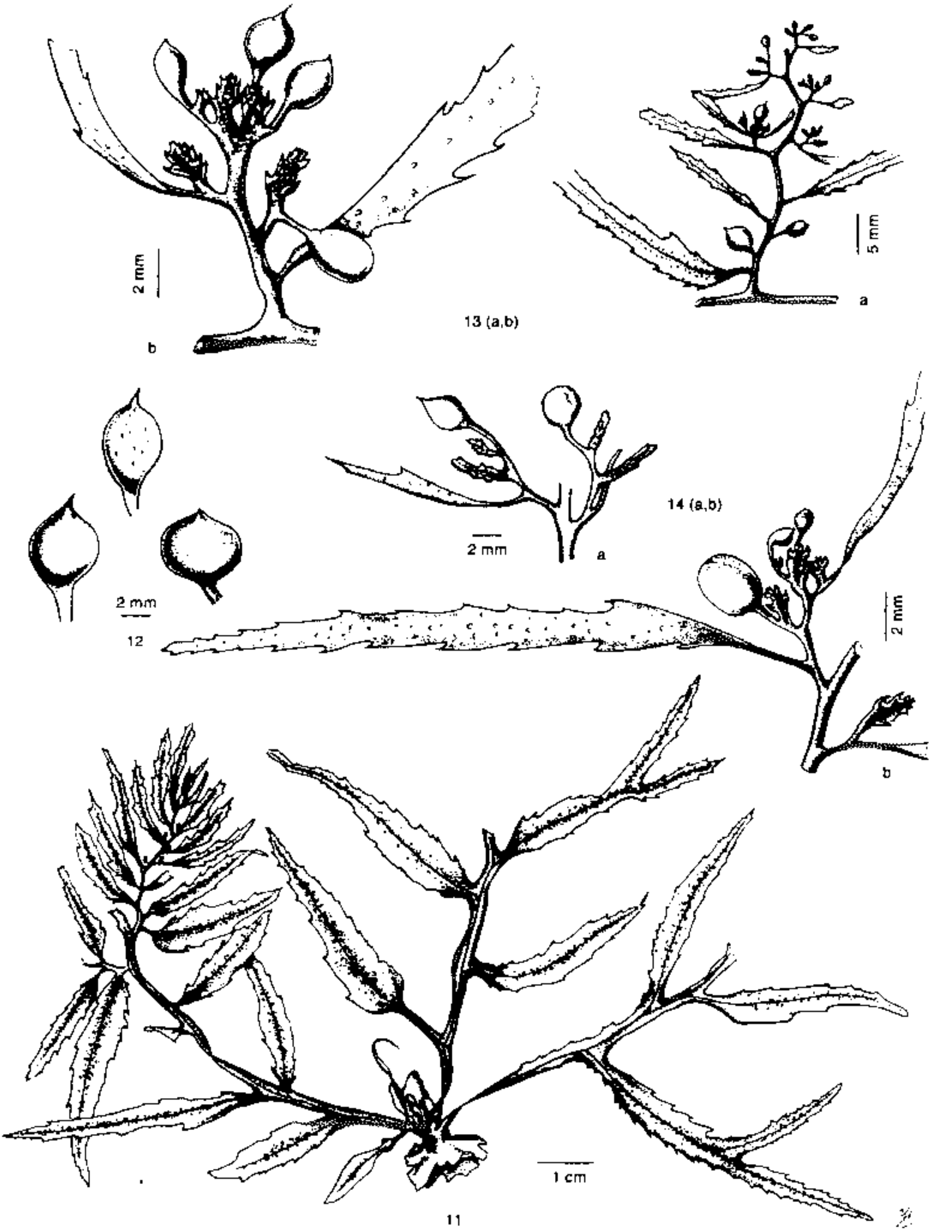
Remarks: Several Asian species of *Sargassum* have creeping rhizoidal outgrowths (e.g., *S. ammophilum* Yoshida et Konno, *S. miyabei* Yendo, and *S. nipponicum* Yendo). These species belong to the subgenus *Bactrophycus* (Tseng et al. 1985), whereas *S. carpophyllum* and *S. cornutifructum* are assigned to the subgenus *Sargassum*. The rhizoids that give rise to erect axes in *S. cornutifructum* differ from those described for any other species of *Sargassum*. However, the genus has many species, especially species described on the basis of specimens collected as drifting material, that lack holdfasts of any kind. Perhaps, at some time, similar holdfasts will be found in a species that is already named.

### *Sargassum carpophyllum* var. *honomense* H. D. Nguyen et Q. N. Huynh, var. nov. (Figs. 10–14)

Frondes luteo-fuscae, molles, in siccitate chartae adhaerentes, usque ad 50–150 cm altae. Haperon discoideum usque ad 8–10 mm in diametro. Caulis teres, brevis, usque ad 2–5 mm longus, 1.5–2 mm in diametro, pagina verrucata, 3–5 ramorum principales enastus. Rami principali complanati et foliacei, usque ad 50–80 cm longi, 3–5 mm lati, costate in parte inferiore, cylindraceis in parte superiore, pinnatim ramiferi. Rami secondarii compressi. Folia in ramo principali lanceolata, simplicia vel pinnata, usque ad 3–8 cm longa, 4–5 mm lata, costa percurrenti vel evanescenti infra apice, margine integro vel vadoso denticulatis. Cryptostomata in multiseriatim utroque costae latere. Folia in ramo secondari elongato-lanceolata, usque ad 2–4 cm longa, 2–4 mm lata, raro furcata, margine acute denticulata,

Fig : 10

**Figs. 10–14. *Sargassum carpophyllum* var. *honomense* H. N. Nguyen et Q. N. Huynh, var. nov. Fig. 10, Holotype specimens with conspicuous pinnate branching of primary branches.**



Figs. 10–14. *Sargassum carpophyllum* var. *honomense* H. N. Nguyen et Q. N. Huynh, var. nov. Fig. 11, Lower part of plant with holdfast and winged-to-foliaceous primary branches. Fig. 12, Apices of vesicles with a single spine on 2 vesicles and 2 barely emergent spines on the third vesicle. Fig. 13a, Triquetrous female receptacles. Fig. 13b, Triquetrous male receptacles. Fig. 14a, Compressed female receptacles. Fig. 14b, Compressed male receptacles.

costa inconspicua, evanescenti sub apices; crypto-stomatibus seriatim utroque costae latere. Vesiculae sphaericae vel obovatae, saepe apices breve spina, 3–5 mm in diametro, stipitate teretes, breviore vel idem quam vesiclis.

Planta androgyna. Receptacula compressa vel triquetra, margine denticulata, usque ad 3–6 mm longa, 1–2 mm in diametro, simplicia vel bis furcata, racemoso disposita, holozygocarpicae.

Holotype: 31395 QB, deposited in the herbarium of Nha Trang Institute of Material Science, Nha Trang, Vietnam.

Habitat: Growing on subtidal rocks at depth of 1–3 m, maturing in March to April. Nom Island, Quang Trach, Quang Binh Province, Vietnam.

Etymology: Named for the geographic area (Hon Nom) where the species was found.

Fronds (Fig. 10) yellow-brown, soft in substance, adhering well to paper on drying, up to 50–150 cm tall; holdfast discoid up to 8–10 mm in diameter. Stem terete, short, 2–5 mm long, 1.5–2 mm in diameter, with warty surface, bearing 3–5 primary branches at the top (Fig. 10). Primary branches flattened, winged to foliaceous (Fig. 11), 50–80 cm long, 3–5 mm wide, pinnately branched with rachis tapering upward and disappearing into ends of branches. Secondary branches compressed to cylindrical. Leaves on the primary branches lanceolate, single or pinnate pinnately divided, up to 3–8 mm long, 4–5 mm wide, midrib percurrent or vanishing below the apices, entire or shallowly toothed at the margins, several rows of cryptostomata on both sides of midrib. Leaves on secondary branches elongate-lanceolate, up to 3–8 cm long, 4–5 mm wide, rarely furcate, with sharp teeth at the margins, midrib inconspicuous, vanishing below the apices; cryptostomata in 1 row on each side of the midrib. Vesicles spherical or round-obovate, many with 1 sharp, short spine at the apices (Fig. 12), rarely with branched spine; vesicles 3–5 mm in diameter, stipe terete, shorter or equal to the length of the vesicles.

Plant androgynous, receptacles compressed (Figs. 14a and 14b) to triquetrous (Figs. 13a and 13b) with dentate margins, up to 3–6 mm long, 1–2 mm in diameter, simple or branched furcately twice, racemosely arranged (Figs. 13b and 14b). Holozygocarpic.

Remarks: The initial specimens were collected at Nom Island in 1995. The pinnately branched primary branches that are flattened are characteristic of this new variety. Specimens of *S. carpophyllum* from other collections do not have this characteristic.

## Acknowledgments

We thank Dr. James Sullivan, California Sea Grant College System, for his continuing support and funding that allow us to participate in these valuable workshops. We acknowledge with gratitude the interest of Professor T. Yoshida and the "Sargassum Group" at the workshop in checking and discussing with us our *Sargassum* specimens, and we thank him for translating the Latin for us and for his kind advice. We also thank Dr. I. A. Abbott of the University of Hawaii for reviewing, commenting on, and improving our manuscript. We thank Mr. Vo Xuan Mai for preparing our photographs and drawings.

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# Section II. *Gelidiales*

## INTRODUCTION

Isabella A. Abbott

Santelices and Hommersand (1997) created a new genus, *Pterocladiella,* to accommodate the anatomical differences shown by *Pterocladia capillacea* and *Pterocladia lucida. Pterocladia lucida* is now the type species of the genus *Pterocladia,* which as currently circumscribed has only a few species in it. *Pterocladiella capillacea* is the type species of *Pterocladiella* as *P. capillacea* (Gmelin) Santelices et Hommersand. Santelices (1997) "tested" the criteria used for recognizing *Pterocladiella* on an isolated species of *Pterocladia, P. bulbosa* Loomis from Hawaii, and to no one's surprise (of those who know the steady, painstaking way in which Dr. Santelices works), he was able to transfer this species to *Pterocladiella.* In this volume, Xia Bangmei reports *Pterocladiella caloglossoides* (Howe) Santelices from China, a new combination made by Santelices (1998). As people say, "It's a small world."

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# PATTERNS OF CARPOSPORANGIAL PRODUCTION AMONG SPECIES OF *GELIDIUM* (GELIDIALES, RHODOPHYTA)

Bernabé Santelices

## Abstract

Segregation characters within the genus *Gelidium* were studied. Events that occurred after fertilization were examined in 12 species. The findings indicated marked interspecific differences in the size and extension of the fusion network, the shape of the gonimoblastic cell that initiates carposporangia, the way that carposporangia are produced, and the final arrangement of carposporangia in the cystocarp. The resulting groups contain species that also differ in size and morphological complexity, suggesting that thallus anatomy might be more important than currently thought. Research combining vegetative and reproductive morphology should help settle the currently recognized heterogeneity within the genus *Gelidium*.

## Introduction

Previous studies on the structure of cystocarps (Santelices 1991a, 1991b) detected intrageneric heterogeneity within *Pterocladia* and *Gelidium* that was later supported by parsimony analysis of *rbcL* nucleotide sequences from 32 species of Gelidiales (Freshwater et al. 1995). More detailed studies on key species in the genus *Pterocladia* found differences within the genus in the way in which nutritive filaments are disposed after fertilization and how carposporangia are produced (Santelices 1991a, 1991b; Hommersand and Fredericq 1996). On the basis of these findings, the new genus *Pterocladiella* was proposed (Santelices and Hommersand 1997), and after reexamination, most of the valid species of *Pterocladia* were transferred to the new genus (Santelices and Hommersand 1997; Santelices 1997, 1998).

In contrast, the heterogeneity in *Gelidium* remains unsettled. Intrageneric differences observed include the role of cortical filaments in the formation of a fusion network during cystocarpic development (Santelices 1991b) and the medullary structure of apical parts of thalli (Rodríguez and Santelices 1996). However, species grouping based on a single character does not always coincide with species grouping based on other characters. Therefore a search is needed for additional characters that can be used within the genus.

Probably because of the scarcity of fertile female thalli in most taxonomic collections of species of *Gelidium*, previous studies did not examine interspecific morphological differences in the fusion network, the shape of the cell that produces the carposporangia, the planes of cell division during the production of carposporangia, and the importance of all these characters in the overall morphology of cystocarps. In fact, detailed studies on patterns of carposporangial production within *Gelidium* are restricted to *G. pteridifolium* (Hommersand and Fredericq

1988). Examination of these characters in 12 species of *Gelidium* revealed 4 different patterns of production of carposporangia and indicated that each pattern occurs in more than 1 species. This chapter describes the various patterns found.

## Materials and Methods

The species examined are listed in Table 1; most were used in previous studies (Santelices 1991b, Santelices and Flores 1995). Cystocarps were gradually rehydrated, in a manner designed to avoid tissue damage, and fixed in a 10% solution of formaldehyde in seawater. Fixed cystocarps were sectioned by using a Leitz freezing microtome. Sections were stained with 1% aniline blue and mounted in 50% Karo brand corn syrup. Photographs were taken with a Nikon Biophot microscope.

**Table 1. Cystocarpic Specimens of *Gelidium* Used in This Study**

| Species | Locality | Determined by | Collection Number |
|---|---|---|---|
| *G. abbottorium* R. E. Norris | South Africa | R. Anderson | SS/UC 6814 |
| *G. amansii* (Lamouroux) Lamouroux | Enoshima Bay, Japan | T. Yoshida | SS/UC 6671 |
| *G. australe* J. Agardh | Point Lonsdale, Victoria, Australia | A. Millar | SS/UC 6813 |
| *G. capense* (Gmelin) Silva | Cape St. Frances, South Africa | R. Anderson | SS/UC 6716 |
| *G. chilensis* (Montagne) Santelices | Pelancura, Chile | B. Santelices | SS/UC 6715 |
| *G. galapagense* Taylor | Golfo de Fonseca, El Salvador | E. Y. Dawson | US 3650 (ex BF) |
| *G. pluma* Loomis | Pupukea, Oahu, Hawaii, USA | B. Santelices | SS/UC 6815 |
| *G. pristoides* (Turner) Kützing | Kommetjie, Cape Peninsula, South Africa | A. Critchley | SS/UC 6640 |
| *G. pteridifolium* R. Norris, Hommersand et Fredericq | Dwesa Reserve, Transkei, South Africa | B. Santelices | SS/UC 6674 |
| *G. rex* Santelices et Abbott | Pelancura, Chile | B. Santelices | SS/UC 6717 |
| *G. robustum* (Gardner) Hollenberg et Abbott | Bahia Tortugas, Baja California, Mexico | L. Aguilar | SS/UC 6817 |
| *G. sesquipedale* (Clemente) Thuret | Santander, Spain | M. Salinas | SS/UC 6713 |

## Results

### Pattern in *Gelidium robustum* and *Gelidium sesquipedale*

A transverse section of a mature cystocarp of *G. robustum* (Fig. 1a) shows carposporangia in various degrees of development. The fusion network has developed around the medullary cells on both sides of the frond (Figs. 1a and 1b), reaching, on each side, a thickness 2–3 times the diameter of the medullary cells. Carposporangia are cut off by oblique and transverse divisions (Figs. 1c and 1d) from elongated, clavate, sometimes cup-shaped gonimoblast cells. Often, only a single carposporangium is cut off from the central part of the cup-shaped cell. However, up to 3 cells can be produced simultaneously from the apical end of this cell.

Cross sections through a cystocarp of *G. sesquipedale* (Figs. 2a–2d) show a similar pattern of carposporangial production. The fusion network also is thick and completely surrounds the medullary cells. Carposporangia are produced singly (Figs. 2b and 2c) or in short series of 2 or, more rarely, 3 carposporangia (Fig. 2d) from cup-shaped ends of gonimoblast cells.

A comparison of *G. robustum* and *G. sesquipedale* suggests some differences in shape and vacuolization of the gonimoblast cell, but the overall pattern of production of carposporangia appears to be similar in these 2 large species of *Gelidium*.

### Pattern in *Gelidium abbottorium* and Other Cylindrically Branched Species

Longitudinal sections of a mature cystocarp of *G. abbottorium* (Fig. 3a) also show mixtures of carposporangia of different maturity. Although spores of various sizes are present, they are arranged more or less regularly as clusters of carposporangia of approximately similar length surrounding the medullary cells. The fusion network develops on both sides of the frond around the medullary cells, reaching a thickness 1–2 times the diameter of the medullary cells (Fig. 3b). Gonimoblast cells are elongated and highly vacuolated (Figs. 3a–3c). They cut off carposporangia by oblique divisions in an irregularly alternate pattern, forming clusters of up to 8 carposporangia. Often the carposporangia at the tip of the cluster are the largest ones.

Among the materials studied, similar patterns of carposporangial production were found in *G. pteridifolium* (Figs. 4a and 4b), *G. amansii* (Fig. 4c), and *G. capense* (Fig. 4d). This type of cystocarpic construction seems to be common among medium-sized, cylindrically branched species of *Gelidium*.

### Pattern in *Gelidium pluma* and Other Broad-Bladed Species

Longitudinal (Fig. 5a) and transverse sections of the cystocarp of *G. pluma* also show a mixture of carposporangia of various sizes coexisting without special order. The fusion network (Fig. 5a) develops around the medullary cells on both sides of the frond. The thickness of the network may be similar to or smaller than

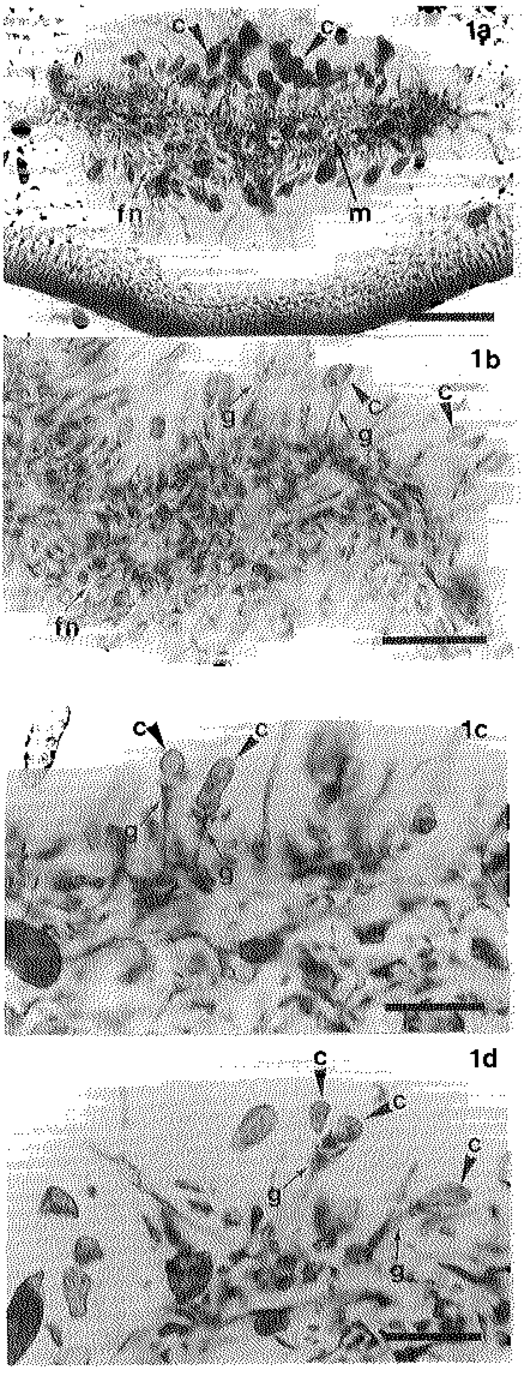


Fig. 1. *Gelidium robustum*. Fig. 1a, Cross section through a cystocarp shows medullary cells (m), fusion network (fn), and carposporangium (c) in various degrees of development. Bar = 100 μm. Fig. 1b, Detail of the fusion network around the medullary cells. Carposporangia (c) are terminal on elongated or clavate gonimoblast cells (g). Bar = 50 μm. Fig. 1c, Detail of production of carposporangia by transverse division from cup-shaped cells. Bar = 25 μm. Fig. 1d, Detail of bilateral production of carposporangia by gonimoblast cells. In 1 instance (left), 2 carposporangia have been simultaneously cut off at the tip of a clavate gonimoblast cell. In the other instance (right), the clavate cell is dichotomously divided apically, and each side is potentially able to produce carposporangia. Bar = 25 μm.

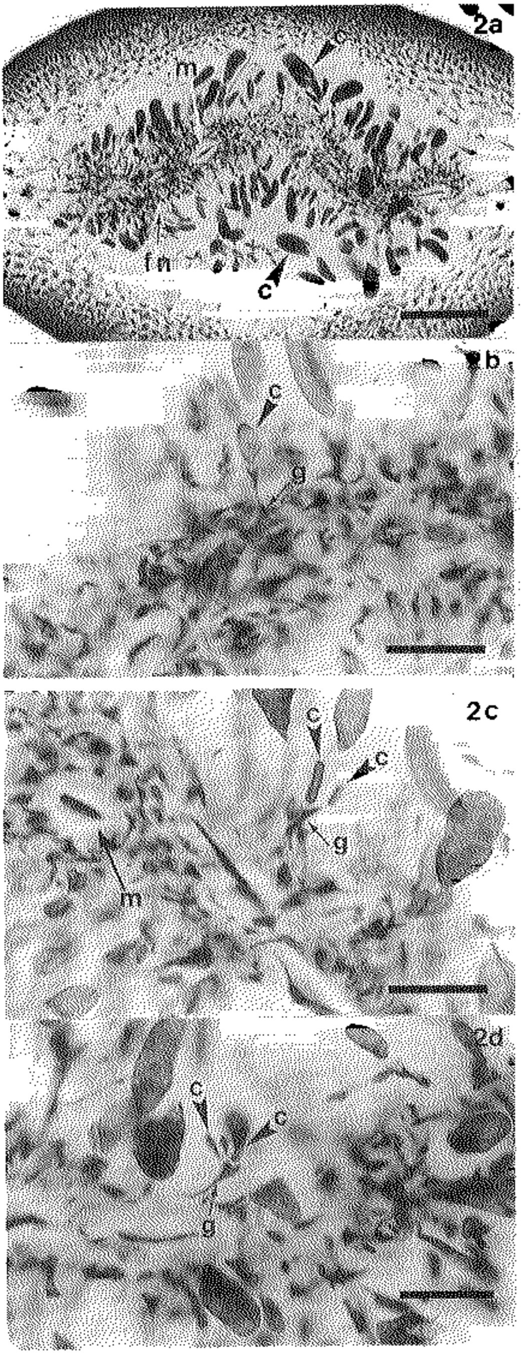


Fig. 2. *Gelidium sesquipedale*. Fig. 2a, Cross section through a cystocarp shows medullary cells (m), fusion network (fn), and carposporangia (c) in various degrees of development. Bar = 100 µm. Fig. 2b, Detail of an elongated gonimoblast cell (g) with dichotomous ends, each ending in cup-shaped tips (arrow). One carposporangium (c) is being cut off from 1 of these cup-shaped tips (arrowhead). Bar = 25 µm. Fig. 2c, Two carposporangia (c, arrowheads) are being produced from each of the tips of the cup-shaped gonimoblast cell (g). Bar = 25 µm. Fig. 2d, Cup-shaped gonimoblast cell (g) producing up to 3 carposporangia in a short series. Bar = 25 µm.

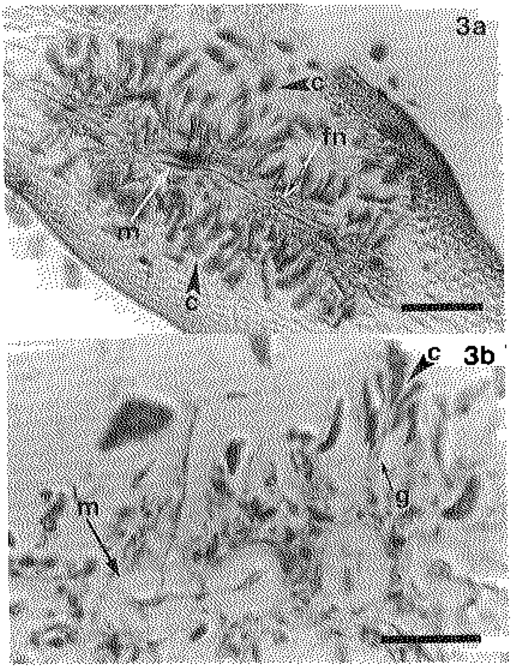
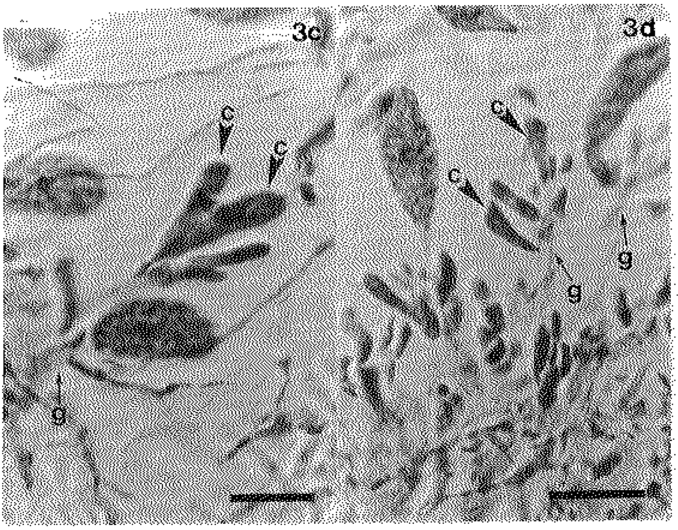
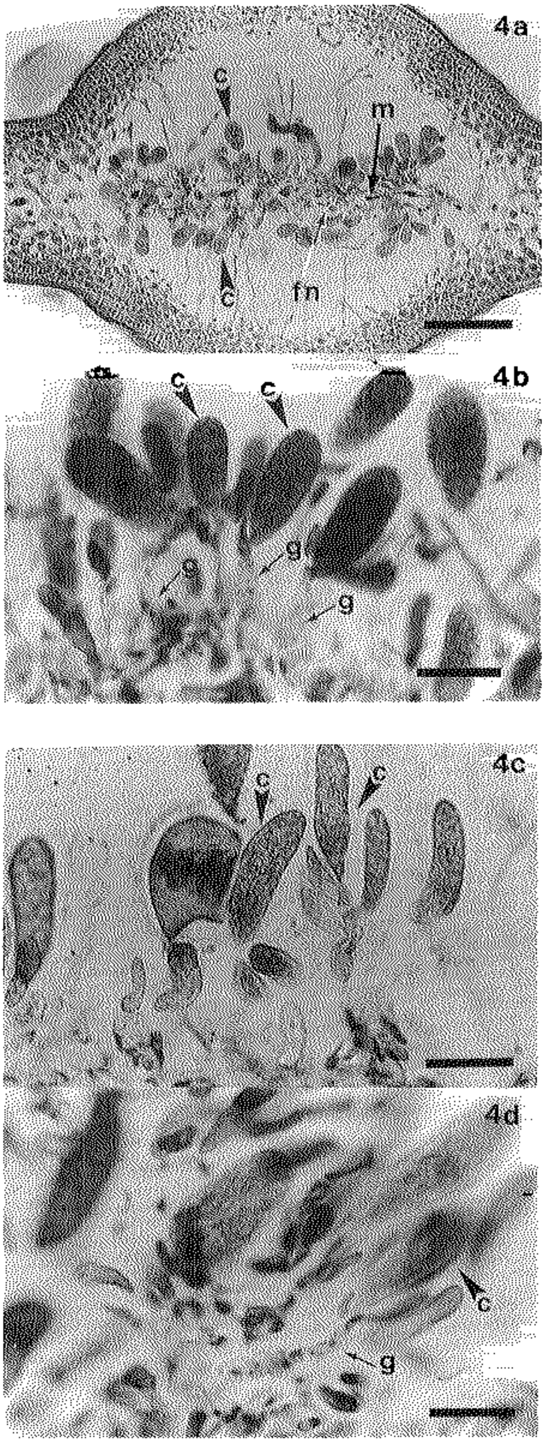


Fig. 3. *Gelidium abbottorium*. Fig. 3a, Longitudinal section through cystocarp shows medullary cells (m), fusion network (fn), and carposporangia (c) in various degrees of development. Bar = 100 µm. Fig. 3b, Detail of the medullary cell (m) in cross section shows the fusion network, highly vacuolated gonimoblast cell (g), and the cluster of carposporangia being produced at its tip. Bar = 50 µm. Fig. 3c, Details of gonimoblast cell (g) and clusters of carposporangia (c). Bar = 25 µm. Fig. 3d, Details of a cluster of spores (c) produced at the tip of gonimoblast cells (g).





Figs. 4a–4d. *Gelidium pteridifolium*, *Gelidium amansii*, and *Gelidium capense*. Fig. 4a, Cross section through a cystocarp of *G. pteridifolium* shows medullary cells (m), fusion network (fn), and carposporangia (c) in various degrees of development. Bar = 100 μm. Fig. 4b, Detail of the fusion network around medullary cells in *G. pteridifolium*. Carposporangia (c) are produced in an alternate pattern close to the apical tip of elongated gonimoblast cells (g). Bar = 25 μm. Fig. 4c, Detail of the cluster of carposporangia (c) in *G. amansii*. Bar = 25 μm. Fig. 4d, Elongated, vacuolated gonimoblast cell (g) and cluster of carposporangia (c) in *G. capense*. Bar = 25 μm.

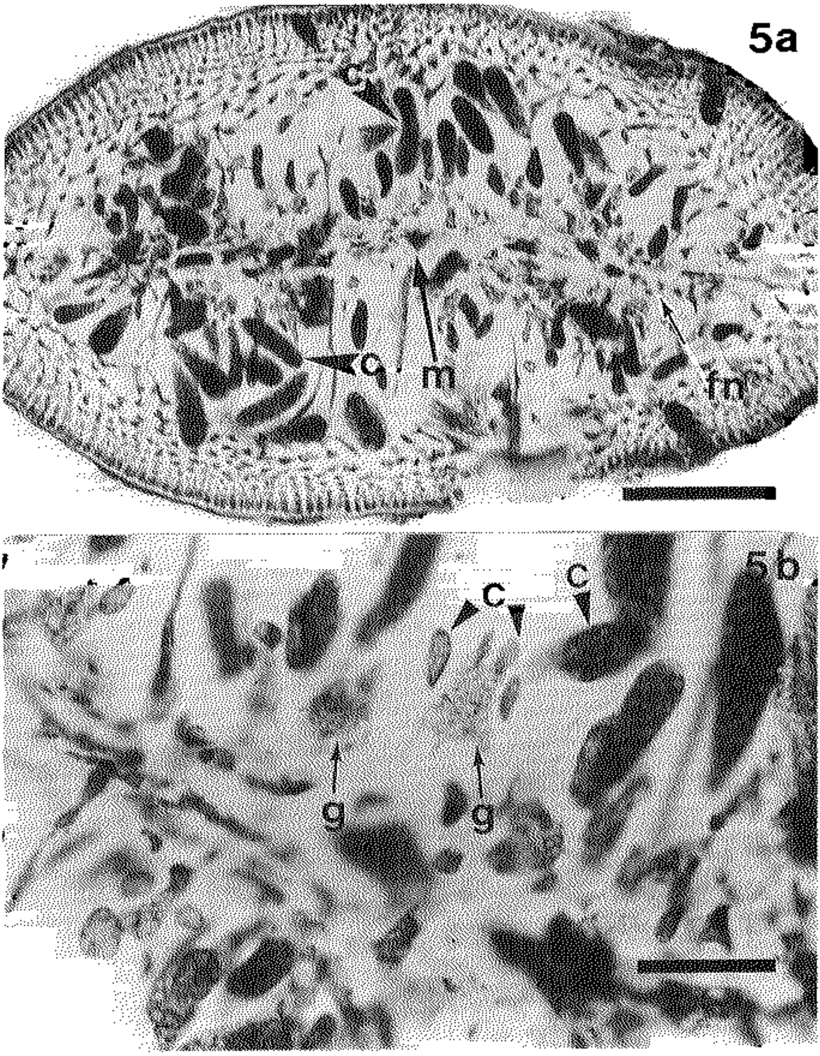
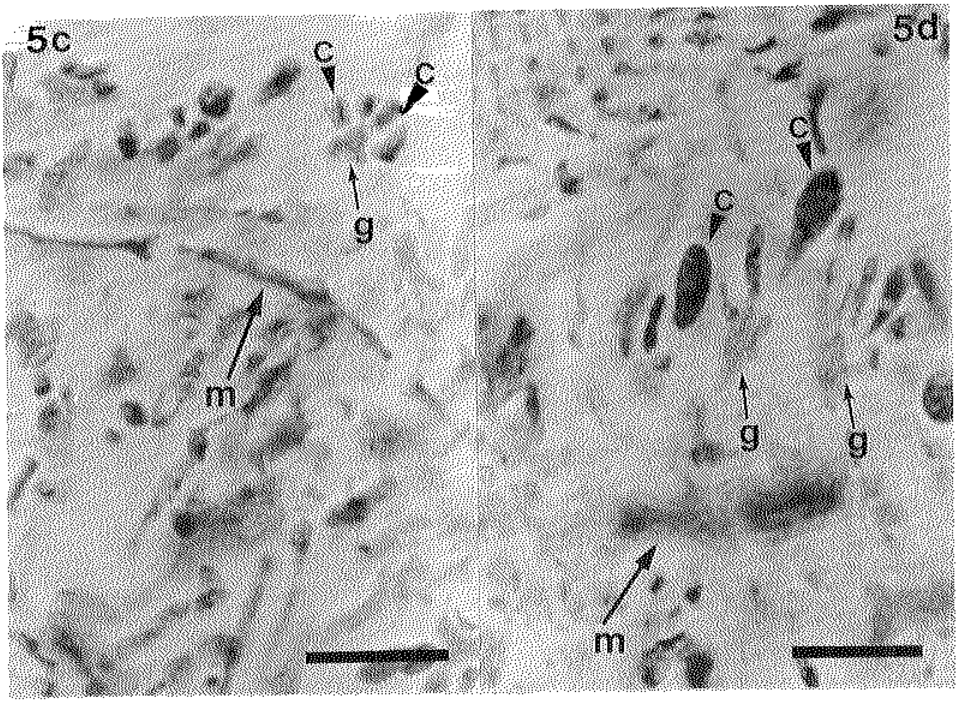


Fig. 5. *Gelidium pluma.* Fig. 5a, Longitudinal section through a cystocarp shows elongated medullary cells (m), the narrow fusion network (fn), and irregularly arranged carposporangia (c). Bar = 100 μm. Fig. 5b, Details of production of carposporangia (c) from triangular or irregularly shaped gonimoblast cells (g). Carposporangia emerging from each gonimoblast cell are of similar or very different sizes. Bar = 25 μm.



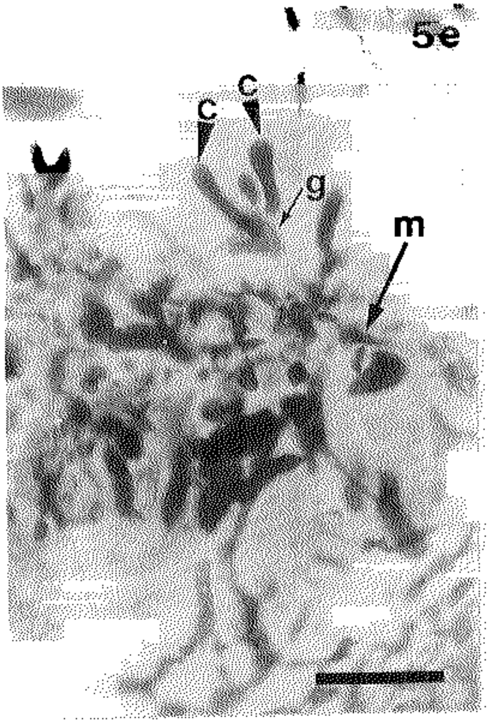


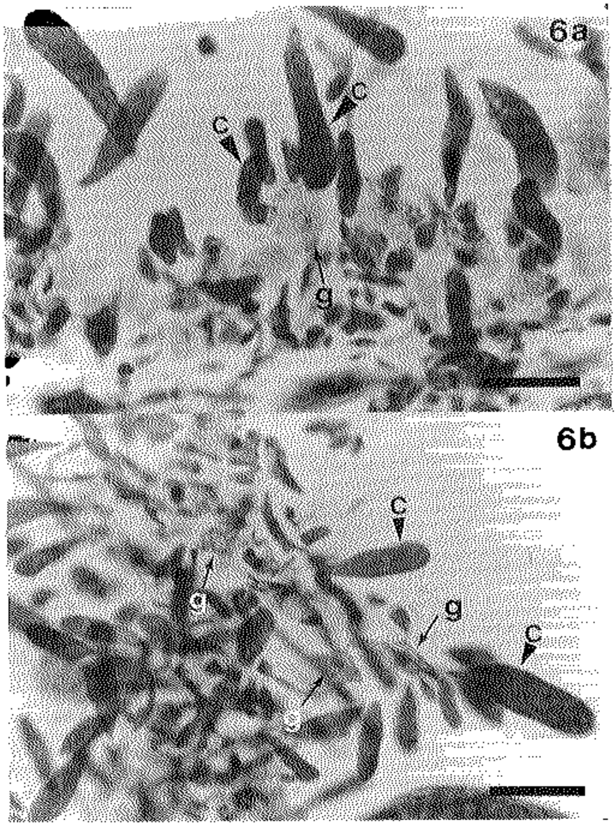
Fig. 5. *Gelidium pluma.* Figs. 5c–5d, Longitudinal section through a cystocarp shows elongated medullary cells (m), and details of production of carposporangia (c) from triangular or irregularly shaped gonimoblast cells (g). Carposporangia emerging from each gonimoblast cell are of similar or very different sizes. Bar = 25 μm. Fig. 5e, Detail of production of carposporangia seen from above. Carposporangia (c) appear as pigmented buds emerging from pale and vacuolated gonimoblast cells (g). Bar = 25 μm.

the thickness of the medullary cells, but in old cystocarps, the network can be twice as thick as the medullary cells are.

Independent of the thickness of the fusion network, gonimoblast cells in the network that initiate carposporangia are subquadrate, triangular, or irregularly shaped and flat and unbranched. Carposporangia originate as buds (Figs. 5b–5e) from highly vacuolated gonimoblast cells.

Carposporangia are produced in groups of 1–6, generally with each group in a different maturation stage, an observation that suggests successive emergence of carposporangia. However, simultaneous production of various carposporangia in approximately the same maturation stage also occurs (Fig. 5c).

Among the materials examined in this study, *G. chilensis* (Fig. 6a), *G. pristoides* (Fig. 6b) and *G. rex*, had a pattern of carposporangia production similar to that described for *G. pluma.*



**Figs. 6a and 6b. *Gelidium chilensis* and *Gelidium pristoides*. Fig. 6a, Detail of production of carposporangia (c) in *G. chilensis* from a pale, vacuolated, flat gonimoblast cell (g). Bar = 25 µm. Fig. 6b, Detail of production of carposporangia (c) in *G. pristoides* from pale, vacuolated, flat gonimoblast cells (g). Bar = 25 µm.**

### Pattern in *Gelidium australe* and *Gelidium galapagense*

Cross sections through a cystocarp of *G. australe* (Fig. 7a) show carposporangia that are regularly arranged, although of different sizes. The fusion network around the medullary cells (Fig. 7a) is thin, normally about the same or smaller in diameter than the medullary cells.

Carposporangia are generally cut off in a dichotomous manner at the tip of elongated, slightly clavate, vacuolated gonimoblast cells (Figs. 7b and 7c) that originate from the fusion network. Generally the 2 carposporangia produced are of different sizes, a finding that suggests that they are of different ages.

A similar pattern of production of carposporangia was found in *G. galapagense* (Figs. 8a and 8b). In this species, the fusion network is not abundant; it barely covers the medullary cells. Spores originate singly or dichotomously (Fig. 8b) from an elongated, slightly claviform gonimoblast cell.

## Discussion

The results presented here suggest critical differences among species of *Gelidium* in the size and extension of the fusion network and in the way in which carposporangia are produced. The extension of the fusion network can range from massive and thick, as in *G. sesquipedale* and *G. robustum,* to reduced and simple, as in *G. galapagense.* On the other hand, the shape of the gonimoblast cell that initiates formation of carposporangia, the way the carposporangia are formed, and the final arrangement of carposporangia also vary among groups of species. Carposporangia are produced singly or in small numbers by cup-shaped gonimoblast cells, as in *G. robustum* and *G. sesquipedale,* or they can be produced in larger numbers, forming clusters around the tips of elongated, cylindrical gonimoblast cells, as in *G. abbottorium, G. capense,* and *G. pteridifolium.* Alternatively, they may be budded off in large numbers by irregularly shaped, flat gonimoblast cells, as in *G. pluma, G. pristoides,* and *G. chilensis,* or be produced dichotomously by cylindrical gonimoblast cells, as in *G. australe* and *G. galapagense.*

In *Gelidium,* the fusion network is produced by proliferation of the gonimoblast filaments after the filaments have fused with nutritive cells and with fusion cells. The abundance of nutritive filaments is a character directly related to the medullary structure of the species of *Gelidium,* because nutritive filaments are initiated by basal cells of filaments of the third order. During development, nutritive tissues also envelop nearby cells of the second order (Fan 1961, Hommersand and Fredericq 1988). Therefore, the differences among groups of species of *Gelidium* with respect to this character seem to be related to the general pattern of construction of the individual thalli. Species with large thalli generally have a larger number of medullary cells than do smaller thalli, and the size of the medullary components of the large thalli also seems to be larger. In addition, the fertile areas in species of *Gelidium* are close to the tip, precisely the part of the thallus in which

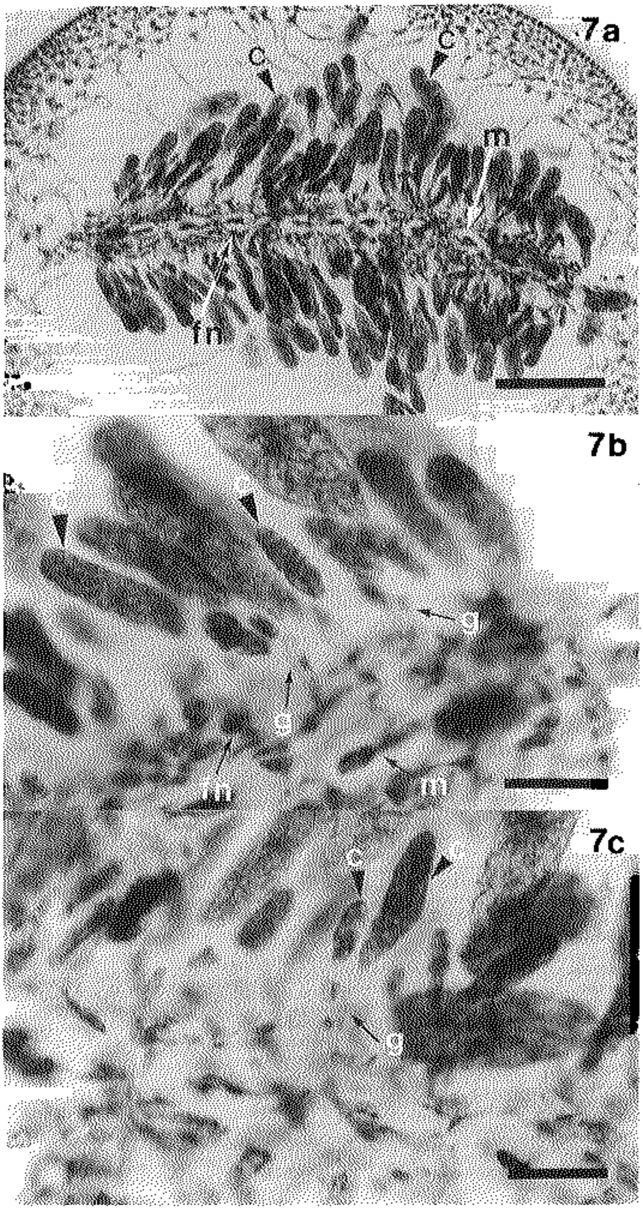
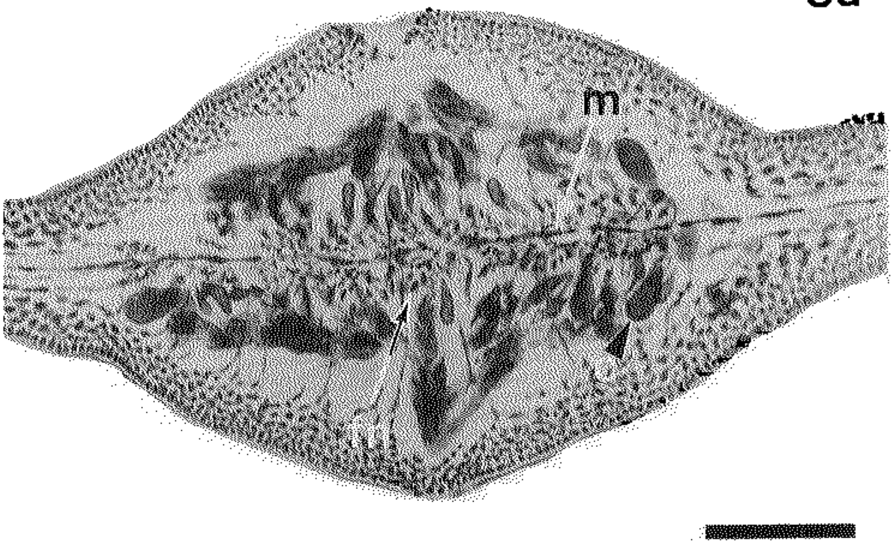


Fig. 7. *Gelidium australe.* Fig. 7a, Cross section through a mature cystocarp shows medullary cells (m), fusion network (fn), and regularly arranged carposporangia (c). Bar = 100 μm. Fig. 7b, Detail of production of carposporangia shows medullary cells (m), the thin fusion network (fn), and gonimoblast cells (g) initiating carposporangia (c). Bar = 25 μm. Fig. 7c, Detail of production of carposporangia shows the gonimoblast cell (g) in frontal view and carposporangia (c). Bar = 25 μm.

8a



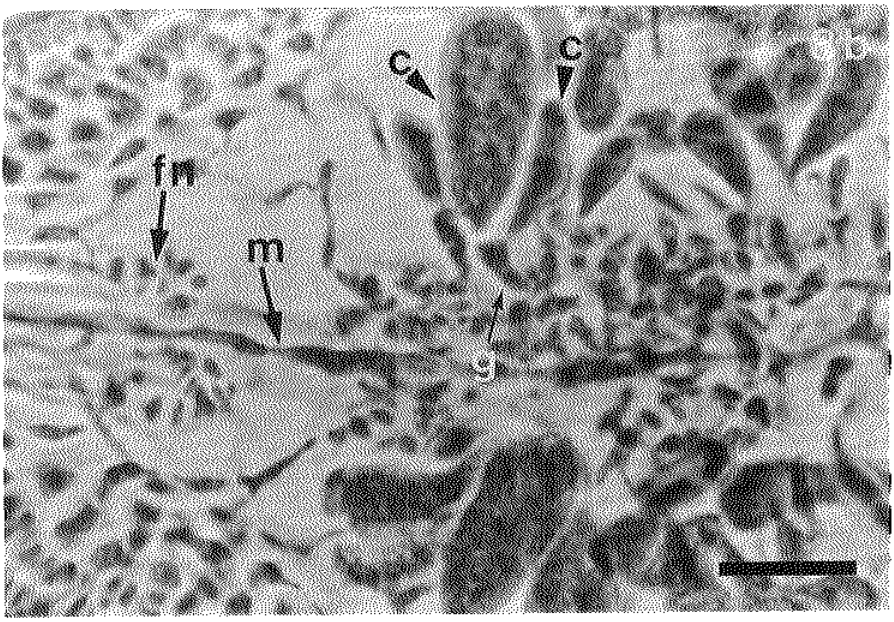


Fig. 8. *Gelidium galapagense*. Fig. 8a, Longitudinal section through cystocarp shows carposporangia (arrowhed) , thin fusion network (fn), and elongated medullary cells (m). Bar = 100 µm. Fig. 8b, Detail of carposporangial production shows the medullary cells (m), the fusion network (fn), the slightly clavate gonimoblast cell (g), and the carposporangia (c). Bar = 25 µm.

differences were found in medullary cells among groups of species of *Gelidium* (Rodríguez and Santelices 1996).

Therefore, differences in anatomy among these species might be more important than is currently thought, because these anatomical differences also determine differences in events that occur after fertilization. Additional studies should help elucidate whether or not the differences in the size and extension of the fusion network are quantitative characters directly related to the size and shape of medullary cells or if these different types of medullary cells also determine important differences among species in patterns that occur after fertilization. Such studies should also clarify whether or not the pattern of production of carposporangia in any given species changes with the stage of cystocarpic development, and the age of the plant.

Data suggest that the structure of the inner cortical cells should also be considered. In several species of *Gelidium,* during early events that occur after fertilization, cortical cells close to the carpogonium take part in the formation of fusion cells (Dixon 1959, Fan 1961, Hommersand and Fredericq 1988). On the other hand, the innermost cells of cortical filaments running between the cortex and the fusion network in *G. coulteri* become part of the fusion network, later producing spore initials (Santelices 1991b). In *G. musciformis*, on the other hand, the cortical filaments may fuse with the nutritive filaments and may branch freely within the cystocarpic cavity to the point of filling the cavity at later stages after fertilization. Additional studies, therefore, should critically evaluate the functions these cells play at the various stages of cystocarpic development.

The possibility that groups of species of *Gelidium* can be segregated at a generic level on the basis of characters that include both reproductive and vegetative morphologic features is consistent with the characterization so far used for other genera in the family. *Porphyroglossum, Acanthopeltis, Yatabella, Ptilophora,* and *Suhria* are all segregated mainly on the basis of vegetative characters (Fan 1961). Similarly, recent reexamination of species of *Pterocladia* (Santelices 1998) resulted in 2 groups of species *(Pterocladia* and *Pterocladiella),* each with different sizes, geographic distribution, and morphological structure. Combined research on the vegetative and reproductive morphology of the species of *Gelidium* should help determine whether similar levels of differences can be distinguished.

## Acknowledgments

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# TAXONOMIC STATUS OF THE SPECIES ORIGINALLY ASCRIBED TO THE GENUS *PTEROCLADIA* (GELIDIALES, RHODOPHYTA)

Bernabé Santelices

## Abstract

Significant taxonomic changes have occurred with the species originally described in the genus *Pterocladia*. Some of the species belong to other genera, and others have become synonyms of valid species. This study updates the current taxonomic status of the 28 taxa originally ascribed to *Pterocladia*.

## Introduction

The genera *Gelidium* and *Pterocladia* are the most diverse and the most taxonomically confused in the family Gelidiaceae. In each of these 2 genera, a number of specific epithets that are nomenclaturally and taxonomically correct coexist with synonyms and later homonyms of other species in the same genus and with basionyms of species belonging to different genera. In the case of the specific epithets ascribed to the genus *Pterocladia*, some of the names are synonyms of other species (e.g., Stewart 1968, Santelices 1976), and many names indicate species that belong in other genera (e.g., Stewart 1974, Stewart and Norris 1981, Santelices 1991). In the case of *Pterocladia*, the situation has become especially confusing because of the recent creation of the genus *Pterocladiella* (Santelices and Hommersand 1997) and the subsequent transfer to that genus of most of the valid species of *Pterocladia* (Santelices 1997, 1998).

Because of the taxonomic and nomenclatural changes that have occurred with the species of *Pterocladia*, a list of the current taxonomic status of the 28 species originally assigned to the genus is useful. The following is such a list, in alphabetical order.

## Current Taxonomic Status of *Pterocladia* Species

### 1. *Pterocladia americana* Taylor

Originally described for Port Antonio, Jamaica (Taylor 1943, pp. 154–156, pl. IV, fig. 1), *P. americana* Taylor has been found also in Bermuda, North Carolina, Florida, Texas, Hispaniola, Barbados, Costa Rica, Venezuela, Trinidad, and Tobago (Taylor 1960). The internal cystocarpic structure is of the Gelidium-type (Santelices 1976). Therefore, the species was transferred to the genus *Gelidium* as *G. americanum* (Taylor) Santelices.

### 2. *Pterocladia bartlettii* Taylor

*Pterocladia bartlettii* Taylor was described by Taylor (1943, p. 150, pl. 4, fig. 2) for Saint Louis du Sud, Haiti. It is now known from Texas and the Gulf of Mexico; several Caribbean islands, including Cuba, Jamaica, Puerto Rico, Hispaniola, and Guadeloupe; and various localities in Venezuela (see Santelices 1998 for references). The internal cystocarpic structure is of the Pterocladiella-type. Therefore, the species was transferred to the genus *Pterocladiella* as *Pterocladiella bartlettii* (Taylor) Santelices.

### 3. *Pterocladia bulbosa* Loomis

*Pterocladia bulbosa* Loomis was described by Loomis (1960, pp. 7–8, pl. 9, figs. 2–3; pl. 10, fig. 3; pl. 11, figs. 1 and 4) from materials collected in Molokai, Hawaiian Islands. Currently, the species is known for the Hawaiian Archipelago only. The internal cystocarpic structure is of the Pterocladiella-type. Therefore the species was transferred (Santelices 1997) to the genus *Pterocladiella* as *Pterocladiella bulbosa* (Loomis) Santelices.

### 4. *Pterocladia caerulescens* (Kützing) Santelices

*Pterocladia caerulescens* (Kützing) Santelices, originally assigned to the genus *Gelidium* (Kützing 1868, p. 19, pls. 56c and 56d) was described on the basis of plants collected in New Caledonia. Currently, the species is also known to occur in Vietnam, Guam, Indonesia, and the Hawaiian Islands. The internal cystocarpic structure is of the Pterocladiella-type (Santelices and Hommersand 1997). Therefore, the species was transferred to the genus *Pterocladiella* as *Pterocladiella caerulescens* (Kützing) Santelices et Hommersand.

### 5. *Pterocladia caespitosa* (Kylin) R. E. Norris

Originally described as a *Gelidium* from Kenya (Kylin 1938, p. 8, figs. 2E–2H), *P. caespitosa* (Kylin) R. E. Norris is also known from Natal, Mozambique, and the Seychelles (Santelices 1998). The internal cystocarpic structure is of the Pterocladiella-type (Santelices 1998). Therefore, the species was transferred to the genus *Pterocladiella* as *Pterocladiella caespitosa* (Kylin) Santelices.

### 6. *Pterocladia caloglossoides* (Howe) Dawson

Originally described as a species of *Gelidium* from the coasts of central Peru (Howe 1914, p. 96, pl. 34, fig. 7, pl. 35), *P. caloglossoides* (Howe) Dawson has an extended geographic distribution in temperate Pacific South America (central Chile to northern Peru), Pacific North America (Mexico to Washington and British Columbia), the Hawaiian Islands, Indonesia, the Great Barrier Reef in Australia, Guadeloupe, Natal, Tanzania, and China. The internal cystocarpic structure is of the Pterocladiella-type (Santelices 1998). Therefore the species was transferred to the genus *Pterocladiella* as *Pterocladiella caloglossoides* (Howe) Santelices.

### 7. *Pterocladia capillacea* (Gmelin) Bornet et Thuret

*Pterocladia capillacea* (Gmelin) Bornet et Thuret was described by Gmelin (1768, T 15, fig. 1) on the basis of materials collected in the "Mediterranean." Currently, this species is recognized as a widely distributed taxon, known from many sites in temperate and tropical waters (see Santelices and Stewart 1985). The internal cystocarpic structure is of the Pterocladiella-type (Santelices and Hommersand 1997). Therefore the species was transferred to the genus *Pterocladiella* as *P. capillacea* (Gmelin) Santelices et Hommersand. *Pterocladiella capillacea* is the type species of the genus *Pterocladiella.*

### 8. *Pterocladia complanata* Loomis

*Pterocladia complanata* Loomis was described by Loomis (1949, p. 4, pl. 6, figs. 1 and 2; pl. 7, figs. 1–4; pl. 10) on the basis of drifted materials collected in Orange County, in Southern California, in the United States. In her study on morphological variations of *Pterocladiella* (=*Pterocladia*) *capillacea* in California, Stewart (1968) concluded that the type materials of *P. complanata* represented 1 of several intergrading variants of intertidal *P. capillacea*. Therefore, *P. complanata* is now regarded as a synonym of *P. capillacea*.

### 9. *Pterocladia densa* Okamura

*Pterocladia densa* Okamura was described on the basis of materials collected in Kashiwadima (=Kashiwa jima), Tosa Province, and in Hatydyodima (=Hachijō jima), Japan (Okamura 1934, p. 63, pl. 30, figs. 1–2; pl. 33, figs. 4–8). After studying the morphological variations of *P. capillacea* in Southern California, Stewart (1968) suggested that *P. densa* might be a variant of *P. capillacea*. The type materials of *P. densa* at the herbarium in Hokkaido University contain 2 plant fragments, both illustrated by Okamura (1934). Both fragments are *P. capillacea* with congested branching similar to that of thalli of *P. capillacea* described by Gardner (1927, pl. 37, fig. 1) as *G. pyramidale*. One of the fragments (Okamura 1934, p. 30, fig. 2) is densely branched; the other (Okamura 1934, pl. 30, fig. 1) maintains the pyramidal appearance so typical of *P. capillacea*. Therefore, *P. densa* also is considered a synonym of *P. capillacea*.

### 10. *Pterocladia heteroplatos* (Børgesen) Umamaheswara Rao et Kaliaperumal

Described as a species of *Gelidium* by Børgesen (1934, p. 3, fig. 3), *P. heteroplatos* (Børgesen) Umamaheswara Rao et Kaliaperumal is reported from India and Ceylon. Unilocular cystocarps have been found in fertile female thalli (Umamaheswara Rao and Kaliaperumal 1980). However, the internal cystocarpic structure of *P. heteroplatos* has not been compared with that of *Pterocladiella* species. Therefore, although *P. heteroplatos* (Børgesen) Umamaheswara Rao et Kaliaperumal remains in the genus *Pterocladia,* it may belong to the genus

*Pterocladiella*. The size and the geographic pattern of distribution of *P. heteroplatos* are more consistent with the respective patterns found in *Pterocladiella* than with the current delimitation of *Pterocladia* (Santelices 1998). Future studies also should assess the specific limits between *P. heteroplatos* and *P. media,* because both species are morphologically similar (see Santelices 1998).

### 11. *Pterocladia lindaueri* Fan

The description of *P. lindaueri* Fan was based on materials collected in Bay of Islands, Long Beach, New Zealand (Fan 1961, p. 335). However, the topotype material of this species reportedly was indistinguishable from *P. capillacea* from New Zealand (Adams 1994). Therefore, *P. lindaueri* Fan is considered a synonym of *P. capillacea.*

### 12. *Pterocladia lucida* (R. Brown) J. Agardh

Originally described by Turner (1819, p. 98, pl. 238)) from the "south coast of N. Holl" (=Australia), *P. lucida* (R. Brown) J. Agardh occurs in New Zealand, western and southern Australia, and Tasmania. It has also been reported from Java and Sri Lanka. *Pterocladia lucida* (R. Brown) J. Agardh is the type species of the genus *Pterocladia.*

### 13. *Pterocladia macnabbiana* Dawson

First described from inner Golfito Bay, Golfo Dulce, Costa Rica (Dawson 1957, p. 14, figs. 4c–4d), *P. macnabbiana* Dawson was later reported from Puerto Peñasco (Gulf of California), Bahia Culebra in El Salvador, and northern Peru. The internal cystocarpic structure is of the Gelidium-type (Santelices 1998). Therefore, the species was transferred to the genus *Gelidium* as *G. macnabbianum* (Dawson) Santelices.

### 14. *Pterocladia media* Dawson

*Pterocladia media* Dawson was originally described (Dawson 1958, p. 60, pl. 2, figs. 3–4; pl. 24, fig. 1) on the basis of vegetative specimens gathered in La Jolla, California. Later, Stewart (1974) assigned *G. crinale* var. *luxurians*, as identified by Dawson from Puerto Peñasco, to *P. media*, expanding significantly the description. A new study on the limits of *P. media* and critical comparisons with the morphologically similar *P. heteroplatos* are necessary to confirm the status of this taxon. The size and geographic pattern of distribution of *P. media* suggest that the species, if valid, may belong in the genus *Pterocladiella.*

### 15. *Pterocladia melanoidea* (Schousboe ex Bornet) Dawson

*Pterocladia melanoidea* (Schousboe ex Bornet) Dawson was described (Bornet 1892, p. 269) on the basis of materials collected in Morocco. The species is now known to occur in the Mediterranean, the Iberian peninsula, the Atlantic coast of Morocco, and Senegal. Dawson (1962) reported this species from Costa Rica, and although he did not find cystocarps, he transferred the species to *Pterocladia*. He based his decision on the arrangement of tetrasporangia in decussate rows and the presence of rhizines in the central medulla. None of these characters, however, singly or together, distinguishes *Gelidium* from *Pterocladia*.

Using an isolate from Mallorca (Balearic Islands), Frederiksen and Rueness (1990) completed the life history of *P. melanoidea* (Schousboe ex Bornet) Dawson in culture. They found unilocular cystocarps with carposporangia developing in short chains. However, seemingly unaware of Dawson's transfer, they proposed the new combination *P. melanoidea* (Schousboe ex Bornet) Frederiksen et Rueness. Unfortunately this combination is a later homonym of the combination proposed by Dawson (1962).

On the basis of the clear illustrations published by Frederiksen and Rueness (1990, figs. 12 and 13), Hommersand and I (Santelices and Hommersand 1997) concluded that the species belongs to *Pterocladiella*. Therefore it was transferred to that genus as *Pterocladiella melanoidea* (Schousboe ex Bornet) Santelices et Hommersand.

*Pterocladiella melanoidea* is the valid name for the European materials. The Costa Rican specimens, assigned by Dawson (1962) to this species, await additional analysis. Without evidence of fertile female thalli, these specimens cannot be assigned to *Gelidium*, *Pterocladia*, or *Pterocladiella*.

### 16. ***Pterocladia mexicana*** **Taylor**

The description of *P. mexicana* Taylor was based on materials dredged from Pacific Baja California (Taylor 1945, p. 159, pl. 35). The morphological variation of *P. capillacea* in California includes this form (Stewart 1968). Therefore, *P. mexicana* is now considered to be a synonym of *P. capillacea*.

### 17. ***Pterocladia musciformis*** **Taylor**

*Pterocladia musciformis* Taylor was described on the basis of specimens collected at Golfo Dulce, Costa Rica (Taylor 1945, p. 159). The materials were sterile, but Taylor assigned the species to *Pterocladia* on the basis of the distribution of the hyphae. The species has also been reported from Colima in Pacific Mexico and from El Salvador. Examination of cystocarpic materials showed cystocarps of the Gelidium-type. The species was transferred earlier to the genus *Gelidium* as *G. musciformis* (Taylor) Santelices (Santelices 1991, p. 4).

### 18. ***Pterocladia nana*** **Okamura**

*Pterocladia nana* was described by Okamura (1901, p. 57, pl. 278, figs. 1–14) on the basis of materials collected in Seto and Koshikidima (=Koshiki jima), Japan. Later, others (e.g., Stewart 1968, Santelices 1977) showed that local morphological variability of natural populations of *P. capillacea* may include the taxonomic features of *P. nana*. Furthermore, the type materials in Okamura's herbarium in

Hokkaido University contain 2 plants, both illustrated by Okamura (1934, pl. 33, fig. 9). Both can be identified as *P. capillacea* with terete cylindrical axes, and a pyramidal form. Remarkably, despite the small size (2–4 cm long) of the plants, the thalli are fertile. Because of the morphological variability known for *P. capillacea,* small, fertile plants do not justify specific segregation of the Japanese species. *Pterocladia nana* therefore should be considered a synonym of *P. capillacea.*

### 19. *Pterocladia okamurae* (Setchell and Gardner) Taylor (as "okamurai")

Originally described as a species of *Gelidium* from Revilla Gigedo Islands (Setchell and Gardner 1937, p. 75, pl. 6, fig. 16; pl. 7, fig. 38) *P. okamurae* was later reported also from the Galapagos (Taylor 1945). However, the morphological variability exhibited by *P. capillacea* in Southern California (Stewart 1968) includes forms such as *P. okamurae.* Therefore, *P. okamurae* is considered to be a synonym of *P. capillacea.*

### 20. *Pterocladia parva* Dawson

*Pterocladia parva* was described (Dawson 1953, p. 77, pl. 6, fig. 2) on the basis of materials collected in northeastern Gulf of California. Dawson recognized that the new species was similar to *P. caloglossoides* but differed in having "decidedly pinnate erect parts." After studying new collections from the Gulf of California and culturing the species under controlled conditions, Stewart and Norris (1981) concluded that *P. caloglossoides* and *P. parva* belong to the same species. Therefore, *Pterocladea parva* is now considered to be a synonym of *Pterocladiella caloglossoides.*

### 21. *Pterocladia pinnata* (Hudson) Papenfuss

The name *P. pinnata* was proposed by Papenfuss (1950) to replace *P. capillacea.* The reason was that *pinnatus,* based on *Fucus pinnatus* Hudson (1762), antedates *capillaceus* derived from *F. capillaceus* Gmelin (1768). Therefore *pinnatus* was to be considered the correct specific epithet for the taxon. A study of the nomenclature of the species led Dixon (1960) to reject this proposal. He observed that 2 editions of Hudson's *Flora Anglica* exist and that the original description of *F. pinnatus* (Hudson 1762, p. 474) differs from the description in the second edition (Hudson 1778, p. 568). Although the alga described in the second edition might be referable to *Pterocladia,* the alga described in the first edition as *F. pinnatus,* to which the name must legally be applied, is referable to algae that are "membranous," and *Pterocladia* clearly is not. Because partial destruction of Hudson's herbarium made typification impossible, Dixon (1960) proposed rejection of the epithet *pinnatus,* according to Article 65 of the International Code of Botanical Nomenclature. Based on the priority of the first edition of Hudson (1762), *Fucus pinnatus* Hudson cannot serve as the type of *Pterocladiella,* instead of *P. capillacea,* since it is not, in any sense, membranous.

### 22. *Pterocladia pyramidale* (Gardner) Dawson

*Pterocladia pyramidale* was originally described as a species of *Gelidium* (Gardner 1927, p. 273, pl. 36; pl. 37, fig. 1; pl. 45; pl. 46, fig. 2) on the basis of specimens collected in La Jolla, California. The morphometric study of *P. capillacea* done later by Stewart (1968) showed that the taxonomic features of *P. pyramidale* could be included in the local variation of *P. capillacea*. Therefore, *P. pyramidale* is now considered a synonym of *P. capillacea.*

### 23. *Pterocladia rectangularis* (Lucas) Womersley et Guiry

*Pterocladia rectangularis* was described as a species of *Gelidium* (Lucas 1931, p. 407, pl. 23, fig. 1) on the basis of specimens collected in Flinders Bay, Australia. Currently, the species is known from Safety Bay in western Australia and from St. Francis in southern Australia (Womersley 1994). Cross sections of fertile female thalli reveal a morphology typical of *Pterocladia* (Womersley 1994). Therefore, *P. rectangularis* remains in that genus.

### 24. *Pterocladia rigida* Loomis

*Pterocladia rigida* was described on the basis of specimens collected at Paia, Maui, Hawaii (Loomis 1960, pp. 8–9, pl. 12, figs. 1–4). However, later studies (Santelices 1976) showed that *P. rigida* can be included within the morphological variation of *Pterocladiella (=Pterocladia) caerulescens*. Thus, *P. rigida* is now considered a synonym of *P. caerulescens.*

### 25. *Pterocladia robusta* Taylor

*Pterocladia robusta* was originally described on the basis of drifted and dredged specimens collected in the Galapagos Islands (Taylor 1945, p. 159, pl. 36). However, according to Stewart (1968), this form should be included within the morphological variability of *P. capillacea* in Southern California. Therefore, *P. robusta* is now considered a synonym of *P. capillacea*.

### 26. *Pterocladia tenuis* Okamura

*Pterocladia tenuis* was described by Okamura (1934, p. 62, pl. 30, fig. 3; pl. 33, figs. 1–3) on the basis of specimens collected in several localities of Japan. In his original description, he recognized that the species closely resembles *P. capillacea* and that that name had been used in previous reports. However, according to Okamura, Howe could not agree with Okamura's determination of *P. capillacea*. After studying the morphological variability of *P. capillacea* in California, Stewart (1968) concluded that *P. tenuis* is a synonym of *P. capillacea*.

### 27. *Pterocladia tripolitana* De Toni et Levi

According to Felicini and Perrone (1994), *Pterocladia tripolitana* was assigned with doubts to *Pterocladia* by De Toni and Levi (1888) on the basis of specimens collected in Tripoli, Libya. Apart from the inclusion of this species in a floristic list of the algae from Libya (Nizamuddin et al. 1979), no additional report on this taxon seems to exist.

### 28. *Pterocladia tropica* Dawson

*Pterocladia tropica* was described on the basis of materials collected at Palmyra Island at a depth of 5–25 ft (1.5–7.5 m) (Dawson 1959, pp. 40–42, figs. 21A–21D, fig. 22 B). Studies on the morphological variation of *P. caerulescens* in Hawaii suggested that the ranges of variation in *P. caerulescens* could easily accommodate the description of *P. tropica* (Santelices 1976) Therefore, *P. tropica* is now considered a synonym of *P. caerulescens.*

## Conclusions

Data suggest that only 2 of the 28 species originally described as species of *Pterocladia* belong with that genus (Santelices and Hommersand 1997): *P. lucida,* the type species of the genus, and *P. rectangularis.* The genus *Pterocladia* appears to be restricted principally to the Australian area, being present in New Zealand, southern and western Australia and Tasmania. Reports from areas other than Australia should be reinvestigated.

Thirteen of the 28 specific epithets are synonyms of other species. The number of synonyms is clearly related to the morphological variability and widespread geographic distribution of the species. The geographically widespread and morphologically variable *P. capillacea* accounts for 10 of the 13 synonyms: *P. complanata, P. densa, P. lindaueri, P. mexicana, P. nana, P. okamurai, P. pinnata, P. pyramidale, P. robusta,* and *P. tenuis. Pterocladiella caerulescens* is the second most variable species, and it also has been described under other names, namely *P. rigida* and *P. tropica.* Finally, the widespread *P. caloglossoides* also has a synonym *(P. parva),* despite the consistency of several of its morphological characters.

Ten of the species originally assigned to *Pterocladia* have been transferred to other genera. Three, *P. americana, P. macnabbiana,* and *P. musciformis,* have been transferred to *Gelidium.* The other 7, *P. bartlettii, P. bulbosa, P. capillacea, P. caerulescens, P. caespitosa, P. caloglossoides, and P. melanoidea,* have been transferred to the genus *Pterocladiella* (Santelices and Hommersand 1997), in which *P. capillacea* is the type species for the genus.

Two types of studies have been most useful for clarifying the taxonomic status of these species. Extensive studies on field variability (e.g., Stewart 1969, Santelices 1976) have helped circumscribe the specific limits of taxonomically variable species, and studies of internal cystocarpic structure have contributed to sharper generic distinctions. Fertile female thalli often have been obtained from the field, but in a few instances (e.g., *P. melanoidea*), the fertile materials were produced under laboratory cultivation.

Most likely, these methods could also be applied to the 3 species that remain with doubtful taxonomic status. Studies on new collections should evaluate whether or not *P. tripolitana* is a valid species and if it should be included in *Pterocladia*. Comparative studies should also help trace the specific limits between *P. heteroplatos* and *P. media* and determine if these 2 species belong with *Pterocladia* or *Pterocladiella*.

## Acknowledgments

I thank Dr. I. A. Abbott for the invitation to participate in the workshop and for reviewing and editing the manuscript. Cofunding by California Sea Grant College System and Grant SAREC-CONICYT 90-7 enabled me to participate in the workshop. My gratitude to Dr. J. Sullivan for making this participation possible.

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# TAXONOMIC STUDIES ON *PTEROCLADIELLA* (GELIDIACEAE, GELIDIALES, RHODOPHYTA) FROM CHINA

Xia Bangmei and Wang Yongqian

## Abstract

Two species of *Pterocladiella* Santelices et Hommersand, *P. capillacea* (Gmelin) Santelices et Hommersand and *P. caloglossoides* (Howe) Santelices are described from China. The latter species is reported from China for the first time.

## Introduction

*Pterocladiella* Santelices et Hommersand is a widespread genus of red algae and an important economic seaweed that, along with *Gelidium*, is used as raw material for industrially or domestically produced agar. About 150 metric tons of dry *Gelidium* and *Pterocladiella* are gathered in mainland China each year.

## Key to the Chinese Species of *Pterocladiella*

1. Thalli small, 1–1.5 cm tall, erect or decumbent, attached by means of stoloniferous branchlets, 1–2 times pinnately branched ...... *P. caloglossoides*
1. Thalli large, erect, 5–15 cm tall, regularly 2–3 times pinnately branched, with pyramidal form ........................................................ *P. capillacea*

## Description of the Species

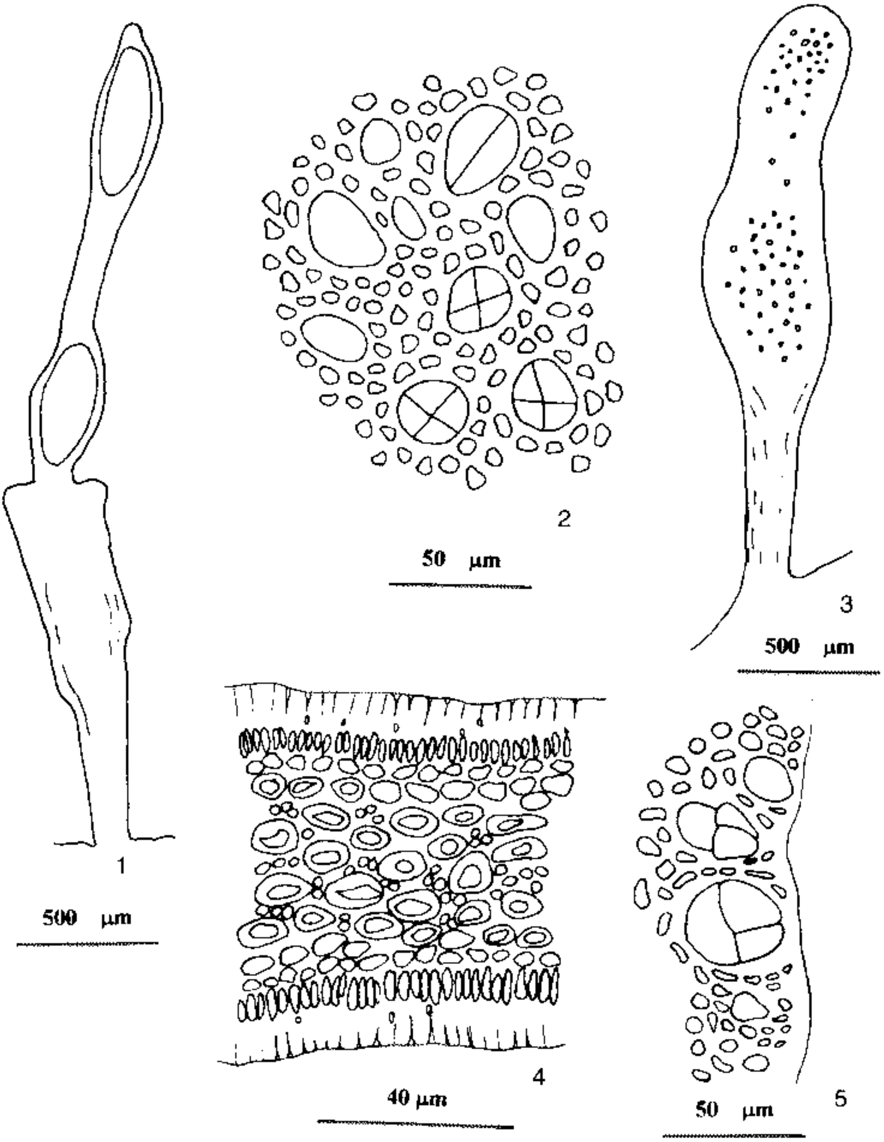
*Pterocladiella caloglossoides* (Howe) Santelices. J. Appl. Phycol. 10:237–152, 1998.

(Figs. 1–8)

Basionym: *Gelidium caloglossoides* Howe, Mem. Torrey Bot. Club 15:96, 1914.

Type Locality: San Felipe, Gulf of California.

Thalli small, brownish red, growing as a dense turf, 1–1.5 cm tall, consisting of suberect or compressed rhizomelike creeping parts from which arise erect branches, complanate, 564–597 μm wide, 1–2 times pinnately branched, ultimate pinnae of irregular length, usually with acute tips. Subcartilaginous, adhering imperfectly to paper on drying. In transverse section, numerous rhizoidal filaments aggregated within medullary central tissue, medullary cells irregularly ovate or oblong, 10–13 μm × 6–10 μm, cortical cells 1 layer thick, frond about 100 μm thick. Cystocarps borne on branchlets, swollen on 1 side, 365–382 μm × 631–681 μm, slightly rostrate, nonconstricted at base; in longitudinal section, gonimoblast consisting of very small cells, carposporangia ovate or obviate, 17–33 μm × 6.6–17 μm; pericarp 66–86 μm thick, consisting of 5–6 layers of cells. Tetrasporangia and spermatangia not seen.



**Figs. 1–5.** ***Pterocladiella caloglossoides*** **(Howe) Santelices. Fig. 1, Spermatangia in oblong nemathecia at apices of branchlet (AST 56-595). Fig. 2, Surface view of tetrasporangia (AST 57-799). Fig. 3, Tetrasporangia in apices of branchlet (AST 57-531a). Fig. 4, Transection of part of spermatangial sorus (AST 56-595). Fig. 5, Transection of part of tetrasporangial sorus (AST 57-945).**

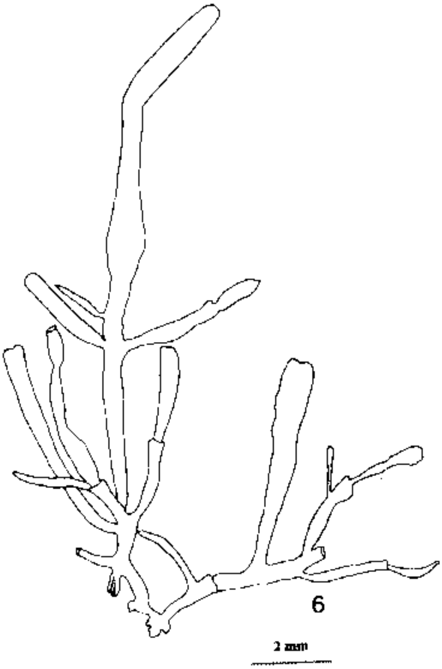


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**Fig. 6. *Pterocladiella caloglossoides* (Howe) Santelices (AST 60-4586). Sketch of habit of frond.**

Habitat: Growing on intertidal rocks.
Distribution: Shipanhe, Weizhoudao, Guangxi Province.
Remarks: This is a new record for China.

*Pterocladiella capillacea* (Gmelin) Santelices et Hommersand, Phycologia 36:118, 1997.

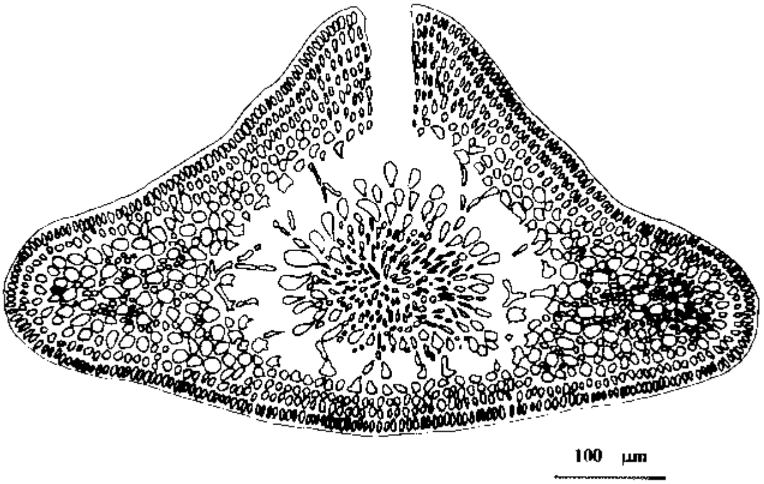
(Figs. 9–13)

Basionym: *Fucus capillaceus* Gmelin, Historia fucorum, p. 146, pl. 15, fig. 1, 1768.

Type Locality: Mediterranean Sea.

Synonym: *Pterocladia tenuis* Okamura, J. Imp. Fish. Inst. 29:62, pl. 29, pl. 30, fig. 3, pl. 33, figs. 1–3, 1934; Tseng et al., Economic Seaweeds of China, p. 122, pl. VII:56, figs. 27:2, 28:3–4, 1962; Xia Bangmei et al., in Tseng, ed., Common Seaweeds of China, p. 68, pl. 37, fig. 3, 1983.

Thalli purplish red, compressed, 5–15 cm tall, consisting of 1 to several distichously, pinnately branched percurrent axes rising from a holdfast of entangled stolons. Erect axes slightly flattened at bottom of axes, strongly flattened at top, with spatuliform or attenuated apices, up to 0.5 mm in diameter at the bases and up to 1.8 mm wide in the flat parts. Branching 2–3 times pinnate in the pyramidal outline, with opposite or alternate pinnules, 1–2 mm wide, abruptly



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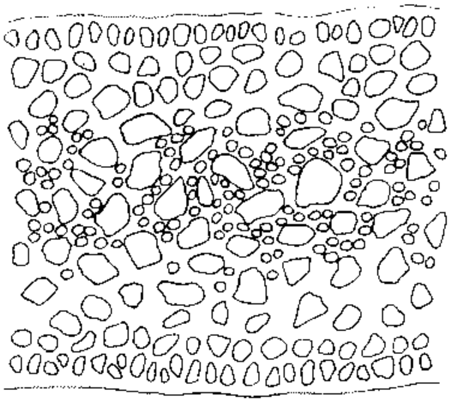

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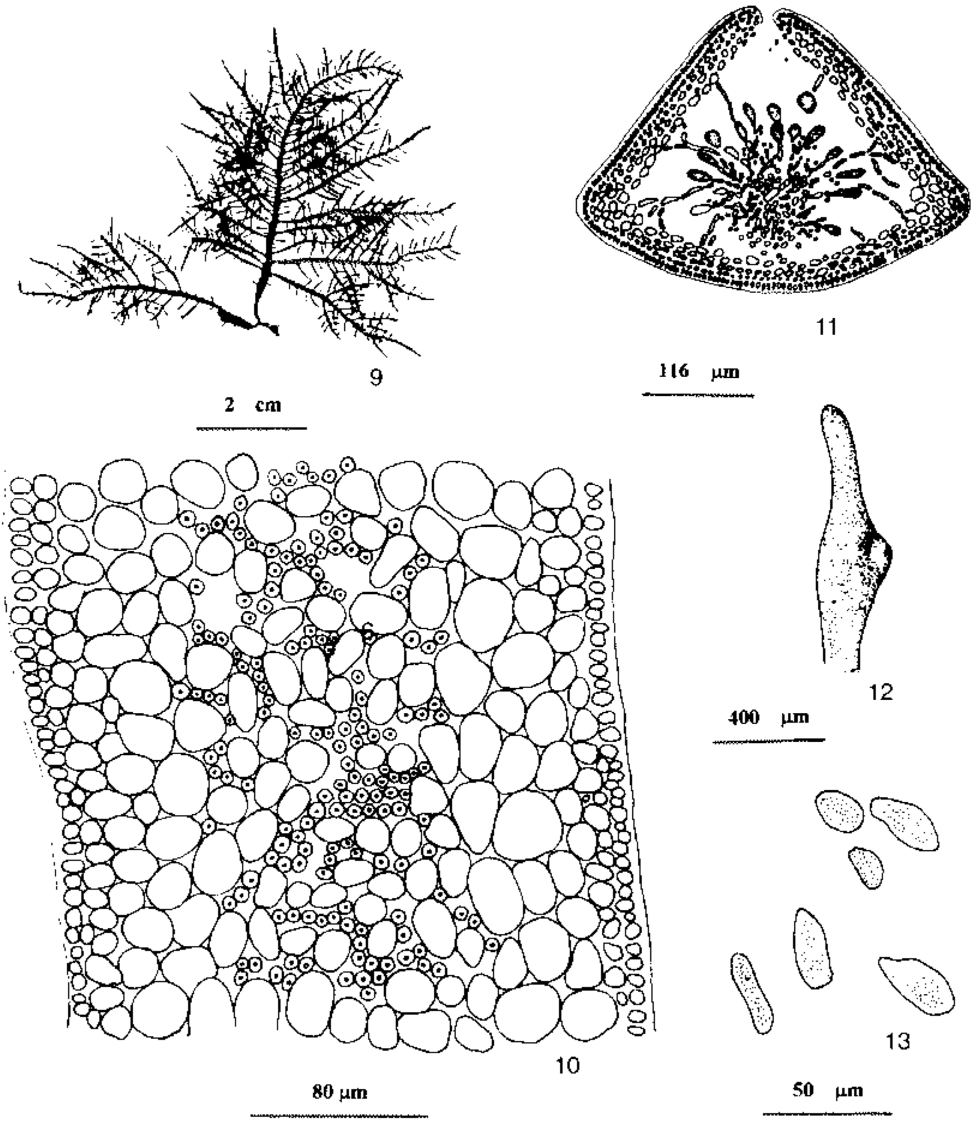
**Figs. 7, 8. *Pterocladiella caloglossoides* (Howe) Santelices (AST 60-4586). Fig. 7, Transection of part of frond. Fig. 8, Longitudinal section of cystocarp.**

constricted at the base and with obtuse apices. Cartilaginous, adhering imperfectly to paper on drying. In transverse section, rhizoidal filaments only scattered in the middle part of central tissue, medullary cells irregularly oblong, 23–30 µm × 10–23 µm; cortical cells 1–2 layers, round or square, 3.3–5 µm thick. Tetrasporangial sori in ultimate ramuli, scattered among cortical layers of frond, circular or ovoid in surface view, 26–30 µm × 23–30 µm, ovoid or circular in transverse section, 33–40 µm × 23–33 µm, cruciately divided, surrounded by modified cortical cells; cystocarps formed on the median line of ramuli, swollen on 1 side, roundish, 249–300 µm × 300–332 µm, slightly rostrate, nonconstricted at base; in longitudinal



Figs. 9–13. *Pterocladiella capillacea* (Gmelin) Santelices et Hommersand. Fig. 9, Habit of frond (AST 82-627). Fig. 10, Transection of part of frond (AST 64-99). Fig. 11, Longitudinal section of cystocarp (Tseng et al., 1962, fig. 28:3). Fig. 12, Cystocarpic branchlet (Tseng et al. 1962, fig. 28:4). Fig. 13 Carpospores (AST 56-851).

section, gonimoblast consisting of very small cells, carposporangia oblong or obovoid, 26–40 μm × 13–20 μm; pericarp 33–53 μm thick, consisting of a layer of 4–5 cells. Spermatangial sori on slightly compressed ramuli, 498–697 μm long and 149 μm in diameter, spermatangia cut off directly from outer cortical cells.

Habitat: Growing on intertidal to subtidal rocks.

Distribution: Common on entire coast of China.

## Acknowledgments

We are especially grateful to Professor Isabella A. Abbott for reviewing and editing the manuscript. Thanks to Dr. J. Sullivan for financial support for participation in the workshop provided by the California Sea Grant College System.

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# Section III. *Gracilariales*

## INTRODUCTION

Isabella A. Abbott

What is of note to me is that the Gracilariales section in this volume has 5 chapters, 3 on *Gracilaria* and *Gracilariopsis* and 2 on parasites of Gracilariaceae. Both types of chapters wrestle with the same important problem: what names should be applied to the material?

I am impressed by Dr. Yamamoto's study of so-called *G. coronopifolia*, the type locality of which is the Hawaiian Islands. Dr. Yamamoto found that the Japanese and Philippine plants given the name *G. coronopifolia* are not even close to Hawaiian *G. coronopifolia*. He knew that the plants from these 3 locations differed when he first saw the Hawaiian plants in the market during the workshop held in Honolulu in 1993, because the axes and branches did not entangle and adhere to one another as those of the Japanese plants do. That observation was the beginning of growing the plants in culture and later making sections and examining the polycavernosa- vs. verrucosa-type spermatangial conceptacles. I say, "Banzai!" to that piece of research.

The second noteworthy feature is the training of and "passing the torch to" the next generation of students—having them get out in the field to collect specimens and continue research on the adelphoparasites. I hope that the students will be able to see the Leiden specimens of Dr. Weber-van Bosse in order to put the correct names on the algae the students collect.

# ON SO-CALLED *GRACILARIA CORONOPIFOLIA* FROM THE PHILIPPINES AND JAPAN

Hirotoshi Yamamoto, Ryuta Terada, and Daisuke Muraoka

## Abstract

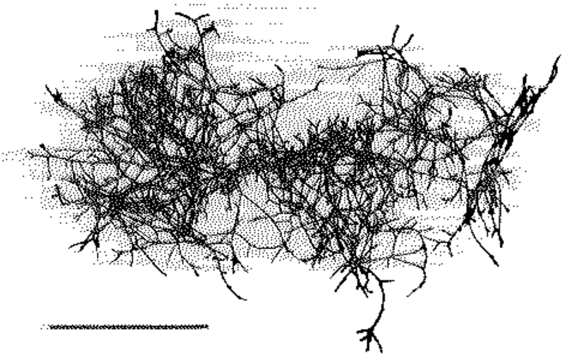
Culture studies showed that Philippine and Japanese specimens of *Gracilaria "coronopifolia"* have multicavitied or polycavernosa-type spermatangial conceptacles rather than the verrucosa type reported previously for true *G. coronopifolia* from Hawaii, which is the type locality. Branches adhered readily to one another and to the surface of culture vessels. These results indicate that the 2 taxa should not be referred to *G. coronopifolia* of Hawaii, which has verrucosa-type spermatangial conceptacles and no adhesion of branches, and suggest that *G. coronopifolia* is not distributed in the western Pacific region.

## Introduction

*Gracilaria coronopifolia* was established by J. Agardh (1852) on the basis of Hawaiian materials. Galutira and Velasquez (1963) were the first to report this species from the Philippines. Studies since then have shown that this alga is among the most common species in the Philippine marine algal flora. Trono et al. (1983) reported that the Philippine taxon forms a large and dense mass in which the fronds adhere to one another with short rhizoidlike processes issuing from the axes and branches. Trono et al. 1983 described the spermatangial conceptacles as "cup-shaped" and "narrow-mouthed," characteristics suggestive of verrucosa-type conceptacles. Although the description is not detailed, the spermatangial type fits that of Hawaiian materials. However, the identification of the Philippine taxon is still in question because of its distinctive mass-forming habit, which is caused by the adhesion among branches. Accordingly, we cultured the Philippine taxon in vitro to review the spermatangial structure and to confirm the ability of the plants to adhere. In addition, we compared the spermatangial structure and adhesion of the Philippine plants with the structure and adhesion of cultured *G. coronopifolia* identified from Japan.

## Materials and Methods

A single, mature cystocarpic plant (Figs. 1–2) was collected (by H. Y.) at the Marine Station of the University of the Philippines, in Bolinao, in January 1989, and carpospores were released immediately by using the method of Yamamoto and Sasaki (1987). The spores released were transferred into 50-mL glass bottles by pipette to establish unialgal cultures and were brought back to Japan to be cultured at the laboratory of the Faculty of Fisheries, Hokkaido University. The sporelings (about 5 mm long in 40-day cultures) were detached from glass bottles and transferred into 500-mL flasks for free-living culture.



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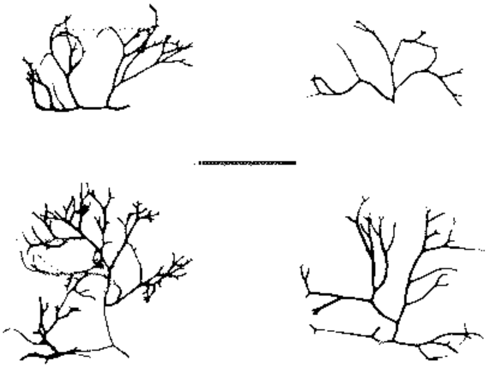

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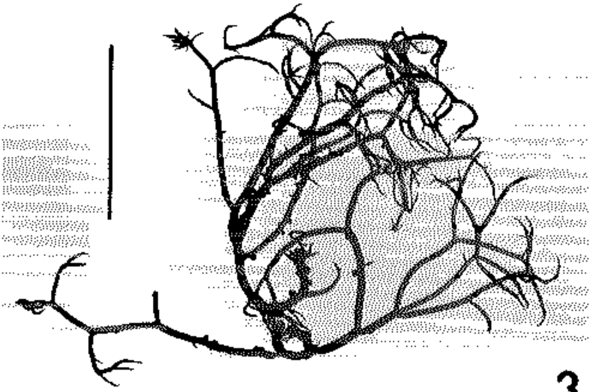

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Figs. 1–3. Philippine *Gracilaria "coronopifolia."* Fig. 1, Habit of wild fronds in entangled mass. Fig. 2, Habit of wild fronds detached from entangled mass. Fig. 3, A cystocarpic frond raised in culture. Scale bars: 5 cm for Fig. 1, 3 cm for Figs. 2, 3.

Plants were cultured at 25°C–26°C, with a light intensity of approximately 70 $\mu$mol $m^{-2}$ $s^{-1}$ with cool white fluorescent lamps, a photoperiod of 14 h of light and 10 h of dark, and aeration (about 0.1 L/min). PES medium (50% concentration of original prescription, without vitamins) was changed about once a week throughout the culture period.

A few male gametophytes were collected (by R. T.) at Makurazaki, Kagoshima Prefecture, in April 1996. Y. Yamagishi, a graduate student of Hokkaido University, supplied us with some tetrasporophytes collected at Ei, Kagoshima Prefecture, in June 1996. Release of tetraspores, germination, and culture methods were the same as those used for the gametophytes (Figs. 7–9).

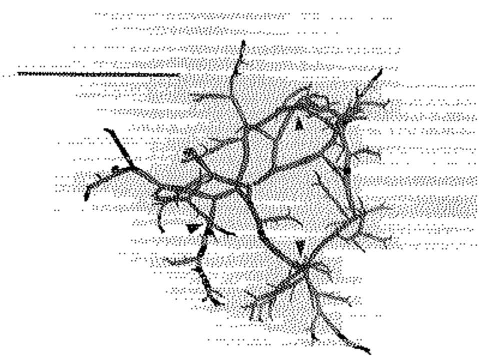
## Results

Carpospore-derived fronds from the Philippines developed into tetrasporophytes (5–7 cm long) in about 70 days. Tetraspores released gave rise to gametophytes on which cystocarps were clearly recognized in 70 days, although some fronds still remained sterile. Carpospores developed normally, thus showing a Polysiphonia-type life history. Spermatangial conceptacles were of the polycavernosa type, that is, multcavitied (Fig. 6). The fronds were constantly attaching to one another, and plants adhered and formed a rounded to irregular mass.

Tetraspore-derived fronds (Fig. 3) from Japan also had a Polysiphonia-type life history similar to that of the Philippine plants and had Polycavernosa-type spermatangial arrangements (Figs. 10–11). Adhesion among branches was not as frequent as in Philippine fronds (Fig. 7).

## Discussion

The culture experiments revealed that both Philippine and Japanese specimens of *"G. coronopifolia"* have polycavernosa-type spermatangial conceptacles. These findings differ from the descriptions (verrucosa type) of Trono et al. (1983) and Yamamoto (1978) and from the verrucosa type of the authentic Hawaiian taxon (Dawson 1949, Abbott 1985, Abbott et al. 1991). Philippine fronds easily adhered to one another, even to the walls of culture flasks, and made an entangled mass. Japanese fronds adhered less frequently than the Philippine ones did, but this characteristic habit is common to both taxa, making these species clearly distinctive ecologically. The branches of the other *Gracilaria* species never adhere to one another in the field or in culture vessels, as far as we know. Accordingly, we think that the adhesive habit suggests that the Philippine and Japanese taxa are conspecific, separated from other taxa that look similar but lack this habit. Yamamoto (1978) earlier reported that branches of Japanese *"G. coronopifolia"* adhere to form a loosely entangled mass. Our results verify that the Philippine and Japanese taxon clearly differ from the authentic Hawaiian species and suggest that *G. coronopifolia* is not distributed in the western Pacific region.



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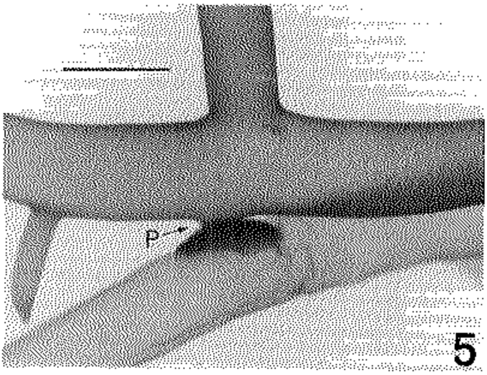
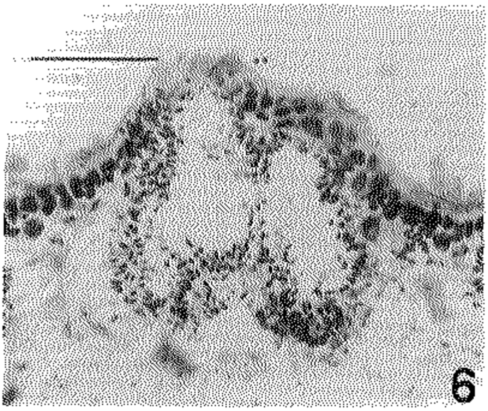
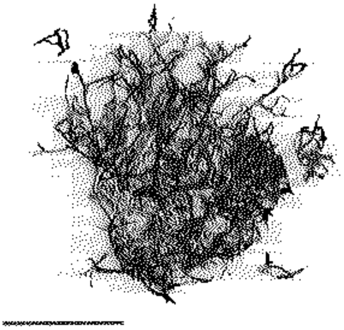




Figs. 4–6. Philippine *Gracilaria "coronopifolia."* Fig. 4, Fronds with adhesion in culture. Arrowheads show adhering branches. Fig. 5, Close-up of disclike adhesion between branches in culture, showing a short process (P) connecting upper and lower branches. Fig. 6, Polycavernosa-type spermatangial conceptacle in cross section of a cultured frond. Scale bars: 3 cm for Fig. 4, 1 mm for Fig. 5, and 2.5 cm for Fig. 6.



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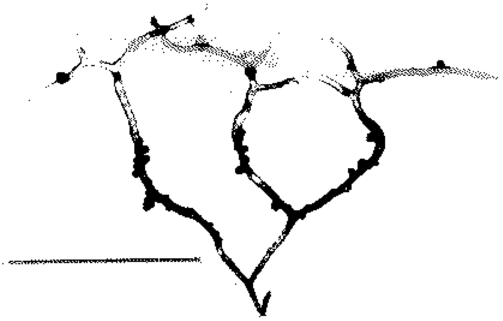

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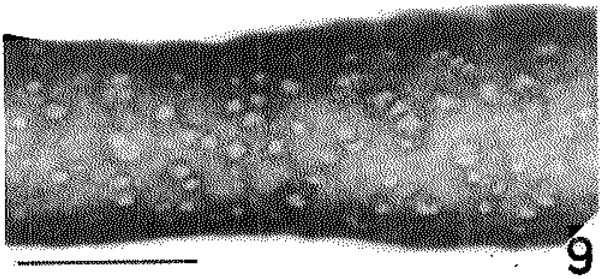

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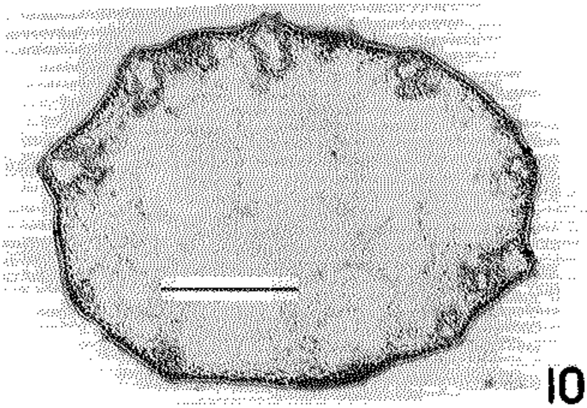
Figs. 7–9. Japanese *Gracilaria "coronopifolia."* Fig. 7, Habit of wild fronds in loosely entangled mass. Fig. 8, A cystocarpic frond raised in culture. Fig. 9, Surface view of male frond raised in culture. Scale bars: 2 cm for Fig. 7, 5 cm for Fig. 8, 500 μm for Fig. 9.



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Figs. 10–11. Japanese *Gracilaria "coronopifolia."* Fig. 10, Cross-sectional view of male frond raised in culture. Two conceptacles at 2 o'clock and 4 o'clock could be mistaken for verrucosa type if those 2 conceptacles were the only ones observed. Fig. 11, Polycavernosa-type spermatangial conceptacle in cross section of male frond raised in culture. Scale bars: 300 µm for Fig. 10, 50 µm for Fig. 11.

*Gracilaria "coronopifolia"* has been reported in many areas of the western Pacific (Table 1), and its morphology is similar to that of *G. edulis*. May (1948) even treated *G. coronopifolia* as a form of *G. lichenoides* (=*G. edulis*).

**Table 1. Distribution of *Gracilaria coronopifolia* and *Gracilaria edulis* in the Western Pacific Region**

| Region | *G. coronopifolia* | *G. edulis* | Main Reference |
|---|---|---|---|
| Japan | X | X | Yamamoto (1978) |
| China (mainland) | X | X | Chang and Xia (1963, 1976)<br>Abbott et al. (1991) |
| Taiwan | X | – | Chiang (1985) |
| Philippines | X | X | Galutira and Velasquez (1963) Trono et al. (1983) |
| Vietnam | – | X | Nguyen (1992) |
| Malay Peninsula | X | X | Phang (1994) |
| Thailand | – | X | Abbott (1988a)<br>Lewmanomont (1994) |
| Indonesia | – | X | Weber-van Bosse (1928)<br>Abbott (1988b) |
| Australia | X | X | May (1948) |
| Micronesia | X | X | Tsuda (1985) |
| Sri Lanka | – | X | Durairatnam (1961) |
| India | – | X | Rao (1972) |

(X = present; – = absent).

Abbott (1994) merged *Polycavernosa fastigiata* with *G. edulis* on the basis of examination of *G. lichenoides* of Rumphius. Thus, *G. edulis* is characterized by polycavernosa-type spermatangial conceptacles and rhizomes (stolon) from which new erect axes can rise (see May 1948, p. 29, and Chang and Xia 1963). However, rhizomes were not shown in the illustrations of Rumphius (Abbott 1994, p. 115, figs. 1–4).

As stated earlier, *G. coronopifolia* from Hawaii has verrucosa-type spermatangia. Any species that resembles this species morphologically must be examined for types of spermatangia, as well as other features.

We do not yet have sufficient information on Asian *G. "coronopifolia"* to propose a new name for it. Accordingly, we give descriptions of Philippine and Japanese taxa, which form entangled masses, for future studies:

Fronds terete, sometimes slightly compressed, up to 10 cm long, up to 1.5 mm wide, with discoid holdfast, alternately or dichotomously branching, with divisions usually frequent in upper half of main axes; branches of upper orders adhering to one another by short rhizoidlike processes issuing from main axes and lower branches. Reddish purple to brown, sometimes yellowish or greenish brown.

Cartilaginous in texture. Cortical cells 6–11 µm × 6–8 µm, increasing in cell size toward the center, up to 500 µm in diameter. Transition of cell size from cortex to medulla abrupt. Cystocarps borne on axes and branches except on apical and basal parts, up to 1500 µm in diameter. Traversing filaments present, penetrating into pericarp. Spermatangia borne in cavities, with multicavitied structure composed of 5–6 or more conceptacles (Polycavernosa-type) in extent of up to 200 µm deep and up to 240 µm wide. A group of conceptacles may form nemathecia elevating beyond vegetative level.

Tetrasporangia borne throughout fronds except on apical and basal parts.

This species forms more or less entangled masses on rocks in intertidal zones.

## Acknowledgments

We express our heartiest thanks to Dr. I. A. Abbott for critical reading of the manuscript. We also thank Mr. Y. Yamagishi, a graduate student of Hokkaido University, for supplying some of the materials for this study.

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# THE SPECIES OF *GRACILARIA* FROM VIETNAM

Masao Ohno, Ryuta Terada, and Hirotoshi Yamamoto

### Abstract

A geographic survey was done in Vietnam in February to March of 1993 and 1994 to collect specimens of Gracilariaceae. The habitats and distribution of 9 species of *Gracilaria* from northern, central, and southern Vietnam are reported: *G. arcuata, G. edulis, G. eucheumoides, G. changii, G. firma, G. fisheri, G. heteroclada, G. salicornia,* and *G. tenuistipitata* var. *liui.* Species under cultivation, such as *G. heteroclada* and *G. tenuistipitata* var. *liui,* were found in ponds. *Gracilaria changii, G. fisheri,* and *G. tenuistipitata* var. *liui* are new records from Vietnam. The best habitats for *Gracilaria* plants are in southern Vietnam.

## Introduction

A survey of seaweed flora was done in southern Vietnam in January to February 1993 and in northern Vietnam in March 1994 (Fig. 1). The specimens collected are deposited in the herbarium of Usa Marine Biological Institute, Kochi University. Species of Gracilariaceae from Vietnam have been reported by Dawson (1954), Pham (1969), and Nguyen (1992). However, it is not clear where the specimens in their lists are kept in Vietnam. In this chapter, we describe, with ecological notes, the specimens collected in the 1993 and 1994 survey.

## Collection Sites

Specimens were collected from the following locations in 1993:

Tai An, Ninh Hai, Ninh Thuan Province
My Hoa, Ninh Hai, Ninh Thuan Province
Bai Tien, Nha Trang, Khanh Hoa Province
Son Hai, Ninh Phuoc, Ninh Thuan Province
Hon Rua (Tortoise Island), Nha Trang, Khanh Hoa Province
Cu Lao (mouth of Cai River), Nha Trang, Khanh Hoa Province
Phuoc Son, Tuy Phuoc, Binh Dinh Province
Binh Vinh, Ly Son Island, Quang Ngai Province
Hoi An, Quang Nam-Da Nang Province
Mui Nai, Ha Tien, Kien Giang Province
Bai No, Ha Tien, Kien Giang Province

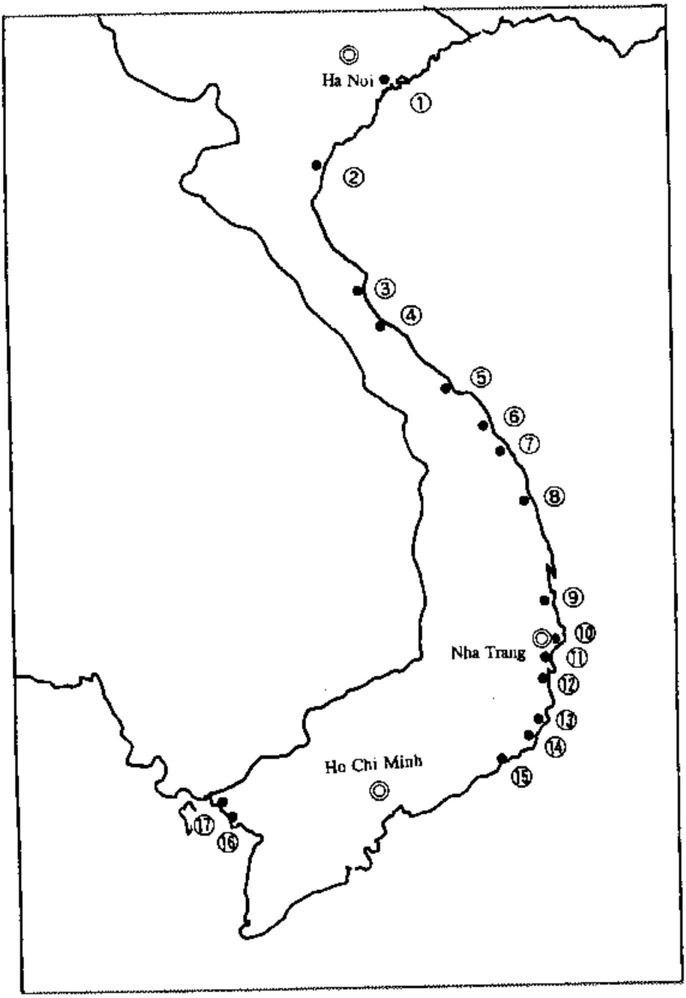

Fig. 1. Locations in Vietnam where specimens were collected. 1, Qui Kim Kiem Tituy, Haiphong (pond); 2, Quang Cu Sam Song, Thanh Hoa Province; 3, Gianh River Quang Trach, Quang Binh Province; 4, Vinh Quang Vinh Linh, Quang Binh Province; 5, Sam Chuong Tam Giang, Thua Thien-Hue Province (*Gracilaria* pond); 6, Hoi An, Quang Nam-Da Nang Province; 7, Binh Vinh, Ly Son Island, Quang Ngai Province; 8, Phuoc Son, Tuy Phuoc, Binh Dinh Province; 9, Dong Xuan, Phu Yen Province, 10, Cu Lao (mouth of Cai River ), Nha Trang, Khanh Hoa Province; 11, Hon Rua (Tortoise Island), Nha Trang, Khanh Hoa Province; 12, Bai Tien, Nha Trang, Khanh Hoa Province; 13, Tai An, Ninh Hai, Ninh Thuan Province; 14, My Hoa, Ninh Hai, Ninh Thuan Province; 15, Son Hai, Ninh Phuonc, Ninh Thuan Province; 16, Mui Nai, Ha Tien, Kien Giang Province; 17, Bai No, Ha Tien, Kien Giang Province.

Specimens were collected from the following locations in 1994:
Qui Kim Kiem Tituy Haiphong (pond)
Quang Cu Sam Song, Thanh Hoa Province
Gianh River Quang Trach, Quang Binh Province (*G. tenuistipitata* natural)
Vinh Quang Vinh Linh, Quang Binh Province
Dong Xuan, Phu Yen Province (*Gracilaria*)
Sam Chuong Tam Giang, Thua Thien-Hue Province (*Gracilaria* pond)

## Key to Species of *Gracilaria* from Vietnam

1. Plants erect, cylindrical, or slightly flattened .................... 2
1. Plants prostrate, axes compressed, with marginal lobes extending into terete or compressed branches .................... *G. eucheumoides*
  2. Plants cylindrical, axes and branches succulent, at upper branches wholly or partly constricted or jointed at nodes .......... *G. salicornia*
  2. Plants not succulent, never constricted or jointed .................... 3
3. Branches secund or curving (arcuate) .................... 4
3. Branches not secund or curving .................... 5
  4. Branches smaller in diameter than are main axes .................... *G. arcuata*
  4. Branches nearly the same diameter as main axes .................... *G. firma*
5. Plants with branches in elongate or short clusters, spermatangial arrangements polycavernosa type .................... *G. edulis*
5. Plants with branches not clustered, with differing spermatangial arrangements .................... 6
  6. Main axes percurrent, thin, surrounded by branches of various lengths, rebranched once to several times, or spinelike .................... *G. tenuistipitata* var. *liui*
  6. Main axes not percurrent, branching not extensive .................... 7
7. Primary axes not distinguished in size from leading branches, 1–3 orders of branching .................... 8
7. Mostly 1–2 orders of branching, branches short and spinelike; chorda-type spermatangial arrangements .................... *G. heteroclada*
  8. Primary axes elongate, up to 30 cm long, forming equally elongate primary and secondary branches; polycavernosa type spermatangial arrangements .................... *G. fisheri*
  8. Primary axes and branches inflated, tapering at each end, rarely more than 2 orders of branching; polycavernosa-type spermatangial arrangements .................... *G. changii*

## Description of the Species

*Gracilaria arcuata* Zanardini, Mem. Inst. Veneto 7, p. 265, 1858.

(Fig.2)

Thalli 3–6 cm long with cylindrical or slightly compressed branches. Main axis attenuating toward base 2–4 mm in diameter, often curved with attenuated apices. Branches irregularly alternate or dichotomous, slightly curved, similar in shape to main axis and tapering toward apex, unconstricted at base, with similarly shaped branches on opposite sides at irregular intervals. Yellowish or purplish green to pinkish purple.

Distribution: *Gracilaria arcuata* grows on the rocks of lower intertidal zones in the open sea and is reported from subtropical waters in Japan, China (Xia and Yamamoto 1985), and the Philippines (Abbott 1988).

Collection Sites: Binh Vinh, Ly Son Island; Hon Rua, Nha Trang; and Tai An, Ninh Hai.

Remarks: This species has been reported by Pham (1969) from southern Vietnam. *Gracilaria arcuata* is easily distinguished from other gracilariaceous species on the basis of its peculiarly arcuate branching pattern.

*Gracilaria changii* (Xia et Abbott) Abbott, Zhang, et Xia, Pac. Sci. 45:23, 1991.

(Fig. 3)

Basionym: *Polycavernosa changii* Xia et Abbott, Phycologia 26:407, 1987.

Thalli 5–7 cm long, percurrent axis with many branches arising from a small discoid holdfast. Branching alternately or irregularly of 2–4 orders. Branches cylindrical or inflated, 1–2 mm in diameter, abruptly constricted at bases, tapering toward apices.

Distribution: *Gracilaria changii* grows on gravel, shells, and rock fragments in sandy to muddy bottoms in calm waters. It is common in southern Asia, Thailand (Lewmanomont 1994), and Malaysia (Phang 1994).

Collection Sites: Mui Nai, Ha Tien, and Bai No, Ha Tien.

Remarks: This species is a new record from Vietnam.

*Gracilaria edulis* (Gmelin) Silva, Univ. Calif. Publ. Bot. 25:293, 1952.

(Fig. 4)

Basionym: *Fucus edulis* Gmelin, Hist. Fuc., p. 113, 1768.

Synonyms: *Polycavernosa fastigiata* Chang et Xia, Stud. Mar. Sinica 3:125, 1963, and *Hydropuntia fastigiata* (Chang et Xia) Wynne, Taxon 38:477, 1989.

Plants 6–11 cm or more long with many branches. Branches wiry and entangled, arranged irregularly and dichotomously on axis. Main axis less than 2 mm in diameter. Ultimate branches short and spinelike or with tendrils. Thalli appear

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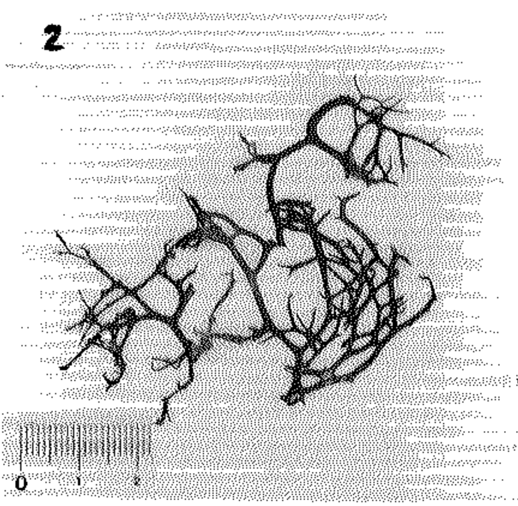

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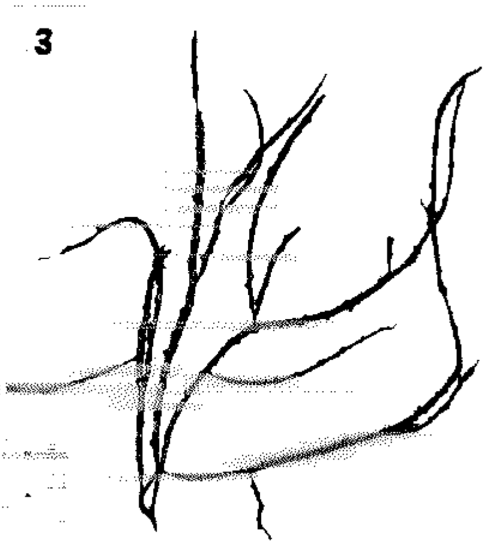

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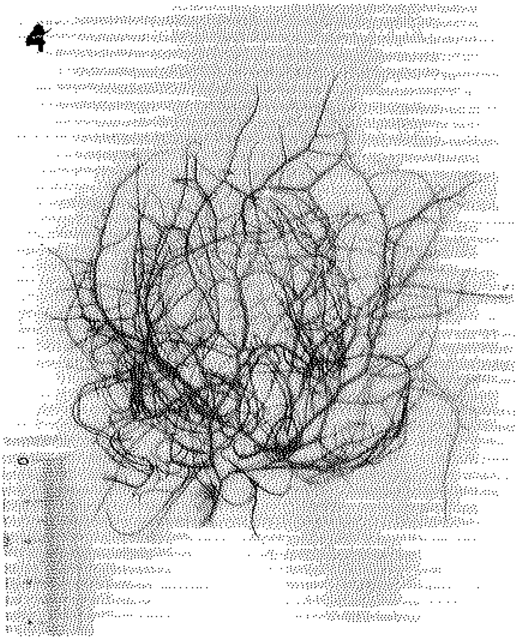

Fig. 2. *Gracilaria arcuata* from Binh Vinh, Ly Son Island, Quang Ngai Province, central Vietnam. Fig. 3. *Gracilaria changii* from Bai No, Ha Tien, Kien Giang Province, southern Vietnam. Fig. 4. *Gracilaria edulis* from Mui Nai, Ha Tien, Kien Giang Province, southern Vietnam.

bushy because of the short branches.

Distribution: *Gracilaria edulis* is common in southern Asia and is used for *Gracilaria* cultivation in Thailand (Lewmanomont 1994) and Malaysia (Phang 1994). It grows sometimes with *G. changii* on the sandy-muddy bottom in brackish waters.

Collection Sites: Bai Tien, Nha Trang; Tai An, Ninh Hai; My Hoa, Ninh Hai; Bai No and Mui Nai, Ha Tien.

Remarks: This species is reported as *G. coronopifolia* by Pham (1969) and as *P. fastigiata* by Nguyen (1992) from southern Vietnam.

*Gracilaria eucheumoides* Harvey, Proc. Am. Acad. Arts Sci. 4:331, 1859.

(Fig. 5)

Thallus compressed, varying in length, from less than 5 cm to up to 19 cm long, thick and succulent, prostrate on rocks, attaching by discoid holdfasts, branching pinnately to dichotomously. Branches 1–3 cm long, 0.5–1.0 cm wide, 1–2 mm thick with dentate margins.

Distribution: This species grows well on rocks in the intertidal and subintertidal zone in open sea or coral areas.

Collection Sites: Tai An, Ninh Hai; Son Hai, Ninh Phuonc; Hon Rua, Nha Trang; and Binh Vinh, Ly Son Island.

Remarks: *Gracilaria eucheumoides* was reported by Dawson (1954) and Pham (1969) from southern Vietnam. Vietnamese families in Nha Trang, in central Vietnam, use dried *G. eucheumoides* for cooking.

*Gracilaria firma* Chang et Xia, Stud. Mar. Sinica 11:143, 162, 1976.

(Fig. 6)

Thalli 10–18 cm long, caespitose with many branches coming from a small discoid holdfast. Branching alternately or irregularly, often angular. Branches sometimes longer than 5 cm and more than 1.5–2.5 mm in diameter, sometimes similar to axis, always constricted at bases. Yellowish brown and very firm when dried.

Distribution: This species grows well on the shallow bottom in sandy and muddy areas of calm waters.

Collection Sites: Mui Nai, Ha Tien, and Bai No, Ha Tien.

Remarks: Yamamoto et al. (1994) reported that the spermatangia of this species are of the verrucosa type. They found that in culture, the life history was completed in about 250 days and was the typical Polysiphonia-type. The natural plants of *G. firma* have been harvested for agar products at the sea shore of Mui Nai, Ha Tien, in southern Vietnam. The species was previously published as *G. blodgettii* by Nguyen (1969, 1972) and as *G. rhodotricha* by Pham (1969).

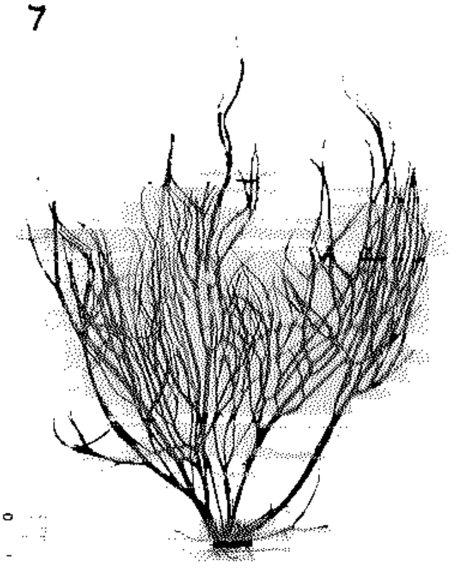

**Fig. 5.** *Gracilaria eucheumoides* from Mui Nai, Ha Tien, Kien Giang Province, southern Vietnam. **Fig. 6.** *Gracilaria firma* from Mui Nai, Ha Tien, Kien Giang Province, southern Vietnam. **Fig. 7.** *Gracilaria fisheri* from Bai No, Ha Tien, Kien Giang Province, southern Vietnam.

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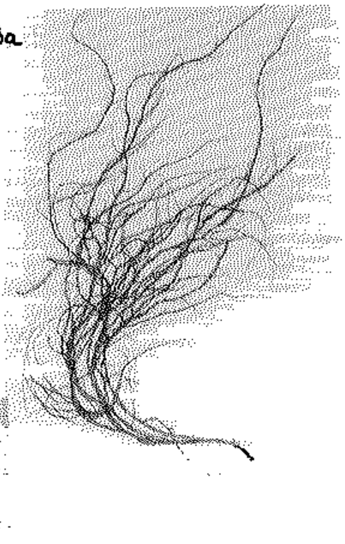

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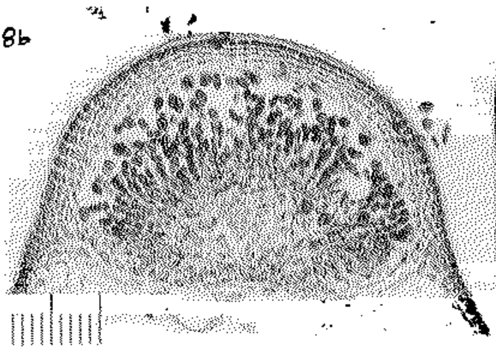

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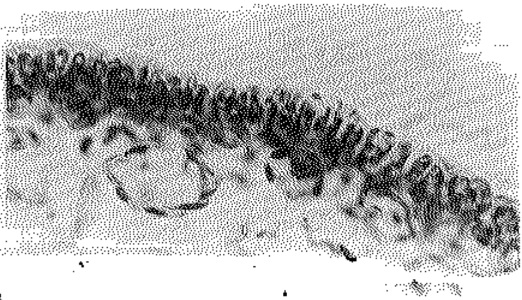

Fig. 8a. Habit of *Gracilaria heteroclada* from Vinh Quang, Vinh Linh, Quang Binh Province, northern Vietnam. Fig. 8b. *Gracilaria heteroclada* from Vinh Quang, Vinh Linh, Quan Binh Province, northern Vietnam. Longitudinal section of cystocarp. Fig. 8c. *Gracilaria heteroclada* from Vinh Quang, Vinh Linh, Quang Binh Province, northern Vietnam. Cortical cells showing small terminal spermantangia in Chorda-type arrangement.

*Gracilaria fisheri* (Xia et Abbott) Abbott, Zhang, et Xia, Pac. Sci. 45:23, 1991.

(Fig. 7)

Basionym: *Polycavernosa fisheri* Xia et Abbott, Phycologia 26:411–413, figs. 5 and 13, 1987.

Synonym: *Hydropuntia fisheri* (Xia et Abbott) Wynne, Taxon 38:477, 1989.

Plants 10–15 cm long, bushy, with many branches from a short stipe or from percurrent axis. Branches cylindrical, 0.5–2.0 mm in diameter, branching alternately with 3–4 orders, constricted at bases and tapering toward apices.

Distribution: This species grows on the shallow sandy to gravel bottom of calm bays in southern Vietnam.

Collection Sites: Mui Nai, Ha Tien, and Bai No, Ha Tien.

Remarks: *Gracilaria fisheri* is reported as a new record. The specimens collected from Vietnam are smaller than Thai specimens, which are up to 45 cm tall (Lewmanomont 1994).

*Gracilaria heteroclada* Zhang et Xia, Tax. Econ. Seaweeds 2, p. 132, 1988.

(Figs. 8a–8c)

Plants usually 20–50 cm long, solitary or caespitose. Axis thick and cylindrical, 1–3 mm in diameter, arising from a small disc with 2–4 orders of branches. Main axis fleshy, brittle, and easily broken. Color of main axis light red to dark green or dark brown. Branches irregularly alternate, secund or furcate, with second-order branches long, third-order branches short, sometimes spinose, 0.2–0.5 mm in diameter, gradually tapering toward apex and not constricted at base. Branches and branchlets clearly distinguished. In transverse section, medulla contains large parenchymatous cells, about 400 μm in diameter, with walls about 10 μm thick, surrounded by 2–3 layers of small roundish cells. Cystocarps (Fig. 8c) prominently protruding or subconical, about 500 μm in diameter, nonrostrate or slightly rostrate, nonconstricted at base; gonimoblast made up of parenchymatous cells, the cell wall obscure and cell contents irregularly connected to each other, about 23–82 μm × 13–20 μm in diameter, with 7–8 layers of cells, cells in outermost layer pigmented and roundish-cuboidal to oval, but cystocarp without traversing filaments. Spermatangia (Fig. 8c) superficial and continuous over surface of thallus, similar to those of *G. chorda.*

Distribution: This species is found as many bushy plants in the shallow bottom in lagoons in southern Vietnam. Plants were transplanted to the shrimp ponds by this survey project. They were still growing vigorously 1 year later, and the quality of agar was good.

Collection Sites: Vinh Quang, Vinh Linh.

Remarks: *Gracilaria heteroclada* is reported as *G. bursa-pastoris* by Nguyen (1992). Yamamoto et al. (1994) confirmed that spermatangia of *G. heteroclada* are formed superficially (chorda type) all over the fronds and that in culture, released carpospores develop normally and complete a typical Polysiphonia-type life history in about 140 days from the time of the initial culture. Some workers

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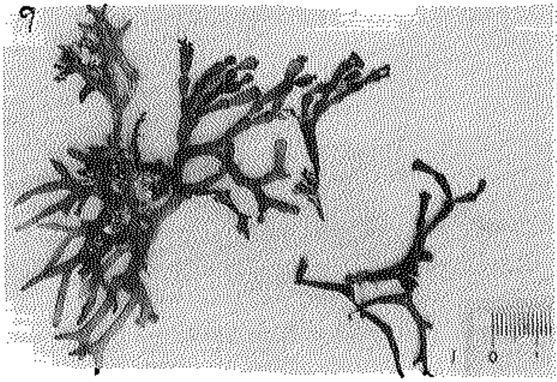

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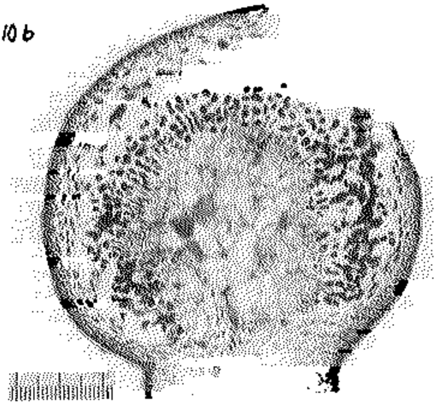

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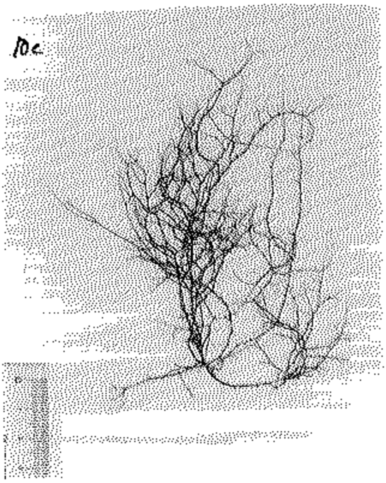

Fig. 9. *Gracilaria salicornia* from My Hoa, Ninh Hai, Ninh Thuan Province, central Vietnam. Figs. 10a–c. *Gracilaria tenuistipitata* var. *liui* from Phuoc Son, Tuy Phuoc, Binh Dinh Province, central Vietnam.

place *G. heteroclada* in the genus *Gracilariopsis.*

*Gracilaria salicornia* (C. Agardh ) Dawson, Bull. South. Calif. Acad. Sci. 53:1–7, 1954.

(Fig. 9)

Basionym: *Sphaerococcus salicornia* C. Agardh, Icones algarum ineditae 1, pl. 8, p. 302, 1820.

See Xia (1986) for other synonyms.

Plants succulent or crisp and firm, creeping to nearly erect, up to 3–6 cm long with 2–4 regular branches forming tightly entangled masses when internodes are long and low prostrate clumps when internodes are short, long internodes associated with plants growing in silted, muddy coral areas and in areas with mangroves.

Distribution: This species is found commonly on the rocks and lagoon in central and southern Vietnam. It is widely distributed in the Pacific and Indian oceans.

Collection Sites: Tai An, Ninh Hai; My Hoa, Ninh Hai; Son Hai, Ninh Phuonc; Mui Nai, Ha Tien; and Bai No, Ha Tien.

Remarks: *Gracilaria salicornia* is reported as *G. crassa* by Dawson (1954) and Pham (1969) in central Vietnam and as *G. cacalia* by Nguyen (1972) in northern Vietnam.

*Gracilaria tenuistipitata* var. *liui* Zhang et Xia, Tax. Econ. Seaweeds 2, pp. 131–132, figs. 1, 3–9, 1988.

(Figs. 10a–10c)

Plants (Figs. 10a–b) 10–20 cm long, slender with branching more dense than that of *G. tenuistipitata* var. *tenuistipitata* and with 2–3 orders of branching. Branching alternately or irregularly with ends curving away from percurrent axes, numerous delicate branchlets 0.25 mm in diameter. More common than *G. tenuistipitata* var. *tenuistipitata* (Fig. 10c) in the field; detaches and forms large masses of contorted thalli. In transverse section, medulla made up of cells 800–1000 μm in diameter (Fig. 10b), with wall about 10 μm in diameter. Medulla surrounded by 1–2 layers of cortical cells. Cystocarps about 830 μm in diameter. Pericarp 40–50 μm thick, with 4–5 layers of cells.

Collection Sites: *Gracilaria* cultivation ponds at Sam Chuong, Tam Giang Thua Tien, Hue; Hoi An, Quang Nam-Da Nang; and Phuoc Son, Tuy Phuoc, Binh Dinh.

Remarks: These specimens were collected in 3 locations where *Gracilaria* are cultivated in ponds. *Gracilaria tenuistipitata* var. *liui* is reported as a new record in Vietnam, although Nguyen (1992) reported *G. tenuistipitata.*

## Discussion

Nine species of *Gracilaria* were previously reported from Vietnam:

*Gracilaria articulata* Chang et Xia by Nguyen (1992) from northern Vietnam

*Gracilaria asiatica* Chang et Xia, as *G. verrucosa,* by Dawson (1954) and

Nguyen (1969) from Vietnam

*Gracilaria gigas* Harvey by Nguyen (1962) from northern Vietnam

*Gracilaria hainanensis* Chang et Xia by Nguyen (1962) from northern Vietnam

*Gracilaria spinulosa* (Okamura) Chang et Xia by Nguyen (1992), a new record from northern Vietnam

*Gracilaria punctata* (Okamura) Yamada by Nguyen (1992) from southern Vietnam

*Gracilaria textorii* (Suringar) Hariot by Nguyen (1992) from northern Vietnam

*Gracilaria chorda* Holmes by Nguyen (1992) from northern Vietnam

*Gracilaria bangmeiana* Zhang et Abbott by Nguyen (1992) from northern Vietnam

Most of these 9 species are reported from northern Vietnam. In this part of Vietnam, the sea shore is brackish, and the temperature of the water is lower than it is in central and southern Vietnam. We found *Gracilaria* materials on the coasts of northern Vietnam in March, but the seaweed flora on the coast at that time is poor. A different time may be better for collecting seaweeds, especially specimens of *Gracilaria*.

## Acknowledgments

This study was carried out under the title "Scientific Survey of Marine Algae and Their Resources in Vietnam," a project supported by a Grant-aid for Science Research (International Science Research Program, Field Research No. 0404105) from the Ministry of Education, Science, and Culture, Japan. We thank Drs. Hyunh Quang Nang and Nguyen H. Dinh, Nha Trang Institute of Material Science, Center for Production of Seaweeds in Vietnam, for cooperating on the survey with us in this project. We also thank Dr. I. A. Abbott for critically reading the manuscript and correcting it.

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# THE GENERA *GRACILARIA* AND *GRACILARIOPSIS* FROM NORFOLK ISLAND, SOUTHWESTERN PACIFIC

Alan J. K. Millar and Xia Bangmei

## Abstract

Three species of *Gracilaria*—*G. bangmeiana*, *G. coronopifolia*, and *G. rhodymenioides*—and 1 species of *Gracilariopsis*—*G. lemaneiformis*—are recorded from Norfolk Island. This report is the first for *G. bangmeiana* for the Australian mainland.

## Introduction

Studies on the Australian species of the genus *Gracilaria* have recently been published. Withell et al. (1994) described tropical and subtropical taxa, and Womersley (1996) discussed the southern or temperate species. Additional research has been done on various terete (Millar and Xia 1997) and flattened (Millar 1997) species as a direct result of these workshops on the taxonomy of economic seaweeds. This chapter deals with those species principally from Norfolk Island in the southwestern Pacific as part of ongoing studies on the marine algae there.

Three species of *Gracilaria* and 1 species of *Gracilariopsis* have been identified from Norfolk Island. Surprisingly, none of these is common to the neighboring island, Lord Howe Island, where *G. stipitata* Withell, Millar et Kraft, *G. howensis* Lucas (=*G. salicornia* [C. Agardh] Dawson), *G. edulis* (Gmelin) Silva, *G. secundata* Harvey, and *G. textorii* (Suringar) De Toni have been recorded by Withell et al. (1994). *Gracilaria bangmeiana* is recorded from Australia (namely New South Wales) for the first time. The genus *Gracilariopsis* is also a relatively recent addition to the southwestern Pacific region.

## Materials and Methods

Specimens were collected by scuba divers and were preserved in a 4% solution of formalin in seawater. For microscope slides, sections were stained with a mixture of aniline blue and Karo brand corn syrup (Millar and Wynne 1992). The slides are on file at the National Herbarium of New South Wales (NSW). Herbarium abbreviations are according to Holmgren et al. (1990). All sections were made by hand with single-edged razor blades. Photomicrographs were obtained with a Wild Leitz MPS51 Ortholux II system. Drawings were made by using a *camera lucida* attached to an Olympus CH-2 compound microscope. Photographs were printed according to previously described methods (Millar 1990).

## Key to the Species

1. Plants with terete stipe, distally flattened into dichotomous blades ........ *Gracilaria rhodymenioides*
1. Plants terete throughout ........ 2
    2. Plants with percurrent axes, traversing cells linking gonimoblast to pericarp tissue lacking ........ *Gracilariopsis lemaneiformis*
    2. Plants without percurrent axes, mostly dichotomously or irregularly branched, traversing cells abundant ........ 3
3. Plant axes up to 2 mm thick, robust, with acute apices and numerous spinelike lateral branchlets at right angles to main axes ........ *Gracilaria bangmeiana*
3. Plant axes up to 1 mm thick, wiry, with acute and obtuse apices but lacking spinelike laterals ........ *Gracilaria coronopifolia*

## Description of the Species

*Gracilaria rhodymenioides* Millar, Tax. Econ. Seaweeds 6, p. 114, figs. 5–12, 1997.

(Fig. 1)

Plants up to 4 cm tall, flattened except for terete stipes up to 15 mm long and 1 mm in diameter. Blades regularly dichotomous, up to 4 mm wide, with smooth margins. Apices rounded. Plants sterile.

Type Locality: Coffs Harbour, New South Wales, Australia.

Distribution: From Sydney to Byron Bay on the New South Wales coast and at Norfolk Island.

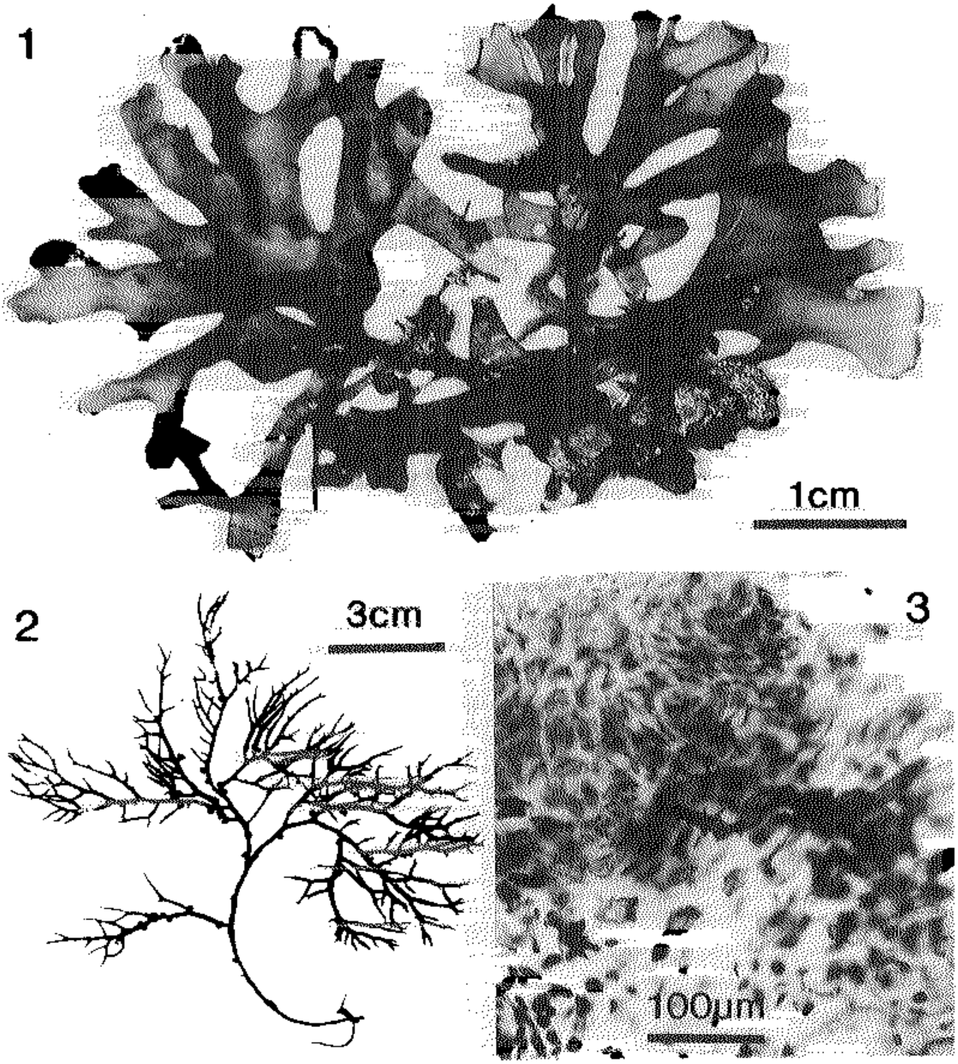
Specimens Examined: NSW 391965, collected at Norfolk Island, Duncombe Bay, by A. J. K. Millar and P. G. Richards, December 16, 1994.

Remarks: This distinctive species was recently described (Millar 1997) from the eastern seaboard of the Australian mainland. Its presence on Norfolk Island considerably extends its distribution eastward, yet, surprisingly, it has not been collected from Lord Howe Island, which lies almost equidistant between Norfolk and the New South Wales coastline.

*Gracilaria bangmeiana* Zhang et Abbott, in Abbott, Zhang, and Xia, Pac. Sci. 45, p. 23, 1991.

(Figs. 2 and 3)

Homotypic Synonyms: *Polycavernosa ramulosa* Chang et Xia, Stud. Mar. Sinica 3:125, 1963; *Hydropuntia ramulosa* (Chang et Xia) Wynne, Taxon 38:477, 1989; non *G. ramulosa* J. G. Agardh, Epicrisis, p. 417, 1876 (in Western Australia =*G. cliftonii*); and non *G. ramulosa* (Martius) Greville, in Saint-Hiliare, Voyage dans le district des diamans et sur le littoral de Brésil, Vol. 2, p. 448, 1883 (Brazil).



Figs. 1–3. *Gracilaria rhodymenioides* and *Gracilaria bangmeiana*. Fig. 1, Habit of *G. rhodymenioides* (NSW 391965). Fig. 2, Habit of *G. bangmeiana* (NSW 419014). Fig. 3, Portion of carposporophyte showing carposporangia of *G. bangmeiana* (NSW Slide 20-59).

Plants up to 12 cm tall (Fig. 2), terete throughout, often forming firm, tight, entangled masses within crevices of coral and rocky outcrops. Axes up to 2 mm in diameter, dichotomously, irregularly to profusely, although mostly openly, branched, often with small spinelike branchlets at right angles along main axes; apices always acute. Cystocarps large, up to 2 mm in diameter, spherical with protruding nipple for ostiole. Traversing cells numerous, but always basal to, never on sides or in upper parts of, carposporophyte (Fig. 3), elaborately lobed. Tetrasporangia not observed. Spermatangia not observed but known to be of the polycavernosa type.

Type Locality: Jiaotou, Ya District, Hainan Island, China.

Distribution: Hainan Island, China; central New South Wales coast; and Norfolk Island.

Specimens Examined: At Norfolk Island, NSW 397723, collected at Swiss Cheese Reef, off Kingston jetty, by A. J. K. Millar and P. G. Richards, December 15, 1994, and NSW 397724 and 397725, collected at Claytons Reef, west of Nepean Island, by A. J. K. Millar and P. G. Richards, December 12, 1994. From New South Wales, collected at Jervis Bay, Green Point, by B. Lo, March 27, 1994.

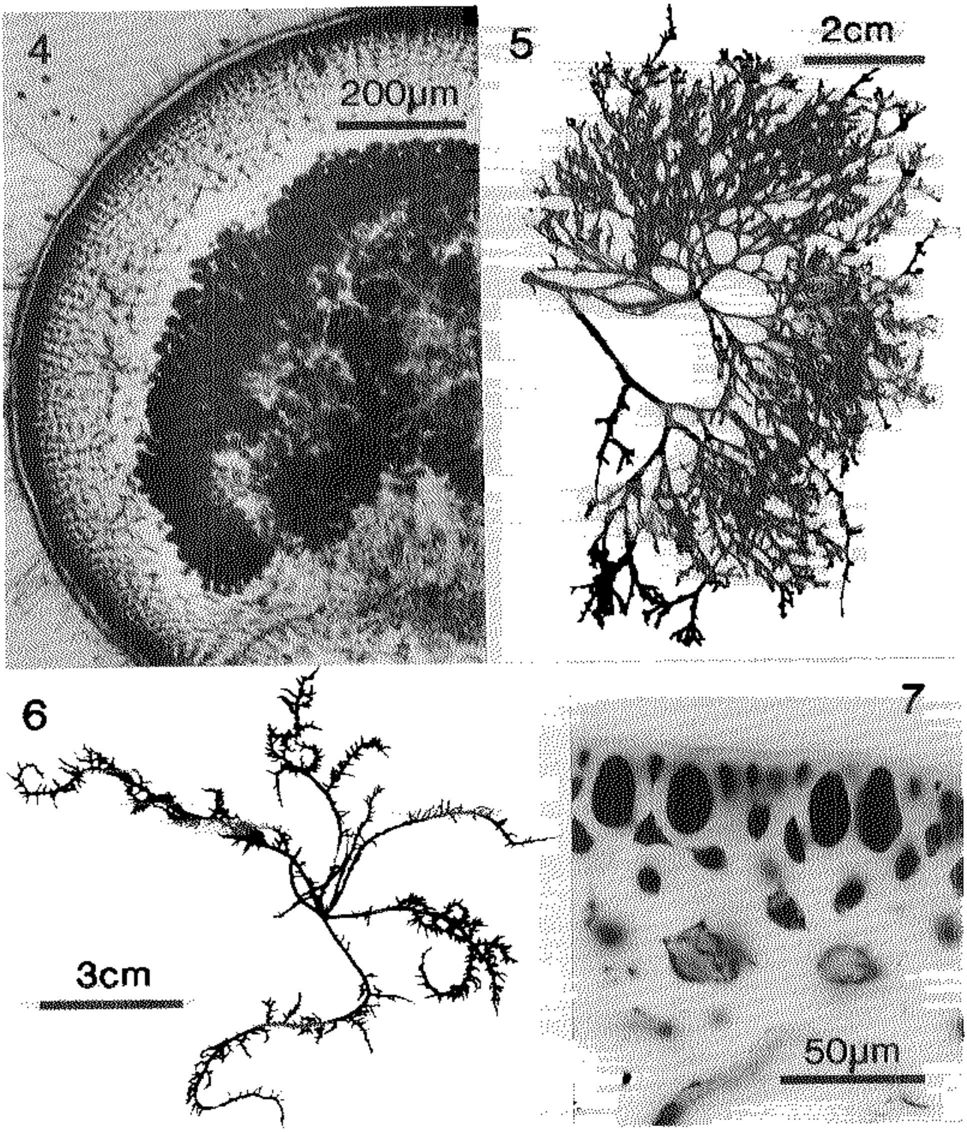
Remarks: This species was first described from China as *P. ramulosa* by Chang and Xia (1963). When investigations showed that the genus *Polycavernosa* was indistinguishable from *Gracilaria,* Abbott et al. (1991) transferred the species but were obliged to change the name to *G. bangmeiana* because of the previous existence of *G. ramulosa* (Martius) Greville (see Silva et al. 1996 for bibliographic details). J. G. Agardh (1876) gave the same name (i.e., *G. ramulosa*) to an entirely different species from southern Australia, which Withell et al. (1994) have decided is probably conspecific with *G. cliftonii. Gracilaria bangmeiana* and *G. cliftonii* are quite different species. *Gracilaria bangmeiana* has traversing cells only at the very base of the gonimoblast, and spermatangia are borne in deep polycavernosa-type conceptacles. *Gracilaria cliftonii* has traversing cells mostly in the upper parts of cystocarps, and spermatangia are borne in verrucosa-type pits.

*Gracilaria coronopifolia* J. G. Agardh, Sp. gen. ordines algarum, vol. 2, p. 592, 1852.

(Figs. 4 and 5)

Misapplied Names: *G. lichenoides* f. *coronopifolia* (J. Agardh) May, Commonwealth Aust. Coun. Sci. Ind. Res. Bull. 235, p. 37, pl. 6, fig. 1, 1948, and *G. edulis* sensu Withell, Millar and Kraft, Aust. Syst. Bot. 7, p. 346, 1994.

Plants up to 7 cm tall (Fig. 5), terete throughout, forming erect, wiry, almost brittle clumps. Axes firm, up to 1200 μm in diameter, dichotomously, irregularly and profusely, compactly branched. Apices mostly acute although sometimes obtuse. Cystocarps spherical without protruding ostiole, up to 1 mm in diameter; traversing cells restricted to sides and top of carposporophyte (Fig. 4), mostly without lobes. Tetrasporangia not observed. Spermatangia not observed but known to be of the verrucosa type.



Figs. 4–7. *Gracilaria coronopifolia* and *Gracilariopsis lemaneiformis.* Fig. 4, Section of cystocarp of *G. coronopifolia* shows traversing cells on sides and top (NSW Slide 20-60). Fig. 5, Habit of *G. coronopifolia* (NSW 402103). Fig. 6. Habit of *G. lemaneiformis.* (NSW 397851). Fig. 7, Cross section of *Gracilariopsis lemaneiformis* shows undivided tetrasporangia in cortex (NSW Slide 20-56).

Type Locality: Oahu, Hawaiian Islands.

Distribution: Singapore, China, Hawaii, and Norfolk Island.

Specimens Examined: NSW Slides 20–60, all material collected at Norfolk Island, The Cockpit, off Cascade jetty, by A. J. K. Millar and J. Marges, May 6, 1966, and May 11, 1996; NSW 402103, collected at Little Organ, off Captain Cook Memorial, by A. J. K. Millar and K. Christian, May 13, 1996; and NSW 415249 and 415250, probably collected at Slaughter Bay, by I. Robinson, April 1904.

Remarks: May (1948) examined 2 specimens of *G. coronopifolia* collected in 1904 from Norfolk Island (NSW 415249 and 415250) and identified them as *G. lichenoides* f. *coronopifolia*. Although they did not actually look at either of these 2 specimens, Withell et al. (1994) thought that May's interpretation of this forma was more indicative of *G. edulis*. Although these Norfolk Island specimens (which we have examined) are sterile and poorly preserved, they seem to match well with material recently collected, which includes cystocarpic material. Examination of the cystocarps of *G. coronopifolia* reveals that traversing cells link the sides and top of the carposporophyte to the surrounding pericarp tissue, whereas in *G. edulis*, traversing cells link only the basal parts of the carposporophyte to the gametophytic tissue. The 2 species are thus quite distinct.

*Gracilariopsis* cf. *lemaneiformis* (Bory de Saint Vincent) Dawon, in Dawson, Acleto and Foldvik, Seaweeds of Peru, p. 59, pl. 56, fig. A, 1964.

(Figs. 6 and 7)

Plants erect (Fig. 6), terete throughout, up to 8 cm tall, with a single axis to several percurrent axes up to 1 mm in diameter. Axes irregularly branched, beset with numerous short, up to 5 mm long, spinelike lateral branchlets at right angles to main axes. Apices acute. Tetrasporangia (Fig. 7) cruciately divided, scattered over surfaces of distal branches. Cystocarps and spermatangia not observed.

Type Locality: Paita, Peru.

Distribution: India, Thailand, Yemen, China, Hawaii, Chile, the western coast of North America, Norfolk Island, and tropical and subtropical western Atlantic.

Specimens Examined: NSW 397850 and 397851, collected at Norfolk Island, Claytons Reef, west of Nepean Island, by A. J. K. Millar and P. G. Richards, December 12, 1994.

Remarks: Currently, only tetrasporic specimens bearing cruciate tetrasporangia have been collected; hence, the generic and specific identification remains tentative. However, the habit and anatomy of the specimens examined in this study match well with those of specimens of *G.* cf. *lemaneiformis* from other Pacific localities. Womersley (1996) records this genus and species from Robe in South Australia, suggesting that it may be an adventive and that it could have been introduced by shipping activity to that area. The Norfolk Island collections suggest a sensible link to the otherwise northern and eastern Pacific distribution of this species. In addition, because much of the freight of Norfolk Island is via international ships, introduction by shipping may be the case at Norfolk Island also.

## Acknowledgments

Sincere thanks to Professor Isabella Abbott for the invitation to participate in this workshop and to Dr. James Sullivan and the California Sea Grant College System for financial sponsorship. Professor Khanjanapaj Lewmanomont and Dr. Anong Chirapart, Kasetsart University, Bangkok, Thailand, organized accommodation and excellent guidance and company during the workshop. Professor Xia Bangmei was politely critical of my initial identifications and is therefore acknowledged with authorship of this paper. Rachel Wakefield kindly printed the photographic plates.

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# OBSERVATIONS ON AN ADELPHOPARASITE GROWING ON *GRACILARIA SALICORNIA* FROM THAILAND

Ryuta Terada, Hirotoshi Yamamoto, and Daisuke Muraoka

## Abstract

An adelphoparasite of Gracilariaceae growing on *Gracilaria salicornia* from Thailand was observed. This parasite lacks rhizoids and has a short or long stalk, cruciately divided tetrasporangia, and verrucosa-type spermatangial conceptacles. These characteristics are similar to those of the adelphoparasites from Malaysia and from southern China. The presence of rhizoids, type of sporangia, and type of spermatangia differ among the genera *Congracilaria, Gracilariocolax,* and *Gracilariophila*. The Thai and Malaysian parasites most likely belong to the same genus.

## Introduction

Previously, 10 adelphoparasitic species in 3 genera in the Gracilariaceae have been reported from the various regions of Asia (Table 1). Weber-van Bosse (1928) established a new monotypic genus, *Gracilariocolax,* on the basis of a parasite growing on *Gracilaria radicans* Hauck from Indonesian waters. This parasite was characterized by the absence of rhizoids penetrating into the host tissue, a deep spermatangial conceptacle, and monosporangia. Weber-van Bosse also described 4 species of *Gracilariophila,* which have no rhizoids and have superficial spermatangia.

Chang and Xia (1978), following the opinion of Weber-van Bosse, reported 3 species of *Gracilariophila* growing on *Gracilaria crassa* (=*Gracilaria salicornia* [C. Agardh] Dawson) from southern China. These parasitic species lack rhizoids and have spermatangial conceptacles. However, Yamamoto and Phang (1997) indicated that *Gracilariophila* sensu Weber-van Bosse and *Gracilariophila* of Setchell and Wilson in Wilson (1910) differ from *Gracilariophila* of Chang and Xia (1978) because of their superficial spermantangia (Table 1).

Yamamoto (1986) established a new monotypic genus, *Congracilaria,* on the basis of Japanese materials growing on *G. salicornia.* The parasite found on the Japanese materials is characterized by bisporangia in which each cell has 2 nuclei, no rhizoids, and reproductive organs structurally similar to those of the host plant. The spermatangial conceptacle is the verrucosa type (see Yamamoto 1991, fig. 9). Yamamoto (1991) also reported this taxon growing on *G. salicornia* from the Philippines. He thought that the dividing pattern of sporangia (monosporangia, bisporangia, and tetrasporangia) should be one of the important features along with spermatangial type (superficial or conceptacles) for generic recognition.

**Table 1. Comparison of Adelphoparasitic Genera in the Pacific Region**

| Genus and Reference | Locality | Rhizoid | Type of Spermatangia | Sporangium | *Gracilaria* Host |
|---|---|---|---|---|---|
| *Gracilariocolax*<br>Weber-van Bosse 1928 | Indonesia | Absent | Deep conceptacle | Monosporangium | *G. radicans* |
| *Gracilariophila*<br>Setchell and Wilson in Wilson 1910 | United States | Present | Superficial | Tetrasporangium | *G. lemaneiformis* |
| *Gracilariophila* sensu<br>Weber-van Bosse 1928 | Indonesia | Absent | Superficial | Tetrasporangium | *G. arcuata* |
| *G. salicornia* | | | | | |
| *Gracilariophila* sensu<br>Chang et Xia 1978 | China | ? | Deep conceptacle | Tetrasporangium | *G. salicornia* |
| *Congracilaria*<br>Yamamoto 1986 | Japan | Absent | Deep conceptacle | Bisporangium | *G. salicornia* |
| *Congracilaria*<br>Yamamoto 1991 | Philippines | Absent | Deep conceptacle | Bisporangium | *G. salicornia* |
| Adelphoparasite<br>Yamamoto and Phang 1997 | Malaysia | Absent | Deep conceptacle | Tetrasporangium | *G. salicornia* |
| Adelphoparasite<br>Gerung et al. 1999 | Indonesia | Absent | Deep conceptacle | Bisporangium? | *G. edulis* |
| This study | Thailand | Absent | Deep conceptacle | Tetrasporangium | *G. salicornia* |

We are interested in the homology of spermatangial types among the parasites and the hosts from the phylogenetic point of view. Fredericq et al. (1989) showed that *Gracilariophila oryzoides* Setchell et Wilson has superficial spermatangia that are identical to the spermatangia of the host, *Gracilaria lemaneiformis* (Bory) Weber-van Bosse. Recently, Yamamoto and Phang (1997) reported an adelphoparasite growing on *G. salicornia* from Malaysia. The Malaysian parasite is similar to *Congracilaria babae* and *Gracilariophila* species sensu Weber-van Bosse in external morphology. However, the Malaysian alga has verrucosa-type spermatangial conceptacles (different from the superficial spermatangia of *Gracilariophila*), tetrasporangia, and a distinguishable boundary zone between the parasite and the host. This recognizable boundary is absent in *Gracilariocolax* and *Congracilaria.*

One of us (R. T.) collected many specimens of a parasitic alga in various developmental stages growing on *G. salicornia* in Thailand. The taxonomic relationships among all of these taxa from Asian regions are discussed in the following.

## Materials and Methods

Materials were collected at a fish culture pond in Trat, Rayong, Thailand, May 19, 1997, and preserved in a solution of 5% formalin in seawater. Preparations for microscopic observations were made by using a freezing microtome and were stained with aceto-iron-haematoxylin chloral hydrate (Wittmann 1965) and a solution of aniline blue in 1N HCl.

## Observations

A mass of *G. salicornia*, the host of the adelphoparasites, entangled in a fish culture pond, had many adelphoparasites on the surfaces of the host plants (Fig. 1), with all 3 reproductive phases on a single host plant. The Thai parasites have a mushroomlike appearance in general (Figs. 2 and 3), with a short or long stalk, 0.1–2.0 mm long. The fronds of the parasites are up to 3 mm long, from the surface of the host to the top of the cap. This appearance is similar, but not identical, to the illustrations of the Malaysian parasite (Yamamoto and Phang 1997, figs. 1–13).

The Thai parasite has no penetrating rhizoids into the host tissue (Figs. 4–6), and the tissue between host and parasite is continuous (Fig. 6), without a boundary of any kind, as shown by Yamamoto and Phang (1997, fig. 14) for the Malaysian parasite.

The shapes of cortical cells in the host and parasite differ slightly. Cortical cells in the sterile part of the parasite are small, narrow, and long, 6–15 μm long and 5 μm wide (Fig. 9), whereas those of the host plants are wide and short, 7 μm long and 8 μm wide (Fig. 7). However, in the mature part of the host, especially in male plants, this difference is indistinct, because the cortical layer becomes thicker as the spermatangial conceptacles develop.

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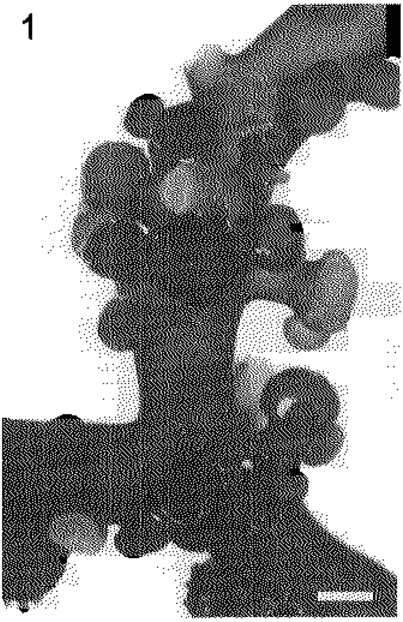

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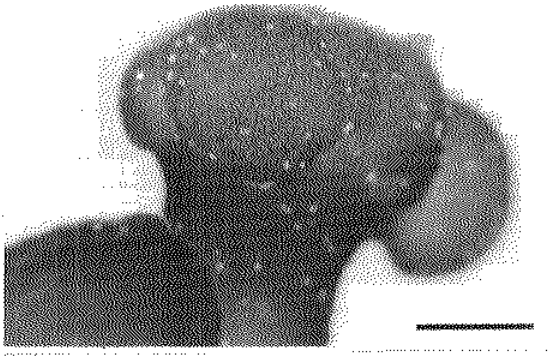

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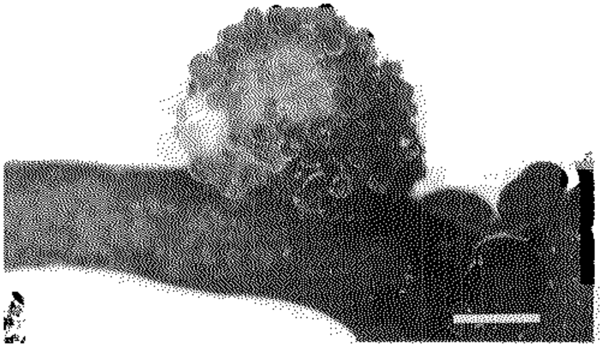
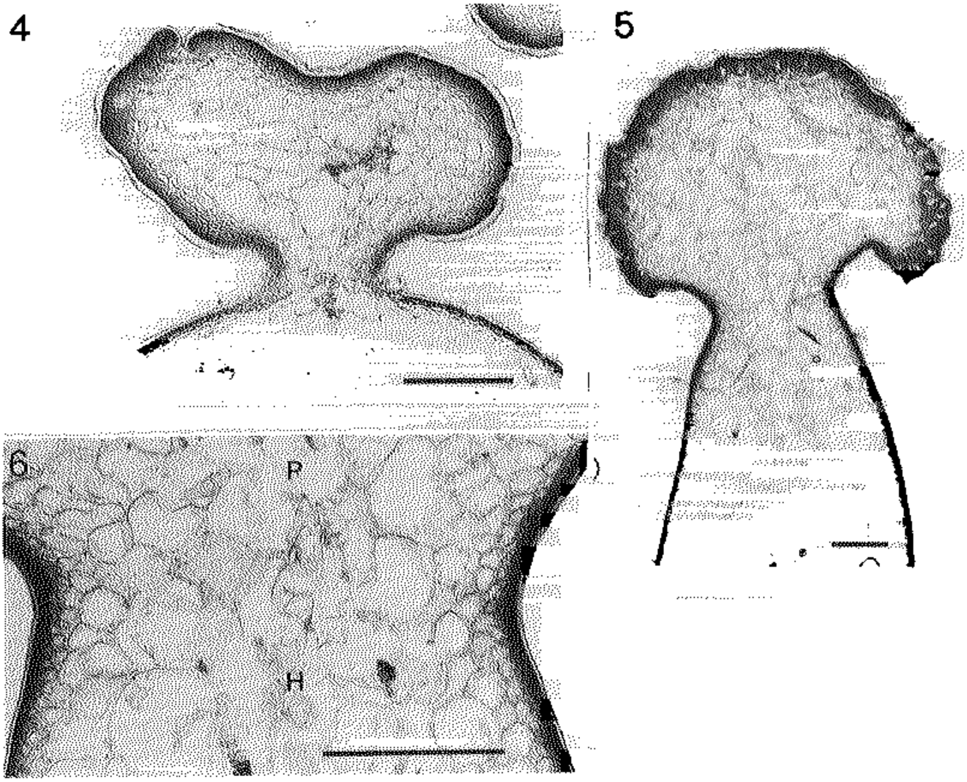
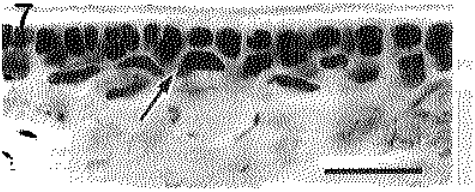
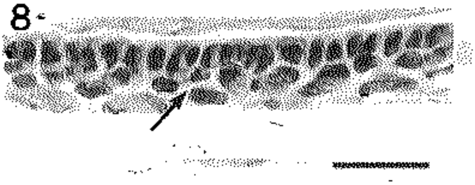


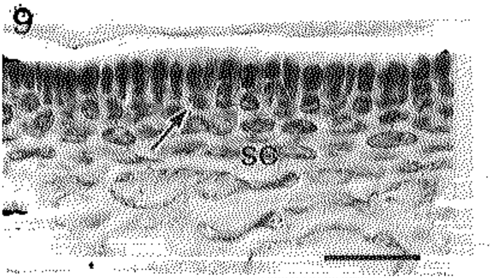
Figs. 1–6. Adelphoparasites growing on *Gracilaria salicornia* from Thailand.
Fig. 1, Mushroomlike appearance of many parasites growing on a single frond.
Fig. 2, Surface view of conceptacles on a mature male frond of the parasite.
Fig. 3, A frond with many vegetative processes on the cap. Scale bars: 2 μm for Figs. 1 and 3; 1 μm for Fig. 2.

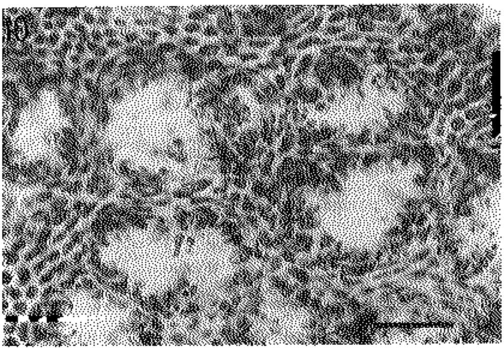


Figs. 1–6. Adelphoparasites growing on *Gracilaria salicornia* from Thailand. Fig. 4, Sectional view of a frond with a very short stipe. Fig. 5, Sectional view of a frond with a long stipe. Fig. 6, Continuous tissue between host (H) and parasite (P) shows absence of rhizoids. Scale bars: 300 µm for Figs. 4–6.









**Figs. 7–13. Adelphoparasites growing on *Gracilaria salicornia* from Thailand. Fig. 7, Sectional view shows wide and short outermost cells (arrow) in a sterile part of the host, *G. salicornia*. Fig. 8, Sectional view of cortical layer of the stalk of adelphoparasite shows cortical cells (arrow) with a shape intermediate between the shape of the cortical cells of the host (Fig. 7) and cap (Fig. 9). Fig. 9. Sectional view of a sterile part of the cap of the adelphoparasite shows narrow and long cortical cells (arrow) and subcortex with flat cells (SC). Fig. 10, Surface view of male gametophyte of the adelphoparasite. Scale bars: 30 μm for Figs. 7–10.**

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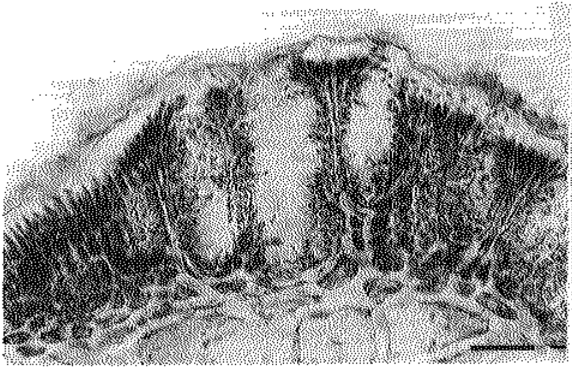

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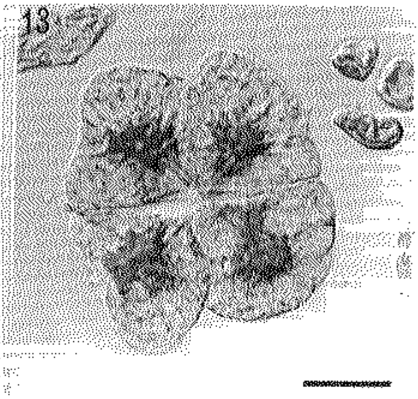

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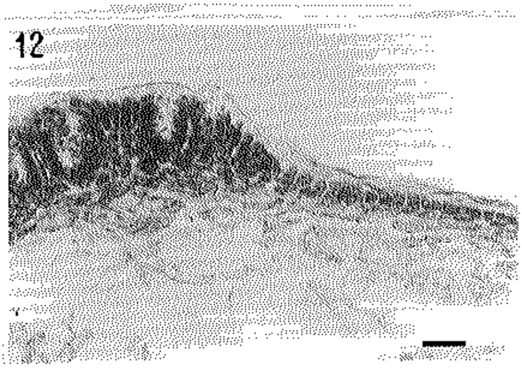

**Figs. 7–13. Adelphoparasites growing on *Gracilaria salicornia* from Thailand. Fig. 11, Longitudinal section of mature spermatangial conceptacles of the parasite shows deep verrucosa-type conceptacles. Fig. 12, Spermatangial conceptacles of the parasite in nemathecium-like elevation. Fig. 13, Cruciately divided tetrasporangium of the adelphoparasites. Scale bars: 30 μm for Figs. 11, 12 and 10 μm for Fig. 13.**

The internal structure of the stalk of the parasite is almost identical to that of the host (Figs. 5 and 8). The stalk is generally regarded as a part of the parasite, but it could be the tissue of the host.

The male reproductive organs of the parasite are of the verrucosa type but form deep conceptacles, up to 50–90 μm deep (Figs. 10 and 11). The cortical layers of mature male gametophytes are thicker than those of sterile part, because during the development of spermatangial conceptacles, a nemathecium-like elevation of the cortical layer around conceptacles occurs (Fig. 12). The male reproductive organs of the host were also deep conceptacles, up to 100 μm deep.

An important character for the taxonomy of adelphoparasitic species is the presence of cruciate tetrasporangium (Fig. 13). Fronds that have both tetrasporangia and spermatangial conceptacles are rare.

## Discussion

The Thai parasitic alga is characterized by a short or long stalk, a continuous zone of similar cells between host and parasite tissues, deep spermatangial conceptacles, and cruciately divided tetrasporangia. Although this adelphoparasite is similar in external morphology to *C. babae* (see Yamamoto 1986, 1991), the Thai parasite has tetrasporangia, whereas *C. babae* does not.

The Thai parasite is also similar to *Gracilariocolax* (Weber-van Bosse 1928); both lack rhizoids (Fig. 5) and have spermatangial conceptacles (Fig. 12). However, *Gracilariocolax* reportedly has monosporangia, whereas the Thai parasite has tetrasporangia (Table 1). Yamamoto and Phang (1997) reported that the descriptions of Weber-van Bosse of monosporangia and of the location of these structures in the tissue were unclear. Although Fredericq et al. (1989) suggested that *Congracilaria* and *Gracilariocolax* be merged, we think that 2 genera should be retained until detailed information is available.

The Thai adelphoparasite differs from *G. oryzoides*, the type species of *Gracilariophila*, and from *Gracilariophila* sensu Weber-van Bosse (1928). Both of these species of *Gracilariophila* have superficial spermatangia, and the type species also has rhizoids. The Thai parasite has neither of these features. This lack of rhizoids and the presence of spermatangial conceptacles in the Thai specimen are similar to characteristics of *Gracilariophila* sensu Chang and Xia (1978). Yamamoto and Phang (1997) said that Chinese parasites should not be placed in the genus *Gracilariophila*, because the spermatangial conceptacles of the Chinese parasites are of the verrucosa type. As far as we know, Asian parasites do not have superficial spermatangia. Yamamoto and Phang also said that if *Gracilariophila* sensu Weber-van Bosse has superficial spermatangia and no rhizoids as she described, a new genus could be proposed for her species.

The Thai adelphoparasite is similar to the parasite from Malaysia in external morphology. Both lack rhizoids and have spermatangial conceptacles and tetrasporangia. Although medullary tissue between parasite and host is almost continuous in the Thai parasite, differing from the distinctive border zone of small cells in Malaysian materials (Yamamoto and Phang 1997, fig. 14), Thai alga showed close relationships with the Malaysian taxon. We think that the Malaysian and the Thai parasites are in the same genus.

## Acknowledgments

We sincerely thank Dr. I. A. Abbott, University of Hawaii, for her critical reading of the manuscript. We also thank Mr. S. Suthewatt and Dr. M. Ohno, Kochi University, and Dr. A. Chirapart, Kasetsart University, for their advice in sampling.

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# AN ADELPHOPARASITE GROWING ON *GRACILARIA EDULIS* (GRACILARIACEAE RHODOPHYTA) FROM MANADO, INDONESIA

Grevo S. Gerung, Ryuta Terada, Hirotoshi Yamamoto, and Masao Ohno

## Abstract

An adelphoparasitic alga was found on *Gracilaria edulis* growing in Manado, Indonesia. Various types of plants were examined, and all lacked rhizoidal penetration of the parasite into the host. Spermatangia of the parasite occur in conceptacles, and sporangia are clearly divided. The external appearance of the plants is similar to that of adelphoparasites reported from Asia previously.

## Introduction

Parasitic red algae have been divided into 2 categories: adelphoparasites and alloparasites. Goff (1982) listed 101 species in 57 genera, and most of the species were adelphoparasites that were closely related to their hosts. Two genera, *Gracilariophila* and *Gracilariocolax,* have been reported in Gracilariaceae, and Yamamoto (1986) found a new species of adelphoparasite and placed it in a new genus called *Congracilaria*. The type species of the genus, *C. babae,* was found at Nishibaru, Okinoerabu Island, Japan. Yamamoto (1991) also studied specimens of *C. babae* from the Philippines. Yamamoto and Phang (1997) reported an adelphoparasite from Malaysia, and Terada et al. (1999), in this volume, report a parasite from Thailand that is similar to *Congracilaria* and *Gracilariocolax*. In this chapter, we report an adelphoparasite found growing on *Gracilaria edulis* from Manado, Indonesia, the site of collections of parasites made by Weber-van Bosse (1928).

## Materials and Methods

The host plants with parasites attached to fragments of coral in areas of flat sandy sea bottom were collected from Manado, Indonesia, in June 1997. The specimens were transported to and cultured at Usa Marine Biological Institute, Kochi University, Japan. Microscopic observations have been made in the Laboratory of Marine Botany Faculty of Fisheries, Hokkaido University, Hakodate. Preparations for microscopic observation were made by hand by using a freezing microtome. A solution of aniline blue in 1 N HCl was used for staining. For the photographs, the materials were preserved in a solution of 5% formalin in seawater. The photographs were obtained with Olympus SZH and Olympus AH-2 cameras.

## Observations

Plants parasitic on various parts of *G. edulis* (Gmelin) Silva have a mushroom-shaped appearance (Figs. 1a–1d). The parasites are the same color as the host in natural conditions and in laboratory cultures. The parasites are up to 2 mm long and up to 3 mm in diameter.

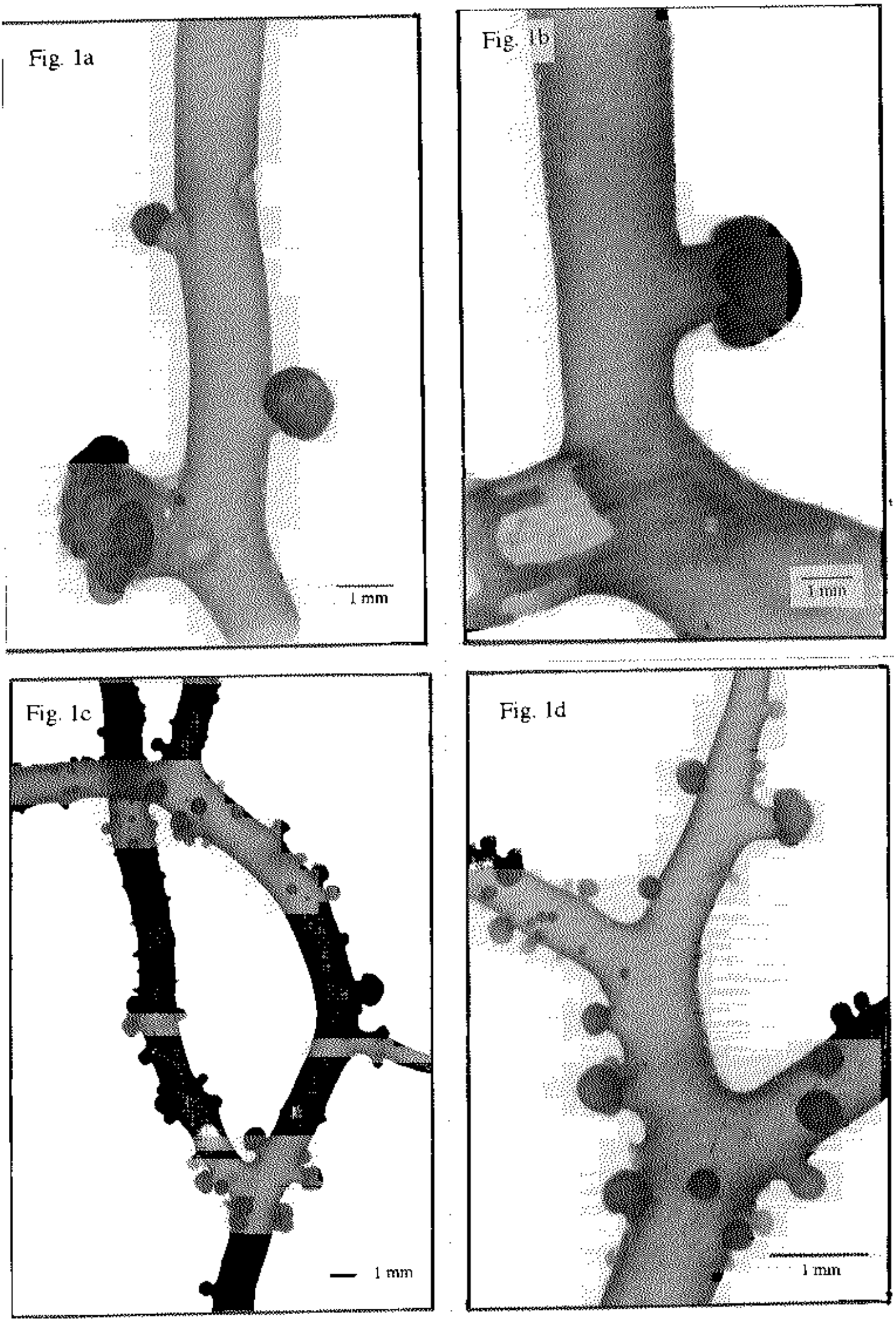
In longitudinal sections, the border between parasite and host tissue is made up of small medullary cells without any penetration of rhizoids into the host (Fig. 4). The stipe is up to 1 mm long and up to 2 mm in diameter. We think that the stipe is not part of the parasite; the parasite begins distal to the small cells in the border between host and parasite and grows toward the apex (Fig. 2). The cortical cells gradually increase in size toward the center, reaching up to 90–100 μm in height and 95–150 μm in width. The cells attach by secondary pit connections.

Figure 3 shows a clearly divided sporangium (perhaps a bisporangium), and Figure 6 shows the verrucosa-type arrangement of the spermatangia. A number of early stages of cystocarpic development (Fig. 5) occur on a single plant.

## Discussion

The sampling site was the same island where Weber-vanBosse obtained the specimens that she reported as *Gracilariophila* (4 species and 1 variety) and recognized as a new genus, *Gracilariocolax* (Weber-van Bosse 1928). Differences between *Gracilariophila* and *Gracilariocolax* are not clear yet, because the genera seem similar to each other. Furthermore, *Gracilariophila* specimens as reported by Setchell and Wilson (in Wilson 1910), Weber-vanBosse (1928), and Chang and Xia (1978) vary in details, so that the characteristics of the genera and how to evaluate the characteristics remain unclear.

Yamamoto (1986) named *Congracilaria* to include plants that were similar to both *Gracilariophila* and *Gracilariocolax* but differed in the pattern of spermatangia and in the nature of mature sporangia. The external appearance of the Indonesian parasites are similar to those of *Gracilariophila*, *Gracilariocolax*, and *Congracilaria*. Indonesian parasites are characterized by the following: parasitic on *G. edulis*, verrucosa-type spermatangial conceptacles, clearly divided sporangia (however, divided only once), and small cells rather than rhizoids between host and parasite. Like *Gracilariocolax*, our material has deep spermatangial conceptacles and no rhizoids, but it lacks the characteristic monosporangia of *Gracilariocolax* reported by Weber-van Bosse (1928). However, the host of *Gracilariocolax* is *Gracilaria radicans*. Yamamoto and Phang (1997) suggested that the monosporangium on *Gracilariocolax* may be early undivided stages or may not be a sporangium. If this possibility is true, our plants could be *Gracilariocolax* on a different host. Many adelphoparasites such as *Janczewskia* are narrow-spectrum parasites; others occur on several different species of the host (Goff 1982). We need to observe the specimens of Weber-van Bosse to determine if they have monosporangia or not.



**Figs. 1a–1d. Adelphoparasitic algae growing on *Gracilaria edulis* from Manado, Indonesia.**

Fig. 2

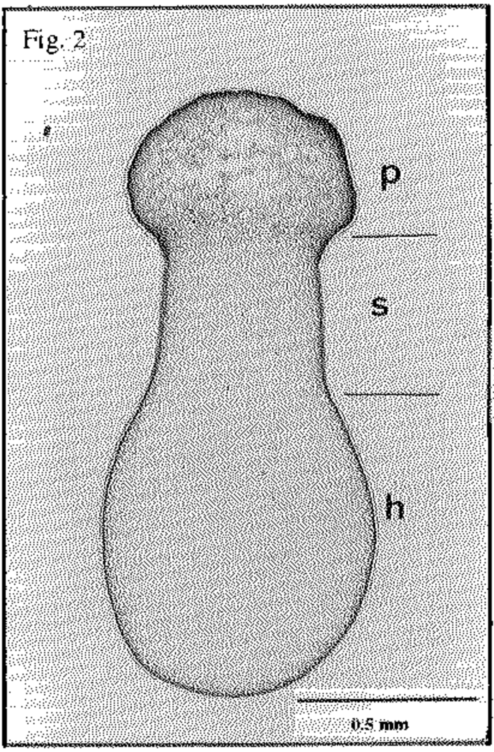


Fig. 3

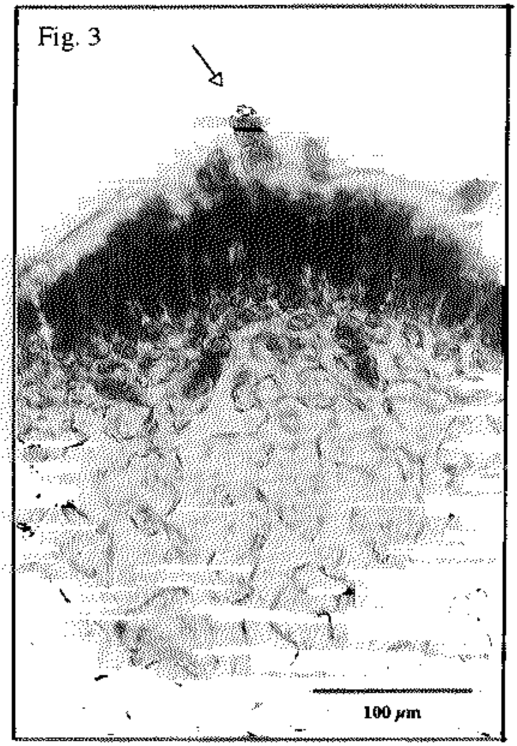
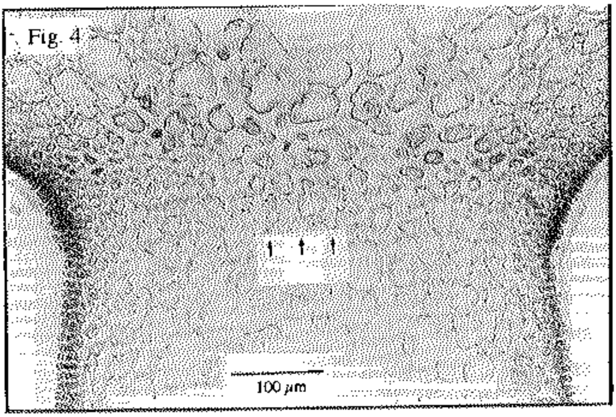
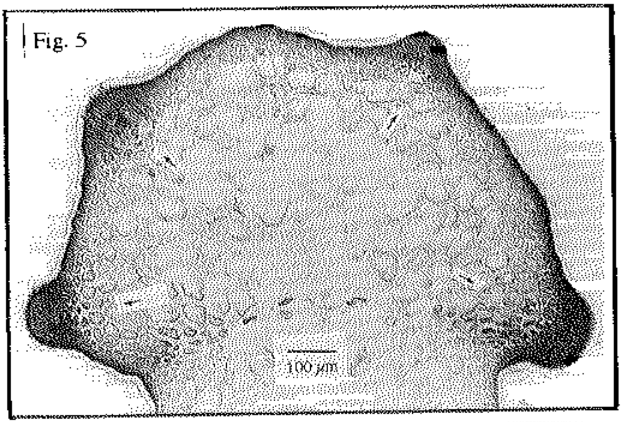


Fig 2. Longitudinal section shows adelphoparasite (p), *Gracilaria edulis* host (h), and stipe (s) between host and parasite. Fig. 3. Longitudinal section of adelphoparasite shows sporangium (arrow) with a single division.





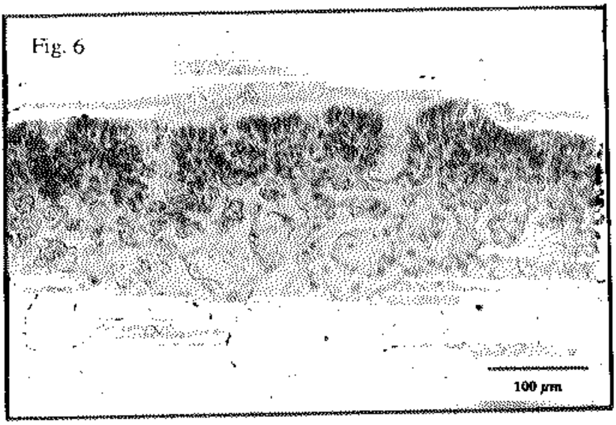


**Fig. 4. Longitudinal section shows the small medullary cells (arrows) in the border between the stipe and the parasite. Fig. 5. Longitudinal section shows several cystocarps of the adelphoparasite in early stages of development. Fig. 6. Sectional view shows verrucosa-type spermatangial arrangement in the adelphoparasite.**

Unlike our materials, *Gracilariophila,* as described by Setchell and Wilson, has rhizoids and superficial spermatangia (chorda type), and the host plant is *Gracilariopsis lemaneiformis.* Like our sample, *Gracilariophila* sensu Weber-van Bosse (1928) from Indonesian waters lacks rhizoids, but superficial spermatangial arrangements were reported. The *Gracilariophila* reported from China (Chang and Xia 1978) had verrucosa-type spermatangial conceptacles similar to those of our Thai plants. We cannot adopt the genus *Gracilariophila* for our sample. Yamamoto and Phang (1997) suggested that the materials from China should not be placed in the genus *Gracilariophila* because of the extremely different spermatangial arrangements.

On the basis of the spermatangial conceptacles, divided sporangia, and absence of rhizoids, the Indonesian material seems similar to *Congracilaria* Yamamoto (Yamamoto 1986), an adelphoparasite from Malaysia (Yamamoto and Phang 1997), and from Thailand (Terada et al. 1999). It differs from these in the host that it parasitizes. The host for most *Congracilaria* is *Gracilaria salicornia.* We think that the Indonesian parasites should be placed in the genus *Congracilaria* as a species that inhabits a host other than *G. salicornia.* To make a clear conclusion, we should first examine the specimens of *Gracilariophila* and *Gracilariocolax* collected by Weber-van Bosse. Observations on the adelphoparasitic algae in Gracilariaceae should continue in order to understand the relationship of the reproductive organs between host and parasite.

## Acknowledgments

We thank Dr. I. A. Abbott for critically reading the manuscript.

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Yamamoto, H., and Phang, S. M. 1997. An adelphoparasitic alga growing on *Gracilaria salicornia* from Malaysia. In: Tax. Econ. Seaweeds 6, pp. 91–95.

# A NEW RECORD OF *GRACILARIA, G. RUBRA* C. F. CHANG ET B. M. XIA FROM THAILAND

Anong Chirapart and Rapeeporn Ruangchauy

## Abstract

Specimens of *Gracilaria* collected from Chonburi Province in the Gulf of Thailand and from Ranong Province in the Andaman Sea were examined. The specimens showed the typical cystocarpic and spermatangial characteristics that distinguish this species from other Thai species of *Gracilaria*. This taxon is identified as *G. rubra* C. F. Chang et B. M. Xia and is reported as a new record for Thailand.

## Introduction

The red algal genus *Gracilaria* in Thailand has been previously reported (Velasquez and Lewmanomont 1975, Lewmanomont 1978). Abbott (1988) reported 11 species of Thai gracilarioids, 4 of which were new records. Then, Lewmanomont (1994) reported 13 species of *Gracilaria* from the Gulf of Thailand and the Andaman Sea, of which 4 were new records and 1 was a new species. Later, she reported *G. urvillei* from Satun Province in the Andaman Sea as another new record (Lewmanomont 1995).

In this chapter, we report a new record of *Gracilaria, G. rubra,* first described from southern China, for Thailand.

## Materials and Methods

Specimens were collected from coastal Sri Racha, Chonburi Province, in the Gulf of Thailand in January 1989 and from Haad Toong Nang Dam, Ranong Province, in the Andaman Sea in April 1997. Sections of specimens were prepared by hand, stained with 1% aqueous aniline blue intensified with 1% HCl, and mounted in Karo brand corn syrup on glass slides. The specimens examined are deposited in the herbarium of Faculty of Fisheries, Kasetsart University.

## Description of the Species

*Gracilaria rubra* C. F. Chang et B. M. Xia, Stud. Mar. Sinica 11:160, 1976.
(Figs. 1–8)

Plant light purplish red, membranous-cartilaginous in substance, adhering imperfectly to paper on drying. Thallus erect, cylindrical, arising from a small disc, 1–2 mm in diameter and up to 25 cm long (Figs. 1 and 2). Axes slender, 0.5–1.0 mm in diameter, with long attenuate branches, up to 15 cm long, abruptly constricted at the bases.

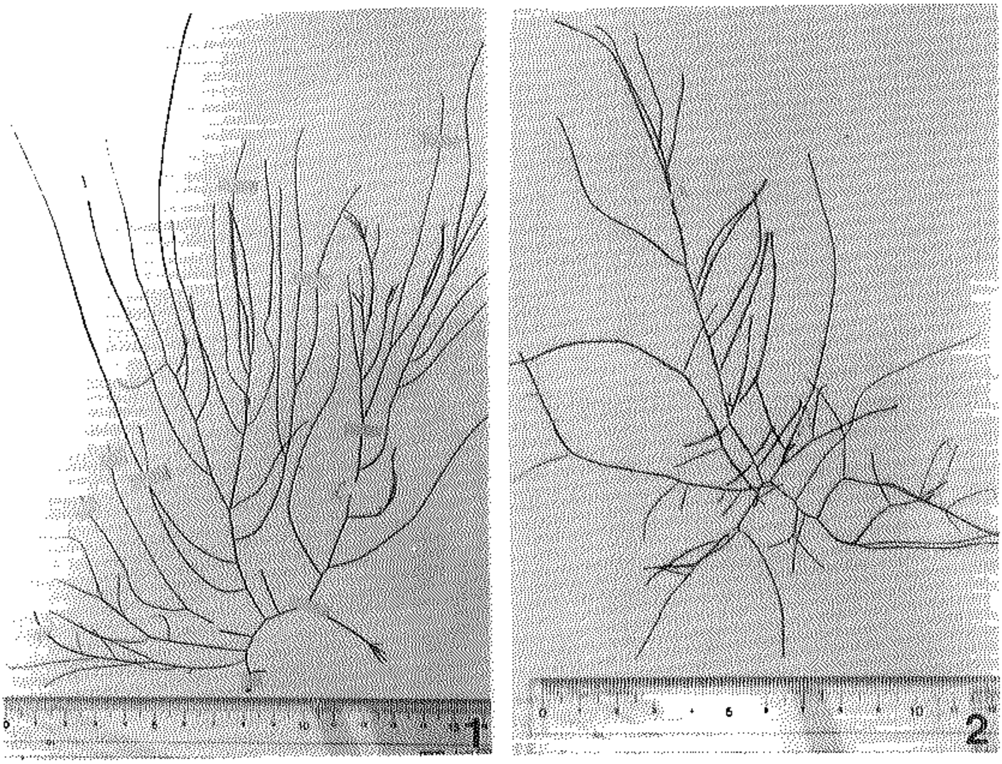
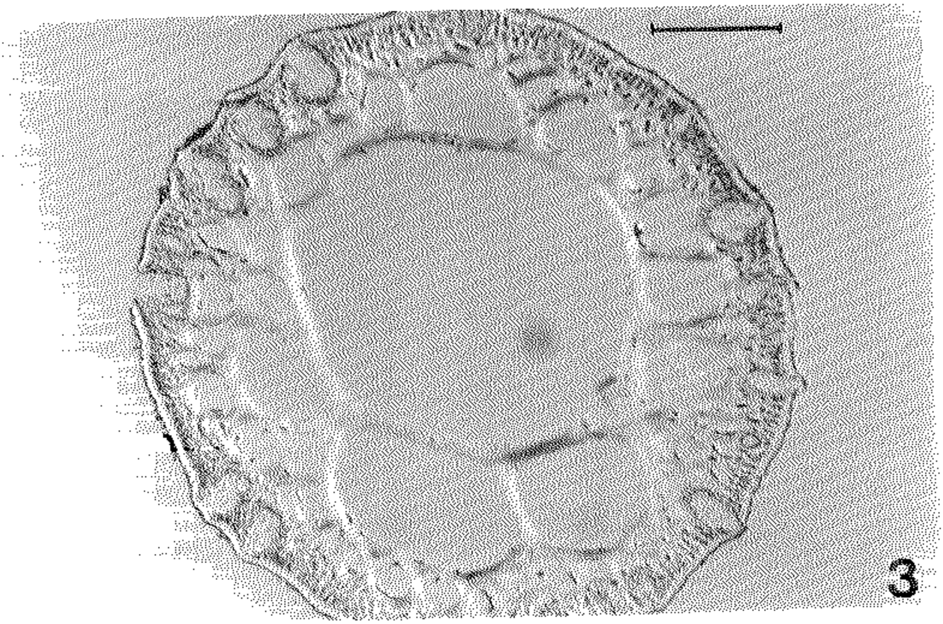


**Fig. 1. Habit of male gametophyte of *Gracilaria rubra* collected from Haad Toong Nang Dam, Ranong Province, in the Andaman Sea in April 1997. Fig. 2. Habit of female gametophyte of *Gracilaria rubra* collected from Sri Racha, Chonburi Province, in the Gulf of Thailand in January 1989.**



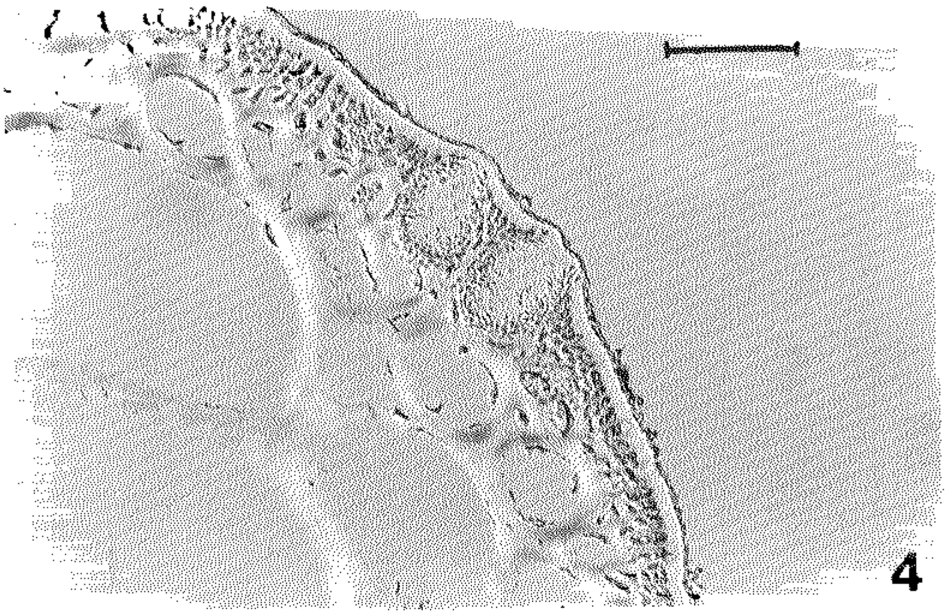


**Fig. 3. Transection of male frond of *Gracilaria rubra* shows arrangement of spermatangial conceptacles. Scale bar = 200 µm. Fig. 4. Magnified transection of cortex of *Gracilaria rubra* shows obovoid spermatangial conceptacles. Scale bar = 100 µm.**

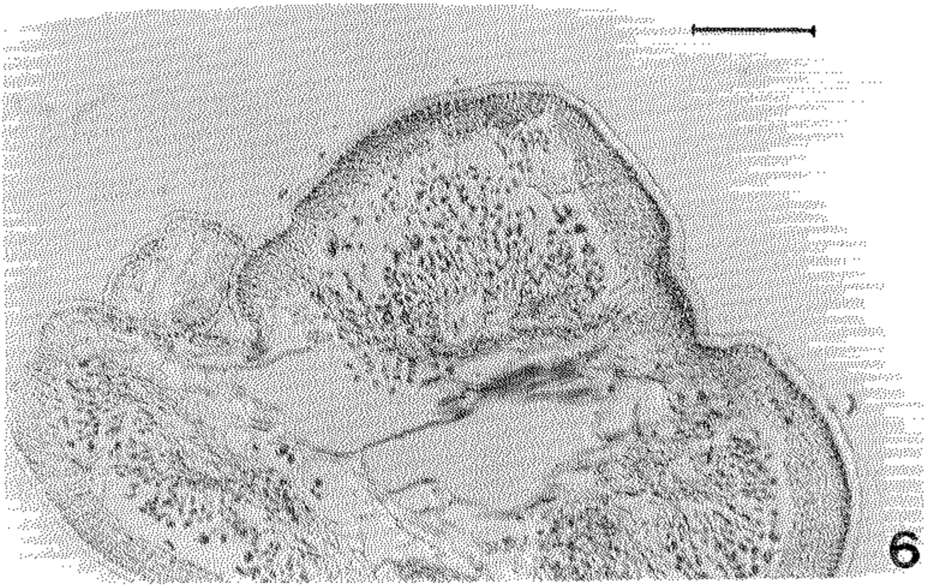


**Fig. 5.** Magnified section of young spermatangial conceptacle of *Gracilaria rubra*. Scale bar = 25 μm. **Fig. 6.** Longitudinal section of female frond of *Gracilaria rubra* shows arrangement of cystocarp. Scale bar = 200 μm.

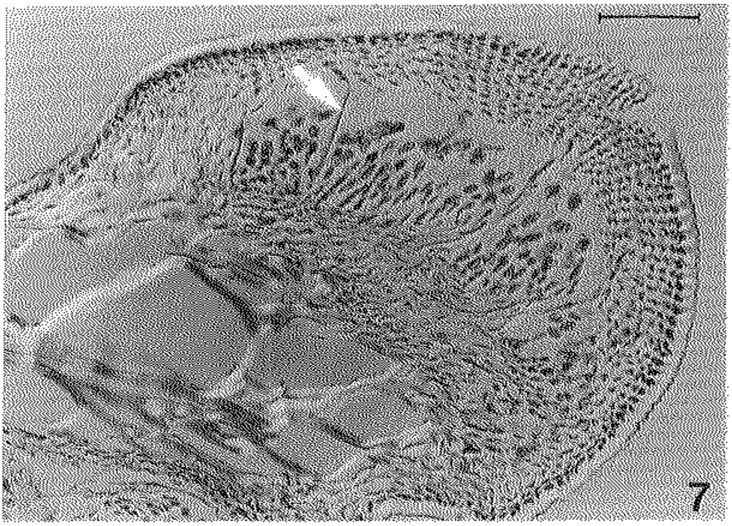


Fig. 7. Magnified transection of cystocarp of *Gracilaria rubra* shows large gonimoblast cells and 4 tubular nutritive filaments. Scale bar = 100 μm. Fig. 8. Magnified transection of cystocarp of *Gracilaria rubra* shows arrangement of pericarp cells and tubular nutritive filament (arrow). Scale bar = 50 μm.

Transition of cell size from cortex to medulla extremely abrupt, medulla made up of large parenchymatous cells, about 115–380 µm in diameter, cell wall 8–12 µm thick, surrounded by a narrow, infracortical layer of 1–2 layers of roundish cells, 16–25 µm in diameter, and 1–2 layers of smaller (outer) cortical cells, pigmented, ovoid or cuboid, about 21–29 µm in diameter. Spermatangia (Figs. 3–5) obovoid to globose, verrucosa-type conceptacles 21–70 µm wide by 25–86 µm deep, surrounded by 2 layers of elongate cortical cells. Cystocarps scattered, base and shape of cystocarp globose or semiglobose, nonrostrate, unconstricted, 517–730 µm wide by 328–492 µm deep (Fig. 6). Pericarp tissue 70–103 µm thick, 9–13 cell layers (Fig. 8); parenchyma of gonimoblast relatively large in cell size (Fig. 7), connected to the pericarp by tubular nutritive filaments (Fig. 8).

Type Locality (Holotype): Xinyigang, Lingao Xian, Hainan Island, Guangdong Province, China.

Distribution: Known previously only from the type locality.

Habitat: Grows on gravel and shells covered with sandy mud from low tide mark down to upper sublittoral zone (1–3 m).

## Discussion

*Gracilaria rubra* was first described by Chang et Xia (1976). This species has some characteristics similar to those of *G. hainanensis* and *G. maramae* (South 1995), which have verrucosa-type male conceptacles, tubular nutritive filaments in the cystocarp, constrictions at the bases of branches, and pericarp with stellate cells.

For our study, female gametophyte plants were collected from coastal Sri Racha, Chonburi Province, in the Gulf of Thailand in January 1989. Male gametophyte plants were collected from Haad Toong Nang Dam, Ranong Province, the Andaman Sea in April 1997. Although the specimens examined were collected from different sites and at different times, they fit the overall morphology and cell characters of the species.

Male conceptacles and cystocarps of the specimens examined differ from those of Thai species of *Gracilaria* reported in previous studies (Abbott 1988; Lewmanomont 1994, 1995). *Gracilaria rubra* seems to have some features similar to those of Thai species of *G. tenuistipitata*, but the former has globose-unconstricted cystocarps, nutritive filaments in the cystocarps, and verrucosa-type male conceptacles, characteristics not found in *G. tenuistipitata*. Additionally, *G. tenuistipitata* typically has percurrent axes, whereas *G. rubra* does not.

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# Section IV. Halymenia

## INTRODUCTION

### Isabella A. Abbott

*Halymenia,* now placed in the Halymeniales, an order recently carved from the old Cryptonemiales, has long been a favorite of mine to eat, since I was a little girl. During my doctoral studies, I examined and published on several species from the California coast. When I heard that Dr. Kawaguchi had finished his doctorate and was on the faculty of Kyushu University, I asked him if he would like to join the taxonomy workshop and work on *Halymenia*. He agreed. I enjoyed the e-mail correspondence with him as he wrestled with anatomical problems in his examinations of material; the experience reminded me of my younger days when I wondered whether or not I was actually interpreting correctly the things I saw. I hope that Dr. Kawaguchi has collected many more species than are covered in this volume, and I encourage him to corroborate or sharpen my observations and to add another contribution in the volume on the next taxonomy workshop.

# MORPHOLOGY AND CULTURE STUDY OF A RED ALGA, *HALYMENIA DILATATA* ZANARDINI, FROM VIETNAM AND JAPAN

S. Kawaguchi and K. Lewmanomont

## Abstract

The vegetative and reproductive features of *Halymenia dilatata* Zanardini (Halymeniaceae, Halymeniales) from Vietnam and Japan were examined and compared with those previously described by Balakrishnan for Indian material. Although some minor differences were found, the major features of these materials were in good agreement in the following respects: (1) The blade is foliose, oblong to circular, or irregularly lobed, with a laciniate to sinuate margin. (2) The surface of the blade is mottled in a peculiar pattern (maculae). (3) The medulla is made up of sparsely intermeshed filaments, some of which are anticlinally oriented. (4) Highly refractive ganglionic cells are occasionally found in the medulla. (5) Auxiliary-cell ampullae are conical to wide across the top, with numerous branched secondary filaments.

Culture studies showed that carpospores develop into acrochaetioid filaments from which are produced upright thalli. This pattern of spore development agrees well with that of other species of this genus, including the type species, *H. floresia* (Clemente) C. Agardh.

## Introduction

Members of the red algal genus *Halymenia* (Halymeniaceae, Halymeniales) are widely distributed but are particularly abundant in tropical and subtropical regions. In the Indo-West Pacific region, more than 20 species have been recorded (Weber-van Bosse 1921; Okamura 1936; Dawson 1954; Pham 1969; Silva et al. 1989, 1996). However, because species of *Halymenia* have received little attention, the circumscription of this genus has not been completely established. Some of the western Pacific species seem to be poorly defined, and the specific discrimination of them should be reexamined. As a first step in establishing a better classification system for the western Pacific species, we studied *H. dilatata* Zanardini.

*Halymenia dilatata* was originally described from the Red Sea as follows: "H. fronde gelatinoso-membranacea basi callosa subsessili subflabellatim dilatata vage sinuosa, sinubus obtusissimis rotundatis, laxedentato-ramentacea vel prolifera, ramentis apice obtusis; tetrasporis cruciatim divisis in soros maculaeformes collectis per totam fondem confluentes" (Zanardini 1851). In 1858, Zanardini published additional descriptions of the alga with several illustrations of its habit and anatomic structures. Since then, several workers have reported this species from around the western Pacific (Okamura 1921, Weber-van Bosse 1921, Dawson 1954). In 1961, Balakrishnan gave a detailed description of vegetative and reproductive structures of the alga based on material from the Indian Ocean, but he did not illustrate the habits. In this chapter, we describe this alga in full detail on the basis of material from Japan and Vietnam, compare our specimens with Indian material, and present the results of culture studies of carpospores.

## Materials and Methods

Materials from Vietnam were dried specimens of plants collected by N. H. Dinh at Nha Trang, central Vietnam, in 1991 and 1992. Materials from Japan were dried and liquid-preserved specimens of plants from Kagoshima and Okinawa prefectures, southern Japan, collected by M. Masuda, S. Arai, and one of us (S. K.) from 1983 to 1996. The specimens used for this study are kept in part in the herbarium of the Graduate School of Science, Hokkaido University (SAP), and held in part by one of us (S. K.; Figs. 1–8). In addition, many fragmentary specimens from Japan were also examined.

Sections were made by hand with a razor blade, mounted on glass slides, and stained with 0.5% cotton blue in a 1:1:1:1 mixture of water, phenol, lactic acid, and glycerol.

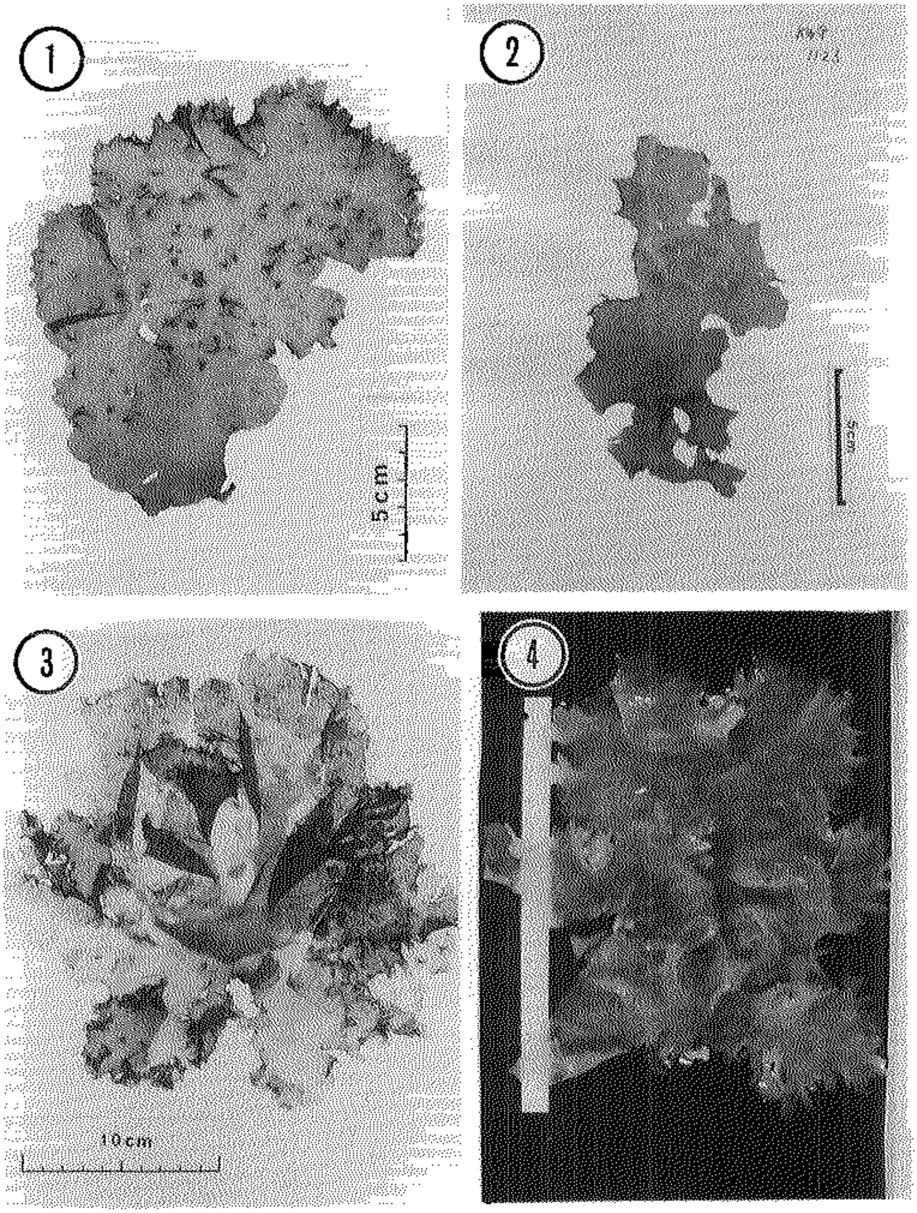
Carpospores were obtained from a fragmentary specimen cast ashore at Ohdomari, Kagoshima Prefecture, on August 10, 1988. Liberated spores were inoculated onto petri dishes containing pasteurized seawater enriched with PES medium. These dishes were placed in an incubator illuminated with white-fluorescent light, 40–50 µmol $m^{-2}$ $s^{-1}$ , under a photoregimen of 14 hours of light and 10 hours of dark, at 22°C–24°C. The medium was changed biweekly.

## Observations

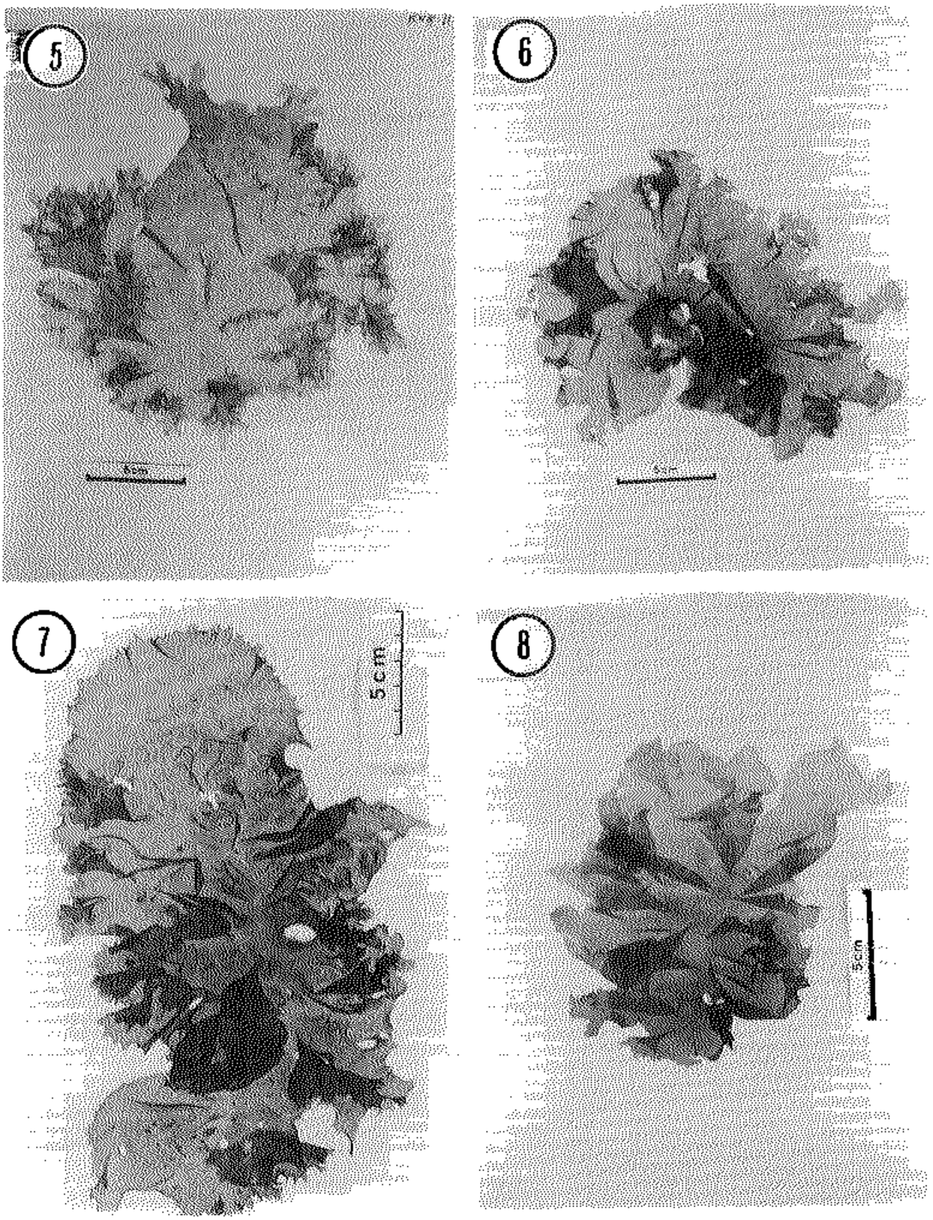
### Vegetative Morphology

The plants are attached to rocks or dead corals by marginal or submarginal discoid holdfasts and vary from being almost sessile to having a short, thick stipe 1 cm long, abruptly expanding into a foliose blade with a subpeltate, reniform, or cuneate base. The blade is broadly oblong to circular or irregularly lobed, up to 40 cm long, 20 cm wide, with entire, or mostly laciniate to sinuate, margins. The surface is undulate and mottled in a peculiar pattern (maculae) and commonly beset with small, ligulate proliferations. The texture is generally lubricous but becomes somewhat rugose as the plants mature. Plants are usually bright red to yellowish; older plants are sometimes brownish to dark red (Figs. 1–8).

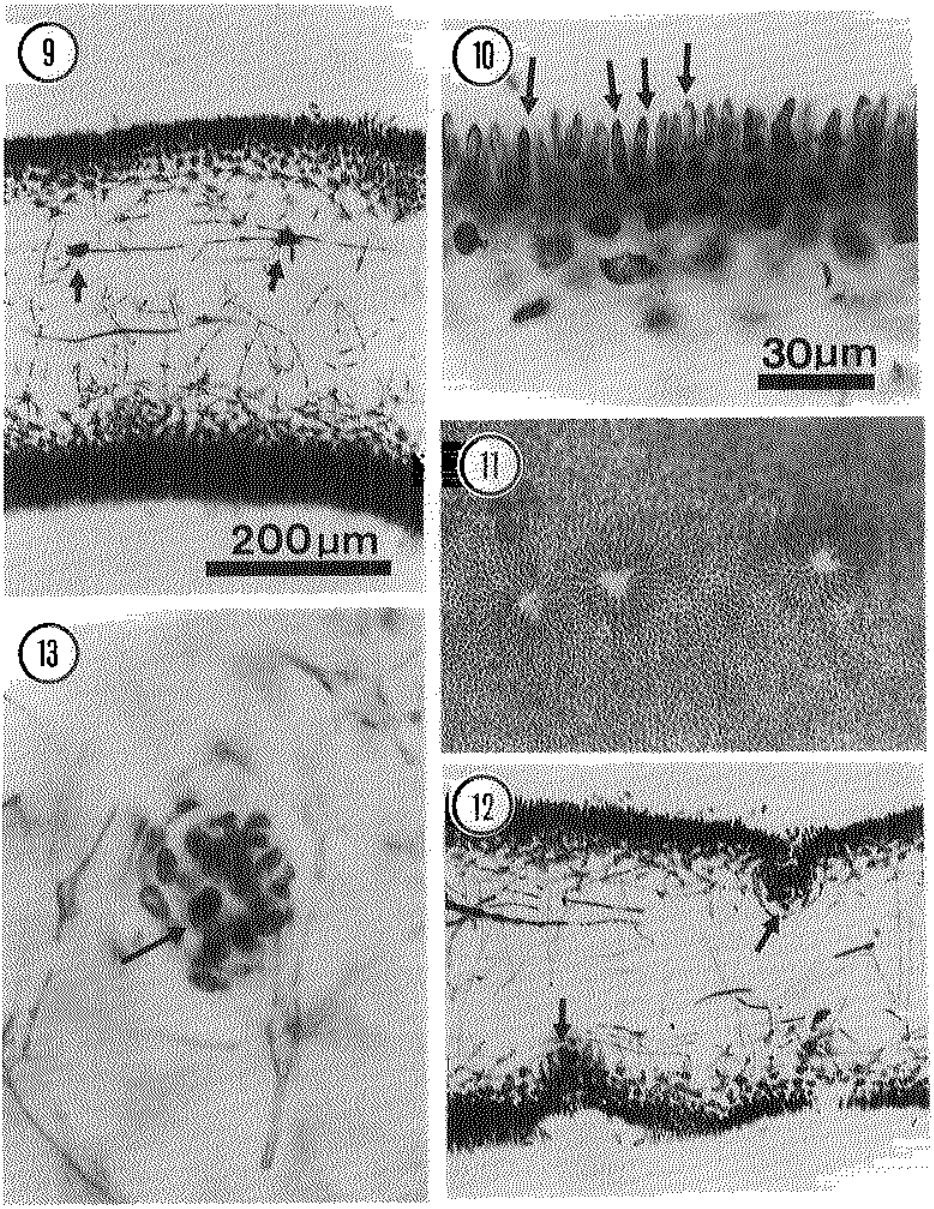
The thallus is 350–400 µm thick with a comparatively shallow cortex and a loosely arranged, filamentous medulla (Figs. 9 and 12). The cortex has 5–7 layers of cells. The outermost cells are occasionally elongated (shaped like a rabbit ear), up to 20 µm long, and slightly pointed (Fig. 10). The cortical cells in the next 1–2 layers from the surface are rounded to ellipsoidal; those in the next 2–4 layers (inner cortical cells) become larger and stellate. The inner cortical cells are connected to one another by secondary pit connections. The medulla contains simple or branched filaments rather sparsely intermeshed, some of which are anticlinally oriented from 1 cortex to another (Fig. 9). Intermixed with these normal



Figs. 1–4. Dried and liquid-preserved specimens of *Halymenia dilatata* Zanardini from Kagoshima Prefecture, Japan. Fig. 1, Cystocarpic specimen with superficial proliferations. Collected June 14, 1983, by S. Kawaguchi; SAP 047489. Fig. 2, Cystocarpic (old) specimen. Collected July 21, 1997, by M. Masuda; Kawaguchi 1123.
Fig. 3, Tetrasporangial specimen. Collected June 14, 1983, by S. Kawaguchi; SAP 047488. The color of the thallus preserved in formalin-seawater turned partly into white. Fig. 4, Liquid-preserved female specimen. Collected June 10, 1996, by S. Kawaguchi; Kawaguchi 1126.



Figs. 5–8. Dried specimens of *Halymenia dilatata* Zanardini from Okinawa and Kagoshima prefectures, Japan, and from Nha Trang, Vietnam. Fig. 5, Sterile specimen from Japan. Collected April 17, 1986, by S. Arai; Kawaguchi 1121. Fig. 6, Cystocarpic specimen from Vietnam. Collected June 15, 1992, by N. H. Dinh; Kawaguchi/Dinh 2002. Fig. 7, Cystocarpic specimen from Japan. Collected June 14, 1983, by S. Kawaguchi; SAP 047490. Fig. 8, Tetrasporangial specimen from Vietnam. Collected June 21, 1991, by N. H. Dinh; Kawaguchi/Dinh 2001.



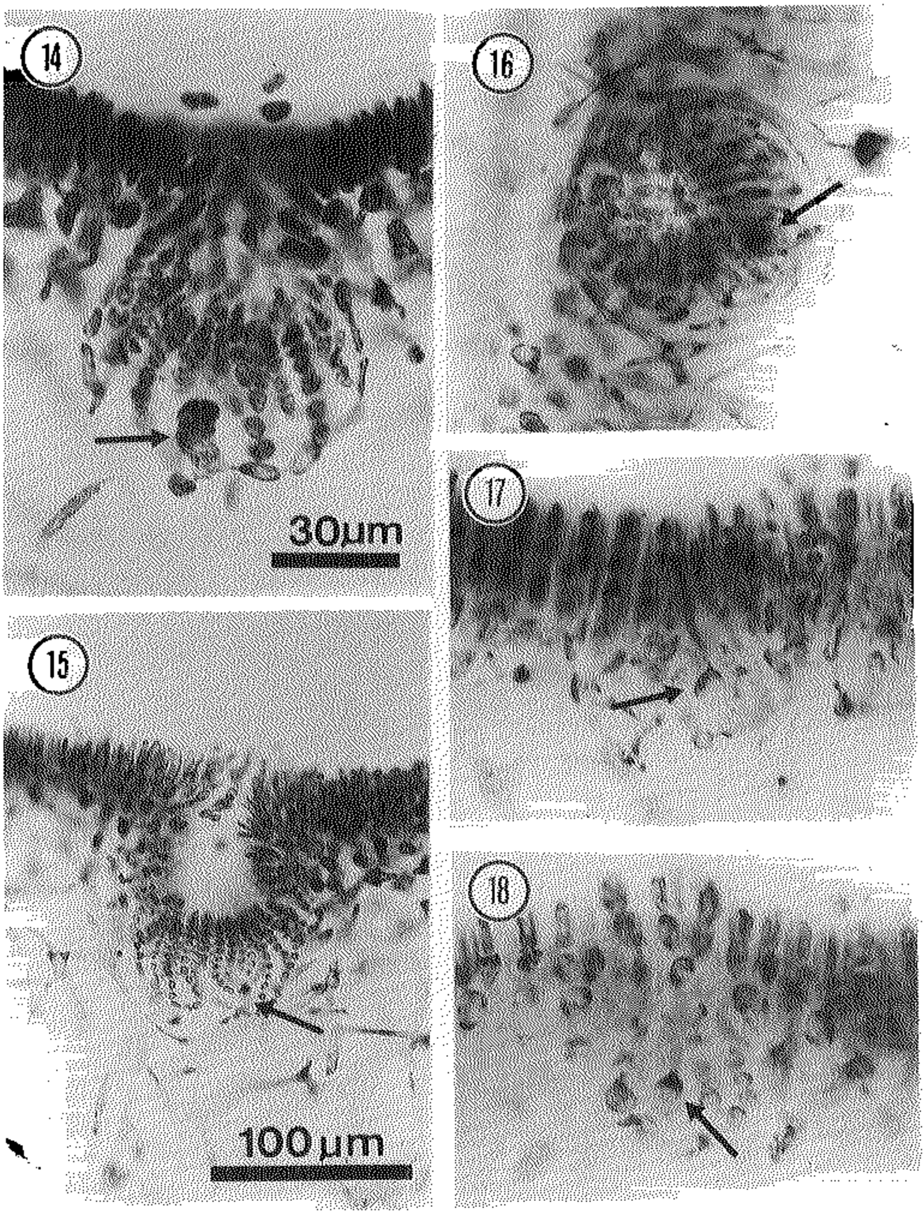
Figs. 9–13. Vegetative and reproductive structures of *Halymenia dilatata* Zanardini. Fig. 9, Cross section of vegetative part of thallus shows highly refractive ganglionic cells (arrows). Fig. 10, Cross section shows arrangement of cortical cells with elongated outermost "rabbit ear" cells (arrows). Fig. 11, Surface view of young cystocarpic thallus shows distinct carpostome. Fig. 12, Cross section of female specimen shows auxiliary-cell ampulla (arrow). Fig. 13, Young auxiliary-cell ampulla seen from the bottom. Arrow indicates auxiliary cell. Scale bar in Fig. 9 applies also to Figs. 11 and 12; scale bar in Fig. 10, to Fig. 13.

medullary filaments are large stellate ("ganglionic") cells with long arms and highly refractive contents (Fig. 9, arrow).

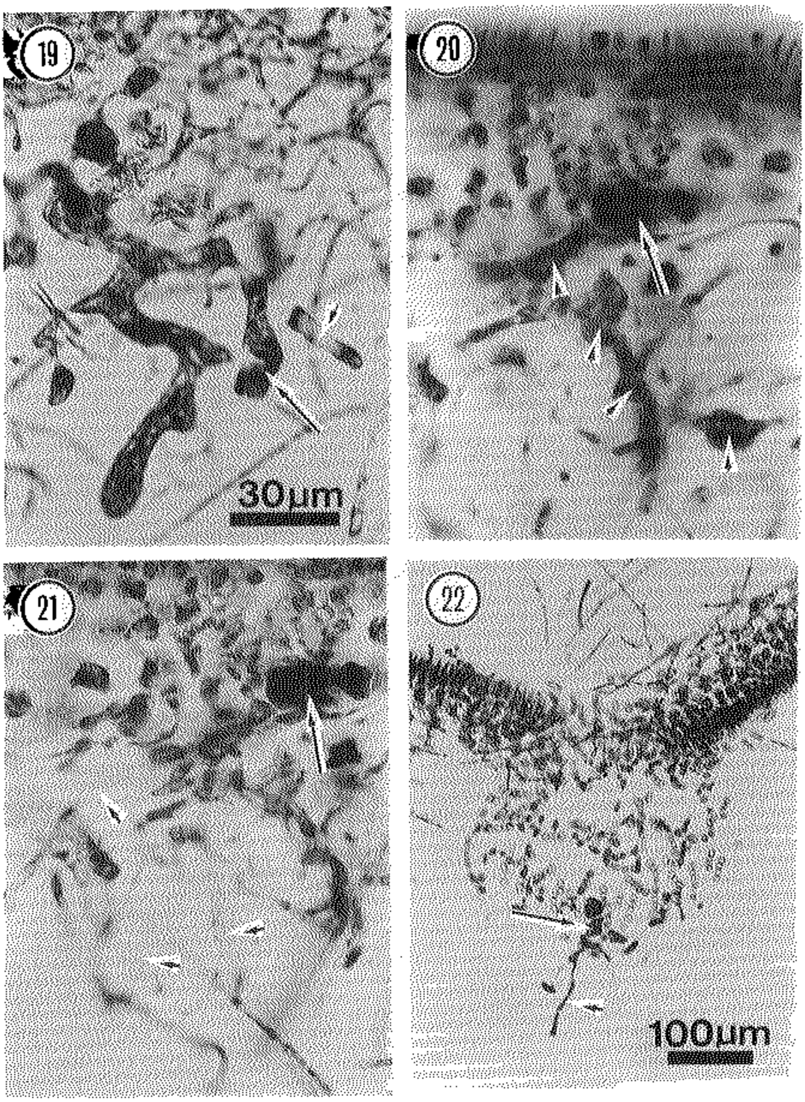
### Reproductive Morphology

Male reproductive structures were not observed. Carpogonial branches and auxiliary cells are formed in ampullae. The carpogonial-branch ampulla is rather sparingly branched, smaller in outline and more compactly constructed than the auxiliary-cell ampulla (Figs. 17 and 18). The carpogonium with trichogyne is detectable at the bottom of the ampulla, but the number of cells constituting a carpogonial branch was not clearly ascertained in this study (probably 2-celled). The auxiliary-cell ampulla is larger in outline and is constructed more laxly, but with more secondary ampullar filaments, than is the carpogonial-branch ampulla. In auxiliary-cell ampullae, the cells of primary filaments are elongated, and many of these cells produce a secondary filament that is further branched. The secondary filaments become shorter toward the periphery of the ampulla. Therefore the ampulla is conical, flask shaped when young (Figs. 13 and 14) and becomes wide across the top when mature (Figs. 15 and 16). The fully developed auxiliary-cell ampulla is up to 150 µm in diameter (Fig. 16). The auxiliary cell is a large, oval or oblong, intercalary cell of a secondary ampullar filament borne on the primary filament (Fig. 14). The auxiliary cell is easily recognizable because it is larger and darker when stained than other cells in the ampullar filaments.

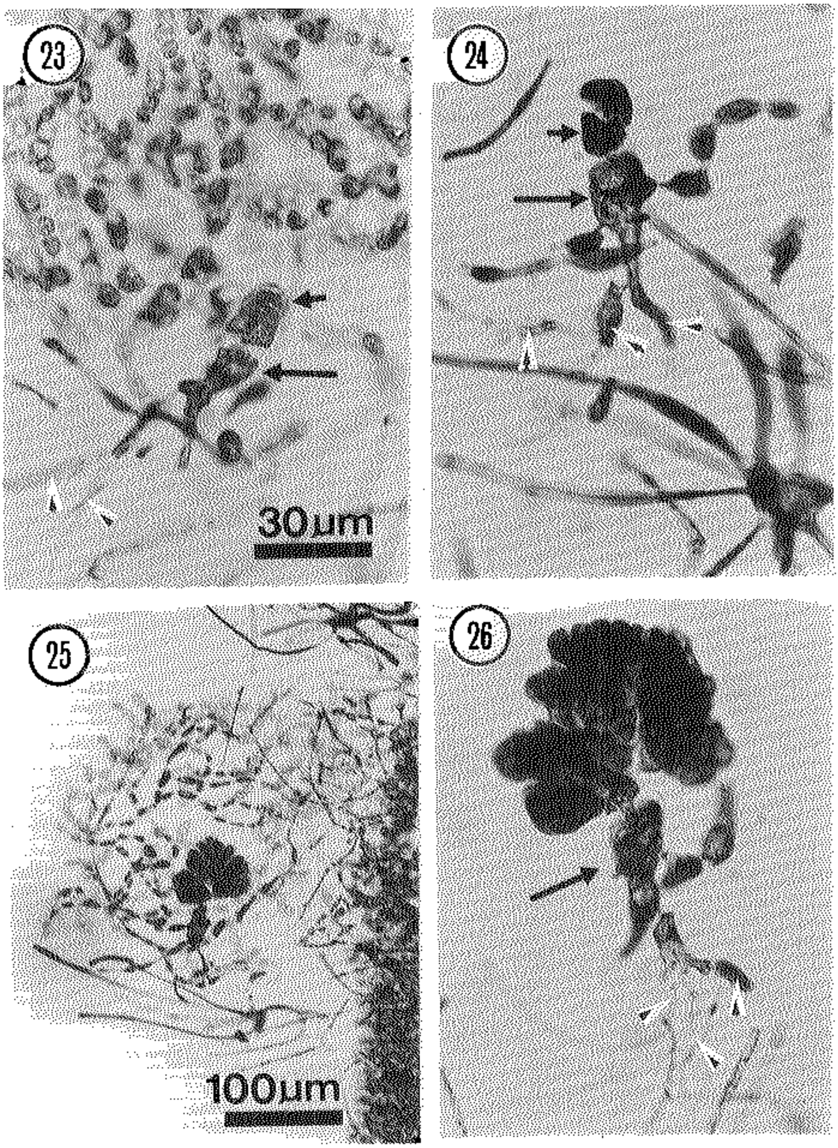
Early stages of development after fertilization were not fully ascertained, because fertilized carpogonia were rarely observed. However, in a few instances, we found primary connecting filaments produced from irregularly shaped, large interconnected cells (Figs. 19–21). These irregularly shaped cells are apparently derived from the fertilized carpogonium and produce many more connecting filaments. The connecting filament grows toward an auxiliary cell and fuses with the cell at the lower side of the cell (Figs. 22–26). After contact, the auxiliary cell cuts off an outgoing (secondary) connecting filament, which soon divides to form several, additional connecting filaments (Figs. 24 and 26), and a gonimoblast initial cell toward the surface of the thallus (Figs. 22–24). The gonimoblast initial cell successively divides to form gonimoblast cells, most of which develop into carposporangia (Figs. 25–28). The mature cystocarp is spherical to subspherical, 200–250 µm in diameter, is deeply submerged within the medulla, and has a carpostome (Fig. 11). The remnant ampullar filaments thinly surround the cystocarp as loose sterile filaments (Fig. 29). Tetrasporangia were scattered over both surfaces of the thalli (Fig. 30). Tetrasporangial initial cells were cut off from the cortical cells in the third or fourth layer from the surface. Mature sporangia are broadly ellipsoidal, 13–15 µm wide, 25–35 µm long, embedded in the cortex, and cruciately divided (Fig. 31).



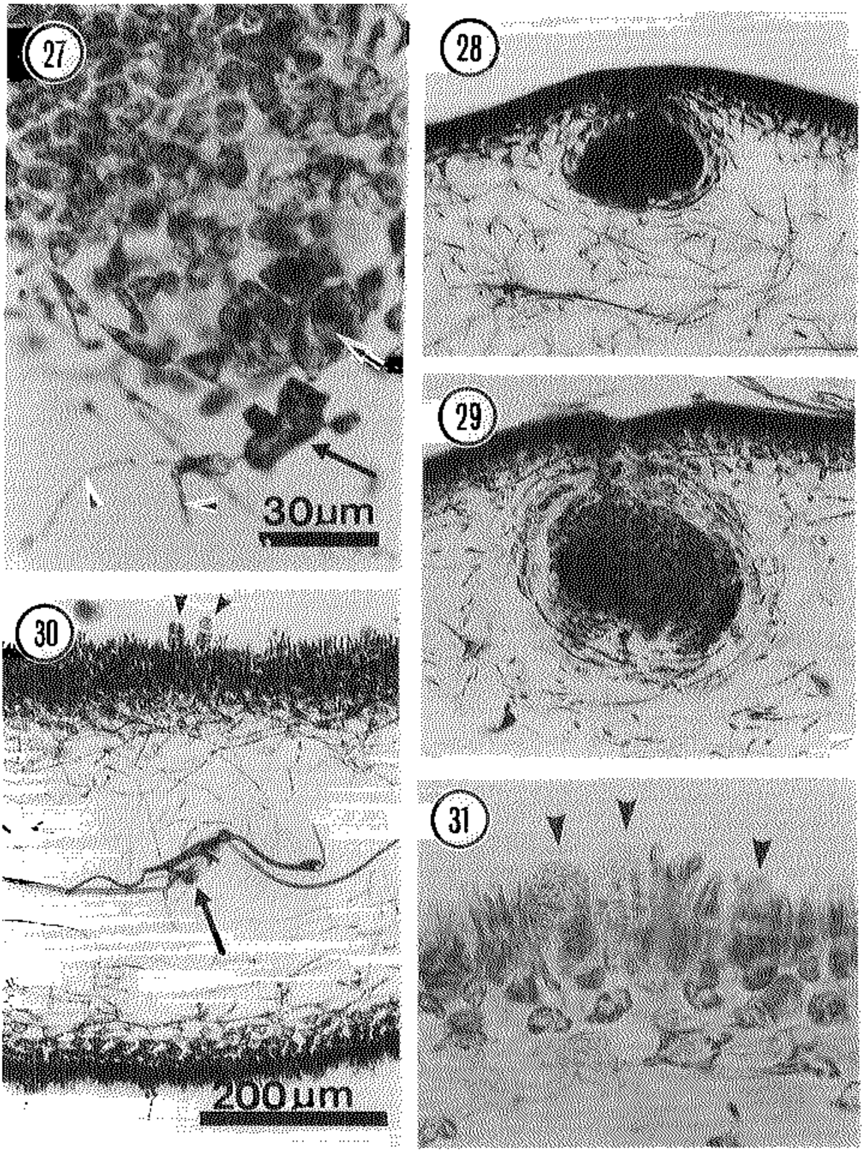
Figs. 14–18. Reproductive structures of *Halymenia dilatata* Zanardini. Fig. 14, Cross section of profusely branched, young auxiliary-cell ampulla shows auxiliary cell (arrow) at the bottom of the ampulla. Fig. 15, Cross section shows fully developed auxiliary-cell ampulla is wide across the top. Arrow indicates auxiliary cell. Fig. 16, Fully developed auxiliary-cell ampulla seen from the bottom. Auxiliary cell (arrow) is located at the periphery of the ampulla. Figs. 17 and 18, Carpogonial ampullae. Arrows indicate carpogonium with trichogyne. Scale bar in Fig. 14 applies also to Figs. 17 and 18; scale bar in Fig. 15, to Fig. 16.



Figs. 19–22. Reproductive structures of *Halymenia dilatata* Zanardini.
Fig. 19, Formation of connecting filaments. Long arrow indicates initial cell forming the connecting filament (short arrow inside arrowhead). Fig. 20, Later stages of formation of connecting filaments. Arrow shows enlarged, fertilized carpogonium or its fusion complex. Note that primary connecting filaments are produced from initial cells (arrowheads). Fig. 21, The same as Fig. 20, but the focus and the position are slightly changed. The long arrow indicates the same cell as that shown in Fig. 20, and the short arrows inside arrowheads indicate the connecting filaments.
Fig. 22, Very early stage of gonimoblast development. Long arrow indicates an auxiliary cell producing a gonimoblast initial cell after contact with connecting filament. Note that outgoing (secondary) connecting filament (short arrow inside arrowhead) is branched soon after being cut off. Scale bar in Fig. 19 applies also to Figs. 20 and 21.



Figs. 23–26. Gonimoblast development of *Halymenia dilatata* Zanardini.
Fig. 23, Young stage of gonimoblast development. Long arrow indicates auxiliary cell, and short arrow indicates gonimoblast initial cell. Note that outgoing (secondary) connecting filament (arrowheads) is branched. Fig. 24, Young stage of gonimoblast development. Long arrow indicates auxiliary cell, and short arrow indicates gonimoblast initial cell. Note that incoming (arrowhead on right side) and outgoing connecting filaments (arrowheads on left side) are branched. Figs. 25 and 26, Advanced stage of gonimoblast development. Arrow indicates auxiliary cell and arrowheads indicate connecting filament. Scale in Fig. 23 applies also to Figs. 24 and 26.



Figs. 27–31. Gonimoblast development and tetrasporangial formation of *Halymenia dilatata* Zanardini. Fig. 27, Advanced stage of gonimoblast development. Note auxiliary cell (long black arrow), developing gonimoblast (short black arrow inside white arrow), and connecting filament (arrowheads). Fig. 28, More advanced stage of gonimoblast development. Fig. 29, Mature cystocarp. Note that ampullar filaments are faintly present around the gonimoblast. Fig. 30, Transverse section of tetrasporangial thallus shows highly refractive ganglionic cell (arrow) and cruciately divided tetrasporangium (arrowheads). Fig. 31, Formation of tetrasporangia. Arrowheads indicate tetrasporangia embedded in the outer cortex. Scale bar in Fig. 27 applies also to Fig. 31; scale bar in Fig. 30, to Figs. 28 and 29.

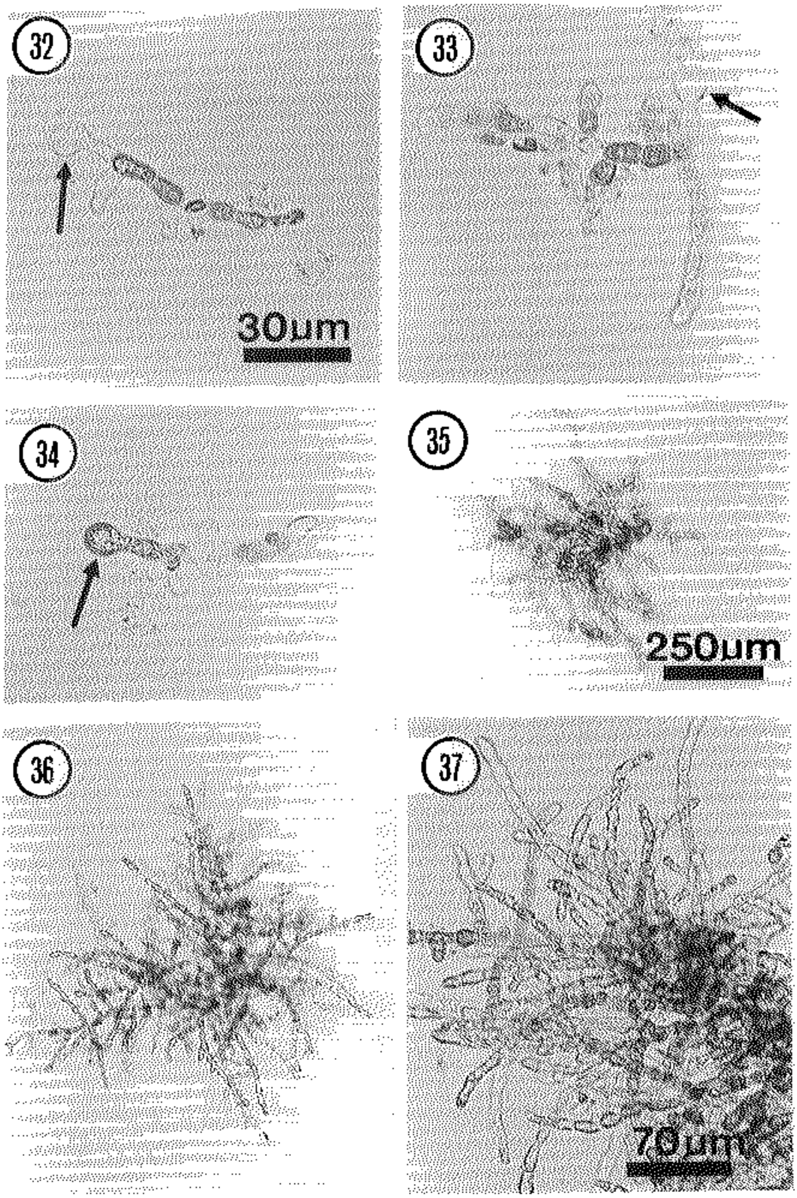
### Carpospore Cultures

Liberated carpospores are 20–25 µm in diameter and produce germ tubes 1–2 days after liberation. Spore contents then migrate into the germ tubes and divide to form multicelled, uniseriate filaments (Figs. 32 and 33). Occasionally, spore contents remain in the spore walls and form germ tubes (Fig. 34). This type of spore also develops successively in the same manner as that described for most spores. The multicelled filaments start to form lateral filaments about 1 week after liberation. The original, empty spore walls are still recognizable at this stage (Figs. 32 and 33). These filaments grow further (Fig. 35) and develop into acrochaetioid plants about 500 µm in diameter in about 3 weeks (Figs. 36 and 37). In 1 month or a little more, the acrochaetioid plants are 750 µm in diameter, and upright thalli develop from among the filaments (Fig. 38). The initially cylindrical, upright thalli become flattened and grow up to 600 µm in length about 2 months after initiation (Figs. 39 and 40). They continue to grow and develop into lobed, foliose thalli up to 2 cm long and 1 cm wide within 6 months after initiation (Fig. 41). Further observations were not possible because these cultures became overgrown by contaminants and died without forming reproductive structures.

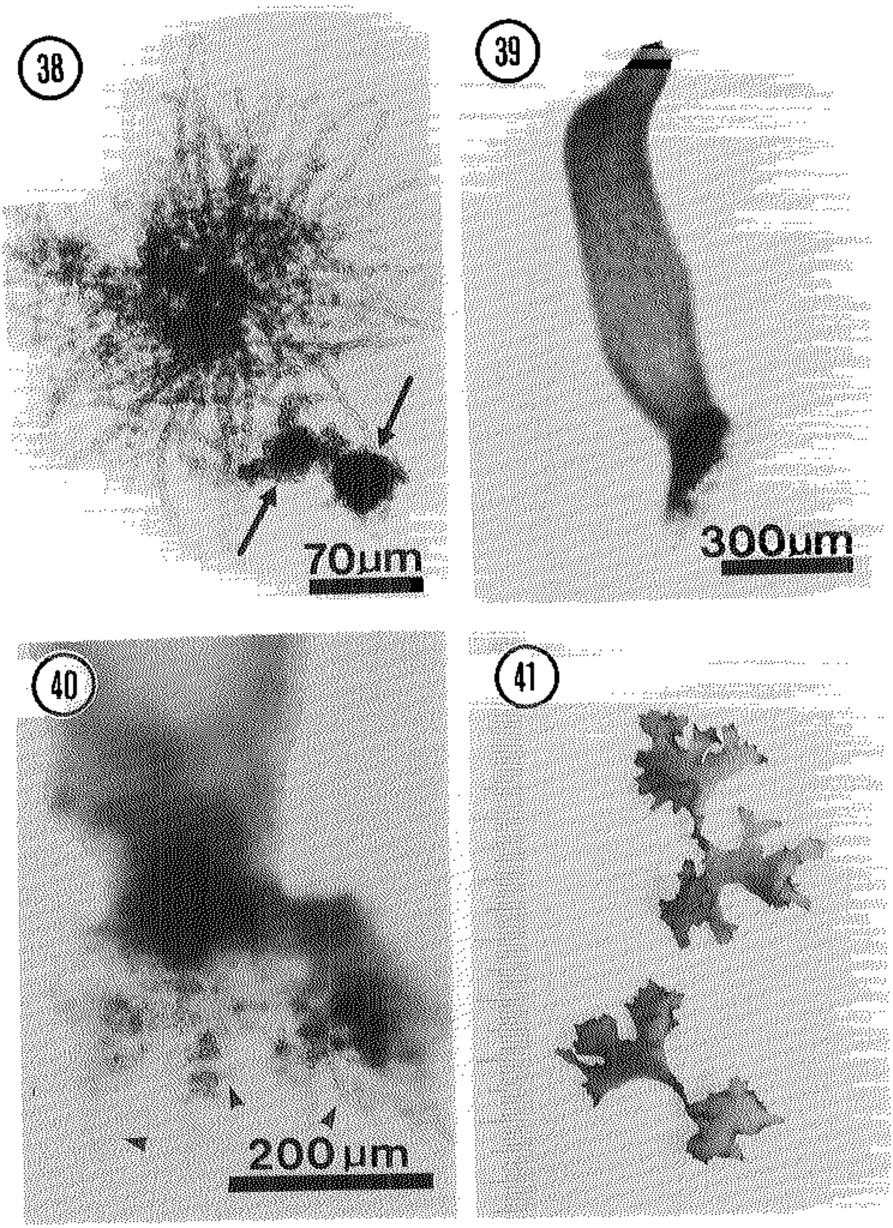
## Discussion

All the materials of *H. dilatata* from Japan, Vietnam, and India have oblong to irregularly lobed fronds, laciniate or roughly dentate margins, undulate surfaces with deeply pigmented spots (maculae), and occasional surface proliferations (Okamura 1921, Balakrishnan 1961, this study). These features are in good agreement with the original and additional descriptions by Zanardini (1851, 1858). Some of our specimens (Figs. 2 and 4) are quite similar to the illustration given by Zanardini (1858, tab. 3, fig. 1). The vegetative morphologies of our material and that from India are extremely similar, although the thalli and the cortex of our material are slightly thicker than those of Indian material (350–400 µm thick and 5–7 layers of cortical cells vs. 150–200 µm or more thick and 3–5 cells). The thickness of thalli and cortex, however, can vary according to the age of the plants and also according to the places where sections were made. We assume that this difference might be included within the range of morphological variations of this alga.

We noticed slight differences between the reproductive morphologies of the 2 materials. In Indian material, the plants are monoecious with spermatangia aggregated in irregular sori in the younger parts of the plants; after fertilization, the connecting filaments are nonseptate and usually cease to grow further after contact with a given auxiliary cell; and lateral branchlets are formed from the ampullar cells during the development of gonimoblasts (Balakrishnan 1961). These features seem to differ from those of our material, in which spermatangia were not found, an outgoing connecting filament is cut off from the auxiliary cell and soon branches into several filaments, and lateral branchlets were not formed from the ampullar cells. We cannot discuss male structures, because we do not



Figs. 32–37. Culture of *Halymenia dilatata* Zanardini. Figs. 32 and 33, One-week-old germling of carpospore. Note empty spore wall (arrows) and developing branched filament. Fig. 34, One-week-old germling of carpospore. In some cases, spore contents are not evacuated from the original spore wall (arrow). Fig. 35, Four-week-old germling. Fig. 36, Six-week-old germling with a mass of branched filaments. Fig. 37, The same as Fig. 36 but showing detail of filaments. Scale bar in Fig. 32 applies also to Figs. 33 and 34; scale bar in Fig. 35, to Fig. 36.



Figs. 38–41. Culture of *Halymenia dilatata* Zanardini. Fig. 38, Formation of erect thallus (arrows) 6 weeks after liberation of spores. Note that the thallus is formed among branched filaments. Fig. 39, Erect thallus 2 months after initiation of culture of carpospores. Fig. 40, Basal part of erect thallus shown in Fig. 39. Note the many filaments (arrowheads). Fig. 41, Thalli 6 months after initiation of culture of carpospores.

have spermatangial plants. With regard to the growth of connecting filaments, Balakrishnan (1961) noticed similar events in a few instances in which a short cell was formed at the base of a new connecting filament from which a few more connecting filaments were produced. We did not observe production of lateral branchlets from the ampullar cells during the development of gonimoblasts. However, we might have overlooked such branchlets, because the ampullar filaments are numerous and close to one another. Even so, formation of lateral branchlets from the ampullar cells was rare in our material. All the differences between the 2 materials seem to be minor and are assumed to be morphological variations.

Like Balakrishnan (1961), we did not fully ascertain the stages of development after fertilization. Fertilization is rare in *H. dilatata*; despite observation of more than 200 sections, we found production of connecting filaments only 3 times. This scarcity of fertilization in this alga, however, appears to be compensated for by the 2 processes by which connecting filaments are amplified. First, production of connecting filaments from the fertilized carpogonium clearly involves the formation of connecting-filament initial cells that in turn produce many more connecting filaments than does the fertilized carpogonium alone. Second, after first contact with an auxiliary cell, the connecting filament not only continues to grow beyond the auxiliary cell but also divides into several filaments near the auxiliary cell. A similar amplification of connecting filaments was observed in *H. floresia* (Clemente) C. Agardh (S. K. Kawaguchi, unpublished data) and in some species of *Grateloupia* (Kawaguchi 1990, 1997) from Japan. This feature is therefore not unusual in members of the Halymeniaceae.

The development of carpospores of *H. dilatata* was similar to that reported for the type species, *H. floresia*, from the Mediterranean Sea (van den Hoek and Cortel-Breeman 1970, Codomier 1974) and for *H. latifolia* Kutzing from Ireland (Maggs and Guiry 1982). In our cultures, upright thalli were also formed from the acrochaetioid plants grown from the carpospores about 1 month after liberation of the spores. These upright thalli are apparently tetrasporophytes, and the life cycle of this alga is thus considered the Polysiphonia type, although the life cycle was not completed in our study.

Overall vegetative and reproductive features of *H. dilatata* agree well with the currently accepted concept of *Halymenia*: members of the genus have (1) lubricous fronds with primarily anticlinally oriented medullary filaments, (2) highly refractive ganglionic cells in the medulla, and (3) profusely branched (to the third to fourth order), conical to cup-shaped auxiliary-cell ampullae (Kraft and Abbott 1997). In addition, the pattern of spore development might be another feature that distinguishes *Halymenia* from the allied genera. The spores of other genera mediately develop into discs without developing into acrochaetioid plants as was earlier noted (Kawaguchi 1990). Currently, no single feature most distinctively characterizes *Halymenia*. As Kraft and Abbott (1997) correctly pointed out, "Extended comparisons of *Halymenia* species will confirm or refute the stability of this and other generic characters." This statement is true not only for *Halymenia* but also for some other genera of Halymeniaceae.

## Acknowledgments

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# NOTES ON SOME SPECIES OF *HALYMENIA* IN THE SOUTHWESTERN PACIFIC

Isabella A. Abbott

## Abstract

Examination of western Pacific specimens of *Halymenia* from the herbaria of the University of California, Berkeley, and the B. P. Bishop Museum, Honolulu, yielded 5 species for the western Pacific—*H. durvillei* Bory de Saint-Vincent, *H. maculata* J. Agardh, *H. dilatata* Zanardini, and 2 unidentified, but distinct, taxa. One specimen was removed from the genus. Descriptions of herbarium specimens are given for *H. durvillei* and *H. maculata*. Several specimens in the Berkeley collection previously identified as *H. floresia* (Clemente y Rubio) C. Agardh, the type species of the genus, had characteristics associated with *H. durvillei* and cannot be correctly identified on the basis of morphology alone.

## Introduction

Examination of many suites of specimens—in the case of some species of *Sargassum* and *Gracilaria*, dozens of them—from a given geographic region usually shows a grouping of 2 or 3 sets. One set may contain many species that are "common" to the geographic region being studied. A second set may contain few species that are less common. A third set (after much study) may contain fewer species than the second set, yet the species in this third set may be considered endemic to the area.

The set that is common to the region being studied may also be common to other geographic regions (near or far). In the Pacific tropics, as far east as Easter Island, north to the Hawaiian Islands, west to southern Vietnam, and south to Fiji, the green algae *Ventricaria ventricosa* and *Halimeda opuntia*, the brown algae *Hincksia breviarticulata* and *Lobophora variegata*, and the red algae *Asparagopsis taxiformis* and *Centroceras clavulatum* can be found (Abbott 1995). The morphology of these 6 taxa is sufficiently distinct that they cannot be confused with any other species. Although other taxa may be as common as these 6 algae, the other taxa may be more difficult to categorize because of similarities with closely related taxa, or a specialist may be needed to define them.

For example, I think that certain species of *Laurencia* (Rhodomelaceae) are among the most common species in the tropics, but the identification of many of the species in this genus requires close attention to the details of a suite of specimens. In other words, it is nearly impossible to identify *Laurencia* species on the basis of a single specimen. The crustose and erect corallines are also common, but most phycologists do not trust their own identifications of these plants.

At the seventh taxonomy workshop, agreement among researchers on some species of *Sargassum* indicated that several species of this genus can be placed into the group characterized as common, of widespread geographic distribution. Two of these common species are *S. cristaefolium* and *S. polycystum*. They are distributed widely north and south in the western Pacific and also into the eastern Indian Ocean (Phillips 1995). Two species with a rather more narrow distribution are *S. hemiphyllum* from Korea and coastal and island Asia to Vietnam and *S. oligocystum* from Indonesia, the Philippines, and New Caledonia (Phillips 1995); these species make up the second set of uncommon species. Both China and Japan have many endemic species of *Sargassum*, and these species, at least for now, qualify for the third set.

The material available on *Halymenia* illustrates all 3 of the categories described: common, uncommon, and endemic. In an examination of the habits of *H. dilatata* Zanardini, Kawaguchi and Lewmanomont (1999, figs. 1–8) found a relatively wide range of form in the essentially broad blade that characterizes the species. Yet none of their 8 illustrations closely resembles Zanardini's plant from the Red Sea (type locality) shown in his plate 5, figure 1 (Zanardini 1858). However, anatomical studies show that among these external variations in morphology, the internal structure is more stable.

The range of external form in 2 species described in this chapter, *H. maculata* J. Agardh and *H. durvillei* Bory de Saint-Vincent, is more difficult to delineate precisely, as the illustrations show. As wide as the variability of these 2 species may be, however, it is not great enough to encompass the 2 unidentified specimens discussed in this chapter, which I suspect may be new species.

In the Siboga Expedition report, Weber-van Bosse (1921) listed 11 species of *Halymenia* from a slightly wider geographic range than the random collections found in the 2 herbaria I obtained loans from. If her recognition of that number is correct, then the number described here (at most, 5 species) is a great underrepresentation of the *Halymenia* species in the southwestern Pacific. However, in the material I examined for this study, specimens that were more than 80 years old were too fragile to section, because polymerization of the colloidal wall material causes the specimens to fracture when sectioned. Newer collections would be necessary for adequate examination.

Therefore, the purpose of this chapter is not to present a detailed examination of *Halymenia* species in the southwestern Pacific but to furnish pictures and notes sufficient to help other researchers tentatively identify species in that area. Because *H. dilatata* is described in excellent detail elsewhere in this volume, it is not described here.

## Materials and Methods

Herbarium specimens were loaned by the University of California, Berkeley (UC), and the B. P. Bishop Museum, Honolulu (BISH). Sections were cut by hand by using a single-edged razor blade and a dissecting microscope. The sections were floated in a drop of water, stained with 1% aqueous aniline blue, intensified with a small drop of 1% HCl, blotted, and mounted in 50% Karo brand corn syrup.

## Results

*Halymenia durvillei* Bory de Saint-Vincent, Cryptogamie. In L. I. Duperrey, *Voyage autour du monde . . . La Coquille. . . .* pp. 180–181, pl. 15, 1828.

Figs. 1–4

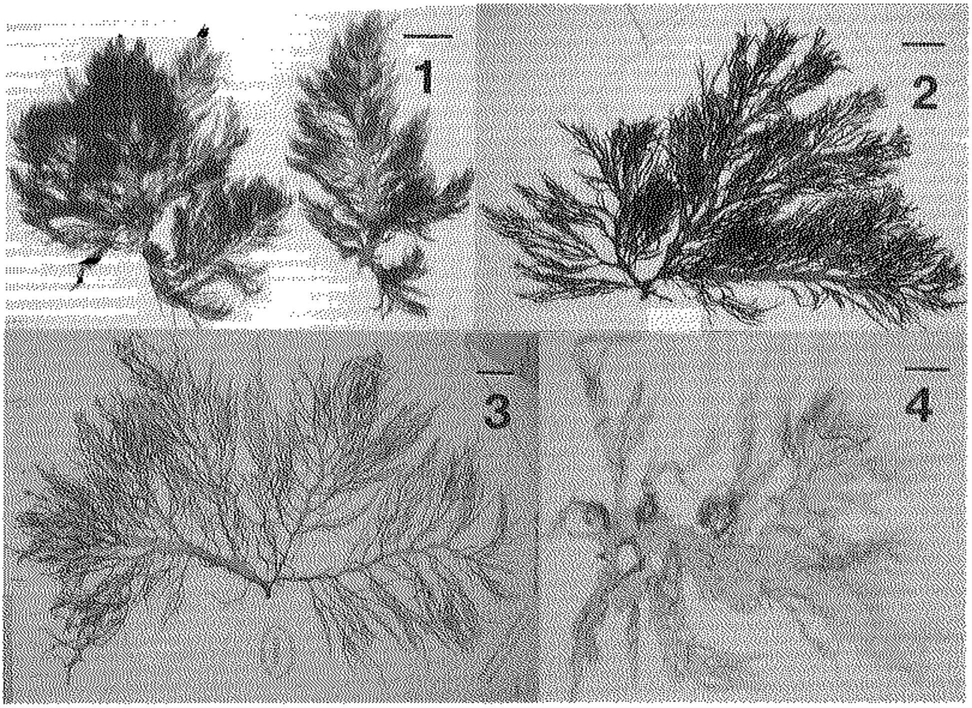
Plants very slippery, rarely more than 20 cm tall; central axis if present flattened and bladelike (Fig. 1), rarely more than 1 cm wide, with second-order divisions having flattened central part of various widths, bearing dense third- and fourth-order branches, mostly divided gradually to abruptly to about 1 mm wide at apices. Primary laterals branching from the lateral margins of flattened axes in a single plane (Fig. 1, right) or dividing rapidly as if a planar blade had become cleft and each segment redivided nearly simultaneously, forming in more than a single plane (Fig. 2). The latter shape was the more common for the specimens examined.

In cross section, fronds about 250 μm wide, with more than half occupied by medullary filaments mostly periclinally arranged, and with refractive, deeply staining, conspicuous ganglionic cells lying between the subcortex and the medulla, 3 or 4 connecting and extending the length of the sections (about 2 mm), the ganglionic center of each about 40 μm in diameter, with 4–6 primary arms, arms occasionally 92 μm long before the first constriction. Outer cortex 2-celled, the outermost part 2–3 cells thick, each cell averaging scarcely 3 μm in diameter, 6–7 μm long, attached to inner cortical cells; subcortex 56–75 μm thick with netlike arrangement of cells 4–6 layers thick, without conspicuous stellate filaments joining to outer medullary filaments.

Tetrasporophytes tend to have more orders of branches, each thinner (UC M258394, Fig. 2) than similar branch number in female gametophytes (UC M256388, Fig. 1). Tetrasporangia about 8 μm wide by 20 μm long. Cystocarps 250–270 μm wide, with 3 gonimolobes of various sizes, and an inconspicuous carpostome. Spermatangial plants were not seen.

Specimens examined were identified as *H. durvillei* on the basis of their elongate outer cortical cells ("rabbit ears"); a subcortex 4–6 layers thick; and large, glistening, deeply staining ganglionic cells. Their external aspect is one of finely dissected fronds lying in a single plane when pressed but more or less twisted radially when fresh. The second and higher orders of branches tend to be elongate and attenuating toward the apices; the surfaces of the frond are usually smooth, very rarely with short proliferations on the flat surfaces.

Specimens Examined: UC M256394, collected at Guadalcanal (Maraunibina Island) by A. Bailey, September 20, 1965 (2 specimens, on the same sheet, the upper one shown in Fig. 2); UC M256388, collected at Guadalcanal (Kurum), by H. B. S. Womersley and A. Bailey, August 8, 1965 (3 specimens, the upper 2 shown in Fig. 1); UC 624708, collected at Bali (Sanoer) by an unknown collector, June 15, 1929; UC 417144, collected at Singapore by E. J. H. Corner in June 1929; UC 699163, collected at Lamao, Bataan, Luzon, Philippines, by W. R. Shaw, May 20, 1911; UC 1516543, collected at Alominos-Lingayen Gulf,



Figs. 1–4. *Halymenia* species. Fig. 1, Two cystocarpic specimens of *H. durvillei* from Maraunibina Island, near Guadalcanal (UC M256394). Fig. 2, Tetrasporangial specimen of *H. durvillei* from Kurum, Guadalcanal (UC M256388). Fig. 3, Tetrasporangial specimen of *H. durvillei* with extremely fine branching, from Lumao, the Philippines (UC 699163). Fig. 4, Specimen of *Halymenia* that lacks the anatomy of the specimens in Figs. 1–3, from Paruru, Guadalcanal (UC M256390). Scale bars = 3 cm.

Pangasinan, Philippines, by F. Fenix in October 1929; UC M31347, collected at Tumon Bay, Guam, by R. Moran, August 4, 1954; IA 18648 (BISH), collected at Pago Pago, American Samoa, by G. Yamasaki, in 1988; IA 23438, collected at Köqa, Vavuda, Babatana, Choiseul (Lauru), Solomon Islands, by W. McClatchey in May 1998; IA 22439, collected at Sasamuqa Bay, Sasamuqa, Babateana, Choiseul (Lauru), Solomon Islands, by W. McClatchey in May 1998.

Remarks: The distribution is extended beyond the Indian Ocean locations listed in Silva et al. (1996) to the Solomon Islands (Guadalcanal, reported earlier by Womersley and Bailey, 1970); Choiseul (Lauru), newly reported here; the Philippine Islands, Guam, and Samoa; and added to Indonesia at Bali and to Singapore. As far as I know, the Philippine, Guamanian, and Samoan records are new. Two specimens were excluded from this identification because they did not meet 2 or more of the previously described features: UC M256390, as *H. durvillei* from Guadalcanal (Fig. 4, this chapter), and UC M099286, as *H. durvillei* var. *ceylanica* from the Amami Islands (Japan), collected by T. Tanaka, July 9, 1957.

The 4 varieties of *H. durvillei* proposed by Weber-van Bosse (1921, pp. 234–236) are based on external morphology and show intergrades among themselves. To apply the concepts that were used for their recognition would not improve an understanding of the limits of the species. The anatomical observations made here appear to furnish a greater stability for the taxonomy than the external morphology does. Further studies that include observations of internal anatomy in a suite of specimens should be done when more specimens are available.

*Halymenia floresia* (Clemente y Rubio) C. Agardh, Synopsis algarum Scandinaviae . . . Lund, p. xix, 1817.

Basionym: *Fucus floresius* Clemente y Rubio, Ensayo sobre las variedades de la vid . . . Andalucia. p. 312, 1807.

Remarks: Several western Pacific specimens in the Berkeley collection were listed as *H. floresia*, but none of them had the anticlinal filaments crossing the medulla that are typical of the lectotype material from Cadiz, Spain, and that are required by other workers (Balakrishnan 1961, Codomier 1974, Womersley and Lewis 1994) for identification of this species. Some Pacific specimens of *H. durvillei* (type locality, New Ireland, northeast of New Guinea) externally are quite similar to the numerous morphs of *H. floresia*, whether the latter are from the Mediterranean, the Caribbean or Australia. Specimens must be sectioned in several places to ensure that anticlinal medullary filaments are not present, and for the time being, until proved incorrect, that a subcortex of 4–6 layers of cells is present; both of these features are characteristic of *H. durvillei*. The identification of some of these "look-alike" specimens cannot be based on external morphology alone; examination of the internal anatomy is also required.

*Halymenia maculata* J. Agardh, Lund Univ. Arskrift. Afd. Kongl. Fysiograf. Sallsk. 21(8), p. 12, 1885.

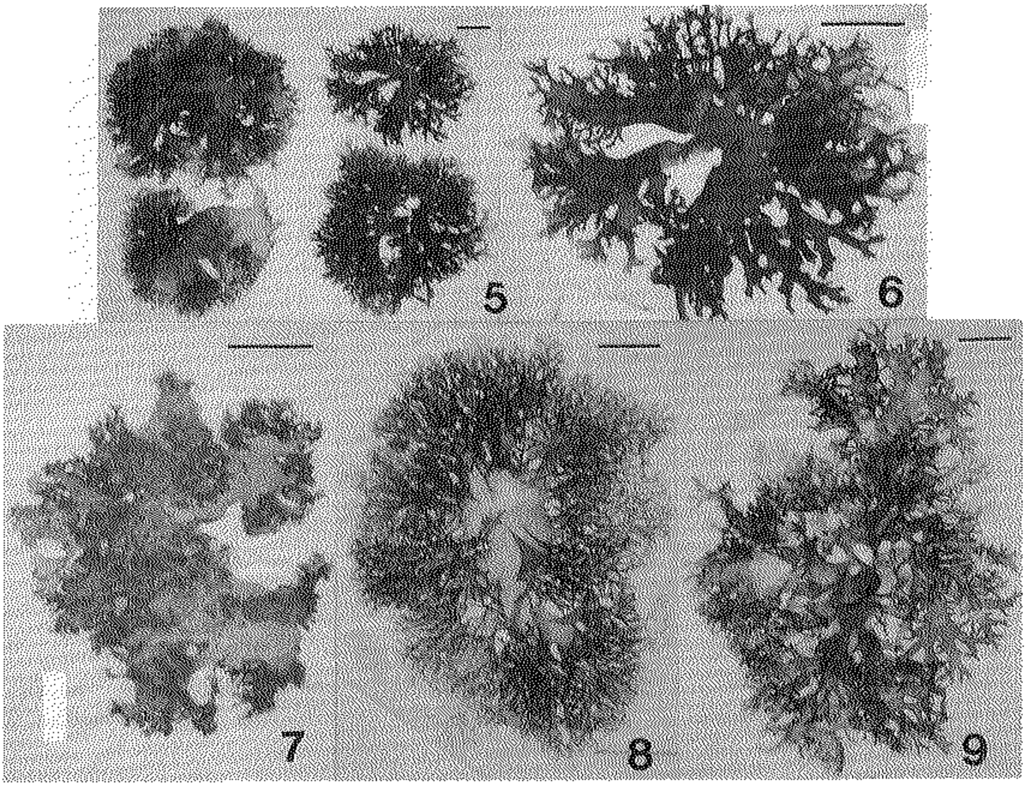
Figs. 5–9

Plants up to 10 cm tall or slightly taller, growing in an open cluster from a short, thickened holdfast, fronds attached from near the center of the base and arranged with broad circular blades erect, like leaves of lettuce in life, but when pressed, a somewhat circular, flattened, cleft blades and margins very strongly dissected (Figs. 5, 6, 8, 9) with repeatedly divided segments, the margins often fimbriate, the segments often densely ruffled (Fig. 7). (Except for Fig. 7, the remaining plants were from the same collection off Cau Da wharf, Nha Trang, Vietnam).

In cross section, a sterile or cystocarpic frond is 250–300 µm wide, with a tightly branched cortex of 1 (rarely 2) outer cortical cells, with a subcortex of 3–4 layers, and in the medulla, 4–6 periclinally arranged fusiform, slightly refractive filaments 3–10 µm in diameter without conspicuous ganglionic centers, and occasional anticlinal medullary filaments about 10 µm in diameter from one cortex to the opposite cortex. The sections of tetrasporangial plants differ in 2 ways from a sterile or cystocarpic blade. First, the cortex of the tetrasporangial plant is deeper, with outer cortical cells in 2 layers, and individual cells are more elongate. From the basal cell of the cortical filament, from which there are no further lateral divisions, the 2 outer cortical cells are 26 µm long; in a sterile blade, the average length of an outer cortical cell is 10 µm. In both cases, however, the terminal cell is rarely more than 2.5 µm in diameter. Although measuring the cortex in surface or lateral view is difficult, cortical filaments seem to be more crowded per unit observed in tetrasporophytes than in sterile blades. Second, the inner 2 layers of subcortical cells in tetrasporangial plants are often inconspicuously stellate; that is, their pit connections are slightly elongate. In sterile fronds, the inner subcortical cells show little distinction from the sister cells distal to them.

Tetrasporangia are initiated on the basal cell of the outer cortical filaments and are therefore not directly at the surface as in most *Halymenia* species that have shorter cortical filaments. Thus, the elongated outer cortical filaments act as paraphyses. Tetrasporangia are cruciately divided, 18–20 µm x 28–31 µm, somewhat obovate. Spermatangia are superficially borne on outer cortical cells, covering most of the surfaces. Cystocarps are relatively small (young?), 96 × 120 µm, with several gonimolobes, and surrounded by a moderate number of sterile filaments.

Specimens Examined: UC 435363 (isotype), collected in Mauritius by J. C. Melvill in 1887; UC 624704, collected east of Boeleleng, Bali; UC 34153, collected from Pasir Panjang, near Singapore; Dawson 11441, collected "on coral heads in 2–3 meters in harbor area north of Cau Da wharf," Nha Trang, Vietnam. The Dawson 11441 specimens are widely distributed to herbaria and include UC M098849 and M098848. Other Dawson collections include BISH 53382, 533833, spermatangial; BISH 533845, tetrasporangial; and BISH 533848, cystocarpic.



**Figs. 5–9.** ***Halymenia maculata.*** **The specimens in Figures 5, 6, 8, and 9 are part of the Dawson 11441 collection from north of Cau Da wharf, Nha Trang, Vietnam. Fig. 5, Tetrasporangial specimens (UC M098849) Fig. 6, Enlargement of specimen in upper right corner of Fig. 5 shows dissection of blade. Fig. 7, Specimen from east of Boeleleng, Bali (UC 624704). Figs. 8 and 9, Two other specimens from north of Cau Da wharf, Nha Trang, Vietnam (Dawson 11441, UC M098848). Scale bars = 3 cm.**

Remarks: Specimens examined that are circular, with highly dissected margins, or ruffled can be almost unhesitatingly be identified as *H. maculata*. The specific epithet, *maculata*, refers to the spotted or blotched markings on the tetrasporangial blades, but this feature is common to many species of *Halymenia*. In section, the several parallel, slightly refractive periclinal filaments of the medulla of *H. maculata* seem to differ from those of other *Halymenia* species in the western Pacific.

## Miscellaneous Notes

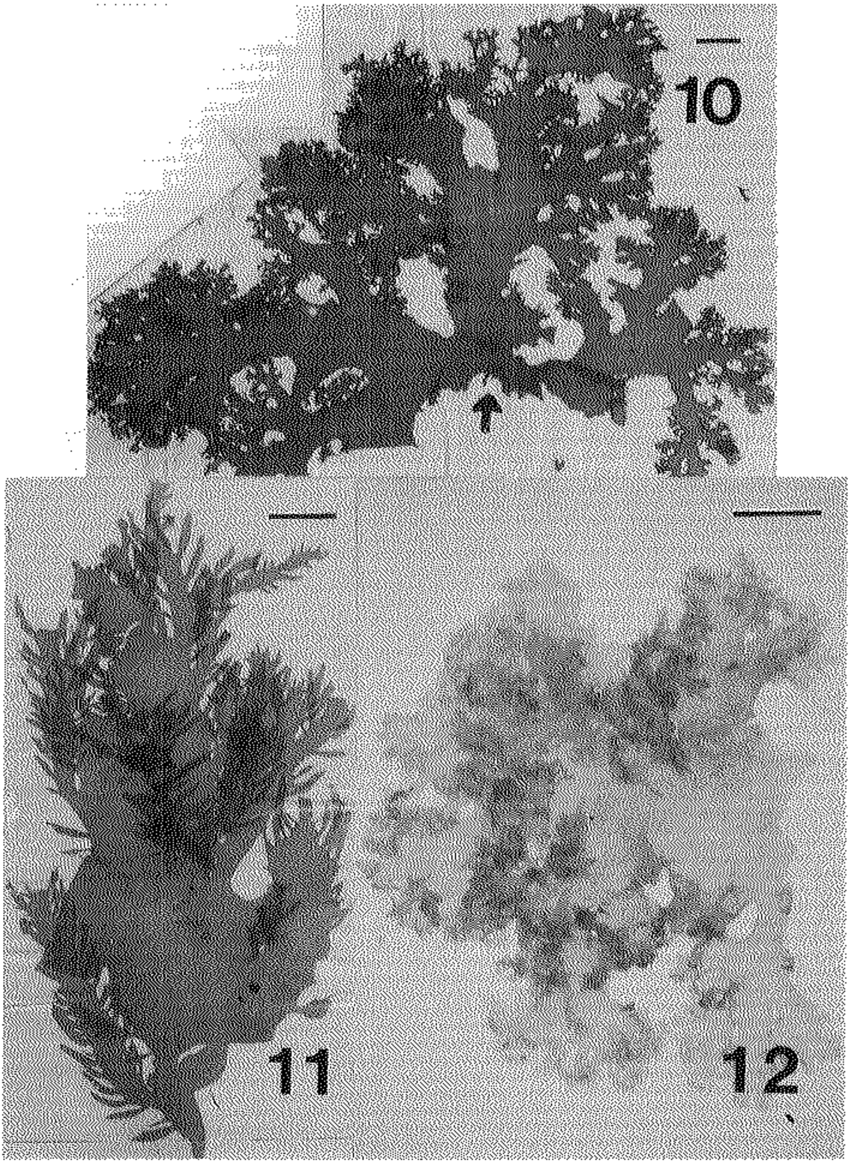
Three specimens in the Berkeley (UC) collection are illustrated in Figures 10–12; of these, 2 are unusual and might be collected again. Figure 10 shows 1 of 3 specimens, collected at a locality called "Labrador" toward the southeast of the city of Singapore. UC 417147 (Fig. 10), UC 417448, and UC 417149 might be exuberant "maculata," but in microscope sections, they have only one thing in common with *H. maculata*: rabbit-ear cortical cells. The specimens are tetrasporangial and were collected in June 1929 by E. J. H. Corner. From the fleshy holdfast (Fig. 10, arrow), the specimen is 22 cm toward the top of the illustration. I have not seen other specimens like these.

Figure 11 also shows a large specimen (41 cm tall), collected in the Jedan Islands (Malaysia) at 10.5-m depths by the Siboga Expedition (UC 953308), and identified by Weber-van Bosse as *H. floresia*. The specimen lacks anticlinal medullary filaments and has a narrow cortical layer, with outer cortical cells only 5–6 µm tall, not at all elongate. What may be cystocarps are poorly preserved, and I could not see any details. Weber-van Bosse (1921) reported 11 species of *Halymenia* in the Siboga collections; 5 of the 11 were collected at the Jedan Islands by dredging to 10-m depths.

The third specimen (UC 160737) was collected in Mauritius by Nicholas Pike, a well-known collector of algae from Mauritius and the Pacific coast of North America. Identified by Setchell (*in herbario*) as *H. maculata* or *H. dilatata*, this specimen has the external morphology of some species of *Halymenia* but is not this genus. Microscope sections show a nonfilamentous medulla and gland cells, neither of which is a feature found in species of *Halymenia*. Because the specimen appears to be sterile, it cannot be assigned to a genus.

## Acknowledgments

I thank Dr. Paul C. Silva, Herbarium of the University of California, Berkeley, and Jack Fisher of the Bishop Museum, Honolulu, for the loan of specimens, which made this study possible. I am pleased to acknowledge the collections of the new specimens from the Solomon Islands (Choiseul Island) by Will McClatchey of the University of Hawaii. I also thank Kaleleonalani Napoleon and Maya LeGrande for photographic assistance.



Figs. 10–12. *Halymenia* species and unknown. Fig. 10, Tetrasporangial specimen (UC 417147) of an unknown species of *Halymenia* from "Labrador," Singapore, with holdfast (arrow). Fig. 11, Very large plant, 41 cm tall, cystocarpic, from Jedan islands, Malaysia, collected by the Siboga Expedition. Because it lacks anticlinal medullary filaments, it cannot be identified as *H. floresia*. Fig. 12, Although this specimen has the habit of some species of *Halymenia* that are ruffled, it is not a species of this genus. Scale bars = 3 cm.

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# TAXONOMIC STUDIES ON *HALYMENIA* (HALYMENIACEAE, HALYMENIALES, RHODOPHYTA) FROM CHINA*

Xia Bangmei and Wang Yongqian

## Abstract

Two species of *Halymenia* C. Agardh, *H. dilatata* Zanardini and *H. maculata* J. Agardh, are described from China. This report is the first record of *H. maculata* J. Agardh from China.

## Introduction

Two species of *Halymenia* are distributed in southern China. The specimens of *H. dilatata* Zanardini came from sublittoral habitats in Xisha and Nansha islands. The specimens of *H. maculata* J. Agardh came from sublittoral habitats in Hainan Island. No species of *Halymenia* have been found in mainland China.

## Key to the Chinese Species of *Halymenia*

1. Thallus thin, 133–166 µm, margins entire or crisp or sometimes with small teeth; cortical layer made up of short filaments ................. *H. dilatata*
1. Thallus thick, 282–365 µm, margins provided with densely placed irregularly shaped fimbriate proliferations, cortical layer made up of elongated papilla-like cells ........................................... *H. maculata*

## Description of the Species

*Halymenia dilatata* Zanardini, Flora 34:35, 1851; Okamura, Icones of Japanese algae, IV:109, pls. 176–177, figs. 3–4, 1921; Dawson, Pac. Sci. 8:433, fig. 43, 1954.

Figs. 1–3

Thallus purple-red when fresh, 5–14 cm high, arising from a discoid holdfast, abruptly expanding into a broad bladelike, suborbicular or transversely expanded or irregular oblong, simple or more or less lobed blade, 10–20 cm wide; margin entire, crenate or crisp; rarely proliferous from surfaces; gelatinous, membranous, adhering perfectly to paper upon drying. In transverse section, thallus 133–166 µm thick, with a thin cortex and a lax medulla. Cortex made up of 4 cells, with an outer layer of 1–2 elliptical to oblong cells arranged in anticlinal rows and an inner layer of 1–2 irregularly shaped cells often laterally connected by secondary pit connections. Medulla made up of sparse filaments, running in various directions.

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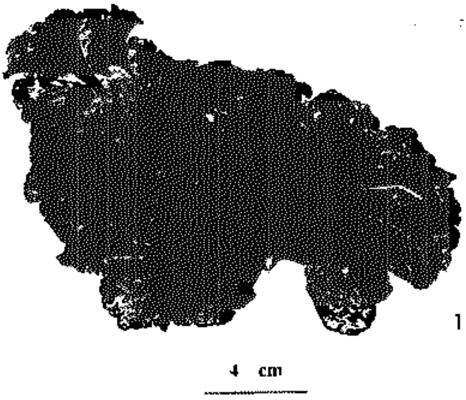
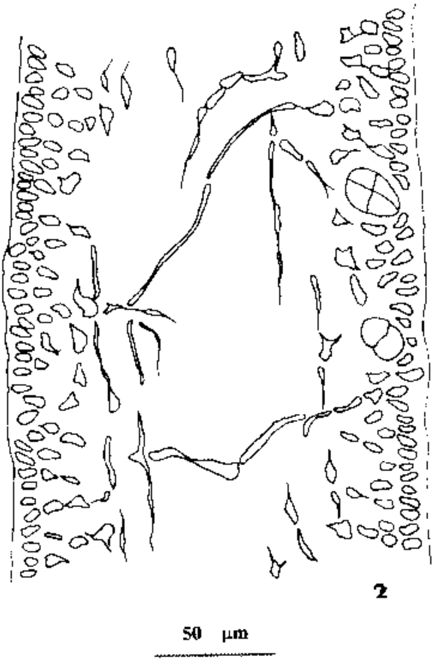
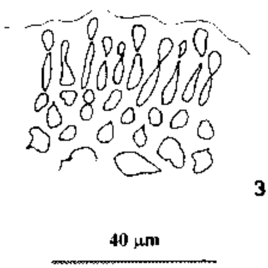
*Contribution No. 3281 from the Institute of Oceanology, Chinese Academy of Sciences







**Figs. 1–3. *Halymenia dilatata* Zanardini. Fig. 1, Habit of a frond (AST 58-4782). Fig. 2, Transection of part of frond (AST 58-4255). Fig. 3, Transection of part of spermatangium (AST 76-1324).**

Tetrasporangia scattered over the cortex of the blade, obovate or oblong in transverse section, 17–20 μm × 13.2 μm, cruciately divided; spermatangial sori covering the margins of thallus, formation of spermatangial mother cells perhaps preceded by a division of cells of outer layer in the cortex; cystocarp not seen.

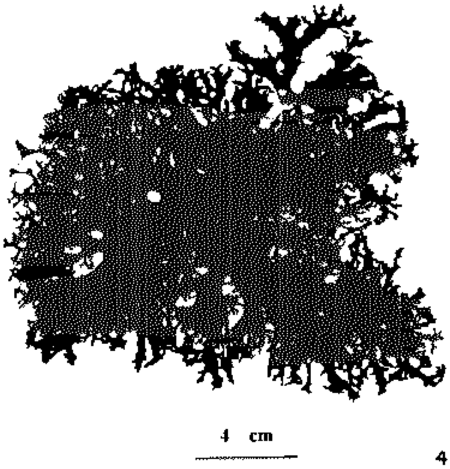
Habitat: Growing in the shallow subtidal 1–1.5 m in coral beds.

Distribution: Xisha and Nansha islands in China. The type locality is the Red Sea. Also found in the Ryukyu Islands, the Philippines, and Vietnam.

*Halymenia maculata* J. Agardh, Till Algernes Systematik, Nya bidrag. 4de afdl. VII. Florideae, p. 12, 1885; Børgesen, Kgl. Danske Vidensk. Selsk. Biol. Medd. 18(11):9, figs. 2–3, 1950; Dawson, Pac. Sci. 8:433, fig. 44, 1954.

Figs. 4–6

Thallus purple-red, 8–12 cm tall, with several irregularly shaped lamina-like lobes growing out from lower part of terete stipe, larger and smaller lobes cuneate, with roundish bases, margins provided with densely placed irregularly shaped fimbriate proliferations; gelatinous, membranous, adhering perfectly to



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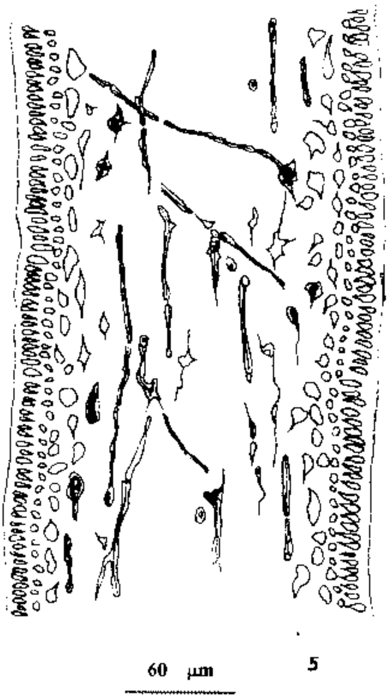

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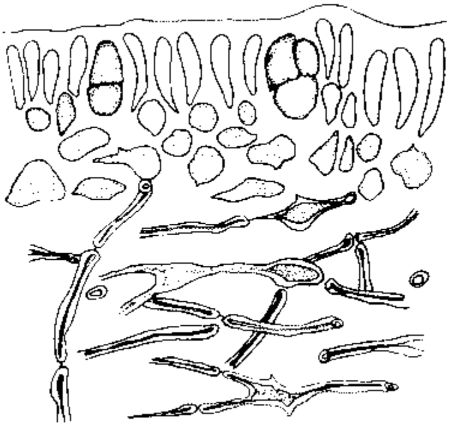

6

**Figs. 4–6. *Halymenia maculata* J. Agardh. Fig. 4, Habit of a frond (AST 80-2089). Fig. 5, Transection of part of frond (AST PH 199). Fig. 6, Transection of part of (tetrasporangial) plant (AST PH 199).**

paper upon drying. In transverse section, medullary layer of thallus made up of sparse filaments, running in various directions, and a layer of much-elongated papilla-like outer cortical cells, 13–20 µm × 2–3.3 µm, and 2–3 layers of irregularly shaped inner cortical cells, 6.6–20 µm × 3.3–10 µm. Frond 282–365 µm thick.

Tetrasporangia in outer part of cortex, ovoid or oblong in transverse section, 23–30 µm x 10–17 µm, cruciately divided. Cystocarp and spermatangia not seen.

Habitat: Growing subtidally on dead coral.

Distribution: Hainan Island in China. The type locality is Mauritius. Also found in Vietnam.

Remarks: This record is a new one for China.

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