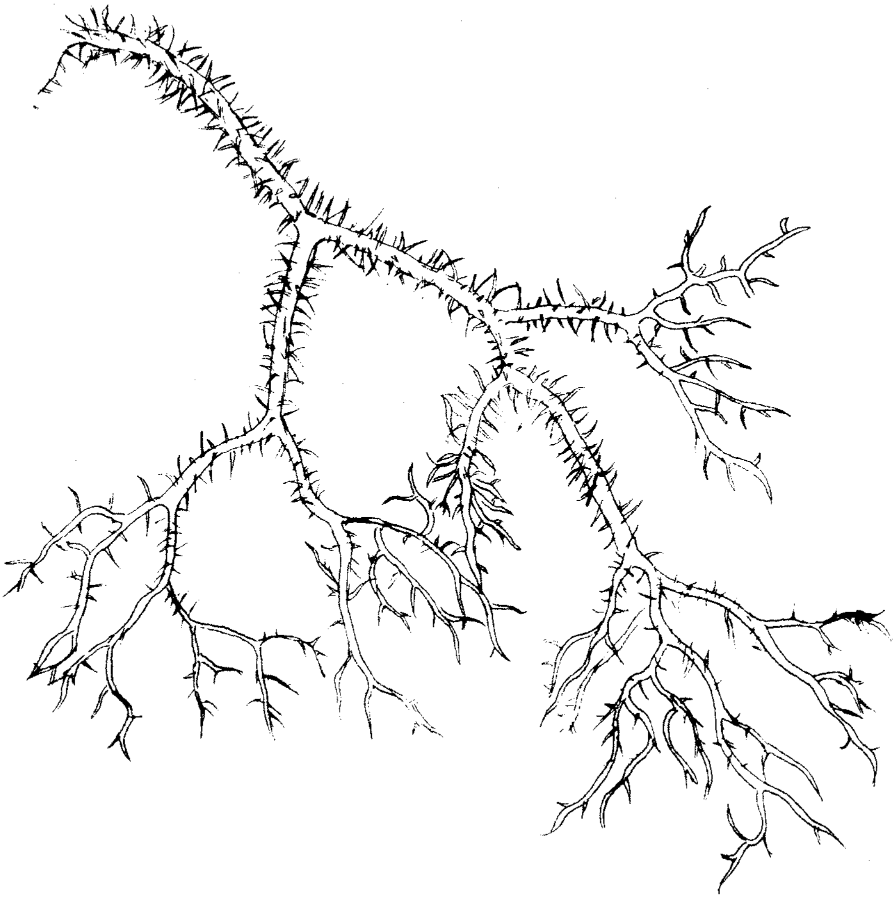
TAXONOMY OF ECONOMIC SEAWEEDS

With reference to some Pacific species

Volume VI

Isabella A. Abbott, Editor



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TAXONOMY OF ECONOMIC SEAWEEDS

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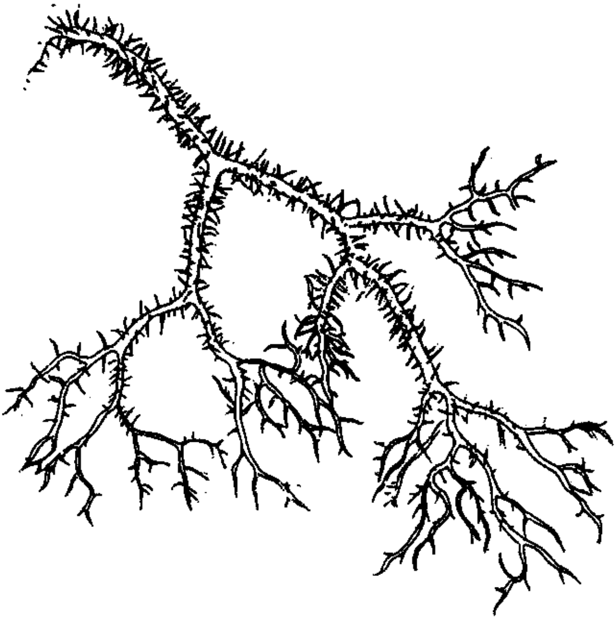
Isabella A. Abbott, Editor

Results of an international workshop sponsored by the California Sea Grant College System in cooperation with the Pacific Sea Grant College Programs of Alaska, Hawaii, Oregon, and Washington and hosted by the University of Malaya, Kuala Lumpur, July 1995.



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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

The Kuala Lumpur meetings brought together participants in the Sea Grant workshop (old friends by now, with the addition of two new faces and accents, Alan Millar from Australia and Put O. Ang, Jr., of Hong Kong) and many wanting to learn aquaculture techniques and basic information, which were handled in the subsequent training session. Holding the two kinds of meetings together reminded the taxonomists that their studies require an applied technology outcome. Having the training group allowed trainees to see and hear real live "big names" come to life. The greatest trouble for all concerned was that both kinds of meetings did not last long enough. To make up for this, four or five of the Japanese workers went back later to other parts of Malaysia with Dr. Phang as their guide. As for the training group, they will hold another meeting in 1997, to include aquaculturists who could not come to the first training session.

The impact of Sea Grant workshops, beyond their contributions to taxonomy of economic algae and the stimulation of training sessions for applied phycology, this year includes a beautiful new seaweed picture book, *Common Seaweeds and Seagrasses of Thailand*, by Khanjanapaj Lewmanomont and Hisao Ogawa (published by Kasetsart University, Faculty of Fisheries, Bangkok, Thailand). The book was supported by Japan International Cooperation Agency and the Southeast Asian Fisheries Development Center. The book has 163 pages, with Thailand English comments under each picture. Fourteen pages are devoted to *Gracilaria* species, alone, probably the best photographed of any I have seen, and certainly with the most correct names. The identification of these is wholly or in great part due to Sea Grant support to me, Xia Bangmei, Zhang Junfu, and Professor Lewmanomont, who spent much of her time associated with several sessions of the workshop learning the ins and outs of *Gracilaria* species from her country. Hearty congratulations to her for such a fine book, and a potentially useful one.

Looking back on 10 years of workshop influences, the U.S. National Sea Grant Program can be proud of its contributions to the knowledge of some economic seaweeds of which these are the latest achievements. They could also count the numbers of papers published within the "proceedings" that have followed each workshop (92 contributed papers in volumes 1–5), and perhaps 8 more that were published in scientific journals as a result of information garnered in specific workshops. No other Sea Grant–supported project has a record like this. Again, we are grateful to Dr. Sullivan and the California Sea Grant College System for continued support and enthusiasm for the taxonomy of economic seaweeds.

We have now met in Guam, Qingdao, La Jolla, Sapporo, Honolulu, and Kuala Lumpur. We have been exposed to Guamanian (sort of American-Filipino), Chinese, American, Japanese, Hawaiian (sort of a Chinese, Japanese, and Korean mixture with some Hawaiian and American thrown in), and hot, hot (spicy!) Malaysian and Chinese food and so have become international gourmets of sorts. We are international in our seaweeds, too—it is hard for those who do not work on economic seaweeds to understand that we have such fun with our meetings, which everyone can see are productive of results. Dr. Max Hommersand told me recently that he thought I did not realize how much interest there was included in the workshop proceedings.

Field trips are an important aspect of these meetings, short as the trips are because of our dedication and application to sharing information in the laboratory with our colleagues. Those *Sargassum* people form a large group, and in the laboratory they discuss *all the time*. They are always disappointed when we do not find specimens for them to examine (but they have been known to take home the specimens they brought—with only half of the seaweeds identified).

Acknowledgments

I thank Dr. Phang and her students for their wonderfully warm hospitality: the attention to details, arrangements, and desires that was evident every day in every way. It taught us Westerners soon that you do not wish aloud for something, or you may get it (the *jinni* inherent in a Moslem society, perhaps, that influences Kuala Lumpur). Our visits to the Bazaar after dinner were memorable, as was the final banquet at a country club. I particularly enjoyed dinner at Dr. Phang's home, giving all of us an opportunity to meet her husband and the lively 6-year old Miao Shan and to eat some local Malaysian fruits and to sit around and talk on a social level. We found that "jack fruit" (*Artocarpus heterophyllus*), a relative of breadfruit (*Artocarpus altilis*), tasted very different from jack fruit in Hawaii, where it is not common at all. It not only tasted different, its color was different also, making it clear that when a market exists for a product, horticultural variation and improvement in it exist too. (Maybe we could apply this notion to seaweeds?)

On behalf of all participants, I thank Dr. Phang, her students, and her family for helping us so well, and I thank Dr. Sullivan for his own special involvement with the seaweeds, and his leadership of the Sea Grant directors of Alaska, Washington, Oregon, and Hawaii in their cooperation and support of the Taxonomy of Economic Seaweeds workshops.

Isabella A. Abbott

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Workshop participants. (Front row, left to right): Anong Chirapart, Hirotoshi Yamamoto, Young-Meng Chiang, Michio Masuda, Siew-Moi Phang, Huynh Quang Nang. (Middle row, left to right): Alan Millar, Melor, Khanjanapaj Lewmanomont, Tetsuro Ajisaka, Isabella Abbott, Tadao Yoshida, Lu Baoren, Xia Bangmei. (Top row, left to right): Masao Ohno, Yukimasa Yamagishi, Nguyen Huu Dinh, Bernabé Santelices, Put O. Ang, Jr.

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

this volume, all references to volumes (1–4) from the first four workshops are listed in nomenclature setups and in Literature Cited as "Tax. Econ. Seaweeds 1 (or 2, 3, 4)," 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.

Taxonomy of economic seaweeds: with reference to some Pacific species, vol. 4. I.A. Abbott, ed. [i–ii] + iii–xvii + 1–200, 1994. California Sea Grant College, University of California, La Jolla, Calif. Report No. T-CSGCP-031.

Taxonomy of economic seaweeds: with reference to some Pacific species, vol. 5. I.A. Abbott, ed. [i–ii] + iii–xx + 1–254, 1995. California Sea Grant College System, University of California, La Jolla, Calif. Report No. T-CSGCP-035.

Section I. *Sargassum* Species

INTRODUCTION

Isabella A. Abbott

As editor of this series, I always raise a cheer when I see that the *Sargassum* group is going to (or has) placed a species or a variety in synonymy, because as is obvious to all, there *cannot* be as many species of *Sargassum* as the books say there are. Of course this is an unscientific view, but it is helpful to be skeptical when working with genera that have "too many" species. Varieties and species of *Sargassum* are on the books (especially created by Grunow at the end of a long life devoted to the study of algae) that have only a single scrap serving as the only known specimen or the type specimen. So it is with good cheer that I report that Dr. Ajisaka and his *Sargassum* cohorts have clarified the status of Vietnamese *Sargassum* species and varieties and have redefined the features that characterize *S. duplicatum* and *S. cristaefolium* with broader geographical implications. Fortuitously, Tseng and Lu have independently arrived at the same conclusion about *S. duplicatum*. Dr. Ajisaka, like Dr. Yoshida before him, is among the first of the Asian phycologists fortunate enough to have funds to travel to European herbaria to gather information on *Sargassum* specimens to better understand how more recently collected specimens fit in with the earlier collected ones. In this way, progress will be made more surely and quickly.

I would also like to note that, as of March 1, 1997, the Chinese *Journal of Oceanology and Limnology* had not published the paper that validates the new species described in "Studies on the Glomerulate Sargassum of China: IV. Series *Platycarpae*" because of a large backlog of papers. The four species in this chapter by Tseng and Lu do not have Latin descriptions so this is not the official place of publication; the September 1997 issue of *Chin. J. Oceanol. Limnol.* (Vol. 15) will have the Latin descriptions.

STUDIES ON THE BISERRULIC *SARGASSUM* OF CHINA: I. TAXONOMY OF THE SUBSECTION *BISERRULAE*

C.K. Tseng and Lu Baoren

Abstract

Historical review of the subsection *Biserrulae* was made, following the classification of J. Agardh and Grunow. Three series, *Parvifolia, Ilicifolia,* and *Coriifolia*, are recognized, with a total of 57 species. *Dentifolia* with its 2 species has been eliminated and relegated to series *Coriifolia.* A list of *Biserrulae* recorded from China to date is given.

Introduction

The acanthocarpic subsection *Biserrulae* (J. Agardh) Tseng et Lu of *Sargassum* was divided by J. Agardh (1889) into four "species groups," *Ilicifolia, Coriifolia, Parvifolia,* and *Dentifolia,* with nine, four, six, and one species, respectively. Classification was principally based on the characteristics of the leaves. Following the classification of J. Agardh, Grunow (1915) studied these *Sargassum* species, but did not assign subtribal status to them as he did with the *Glomerulatae.* This decision reflects Grunow's doubt about the classification.

Species groups have no nomenclatural standing under the International Code of Botanical Nomenclature (see Abbott et al. 1988). In this chapter the species that were classified by Grunow (1915) on the basis of species groups are placed in series.

In the first group, *Ilicifolia,* Grunow followed J. Agardh strictly. He accepted the 9 species credited by Agardh and added 19 species, making a total of 28 species. In *Coriifolia*, Grunow also followed Agardh strictly, accepting the 4 species of Agardh and adding 1, making a total of 5. In *Parvifolia,* however, Grunow only partially followed Agardh. He accepted 6 *Parvifolia* species of Agardh and added 7 of the 8 species in the J. Agardhian *Glandulariae* of the malacocarpic *Racemosae* and 11 other species, for a total of 24 species. The fourth and last group, *Dentifolia,* was based on a single species. Grunow added 1 more species, making a total of 2. Thus, according to the treatment by Grunow, the *Biserrulae* subsection has altogether 59 species: 28 in the *Ilicifolia* group, 5 in the *Coriifolia* group, 24 in the *Parvifolia* group, and 2 in the *Dentifolia* group. Two species were recently removed from the *Parvifolia* to *Zygocarpicae,* namely, *S. polycystum* C. Agardh by Tseng and Lu (1978) and *S. myriocystum* J. Agardh by Ajisaka et al. (1993). Therefore, currently, in Grunow's treatment of the *Biserrulae,* only 57 species remain.

Problems in the Grunowian Taxonomy

Despite his addition of so many species and the changes in his concept of the *Parvifolia*, Grunow (1915) still kept these species groups. Grunow agreed with J. Agardh's treatment of the first, second, and fourth species group but made a change in the third species group, by including most of the *Glandulariae* of the *Racemosae* subsection in the *Parvifolia* species group. He suggested that because the seven members of the *Glandulariae* transferred to *Biserrulae* are male and malacocarpic, their female receptacle could be acanthocarpic. This notion is evident in the *Parvifolia* as a group. In fact, in his new definition of *Parvifolia*, Grunow emphasized entirely the dioecious nature of the group, with the males malacocarpic and the females acanthocarpic. Setchell (1936) in his discussion of *S. granuliferum* C. Agardh and *S. baccularia* (Mertens) C. Agardh touched on this problem. However he was uncertain about the taxonomic position of *S. baccularia*. Evidently he thought of *S. baccularia* and *S. parvifolium* as sexual stages of the same species: "Since the plants with triquetrous, spinous receptacles (of *S. parvifolium*) are largely or entirely oogonial and those with unarmed cylindric-torulose receptacles (of *S. baccularia*) are largely antheridial, it seems reasonable that the two species are merely 'sex-states', one of the other." Setchell, however, still followed the Agardhian system and treated the two species separately, placing *S. baccularia* among the *Malacocarpicae* J. Agardh.

Another problem in the J. Agardhian system is the last species group, *Dentifolia*. J. Agardh described this species group entirely on the basis of the leaves, but Grunow added the androgynous nature of the receptacles and the biseriate nature of the cryptostomata. Only a few differences in leaves are evident between plants of the five species of *Coriifolia* and plants of the two species of *Dentifolia*. Leaves of both groups have a subequal base, and the *Coriifolia* plants have few or no cryptostomata and lanceolate leaves, whereas the *Dentifolia* plants have conspicuous, biseriate cryptostomata and linear leaves.

Our Suggestions About the Taxonomy

With the differences between the species groups *Coriifolia* and *Dentifolia* in mind, we examined some authoritative specimens of the *Coriifolia* group and found that these differences are relative rather than absolute. Therefore, we suggest that the two species in the *Dentifolia* be placed in the *Coriifolia* species group and that the *Dentifolia* group be eliminated. The three species groups we recognize should therefore be placed in the status of series as follows:

Series *Parvifolia* (J. Agardh emend. Grunow) Tseng et Lu, stat. nov.
Basionym: Species group *Parvifoliae* J. Agardh, emend. Grunow (1915, p. 439).
Type Species: *S. parvifolium* (Turner) C. Agardh, Sp. algarum, p. 30, 1820.
Series *Ilicifolia* (J. Agardh) Tseng et Lu, stat. nov.
Basionym: Species group *Ilicifolia* J. Agardh (1889, p. 92).
Type Species: *S. ilicifolium* (Turner) C. Agardh, Sp. algarum, p. 11, 1820.
Series *Coriifolia* (J. Agardh) Tseng et Lu, stat. nov.
Basionym: Species group *Coriifolia* J. Agardh (1889, p. 96).
Type Species: *S. coriifolium* J. Agardh, Sp. Sargassorum...p. 96, 1889.

On the basis of the assumption that the acanthocarpic forms evolved from the malacocarpic ones, we consider the series *Parvifolia* with acanthocarpic female receptacles and malococarpic male receptacles the most primitive of those three series. When the male receptacles become acanthocarpic, the evolution comes to a higher step and then we have the *Ilicifolia* series. The *Coriifolia* are all androgynous. We are not sure whether the androgynous condition is more primitive or more advanced. For the time being, we consider the *Coriifolia* as the most advanced of the three series.

The three series can be distinguished by the following key:

1. Receptacles dioecious, female receptacles acanthocarpic and male receptacles malacocarpic....................... .... *Parvifolia*
1. Receptacles androgynous or dioecious; when dioecious, both the male and female receptacles acanthocarpic 2
    2. Receptacles androgynous or dioecious, leaves of various shapes, relatively smaller with conspicuously oblique base part, with inner margin inwardly curved, entire or lightly toothed and other margin outwardly curved and coarsely toothed.......... .... *Ilicifolia*
    2. Receptacles androgynous, leaves lanceolate to linear, relatively larger, with subequal basal part .... *Coriifolia*

Species of Biserrulae Recorded from China

Deveaux (1875) recorded one species from Hong Kong:
1. *S. gracile* J. Agardh

Martens (1866) recorded three species from Macao and Taiwan Strait:
2. *S. subrepandum* (Fossk.) J. Agardh f. *turneri* (Kuetzing) Grunow (*Carpacanthus turneri* Kuetzing)
3. *S. gaudichaudii* Montagne

In his monographic treatment of the Sargassaceae, Grunow (1915, 1916) reported 16 species from the China Sea. They may all ultimately be found on or near the coast of China. Among these records, the following three species have been definitely recorded from China:

4. *S. spinifex* C. Agardh
5. *S. brevifolium* Greville *f. chinensis* Grunow
6. *S. baccularia* (Mertens) C. Agardh, var. ? *lantowensis* Grunow

In 1925, Yamada recorded two species from Taiwan:

7. *S. coriifolium* J. Agardh
   S. coriifolium J. Agardh f. *duplicatum* Yamada
   S. coriifolium J. Agardh f. *prolongatum* (Okamura) Yamada
8. *S. ilicifolium* (Turner) C. Agardh

Setchell (1936) recorded two species:

9. *S. granuliferum* C. Agardh
10. *S. parvifolium* (Turner) C. Agardh

In 1942 and 1944, Yamada recorded one species from Taiwan:

11. *S. amabile* Yamada

Yamada recorded one species in 1950:

12. *S. sandei* Reinbold
    S. sandei Reinbold f. *heterophyllum* Yamada

Tseng and Lu (1979) recorded three species:

13. *S. parvivesiculosum* Tseng et Lu
14. *S. turbinatifolium* Tseng et Lu
15. *S. xishaense* Tseng et Lu

Chou and Chiang (1981) recorded one species:

16. *S. heterocystum* Montagne

Therefore, currently 16 species recorded from China belong to the *Biserrulae.*

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STUDIES ON THE GLOMERULATE *SARGASSUM* OF CHINA: IV. SERIES OF *PLATYCARPAE*

C.K. Tseng and Lu Baoren

Abstract

The Chinese species of glomerulate *Sargassum* that belong to the series *Platycarpae* were studied. The *Platycarpae* are differentiated from the *Binderiana* by the multifarious filiform or subcylindrical nature of the upper parts of the primary branches of the *Platycarpae*. This series has 16 species. The following 7 have been recorded from China: *S. crassifolium* J. Agardh, *S. cristaefolium* C. Agardh, *S. dazhouense* Tseng et Lu, *S. duplicatum* Bory, *S. megalocystum* Tseng et Lu, *S. sanyaense* Tseng et Lu, and *S. yongxingense* Tseng et Lu.

Introduction

The subsection *Glomerulatae* was divided by Grunow (1915) into two subtribes: *Binderiana* and *Platycarpae*. In accordance with the current practice, we have suggested raising the two subtribes to series, namely, series *Binderiana* and series *Platycarpae* (Tseng and Lu 1995a). Our studies of the Chinese species of *Binderiana* are presented in volume 5 of *Taxonomy of Economic Seaweeds* (Tseng and Lu 1995a–1995c). The series *Platycarpae* is characterized by the multifarious filiform to subcylindrical nature of the upper parts of the primary branches, alternately giving rise to secondary branches from their foliar axils. J. G. Agardh (1889) listed the following 9 species: *S. platycarpum* Montagne, *S. crassifolium* J. Agardh, *S. obovatum* (Harvey) J. Agardh, *S. duplicatum* Bory, *S. berberifolium* J. Agardh, *S. marginatum* J. Agardh, *S. cristaefolium* C. Agardh, *S. liebmanni* J. Agardh, and *S. hystrix* J. Agardh. Grunow (1915) accepted 8 species; renamed the 9th species, *S. berberifolium* J. Agardh (1889, p. 90, pl. 26V, not 1848, p. 337), as a variety of his *S. spinipes*, namely, *S. spinipes* Grunow var. *berberifolioides* Grunow; and added 4 species: *S. polyceratium* Montagne, *S. spinipes* Grunow, *S. turbinarioides* Grunow, and *S. telephifolium* (Turner) C. Agardh. Tseng and Lu (1997) reported 4 new species in the *Platycarpae*: *S. yongxingense*, *S. sanyaense*, *S. megalocystum*, and *S. dazhouense*. Thus, to date, the series *Platycarpae* has a total of 16 species.

The first record of a Chinese species of *Platycarpae* is *S. cristaefolium* C. Agardh, which was reported by Cotton (1915). Yamada (1925) added one platycarpic Sargassum from Taiwan: *S. duplicatum* Bory. Okamura (1931) later added another from Taiwan, *S. telephifolium* (Turner) C. Agardh and Yamada (1950) added *S. crassifolium* J. Agardh from the same place. With the four new species described by Tseng et Lu (1997), a total of eight species are found in China. One of the eight species is, however, a doubtful one: *S. telephifolium* (Turner) C. Agardh reported by Okamura (1931) from Kotosho, Taiwan. The species was placed in *Cymosae* by Okamura (1936), whereas it is a member of the *Platycarpae* of the glomerulate *Sargassum*. It is evident that Okamura had before him a malacocarpic *Sargassum* with cymose inflorescence rather than an acanthocarpic one. We shall keep this as a doubtful record until we can observe the specimen.

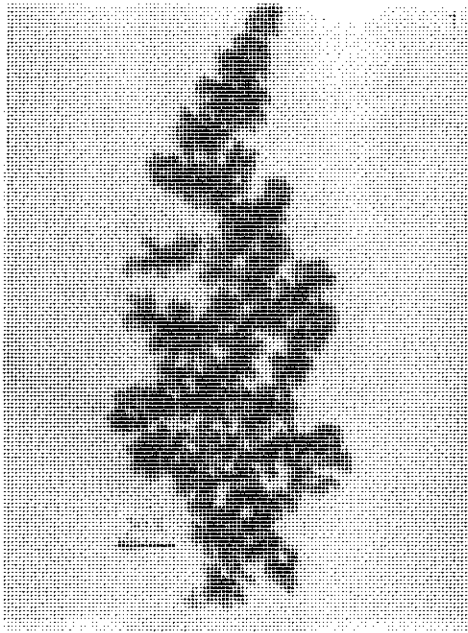
Key to the Chinese Species of the *Platycarpae*

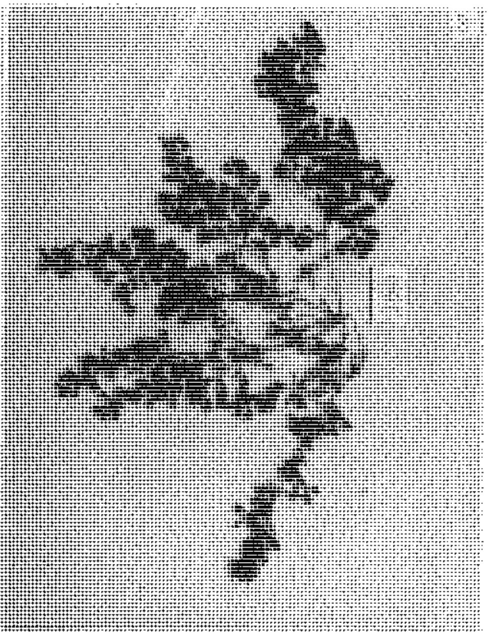
1. Leaves spatulate, usually duplicate, forming cuplike structures at apices 2
1. Leaves oblong or elliptical, double serrulate at apices 3
   2. Branchlets with many conspicuously raised glands .... *S. yongxingense*
   2. Branchlets without raised glands .... *S. duplicatum*
3. Branchlets with conspicuously raised glands .... *S. sanyaense*
3. Branchlets without conspicuously raised glands 4
   4. Vesicles spherical, usually rounded or acute at apices 5
   4. Vesicles oblong or elliptical, obtuse or acute at apices 6
5. Vesicles rounded at apices, earlike at the margins .... *S. cristaefolium*
5. Vesicles acute at apices, with thin spiny fringing margins .... *S. dazhouense*
   6. Vesicles elliptical, usually with small leaves at apices .... *S. crassifolium*
   6. Vesicles large, oblong, acute at apices .... *S. megalocystum*

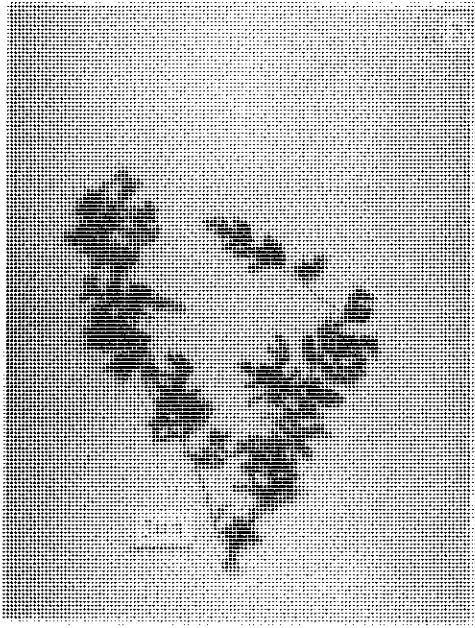
Description of the Species

Sargassum duplicatum Bory, Cryptogamie, p. 127, 1828.
(Figs. 1 and 8)

Fronds yellow-brown, attaining a height of 45 cm, with discoid holdfast, up to 10 mm in diameter, and a terete, smooth, main axis. Stem 7–8 mm tall, 3–4 mm in diameter, giving rise to several primary branches from its upper parts. Primary branches cylindrical or subcylindrical, smooth, 39–44 cm long, 2.0 mm in diameter; secondary branches shorter, cylindrical, smooth, 5–10 cm long, 1.5 mm in diameter, beset with short, fructiferous branchlets, 1–2 cm long, 1 mm in diameter. Leaves spatulate, oblong, usually 1.5–1.8 cm long, 10–12 mm wide, duplicate at the apex, forming cuplike structures irregularly serrate at the margins, symmetrical, cuneate at the bases, with conspicuous midribs, generally vanishing below the apex, and conspicuous, slightly raised cryptostomata, irregularly arranged on both sides of the midrib. Vesicles spherical, or subspherical, usually 7–8 mm in diameter, rounded at apex, with earlike wings on both sides and cylindrical, short pedicels, 2–3 mm long, 1 mm in diameter; generally with a few cryptostomata on the vesicles and pedicels.







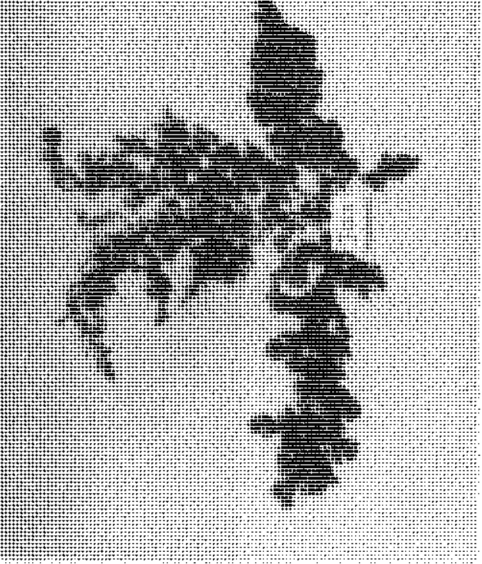
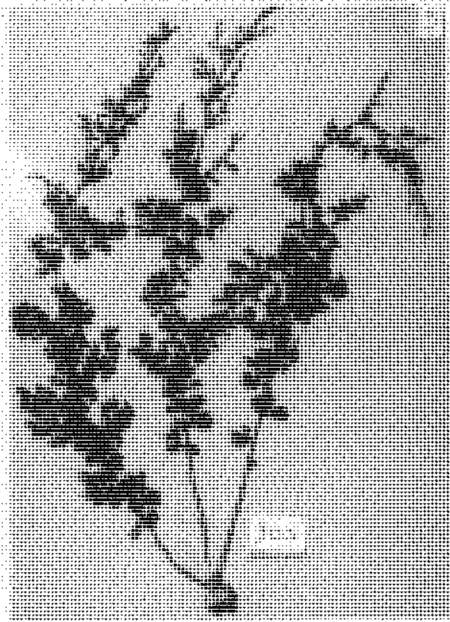
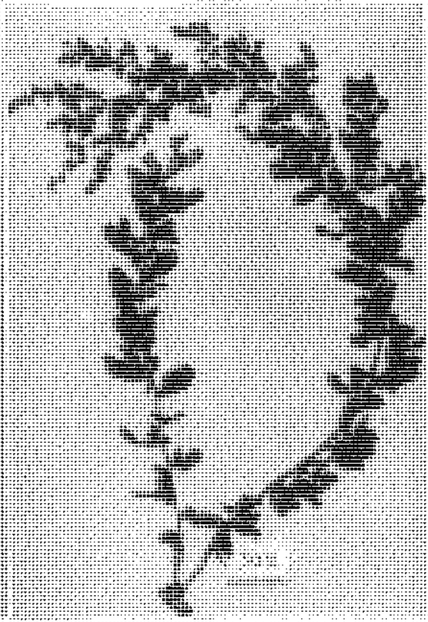


Fig. 1. *Sargassum duplicatum* Bory (AST 76-0335).
Fig. 2. *Sargassum yongxingense* Tseng et Lu (AST 58-4012).
Fig. 3. *Sargassum cristaefolium* C. Agardh (AST 58-5481).
Fig. 4. *Sargassum sanyaense* Tseng et Lu (AST 76-1972).





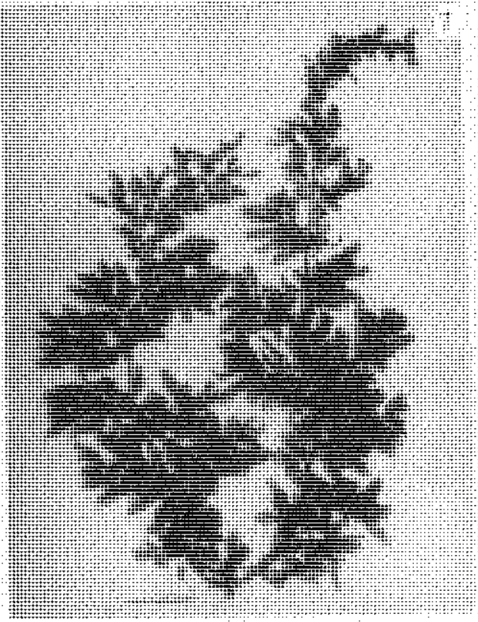


Fig. 5. *Sargassum megalocystum* Tseng et Lu (AST 57-5616).
Fig. 6. *Sargassum dazhouense* Tseng et Lu (AST 57-5615).
Fig. 7. *Sargassum crassifolium* J. Agardh (AST 82-0391).

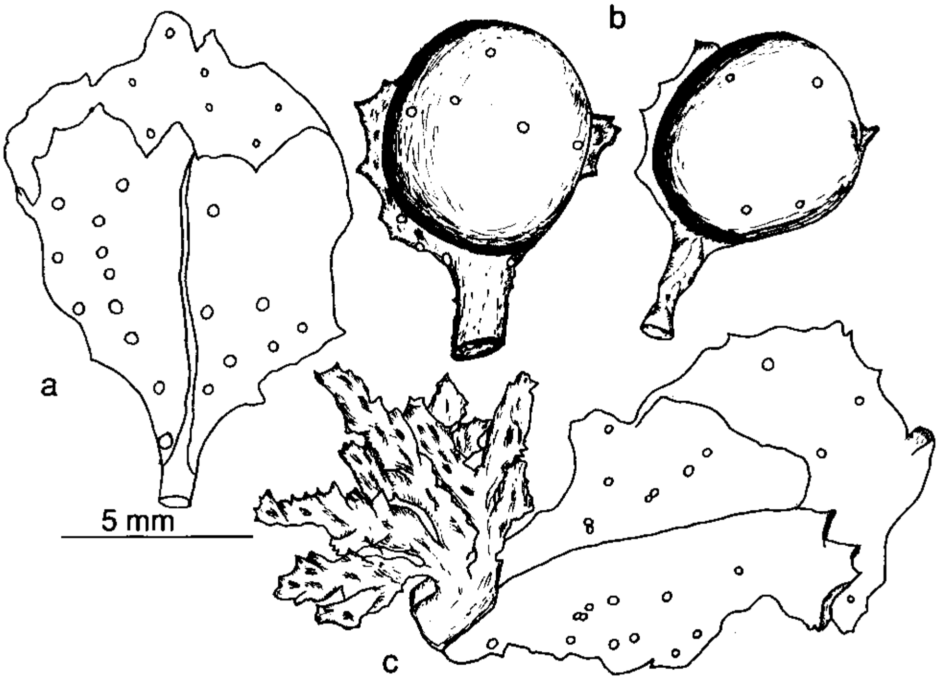


Fig. 8. ***Sargassum duplicatum*** **Bory (AST 76-0335). a, Leaf with cuplike structure at apex. b, Vesicles. c, Receptacles with leaf.**

Plants androgynous with compressed to subcylindrical receptacles provided with small spines, irregularly forked, 4–5 mm long, 0.5–1.0 mm wide. Receptacles cymosely arranged in glomerules.

Habitat: Growing on the lower intertidal and subtidal rocks. Sanya (AST 57-5751, 58-4597, 58-5469, 58-5483, 58-5518, 59-3032, 75-1307), Xisha Islands (AST 75-1188, 75-1242, 75-1298, 75-1308, 76-0335, 76-1241, 76-1305, 76-1386, 76-1458, 76-1571, 76-1577, 80-0715). All in April to June, Hainan Province.

Distribution: Japan, China, Vietnam, Indonesia, Malaysia, and the Philippines.

Remarks: *Sargassum duplicatum* Bory is characterized by branches that are subcylindrical or cylindrical and smooth; leaves that are spatulate, oblong, and duplicate at the apices forming cuplike structures; and vesicles that are spherical or subspherical, rounded at the apices, usually with earlike wings on both sides. This species is closely related to *S. cristaefolium* C. Agardh, but the leaves of *S. cristaefolium* do not form cuplike structures at the apices.

The problem with *S. duplicatum* is a difficult one. When J. Agardh published the species in 1889, he put in brackets, "vix *S. duplicatum* Bory voy coquil no. 27." The following species were listed by him as synonyms: *S. ilicifolium* var. *duplicatum* J. Agardh, *S. cristaefolium* sensu Harvey, non C. Agardh, and *S. pfeifferae* Grunow. The last mentioned synonym was later made a variety of *S. obovatum* Harvey by Grunow (1915, p. 392). When Grunow (1915) listed *S. duplicatum* J. Agardh, he placed a question mark after *S. duplicatum* Bory. Grunow also quoted *S. ilicifolium* var. *duplicatum* J. Agardh and *S. cristaefolium* Harvey as synonyms and added their varieties. The species apparently was thought to be widely distributed. Womersley and Bailey (1970) concluded that *S. duplicatum* J. Agardh was a synonym of *S. cristaefolium* C. Agardh.

The problem therefore involves *S. duplicatum* J. Agardh (1889), *S. duplicatum* Bory (1828) and *S. cristaefolium* C. Agardh (1820). Previously, phycologists mostly used the name *S. duplicatum* J. Agardh for the *Sargassum* with duplicate leaves. Recently, one of us (Lu) had a discussion with the Japanese phycologist T. Yoshida. Yoshida stated that *S. duplicatum* J. Agardh and *S. duplicatum* Bory should be treated as two distinct species. *Sargassum duplicatum* J. Agardh is synonymous with *S. cristaefolium* C. Agardh, whereas *S. duplicatum* Bory characterized by the cup-shaped duplicate leaves is a good species. We thank Dr. Yoshida for this information and have followed his advice.

Sargassum duplicatum J. Agardh has been previously studied by Grunow (1915, p. 392), Okamura (1923, p. 10, pl. 205), Yamada (1925, p. 253), Pham (1967, p. 302, fig. 18), Chou and Chiang (1981, p. 138, pl. I, fig. 5, pl. II, fig. 6), Lu and Tseng (1983, p. 228, pl. 115, fig. 1), and Yoshida (1988, pp. 12–14, fig. 8; as a synonym of *S. cristaefolium*). Most of these records, however, indicate plants of *S. duplicatum* Bory, non J. Agardh, as shown by the cupshaped structure at the top of the leaves in Okamura (1931) and Chou and Chiang (1981) and in the general habitats of the plants.

Sargassum yongxingense Tseng et Lu, Oceanol. Limnol. Sin. 1997.
(Figs. 2 and 9)

Fronds short, yellow-brown, attaining a height of 20 cm. Holdfasts discoid, about 5 mm in diameter, giving rise to several primary branches from its upper parts. Primary branches cylindrical, smooth, to about 19 cm long, 2 mm in diameter; secondary branches short, arising from foliar axil, alternate, at intervals of 1.5–2.0 cm, cylindrical, with a few raised glands, usually 5–6 cm long, 1.0–1.5 mm in diameter; branchlets shorter, cylindrical, with many raised glands on the surface, about 0.8–1.0 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves spatulate, obovate, usually 1.0–1.2 cm long,

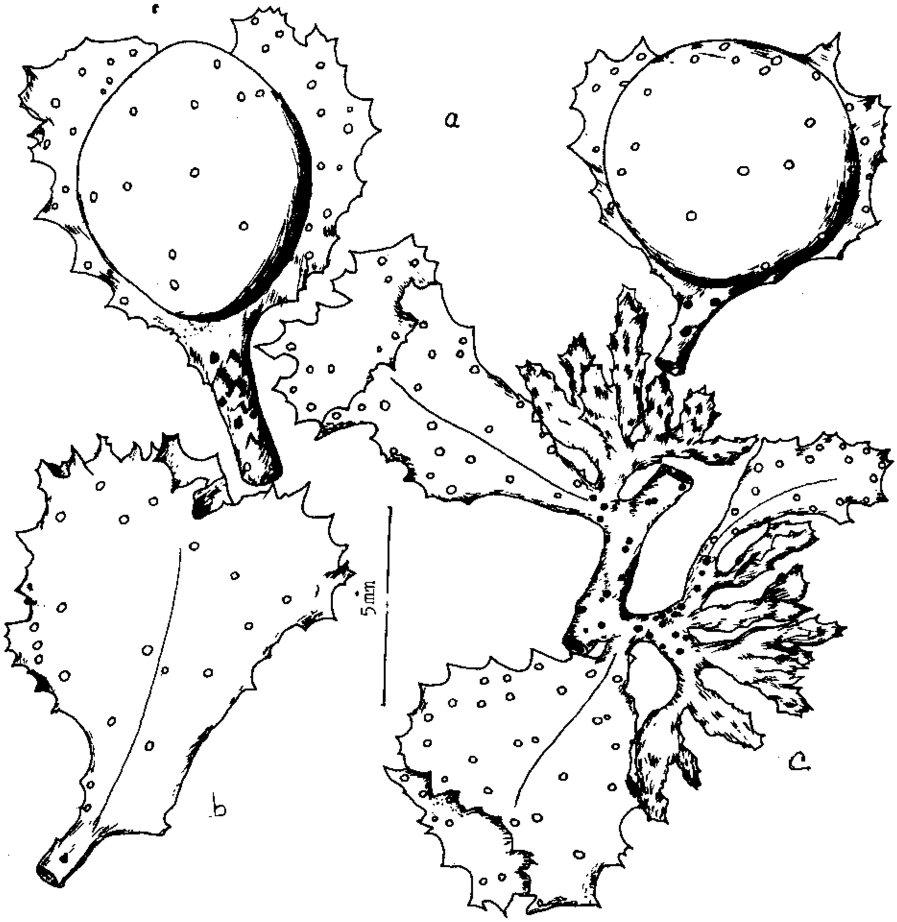


Fig. 9. ***Sargassum yongxingense*** **Tseng et Lu (AST 58-4012). a, Vesicles. b, Leaf with cuplike structure at apex. c, Receptacles with leaves.**

6–8 mm wide, usually duplicate, forming cuplike structures at the apices, symmetrical, cuneate at the bases, denticulate at the margins, midrib not percurrent, usually vanishing in the middle parts of the leaves; cryptostomata conspicuous, raised, irregularly arranged on both sides of the midribs and compressed, subcylindrical, stipitate, with a few spines. Vesicles small, spherical, usually 5–6 mm in diameter, rounded at apices, with earlike wings on both sides, or small, foliar structures surounding the margins except the apices; vesicle pedicels cylindrical, usually with a few spines, both with conspicuously raised cryptostomata irregularly arranged.

Plants androgynous. Receptacles usually compressed at the upper parts, subclindrical below, with small spines, forked, 4–5 mm long, 0.8–1.0 mm wide;

several receptacles cymosely arranged in glomerules.

Habitat: Growing on lower intertidal reefs, Yongxing Island, Xisha Islands, in March to June (AST 57-5167a, 57-5483a,58-4012, 58-4847, 58-4871).

Distribution: Endemic in China.

Remarks: This species is characterized by cylindrical branches and secondary branches and branchlets with conspicuously raised glands on the surface; by small, spatulate, obovate duplicate leaves, forming cuplike structures at the apices, and by compressed stipes with a few spines; by spherical vesicles rounded at the apices, usually with earlike wings on both sides or small foliar structures surrounding the margins except the apices and cylindrical pedicels with a few spines; and by androgynous, compressed receptacles, usually cymosely arranged in glomerules. This species is closely related to *S. duplicatum* Bory, differing in its secondary branches and branchlets with some conspicuously raised glands, smaller leaves with compressed and somewhat spinous stipes and vesicles usually surrounded by small foliar structures except at the apices.

Sargassum cristaefolium C. Agardh, Species algarum, p. 13, 1820.
(Figs. 3 and 10)

Fronds yellow-brown, usually reaching a height of 32 cm. Holdfast discoid, about 1.0–1.5 cm in diameter, main axis cylindrical about 6–8 mm long, smooth, about 1 cm long, 2 mm in diameter. Primary branches arising from the upper parts of the axis, cylindrical, smooth, usually up to 30–31 cm long, 1.5 cm in diameter; secondary branches giving rise to foliar axil, short, cylindrical, smooth, usually 4–7 cm long, 1 mm in diameter, beset with fructiferous branchlets usually 1.0–1.5 cm long, less than 1 mm in diameter. Leaves on the primary branches, oblong,usually 2.5–3.0 cm long, 8–10 mm wide, double serrulate at the apex, irregularly dentate at the margins, cuneate at the base, midrib not percurrent, vanishing below the apex, cryptostomata conspicuous, slightly raised, irregularly arranged on both sides of the midrib; leaves on the secondary branches and branchlets smaller, oblong, rounded at the apices, sometimes double dentate, 1.5–2.0 cm long, 7–8 mm wide, very similar to those on the primary branches in form. Vesicles cylindrical or subcylindrical, about 4–5 mm in diameter, rounded at apices, most of them with earlike wings on both sides of the vesicle, pedicels compressed upward and cylindrical below, cryptostomata conspicuous, irregular in different parts of the vesicles and pedicels.

Plants dioecious. Female receptacles compressed, with a few spines, sometimes triquetrous, forked at its upper parts, 5–6 mm long, 1.5–1.8 mm wide. Male receptacles cylindrical, smooth, sometimes forked, about 6–8 mm long. Several receptacles cymosely or closely racemosely arranged in glomerules.

Habitat: Growing on subtidal reef. Qinglan in March to April (AST 76-0299, 92-0272), Qionghai in March (AST 80-2701), Wanning in February (AST 76-0170), Lingshui in April (AST 58-5481), and Yulin in April (AST 75-1310, 92-0382). All in Hainan Province.

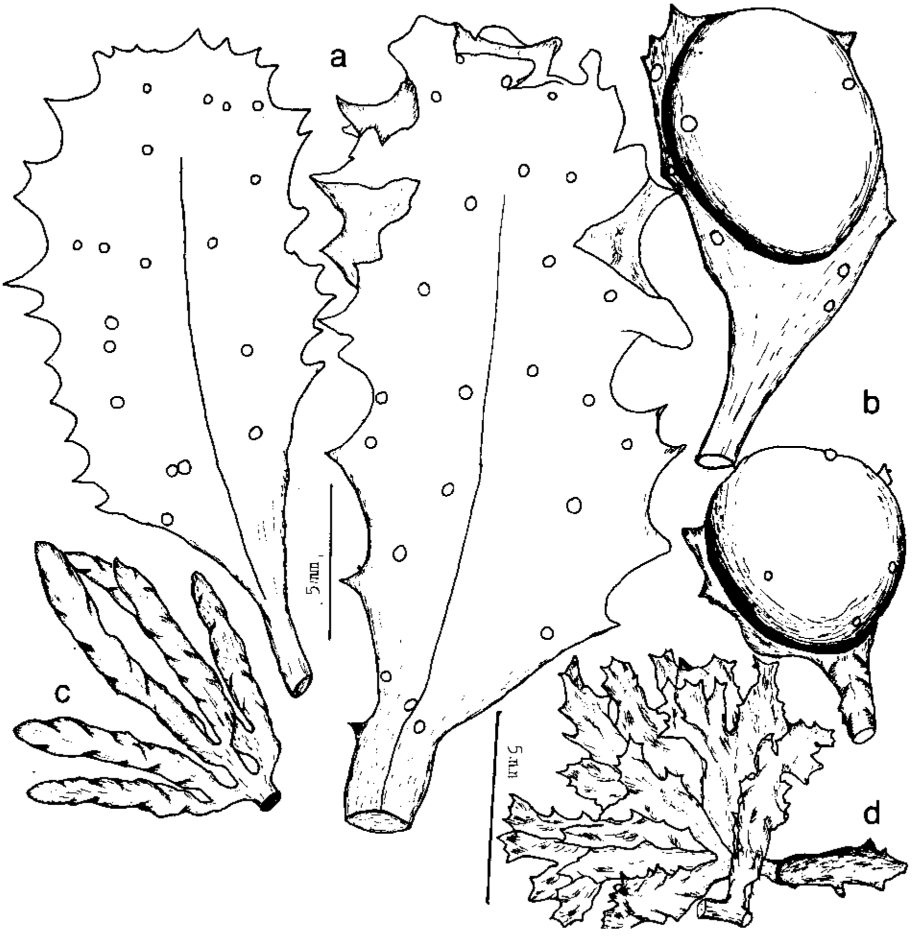


Fig. 10. ***Sargassum cristaefolium*** **C. Agardh (AST 58-5481). a, Leaves. b, Vesicles. c, Male receptacles. d, Female receptacles.**

Distribution: Japan, Vietnam, the Philippines, Solomon Islands, and China (Taiwan and Hainan Provinces).

Remarks: This species is characterized by its cylindrical, smooth branches, leaves on the primary branches large, oblong, usually double serrutate at the apex; spherical or subspherical vesicles, usually with earlike wings on both sides of the vesicles; and compressed female receptacles, sometimes triquetrous at the upper parts and subcylindrical below, with some spines on the apex. Womersley and Bailey (1970) believed that *S. duplicatum* Bory and *S. cristaefolium* C. Agardh belonged to the same species and that the former was a synonym of the latter. We think, however, that they are different species and that the main difference is in the leaves. Those of *S. duplicatum* Bory are duplicate at the apices, forming a cuplike structure, whereas those of *S. cristaefolium* C. Agardh are double serrate at the apices.

Sargassum cristaefolium C. Agardh has been previously studied by C. Agardh (1824, p. 297), J. Agardh (1848, p. 325; 1889, p. 91), Reinbold (1913, p. 157), Grunow (1915, p. 398), Cotton (1915, p.110), Setchell (1935, p. 265), Boergesen (1936, p. 79), Durairatnam (1961, p. 45, pl. 10, figs. 3–5), and Yoshida (1988, p. 12).

Sargassum sanyaense Tseng et Lu, Oceanol. Limnol. Sin. 1997.
(Figs. 4 and 11)

Fronds yellow-brown, reaching a height of 35 cm. Holdfasts discoid, 1.5 cm in diameter, each giving rise to a main axis, cylindrical, short, smooth, about 4 mm long, 1.5 mm in diameter. A few primary branches from upper part of the axis, subcylindrical or cylindrical, smooth, usually 24–35 cm long, 2 mm in diameter; secondary branches cylindrical, 8 cm long, 1.5 mm in diameter, alternate at intervals of 1.0–2.5 cm, with some glandular dots; branchlets short and slender, cylindrical, with close, raised glandular dots and beset with leaves, vesicles, and receptacles. Leaves on the primary branches larger, spatulate, oblong, usually 2 cm long, 15 mm wide, obtuse, generally double serrulate at the apices, irregularly dentate at the margins, symmetrical, cuneate at the base with midrib usually vanishing at the top one third of the leaves and cryptostomata conspicuously raised, arranged on both sides of the midribs; leaves on the secondary branches and branchlets smaller, ellipsoidal, about 1.0–1.5 cm long, 7 mm wide, obtuse, usually double serrulate at the apices, asymmetrical, oblique at the base, with midrib usually vanishing at the middle part of the leaves, cryptostomata slightly raised, and stipe compressed with a few spines. Vesicles spherical or subspherical, 4–6 mm in diameter, rounded at apices, with earlike wings at both sides or foliar structures surounding their margins, and short, cylindrical or subcylindrical pedicels, about 1.5–2.0 mm long, 0.5 mm in diameter.

Plants androgynous. Receptacles usually forked, and compressed at the upper parts, subcylindrical below, 4–5 mm long, 0.5–0.6 mm wide, with spines on both sides and apices, cymosely arranged in glomerules.

Habitat: Growing on lower intertidal or subtidal rocks. Sanya, Hainan Province, in April (AST 62-2543, 76-1972, 80-2037).

Distribution: Endemic in China.

Remarks: This species is characterized by cylindrical, smooth primary branches, and secondary branches and branchlets with some conspicuously raised glandular dots. Leaves on the primary branches are spatulate or oblong, usually double serrulate at the apices and symmetrical cuneate at the base. Leaves on the secondary branches are ellipsoidal, usually double serrulate at the apices, asymmetrical, and oblique at the base. The stipe has a few spines. The vesicles are spherical or subspherical, rounded at apices, with earlike wings at

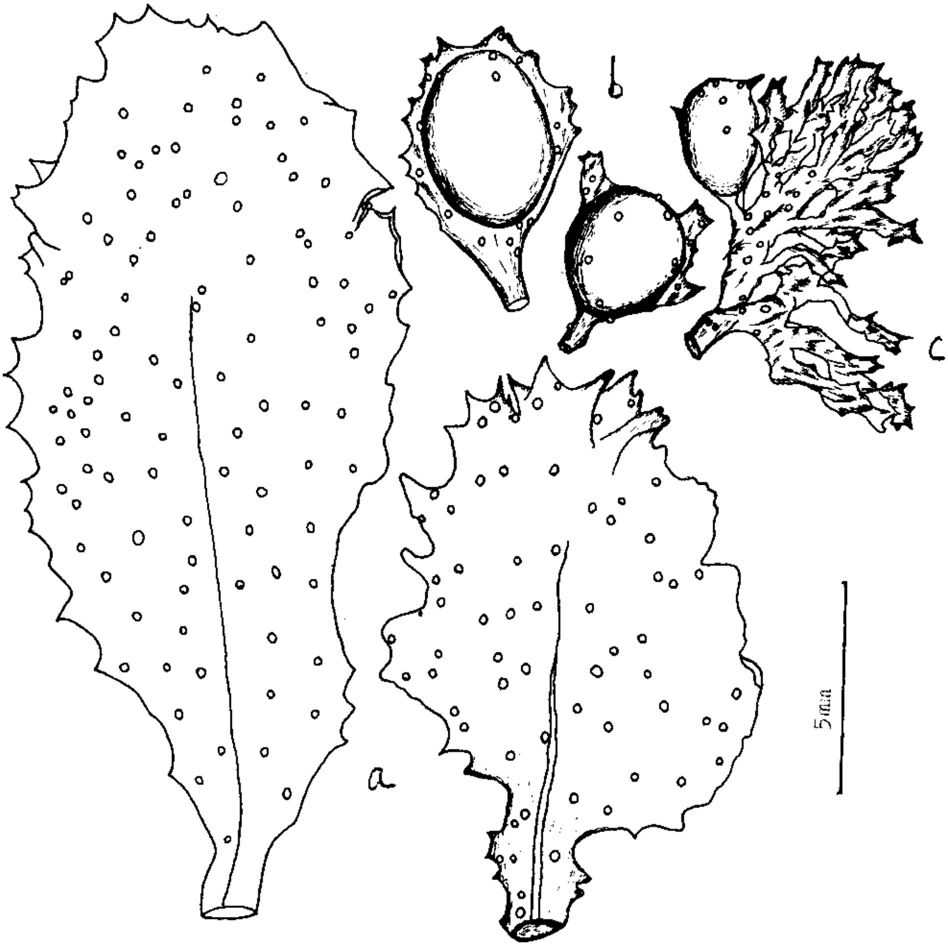


Fig. 11. ***Sargassum sanyaense*** **Tseng et Lu (AST 76-1972). a, Leaves. b, Vesicles. c, Receptacles with small vesicles.**

both sides or with foliar structures surounding the margin. Its receptacles are androgynous, compressed at the upper parts and subcylindrical below. Like *S. cristaefolium*, it has double serrulate leaves; unlike *S. cristaefolium*, it has raised glandular dots on the secondary branches and branchlets. It is closely related to *S. yongxingense*. Both have conspicuously raised glands on the surface of secondary branches and branchlets. However, of the two, only *S. sanyaense* has double serrulate leaves, and it does not form cuplike structures at the apices.

Sargassum megalocystum Tseng et Lu, Oceanol. Limnol. Sin. 1997.
(Figs. 5 and 12)

Fronds yellow-brown, attaining a height of 48 cm, with discoid holdfast, 2 mm in diameter, giving rise to smooth cylindrical main axes up to 0.5 cm long, 3 mm in diameter, several primary branches arising from the upper parts. Primary branches subcylindrical or cylindrical, smooth, 45–47 cm long, 2 mm in diameter; secondary branches short, cylindrical, smooth, about 6–9 cm long, 1.0–1.5 mm in diameter, alternate at intervals of 1.5–2.0 cm; branchlets short, cylindrical, usually 2 cm long, less than 1 mm in diameter. Most leaves on the primary branches obovate, a few oblong, about 2.0–2.5 cm long, 8–10 mm in diameter, rounded, usually double serrulate at apices, the upper part larger than the lower part, midrib usually vanishing at the middle part of the leaves, asymmetrical, obliquely cuneate at the base, irregularly dentate at the margins, more in the upper parts and fewer at the base, with scattered cryptostomata. Leaves on the secondary branches and branchlets obovate, 1.5 cm long, 8 mm in diameter, rounded at the apices, irregularly dentate at the margins, similar to those of the primary branches. Vesicles very large, oblong, sometimes opposite, up to 11 mm long, 7 mm in diameter, slightly acute at the apex, sometimes with irregular spiny fringing margins, with flattened pedicels, foliose at the upper parts, subcylindrical below, 4–5 mm long, 1.2–1.5 mm wide, with a few cryptostomata.

Plants androgynous. Receptacles flattened, sometimes triquetrous in the upper part, 5 mm long, 1 mm wide, with some spinules at the apex and margins, several receptacles cymosely arranged in glomerules.

Habitat: Growing on lower intertidal rocks. In March (AST 57-5616) at Dazhou Island, Hainan Province.

Distribution: Endemic in China.

Remarks: This species is characterized by obovate leaves that are sometimes oblong rounded, sometimes double serrulate at the apices; by particularly large, oblong vesicles, almost as large as the obovate leaves, slightly acute at the apices and surrounded by irregularly spiny fringing margins; by double serrulate apices of the leaves; and by flattened receptacles, sometimes triquetroue in the upper parts. It is related to *S. cristaefolium* C. Agardh, but *S. megalocystum* has nonglandular branchlets, and its large, oblong, vesicles are usually surrounded by irregularly spiny fringing margins.

Sargassum dazhouense Tseng et Lu, Oceanol. Limnol. Sin. 1997.
(Figs. 6 and 13)

Fronds yellow-brown, reaching a height of 50 cm, with small discoid holdfasts, 1 cm in diameter, giving rise to short cylindrical, smooth main axes, 5 mm long, 2 mm in diameter, with several primary branches growing from the upper parts. Primary branches cylindrical, smooth, about 50 cm long, 1.5 mm in diameter, giving rise to several secondary branches from their leaf axils; secondary branches alternate at intervals of 2.0–2.5 cm, cylindrical, smooth, about 6–7 cm

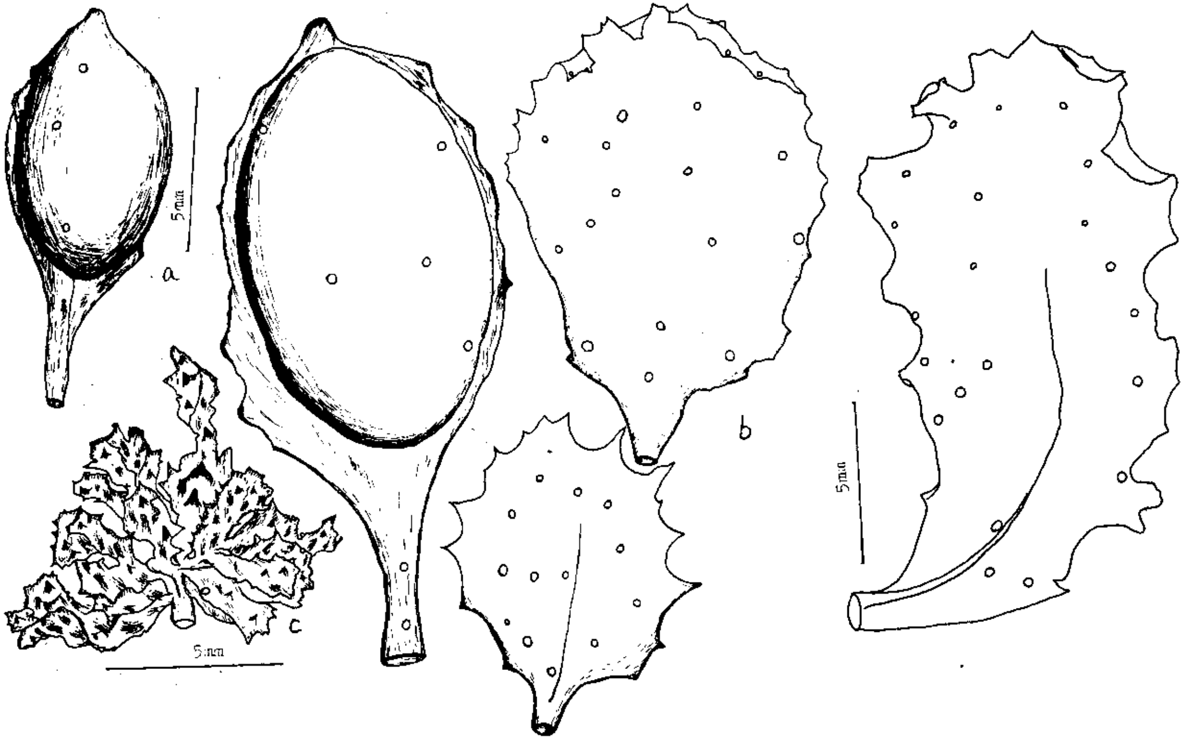


Fig. 12. *Sargassum megalocystum* Tseng et Lu (AST 57-5616). a, Vesicles. b, Leaves. c, Receptacles.

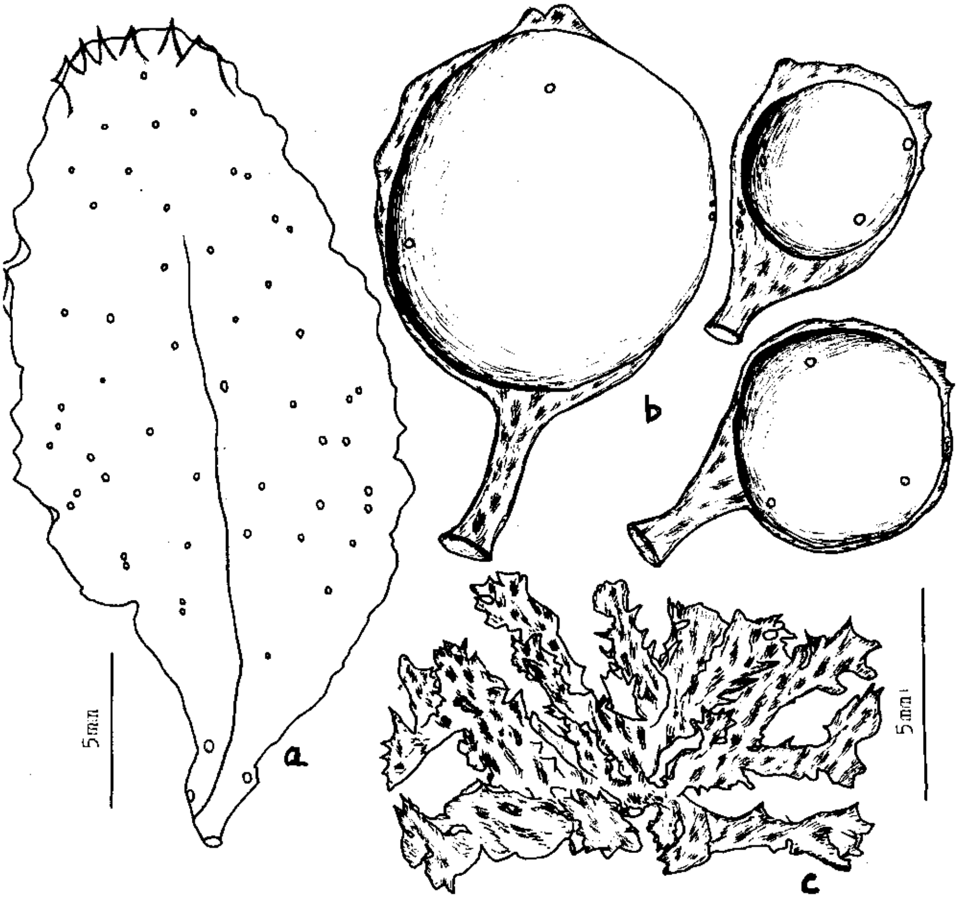


Fig. 13. ***Sargassum dazhouense*** **Tseng et Lu (AST 57-5615). a, Leaf. b, Vesicle. c, Receptacles .**

long, 1.2 mm in diameter, branchlets very short, terete, smooth, generally 2 cm long, 0.6 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves oblong, generally 2.5–3.5 cm long, 10–15 mm wide, apices obtuse, sometimes double serrulate at the apices, oblique and asymmetrical at the bases, irregularly serrulate at the margins, somewhat wavy or dentate in the internal basal part, with conspicuous midrib, vanishing at about two thirds of the length of the leaves, cryptostomata irregularly scattered, and short, compressed stipes, about 4–5 mm long. Vesicles spherical, usually forked and acute at the apices, with thin spiny fringing margins, 5–8 mm in diameter, and short pedicels, compressed on the upper parts, cylindrical below.

Plants androgynous. Receptacles flattened, about 5–6 mm long, 1.5–2.0 mm wide, with numerous spines on sides and apices, cymosely or subracemosly closely arranged in glomerules.

Habitat: Growing on the lower intertidal rocks. Dazhou Island, Hainan Province in June (AST 57-5615, 57-5747).

Distribution: Endemic in China.

Remarks: This species is characterized by oblong or obovate leaves, obtuse apices, sometimes double serrulate at the apices, and spherical vesicles, usually forked and acute at the apices. It is closely related to *S. megalocystum* Tseng et Lu but has smaller spherical vesicles, usually forked and acute at the apices, and narrower leaves.

Sargassum crassifolium J. Agardh, Sp. gen. ordines algarum, Vol. I, p. 326, 1848. (Figs. 7 and 14)

Fronds yellow-brown, attaining a height of 40–50 cm. Holdfast discoid, about 1 cm in diameter, giving rise to very short, cylindrical, smooth main axis, 5–10 mm long, 2 mm in diameter, usually three to four primary branches arising from its upper part. Primary branches compressed, smooth, about 30–50 cm long, 2–3 mm wide; secondary branches arising from the foliar axils of primary branches, cylindrical, alternate at intervals of 2.0–2.5 cm, usually 6–7 cm long, 1 mm in diameter; branchlets short, arising from the foliar axils of the secondary branches, alternate, beset with leaves, vesicles, and receptacles. Leaves thick, elliptic or elongated elliptic, 2–3 cm long, 1.0–1.5 cm wide, rounded at apices, usually double serrulate, with a cuneate base and a short stipe, midribs vanishing at the middle part of the leaves, cryptostomata conspicuous, irregularly arranged on both sides. Vesicles elliptical, usually 1.0–1.6 cm long, 5–10 mm in diameter, usually with leafy apices, sometimes with spiny fringed margins, cryptostomata scattered, and pedicels flat, foliaceous, somewhat denticulate at the margins.

Plants androgynous. Receptacles compressed, 2–3 mm long, 0.8–1.0 mm wide, usually forked, with some spines on the surface, cymosely arranged in glomerules.

Habitat: Growing on lower intertidal reefs. Wenchang in April (AST 92-021), Yulin in March (AST 80-2708), Sanya in April to December (AST 80-2039, 92-0374, 92-0382, 73-0688, 81-0695, 73-0454), Hainan Province.

Distribution: China (Taiwan, Hainan Island, Xisha Islands), Vietnam, Malaysia, Singapore, the Philippines, Guam.

Remarks: This species is characterized by very thick and hard leaves, elliptical to oblong, blunt at the apices, sometimes with double teeth; vesicles elliptical, usually with small leaves at the apices, sometimes with a spiniferous fringing margins; and receptacles compressed, with some spines, cymosely arranged in glomerules.

Sargassum crassifolium J. Agardh has been previously studied by Yamada (1942, p. 511, figs. 14 and 15), Chou and Chang (1981, p. 135, pl. 1, figs. 1 and 2, pl. 2, fig. 4), Lu (1983, p. 226, pl. 114, fig. 2), and Yoshida (1988, p. 12, fig. 6).

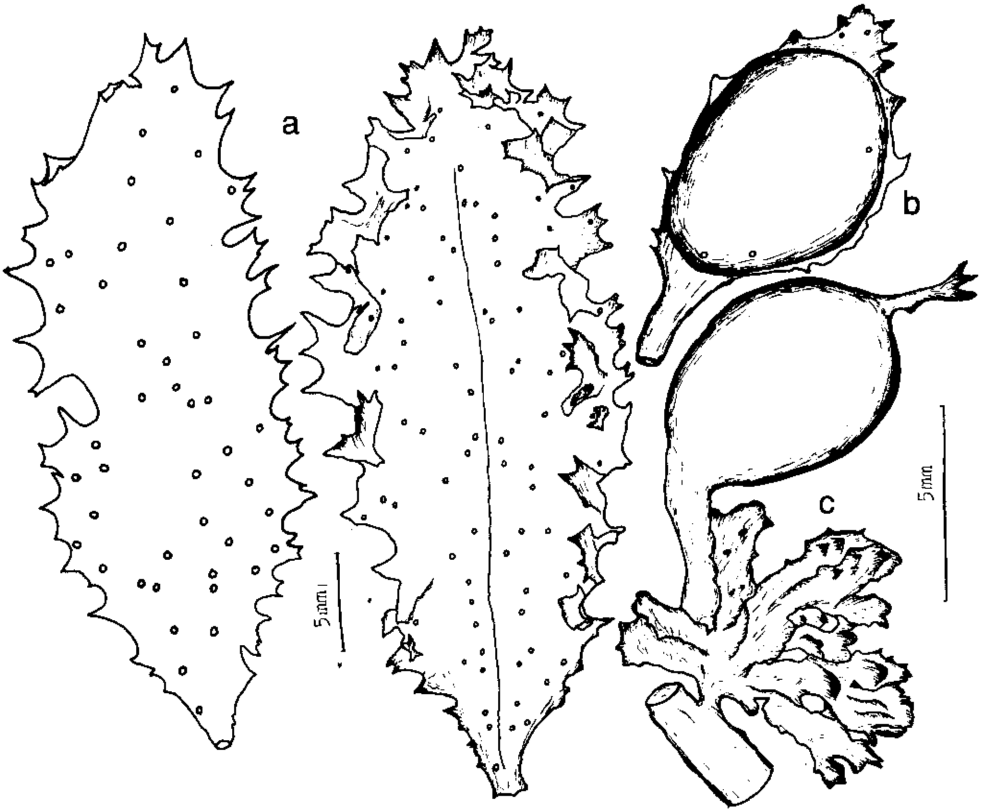


Fig. 14. *Sargassum crassifolium* J. Agardh (AST 82-0391). a, Leaves. b, Vesicle. c, Receptacles with small receptacle.

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TAXONOMIC AND NOMENCLATURAL STUDY OF *SARGASSUM DUPLICATUM* BORY AND RELATED SPECIES

Tetsuro Ajisaka, Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Ang Put, Jr.,
Phang Siew Moi, Tadahide Noro, and Tadao Yoshida

Abstract

Two morphologic types of leaf margins found in certain species of *Sargassum* (subgenus *Sargassum*), together with features of sexuality can be used to separate groups of species. *Sargassum duplicatum* Bory and *S. turbinatifolium* Tseng and Lu have leaf margins that are cup-shaped, whereas *S. crassifolium* and *S. cristaefolium* have margins with two rows of serration. A study of type materials indicated that *S. duplicatum* Bory has cup-shaped leaves and *S. duplicatum* J. Agardh has leaves with two rows of serration at the margin. Previously, *S. duplicatum* Bory was included in the synonymy of *S. cristaefolium,* which has two rows of serrated leaves. However, *S. duplicatum* must be attributed to Bory, and J. Agardh's name must be treated as a later homonym and hence illegitimate.

Introduction

Among the various features of warm-water species of *Sargassum* (subgenus *Sargassum*), the species group characterized by different morphologies of the leaf margins can be separated into two types (Fig. 1). In one, the leaf margin is "duplicated" or forms a pocket producing two rows of serration (one row behind the other). In the other, the terminal leaf margin is expanded, leaving a depression that forms a shallow cup.

The use of the same specific name *S. duplicatum* by Bory (1828) and J. Agardh (1889) has been interpreted by some authors as referring to the same species and by others as referring to different species. Womersley and Bailey (1970), for example, thought that the specimen on the basis of which *S. duplicatum* Bory was named was the same as the earlier named *S. cristaefolium* C. Agardh. On the other hand, they thought *S. duplicatum* J. Agardh was probably the same as *S. crassifolium* J. Agardh. When leaf margin is used as a defining characteristic, the assignment of Bory's specimen, on the basis of cup-shaped leaves, to *S. duplicatum* Bory is assured, and its previous placement in *S. cristaefolium* is in error because the leaves of the latter have two rows of serrated leaves.

To do this study, we examined the type specimens and photographs of the type specimens of *S. duplicatum* Bory, *S. duplicatum* J. Agardh, *S. sandei* Reinbold, and *S. turbinatifolium* Tseng et Lu and compared them with specimens of closely related species, *S. crassifolium* and *S. feldmannii.* From among *S. duplicatum* Bory specimens as recognized in Asiatic waters, we offer the following description. The abbreviations for herbaria are according to Holmgren et al. (1990).

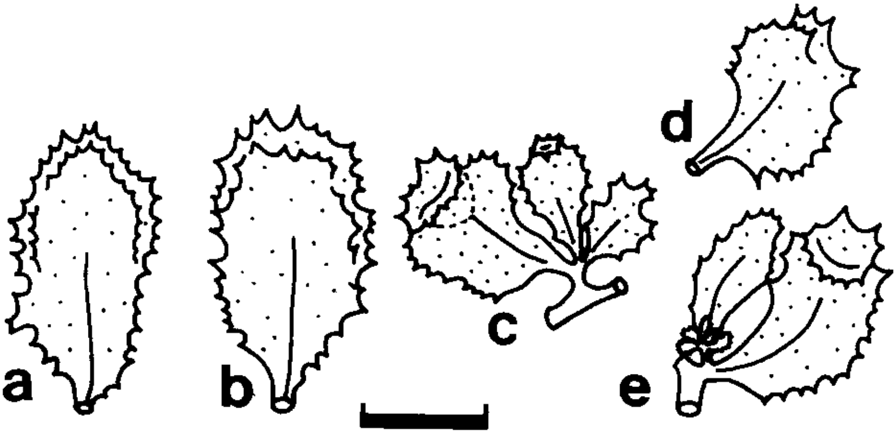

Fig. 1. Morphology of leaf margins. a and b, Two rows of serration *in Sargassum crassifolium* J. Agardh. c–e, Cup-shaped margins in *Sargassum duplicatum* Bory. Scale bar = 1 cm.

Taxonomy Related to Asiatic Species

Sargassum duplicatum Bory de Saint-Vincent, Cryptogamie, p. 127. In: L. Duperrey, ed. Voyage autour de monde...La Coquille..., 1828.

Synonym: *Sargassum sandei* Reinbold, *Sargassum* In: A. Weber van Bosse Siboga Expedite, 59a, p. 158, pl. 4,1913.

Misapplied name: *Sargassum brevifolium* sensu Yendo, J. Coll. Sci. Tokyo Imp. Univ. 21, p. 136, 1907.

We examined a photograph of the type specimen of *S. duplicatum* Bory in PC, and found that the leaves have cup-shaped margins (arrow in Fig. 2), not two rows of serration as in *S. cristaefolium* C. Agardh. However, we found leaves with two rows of serration at the margin (arrow in Fig. 3) in a photograph of J. Agardh's specimen (*S. duplicatum* J. Agardh) in LD. Therefore, we concluded that *S. duplicatum* Bory must be maintained for the species with cup-shaped leaf margins and that J. Agardh's name, *S. duplicatum* J. Agardh, must be treated as a later homonym and hence illegitimate.

After examining some specimens deposited in SAP and TI, we concluded that *S. brevifolium* sensu Yendo is attributable to *S. duplicatum* Bory (Figs. 4 and 5). Examination of holotype specimens in Herbarium Leiden (L) showed that *S. sandei* Reinbold (Figs. 6–10) has dioecious receptacles and cup-shaped leaves on the secondary branches. Because we found no difference between *S. duplicatum* Bory and *S. sandei* Reinbold, the latter species will be a synonym of *S. duplicatum* Bory.

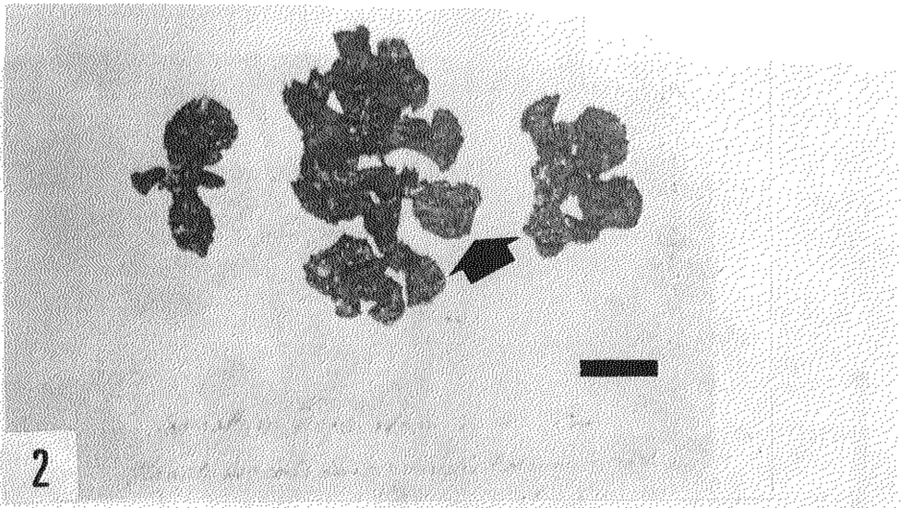
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Fig. 2. Type specimen of *Sargassum duplicatum* Bory deposited in PC. Arrow indicates cup-shaped leaf. Scale bar = 1 cm.

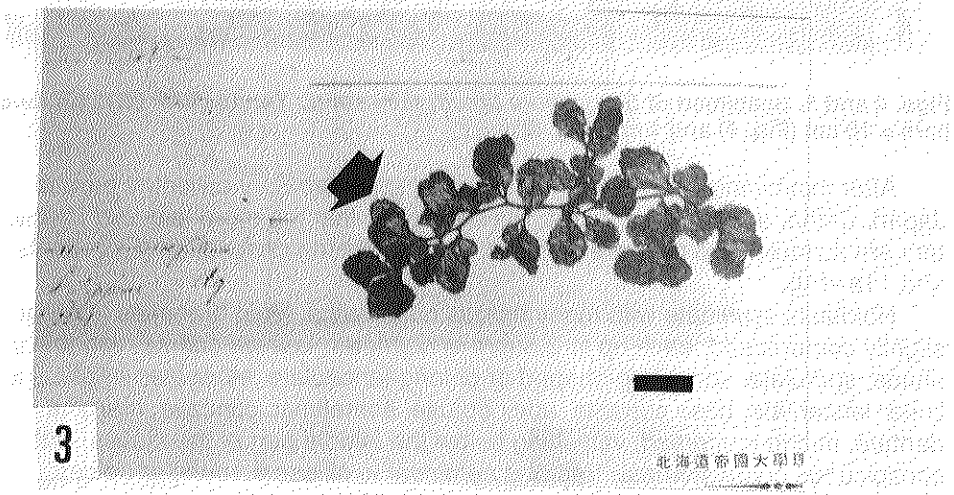
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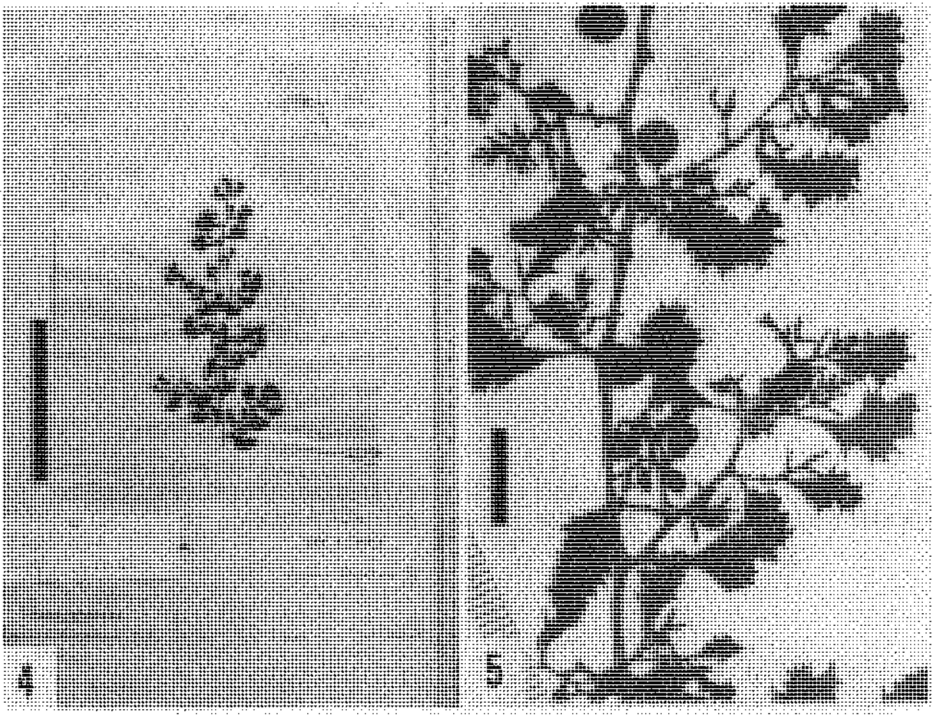
Fig. 3. Type specimen of *Sargassum duplicatum* J. Agardh deposited in LD. Arrow indicates two rows of serrated leaves. Scale bar = 1 cm.

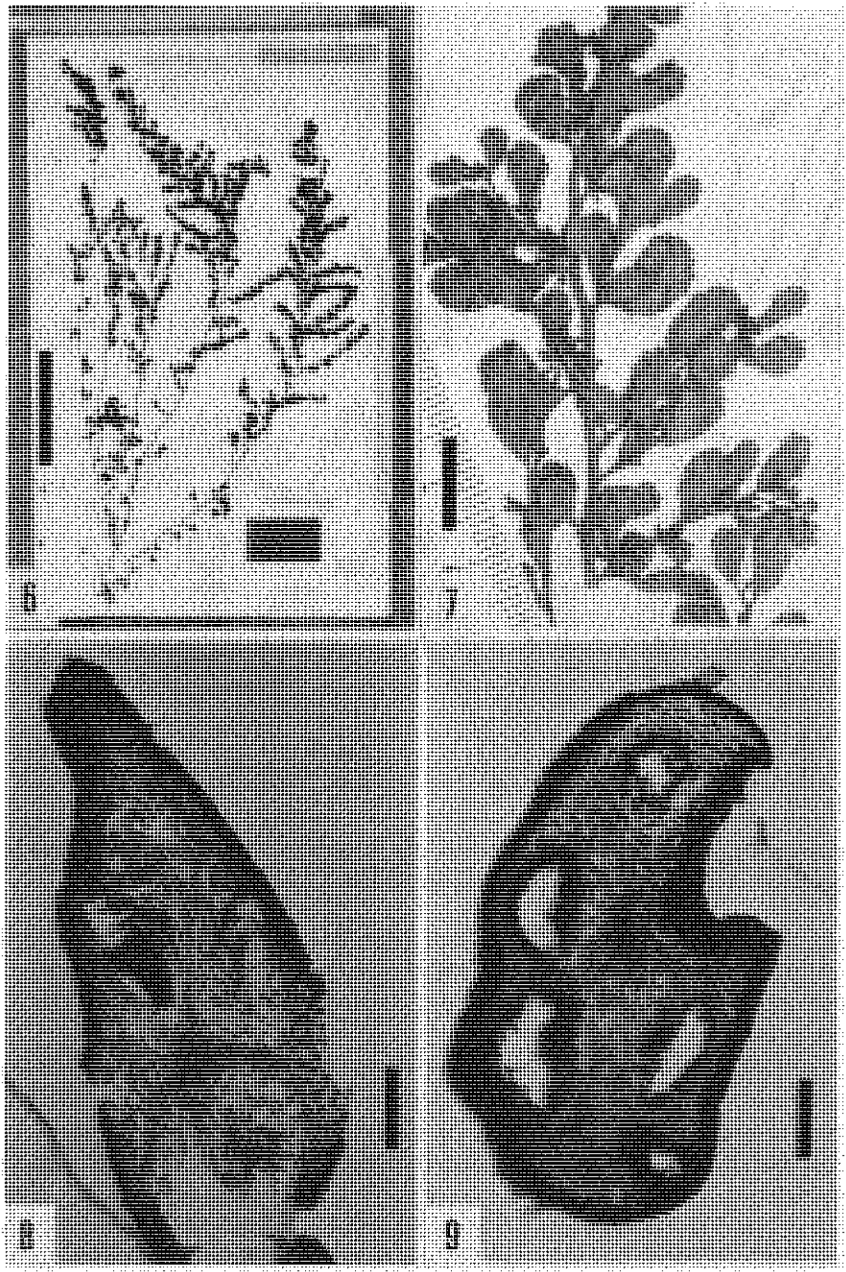


Figs. 4 and 5. Specimen of *Sargassum brevifolium* sensu Yendo (SAP 021249). Scale bars = 10 cm (Fig. 4) and 1 cm (Fig. 5).

After examining many specimens of *S. duplicatum* Bory collected around Japan, China, and the Philippines, we concluded that the morphological characters are suitable, and they are included in the following description (Figs.1c–1e and 11a–11t).

Holdfasts scutellate with many fibrous outgrowths. Main branches terete to slightly compressed, each up to 2.5 mm in diameter. Leaves coarse, variable in shape, spatulate, some cup-shaped or oblong-lanceolate, elongated elliptical to linear lanceolate, base cuneate, apex obtuse, sometimes concave, margins dentate, midrib immersed, vanishing below the middle part of the leaves, with conspicuous cryptostomata. Vesicles spherical to ellipsoid, round at apices, usually with earlike wings on both sides, stalks terete to foliaceous, shorter than vesicles.

Plant dioecious. Female receptacles flattened to triquetrous at distal part, with spines, male receptacles longer than female receptacles, terete, without spines or flattened/triquetrous with spines. Both sometimes divided, racemosely arranged.



Figs. 6–9. Type specimen of *Sargassum sandei* Reinbold deposited in Leiden herbarium. Fig. 6, Holotype specimen (L942.246-215). Fig. 7, Branchlet of isotype specimen (L937.109-19). Figs. 8 and 9, Cross sections of female (Fig. 8) and male (Fig. 9) receptacles. Scale bars = 10 cm (Fig. 6), 1 cm (Fig. 7), and 100 µm (Figs. 8 and 9).

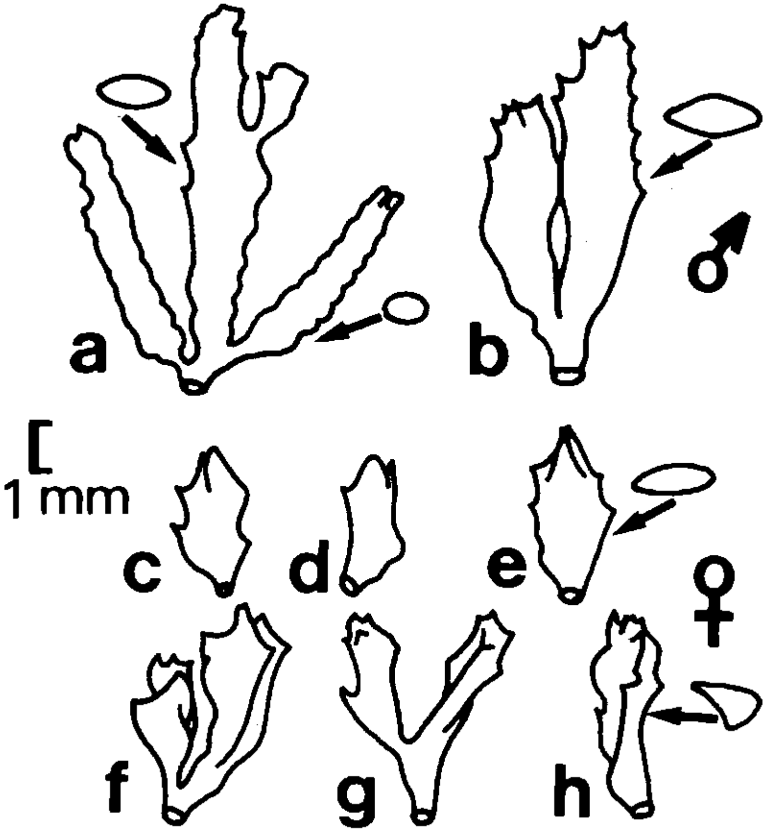


Fig. 10. Receptacles of isotype specimens of *Sargassum sandei* Reinbold. a and b, Male receptacles. c–h, Female receptacles. Scale bar = 1 mm.

Sargassum turbinatifolium Tseng et Lu, Stud. Mar. Sin. 15, p. 9, fig. 6, pl. 7, 1979.

Material brought to the workshop from China was compared with material from the Philippines identified by Trono (1992, p. 66, figs. 42, 45, and 119) as *S. turbinarioides* Grunow (1915).

A search for the type specimen of *S. turbinariodes* Grunow in Vienna (W) was unsuccessful. As the original description (Grunow 1915, p. 395) does not clearly describe the material at hand, we choose to use the name *S. turbinatifolium* Tseng et Lu (1979). Because of the loss of the type specimen of *S. turbinariodes,* we believe that the continued use of that name (Pham 1967, p. 304, fig. 19; and Trono 1992, p. 55, figs. 42–45) does not contribute to a stable taxonomy. We can never know what the plant Grunow had looked like. We believe *S. turbinariodes* Grunow is a *nomen ambiguum* and should be abandoned.

The description by Tseng and Lu (1979) is full and complete and, in terms of this discussion, the species is shown to have small cup-shaped leaf margins and androgynous receptacles.

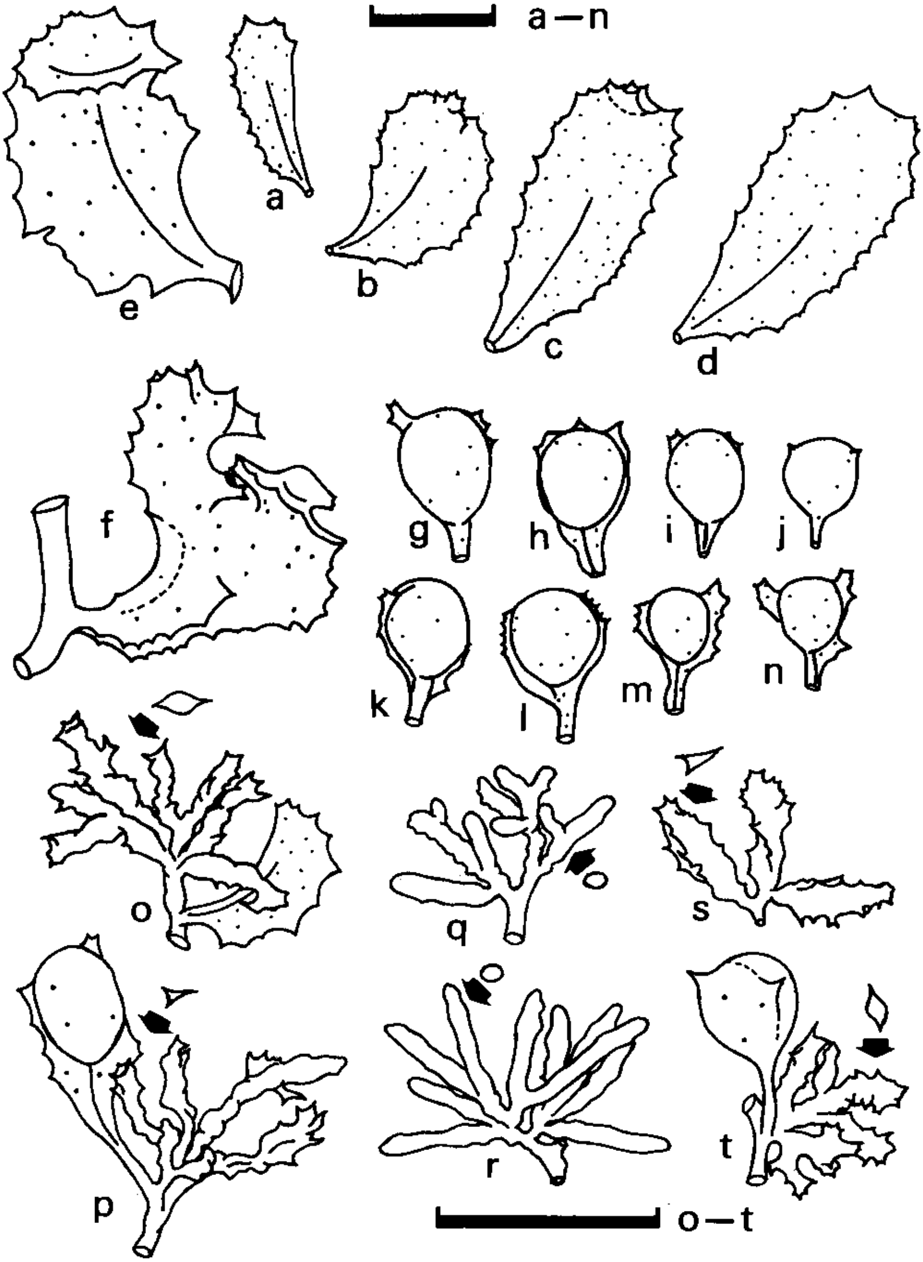


Fig. 11. Variations in morphological characters of *Sargassum duplicatum* Bory from one population, Kushimoto, Japan. a–d, Leaves of secondary branch. e and f, Leaves of primary branch. g–n, Vesicles. o and p, Flattened or triquetrous male receptacles with spines. q and r, Terete male receptacles without spines. s and t, Flattened or triquetrous female receptacles with spines. Arrows indicate the shapes of cross sections of receptacles. Scale bars = 1 cm.

Sargassum crassifolium J. Agardh, Sp. gen. ordines algarum, vol. 1, p. 326, 1848.

Synonym: *Sargassum feldmannii* Pham, Ann. Fac. Sci. Saigon, p. 297, fig. 15, 1969.

Missapplied name: *Sargassum cristaefolium* sensu U Soe-Htun et T. Yoshida, Jpn. J. Phycol. 34, p. 275, figs. 1–4, 1986; Yoshida 1988 In: Tax. Econ. Seaweeds 2, pp.12–14, fig. 8.

The synonymizing of *S. feldmannii* Pham with *S. crassifolium* is due to the examination of type material by Nang and Dinh (personal communication). Their study showed a monoecious species with androgynous receptacles, with vesicles having a tendency to become leaflike (phyllocystous), characteristics of *S. crassifolium.* The material studied by U Soe-Htun and Yoshida (1986) also had these features. Morphological characters of this species from Asian area were as follows (Figs. 1a and b, 12a–12r):

Holdfast discoid. Main branches terete to slightly compressed, each up to 2–3 mm in diameter. Leaves coarse, elongated elliptical, base cuneate, apex obtuse, margin dentate with two rows of serration at the apex, midrib immersed, vanishing near the middle or upper part of the leaves, conspicuous cryptostomata disposed. Vesicles spherical to ellipsoid, usually provided with foliose wings, sometimes phyllocyst, stalk foliaceous, shorter or longer or equal to the vesicle.

Plant monoecious. Receptacles cylindrical to slightly compressed with small spines, divided to make dense racemose clusters.

Sargassum cristaefolium J. Agardh, Species algarum, p. 13, 1820.

Holotype: In LD herbarium Agardh.

Remarks: Like *S. crassifolium, S. cristaefolium* has two rows of serrated leaves. However, the latter species is dioecious.

Acknowledgments

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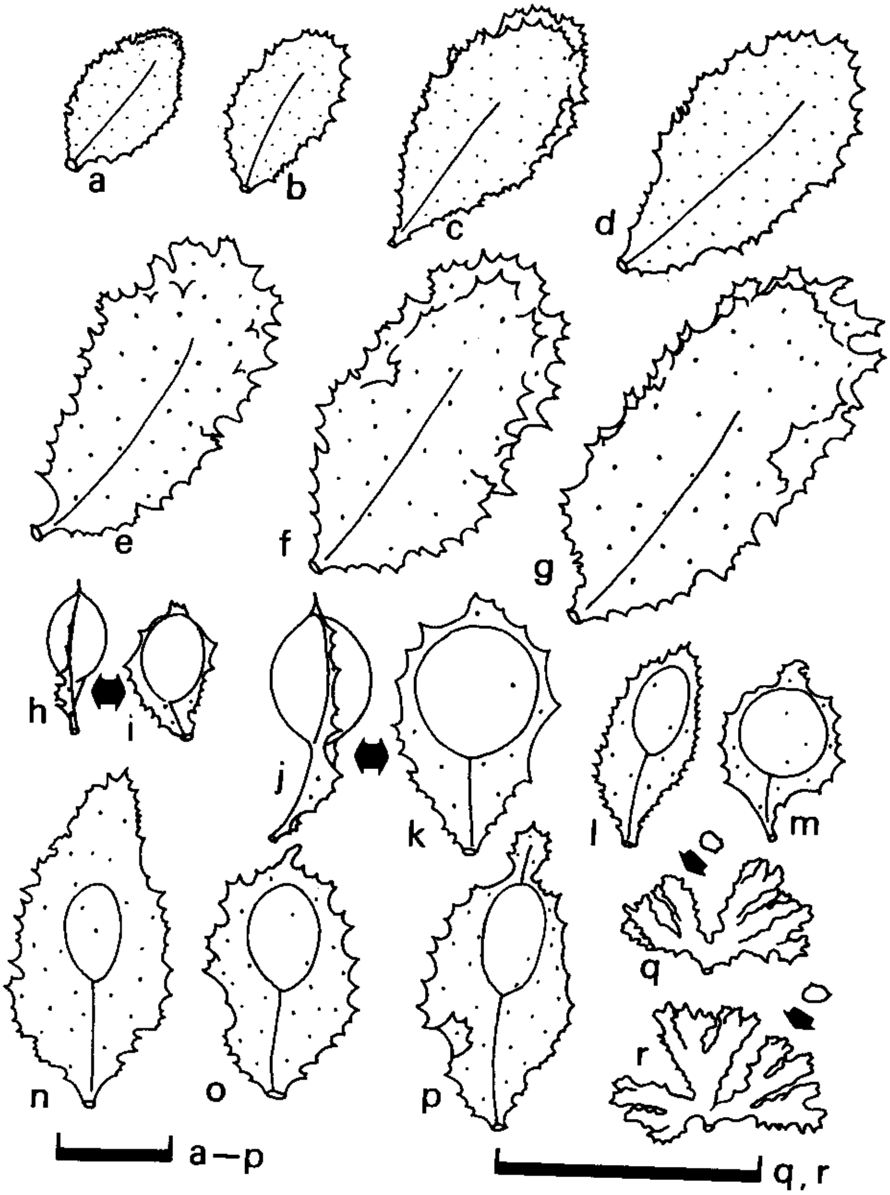


Fig. 12. Variations in morphological characters of *Sargassum crassifolium* J. Agardh from one population, Zampa Peninsula, Okinawa, Japan. a–d, Leaves of secondary branch. e–g, Leaves of primary branch. h–p, Vesicles. q and r, Cylindrical, clustered, androgynous recepatcles with spines. Arrows indicate the shapes of cross sections of receptacles. Scale Scale bars = 1 cm.

U Soe-Htun and Yoshida, T. 1986. Studies on morphological variations in *Sargassum cristaefolium* C. Agardh (Phaeophyta, Fucales). Jpn. J. Phycol. 34:275–281.

Womersley, H. B. S., and Bailey, A. 1970. Marine algae of the Solomon Islands. Phil. Trans. R. Soc. London B. Biol. Sci. 259:257–335.

SARGASSUM HEMIPHYLLUM (TURNER) C. AGARDH VAR. *CHINENSE* J. AGARDH FROM VIETNAM, THE CHINESE MAINLAND, AND TAIWAN

Tetsuro Ajisaka, Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Young-Meng Chiang, and Tadao Yoshida

Abstract

Morphological characters in the specimens of *Sargassum hemiphyllum* (Turner) C. Agardh var. *chinense* J. Agardh recently collected from Vietnam, the Chinese mainland, Hong Kong, and Taiwan were studied. These specimens have very large leaves and vesicles throughout their growth phases, including the juvenile stages, and very well developed, dividing receptacles when mature. It is easy to distinguish this variety from Japanese *S. hemiphyllum* on the basis of these morphological characters in younger plants, but difficult in older plants because most large leaves are lost at maturity and plants from all localities come to resemble each other.

Introduction

Sargassum hemiphyllum (Turner) C. Agardh is a member of the subgenus *Bactrophycus*. Its distribution is from southern Japan to mainland China, Hong Kong, Taiwan, and northern and central Vietnam. It was first described as a new species by Turner (1811) as *Fucus hemiphyllus*, collected by Dr. Horner at Nagasaki Port. This type specimen was characterized by its linear and cuneiform leaves with truncated apex (hemiphyllous), which Turner described as appearing torn. However, this holotype specimen was immature and sterile. C. Agardh (1820) transferred the species from *Fucus* to *Sargassum*. Later J. Agardh (1889) recognized *S. hemiphyllum* var. *micromerum* J. Agardh and *S. hemiphyllum* var. *chinense* J. Agardh, the first from Cape Nomo, near Nagasaki on the west coast of Kyushu, and the second from Macao and Hong Kong. In 1896, J. Agardh raised these two varieties to species rank as *S. micromerum* (J. Agardh) J. Agardh and *S. chinense* (J. Agardh) J. Agardh. Yendo (1907) studied the three species and concluded that *S. hemiphyllum* contained all the variations claimed by J. Agardh (1896) for the three species.

Nevertheless, Grunow (1915) reported *S. hemiphyllum* var. *anisophylla* Grunow from Hong Kong and f. *edentata* Grunow from the eastern shores of Japan. Setchell (1933) reported *S. hemiphyllum* var. *chinense* J. Agardh from Hong Kong and regarded it as a gigantic mutant or hypertrophy of *S. hemiphyllum*. Pham (1967) described *S. hemiphyllum* f. *serratum* Pham from Nha Trang, central Vietnam.

Yoshida (1983, 1985) studied Japanese *S. hemiphyllum*. He examined the type specimen of *S. micromerum* J. Agardh and concluded that there was no need to distinguish it from Japanese *S. hemiphyllum*. He also reported that "Grunow's two taxa (variety *anisophylla* and forma *edentata*) were both based on too fragmentary specimens to give enough idea as for the identity."

To test the characteristics used for evaluating the taxonomy of *S. hemiphyllum*, we studied morphological characters of the specimens of *S. hemiphyllum* var. *chinense* recently collected from Vietnam, the Chinese mainland, Hong Kong, and Taiwan and compared them with the morphological characters of Japanese *S. hemiphyllum* (Fig. 1).

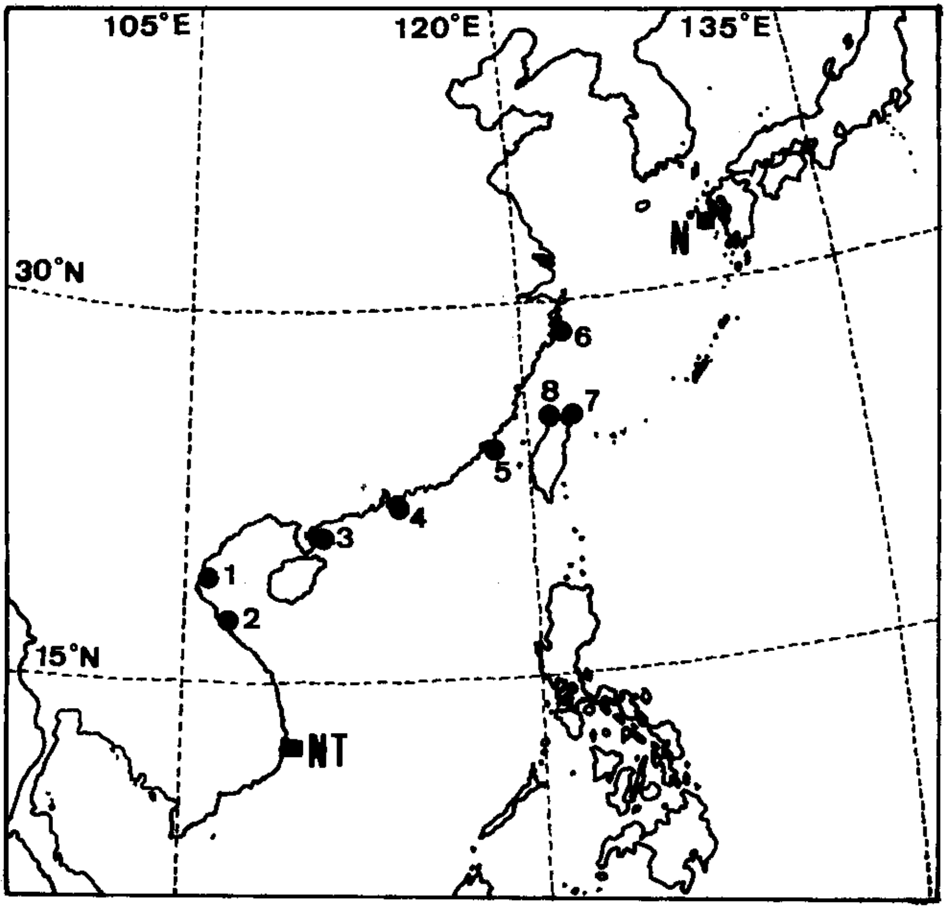


Fig. 1. Localities (1–8) for *Sargassum hemiphyllum* var. *chinense* J. Agardh. Nagasaki (N) is the type locality of *S. hemiphyllum* (Turner) J. Agardh. Pham (1967) collected this species from Nha Trang (NT) in Vietnam.

Materials and Methods

Collecting data are listed in Table 1. Morphological characters of these materials were observed in detail. Receptacles were cross-sectioned to identify the sexes. Setchell's specimens from Hong Kong deposited in SAP were also examined.

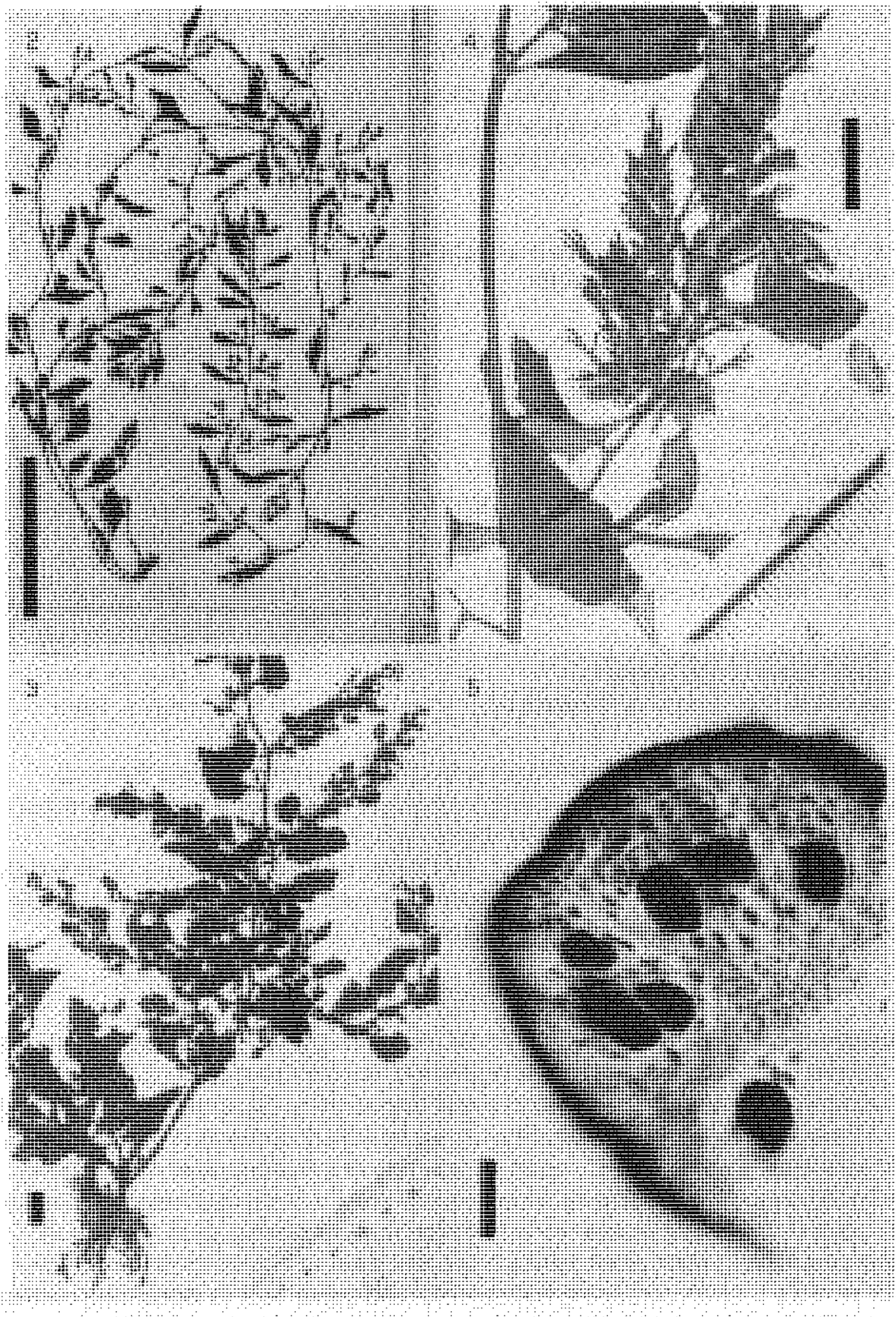
Table 1. Localities on Map in Figure 1 and Collection Date of *Sargassum hemiphyllum* var. *chinense* J. Agardh

Locality (Specimen No.)	Map No.	Collection Date
Vietnam		
Nighi Son, Thang Hoa Province (8 sheets)	1	March 5, 1994
Nighi Son, Thang Hoa Province (4 sheets)	1	May 23, 1994
Thoson, Quang Bin Province (1 sheet)	2	April 1, 1964
Chinese mainland (include Hong Kong)		
Naozhoudao, Guangdong Province (AST871084)	3	April 16, 1987
Stanley Bay, Hong Kong (AST-1367)	4	April 14, 1941
Lishidao, Fujian Province (AST54-2508)	5	May 6, 1954
Zanjidao, Zhejian Province (AST871599)	6	May 27,1987
Taiwan		
Patoutzu, Keelung City (4347)	7	April 21, 1992
Patoutzu, Keelung City (3859)	7	May 23, 1991
Yungauchiao, Penghu (4348, 2 individuals)	8	May 6, 1993

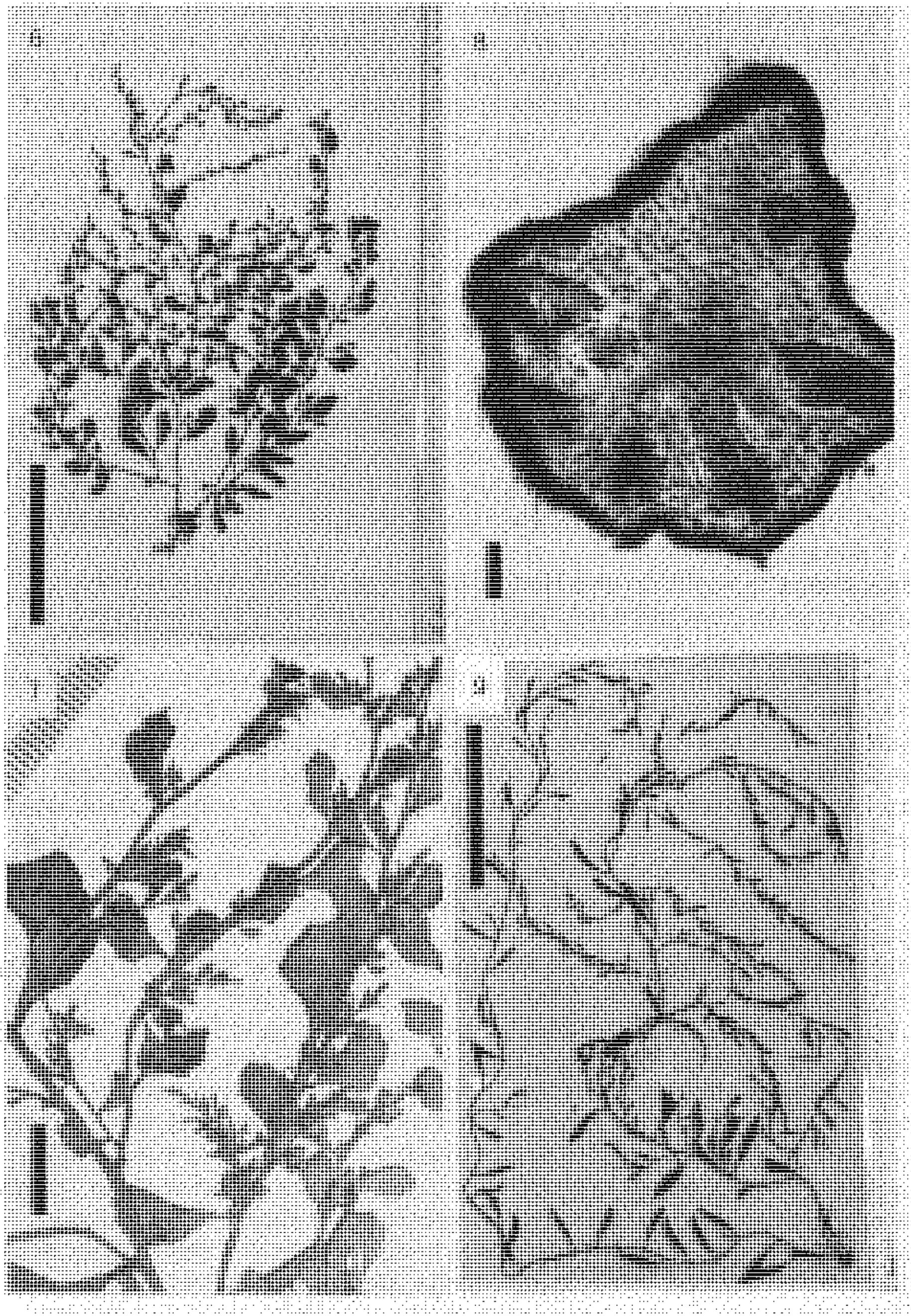
Specimens from Thang Hon Province in Vietnam were collected by H. Q. Nang, N. H. Dinh, and T. Ajisaka during a scientific survey of central to northern Vietnam in February and March, 1994. Other specimens from Vietnam were collected by H. Q. Nang and N. H. Dinh. All Chinese specimens were collected by Lu Baoren, and Taiwanese specimens were collected by H. N. Yang, a graduate student of Dr. Chiang at the National University of Taiwan.

Results

Specimens from Vietnam (Figs. 2–9). Holdfast fibrous, of variable diameter up to 0.5 cm, branched irregularly several times, each branch up to 2.7 cm long, functioning as secondary holdfast with small laterals (Fig. 3). Primary branches up to 45–70 cm long in juvenile plants (Fig. 2), up to 20–25 cm long in mature plants from Thang Hoa (Figs. 3 and 6), up to 40 cm long in a mature plant from Quang Binh (Fig. 9), cylindrical to slightly compressed, up to 3.5 mm diameter in juvenile plants, up to 2.3 mm in diameter in Thang Hoa mature plants, up to 1.5 mm in diameter in a Quang Binh plant, without spines. Several leaves formed near the base of primary branch spreading horizontally and upper leaves becoming vertical. Leaves at the basal part of primary branches oblanceolate to hemiphyllous, up to



Figs. 2–9. *Sargassum hemiphyllum* var. *chinense* J. Agardh from Vietnam. Fig. 2, Juvenile plant from Thang Hoa Province. Figs. 3–5, Female plant from Thang Hoa Province. Fig. 4, Female receptacles. Fig. 5, Cross section of female receptacle.



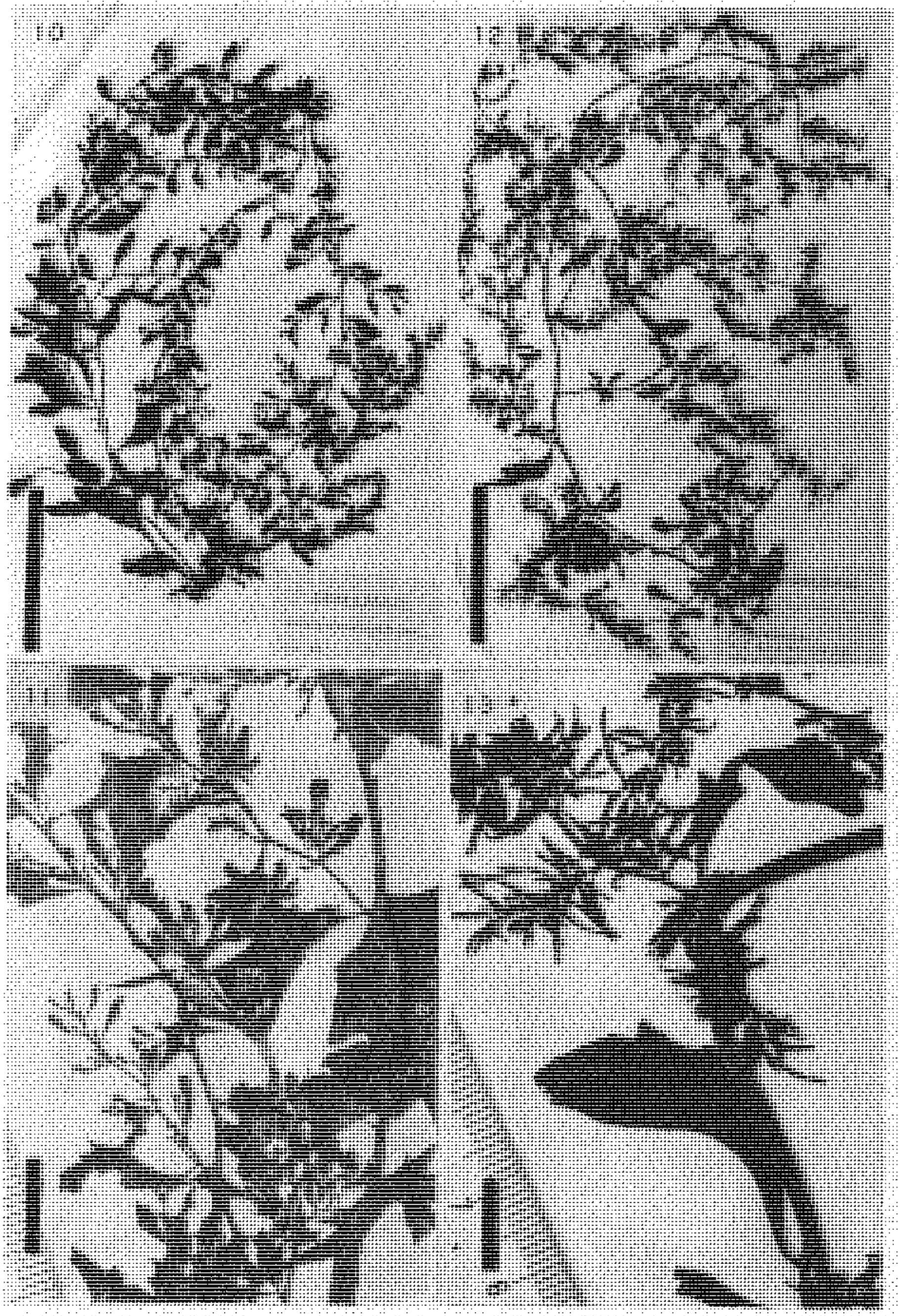
Figs. 6–8, Male plant from Thang Hoa Province. Fig. 7, Male receptacles. Fig. 8, Cross section of male receptacle. Fig. 9, Female plant from Quang Binh Province. Scale bars = 10 cm (Figs. 2, 6, and 9), 1 cm (Figs. 3, 4, and 7), and 100 μm (Figs. 5 and 8).

4.8 cm long, up to 19 mm wide in juvenile plants, up to 2.3 cm long, up to 12 mm wide in Thang Hoa mature plants, and up to 4.2 cm long, up to 9 mm wide in a Quang Binh plant. Leaves at the upper part of primary branches and basal part of secondary branches long oblanceolate to long elliptic, up to 30 mm long, up to 11 mm wide in juvenile plants, up to 17 mm long, up to 7 mm wide in Thang Hoa mature plants, up to 25 mm long, up to 5 mm wide in a Quang Binh plant. Leaves at the upper part of secondary branches linear, up to 4 mm long, up to 2 mm wide in juvenile plants, up to 5 mm long, up to 1 mm wide in Thang Hoa mature plants, and up to 11 mm long, up to 1 mm wide in a Quang Binh plant. Base of leaves cuneate and asymmetrical, apex round or acute, margin entire to coarsely dentate, midrib evanescent or absent, cryptostomata obscure and scattered. Vesicles spherical, obovate, elliptical or fusiform, up to 2.5–5.0 mm long, up to 1.5–5.0 mm in diameter, entire or apiculate at apex; stipe terete, shorter than the vesicles.

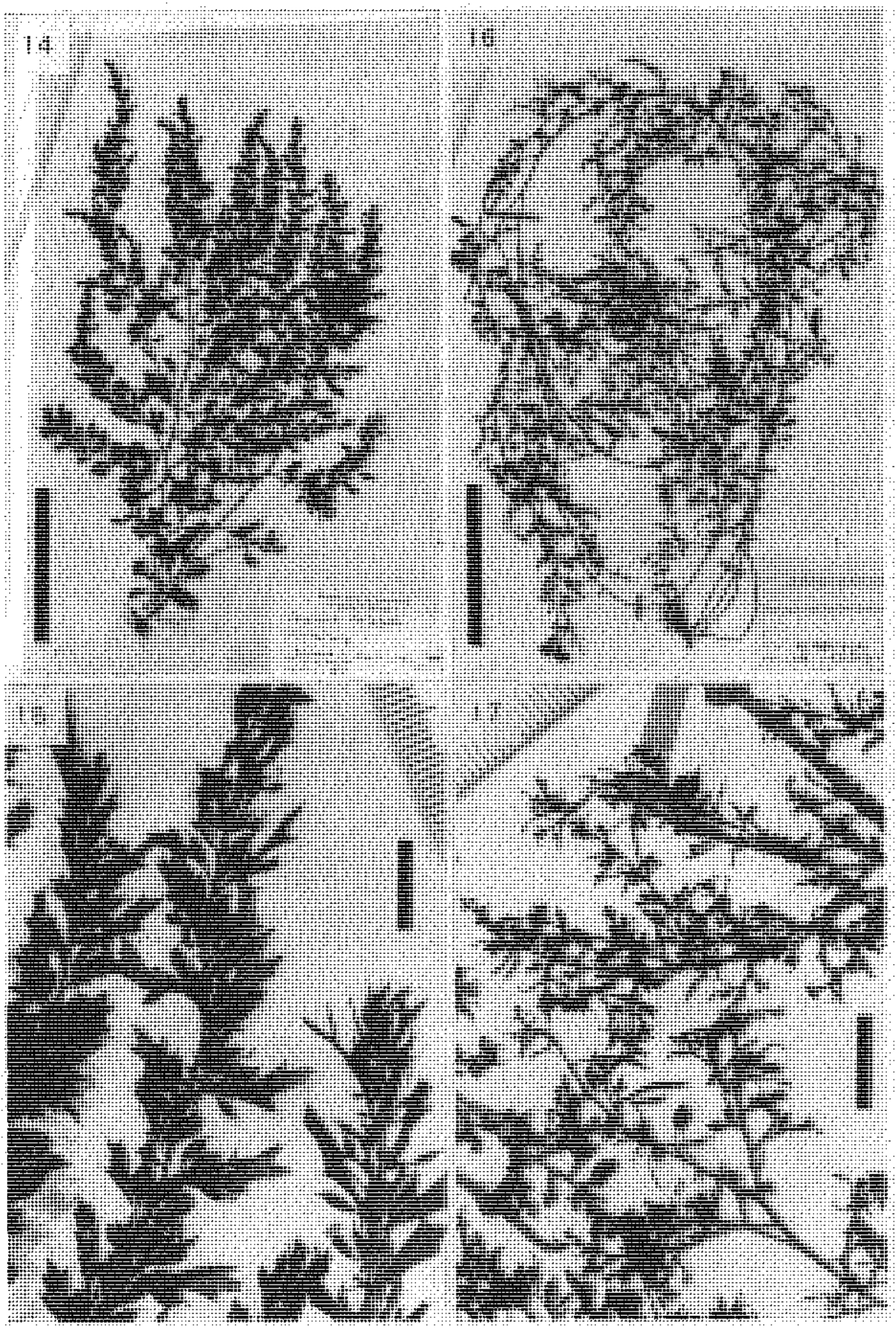
Plants dioecious. Female receptacles terete or fusiform, up to 5–10 mm long, usually divided two to three times, racemosely arranged in Thang Hoa (Figs. 4 and 5) and Quang Binh plants. Male receptacles terete, up to 5–10 mm long, usually divided two to three times, racemosely arranged in Thang Hoa plants (Figs. 7 and 8).

Specimens from China and Hong Kong (Figs. 10–17). Holdfast fibrous, branched irregularly several times, each branch up to 3 cm long, functioning as secondary holdfast issuing small laterals. Primary branches up to 100 cm long in Zhejiang plant (Fig. 16), 30–50 cm long in plants from other localities (Figs.10, 13, and 14), cylindrical to slightly compressed, up to 2.0 mm in diameter or compressed, up to 3.0 mm wide, without spines. Several leaves formed near the base of primary branch spreading horizontally and upper leaves becoming vertical. Leaves at the basal part of primary branches oblanceolate to hemiphyllous, up to 5.4 cm long, up to 17 mm wide in Guangdong plant (AST871084, Fig. 10), up to 5.0 cm long, up to 12 mm wide in Fujian plant (AST54-2508, Fig. 12), up to 2.2 cm long, up to 12 mm wide in Hong Kong plant (AST1367, Fig. 14), and already dropped in Zhejiang plant (AST871599, Fig. 16). Leaves at the upper part of primary branches and basal part of secondary branches long oblanceolate to long elliptic, up to 22 mm long, up to 7 mm wide in Guangdong plant, up to 18 mm long, up to 4 mm wide in Fujian plant, up to 18 mm long, up to 8 mm wide in Hong Kong plant, and up to 23 mm long, up to 6 mm in Zhejian plant. Leaves at the upper part of secondary branches, up to 6 mm long, up to 1.5 mm wide in Guangdong plant, up to 8 mm long, up to 1 mm wide in Fujian plant, up to 10 mm long, up to 2 mm wide in Hong Kong plant, up to 6 mm long, up to 1 mm wide in Zhejian plant. Base of leaves cuneate, asymmetrical, apex round or acute, margin variable, entire to coarse dentate, midrib evanescent or absent, cryptostomata obscure and scattered. Vesicles ellipsoid to fusiform, up to 4–7 mm long, up to 3–5 wide, entire or apiculate at apex; stipe terete, shorter than the vesicles.

Plants dioecious. Female receptacles terete or fusiform, up to 3–4 mm long, usually divided two to three times, racemosely arranged in Hong Kong plant (Fig. 15) and Zhejian plant (Fig. 17). Male receptacles terete, up to 7–10 mm long,



Figs. 10–17. *Sargassum hemiphyllum* var. *chinense* J. Agardh from China. Figs. 10 and 11, Male plant (AST871084) from Guangdong Province. Figs. 12 and 13, Male plant (AST54-2508) from Fujian Province.



Figs. 14 and 15, Female plant (AST-1367) from Hong Kong. Figs. 16 and 17, Female plant (AST871599) from Zhejian Province. Scale bars = 10 cm (Figs. 10, 12, 14, and 16), and 1 cm (Figs. 11, 13, 15, and 17).

usually divided two to three times, racemosely arranged in Guangdong plant (Fig. 11) and Fujian plant (Fig. 13).

Specimens from Taiwan (Figs. 18–23). Holdfast fibrous, branched irregularly several times, each branch up to 2.1–3.7 cm long, functioning as secondary holdfast issuing small laterals. Primary branches up to 14–35 cm long, cylindrical to slightly compressed, up to 1.5–1.8 mm wide, without spines. Several leaves formed near the base of primary branch spreading horizontally and upper leaves becoming vertical. Leaves at the basal part of primary branches oblanceolate to hemiphyllous, up to 1.7 cm long, up to 7 mm wide in Keelung male plant (4347, Fig. 18), up to 4.3 cm long, up to 13 mm wide in Keelung female plant (3859, Fig. 20), and dropped in Yungauchiao plants (4348, Fig. 22). Leaves at the upper part of primary branches and basal part of secondary branches long-lanceolate to linear, up to 12 mm long, up to 3 mm wide in Keelung male plant (4347), up to 12 mm long, up to 5 mm wide in Keelung female plant (3859), and up to 14 mm long, up to 7 mm wide in Yungauchiao plants. Leaves at the upper part of secondary branches linear, up to 5 mm long, up to 1 mm wide in Keelung male plant (4347), up to 5 mm long, up to 1 mm wide in Keelung female plant (3859), and up to 6 mm long, up to 1 mm wide in Yungauchiao plants. Base of leaves cuneate, asymmetrical, apex round or acute, margin entire to coarse dentate, midrib evanescent or absent, cryptostomata obscure and scattered. Vesicles elliptical to fusiform, up to 3.5–5.0 mm long, up to 2.5 mm wide, entire or apiculate at apex; stipe terete, shorter than the vesicles.

Plants dioecious. Female receptacles terete or fusiform, up to 5 mm long, usually divided two to three times, racemosely arranged in Keelung plant (3859, Fig. 21) and Yungauchiao plant (Fig. 23). Male receptacles terete, up to 7 mm long, usually divided two to three times, racemosely arranged in Keelung plant (4347, Fig. 19).

Discussion

Specimens of *S. hemiphyllum* var. *chinense* collected from all localities had horizontal leaves near the base of primary branches and vertical leaves on the upper part of the frond, just as those observed in Japanese specimens. Yoshida (1983) used the terms "horizontal" and "vertical" to express the leaf orientation. Horizontally expanded leaves are those expanding at right angles to the branch on which they are borne, at least at the leaf base (Fig. 24a). When the leaves go downward, we use the term "retroflexed." Vertically expanded leaves are those expanding in the same plane of the branch on which they are borne (Fig. 24b).

The morphological characters observed in the specimens collected from Vietnam, the Chinese mainland, Hong Kong, Taiwan, and Japan are shown in Table 2. Creeping fibrous holdfasts, markedly hemiphyllous leaves, vesicles and terete receptacles were similar in plants from all localities. However, leaves of giant dimensions, up to about 5 cm long at the basal part of primary branches,

Figs. 18–23. *Sargassum hemiphyllum* var. *chinense* J. Agardh from Taiwan. Figs. 18 and 19, Male plant (4347) from Keelung. Figs. 20 and 21, Female plant (3859) from Keelung.

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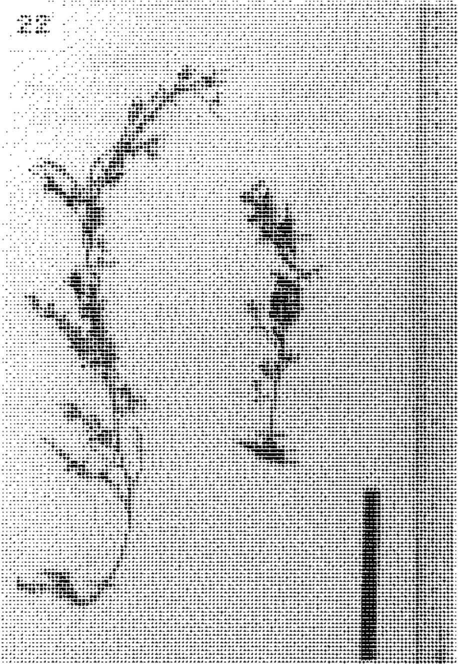

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Fig. 22, Female (left) and male (right) plants (4348) from Yungauchiao. Fig. 23, Female plant (4348) from Yungauchiao. Scale bars = 5 cm (Fig. 18), 10 cm (Figs. 20 and 22), and 1 cm (Figs. 19, 21, and 23).

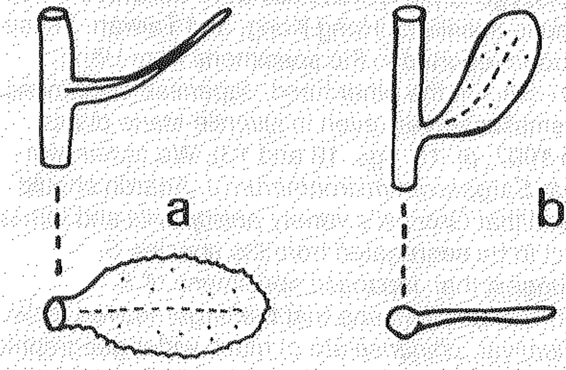

Fig. 24. Leaf orientation to the primary branch. a, Horizontally expanded leaf. b, Vertically expanded leaf.

Table 2. A Comparative Study of Morphological Characters in *S. hemiphyllum* J. Agardh from Vietnam, China, Taiwan, and Japan

Character	Vietnam var. *chinense*	China var. *chinense*	Taiwan var. *chinese*	Japan *S. hemiphyllum* (Yoshida 1983)
Primary branch				
Length (cm)	70	100	30	>100
Diameter (mm)	2.3	3.0	1.8	2.0
Leaves				
Basal primary leaves				
Length (mm)	42	54	43	15
Width(mm)	12	17	13	7
Basal secondary leaves				
Length (mm)	17	22	14	10*
Width (mm)	7	7	7	5*
Upper secondary leaves				
Length (mm)	4	8	6	6*
Width (mm)	2	1	1	1*
Vesicles				
Length	5	7	5	5
Width	5	5	2.5	1.5
Receptacles				
Female				
Length (mm)	10	4	5	3
Male				
Length (mm)	10	10	7	7

*Measurements were established from Japanese materials (Shirahama, Wakayama Prefecture, Japan).
Except for vesicles, all numbers are maximum values.

and usually divided, sometimes holozygocarpic receptacles were observed in the specimens from Vietnam, the Chinese mainland, Hong Kong, and Taiwan. These holozygocarpic receptacles have been reported in the specimens from Hong Kong (Setchell 1933, pl. 14, figs. 7–10). On the other hand, Japanese specimens were distinguished from these by smaller leaves, even in juvenile-stage plants, and simple receptacles (cf. Yendo 1907, pl. 13, figs. 12 and 13). We agree with Yoshida's (1983, 1985) opinion that *Sargassum micronmerum* J. Agardh should be merged with *S. hemiphyllum*, and that Grunow's variety *anisophylla* and forma *edentata* are not sufficiently distinct to be segregated from the species *S. hemiphyllum*. In this chapter we suggest that Japanese specimens of *S. hemiphyllum* be recognized as var. *hemiphyllum* and that the larger-leaved, taller specimens known as *S. hemiphyllum* var. *chinense* are of much wider geographic distribution. We have described the variations of the second taxon in this chapter.

Trono (1992) reported *S. hemiphyllum* (p. 56, figs. 28–30, and 114) from the Philippines, but this seems to be a misidentification, because his specimens show a discoid holdfast and lack hemiphyllous leaves.

In Japan, we also find plants with two kinds of leaves, whereas rather wide leaves are present in the populations of the Pacific Ocean and narrow filamentous leaves are observed in those from the Japan Sea. These observations require further study on more material from the coasts of Japan.

Acknowledgments

We thank Dr. I. A. Abbott, University of Hawaii, for her kind advice on improving the manuscript.

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SARGASSUM CARPOPHYLLUM J. AGARDH VAR. *NHATRANGENSE* (PHAM) AJISAKA COMB. NOV. AND *S. PILULIFERUM* (TURNER) C. AGARDH VAR. *SERRATIFOLIUM* YAMADA FROM VIETNAM

Tetsuro Ajisaka, Huynh Quang Nang, Nguyen Huu Dinh, and Tadao Yoshida

Abstract

The collaboration of Vietnamese phycologists has made possible the examination of specimens and collecting opportunities previously unavailable to foreigners. Critical examination of morphological features shown by holotype and isotype specimens of *Sargassum piluliferum* var. *nhatrangense* Pham has shown that this variety is misallied in this species. It has been transferred to *S. carpophyllum* as *S. carpophyllum* var. *nhatrangense* (Pham) Ajisaka comb. nov. On the other hand, within *S. piluliferum*, we have discovered *S. piluliferum* var. *serratifolium* Yamada at Hon Nom, Quang Binh Province, Vietnam. This variety is reported for the first time outside Japan.

Introduction

Sargassum piluliferum (Turner) C. Agardh var. *nhatrangense* Pham (1967) has been described from Nha Trang, central Vietnam. It was characterized by alternate-pinnate leaves and divided receptacles (Pham 1967, fig.1). We examined the holotype and isotype specimens deposited in Saigon University. On the basis of the alternate-pinnate leaves and holozygocarpic, androgynous receptacles in these type specimens, we have transferred the type specimens of *S. piluliferum* (Turner) C. Agardh var. *nhatrangense* to *S. carpophyllum* J. Agardh var. *nhatrangense* (Pham) Ajisaka comb. nov.

On the other hand, we collected *S. piluliferum* var. *serratifolium* Yamada (1942, 1944) from Hon Nom, Quang Binh Province for the first time from Vietnam.

We studied the morphological characters of these two species in detail.

Materials and Methods

Holotype and isotype specimens of *S. piluliferum* var. *nhatrangense* Pham deposited in Saigon University were examined. Specimens *of S. carpophyllum* collected from other localities in Vietnam (Fig. 1) were also studied. Receptacles of these specimens were cross-sectioned, and the sex was determined. We collected *S. piluliferum* from Hon Nom, Quang Dong Province (Fig. 1). Specimens of *S. carpophyllum* from Quang Ninh Province were collected by H. Q. Nang, N. H. Dinh, and T. Ajisaka during a scientific survey of central to northern Vietnam in February, and March, 1994. Other specimens *of S. carpophyllum* and *S. piluliferum* were collected by H. Q. Nang and N. H. Dinh.

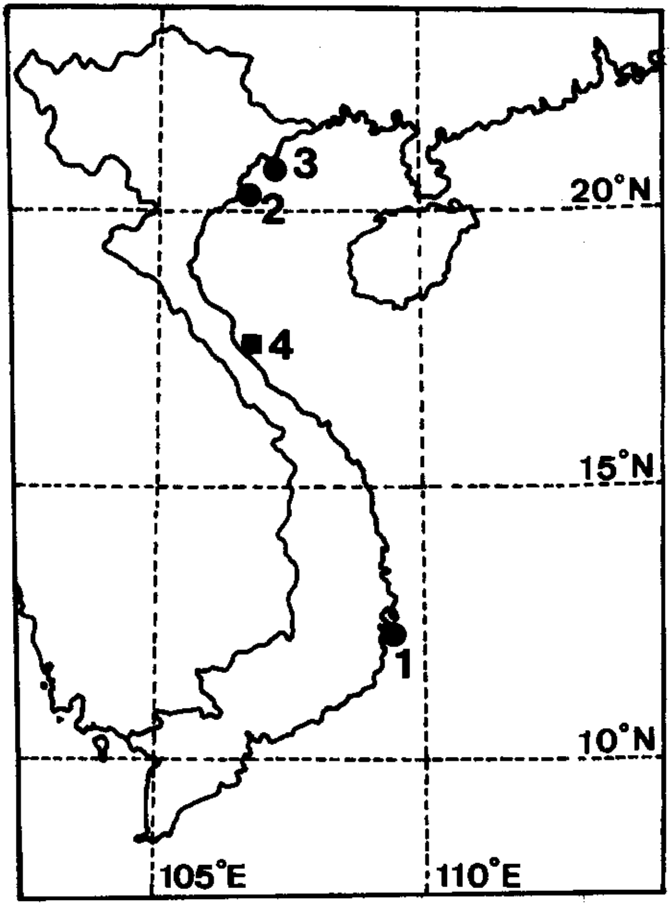
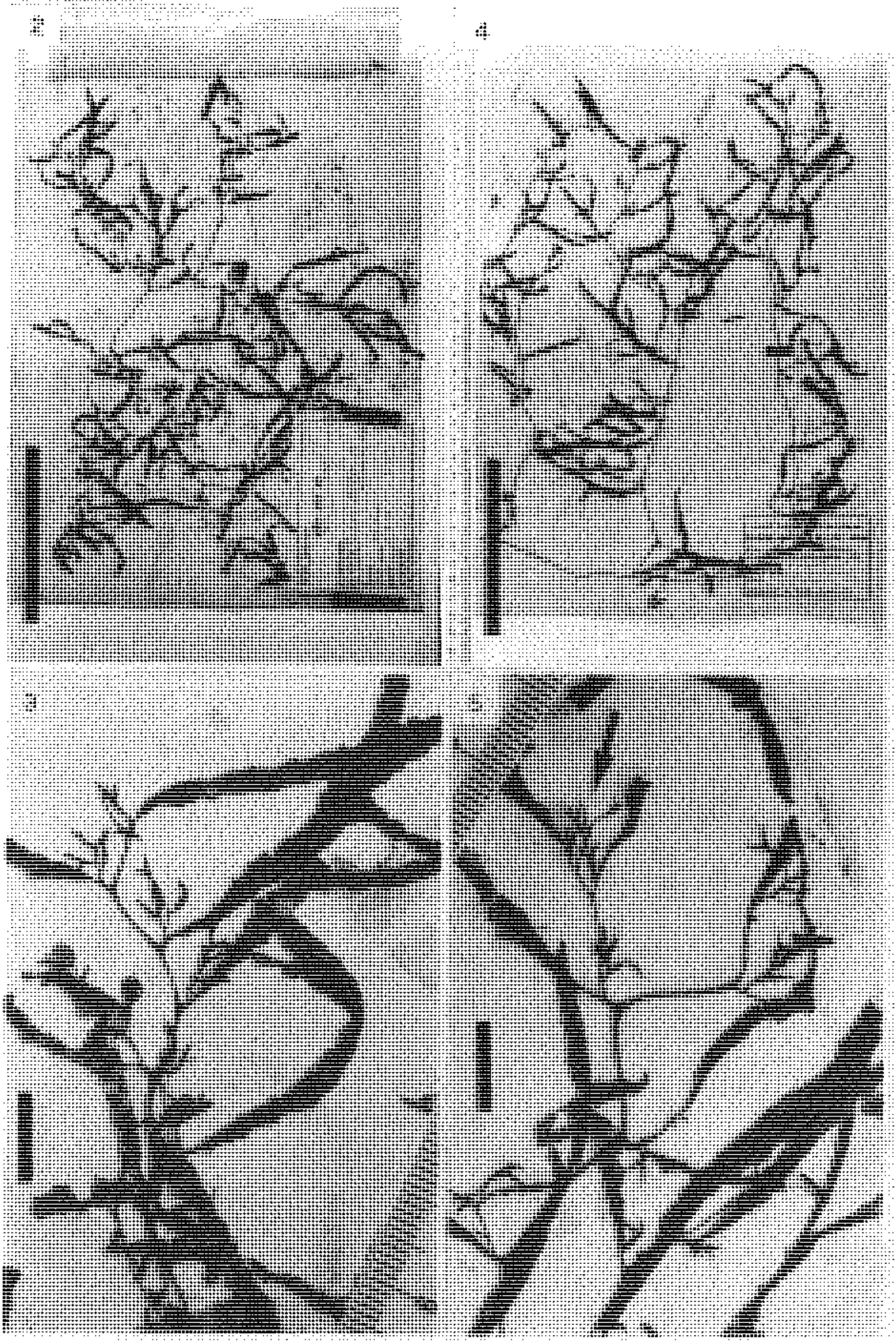


Fig. 1. Map of collection sites in Vietnam, 1: Nha Trang; 2, Do-Son, Hai Phong; 3, Ganh Cao, Tien Yen Bay, Quang Ninh Province; 4, Hon Nom, Quang Binh Province.

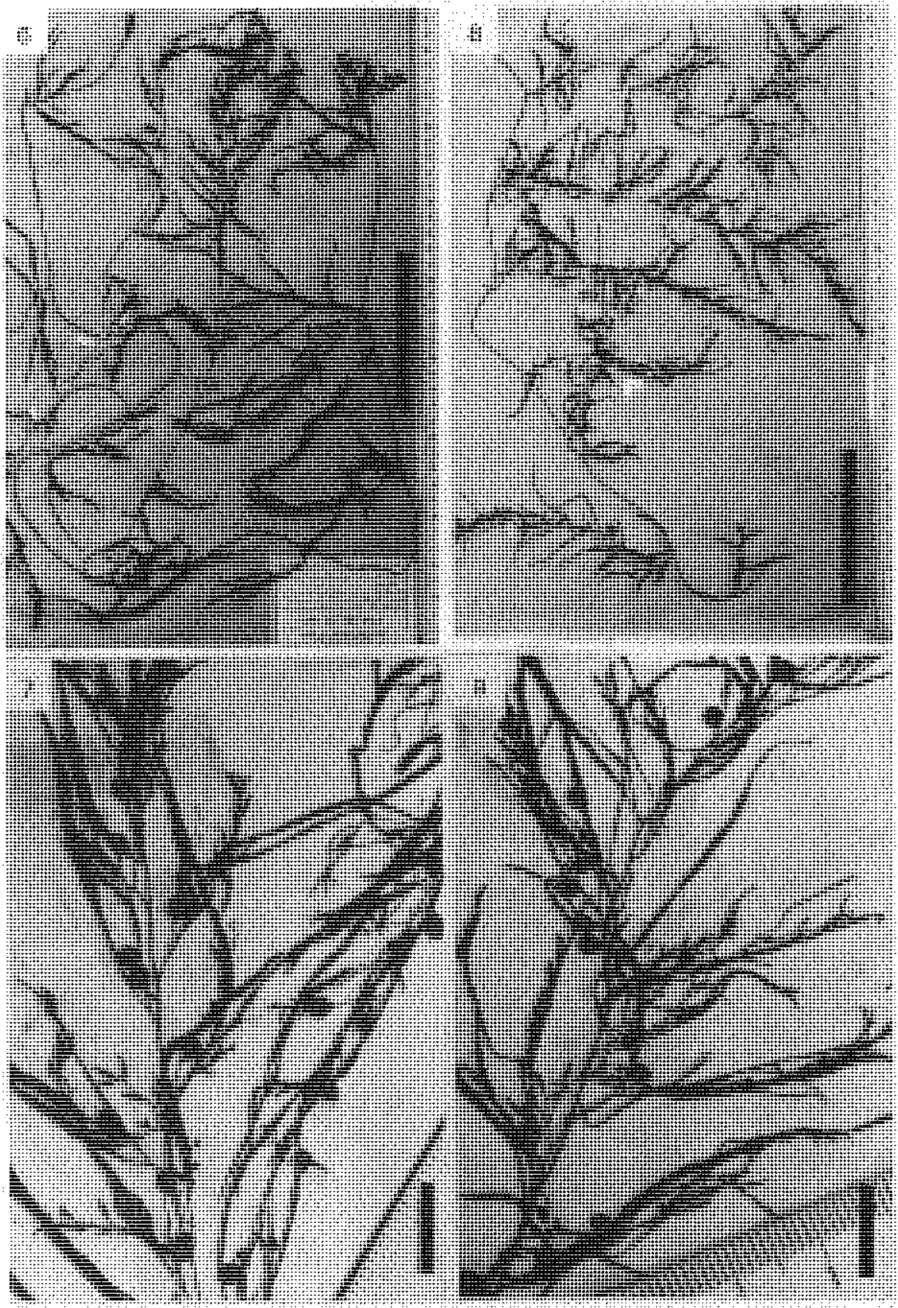
Results and Discussion

Holotype and Isotype Specimens of *Sargassum piluliferum* var. *nhatrangense* Pham (Figs. 2–5, and 14)

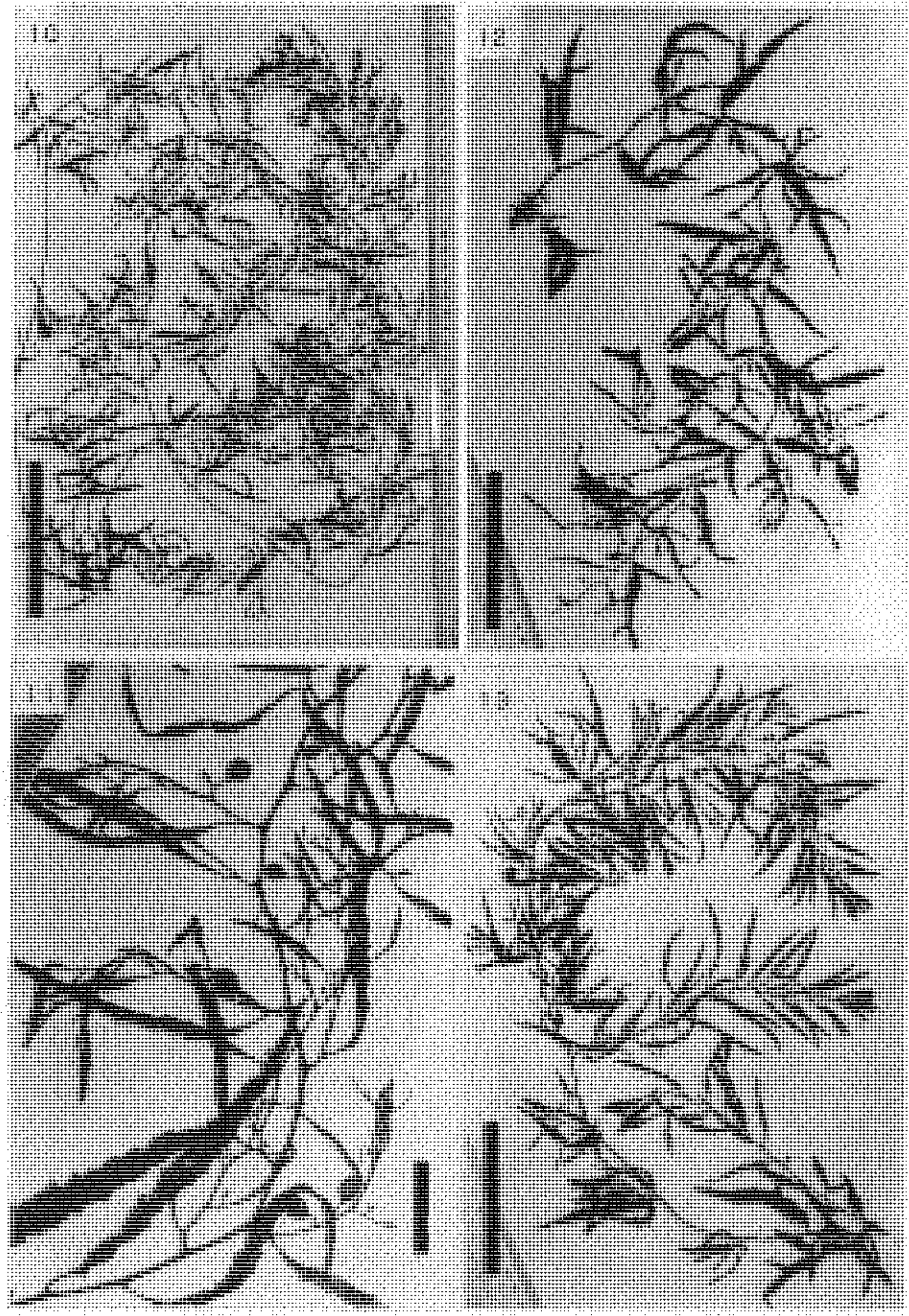
Holdfast and stem lacking, both specimens apparently part of a single primary branch. Primary branches 20–30 cm long, cylindrical, up to 1 mm in diameter, without spines. Secondary branches up to 12 cm long, spirally arranged at intervals of 3–4 cm. Leaves on primary branches thin, furcate three to four times, each lobe lanceolate or linear-lanceolate, up to 8.0 cm long, up to 7 mm wide, leaves on secondary branches simple to furcate one to two times, up to 6.0 cm long, up to 5 mm wide, base asymmetrical, apex acute, margin dentate, midrib distinct and percurrent, cryptostomata scattered. Vesicles spherical, up to 5 mm in diameter, round at apices; stipe terete, longer or equal to the vesicles.



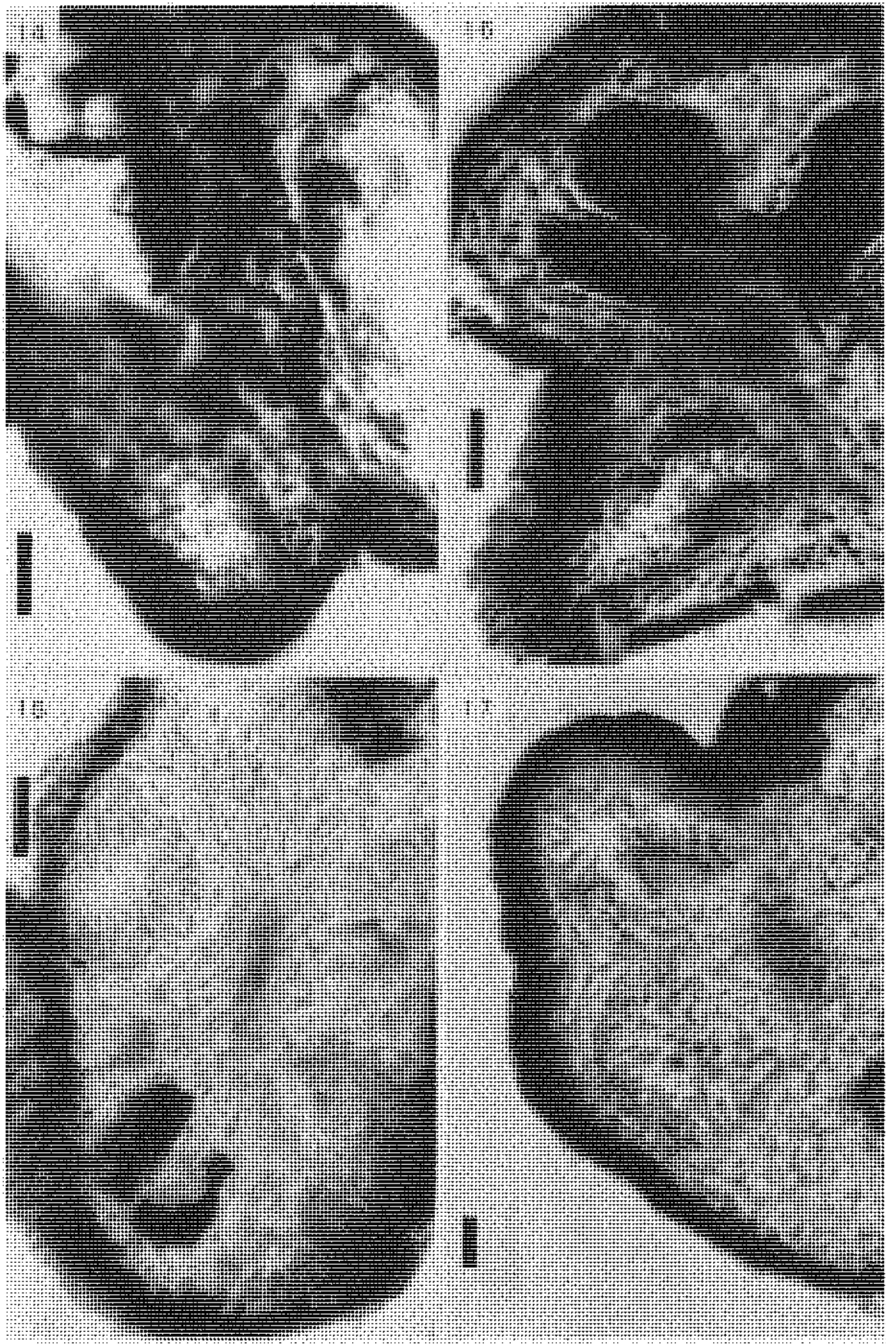
Figs. 2–5. Type specimens of *Sargassum piluliferum* var. *nhatrangense* Pham deposited in the herbarium at Saigon University, Vietnam. Figs. 2 and 3, Holotype (1081). Figs. 4 and 5, Isotype (1078). Arrow indicates holozygocarpic receptacle). Scale bars = 10 cm (Figs. 2 and 4) and 1 cm (Figs. 3 and 4).



Figs. 6–13. *Sargassum carpophyllum* var. *nhatrangense* (Pham) Ajisaka from Vietnam. Figs. 6 and 7, Plant (62725). Figs. 8 and 9, Plant (74189) from Hai Phong.



Figs. 10–13. Plants from Quang Ninh Province. Scale bars = 10 cm (Figs. 6, 8, 10, 12, and 13) and 1 cm (Figs. 7, 9, and 11).



Figs. 14–17. Cross-sectioned receptacles. Fig. 14, Holotype of *Sargassum piluliferum* var. *nhatrangense* Pham. Figs. 15 and 16, *Sargassum carpophyllum* var. *nhatrangense* (Pham) Ajisaka from Hai Phong (62725 and 74189, respectively). Fig. 17, *S. piluliferum* var. *serratifolium* Yamada from Quang Binh Province. Scale bars = 100 μm.

Plant androgynous (Fig.14). Receptacles terete or fusiform, up to 4 mm long, simple or furcate up to three times, sometimes holozygocarpic (Fig. 5, arrow).

Type Specimens: Deposited in Saigon University herbarium: Holotype (1081; Figs. 2, 3, and 14); isotype (1078; Figs. 4 and 5). Collected at Nha Trang, June 15, 1958.

Remarks: Because of their thin leaves and holozygocarpic, androgynous receptacles, these specimens are not referable to *S. piluliferum.* We identified these specimens as a variety new to *S. carpophyllum* (Turner) C. Agardh: var. *nhatrangense* (Pham) Ajisaka. *S. carpophyllum* has been reported from India, China, and Japan. This is the first record from Vietnam. Although *S. carpophyllum* usually has simple leaves, this new variety has alternate-pinnate leaves on the primary branches. We also collected similar mature and immature specimens from places in Vietnam (Fig. 1) other than the type locatility (see following).

Sargassum carpophyllum var. *nhatrangense* (Pham) Ajisaka comb. nov. (Figs. 6–13, 15 and 16).

Basionym: *Sargassum piluliferum* var. *nhatrangense* Pham, Ann. Fac. Sci. Saigon, p. 271, fig. 1, 1967.

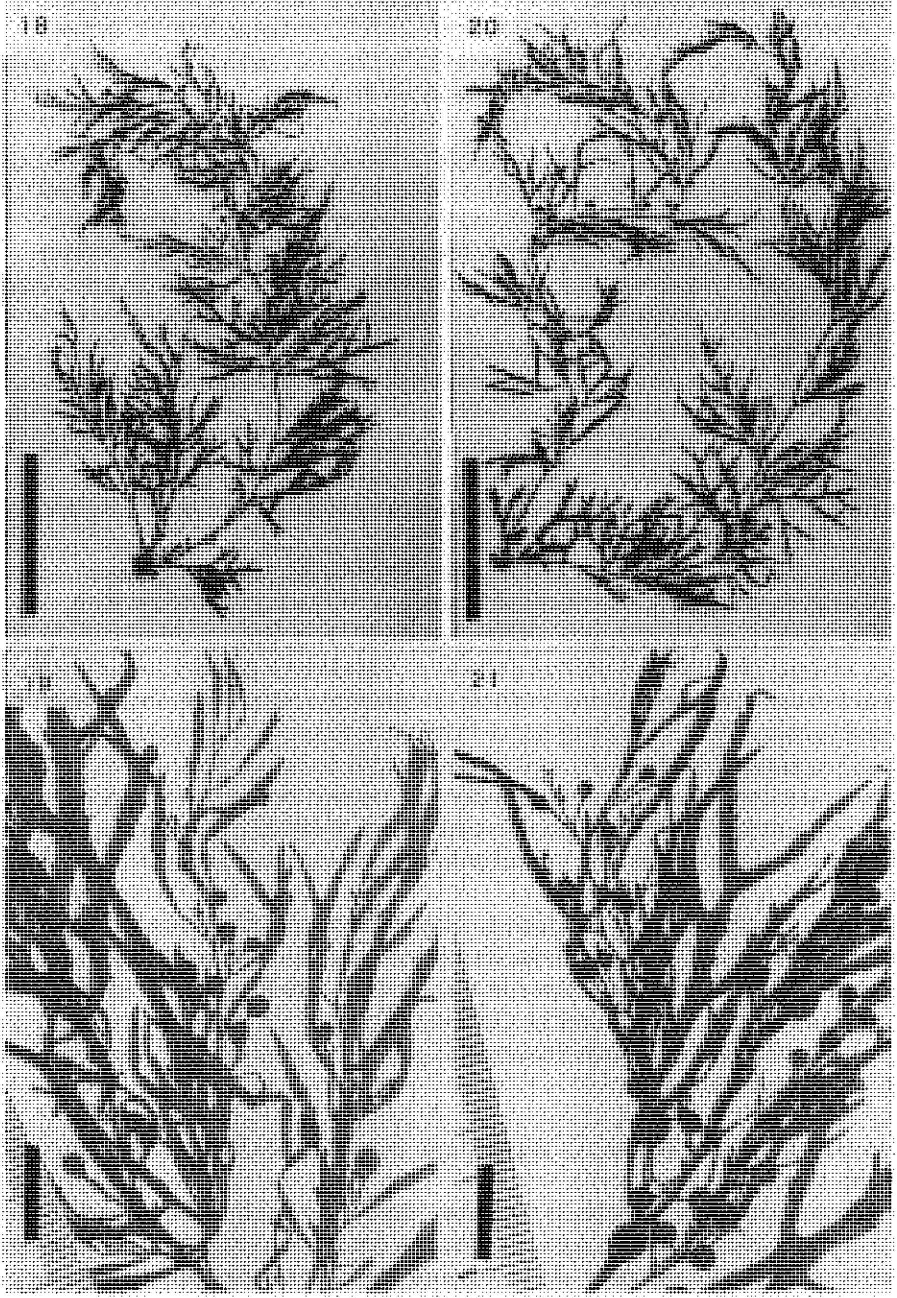
Holdfast discoid, up to 7 mm in diameter. Stem terete, up to 1 cm long, up to 1.5 mm in diameter. with warty surface. Primary branches up to 60 cm long, cylindrical, up to 1 mm in diameter, without spines. Secondary branches up to 20 cm long, spirally arranged at interval of 3–4 cm. Leaves on primary branches thin, simple to furcate one to two times or three to four times, each lobe lanceolate or linear-lanceolate, up to 8 cm long, up to 1 cm wide, leaves on secondary branches simple to furcate one to two times, up to 6 cm long, up to 4 mm wide, base asymmetrical, apex acute, margin dentate, midrib distinct and percurrent, cryptostomata scattered or arranged on both sides of midrib. Vesicles spherical to obovoid, up to 6 mm in diameter, round at apices; stem terete, longer or equal to the vesicles.

Plant androgynous (Figs. 15 and 16). Receptacles terete or fusiform, up to 4 mm long, simple or furcate up to three times, sometimes holozygocarpic.

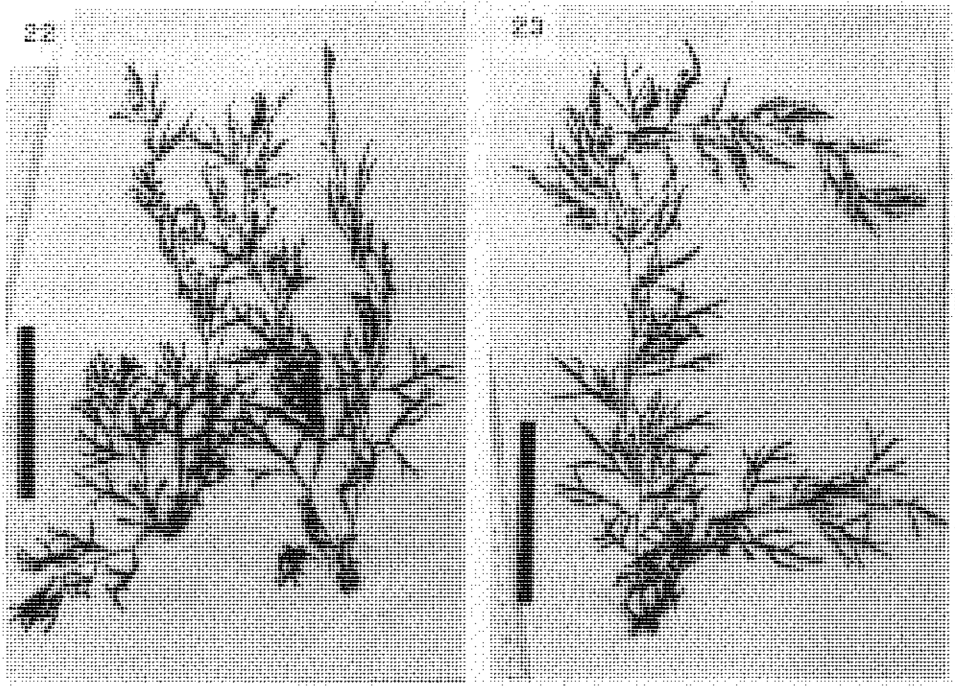
Representative Vietnamese Specimens: Do-Son, Hai Phong (62725, Figs. 6, 7, and 16; and 74189, Figs. 8 and 9); collected April 29, 1967 (mature); Ganh Cao, Tien Yen Bay, Quang Ninh Province (Figs. 10–13 and 15); collected February 28, 1994 (immature).

Sargassum piluliferum (Turner) C. Agardh var. *serratifolium* Yamada from Vietnam (Figs. 17–23)

Holdfast discoid, up to 9 mm in diameter. Stem terete, up to 1 cm long, up to 1.3 mm in diameter, with warty surface. Primary branch compressed to terete, up to 2 mm wide, up to 40 cm long, with no spines. Secondary branches alternately arranged at 1-cm intervals, up to 8 cm long. Leaves on primary branch furcate up to eight times, each lobe lanceolate or linear-lanceolate, up to 8.0 cm long, up to 5 mm wide, leaves on secondary branches simple or furcate up to three times, up to



Figs. 18–21. *Sargassum piluliferum* var. *serratifolium* Yamada from Quang Binh Province, Vietnam. Scale bars = 10 cm (Figs. 18 and 20) and 1 cm (Figs. 19 and 21).



Figs. 22–23. *Sargassum piluliferum* var. *serratifolium* Yamada from Quang Binh Province, Vietnam. Scale bars = 10 cm (Fig. 22) and 1 cm (Fig. 23).

5.0 cm, up to 3 mm wide. Base asymmetrical, apex acute, margin entire at basal ones, dentate at upper ones, midrib distinct and percurrent, cryptostomata obscure, on both sides of the midrib. Vesicles spherical, up to 5 mm in diameter, round at apices; stem terete, longer than the vesicles.

Plant dioecious (Fig. 17). Male receptacles terete or fusiform, up to 3 mm long, simple or once divided, arranged racemosely. Female receptacles unknown.

Representative Vietnamese specimens (Figs. 17–23): Hon Nom, Quang Binh Province, collected March 31, 1995.

Remarks: *Sargassum piluliferum* (Turner) C. Agardh has been reported from Japan, China, and Hong Kong. However, the variety *serratifolium* has been reported only from southern Japan (Yamada 1942, 1944). On the basis of the serrated leaves, these Vietnamese specimens were identified as a variety of *S. piluliferum* (Turner) C. Agardh. Plants growing in this population were not fully matured in this season, but only young male receptacles were observed (Fig. 17). This is the first record for this variety and species in Vietnam, because we identify Pham's specimens as a variety of *S. carpophyllum*.

Acknowledgments

We thank Dr. I. A. Abbott, University of Hawaii, for her kind advice on improving the manuscript.

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SARGASSUM STOLONIFOLIUM PHANG ET YOSHIDA SP. NOV. FROM PENANG ISLAND, PENINSULAR MALAYSIA

Siew-Moi Phang and Tadao Yoshida

Abstract

A new species, *Sargassum stolonifolium* Phang et Yoshida, from Penang Island, Malaysia is described. The identification is based on a growth form recorded for the first time in the genus *Sargassum.* The cauline leaves are transformed into stolons and produce secondary holdfasts on contact with the substratum. New plantlets are then formed.

Introduction

The new species *Sargassum stolonifolium* Phang et Yoshida has a growth form recorded for the first time in this genus. The species was first collected by Liung Cheong Poh during a rock-climbing expedition along the shores of Batu Ferringhi on Penang Island. Subsequent collecting trips by Phang along the 3-km stretch of shoreline showed that this species is found only at the rocky intertidal habitat where it was first collected. The plants are clustered on the side of rocks facing seaward, just above the sea level at low tide (Fig. 1). The plants are generally in the splash zone, regularly washed by waves or sea sprays. The harsh nature of the habitat must have contributed to the unique growth form of this new species.

Materials and Methods

A total of 157 specimens were examined: 89 fertile plants and 68 nonfertile plants. Receptacles of 89 fertile plants were dissected. The receptacles were cut from the tip to the base, and the cross sections were stained with methylene blue, mounted in glycerine, and examined sequentially to verify the unisexual or bisexual condition. The specimens examined were herbarium as well as formalin-preserved materials. All plants were carefully removed from the rock crevices to prevent damage to the many stolons and haptera of the plants.

Results

Plants were collected in June 1994, July and October 1995, and March 1996. Fertile plants were collected during all sampling occasions. Of 89 specimens dissected, only eight were clearly female with the conceptacles containing oogonia. All plants were dioecious; that is, all had single receptacles, all male or all female. Examination of the plants under the dissecting microscope showed different stages of development of stolons and new plantlets from the cauline leaves.

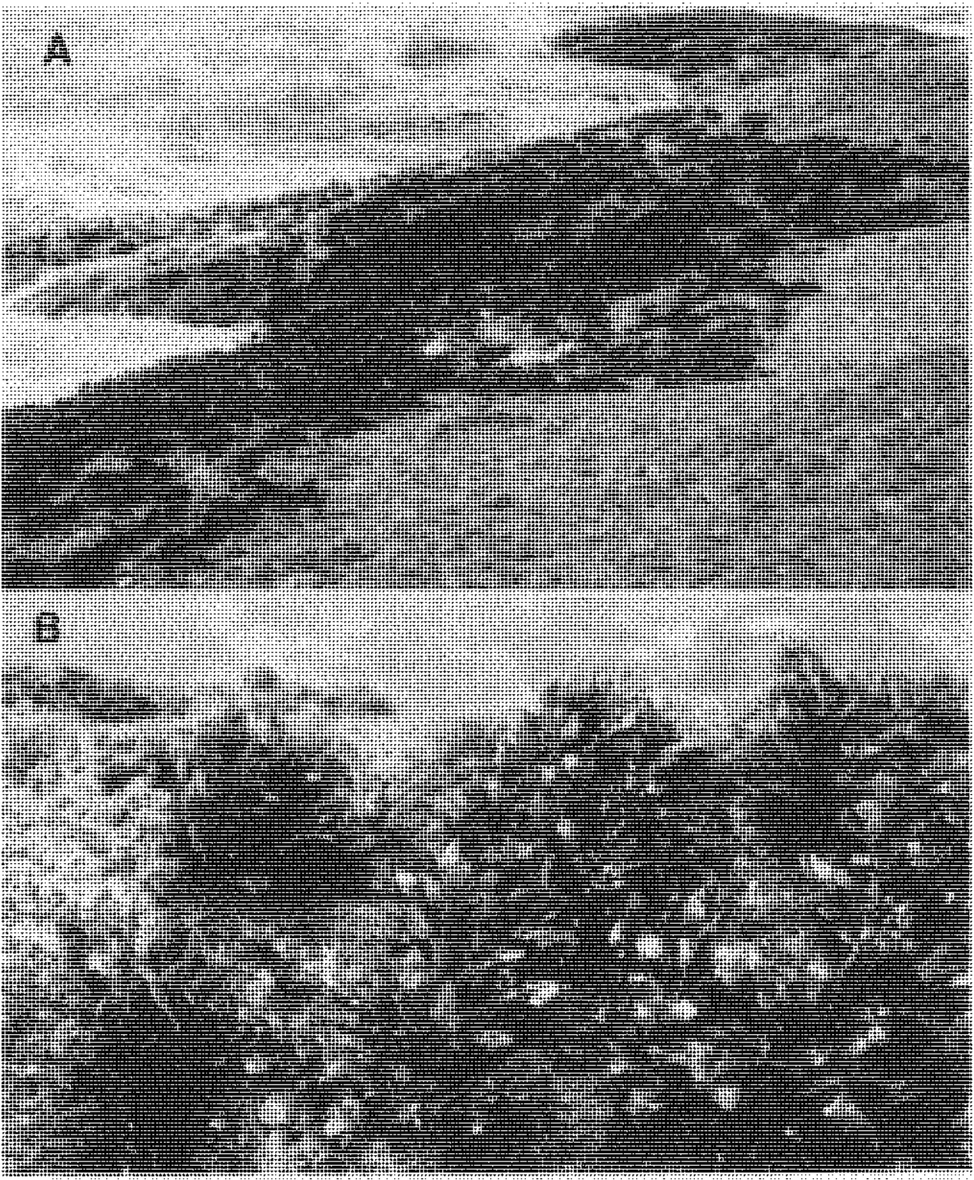

Fig. 1. Habitat of *Sargassum stolonifolium*. A, Population of the *Sargassum* on the side of rocks facing the sea. B, *Sargassum* plants clinging to rock. From the type locality at Batu Ferringhi Beach, Penang Island, Malaysia.

Description of the Species

Sargassum stolonifolium Phang et Yoshida sp. nov.
(Figs. 2–9)

Planta luteo-brunnea in statu vivo, fusco-brunnea in sicco. Thallus plerumque ad 42 cm altus. Hapteron discoideum, 6 mm in diametro. Caulis erectus, teres, 2.5 mm in diametro, usque ad 20 mm altus. Folia caulinis ex parse proximali caulis spiraliter enascentes. Folia caulinis longis, complanatis vel cylindricis, furcatis. Pars distalis folii caulini in hapteron secondalium transiens, ubi ad substrato contactus. ex parse distali caulis enascentes. Aliquot rami principales Rami principali exiles, teres et laeves, spiraliter emitters. Folia rami principales late linearia usque ad 3 cm longa, margine integris, apice obtusis, base cuneata, et costa immerse ad apicem attingens. Cryptostomata praesentia super folia disperse vel linearia secus marginem disposita. Ramii secundarii usque ad 4 cm longi. Vesiculae solitariae, binatae vel triae, obovoideae vel subsphaericae, 3–4 mm in diametro, apicibus mucronatis vel apiculatis, breviter stipitatis.

Planta dioica. Receptacula in parse distali rami racemose disposita. Receptacula masuculina teretia, saepe bifurculata, usque ad 1 cm longa. Receptacula femina usque ad 0.5 cm longa, bifurculata.

Holotype: Male (PSM 1329) collected by Liung Cheong Poh at Batu Ferringhi Beach, Penang Island, June 10, 1994 (Fig. 8). Deposited at the Herbarium, Faculty of Science, Hokkaido University (SAP 062135).

Other Specimens Examined: All plants were collected from Penang Island on the dates given. July 11, 1995, female PSM 1661 (Fig. 9); July 11, 1995, females PSM 1653, 1655, 1659, 1661, 1664, 1667, and 1670 and males PSM 1652, 1656, and 1675; October 25, 1995, males PSM 1689, 1692, 1697, 2064, 2067, 2072, 2077, 2085, and 2091; March 20, 1996, males PSM 2068, 2103, and 2111; July 11, 1995, nonfertile plants PSM 1642, 1646, 1648, 1668, 1677, 1970, and 1975.

Habitat: Growing on the surface of lower intertidal rocks; at the exposed shore.

Remarks: Plants are a rich yellow-brown when fresh and dry to a darker brown. Fertile plants are 10–42 cm tall; nonfertile plants, 6–36 cm. Male plants are 10–42 cm long; female plants, 13–26 cm. Holdfasts are discoid, reaching a maximum diameter of 6 mm, and giving rise to short cylindrical to terete main stems. The main stems are up to 2.5 mm wide and 20 mm long. The lower half of the short stem bears many radially arranged cauline leaves in various stages of development into stolons, with branches, haptera, and even new plantlets (Fig. 2). The cauline leaves are long, flattened or cylindrical, and branched, with each branch ending with a hapteron at the distal end when the end is in contact with the rock surface. A new plantlet then arises at the hapteron. The primary branches arise midway up the stem; branches are slender, terete, smooth, and arranged radially on the stem (Fig. 3). The primary branches bear broadly linear leaves arranged closely and radially along the branch. The leaves have entire margins and have midribs extending all the way to the leaf tips, which are generally

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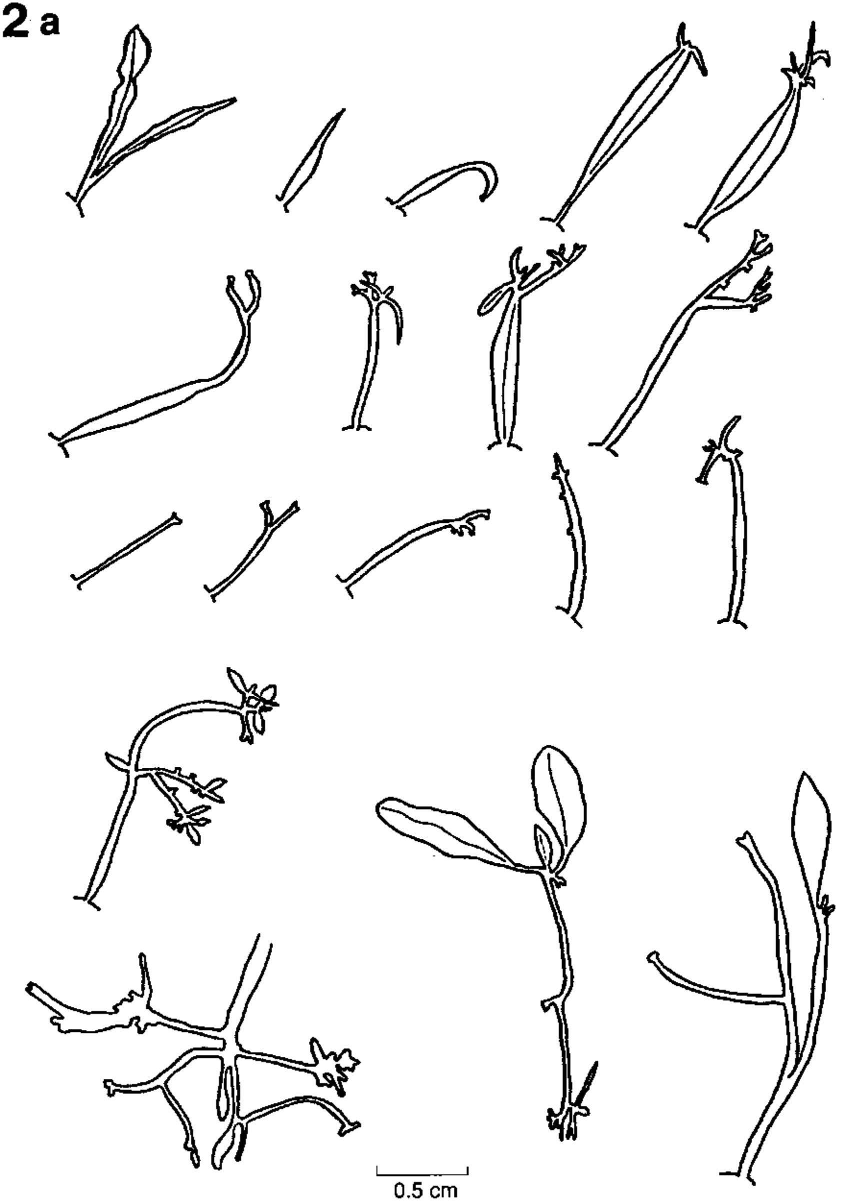

Fig. 2. ***Sargassum stolonifolium.*** **a, Various stages in the transformation of cauline leaves to stolons (freehand drawings).**

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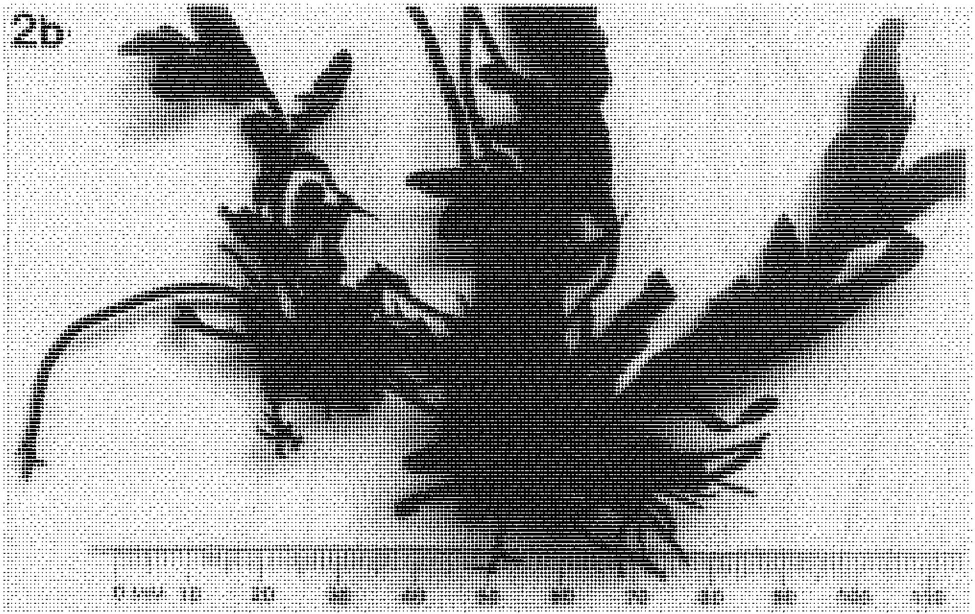

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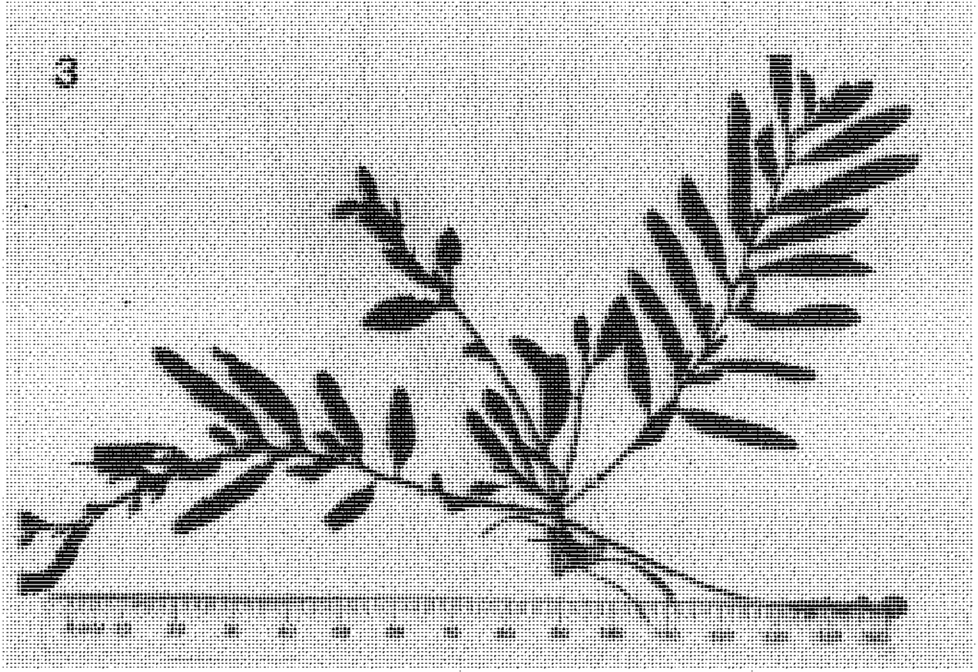

Fig. 2b, Young plant with various cauline leaves and stolon to the left.
Fig. 3. Young plant (PSM 1970) of *Sargassum stolonifolium* showing primary branches.

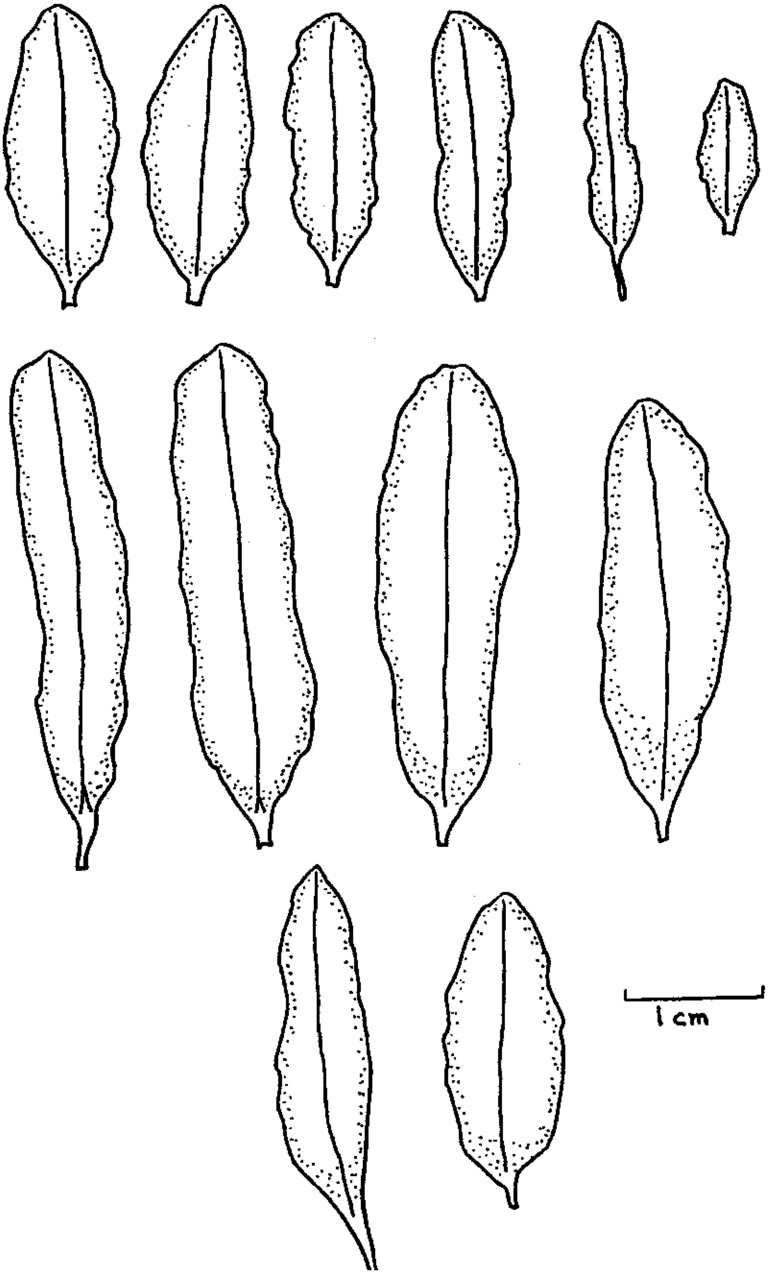

Fig. 4. Variation in leaves of *Sargassum stolonifolium*. Top row, Fertile plant. Middle and lower rows, nonfertile plant.

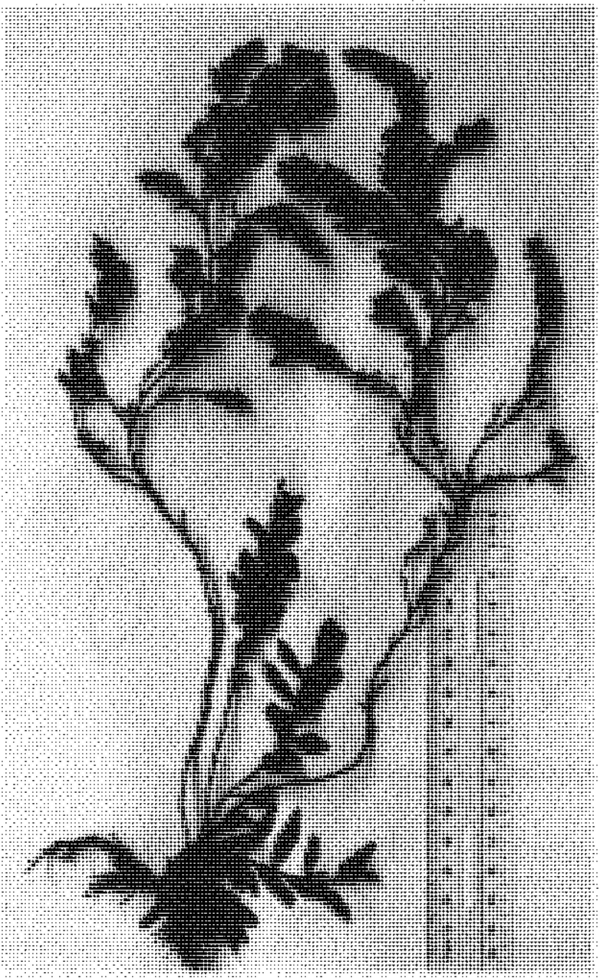

Fig. 5. Older plant of *Sargassum stolonifolium* with primary branches, which become fertile first (PSM 2111, male).

rounded. The leaf bases range from cuneate to broadly rounded (Fig. 4). Leaves reach 3 cm in length but are much shorter on fertile branches. Cryptostomata are found all over the leaf surface but sometimes are confined to a row along the leaf margin. The branches become fertile with age, as shown by the finding that the first branches become fertile when they reach a length between 9 and 40 cm (Fig. 5). The fertile primary branches are generally left with remnants of secondary branches or leaves on the lower half of the branch. The secondary branches are arranged radially on the fertile branches; reach 4 cm in length; and are crowded with branched receptacles, vesicles, and small leaves. Vesicles are solitary, paired, or in groups of three; obovoid to subspherical, smooth or apiculate; with distinct stalks; and scattered among the receptacles (Fig. 6).

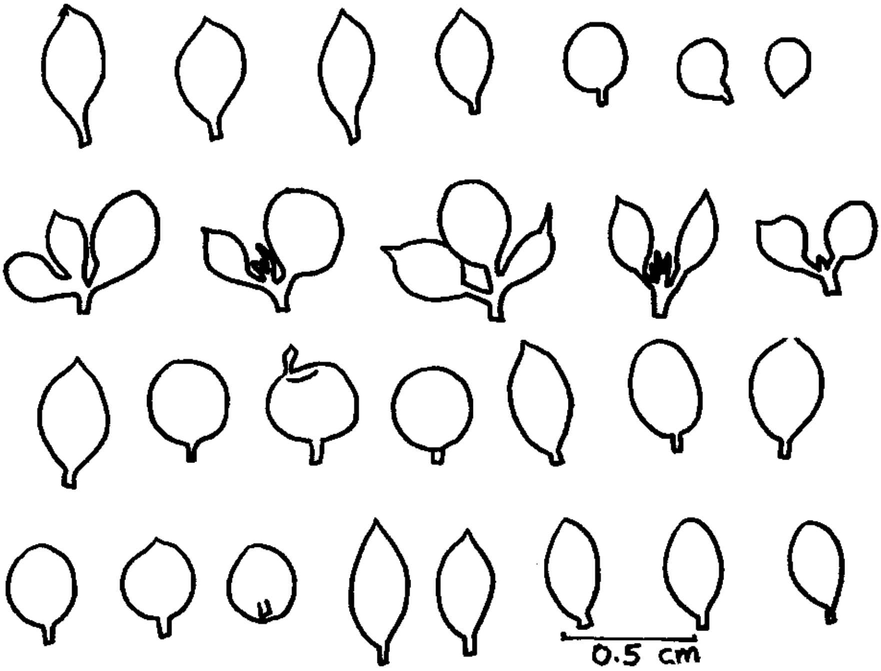

Fig. 6. Variation in shapes of vesicles of *Sargassum stolonifolium.*

Plants are dioecious. Receptacles are arranged racemosely on the branched receptacular branches. The receptacular branches are generally subtended on the leaf bearing solitary vesicles. Receptacles are sometimes carpophyllous. Male receptacles are long, up to 1 cm, terete with wavy outlines, and generally bifurcate (Fig. 7). The female plant has shorter, up to 0.5 cm long, and compressed receptacles with wavy outlines and bifurcate tips (Fig. 7).

Discussion

Two other species of *Sargassum* have proliferation of stolons and new plantlets from primary branches on the stem. *Sargassum polycystum* C. Agardh produces branched stolons from the stem. The stolons arise at the same place on the main stem as the primary branches and bear short protuberances similar to those found on the primary and secondary branches (Chiang et al. 1992). *Sargassum herporhizum* Setchell et Gardner produces erect primary branches in part and to horizontal branches that in turn develop attaching branches, hapteres, on the short stipe. The new species described here is distinct from these. The stolons of the new species are derived from the cauline leaves, which are distinctly

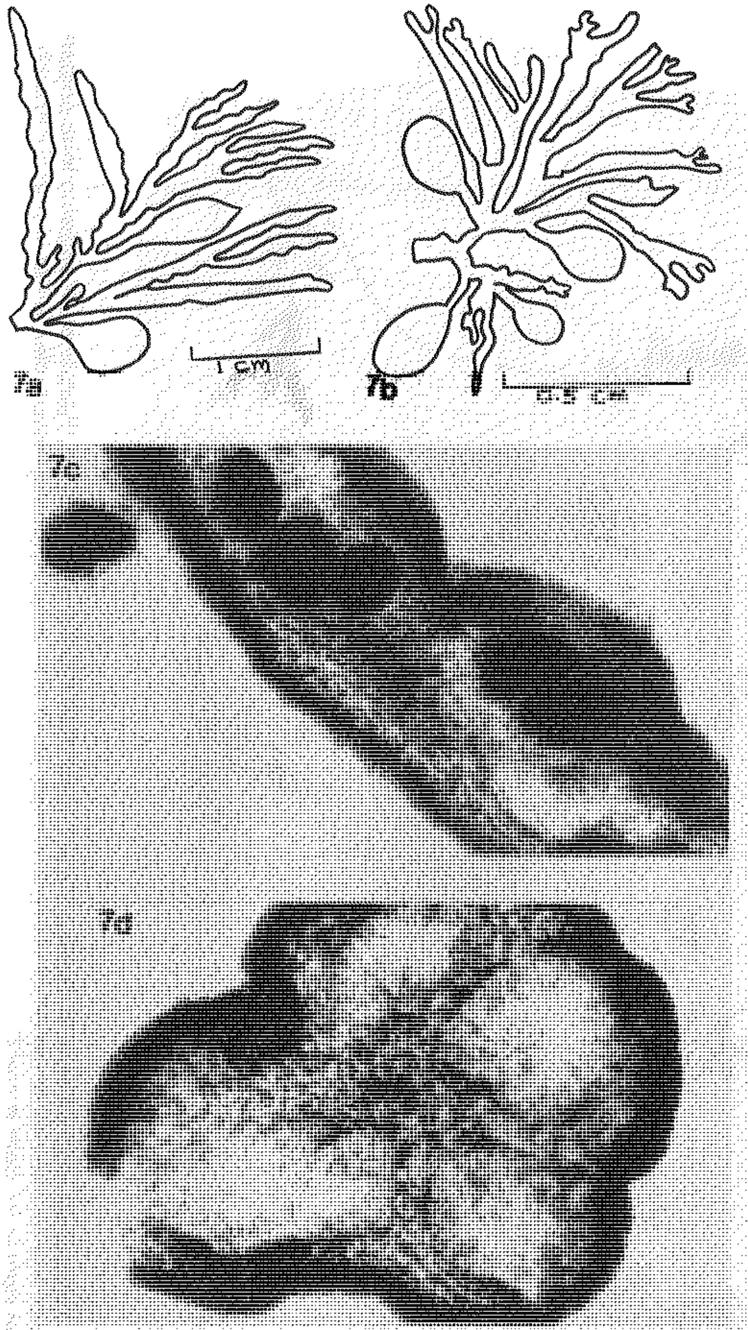

Fig. 7. Receptacles of *Sargassum stolonifolium*. a, Male receptacle. b, Female receptacle. c, Cross-section of female receptacle showing eggs. d, Cross-section of male receptacle.

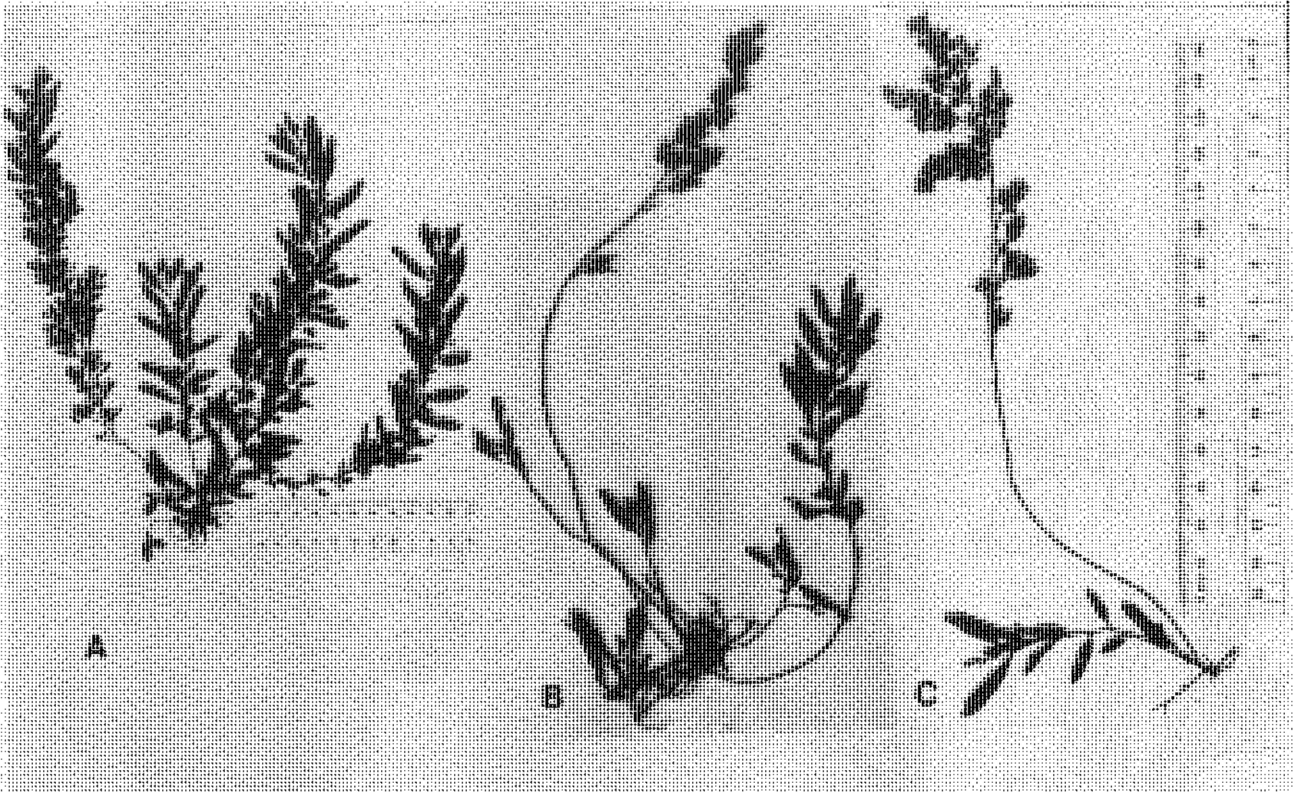

Fig. 8. *Sargassum stolonifolium*. A, Holotype plant, male. SAP 062135 (PSM 1329). B, Female plant showing long primary branches and receptacles at top (PSM 1661). C, Female plant with vesicles among receptacles at top of primary branch. Rule on right is for both B and C.

formed earlier on the lower part of the short stem, whereas the primary branches are formed later on the upper half of the stem (Fig. 9). In contrast, the stolons in *S. herporhizum* and *S. polycystum* are formed from branches (Fig. 9)

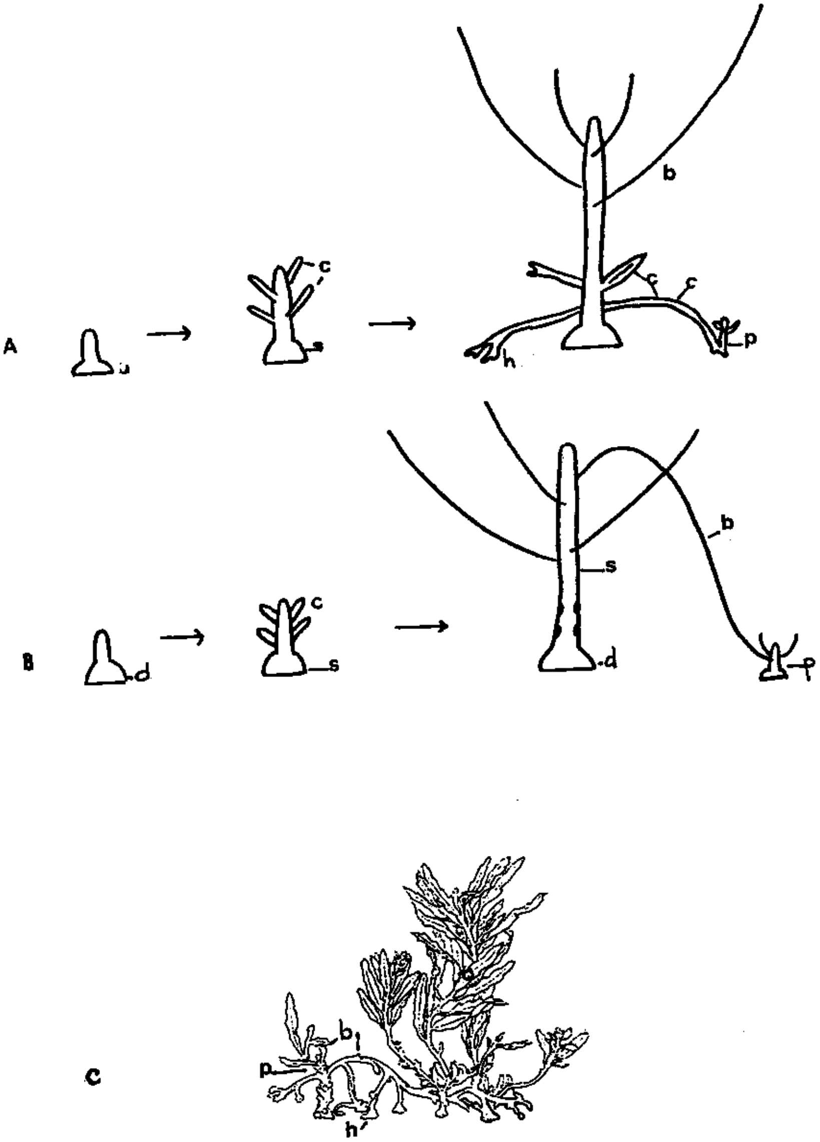

Fig. 9. Diagrams of origin of stolons. A, *Sargassum stolonifolium*. B, *Sargassum polycystum*. C, *Sargassum herporhizum* Setchell et Gardner (1924, pl. 20, fig. 70). b = primary branch, c = cauline leaves, d = disc-shaped holdfast, h = hapteron, p = plantlet, s = stem.

Table 1. Comparison Between *Sargassum herporhizum*, *S. polycystum*, and the New Species

Character	**New Species**	***S. herporhizum***	***S. polycystum***
Thallus length	Up to 42 cm	Up to 80 cm	Up to 2 m
Holdfast	Disc	Disc	Disc
Main stem	Short, cylindrical to terete, gives rise to cauline leaves on lower half and primary branches on upper half	Short, gives rise to primary branches, and horizontal branches that produce haptera and new plants	Short, cylindrical to terete, gives rise to primary branches, cauline leaves, and stolons
Cauline leaves	Numerous, in various forms from cylindrical to flattened with midrib, giving rise to stolons, haptera, and new plants	Deciduous, leaving scar	Deciduous, leaving scar
Primary branch	Cylindrical to terete, smooth	Slender, terete, smooth	Cylindrical, covered with spines
Leaves	Broadly linear, stalked, tips rounded, margin smooth, midrib visible to leaf tip	Sublinear, linear-lanceolate, acute, margin dentate, midrib percurrent	Sessile or short stalk, ovate, oblong, elliptic or oblanceolate, margin dentate, serrate, midrib vanishes at leaf tip
Vesicles	Obovoid to subspherical, solitary, paired or in groups of three, smooth to apiculate, stalked	Spherical to subspherical, smooth, rarely apiculate, stalked	Spherical to ovate, crowned with one to few leaflets or sharp tip, stalked
Receptacles	Dioecious, carpophyllous, racemose	NA	Dioecious, carpophyllous, particulate to racemose
Male receptacles	Long, terete to cylindrical, wavy outline, bifurcate at tip	NA	Smooth, cylindrical to terete
Female receptacles	Shorter than male receptacles, slightly compressed, bifurcate at tips	NA	Compressed. forked with tooth at apex, spines at margin

NA = not applicable.

The primary and secondary branches in *S. polycystum* are covered with short protuberances, whereas the branches in the other two species are smooth. The upper leaves in *S. herporhizum*, especially those in the receptacular branches (Setchell and Gardner 1924, pl. 20, fig. 69), are linear-lanceolate and acute, with sparsely dentate margins. In contrast, the leaves in this new species are broadly linear with rounded tips. A comparison of the new species with the other two species is given in Table 1.

The evolution of a proliferating system from the cauline leaves is probably attributed to the unstable environment that the species has colonized. As soon as a plant is established on the slippery rock surface, it produces cauline leaves, which quickly branch out and produce haptera to attach at as many points as possible to the rock surface. The many attachments ensure that the plant is not washed off by wave and splash action. At points of contact with the rock surface, new plants are formed. This vegetative means of propagation is probably a more successful adaptation for maintaining space and replenishing the species than is sexual reproduction with its extremely low ratio of female to male plants.

Acknowledgments

We thank Professor Isabella Abbott and the California Sea Grant College System for providing the opportunity to work together on the specimens. S.-M. Phang thanks the *Sargassum* group, especially Dr. Tetsuo Ajisaka, for useful discussions on the specimens. This chapter is dedicated to the persons who collected the first specimens of this new species: Liung Cheong Poh and Liung Miao Shan, husband and daughter, respectively, of S.-M. Phang.

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Setchell, W. A., and Gardner, N. L. 1924. Expedition of the California Academy of Sciences to the Gulf of California in 1921: The marine algae. Proc. Calif. Acad. Sci. 12:695–949.

Section II. *Gelidiales*

INTRODUCTION

Isabella A. Abbott

In the introduction to volume 5 of these taxonomy books, I said that "when the *Gelidium* group finishes the 'big' species, I hope it will give concerted attention to the 'small' species that are usually relegated to *G. pusillum* or *G. crinale.*" Dr. Santelices offered me a "middle-sized" species in describing the spermatangia of *Gelidiella acerosa* in this volume.

He found a male plant of this, the type species of *Gelidiella*, among the "pickled" (i.e., liquid preserved) material in Dr. Phang's laboratory. At first, he could not believe his eyes—so we all had to look at the material and offer opinions. Male plants of the genus had never been seen before (and alleged cystocarpic plants only once). I showed Dr. Gerald Kraft, a visitor in my laboratory, Santelice's illustrations, and Gerry said he could not think what else they could be. I am pleased that Dr. Santelices, who could have published this paper in any phycological journal because it is a real contribution to knowledge of the Gelidiales, decided to publish it with his "old friends" (he has been in the workshops since they started in Guam).

THE SPERMATANGIAL SORUS OF *GELIDIELLA ACEROSA* (GELIDIELLACEAE, GELIDIALES)

B. Santelices

Abstract

Fertile spermatangial sori were found in a specimen of *Gelidiella acerosa* collected from a shallow reef in Johore, Malaysia. The structure of the male sorus agrees only partially with previous reports on other genera in the order Gelidiales. The shape, size, and pattern of division of the fertile cells are similar to those described for male sori in *Porphyroglossum* (= *Beckerella*) *subcostatum*. However, in *Gelidiella*, a significant proliferation of internal cortical and external medullary cells occurs. Thus, the fertile sori protrude externally, appearing as rounded, hemispheric swellings along the axes.

The Gelidiellaceae were previously distinguished from the Gelidiaceae by the former's lack of gametophytes and lack of rhizines. The detection of male gametophytes abolishes the first point, but the unique spermatangial sorus in *Gelidiella* adds a further feature that, with the absence of rhizines, provides support for the recognition of two families in the order.

Introduction

Gelidiella is a monotypic genus of the family Gelidiellaceae of the order Gelidiales. However, its generic definition and the validity of the family have been under discussion for the past 10 years (see Maggs and Guiry 1987, Santelices 1990, Melo 1992, Ganzon-Fortes 1994, and Freshwater et al. 1995 for reviews).

The name *Gelidiella* was proposed by Feldmann and Hamel (1934) as a substitute for *Echinocaulon*, a later homonym of a flowering plant genus. The lectotype species, *E. rigidus* Kützing (1868), was considered to be a conspecific with *Fucus acerosus* Forsskål (1775). *Gelidiella acerosa* (Forsskål) Feldmann and Hamel is the type species of *Gelidiella*.

The presence of a distinct dome-shaped apical cell at the apex of axes and branches (Feldmann and Hamel 1934, 1936) leading to a uniaxial structure and the *Gelidium*-type of germination exhibited by its tetraspores (Chihara and Kamura 1963, Sreenivasa Rao 1971, Umamaheswara Rao 1974) support the inclusion of the genus in the order Gelidiales. On the other hand, the absence of thick-walled, delicate fibers (rhizines) in the cortex or medulla (Kützing 1843, Feldmann and Hamel 1934, Melo 1992) and the lack of a known sexual generation were used by Fan (1961) to distinguish the family Gelidiellaceae from Gelidiaceae, the other family in the order. The absence of internal rhizines also is used as a generic character.

The taxonomic limits of *Gelidiella* were questioned by Maggs and Guiry (1987). They assigned the name *G. calcicola* to a small, creeping alga collected from the British Isles and Northern France on the basis of tetrasporangial stichidia with spores arranged in chevrons that developed acropetally and on the lack of rhizines in most of the thallus except in the attachment points of the plant. Citing a study by Sreenivasa Rao and Trivedi (1980) that reported urn-shaped, terminal cystocarps in an unidentified species of *Gelidiella* from India, Maggs and Guiry (1987) also questioned the validity of the family Gelidiellaceae, proposing to merge it back into the Gelidiaceae.

Reexamination of the taxonomic validity of the three previously mentioned characters has yielded conclusive results in only two of them. Chevron or pannosa-type tetrasporangial arrangements are known in species of *Gelidiella*, *Gelidium*, and *Pterocladia* (Santelices 1990, Freshwater et al. 1995) and are not exclusive to *Gelidiella*. On the other hand, lack of internal rhizines has remained a stable character in several species of *Gelidiella*, including *G. acerosa*, despite intensive search for these structures in all plant parts, including the holdfasts (Feldmann 1931, Boudouresque 1967, 1972; Melo 1992).

The absence of a sexual generation in the Gelidiellaceae remains as the most controversial point. The illustration of the urn-shaped, terminal cystocarps published by Sreenivasa Rao and Trivedi (1980) for an unidentified species of *Gelidiella* does not resemble the known cystocarp of any other member of the order (Santelices 1990). On the other hand, meiotic divisions during tetraspore formation in *G. acerosa* have been reported, and alternation of diploid and haploid nuclear DNA levels associated with tetrasporophyte stages and presumptive gametophytes (plants cultured from tetraspores) have been described in this same species (Sreenivasa Rao 1971, Kapraun et al. 1994).

Because of the taxonomic importance of the sexual stages of *Gelidiella*, during this workshop a special search for fertile gametophytes was made among the materials of *G. acerosa* collected from various localities of Malaysia. The search was successful, yielding a small clump of male plants. Plants with cystocarp-like structures were also found, but microscopic studies showed that these structures were galls excavated by immature stages of an endophytic polychaete. This study describes and illustrates the male sorus of *G. acerosa*.

Materials and Methods

The plants were collected by S.-M. Phang in a shallow reef in Kampung Mukut, Pulau Tioman, Johore, on March 7, 1989. They were preserved in a 4% formalin-seawater solution. A Leitz freezing microtome was used to cut fixed materials 15–20 µm thick to avoid destruction of the sporogenous tissues. Sections were stained with methylene blue and photomicrographs were taken with a Nikon Optiphot-2 microscope. Slides and fixed materials are being deposited in the Algal Collection of the Sala de Sistemática, P. Universidad Católica de Chile (SS/UC).

Observations

Although the plant has a small stature, the external appearance of the male specimen conforms well with the description of a typical representative of the species (Fig. 1). The plant was 4 cm high, formed by several tufted, entangled, cylindrical, somewhat arcuate erect axes arising from prostrate, creeping axes that attach to the substratum by clusters of unicellular rhizoids (Figs. 2 and 3). Both types of axes are up to 600 µm in diameter, with rounded or slightly narrowed tips. Erect axes are invested with pinnately or subpinnately arranged branchlets (Fig. 1) that rarely branch a second time. Terminal branchlets are filiform or slightly tapered to the tip, up to 15 mm long. Short laterals arising from one erect axis, may fuse with another erect axis, contributing to the entanglement of erect axes (Fig. 4).

Axial growth is by a lenticular apical cell (Figs. 5 and 6) that cuts off a segment cell below (Fig. 6). The apical cell later divides longitudinally forming a central and two pericentral cells. Close to the apex, the external cortical cells are anticlinally elongated (arrowheads in Fig. 5) and may have longitudinal divisions (arrows in Fig. 6). In subapical parts, they are single and ovoid to rounded (arrows in Fig. 5).

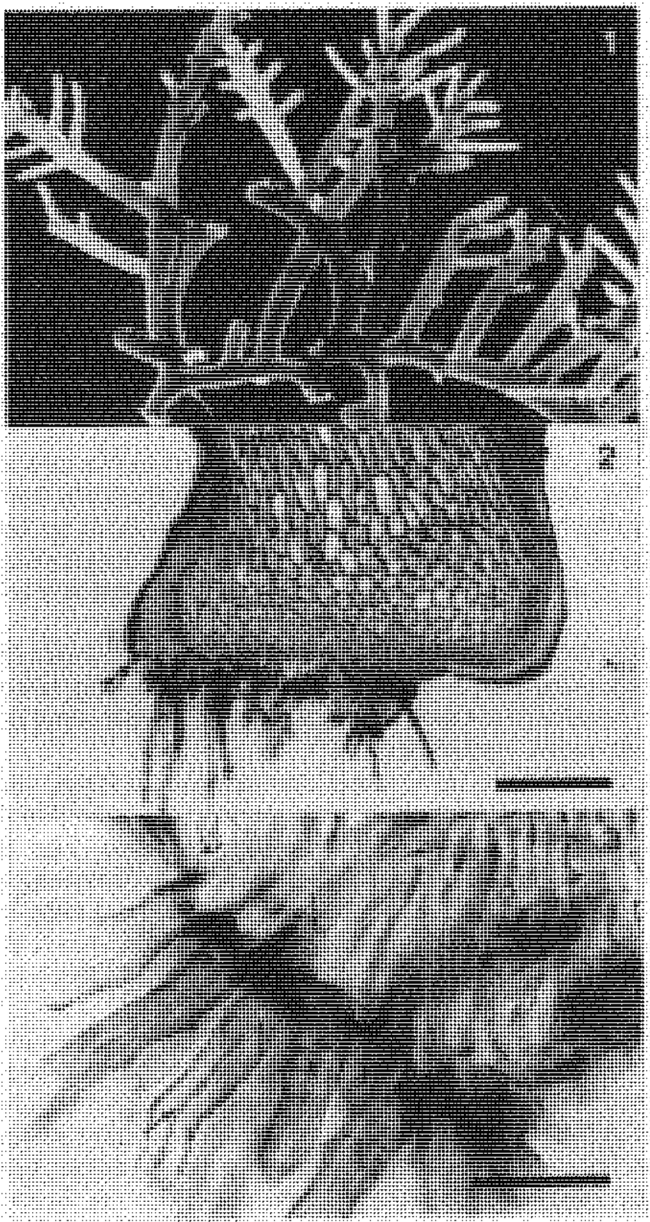
A cross section through a vegetative erect axis shows external cortical cells ovoid or anticlinally elongated, 3–5 µm in diameter, 6–8 µm long, followed by two to three layers of smaller (3 × 4 µm), rounded or slightly ovoid, inner cortical cells that later grade into larger medullary cells.

Spermatangial sori appear as rounded, hemispheric swellings, about 800 µm in diameter, along erect, unbranched, apically rounded low axes (Fig. 7).

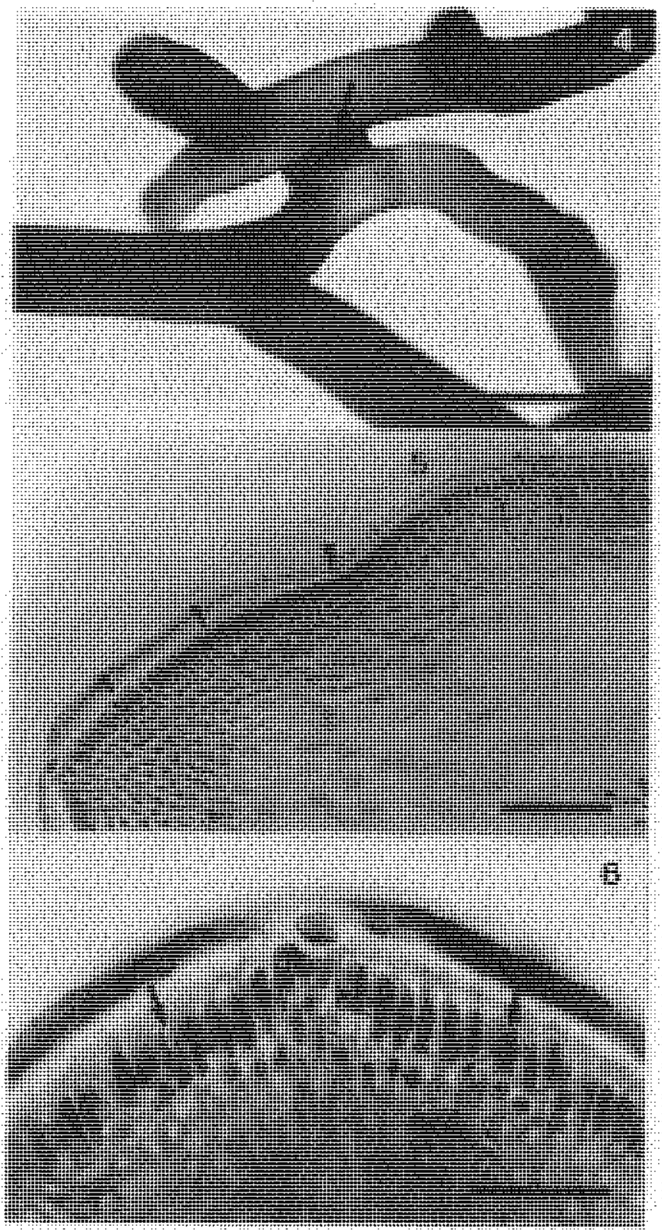
Longitudinal sections through a spermatangial sorus show (Figs. 8 and 10) elongated, external cortical cells underneath a raised and thickened cuticle. The number of rows of inner cortical cells and of external medullary cells is much larger than in vegetative axes, suggesting proliferation of both kinds of cells. The proliferating medullary cells show, in addition, anticlinal alignment in the central part of the sorus (Fig. 8).

In fertile areas, the external cortical cells are elongated, up to 4 µm wide and 8 µm long (Figs. 9 and 11). Longitudinal divisions, like those observed during development of spermatangial parent cells in other members of the Gelidiales are rare (e.g., arrows in Fig. 11). The spermatangial parent cells are elongated, up to 15 µm long, three to five times as long as wide, and usually single, cutting off one spermatangium by transverse divisions (arrowheads in Fig. 11). Spermatangia are up to 8 µm long and 2–3 µm in diameter. Individual conical spermatia were not observed. Entire spermatangia were liberated (Fig. 12) when slight pressure was applied to the coverslip.

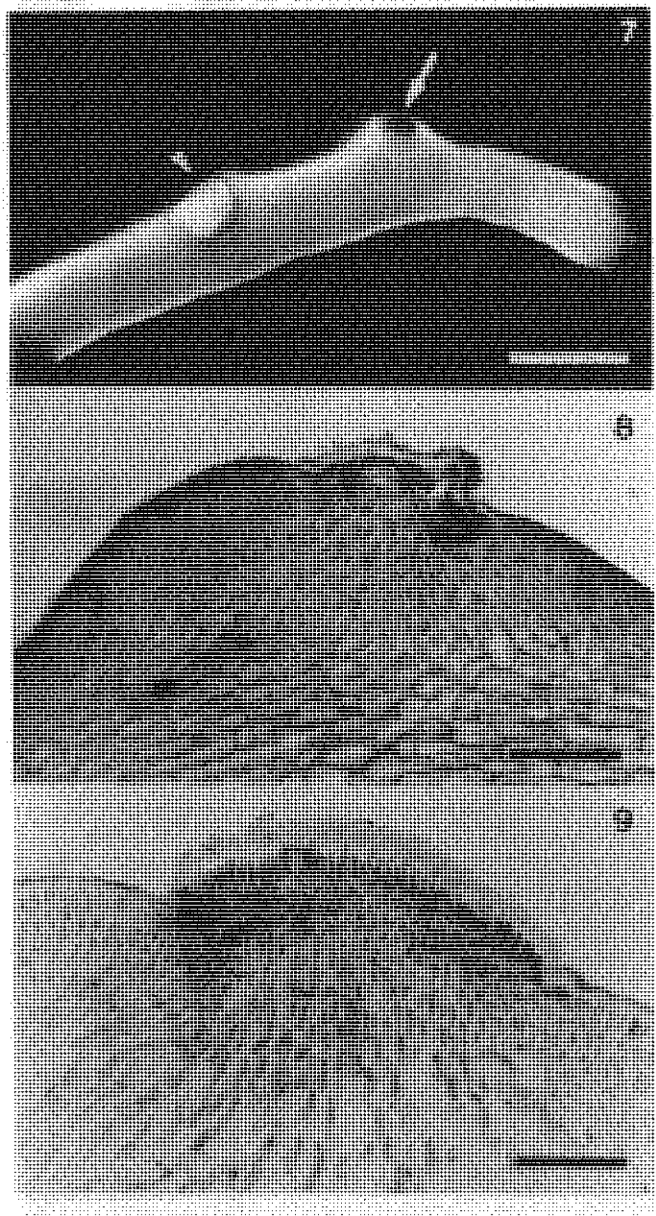
Hemispheric cavities found along the fertile axis (Fig. 13) suggest that several rows of inner cortical and external medullary cells that proliferated during spermatangial formation are lost after release of spermatangia. Cavities are lined internally by 6–10 rows of small, nearly cuboidal, loosely arranged, cortical cells (Fig. 14).



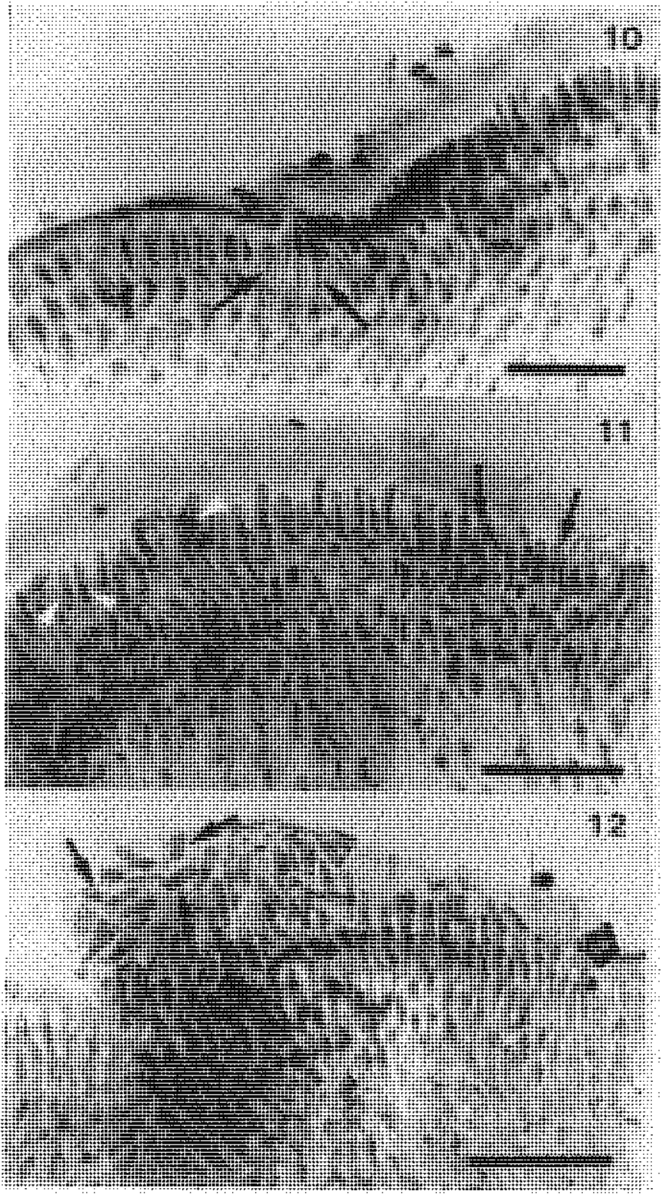
Figs. 1–3. *Gelidiella acerosa* gathered in Malaysia. Fig. 1, External view of creeping and branched erect axes. Scale = 2 mm. Fig. 2, Cluster of unicellular rhizoids attaching the creeping axis to the substratum. Scale = 200 µm. Fig. 3, Detail of unicellular rhizoids (arrows) in creeping axes. Scale = 30 µm.



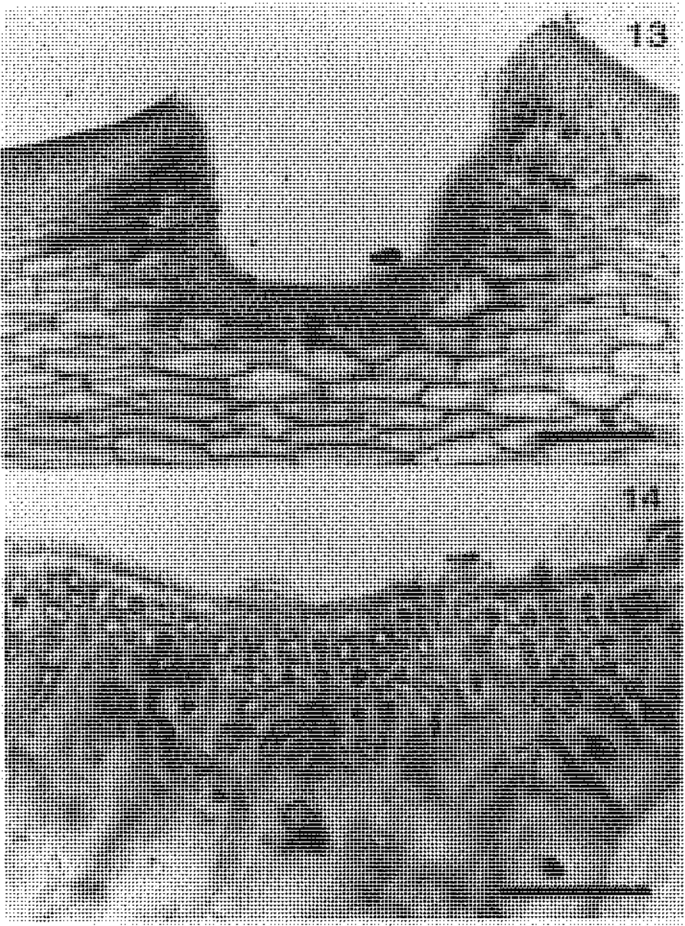
Figs. 4–6. *Gelidiella acerosa* gathered in Malaysia. Fig. 4, Lateral view of the short branches connecting erect axes (arrow). Scale = 1 mm. Fig. 5, Longitudinal section of the apical tip of a branchlet with the apical cell at the left, the anticlinally elongated external cortical cells (arrowheads), and the more rounded external cortical cells in subapical parts (arrows). Scale = 100 µm. Fig. 6, Detail of the apical tip showing the apical cell, the segment cell cut off from the apical one, and the anticlinally elongated cortical cells. Note the longitudinal divisions of some of the external cortical cells (arrows). Scale = 30 µm.



Figs. 7–9. *Gelidiella acerosa* gathered in Malaysia. Fig. 7, Mature (arrow) and empty (arrowhead) spermatangial sori. The axis was immersed for 5 minutes in methylene blue. The dye was retained by the growing tips, the soral tissue, and the cortical cells internally lining the empty sorus. Scale = 600 µm. Fig. 8, Longitudinal section through a spermatangial sorus. Note the proliferation of inner cortical and external medullary cells and the anticlinal alignment of both kinds of cells in the central part of the sorus. Scale = 100 µm. Fig. 9, Longitudinal section through a fertile spermatangial sorus. Note the raised cuticle and the numerous elongated spermatangial parent cells. Scale = 50 µm.



Figs. 10–12. *Gelidiella acerosa* gathered in Malaysia. Fig. 10, Longitudinal section through an immature spermatangial sorus. Note elongation (arrows) of the external cortical cells and the proliferation of inner cortical cells. Scale = 50 µm. Fig. 11, Spermatangial parent cells show longitudinal division (arrows) and transverse divisions (arrowheads). Scale = 30 µm. Fig. 12, Spermatia (arrows) liberated under slight pressure of the coverslip. Scale = 30 µm.



Figs. 13 and 14. *Gelidiella acerosa* gathered in Malaysia. Fig. 13. Hemispheric cavity found along the area with spermatangial sori and interpreted as remnants of old, discharged sorus. Scale = 100 µm. Fig. 14. Detail of the small, nearly cuboidal cortical cells internally lining the hemispheric cavity. Scale = 30 µm.

Discussion

The somewhat raised and thickened cuticle, the shape and size of the modified cortical cells, and the presence of spermatangia cut off from mother cells confirm that the hemispheric swellings found in the specimen from Malaysia are spermatangial sori. The prominent apical cell, the transverse rather than the oblique direction of the division cutting off the spermatangia from the mother cell (Gabrielson and Garbary 1986), the lack of internal rhizines, the internal anatomical construction, and the shape and size of axes and branches confirm that the specimen is *G. acerosa* in the order Gelidiales.

This is the first fertile male gametophyte described for *G. acerosa* and confirms the expectation (Sreenivasa Rao 1971, Kapraun et al. 1994) of a sexual generation in the species. However, the occurrence of male gametophytes also contradicts one of the two characters (lack of sexual generation) used by Fan (1961) to distinguish the family Gelidiellaceae from Gelidiaceae. The presence or absence of internal rhizines remains as the only family-level characteristic that separates these two families.

The male structures of members of the Gelidiaceae has been described several times. Although different cell sizes and shapes have been described in several species, an essentially similar process of development has been recorded (e.g., Dixon 1959; Fan 1961; Akatsuka 1970, 1973, 1979; Renfrew et al. 1989; Norris 1987, 1992; Santelices and Flores 1994). In cross sections of fertile plants, the cortical cells are rounded or slightly cylindrical, 3–6 µm in diameter, and 5–10 µm long. In fertile areas, these cells undergo one or two longitudinal divisions and fade in color. Thus the resulting spermatangial parent cells are generally elongated, three to five times as long as wide, and grouped in numbers of two to four, depending on the number of longitudinal divisions undergone by the cortical cell and its first derivatives. Each spermatangial parent cell cuts off one spermatangium by transverse division. Depending on the species, the spermatangium may vary in length from 1.8 to 7.3 µm. However, the spermatangia are generally elongated and narrow (up to 2.2 µm in diameter). Single, conical spermatia, 1 to 6 µm long, are released from the spermatangium, later becoming rounded or spherical.

The structure of the male sorus of *G. acerosa* agrees only partially with these descriptions. The shape, pattern of division, and especially the size of the spermatangia and spermatangial parent cells, are similar to those of *Porphyroglossum* (= *Beckerella*) *subcostatum* (Akatsuka 1979). However, the evident proliferation of internal cortical and external medullary cells shown by the specimen of *G. acerosa*, which results in a protruding, hemispheric sorus, is unique among equivalent structures so far described for the order. This new character and the lack of internal rhizines contributes another difference for maintaining the Gelidiellaceae as a separate family.

The occurrence of the male organs of *G. acerosa* provides a new and different way to search for fertile plants in the species. A first point is the location of the reproductive structures. The spermatangial sori were found on erect axes located low in the plant, close to the creeping axis. Despite extensive search, not a single sorus was found in the terminal, subdistichous branches of erect axes, a strong difference from the location in *Gelidium*. A second point refers to the persistence of the reproductive structures in the field. On the basis of the presence of hemispheric cavities along the erect axis, the persistence of these sori is most likely limited, because after soral discharge, the whole swelling is lost. A third point refers to the possibility of misidentification of life-history phases in the field. The short lateral branches extending from one erect axis to another may connect gametophytic with sporophytic plants. Because the tetrasporangial sori occur more often and are more conspicuous than the spermatangial sori, under routine taxonomic examination, the whole complex might be identified as sporophytic plants, overlooking the gametophytic component. Finally, in dehydrated, herbarium specimens, the male sorus would not be distinguished easily, or it could be confused with the somewhat rounded tip of new, growing branches. Reexamination of previous collections and additional searches in similar times and areas where this fertile plant was found would perhaps yield the long-awaited cystocarpic specimens that could be examined anatomically in detail and thus furnish the last critical pieces of information for this genus.

Acknowledgements

My gratitude to Dr. S.-M. Phang for the collections of *G. acerosa* from Malaysia and to Dr. I. A. Abbott for the invitation to participate in the workshop and for reviewing and editing the manuscript. Also, I acknowledge with pleasure the help of Dr. James Sullivan and cofunding by SAREC-CONICYT (Grant No. 90-7) and the California Sea Grant College System that enabled me to participate in the workshop in Malaysia and to complete the work in Santiago. The histological and photographic work of Ms. Verónica Flores is acknowledged with gratitude.

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Section III. *Gracilaria and Related Species*

INTRODUCTION

Isabella A. Abbott

Quiet Dr. Yamamoto (whose passion is *Gracilaria* and its relatives) found that the parasite that was so common on *G. salicornia* (on that rainy field trip) is unlike other described *Gracilaria* parasites from the Malaysian area, and in fact not like any that he knows about. The situation will require looking at Madame Dr. Weber-van Bosse's specimens in the Leiden (Netherlands) Herbarium to see if her long-ago observations were correct. Dr. Yamamoto has grown the parasite and its host through four complete life cycles, so he knows quite a lot about it, except what name to give it.

Xia Bangmei helped newcomer Alan Millar understand the terete species of *Gracilaria*. Her English may be a little limited, but put a razor blade and a specimen in her hands and in a few moments she has beautiful sections, and says with a smile, "You look!" and there you have displayed spermatangial configurations or cystocarpic mysteries. Alan was impressed, so much so that he insisted that she be coauthor of his paper on the troublesome terete Australian gracilarioids, because without her help and expertise, he believed that he could not have arrived at such accurate identifications.

AN ADELPHOPARASITIC ALGA GROWING ON *GRACILARIA SALICORNIA* FROM MALAYSIA

Hirotoshi Yamamoto and Phang Siew Moi

Abstract

An adelphoparasite in Gracilariaceae is reported from Malaysia. This taxon has no rhizoids, small medullary cells, pot-shaped spermatangial conceptacles, and tetrasporangia. Its taxonomic status is discussed in relation to other related parasites in the Asian region.

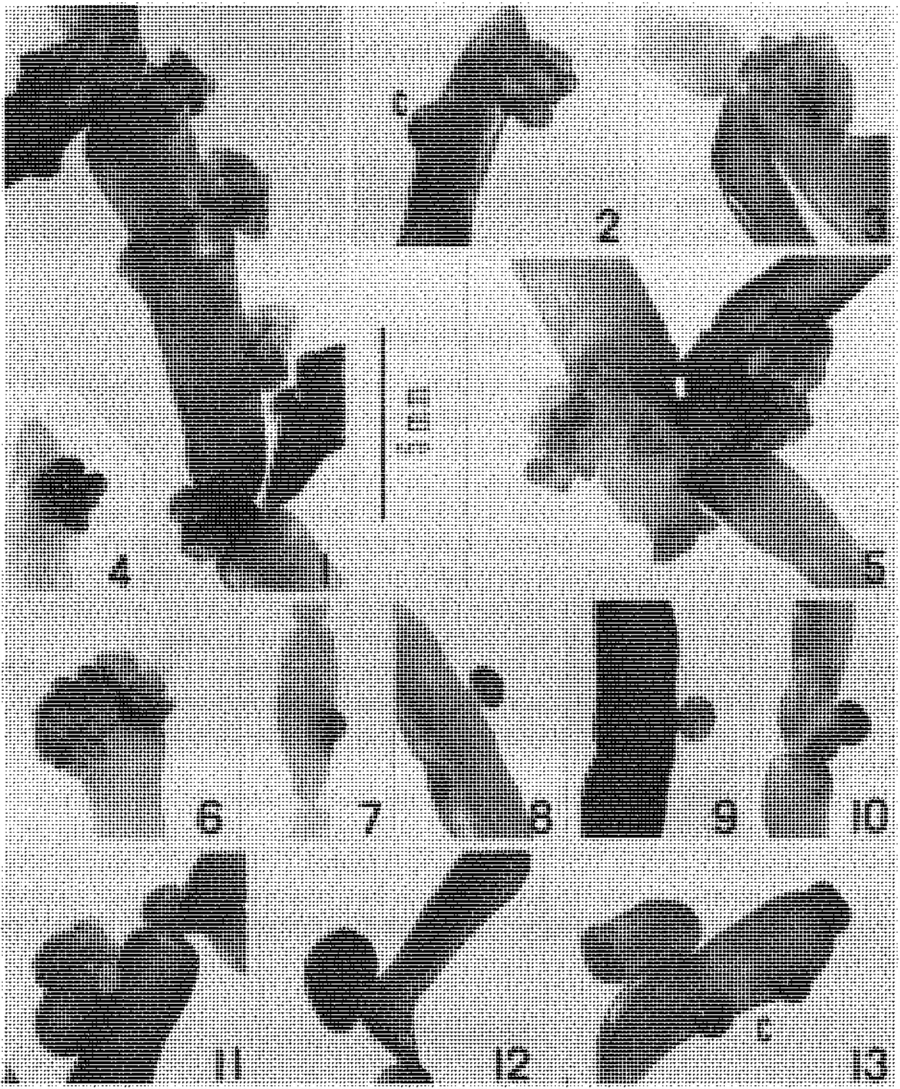
Introduction

Until now, four researchers had recorded five adelphoparasitic species in Gracilariaceae from the Asian region. Weber van Bosse (1928) established a genus *Gracilariocolax* on the basis of a parasite growing on *Gracilaria radicans* from Indonesian waters near Malaysia. It was characterized by the absence of rhizoids penetrating into host tissue, formation of spermatangial conceptacles, and monosporangia. She also described four species of *Gracilariophila,* which have no rhizoids and superficial spermatangia. Absence of rhizoids suggests that her taxa can be separated from original *Gracilariophila* of Setchell and Wilson (in Wilson 1910). Later Chang and Xia (1978) reported three species of *Gracilariophila,* which had already been established by Weber van Bosse (1928), from southern China. However, their species had no rhizoids and had spermatangia in conceptacles, therefore differing from the *Gracilariophila* of Weber van Bosse.

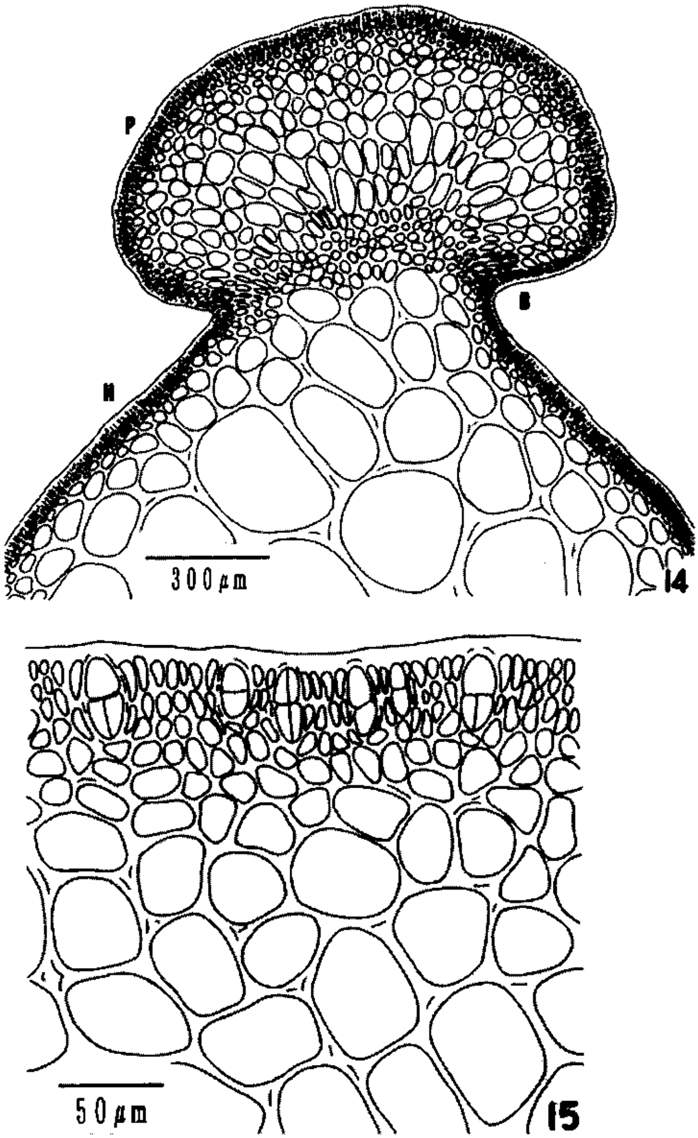
Yamamoto (1986) proposed a new genus, *Congracilaria,* for an adelphoparasite *C. babae* Yamamoto, on the basis of Japanese materials growing on *Gracilaria salicornia,* and in 1991 Yamamoto reported it as growing abundantly on the same host species in the Philippines. This has bisporangia in which each cell has two nuclei and deep pot-shaped spermatangial conceptacles (cf. Yamamoto 1986, fig. 14; 1991, fig. 9).

Descriptions

We collected many specimens of a parasite on *G. salicornia* in a mangrove forest at Morib (Selangor), Malaysia in July 1995 (Figs. 1–13). The Malaysian parasite has a generally small mushroomlike appearance (Figs. 8, 9, and 12, especially). It rarely has a very short stipe or no stipe. Fronds are up to 3 mm high from the surface of the host frond to the top of the cap. Stipes are short, up to 0.2 mm high. The caps are up to 3 mm in diameter. The parasite has no rhizoid penetrating into the host tissue, but the border between host and parasite tissue is distinguishable to some degree by a zone of comparatively small cells (Fig. 14).



Figs. 1–13. Adelphoparasites growing on the host alga *Gracilaria salicornia* from Malaysia. Figs. 1–6, Many cystocarps and male conceptacles grow on a single frond, forming projections. Figs. 7–10, Mushroom-shaped fronds have smooth caps and very short stipes. Fig. 11, A frond shows various projections. Figs. 12 and 13, Mature tetrasporophytes have a smooth surface. C = cystocarps of the host *G. salicornia.* Scale is for all the figures.



Figs. 14 and 15. Sectional views of an adelphoparasitic alga (P) growing on *Gracilaria salicornia* (H) from Malaysia. Fig. 14, Boundary (B) between host and parasite consists of comparatively small cells (cf. Yamamoto 1986, fig. 6). Note considerably smaller medullary cells of parasite compared with those of the host. Fig. 15, Tetrasporophytes with cruciately divided tetrasporangia.

Outermost cells are 6–12 µm high, and about 5 µm wide and increase gradually in size toward the center, reaching 80–90 × 95–140 µm.

A number of projecting cystocarps are formed on a single frond, appearing like tubercles (Figs. 1–6), 480–560 µm high and 400–550 µm wide. The structure of cystocarps is similar to that originally described for *Congracilaria.* Spermatangia are always formed in a deep pot-shaped conceptacle, up to 72 µm deep, and occur in a sorus on the same frond with cystocarps, thus showing the monoecious nature of the species. Tetrasporangia cover the caps completely and are 28–40 µm high, 16–22 µm wide, and cruciately divided.

Discussion

The external appearance of the Malaysian alga is similar to the appearances of parasitic algae already reported from Asian regions. However, the Malaysian parasite is characterized by the following: (1) no stipe or a very short stipe, (2) small-sized cells in the medulla, (3) a zone of small cells between host and parasite, (4) spermatangial conceptacles and (5) tetrasporangia. Some of these items are not similar to features of each of the already known species: Tetrasporangia and a distinguishable border are not present in *Gracilariocolax.* The spermatangial conceptacles differ from those of *Gracilariophila* sensu Weber van Bosse. The size of medullary cells and the tetrasporangia differ from those of *Congracilaria.*

Weber van Bosse (1928) stated that the sporangium of *Gracilariocolax* was a monosporangium. However, her descriptions of the development of monosporangia and their location in the tissue are not clear. The "monosporangium" may be an early undivided stage of a tetrasporangium, or may be another cell, not a sporangium. The size of medullary cells seems to be almost the same for both host and parasite, and the boundary between the parasite and the host is undistinguishable in her figure (Weber van Bosse 1928, fig. 145). However, if the sporangium of *Gracilariocolax* were bisporangial or tetrasporangial, the Malaysian alga could be a species of *Congracilaria* or *Gracilariocolax. Gracilariophila* of Weber van Bosse should be reexamined to confirm the spermatangial structure. If it is superficial as she describes, a new genus could be proposed for her species. Because Chang and Xia (1978) associated the Chinese species with Weber van Bosse's concept of *Gracilariophila,* the Chinese species should not be placed in this genus. Accordingly *Gracilariophila* should be removed from the Asian marine floras.

Gracilariocolax and *Congracilaria* are similar to each other except for the structures of the sporangia. However, we cannot make conclusions about the relationship between the two, because we have not seen specimens of *Gracilariocolax.* At this time, we identify the Malaysian taxon as a new adelphoparasite without specifying the genus. We intend to describe the parasite in detail after we examine more materials gathered from Malaysian and Indonesian waters.

Acknowledgments

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A BISPORANGIAL SPOROPHYTE IN THE LIFE HISTORY OF *GRACILARIA CHORDA* VAR. *EXILIS* (GRACILARIACEAE)

Hirotoshi Yamamoto and Hiroko Yamauchi

Abstract

Gracilaria chorda var. *exilis* grown in culture for five continuous generations had sporophytes only, which bore bisporangia. The sporangia divided transversely into two cells, with a single nucleus in each cell. Comparison with nuclear DNA values for normal gametophytes of this species confirmed that the sporophytes were diploid.

Introduction

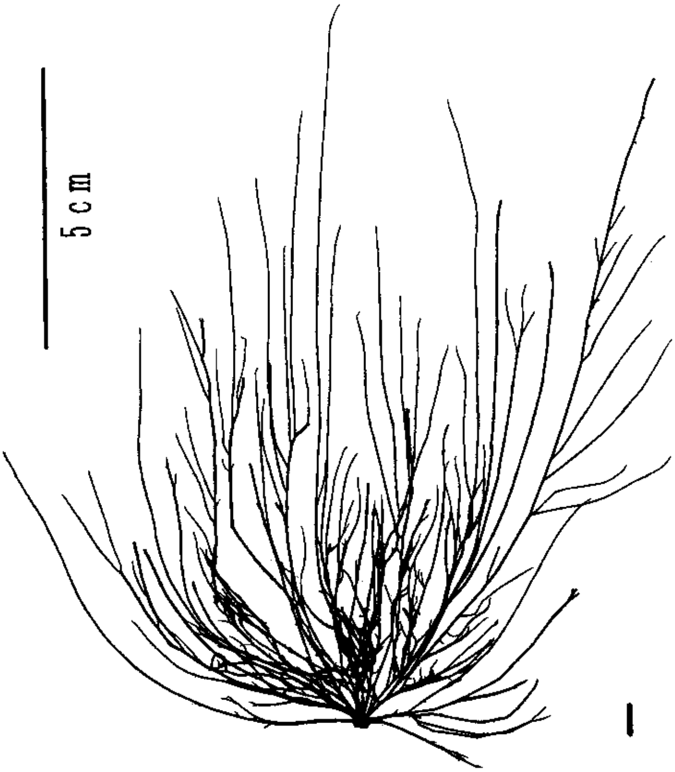
Gracilaria species can have a *Polysiphonia*-type life history, in which gametophytes alternate with tetrasporophytes through the carposporophyte. This finding has been confirmed for many species of *Gracilaria* in culture by several researchers (Table 1). Yamamoto (1978) reported that *G. chorda* has two ecotypic morphologies: var. *chorda* (Fig. 2) and var. *exilis* (Fig. 1; cf. Yamamoto 1995). The former has thick axes and sparse branches and commonly has both tetrasporophytes and gametophytes in regions with warm seawater temperatures. The latter has thin axes and many orders of branching and has more tetrasporophytes and few gametophytes in colder regions. The populations consisting of dominant tetrasporophytes suggest that some individual plants repeat only tetrasporophyte generations.

Materials and Methods

At Esashi (southern Hokkaido, Japan; annual range of seawater temperature, 5–23°C) in September 1993, we collected several mature sporophytes of *G. chorda* var. *exilis* in which sporangia divided into only two cells. The fronds were 25–30 cm long, up to 1.5 mm wide, and reddish brown. They were comparatively smaller than, but otherwise similar to, normal tetrasporophytes.

Several pieces were cut off from the mature sporophytes and shaken with sterile sand to remove surface contamination (cf. Yamamoto and Sasaki 1988). Some pieces were placed overnight in petri dishes with sterile seawater to permit release of spores. Spores released were transferred to 20-ml glass bottles, about 15 spores per bottle, to establish unialgal cultures. Ten sporelings 5–10 mm long (after about 45 days in culture) were detached from the substratum and transferred into a 500-ml flask for free-living cultures.

Culture conditions were as follows: temperature, 20°C; light, about 70 μE m^{-2} s^{-1} from cool white fluorescent lamps; photoperiod, 14 hr light and 10 hr dark; aeration, 0.1 l/min (for free-living cultures only). PES medium without vitamins was changed about once a week throughout the culture period. Bispores from raised fronds were cultured under the same conditions.



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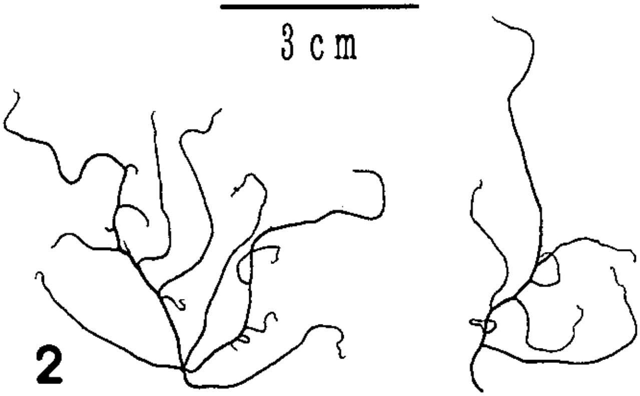

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Figs. 1 and 2. A bisporangial sporophyte in the life history of *Gracilaria chorda* var. *exilis* (Gracilariaceae). Fig. 1., A wild plant with bisporangia that were used to start culture experiments. Fig. 2., Cultured sporophytes in the third generation (F^3).

Table 1. Types of Life History of *Gracilaria* Species Confirmed in Culture

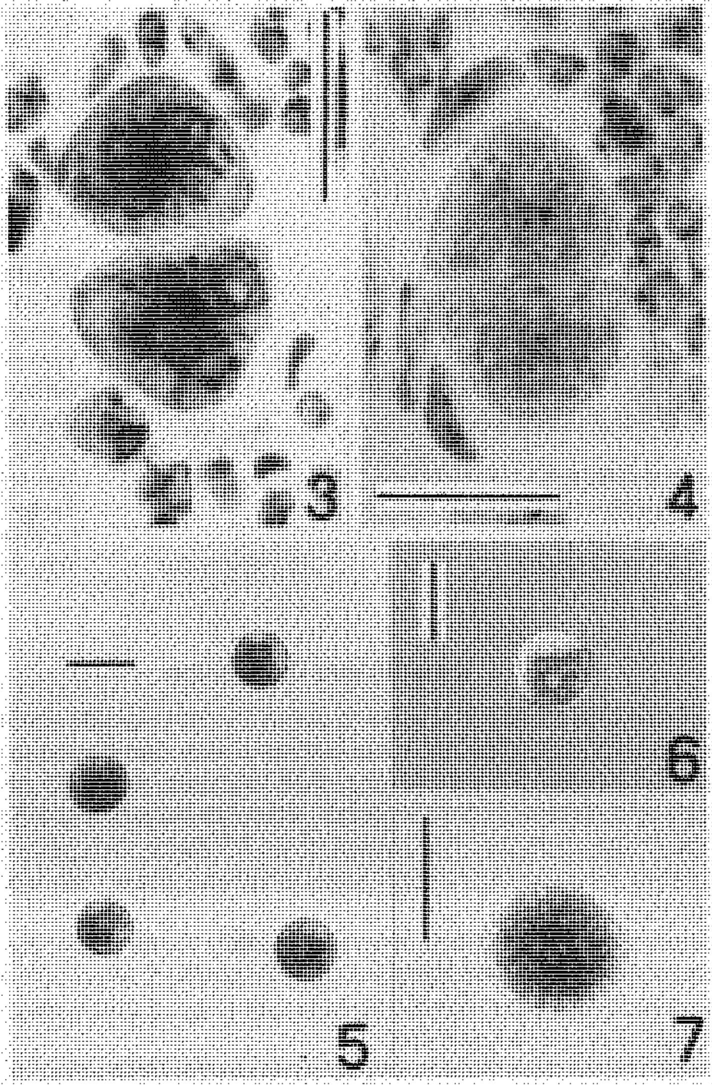
Species (Locality)	Type of Life History	Reference
G. verrucosa (=G. vermiculophylla, Japan)	*Polysiphonia*	Ogata et al. 1972, Yamamoto and Sasaki 1988
G. verrucosa (Britain)		Bird et al. 1982
G. verrucosa (Canada)		
G. foliifera (Canada)		McLachlan and Edelstein 1977
Gracilaria sp. (=G. tikvahiae, Canada*)*		Bird et al. 1977
G. compressa (Britain)		
G. debilis (Brazil)		Oliveira and Plastino 1984
G. arcuata (Philippines)		Yamamoto 1990
G. salicornia (Philippines)		Yamamoto 1991a
Gracilaria sp. (=G. manilaensis, Philippines)		Yamamoto 1991b
G. eucheumoides (Philippines)		Yamamoto and Noro 1993
G. heteroclada (Vietnam)		Yamamoto et al. 1994
G. firma (Vietnam)		Yamamoto et al. 1994
G. irregularis (Thailand)		Lewmanomont 1994
G. chorda var. *exilis* (Japan)	*Hildenbrandia*	This chapter

Results and Discussion

Bispore-derived fronds (F^1) grew to about 15 cm in length and released bispores about 80 days after the initial bispores were transferred to glass bottles. F^1 fronds were smaller (10–15 cm long) than wild ones (up to 30 cm) but similar in morphology and released many bispores, which developed into F^2 sporophytes just like the F^1 sporophytes. The spores of the F^2 plants also gave rise directly to F^3sporophytes, never going through a gametophytic phase. We are now culturing F^5 sporophytes.

Tetrasporangia of *Gracilaria* species generally divide cruciately into spores of almost equal sizes. However, the sporangia in question, which are up to 54 µm high and up to 36 µm wide, divide into two cells (Figs. 3 and 4) with a single nucleus (Figs. 5 and 6) in each cell.

We used microscopic fluorometry to compare the DNA value of the sporophytes with the DNA value of the cortical cells of normal gametophytes, which are N in nuclear phase. We confirmed that the sporophytes showed about double DNA value (2N). Thus, the bispores are always formed apomeiotically to initiate the next generation.



Figs. 3–7. A bisporangial sporophyte in the life history of *Gracilaria chorda* var. *exilis* (Gracilariaceae). Figs. 3 and 4, Fully mature bisporangia with a single nucleus (n) in a cell (spore). Figs. 5 and 6, Released bispores, with a single nucleus (n) each. Fig. 7, Early developmental stage of bispore, with normal division in the direct discoid type of development. Scale bars: 30 μm for Figs. 3–6; 400 μm for Fig. 7.

In this material, sporangia rarely divide unequally into four. They first divide transversely into two cells, with a single nucleus in each cell. Each of these cells divides again longitudinally into two cells, but one of the two is much smaller, has no nucleus, and is considerably pale. Accordingly, the spores released are larger in diameter (30–35 µm; Fig. 7) than the spores (18–23 µm) from normal tetrasporangia of this variety. Nuclear division in a sporangium occurs only once, not twice, even in instances in which a sporangium divides into four cells. In other words, cytokinesis does not follow karyokinesis in this variety. The sporangia are clearly bisporangia.

Although the reasons for this kind of activity are not known, it appears to be hereditary, because of the ability to repeat sporophytes consecutively. However, if these sporangia should divide normally into four cells (spores), the life history might return to the normal *Polysiphonia* type. Also, a mixture of sporophytes with two ploidy levels might occur. we do not know how many such fronds exist in a population of this variety. However, a population with sporophytes only is possible.

Several species of Nemaliales, Cryptonemiales, Gigartinales, Rhodymeniales, and Ceramiales have a life history in which only tetrasporophyte generations occur. This type of life history is called the *Hildenbrandia prototypus* type (cf. Umezaki 1977). It is difficult to conclude the taxonomic meaning of this phenomenon, because the morphology of the fronds in question is similar to that of normal fronds. At present, we can only say that such a condition exists in the field and can be repeated successfully under laboratory conditions for at least five generations.

Acknowledgments

We thank Dr. Isabella A. Abbott for her help in improving this manuscript.

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STUDIES ON TERETE SPECIES OF AUSTRALIAN *GRACILARIA*

Alan J. K. Millar and Xia Bangmei

Abstract

Examination of type and authentic specimens showed conspecificity of the Australian species *Gracilaria bifaria* J. Agardh with the widely distributed *G. edulis* (Gmelin) Silva. Two poorly known forms of *G. lichenoides* Greville, previously reported from Australia, are also representative of *G. edulis*. The distribution and identification of Australian specimens of *G. salicornia* (C. Agardh) Dawson and *G. blodgettii* Harvey are clarified.

Introduction

Because accurate identification of *Gracilaria* species requires not only the observation of all reproductive stages, especially spermatangial and cystocarpic plants, but also a range of specimens and populations, many of those species currently recorded for Australia are still only tentative determinations. As additional material and reproductive stages are collected, identifications are either confirmed or reassessed. This situation is particularly the case for many of the terete species of *Gracilaria* found in Australia because many more terete species than their flattened counterparts are known there. This condition seems to hold true for other continents and coastlines as well.

We had the opportunity to reexamine four terete species from Australia: *G. salicornia*, *G. blodgettii*, *G. edulis*, and *G. bifaria*. We found discrepancies in the literature, which we can now clarify.

Materials and Methods

Specimens were collected by SCUBA divers and were preserved in 4% formalin-seawater. Microscope slide material, stained with a mixture of aniline blue and corn syrup made according to the method of Millar and Wynne (1992), is 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 the methods of Millar (1990).

Results and Observations

Key to Three Species of Australian *Gracilaria*

1. Plants with prominent constrictions at branch bases 2
1. Plants without constrictions................ ....*G. edulis*
    2. Branches arising only at apices in an umbellate, vertcillate manner........................ .... *G. salicornia*
    2. Branches arising along sides and apices of axes. ....*G. blodgettii*

Description of the Species

Gracilaria edulis (Gmelin) Silva, Univ. Calif. Publ. Bot., p. 293, 1952.
(Figs. 1–4)

Basionym: *Fucus edulis* Gmelin, Historia Fucorum ..., p. 113, 1768.

Synonyms: *Polycavernosa fastigiata* Chang and Xia, Stud. Mar. Sinica, p. 125, 1963 (type location, Hainan, China); *Hydropuntia fastigiata* (Chang and Xia) Wynne, Taxon 38, p. 477, 1989; *Gracilaria bifaria* J. Agardh, Sp. gen. ordines algarum 3(4), p. 55, 1901. (type location, Port Stephens, NSW; lectotype, fig. 2); *Gracilaria lichenoides* Greville forma *lemania* (Kützing) May, CSIR Bull. 235, p. 32, 1948; *Sphaerococcus lemania* Kützing, Tab. Phyc. 18, p. 26, pl. 75, figs. a–c, 1868. (type location, New Caledonia); *Gracilaria lichenoides* Greville forma *taenioides* (J. Agardh) May, CSIR Bull. 235, p. 30, 1948; *Gracilaria taenioides* J. Agardh, Sp. gen. ordines algarum 2(2), p. 593, 1852. (type location, Sri Lanka); *Ceramianthemum taenioides* (J. Agardh) Kuntze, Rev. gen. plant. vascul..., p. 887, 1891.

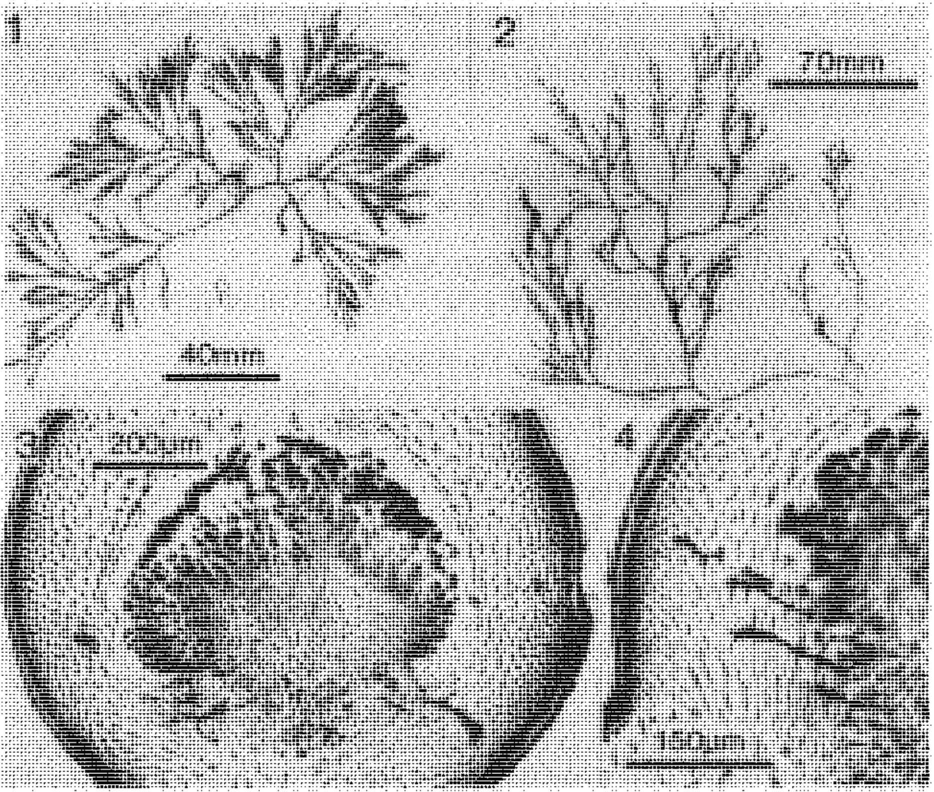
Plants to 12 cm tall, terete throughout. Axes to 500 µm in diameter. Branches fastigiate, alternate to subdichotomous (Figs. 1 and 2), black when dried. Cystocarps up to 1 mm in diameter, spherical with basal constriction (Fig. 3); basal traversing cells numerous, elaborately lobed (Fig. 4), few in upper parts; pericarp to 11 cell-layers thick. Spermatangial plants not yet observed in Australian material, but known to be of the polycavernosa-type.

Type Locality: Indonesia.

Distribution: Indian and Pacific oceans.

Specimens Examined: Queensland: Pretty Beach, H. Flecker, March 23, 1947, NSW (ex N. Qld. Nat. Herb. 10861); Palm Cove, –30 cm at mid tide, G. & R. Kraft, January 8, 1994, MELU K16213; Stradbroke Island, Amity Sand Flats, V. May 620, December 1, 1943, NSW. New South Wales: Port Stephens, Ramsay & Bennett, LD 29074 (lectotype of *G. bifaria*); Botany Bay, Georges River Bridge, V. May 543, March 11, 1945, NSW.

Remarks: May (1948) transferred as two forms of *G. lichenoides* (= *G. edulis*) and two species of *Gracilaria*: *G. taenioides* and *G. lemania*. Examination of the plants studied by May shows that they are not sufficiently different from those typical of *G. edulis* to warrant recognition as separate forms. Two of the specimens are cystocarpic and have prominently lobed traversing cells basal to the



Figs. 1–4. ***Gracilaria edulis.*** **Fig. 1, Cystocarpic plant with fastigiate branching (MELU K16,213). Fig. 2, Lectotype of *G. bifaria* (LD 29074). Fig. 3, Longitudinal section of cystocarp (NSW Slide 17-43). Fig. 4, Detail of traversing cells linking pericarp to gonimoblast (NSW Slide 17-44).**

gonimoblast, and in vegetative cross section, they are identical to that described by Xia and Abbott (1985).

Without examining the type specimen, May (1948) and Millar and Kraft (1993) debated the possible synonymy of *G. bifaria* J. Agardh and *G. edulis,* and Withell et al. (1994) placed *G. bifaria* in their *incertae sedis* section. Although sterile, the lectotype specimen (Fig. 2) of *G. bifaria* J. Agardh (LD 29074), since examined by one of us (AJKM), which was collected from Port Stephens on the north-central coast of New South Wales, Australia, has features considered typical of *G. edulis.* Recently collected cystocarpic specimens that match the type material in other anatomical details also have the traversing cells typically basal to the gonimoblast.

Spermatangial plants have not yet been observed in Australian material, but the habit, vegetative cross sections, cystocarp morphology, and traversing cell position otherwise strongly ally them with *G. edulis.* This alliance has also been confirmed by one of us (XB) and by Abbott, Yamamoto, Lewmanomont, and Ohno (personal communication).

Gracilaria salicornia (C. Agardh) Dawson, Bull. S. Calif. Acad. Sci. 53, p. 4, fig. 3, 1954; Withell, Millar, and Kraft, Aust. Syst. Bot. 7, p. 301, figs. 16–17, 1994 (in part).

(Figs. 5–7)

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

Synonyms: A full list is given by Xia (1986).

See Withell, et al. (1994, pp. 283–284) for a full description of Australian specimens of this species. Plants described by them as having lateral branches borne from the sides of axes are excluded (i.e., their fig. 14).

Type Locality: Manila Harbor, Philippines.

Distribution: Indian and western Pacific Oceans.

Specimens examined: Queensland: Thursday Island, on dead coral mounds, C. McConchie, August 23, 1978, MELU A25064.

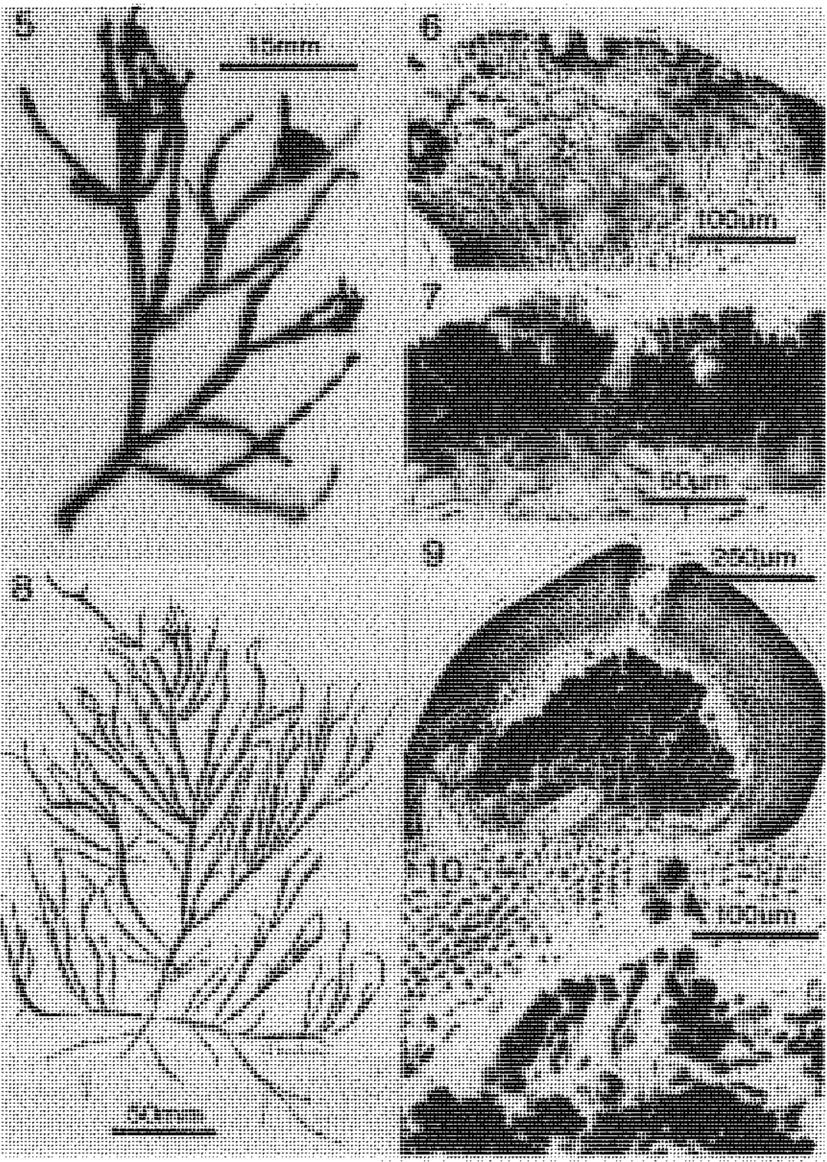
Remarks: Nine species have been reduced to synonymy under *G. salicornia* (Xia 1986). This reduction reflects the large variation in habit that is considered acceptable within this species complex. Branches of plants can be either completely entire, as in *G. canaliculata sensu stricto,* or have many prominent constrictions along their lengths, as in *G. salicornia sensu stricto* (Fig. 5). However, one important observation about constricted plants is the invariable nature of the placement of constrictions. For plants with prominent constrictions, the contrictions are only at branch bases, and the branch apices are obtuse (Fig. 5). Constrictions never occur along branch lengths in an intercalary fashion, and new branches arise only in an umbellate or apical manner. True lateral branches, that is, branches that arise along the side or length of a main branch, do not occur in *G. salicornia.* Within Australia, *G. salicornia* seems to be restricted to the eastern and northern seaboard, the records from Western Australia illustrated by Withell et al. (1994, figs. 14 and 15) actually represent *G. blodgettii* (see following).

All Australian populations collected to date have been monoecious, with verrucosa-type spermatangial pits (Figs. 6 and 7) borne on cystocarpic gametophytes. In addition, cortical paraphyses around spermatangial pits are pronounced in Australian plants (Fig. 7).

Gracilaria blodgettii Harvey, Nereis Boreali-Americana part II, p. 111, 1853.

(Figs. 8–10)

See Withell et al. (1994, pp. 283–284) for a full description of Australian specimens of this species.



Figs. 5–10. *Gracilaria salicornia* (Figs. 5–7) and *Gracilaria blodgetti* (Figs. 8–10). Fig. 5, Habit of typical *G. salicornia* with branching from apical parts only. Note that no branches are lateral to segments (MELU A25064). Fig. 6, Verrucosa-type spermatangial pits (NSW Slide 17-45). Fig. 7, Deep spermatangial pits with extended paraphyses (NSW Slide 17-45). Fig. 8, Habit of plant with lateral branches borne from sides of segments as well as apical parts (MELU K6550b). Fig. 9, Longitudinal section of cystocarp (NSW Slide 17-46). Fig. 10, Detail of traversing cell (NSW Slide 17-46).

Type Locality: Key West, Florida.

Distribution: Western Australia and possibly China and Japan.

Specimens Examined: Western Australia: Safety Bay, in drift, G. & C. Kraft, March 10, 1978, MELU K6550b.

Remarks: For the reasons stated in the remarks section for *G. salicornia* about branch constrictions, we now think that the specimens illustrated by Withell et al. (1994, figs. 14 and 15) as representative of *G. salicornia* actually represent *G. blodgettii* Harvey, a species they have also recorded and illustrated from western Australia. Compare, for example, the specimen from Penguin Island (our Fig. 8), collected from the south of western Australia, with those three illustrated by Withell et al. (1994, figs. 14A–14C) for *G. salicornia* and the three (figs. 2A–2C) illustrated for *G. blodgettii*. In all, lateral branches are common, and this feature is at odds with *G. salicornia,* in which branches arise only from apical parts of main branches and axes. Withell et al. (1994) recorded *G. blodgettii* only from the central-western Australian coast at Port Denison, but it now appears that this species is widespread along that coast. We consider the *G. canaliculata* form of *G. salicornia* illustrated by Withell et al. (1994, figs. 16 and 17) representative of authentic *G. salicornia*.

As described by Chang and Xia (1976), *G. articulata* is similar to Australian plants of *G. blodgettii*, but the former species has verrucosa-type spermatangial conceptacles and the latter has textorii-type pits. Cystocarps in Australian plants have a clearly defined, multilayered pericarp (Fig. 9), with traversing cells concentrated in lateral and upper parts of the gonimoblast (Fig. 10).

Conclusions

The poorly known *G. bifaria* J. Agardh, which was described on the basis of a single sterile specimen from Port Stephens on the New South Wales coast of eastern Australia (J. Agardh 1901), has vegetative features strongly aligning it with the widely distributed *G. edulis*, and thus for the present, we are placing it in synonymy. *Gracilaria salicornia* and *G. blodgettii* share a distinctive feature of branch constrictions. Although both are confirmed from Australia, critical details of the position and development of lateral branches are useful characters for separating these two species. Last, we have confirmed the presence of *G. edulis* in Australia on the basis of specimens collected in the northeastern regions of Queensland.

Acknowledgments

Sincere thanks to Dr. Gerald Kraft (University of Melbourne) for the loan of specimens primarily used in this study. Dr. Per Lassen (LD) kindly made available for loan the type specimen of *G. bifaria*. We thank the organizers of the sixth workshop, Dr. James Sullivan, Professor Isabella Abbott, and Dr. Phang Siew Moi, for the opportunity to participate. Drs. H. Yamamoto, M. Ohno, K. Lewmanomont, and Abbott offered excellent comments and advice on various aspects of the specimens used for this work. David Hardin printed the plates.

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SOME FLATTENED SPECIES OF *GRACILARIA* FROM AUSTRALIA

Alan J. K. Millar

Abstract

Four flattened species of *Gracilaria* from Australia are described. Two, *G. mayae* and *G. rhodymenioides*, are new species. A third, *G. multifurcata*, is a new record for the Pacific, and *G. textorii* is confirmed as occurring in Australia. Review showed that all previously published records of *G. textorii* from Australia do not represent this species.

Introduction

Research on Australian species of *Gracilaria* essentially began with a monograph by Valerie May (1948). Prompted by a wartime shortage of agar in Australia, May examined the then 24 recorded Australian species and concluded that recognition was justified for only 9. Little extra work on this economically important genus has been undertaken within Australia. The exception was research by Withell et al. (1994), who attempted to more clearly identify some of the lesser known species from the Australian tropics and subtropics. Many more poorly known, and inadequately described, species remain to be critically examined. This chapter attempts to clarify four of these species.

Australia has approximately 25–30 species of *Gracilaria* recorded from its shores (Withell et al. 1994). Of these, 6 are distinctly flattened: *G. halogenea* Millar, *G. mammillaris* (Montagne) Howe, *G. preissiana* (Sonder) Womersley, *G. stipitata* Withell, Millar et Kraft, *G. textorii* (Suringar) G. De Toni, and *G. vieillardii* Silva. However, for many years, these flattened species were not reexamined in light of the many new developments in the study of the genus *Gracilaria* (Abbott and Norris 1985; Abbott 1988, 1992, 1994, 1995) since May's (1948) work. Male plants, now considered of paramount importance in the ultimate identification of species, have remained unknown for some species and in others have not been critically compared with authentic material. During the study reported here, I was able to compare four flattened species with others from many countries and critically examine anatomical and reproductive details. The four species include two new ones, *G. mayae* and *G. rhodymenioides,* which are described in the following sections, and *G. multifurcata* Børgesen, which constitutes a new record for Australia and the Pacific. The occurrence of *G. textorii* is also confirmed.

Materials and Methods

Plants were collected by SCUBA divers and were preserved in 4% formalin-seawater. Microscope slide material, stained with a mixture of aniline blue and corn syrup made according to the method of Millar and Wynne (1992), is 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 the methods of Millar (1990).

Results and Descriptions

Key to Four Flattened Species of Australian *Gracilaria*

1. Plants consisting of large, undissected, wide (to 13 cm) blade, ... *G. mayae*
1. Plants branched or lobed, dichotomously or irregularly, less than 7 cm wide ... 2
  2. Branch apices acute, tapering .... *G. multifurcata*
  2. Branch apices broad, rounded 3
3. Plants with prominent terete stipe and strictly dichotomous branching .... *G. rhodymenioides*
3. Plants without terete stipe, irregularly branched or lobed .... *G. textorii*

Description of the Species

Gracilaria mayae Millar, sp. nov.

(Figs. 1–4)

Planta lamina magna complanata usque ad 30 cm longa, 13 cm lata atque 800 µm crassa; cellulae medullosae in cellulas corticales abrupte decrescentes. Cystocarpia hemisphaerica ad 2.5 cm lata et 1.5 mm alta; cellulae travertentes numerosae, in lateribus et tecto cavitatis cystocarpii locatae.

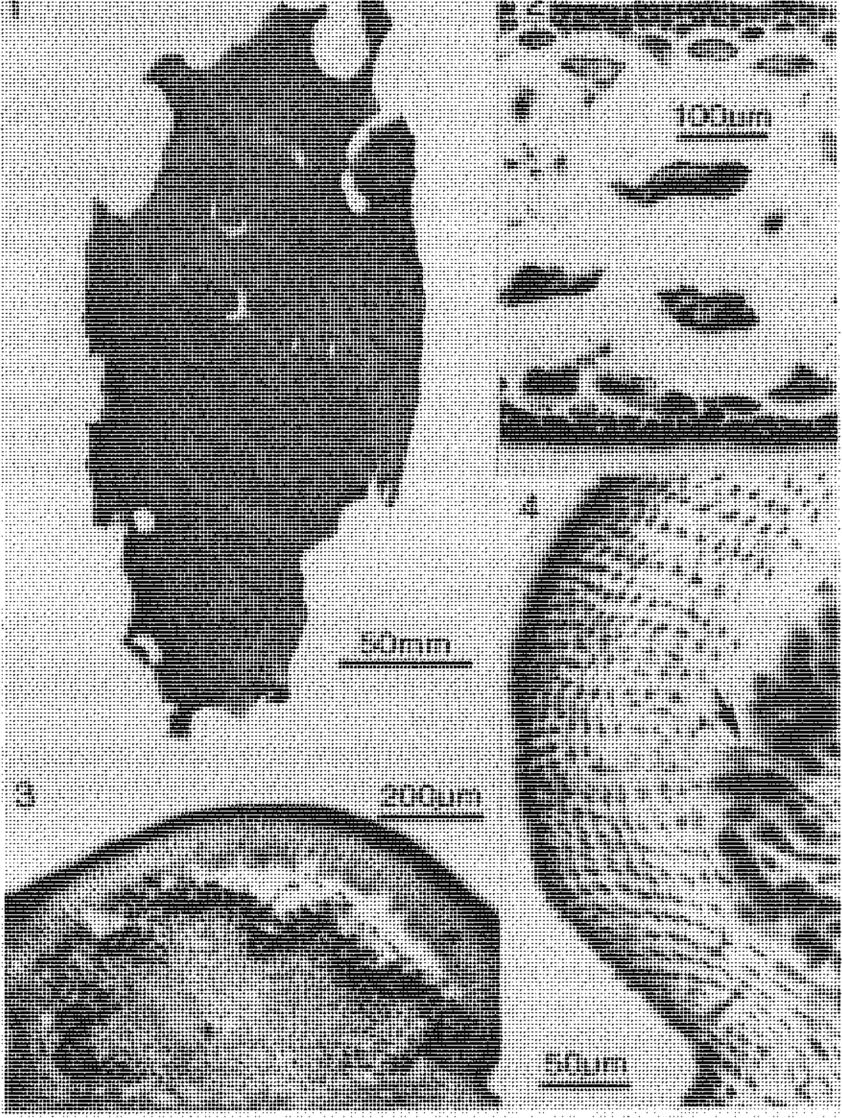
Plant a large flattened blade (Fig. 1), possibly more than 13 cm wide and 30 cm long, the margins broken or split at irregular intervals. Blades up to 800 µm thick, with large isodiametric medullary cells up to 300 µm grading abruptly to small, isodiametric cortical cells up to 10 µm in diameter (Fig. 2). Cystocarps (Fig. 3) large, hemispherical up to 2 mm wide and 1.5 mm high, the carposporangia obovoid to spherical, up to 40 µm in diameter. Traversing cells (Fig. 4) numerous, large, penetrating deep into both pericarp and gonimoblast tissue, borne along sides and roof of cystocarp cavity, never basal to gonimoblast. Pericarps up to 18 cell layers thick.

Etymology: Named in honor of Valerie May (Jones), honorary phycologist at the Royal Botanic Gardens, Sydney, who first collected specimens of this species in 1948 and who pioneered the study of *Gracilaria* in Australia.

Type Locality: Bongin Bongin Bay, Mona Vale, New South Wales, Australia.

Holotype: NSW 285666, A. J. K. Millar and P. G. Richards, March 18, 1994, collected in the drift.

Distribution: So far known only from the Sydney metropolitan area of New South Wales, Australia.



Figs. 1–4. *Gracilaria mayae* Millar, sp. nov. Fig. 1. Holotype fragment bearing numerous cystocarps. NSW 285685. Fig. 2. Cross section through vegetative area of blade. NSW Slide 17-42. Fig. 3. Longitudinal section through mature cystocarp. NSW Slide 17-42. Fig. 4. Section of pericarp and outer gonimoblast showing traversing cell (arrow). NSW Slide 17-42.

Habitat: To date, only six fragments of blades have been collected in the drift; the largest fragment is 13 cm wide and 30 cm long. It is clearly only part of a larger blade. There is no sign of a stipe anywhere around the margin, which is split in parts. Plants have not been observed in situ but most likely reach much larger sizes than what has been seen in the drift.

Specimens Examined: Isotypes, NSW 285664, NSW 285665; paratypes, drift at Collaroy Beach, V. May 2560, February 13, 1948, NSW 369191, NSW 369194, NSW 369195.

Remarks: Describing a new species of *Gracilaria* on the basis of only six fragments might be considered fraught with uncertainty. If the two collections were not from the same place, yet separated by some 50 years and identical in size, shape, and internal anatomical details, this might be the case. May's collections from 1948 were tentatively labelled *Curdiea* (?), but sections of the cystocarps clearly show the diagnostic and unique traversing cells that represent the genus *Gracilaria*. Within the genus, no species is even remotely similar in its presumably single, broad blade and gigartina-like cystocarps covering the entire blade surfaces. It will be advantageous to find spermatangial plants and be better able to place the species within one of the subgenera, but the generic identity and its undescribed status are certain.

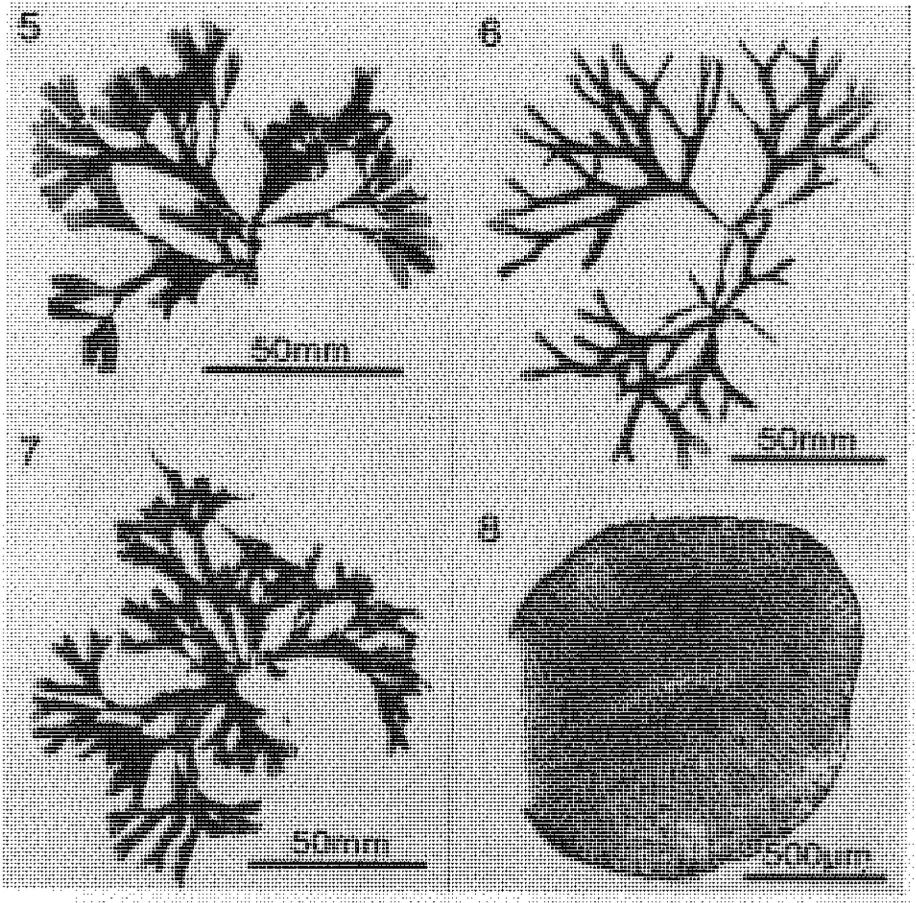
Gracilaria rhodymenioides Millar, sp. nov.

(Figs. 5–12)

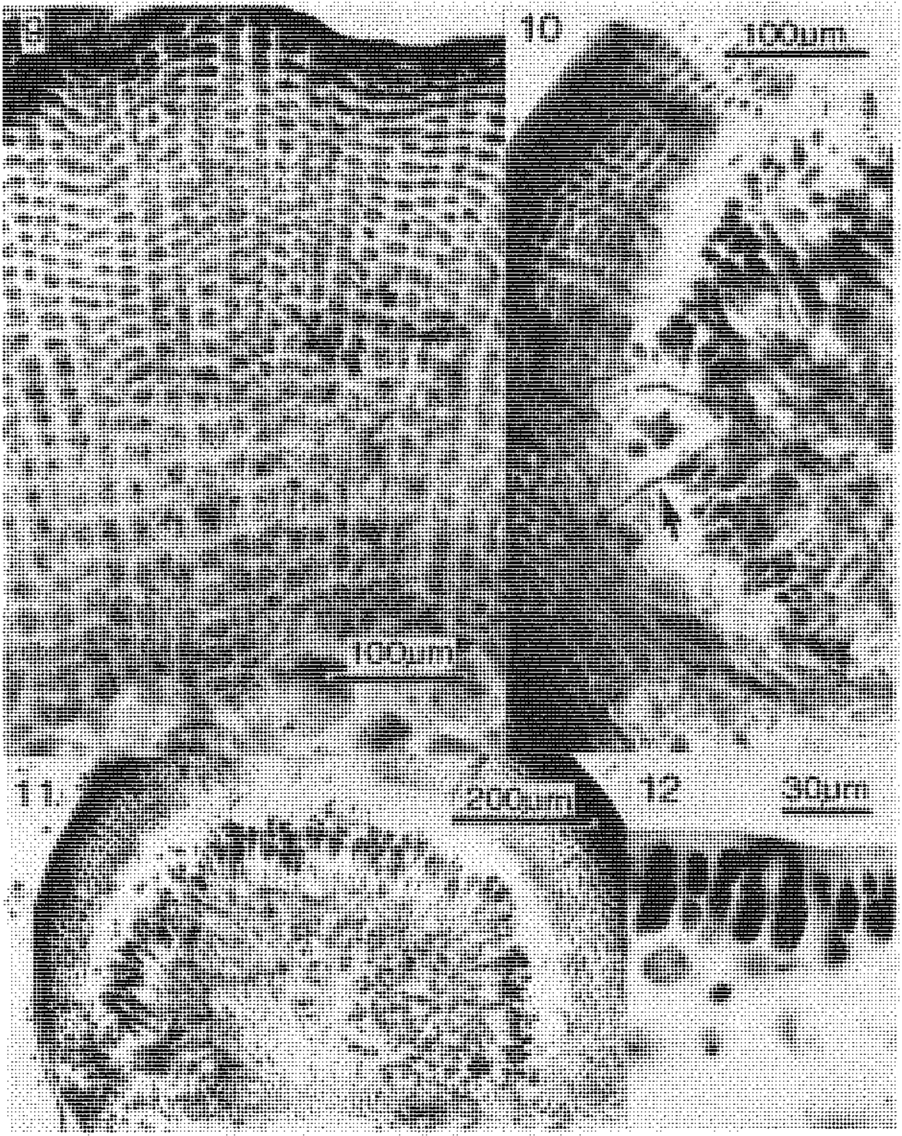
Misapplied Names: *Gracilaria* cf. *veleroae* Dawson *sensu* Millar, Aust. Syst. Bot. 3, p. 338, figs. 18A–18D, 1990. Millar and Kraft, Aust. Syst. Bot. 6, p. 28, 1993; *Gracilaria mammilaris* (Montagne) Howe *sensu* Withel, Millar and Kraft, Aust. Syst. Bot. 7, pp. 312, 347, 348, 1994.

Plantae complanatae ad 11 cm altae ramificatione dichotoma, divisione ad 1.5 cm lata alibi 1–7 mm lata, 200–850 µm crassa; cellulae medullosae gradatim decrescentes peripheriam versus. Cystocarpia ad 2.3 cm diametro, hemisphaerica et basaliter constricta; cellulae travertentes numerosae, in lateribus et tecto cavitatis cystocarpii *locatae*.

Plants (Figs. 5–7) erect from crustose holdfast, several fronds per holdfast, to 11 cm high. (Blades flattened, 200–850 µm thick, up to 1.5 cm wide at dichotomies, 1–7 mm wide elsewhere. Blades borne on a stalk up to 1 cm long and 3 mm in diameter; stalk cross section with pseudoparenchymatous central medulla (Fig. 8) surrounded by radiating anticlinal cortical rows (no obvious "growth rings" present, Fig. 9). Blades to nine times regularly dichotomously branched, when damaged producing numerous branched shoots from either apices or margins; margins otherwise entire and smooth. Medulla composed of subisodiametric, nonpigmented cells up to 200 µm in diameter, decreasing gradually in size peripherally. Cortex sharply defined, composed of one to two layers of small, heavily pigmented cells up to 16 µm in diameter. Tetrasporangia borne in an unmodified cortex (Fig. 12). Spermatangia not observed. Cystocarps (Fig. 11) up



Figs. 5–8. *Gracilaria rhodymenioides* Millar, sp. nov. Fig. 5, Holotype specimen with prominent stipe. NSW 391271. Fig. 6, Regularly branched plant bearing cystocarps. NSW A011535. Fig. 7, Tetrasporangial plant. NSW 391272. Fig. 8, Cross section through stipe. NSW Slide 14-93.



Figs. 9–12. *Gracilaria rhodymenioides* Millar, sp. nov. Fig. 9, Cellular detail of stipe cortex. NSW Slide 14-93. Fig. 10, Traversing cells (arrow) linking pericarp with gonomiblast. NSW Slide 14-90. Fig. 11, Longitudinal section through mature cystocarp. NSW Slide 14-90. Fig. 12, Cruciate tetrasporangia in cortex. NSW Slide 14-91.

to 2.3 mm in diameter, hemispherical and basally constricted, scattered over thallus surface except at bases and apices; pericarp consisting of 15–20 layers of cells in anticlinal rows (Figs. 10 and 11); numerous traversing cells (Fig. 10) present between gonimoblast cells and pericarp.

Etymology: Named for its gross morphological similarity to *Rhodymenia* species.

Holotype: MELU AM 599, Muttonbird Island, Coffs Harbour, New South Wales, Australia, A. J. K. Millar and P. W. Gabrielson, August 13, 1982.

Distribution: From Byron Bay in the north of New South Wales south to metropolitan Sydney and at Norfolk Island in the southwestern Pacific.

Habitat: This species grows on rocks from 7 to 20 m deep, generally on the sandy seabed in the scour zone where little else grows. Although occasionally repent, it is never secondarily anchored to the substratum.

Specimens Examined (paratypes), Byron Bay: Wide Wilsons Reef, 15 m deep, A. Millar and P. Richards, July 29, 1992, NSW A011709; The Nursery, Julian Rocks, 13 m deep, A. Millar and P. Richards, July 28, 1992, NSW A011677. Coffs Harbour: Muttonbird Island, 7 m deep, A. Millar, J. Huisman, and S. Chidgey, January 15, 1982, MELU AM565; A. Millar and S. Chidgey, October 20, 1986, Ex MELU AM1230; 7.6 m deep, A. Millar and P. Richards, November 29, 1992, NSW A011927; Korffs Islet, Coffs Harbour, 20 m deep, A. Millar and P. Gabrielson, January 22, 1982, MELU AM591, AM593, and Ex MELU AM592 (in NSW); Split Solitary Island, 20 m deep, A. Millar and P. Richards, June 3, 1989, NSW A006767–A006770; 20 m deep, A. Millar and R. Millar, February 22 , 1989, NSW A006457, 006456. Port Stephens: Fly Point, 10 m deep, A. Millar and P. Richards, November 22, 1991, NSW A010673, A010683; Halifax Park, 22 m deep, A. Millar and P. Richards, November 23, 1991, NSW A010666; north-northwest of Point Stephens, North of Fingal Island, 22 m deep, A. Millar and P. Richards, May 18, 1993, NSW A011535. Collaroy: near Sydney, drift, V. May 2581, December 23, 1948, NSW 391274; V. May 392, July 15, 1944, NSW 391288, V. May 869, June 8, 1945, NSW 391273. Norfolk Island: Duncombe Bay, 20 m deep, A. Millar and P. Richards, December 16, 1994, NSW 391965.

Remarks: Millar (1990, referred to as *G. veleroae*) has discussed the similarities this Australian species shares with other flattened species such as *G. textorii*, *G. mammillaris*, and *G. peruana*.

This new *Gracilaria* species was first tentatively identified as a *Rhodymenia*, until a section of the cystocarps showed the diagnostic traversing cells typical of many species of *Gracilaria*. The prominent terete stipe from which flattened, dichotomously branched blades arise is similar to that seen in *R. sonderi* Silva et al. (IOC; formerly *R. australis* Sonder) and is unusual for species of *Gracilaria*. Frustratingly, in the many specimens examined, no male plants bearing spermatangia have been discovered, so the subgeneric status of this alga must remain uncertain.

Early collections of this species were tentatively identified as *G. veleroae* Dawson. That species, which is now considered to be synonymous with *G. mammilaris*, does not have the thick, prominent stipe of *G. rhodymenioides* and is considered to be restricted to the central-eastern Pacific.

Gracilaria multifurcata Børgesen, Det. Kongl. Danske Vidensk. Selskab, Biol. Meddel 21(9), p. 42, figs. 15 and 16, 1953.

(Figs. 13–19)

Synonyms: *Polycavernosa multifurcata* (Børgesen) Chang and B. Xia, Stud. Mar. Sinica, 3, p. 123, 1963; *Hydropuntia multifurcata* (Børgesen) Wynne, Taxon 38, p. 477, 1989.

Misapplied Names: *Gracilaria textorii* (Suringar) G. De Toni f. *textorii* May, CSIR Bull. 235, p. 43, pl. 8, fig. 2, pl. 9, fig. 1, 1948; *Gracilaria textorii sensu* Millar and Kraft, Aust. Syst. Bot. 6, p. 28, 1993.

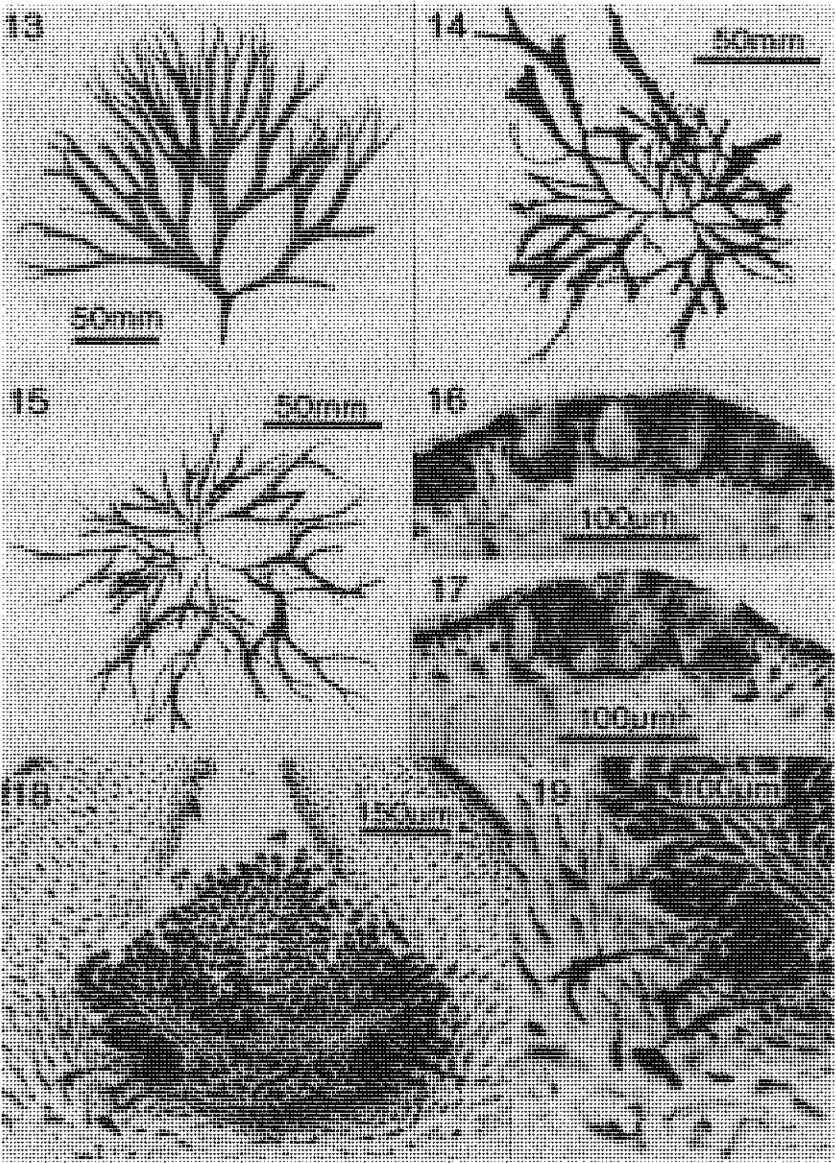
Plants erect (Figs. 13–15) from a small dicoid holdfast, to 22 cm high; branches flattened, 1.2 mm thick and up to 22 mm wide at dichotomies, regularly dichotomously (Fig. 13), divaricately (Fig. 14) to alternately branched (Fig. 15), often with small lateral branchlets (proliferations) bordering main axes (Fig. 15); apices acute, tapered (Figs. 13 and 15), never rounded; medullary cells up to 760 µm in diameter, tapering abruptly to cortical cells up to 10 µm in diameter. Cruciately divided tetrasporangia scattered thoughout cortex, obovate, 40 µm × 28 µm. Spermatangial conceptacles (Figs. 16 and 17) mostly deep and polycavernosa type (Fig. 17), occasionally shallower and verrucosa type (Fig. 16). Cystocarps (Fig. 18) papilate to hemispherical, up to 1.3 mm in diameter; pericarp consisting of 12–15 layers of cells in anticlinal rows; traversing cells numerous (Fig. 19), issuing from base and lower sides of gonimoblast.

Type Locality: Pointe aux Sables, Mauritius.

Distribution: Western Indian (Mauritius and Seychelles) and southwestern Pacific oceans.

Specimens examined: Queensland: Great Barrier Reef, Ribbon Reef 4, 32 m deep, A. Siotas, November 21, 1985, MELU A041735–A041737; Moreton Bay, Fishermans Island, drift, V. May 795, December 24, 1943, NSW 391386; V. May 792, April 1943, NSW 391385. New South Wales: Port Stephens, west side of Cabbage Tree Island, 11 m deep, A. Millar and P. Richards, May 19, 1993, NSW A011727–A011729; Woy Woy, Hawkesbury River, trawled, V. May 791, February 9, 1943, NSW 391384; Botany Bay, A. Lucas, January 1912, NSW 391387; February 1905, NSW 391388; Sandringham, Sans Souci, A. Lucas, January 1904, NSW 391389; Weeny Bay, drift, V. May 887, February 20, 1945, NSW 391381; Quibray Bay, drift, A. Millar, April 6, 1989, NSW A005187–A005189.

Remarks: Although these plants have a superficial similarity to typical habits of *G. textorii*, the Australian plants of *G. multifurcata* are easily recognized by their acute branch apices, somewhat regularly dichotomous habit, and their pliable and leathery texture. Authentic *G. textorii* generally has rounded branch apices and



Figs. 13–19. *Gracilaria multifurcata* Børgesen. Fig. 13, Habit of regularly branched plant without lateral proliferations. NSW 301387. Fig. 14, Habit of tetrasporangial plant. NSW A011728. Fig. 15, Habit of cystocarpic plant bearing lateral proliferations. NSW A011727. Fig. 16, Spermatangial cavities looking like verrucosa type. NSW Slide 17-41. Fig. 17, Polycavernosa-type spermatangial cavities. NSW Slide 17-41. Fig. 18, Longitudinal section through mature cystocarp. NSW Slide 2-99. Fig. 19, Detail of traversing cells. NSW Slide 2-99.

irregular branching and is on the whole much thicker and more cartilaginous. Sections of the Australian male plants also clearly show the polycavernous nature of the spermatangial conceptacles, as was beautifully illustrated by Børgesen (1953) for Mauritius plants. This finding contrasts strongly with the shallow textorii-type pits typical of *G. textorii.* What is interesting about the Australian male plants is that they display spermatangial types that range from the open verrucosa type to the multicavitied polycavernosa type. Possibly, they have two or more verrucosa-type cavities side by side, giving the impression of a polycavernous-type of spermatangial conceptacle (Yamamoto, personal communication). If it were not for the deep cavities, remotely separated from the cortical tissue, this could be the case in other species. This mixture of spermatangial cavities is shared with *G. mixta* Abbott, Zhang and Xia (1991) and *G. harveyana* J. Agardh (Withell et al. 1994), a finding that further strengthens the case for not recognizing *Polycavernosa* as a genus distinct from *Gracilaria. Gracilaria mixta* and *G. harveyana* are very different from *G. multifurcata* in their terete habits.

Børgesen (1953) described Mauritius plants as forming extensive cushions on exposed rocks, a habit and habitat quite different from the free and erect nature and strictly subtidal habitat of the plants collected in Australia. He also described Mauritius plants as being 1–2 mm wide and 500 µm thick, which is considerably narrower (5–10 mm) and thinner (1.5–2.0 mm) than the Australian plants. In addition, the spermatangial cavities were illustrated as being deeply imbedded in the branches and not near the outer cortex as in the Australian populations. The Australian plants may represent a distinct species, but the two populations do have remarkably similar features in their branching patterns, with branch apices tapering to acute points, and in their consistency. Given the variations within other *Gracilaria* species (e.g., *G. salicornia*), this variation within this species probably should be tolerated until further studies are done.

If the spermatangial conceptacles of the Australian species were strictly of the verrucosa type (and not the mixture of verrucosa and polycavernosa types), there would be a strong case for allying the plants with the Japanese species *G. sublittoralis* Yamada and Segawa (Yamamoto 1994). However, the presence of prominent traversing cells basal to and on the lower side of gonimoblast tissue is a character at odds with *G. sublittoralis.* In addition, *G. sublittoralis* has generally broader (to 6 cm) blades and rarely has the lateral proliferations that are a noticeable feature of *G. multifurcata.*

Lucas (1909), Gepp and Gepp (1906), May (1948, 1965), and May et al. (1978) have all incorrectly and consistently identified the Australian plants as *G. textorii.* The preceding description of *G. multifurcata* apparently is the first record of this distinctive species not only for Australian waters but also for the Pacific Ocean.

Gracilaria textorii (Suringar) G. De Toni, Mem. Reale Istituto Veneto Sci., Lett Arti 25, p. 27, 1895.

(Figs. 20–24)

Basionym: *Sphaerococcus* (*Rhodymenia*) *textorii* Suringar, Ann. Musei Bot. Lugduno-Batavi 3, p. 259, 1867. Hedwigia 9, p. 135, 1870.

Plants (Figs. 20 and 21) erect from a single holdfast, up to 15 cm high; blades flattened (up to 800 µm thick), up to 6.5 cm wide, deeply cleft or lobed, occasionally branched and with marginal leaflets that develop from minute, toothlike hairs at the bases of mature blades; apices of lobes rounded (Figs. 20 and 21), never tapered or acute; medullary cells large, isodiametric up to 250 µm, tapering gradually in size to small-celled cortex. Tetrasporangia not observed. Spermatangial conceptacles (Fig. 22) shallow, textorii type. Cystocarps (Fig. 23) hemispherical to slightly basally constricted, up to 1.4 mm in diameter; traversing cells numerous (Fig. 24), connecting sides and roof of cystocarp cavity to gonimoblast tissue, never basal to gonimoblast; pericarp up to 25 layers of cells in anticlinal rows.

Type Locality: Japan.

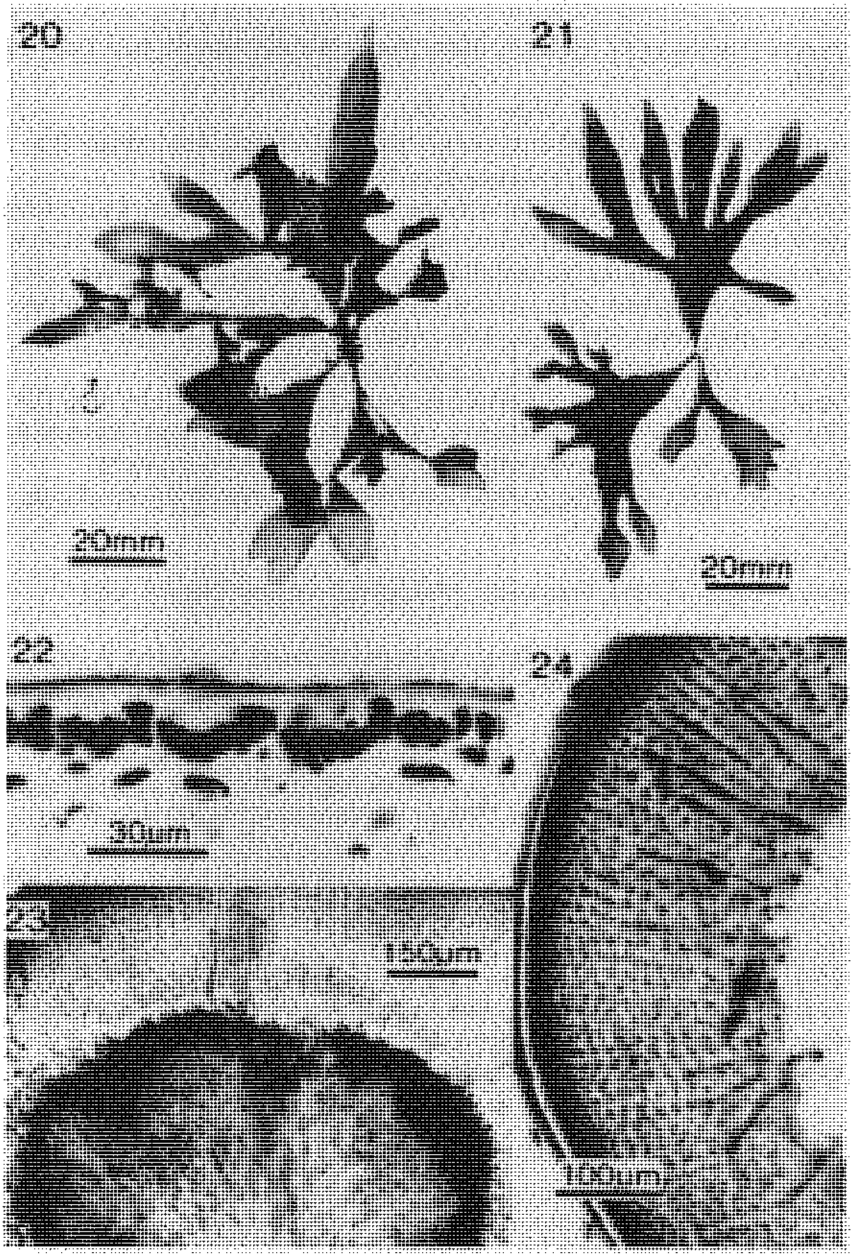
Distribution: Japan, China, Indonesia, Philippines, eastern Pacific, and Australia.

Specimens Examined: Coffs Harbour: Muttonbird Island, 8 m deep, A. Millar and P. Richards, November 29, 1992, NSW A011919–A011926; 5–8 m deep, A. Millar and P. Gabrielson, August 13, 1982, Ex MELU AM597 and AM598.

Remarks: Although *G. textorii* has long been recorded and identified as occurring in Australia, the plants on which such identifications have been based actually represent *G. multifurcata* as described by Børgesen (1953) and in this account. The plants from Coffs Harbour display the broadened apices and the shallow textorii-type spermatangial depressions typical of authentic *G. textorii* and are clearly different from plants of *G. multifurcata* with acute apices and cavernous spermatangial pits. In Australia, the distribution of *G. textorii* would seem to be restricted to the Coffs Harbour region of New South Wales. One collection from the Houtman Abrolhos in Western Australia shows many of the distinctive anatomical and habit features of *G. textorii*. All these plants have so far been sterile, so their actual identity remains uncertain.

Acknowledgements

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. Dr. Phang Siew Moi and students of the University of Malaya organized accommodation and excellent guidance and company during the workshop. Drs. Hirotoshi Yamamoto, Masao Ohno, Bangmei Xia, Khan Lewmanomont, and Anong Chirapart gave superb advice and had sympathetic ears. Thanks also to Dr. Peter Wilson for translating the Latin descriptions and to David Hardin (Royal Botanic Gardens, Sydney) for his photographic help and expertise.



Figs. 20-24. *Gracilaria textorii* (Suringar) De Toni. Fig. 20, Habit of male plant. Note rounded apices of lobes. NSW 282995. Fig. 21, Habit of female plant bearing cystocarps. NSW A011919. Fig. 22, Detail of textorii-type spermatangial pits. NSW Slide 15-50. Fig. 23, Longitudinal section through mature cystocarp. NSW Slide 15-46. Fig. 24, Detail of traversing cells in pericarp. NSW Slide 15-46.

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Section IV. *Hypnea* Species

INTRODUCTION

Isabella A. Abbott

Hypnea species, like corallines and *Ulva* and *Enteromorpha* species, are among the algae to be avoided. In comparison, they make genera like *Gracilaria* or *Pterocladia* seem easy to work with. When is a spinelike protuberance a spine and not a short branch? When is it a protuberance and not a spine, for that matter? Are tetrasporangial sori for any given species *always* in the same position? Why do some species have a central axial strand surrounded by rhizoidlike filaments and other species have only a single axial filament; should not this variation give a hint that there might be a *generic* difference?

I have spent many hours, days, weeks, months, and years on a variety of difficult genera. (I still work on my favorite of all genera, *Liagora,* on which I obtained my master's degree with Prof. W. R. Taylor, when not writing books or editing.) However, I would not, for the world, touch *Hypnea.* As Professor Taylor himself would have told me when I was 20, "You're too old to start a monograph on that genus."

Fortunately for those of us who live with a warm Pacific marine algal flora, Dr. Masuda never heard such warnings, and in his usual organized style, he got his graduate student, Yukimasa Yamagishi, to study Japanese species for Yamagishi's Ph.D. research. I am pleased to present the work on the Japanese species as the centerpiece of this section on *Hypnea.* As satellites, we have contributions by Lewmanomont (Thailand), Young-Meng Chiang (Taiwan), and

Xia Bangmei (China). The opportunity to study "local floras" containing *Hypnea* species was made easier by the larger project of Yamagishi and Masuda, and I thank them for this stimulation. Should *Hypnea* be used again for its colloids, we will have Drs. Yamagishi and Masuda to thank, again.

Note on the Authors of *Hypnea spinella*. In accordance with the work of Haroun and Prud'homme van Reine, the *Hypnea* group used the authorship of *H. spinella* (C. Agardh) J. Agardh, but I noted that the name was "under a cloud" in the Philippine catalog by Silva et al., who used *H. spinella* (C. Agardh) Kützing. I telephoned Dr. Silva, and he told me that Kützing had priority of 3 days. Therefore, according to the International Code of Botanical Nomenclature on priority (Article 11.3), we are required to use Kützing as the combining author (because there are no other limitations). However, Haroun and Prud'homme van Reine might have chosen to follow J. Agardh's taxonomic opinion, so I have left their citation of *H. spinella* with J. Agardh as the combining author. The correct nomenclatural citation, however, must have Kützing as the combining author.

OVERVIEW OF *HYPNEA* (RHODOPHYTA, HYPNEACEAE)

Michio Masuda, Yukimasa Yamagishi, Young-Meng Chiang, Khanjanapaj Lewmanomont, and Xia Bangmei

Introduction

The red algal genus *Hypnea* (Hypneaceae, Gigartinales) with five species was erected by Lamouroux (1813). The generic name is based on its mosslike appearance: "Ainsi nommé parce que ces plantes ressemblent par leur port aux mousses du genre *Hypnum* de Linné" (Lamouroux 1813, p. 131). The genus *Hypnea* was lectotypified with *H. hamulosa* (Turner) Lamouroux by Schmitz (1889, p. 443). However, this binomial is not valid. Lamouroux (1813, p. 132) listed this name as follows: "*Hypnea hamulosa—Fucus hamulosus*? Id. [Turn. Hist.]...Ind. Orient." If its basionym is Turner's *F. hamulosus* (Turner 1809, p. 19), it should be treated as a later homonym of *F. hamulosus* Esper (1800, p. 169). Because later homonyms are illegitimate, *F. hamulosus* Turner cannot serve as a basionym. Indeed, Turner did not describe his plant as new, but identified it with Esper's *F. hamulosus* (therefore, the same species). When Lamouroux (1813) intended to give his plant a new name, the binomial *H. hamulosa* Lamouroux is *nomen nudum*, because neither a description nor an illustration of the plant was given. The name *H. hamulosa* has been attributed to (Turner) Montagne (De Toni 1900, p. 477; Tanaka 1941, p. 245), but this name is not valid as mentioned previously. Kylin (1932, p. 47) proposed *H. musciformis* (Wulfen) Lamouroux as the lectotype (without apparently being aware of Schmitz's proposal fide Papenfuss 1958). Papenfuss (1958) proposed the adoption of Kylin's selection, in view of the confusion associated with nomenclature and taxonomy of *H. hamulosa* and the fact that the epithet *musciformis* must have suggested the generic name *Hypnea* to Lamouroux. Farr et al. (1979, p. 859) cited *H. musciformis* as the lectotype of *Hypnea*.

Circumscription of the Genus

The genus *Hypnea* is circumscribed as follows on the basis of information given by previous workers (Kylin 1956, Hewitt 1960, Tazawa 1975, Abbott and Hollenberg 1976, Millar 1990) and findings from our studies. Plants have uniaxial upright fronds composed of a distinct axial filament surrounded by a pseudoparenchymatous cellular medulla and a cortex. The life history is of the *Polysiphonia* type in which isomorphic, dioecious gametophytes and tetrasporophytes occur and a diploid carposporophyte develops on the female gametophyte.

Spermatangia are produced in slightly or conspicuously swollen parts of terminal branchlets or proliferations or both, and are cut off from outermost cortical cells in chains. Carpogonial branches are three-celled, are formed laterally on inner cortical cells, and are directed outward. An auxiliary cell is a daughter cell of the supporting cell and is identifiable before fertilization. Gonimoblast filaments are first directed toward the medulla (inward) and later outward, forming connections with pericarps and producing terminal, single carposporangia. Pericarps are devoid of distinct carpostomes. Tetrasporangia are terminal on the corticating filaments in nemathecioid, swollen parts on short, terminal branchlets or proliferations or both, often called stichidia, and are zonately divided.

After Lamouroux's work (1813), many species were added to *Hypnea*. J. Agardh (1852) described 19 species (and an additional 3 treated as "species inquirendae") and divided them into three sections on the basis of plant habits: *Virgatae, Spinuligerae,* and *Pulvinatae* in the genus *Hypnea*. Additional species were described during half a century, for a total of about 60 species. De Toni (1900, 1924) enumerated 31 species, some of which synonymized other species. Dawson (1962) recorded 15 new species described since De Toni's publication (1924), although *H. yamadae* Tanaka (1960) was not included. Relatively few species have been added to this genus since Dawson (1962): *H. coccinea* (Clemente) Cremades (Cremades and Pérez-Cirera 1990, p. 490), *H. filiformis* (Harvey) Womersley (1994, p. 438), *H. furnariana* Cormaci, Alongi et Dinaro (Cormaci et al. 1993, p. 228), and *H. volubilis* Searles (Schneider and Searles 1976, p. 53). Thus, the genus *Hypnea* now includes some 50 species, although the status of some species described in the 19th century has not been exactly established.

The species of *Hypnea* have small to large-sized plants and are found in warmer waters in the world. After the work of J. Agardh (1852), these species have been chiefly studied in floral investigations (e.g., Børgesen 1943, Taylor 1960, Dawson 1961, Pham 1969, Millar 1990, Womersley 1994). Even monographic studies of the genus have been limited to regional species (Weber-van Bosse 1928, Tanaka 1941, Mshigeni 1978).

Different circumscription of species concerned might cause taxonomic confusion (cf. Yamagishi and Masuda in this volume). A recent taxonomic revision of the southern Australian species of *Hypnea* has revealed many obscure synonyms (Womersley 1994). Similar taxonomic revisions are obviously needed in other regions. Because many species have wide ranges of geographical distribution, critical reassessment of morphological features is required on the basis of correct information on the type material and/or specimens collected at the type locality to circumscribe each species exactly.

Morphological Characteristics of Possible Taxonomic Value

The following morphological characteristics may have taxonomic values at the species level in *Hypnea* according to previously published information and our observations.

Although at present we cannot assess the variability of these characteristics, we use them provisionally as diagnostic features of species of *Hypnea*. The real taxonomic values of these characteristics should be elucidated by future experimental studies or by morphometric methods.

Basal System and Plant Habit. Plants are attached to the substratum by a primary discoid holdfast and creeping or descending branches with secondary discoid holdfasts. Development of creeping branches characterizes the basal system of most plants. Those with well-developed creeping branches are conspicuously entangled at the basal part and are called entangling ("intricate-caespitose") tufts, because each plant has several axes. Plants with weakly developed creeping branches are not entangled and are called "caespitose" (tufted). This feature has been used by many authors.

Some species have branches coalesced to one another at points and form cushionlike plants; others do not have such branches, and each axis is free from the base or from the entangling basal part. When J. Agardh (1852) established the three sections mentioned earlier, he adopted these habits of plants as a major critical feature of the sections. Tanaka (1941) followed the example of J. Agardh (1852). Many other investigators have used these features to distinguish species groups or species (e.g., Dawson 1961, Mshigeni 1978).

Plant Size. Some species have plants larger than 50 cm, but others have small plants less than 3 cm. This feature has been used by some authors (e.g. Mshigeni 1978).

Plant Texture. Plant texture is also an important feature. Many species have cartilaginous plants; others have soft or membranous plants. This feature has been used by some authors (e.g., Tanaka 1941). Cartilaginous plants of some species are tough, but those of others are brittle when alive.

Plant Color. Plant color is useful for some species, although it may vary depending on habitats and ages of plants. For example, Mshigeni (1978, p. 871) states: "*H. chordacea* is also distinct from the other Hawaiian species from its colour. In a fresh condition its thalli are usually very dark green. The fronds may, however, be pale green when growing in places exposed to bright light" (see also Hewitt 1960, p. 213).

Iridescence. When alive, submerged plants of some species have a brilliant blue iridescence. This feature is helpful to distinguish the species in the field. Iridescence occurs sporadically in a number of marine brown and red algae. It is found in genera belonging to different families of red algae such as Gigartinaceae, Champiaceae, Delesseriaceae, and Rhodomelaceae (Wynne and Ballantine 1991).

Clearness of Main Axes. Each upright frond of *Hypnea* with uniaxial structure has theoretically a main axis. However, some or many branches of the first order become indeterminate and resemble the main axis, often obscuring the main axis. The extremes of the clearness of the main axes are percurrent and not percurrent. Some authors have used this feature to distinguish species (e.g., Tanaka 1941, Womersley 1994). This characteristic may vary according to habitats, especially for a certain group of species. For example, the presence or absence of percurrent axes seems to be variable in the *H. charoides-valentiae* group.

Shape of Main Axes in Transverse Section. Many species of *Hypnea* have terete to subterete main axes, but some have flattened axes. The type of axes is strongly correlated with the branching pattern. Terete to subterete fronds are branched in an alternate-spiral manner, whereas compressed to flattened fronds are branched in an alternate-distichous manner. This feature has been used by some authors (e.g., Tanaka 1941, Millar 1990), and it is consistent among the species concerned.

Abundance of Lateral Branches and Proliferations. Upright axes of many species are profusely branched, but those of a few species are sparsely branched or not branched. Abundance of proliferations may characterize each species concerned. Some species produce numerous proliferations, whereas others do not. These proliferations form reproductive structures. Proliferations have not been distinguished from ordinary lateral branches by many authors (e.g., Tanaka 1941, Hewitt 1960). It is preferable to use proliferations (or adventitious branches or branchlets) for outgrowths that are formed from cortical cells before or after branching at the apex, although it is often difficult to distinguish these proliferations from ordinary branches.

Widths of Axes and Branches. Some species have very slender axes and branches, whereas many species have wide axes and branches. This characteristic has been used by many authors (e.g., Mshigeni 1978, Millar 1990).

Special Branches or Branchlets. Some species produce hamate (hooked) branches. Some of these branches function as tendrils by which the alga clings to other algae. Some other species have branchlets with terminal discoid holdfasts by which the branchlets are attached to the substratum. *Hypnea cornuta* (Kützing) J. Agardh forms stellate or cornuted branchlets. These special branches or branchlets characterize each species concerned.

Direction of Branching. Branches of some species have wide angles, but those of others have narrow angles. This feature has been used by some authors (e.g., Womersley 1994). There is a strong possibility that this character may vary according to habitats, especially for a certain group of species.

Frequency of Lenticular Thickenings in the Walls of Medullary Cells. Many species have lenticular thickenings in the walls of some medullary cells (Tanaka 1941), but some species have no such thickenings (Hewitt 1960). Furthermore, these thickenings are restricted to the proximal part of the plants for some species and in other species are formed throughout the plant except for branchlets.

Presence of Small Cells Around the Axial Cell. Some species have small periaxial cells (and inner medullary cells) around the axial cell, but others are devoid of these cells. This feature has been used by some authors (e.g., Tanaka 1941, Schneider and Searles 1976).

Position of Tetrasporangial Sorus on the Fertile Branchlets or Proliferations. Tetrasporangia are formed in the nemathecium-like sorus produced on short branchlets or proliferations or both. The sorus of many species is restricted to certain parts of these branchlets or proliferations. In a few species, it is extended throughout these branchlets or proliferations save for the apices (Tanaka 1941). In a few species, the tetrasporangial sori tend to occur on one side of branchlets. This last feature has been used by some authors (e.g., Tanaka 1941, Millar 1990).

Hypnea Colloids

Some species of *Hypnea* have been used for food or for production of phycocolloids (Hoppe 1969, Xia and Abbott 1987). Cell wall constituents of many genera of the Gigartinales are known to be carrageenans, sulfated galactans (Craigie 1990). The chemical features of the cell walls of the following species of *Hypnea* have been investigated: *H. ceramioides* Kützing, *H. cervicornis* J. Agardh, *H. japonica* Tanaka, *H. musciformis*, *H. nidifica* J. Agardh, and *H. spicifera* (Suhr) Harvey. All these species are known to produce kappa carrageenans (Santos and Doty 1979 and references therein). However, some previous investigators of the phycocolloids reported a hypnean or a gelan in addition to carrageenans (Hoppe 1969 and references therein). Gametophytes and tetrasporophytes of *H. musciformis* make the same type of carrageenans (McCandless 1981), although some families such as Gigartinaceae and Petrocelidaceae produce different carrageenan arrangements according to life-history phases (McCandless 1981, Craigie 1990).

Acknowledgments

We are deeply indebted to Professor I. A. Abbott for inviting us to participate in this workshop and for critical reading of the manuscript.

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SPECIES OF *HYPNEA* FROM JAPAN

Yukimasa Yamagishi and Michio Masuda

Abstract

Historic and contemporary specimens of 10 species of *Hypnea* (Gigartinales, Rhodophyta) from Japan were examined. *Hypnea spinella* (C. Agardh) Kützing is used instead of *H. esperi* sensu Tanaka. *Hypnea cervicornis* J. Agardh and *H. cenomyce* J. Agardh are excluded from the marine algal flora in Japan. Currently, *H. charoides* Lamouroux cannot be distinguished from *H. valentiae* (Turner) Montagne, so we treat these as a *H. charoides-valentiae* complex. The occurrence of *H. cornuta* (Kützing) J. Agardh in Japanese waters is questionable.

Introduction

The species of *Hypnea* (Rhodophyta, Gigartinales, Hypneaceae) are often dominant members of marine algal floras from spring to summer in southern to central Japan. Twelve species of *Hypnea* are now known in Japanese waters (Yoshida et al. 1995), although Tanaka (1941) reported 14 species from Japan and adjacent regions. The species grow in a variety of habitats, including the intertidal and subtidal zones; in wave-exposed and wave-protected areas; and on stones, shells, rocks, living or dead corals, and other algae. Making distinctions between some closely related entities is difficult because of wide variability in gross morphology. This variability may be chiefly due to environmental factors related to specific habitats. In this chapter, we report the results of examination of historic and contemporary specimens of *Hypnea*. On the basis of our results, we recognize 10 species. In future studies, more species will be described from Japan.

Materials and Methods

Herbarium specimens used by Okamura (1907, 1909) and Tanaka (1941, 1960) and deposited in the herbarium of the Graduate School of Science, Hokkaido University (SAP) and liquid-preserved and herbarium specimens collected recently were examined.

Sections were made by hand, stained with 0.5% (w/v) cotton blue in a lactic acid-phenol-glycerol-water (1:1:1:1) solution and mounted in 50% glycerol-seawater on microscope slides. Abbreviations for herbaria are according to Holmgren et al. (1990).

Key to the Species of *Hypnea* from Japan

1. Main axes terete to subterete, branched in an alternate-spiral manner 2
1. Main axes compressed to flattened, branched in an alternate-distichous manner 8
    2. Main axes percurrent, simple or sparsely branched .... *H. chordacea*
    2. Main axes percurrent or not percurrent, profusely branched 3
3. Plants with hamate (hooked) branches functioning as tendrils .... *H. japonica*
3. Plants without hamate branches 4
    4. Plants with many coalesced branches, showing a cushionlike clump .... *H. pannosa*
    4. Plants with few coalesced branches or without such branches 5
5. Axes and branches slender, less than 500 µm in diameter .... *H. spinella*
5. Axes and branches wide, more than 1 mm in diameter 6
    6. Ultimate branchlets often with discoid attachments .... *H.* species
    6. Ultimate branchlets without discoid attachments 7
7. Small cells present around the axial cells, tetrasporangial sorus extending throughout the fertile branchlets and proliferations .... *H. flagelliformis*
7. Small cells absent around the axial cells, tetrasporangial sorus restricted to the proximal or middle parts of fertile branchlets and proliferations .... *H. charoides-valentiae* complex
    8. Small cells present around the axial cell 9
    8. Small cells absent around the axial cell .... *H. yamadae*
9. Plants entangled, with coalesced branches; branches curved and branchlets often secund .... *H. saidana*
9. Plants not entangled, usually without coalesced branches; branches straight and branchlets pinnate .... *H. variabilis*

Description of the Species

Hypnea charoides-valentiae complex

(Figs. 1–9)

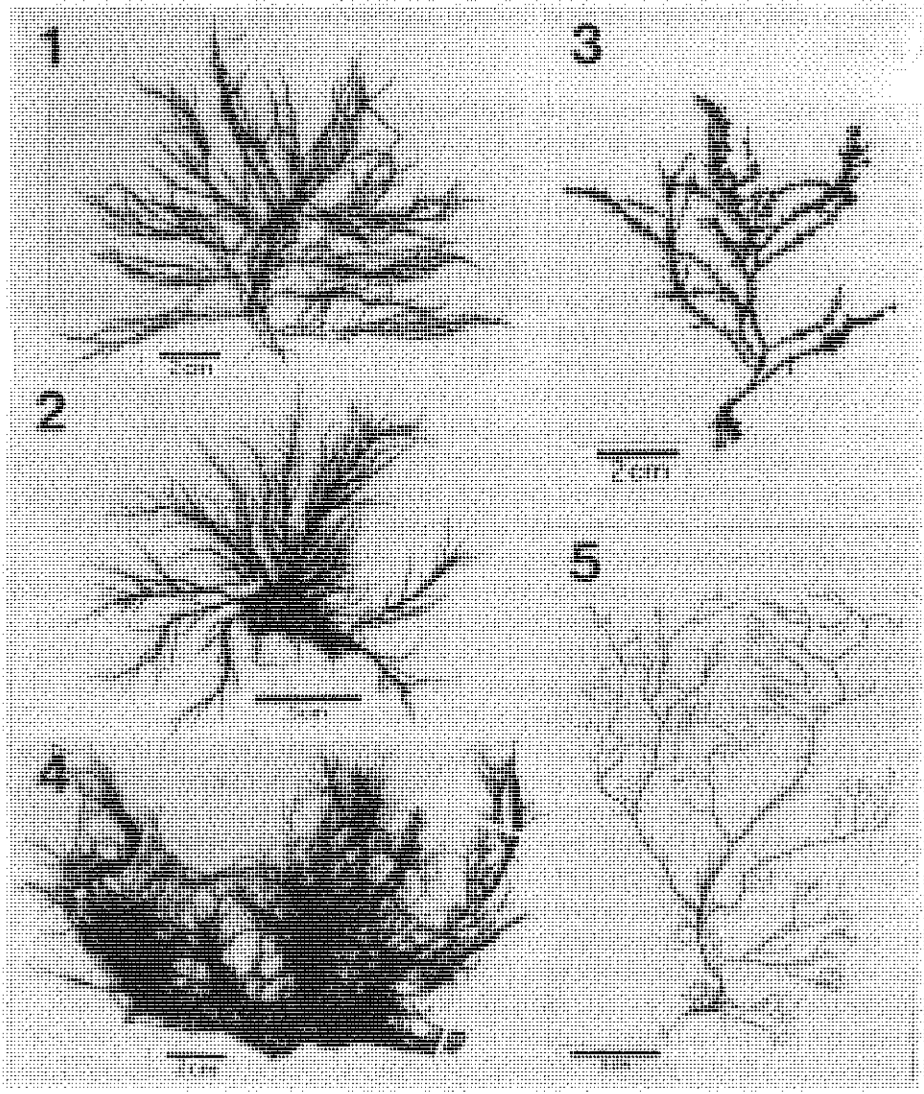
Hypnea charoides Lamouroux, Ann. Mus. Natl. Hist. Nat. 20:132, pl. 10, figs. 1–3, 1813.

Type Locality: Australia.

Holotype Specimen: Not in CN; lectotype designated as Lamouroux's (1813) illustrations fide Womersley (1994, p. 443).

Synonym: *Hypnea seticulosa* J. Agardh, Sp. gen. ordines algarum, 2(2):446, 1852.

Distribution: Northern to southern Japan from southern Hokkaido south to Okinawa Prefecture, Korea, China, Taiwan, Vietnam, Malaysia, Indonesia, Australia, and Mauritius.



Figs. 1–5. Herbarium specimens of *Hypnea charoides-valentiae* complex in SAP. Fig. 1, Tetrasporangial specimen from Ayukawa, Miyagi Prefecture (021718). Fig. 2, Tetrasporangial specimen from Amatsura, Chiba Prefecture (021717). Fig. 3, Cystocarpic specimen from Shigaki, Hakui, Ishikawa Prefecture (021339). Fig. 4, Tetrasporangial specimen from Ebisubana, Tomioka, Kumamoto Prefecture (049934). Fig. 5, Tetrasporangial specimen from Ikata, Ehime Prefecture (042098).

References: Weber-van Bosse 1928, p. 449; Tanaka 1941, p. 241 (as *H. cervicornis*) and p. 243; Børgesen 1943, p. 56; Kang 1966, p. 81; Tazawa 1975, p. 127 (as *H. cervicornis*); Tseng et al. 1983, p. 98; Silva et al. 1987, p. 49; Dinh et al. 1993, p. 268; Verheiji and Prud'homme van Reine 1993, p. 462; Womersley 1994, p. 441.

Hypnea valentiae (Turner) Montagne, Histoire Nat. Iles Canaries, 3:161, 1841.

Basionym: *Fucus valentiae* Turner, Fuci, 2:17, pl. 78, 1809.

Type Locality: Red Sea.

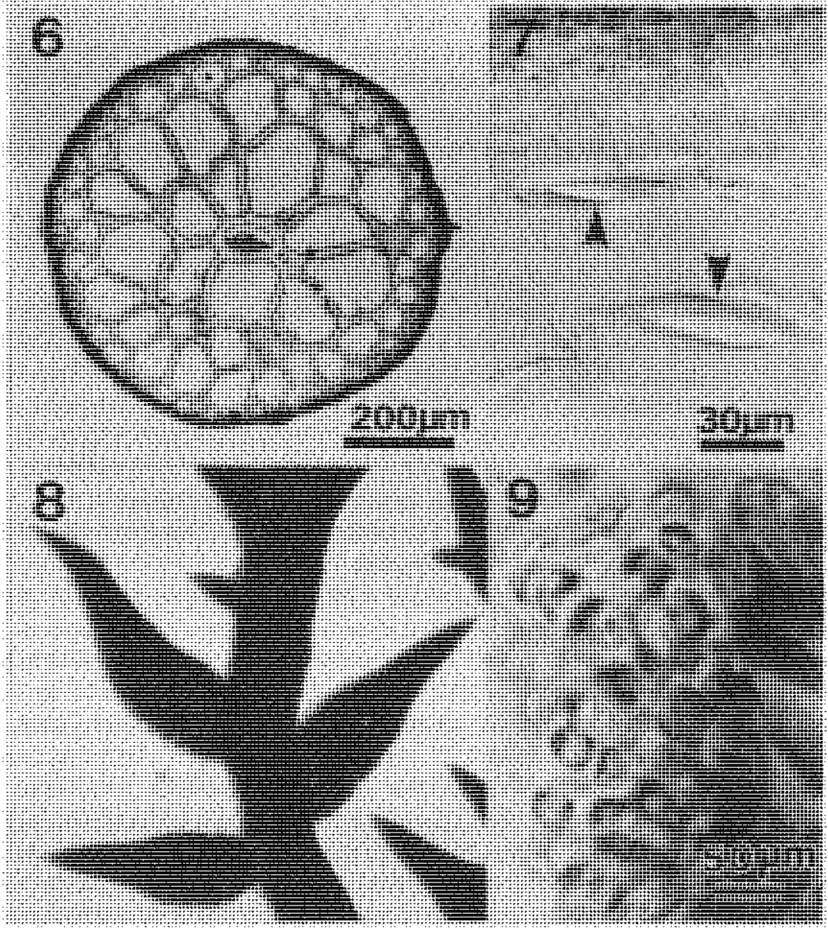
Holotype Specimen: BM (not examined).

Distribution: Philippines, Vietnam, New Guinea, Indonesia, Australia, India, Mauritius, southern California, Pacific Mexico, and Peru.

References: Weber-van Bosse 1928, p. 452; Børgesen 1935, p. 55, 1943, p. 56; Dawson 1954, p. 436 (including *H. charoides* as a synonym), and 1961, p. 238; Dawson et al. 1964, p. 62; Pham 1969, p. 195 (including *H. charoides* as a synonym); Abbott and Hollenberg 1976, p. 489; Silva et al. 1987, p. 50; Huisman and Walker 1990, p. 406; Millar 1990, p. 349; Womersley 1994, p. 445.

Plants yellowish to greenish red or deep red, growing on rocks, stones, shells, or other algae, gregarious, up to 50 cm high, loosely entangled at the basal part, with creeping branches attached to the substratum by secondary discoid holdfasts, somewhat membranous in living condition, alternate-spirally branched profusely, with (Figs. 1–3) or without percurrent main axes (Figs. 4 and 5) usually at acute angles, sometimes at wide angles with rounded axils. In the latter case, branching often appears like dichotomy with the two sides almost symmetrically growing and showing a shape like antlers (Tanaka 1941, fig. 13A); the apices of these branches are often curved. Axes and branches terete to subterete, 0.7–2.5 mm wide, gradually reduced from lower axes to acuminate apices; short proliferations (see previous chapter for the difference between proliferations and branches or branchlets), abundantly formed on axes and branches, usually at right angles but sometimes directed upward; small cells absent around the axial cell (Fig. 6); lenticular thickenings rarely present in the walls of medullary cells (Fig. 7). Tetrasporangia formed in the proximal to middle (Fig. 8), or sometimes upper, swollen parts of ultimate branchlets and proliferations 0.3–5.5 mm long by 140–400 µm wide, encircling the fertile part (Tanaka 1941, fig. 16C); zonately divided tetrasporangia (Tanaka 1941, fig. 16C) 32–70 µm long, 14–32 µm in diameter. Spermatangia formed in chains (Fig. 9) in the proximal to upper swollen parts of branchlets 0.25–1.5 mm long by 150–450 µm wide, encircling the fertile parts, 2–5 µm in diameter. Cystocarps subglobose, 700–1300 µm in diameter.

Remarks. Silva et al. (1987) pointed out that *H. charoides* Lamouroux (1813) was not valid because no description was available. However, according to the provisions of Articles 42.4, 44.1, and 44.2 of the Tokyo Code (International Code of Botanical Nomenclature, Greuter et al. 1994), *H. charoides* can be credited to Lamouroux, because Lamouroux's publication is accompanied by illustrations; his figures 1–3 in plate 10 show a species of *Hypnea*. Thus, these illustrations can be



Figs. 6–9. *Hypnea charoides-valentiae* complex. Fig. 6, Transverse section of lower axis of specimen collected at Shirahama, Shimoda, Shizuoka Prefecture. Fig. 7, Transverse section of lower axis showing lenticular thickenings (arrowheads) of specimen collected at Shionomisaki, Wakayama Prefecture. Fig 8, Tetrasporangial branchlets of specimen from Shirahama, Shimoda, Shizuoka Prefecture. Fig. 9, Transverse section of spermatangial branchlet showing spermatangia formed in chains in specimen collected at Nomozaki, Nagasaki Prefecture (SAP 13181). Scale bar in Fig. 6 also applies to Fig. 8.

considered as showing features that aid in identification, although the illustrations are not sufficient, because they lack details of many characteristics currently required for identification of *Hypnea* species. Many old, original publications of species of this genus, however, are likewise devoid of descriptions of such critical features.

Haroun and Prud'homme van Reine (1993) reduced *H. cervicornis* J. Agardh (1852) to be synonymous with *H. spinella* (C. Agardh) J. Agardh (1847). The type locality of *H. spinella* is the West Indies and that of *H. cervicornis* is near Bahia, eastern Brazil. According to Haroun and Prud'homme van Reine (1993), *H. spinella* is a compact growth form found in habitats with rough wave action, whereas *H. cervicornis* is a more elongate growth form found in habitats with less wave action, and a distinct transition from typical *H. spinella* into typical *H. cervicornis* occurs. Børgesen (1920) pointed out the similarity of these two species. The alga called *H. cervicornis* in Japan (Tanaka 1941) has large plants with wide axes and is different from *H. spinella* (genuine *H. cervicornis*).

The distinction between *H. charoides* and *H. cervicornis* sensu Tanaka (1941) is not clear. The key feature used by Tanaka (1941) is the presence or absence of percurrent principal axes and the absence or presence of upper branches that look like antlers, but these may vary according to habitats. The plants with percurrent axes and without antlerlike upper branches, corresponding to *H. charoides,* grow in more wave-exposed places, whereas the plants without percurrent axes and with antlerlike upper branches, corresponding to *H. cervicornis* sensu Tanaka, grow in more protected places. The extremes of the entity have similar internal anatomical features.

Hypnea hamulosa (Turner) Montagne is a misapplied name and was changed to *H. valentiae* (Turner) Montagne by Silva *et al.* (1987; see also Masuda et al., this volume). The distinction between *H. charoides* and *H. valentiae* seems to be unclear. According to Womersley (1994), *H. charoides* is characterized by fronds without percurrent branches and with all branches bearing numerous, short spinous branchlets, more or less at right angles. In contrast, *H. valentiae* has percurrent main branches and relatively few, spinous branchlets, and these, as well as lesser branches, are directed upward rather than at right angles. However, in the protologue of the original description of *F. valentiae,* Turner (1809, p. 18) stated that "it has also strong character in the horizontal ramuli that clothe the stem and branches, resembling spines in their form, and being in some specimens so numerous as nearly to cover the whole frond." Other than two forms circumscribed by Womersley (1994), many intermediate forms are found in Japanese waters. Some specimens have numerous, spinous branchlets (the majority may be proliferations) on percurrent main axes and branches of any order, but these branchlets are directed upward (Fig. 2). On the other hand, some other plants have relatively few, spinous proliferations at right angles on percurrent axes and branches (Fig. 3). The abundance of proliferations may depend on the age of individual plants. Reproductively advanced plants have many more proliferations. Among plants growing in Japan, no clear-cut differences between

H. charoides and *H. valentiae* are found. The specimen of *H. valentiae* shown by Dawson (1954, p. 436, fig. 47) is similar to the typical form of *H. charoides* found in Japan.

We treat these as a *H. charoides-valentiae* complex. The identity of this complex will be clarified by future, more experimental studies.

Hypnea chordacea Kützing, Sp. Alg. p. 760, 1849.

(Figs. 10–13)

Type Locality: Java.

Lectotype Specimen: L (not examined).

Synonym: *Hypnea simpliciuscula* Okamura in De Toni, Sopra tre Nuo. Alg. Mar. Giap., p. 345, 1895.

Distribution: Central Japan (Shizuoka Prefecture), Taiwan, Indonesia, Mauritius, and Hawaii.

References: Weber-van Bosse 1928, p. 448; Tanaka 1941, p. 230; Børgesen 1954, p. 23; Mshigeni 1978, p. 870.

Plants purplish red, growing on rocks, gregarious, often forming entangled mats, up to 7.5 cm high, loosely caespitose, with creeping branches attached to the substratum by secondary discoid holdfasts, cartilaginous, with percurrent main axes. Axes terete to subterete, 1.5–2.5 mm in diameter, sparsely branched but with numerous, short proliferations at the middle to upper parts (Fig. 10); central part of the axis consisting of many small cells (Fig. 11); lenticular thickenings rare in the walls of medullary cells (Fig. 12). Tetrasporangia formed in the proximal or middle (Fig. 13) swollen parts of proliferations 0.6–2.0 mm long, 200–450 μm in diameter, encircling the fertile part (Tanaka 1941, fig. 4D); zonately divided tetrasporangia 30–58 μm long, 13–26 μm in diameter.

Remarks: This species is characterized by having simple or sparsely branched main axes of which the upper to middle parts are densely covered with short proliferations. It may grow on rocks in wave-exposed locations in tropical to warm temperate regions in the western Pacific. A similarity between *H. chordacea* and *H. spicifera* (Suhr) Harvey (Weber-van Bosse 1928) has been noted. According to Børgesen (1954), however, *H. spicifera* is distinguished from *H. chordacea* by the former's much taller plants with wider axes.

Hypnea flagelliformis J. Agardh, Sp. gen. ordines algarum, 2(2):446, 1852.

(Figs. 14–17)

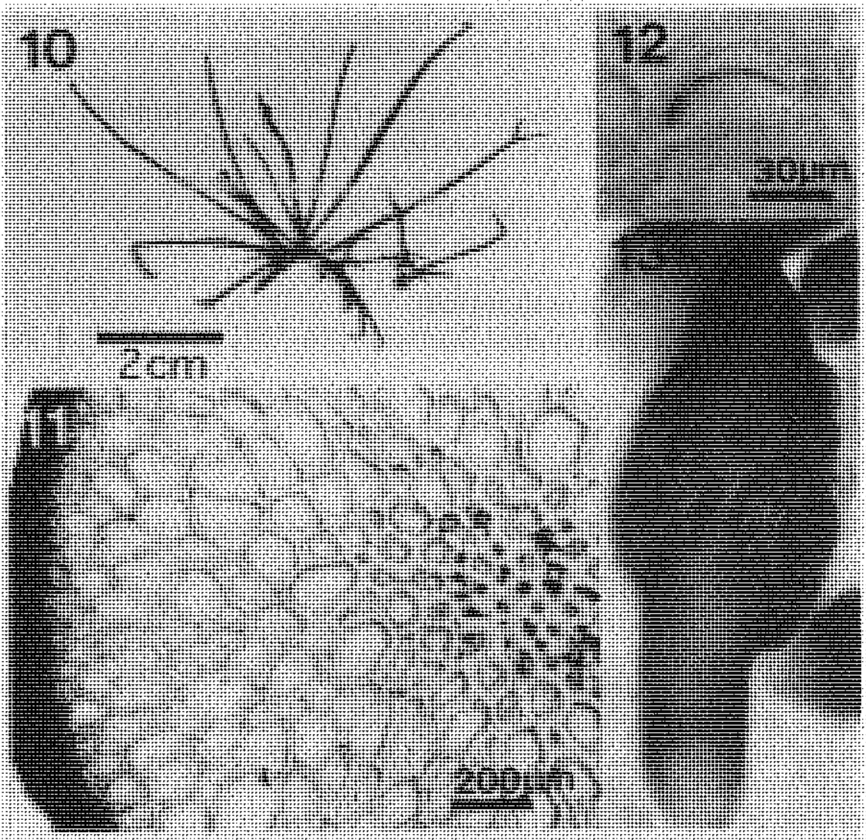
Type Locality: Coast of Bangladesh, Bay of Bengal.

Lectotype Specimen: Probably in LD (not examined).

Distribution: Northern to southern Japan from Aomori Prefecture south to Yamaguchi Prefecture, Vietnam, and Bangladesh.

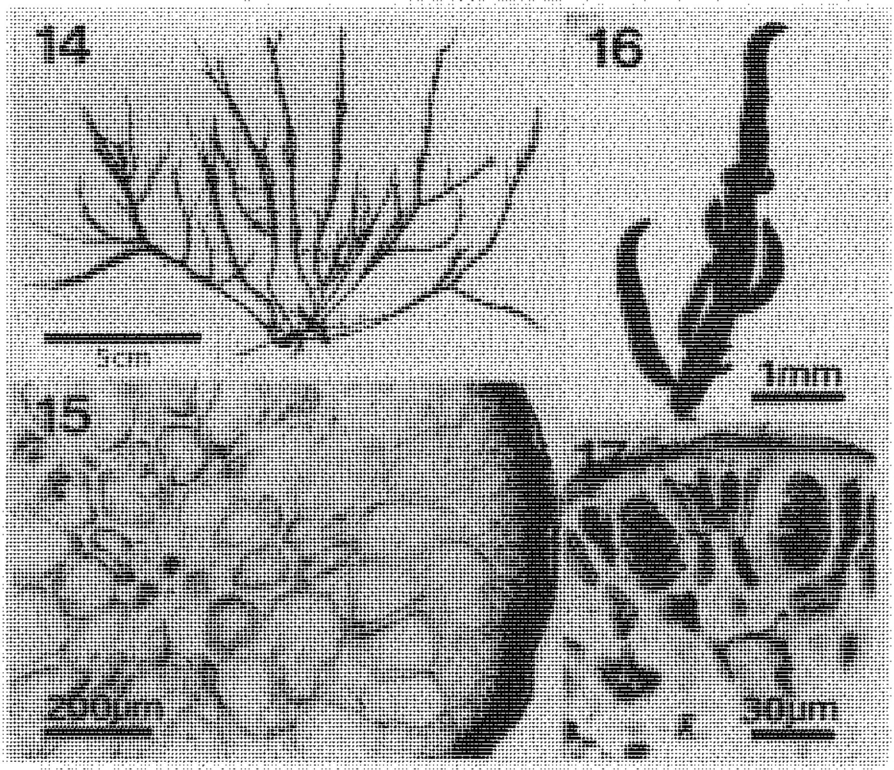
References: Tanaka 1941, p. 232; Dinh et al. 1993, p. 273.

Plants yellowish red, growing on rocks or other algae, gregarious, often forming loosely aggregated mats, up to 10 cm high, with creeping branches



Figs. 10–13. *Hypnea chordacea*. Material collected at Shirahama, Shimoda, Shizuoka Prefecture. Fig. 10, Tetrasporangial specimen. Fig. 11, Transverse section of lower axis. Fig. 12, Transverse section of axis showing lenticular thickening.
Fig. 13, Tetrasporangial proliferation. Scale bar in Fig. 11 also applies to Fig. 13.

attached to the substratum by secondary discoid holdfasts, somewhat cartilaginous, with percurrent main axes. Axes terete to subterete, 0.8–1.8 mm in diameter, alternate-spirally branched; some branches growing indeterminately like the main axis; axes and branches with many short, simple or divided proliferations except at the lower part (Fig. 14); central part of the axis consisting of a few small cells (Fig. 15); lenticular thickenings absent in the walls of medullary cells (Fig. 15). Tetrasporangia formed throughout simple or divided proliferations and branchlets save for their apices (Fig. 16; also see Tanaka 1941, figs. 5B–5D), encircling the fertile parts; fertile proliferations and branchlets 1.0–5.5 mm long, 300–500 µm in diameter; zonately divided tetrasporangia (Fig. 17) 42–62 µm long, 12–28 µm in diameter.



Figs. 14–17. *Hypnea flagelliformis*. Fig. 14, Tetrasporangial specimen from Kamo, Yamagata Prefecture (SAP 035029). Fig. 15, Transverse section of lower axis of specimen collected at Fukaura, Aomori Prefecture. Fig. 16, Tetrasporangial branchlet with some short proliferations of specimen from Fukaura, Aomori Prefecture. Fig. 17, Transverse section of tetrasporangial branchlet of specimen from Fukaura, Aomori Prefecture.

Remarks: This species grows on rocks in wave-exposed localities in tropical to warm temperate regions in the western Pacific and Indian oceans. It is somewhat similar in gross morphology to *H. charoides-valentiae* complex, but unlike this complex, it has small cells around the axial cell and more extended tetrasporangial sori. This species is also somewhat similar in gross morphology to some individuals of *H. chordacea* that have branched main axes. However, inner small cells around the axial cell are less conspicuous, and more extended tetrasporangial sori of *H. flagelliformis* distinguish the species from *H. chordacea*.

Hypnea japonica Tanaka, Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Univ. 2(2):236, pl. 54, figs. 9 and 10, 1941.

(Figs. 18–21)

Type Locality: Nemoto, Chiba Prefecture, central Japan.

Holotype Specimen: SAP 021694, collected in May 1931 by K. Okamura (examined).

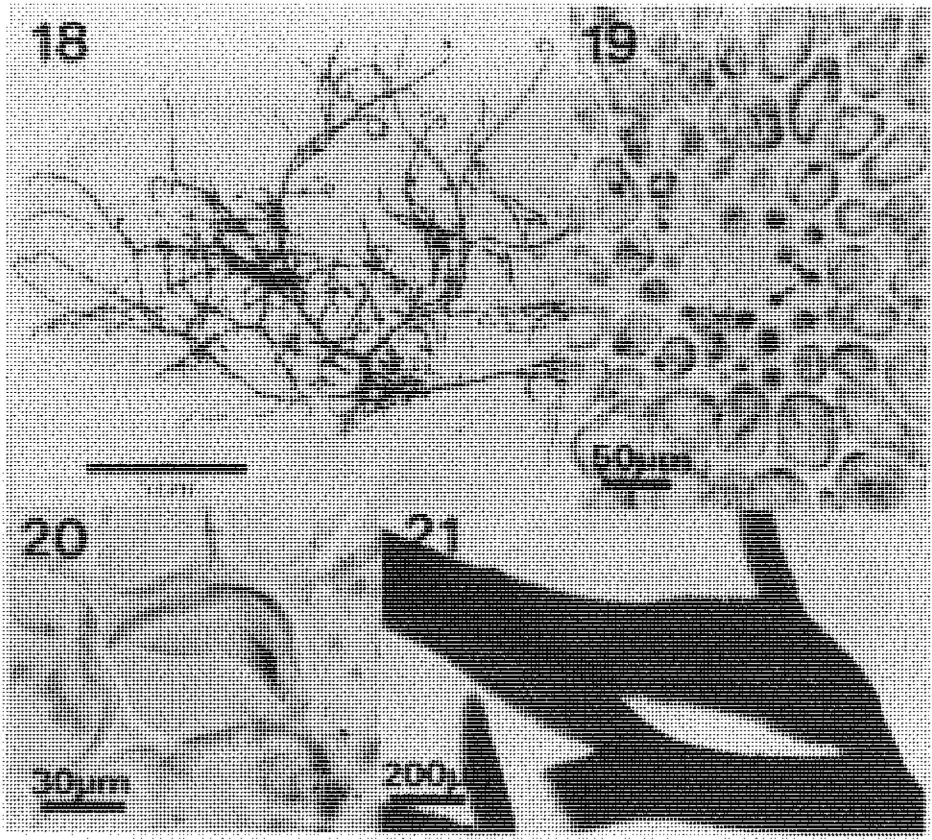
Distribution: Central to southern Japan from Chiba Prefecture to Kagoshima Prefecture, Korea, China, Taiwan, and Vietnam.

References: Okamura 1909, p. 35 (as *H. musciformis*), 1936, p. 609 (as *H. musciformis*); Kang 1966, p. 81; Tseng et al. 1983, p. 98; Dinh et al. 1993, p. 265.

Plants yellowish red to bright red or brownish red but living submerged plants a brilliant iridescent blue, epiphytic on other algae, usually solitary, sometimes gregarious, up to 16 cm high, with percurrent main axes (Fig. 18), cartilaginous. Axes terete to subterete, 0.8–2.8 mm in diameter, alternate-spirally branched; some branches growing indeterminately like the main axis; axes and branches with short, simple or divided, slender proliferations; upper parts of branches becoming thickened and hooked (Fig. 18), some of these hamate branches functioning as tendrils (Tanaka 1941, figs. 9C and 9D); central part of the axis (Fig. 19) and branches (Okamura 1909, pl. 60, figs. 8 and 9) consisting of many small cells; lenticular thickenings present in the walls of medullary cells (Fig. 20). Tetrasporangia formed in the proximal to middle swollen parts of proliferations and branchlets (Fig. 21) 1.1–10.0 mm long, 300–800 μm in diameter, encircling the fertile parts (Tanaka 1941, fig. 9B); zonately divided tetrasporangia 34–90 μm long, 18–46 μm in diameter.

Remarks: This species grows on other algae such as *Sargassum* spp. and articulated corallines in subtropical to warm temperate regions in the western Pacific. It is characterized by the presence of hamate branches, some of which function as tendrils. It is also characterized by larger tetrasporangia among the species examined here.

This alga was first reported as *H. musciformis* by Okamura (1909). Later, Tanaka (1941) recognized it as a new species because of its large and cartilaginous fronds. *Hypnea musciformis* was described on the basis of material from Trieste, Italy, by Wulfen (in Jacquin 1789, p. 154) as *F. musciformis* and was characterized as follows: "Caule membranaceo-coriaceo, filiformi, ramosissimo; ramulis setaceis; marginibus lateralibus caulis ramorumque capillari-ciliatis." Taylor (1960, p. 467) stated: "Texture somewhat fragile, fleshy...; erect branches..., beset with numerous, short, divaricate spur branchlets." *Hypnea japonica* has short, simple or divided, slender proliferations that are not numerous (Fig. 18). In addition to the two features mentioned by Tanaka (1941), the absence of numerous, short proliferations for *H. japonica* is a critical feature distinguishing the species from *H. musciformis*.



Figs. 18–21. ***Hypnea japonica.*** **Fig. 18, Vegetative specimen from Susaki, Shimoda, Shizuoka Prefecture (SAP 022147). Fig. 19, Transverse section of lower axis of specimen collected at Shirahama, Shimoda, Shizuoka Prefecture. Fig. 20, Transverse section of lower axis, showing lenticular thickening in a specimen from Shirahama, Shimoda, Shizuoka Prefecture. Fig. 21, Tetrasporangial branchlets of specimen from Shirahama, Shimoda, Shizuoka Prefecture.**

Hypnea pannosa J. Agardh, Öfvers. Kongl. Vet. Akad. Förh. 4:14, 1847.
(Figs. 22–25)

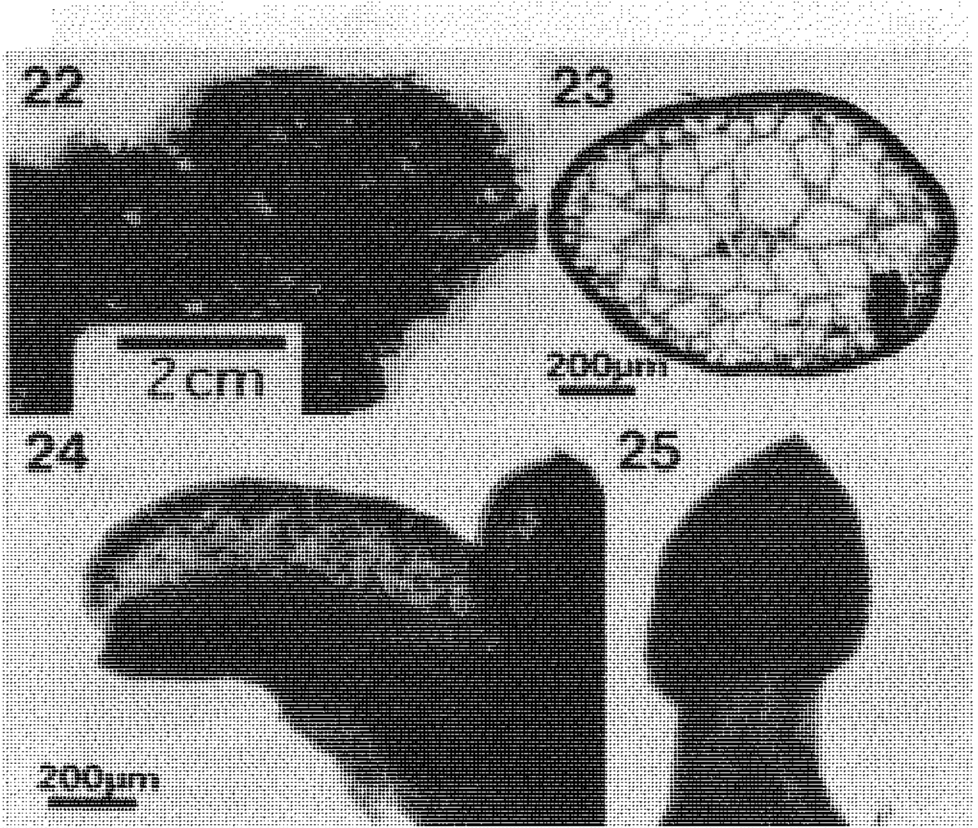
Type Locality: Oaxaca, Pacific Mexico.

Lectotype Specimen: AG 33892 in LD (not examined).

Synonym: *Hypnea nidulans* Setchell, Calif. Acad. Sci. Proc. IV, 12:161, 1924.

Distribution: Southern Japan (Kagoshima Prefecture and Okinawa Prefecture), China, Taiwan, the Philippines, Vietnam, Malaysia, Indonesia, Australia, Mauritius, and Hawaii.

References: Okamura 1907, p. 47; Weber-van Bosse 1928, p. 455; Tanaka 1941, p. 247; Børgesen 1943, p. 56; Tanaka and Pham 1962, p. 37; Pham 1969,



Figs. 22–25. ***Hypnea pannosa.*** **Fig. 22, Liquid-preserved, vegetative specimen from Cape Hedo, Okinawa Prefecture. Fig. 23, Transverse section of lower axis of specimen collected at Cape Hedo, Okinawa Prefecture. Fig. 24, Tetrasporangial branchlet forming tetrasporangial sorus on one side of specimen from Kunigami, Okinoerabu-jima, Kagoshima Prefecture, (SAP 056104). Fig. 25, Tetrasporangial branchlet with encircled, tetrasporangial sorus in the distal part of a specimen collected at Yakomo, Okinoerabu-jima, Kagoshima Prefecture, (SAP 056101). Scale bar in Fig. 24 also applies to Fig. 25.**

p. 196; Mshigeni 1978, p. 870; Cribb 1983, p. 59; Tseng et al. 1983, p. 100; Silva et al. 1987, p. 50; Dinh et al. 1993, p. 268; Verheiji and Prud'homme van Reine 1993, p. 462; Ismail 1995, p. 90.

Plants purplish red or purplish green, but living submerged plants a brilliant iridescent blue, growing on corals or rocks, solitary or gregarious, attached to the substratum by primary discoid holdfast and creeping branches with secondary discoid holdfasts, firmly entangled with coalesced branches except at the upper part, forming a compact tuft, 2–3 cm high, cartilaginous but brittle when alive, without percurrent axes (Fig. 22). Branches terete to subterete, 1.0–1.5 mm thick, alternate-spirally branched densely, with acute apices (Tanaka 1941, fig. 20A); proliferations rare; cells large in the inner layer around the axial cells, becoming smaller outward (Fig. 23); lenticular thickenings absent in the walls of medullary cells (Fig. 23). Tetrasporangia formed in the proximal, middle, or distal swollen part of ultimate branchlets, first on one side (Fig. 24) and later encircling the fertile part (Fig. 25); fertile branchlets 0.7–3.0 mm long, 400–650 μm in diameter; zonately divided tetrasporangia 30–58 μm long, 12–26 μm in diameter.

Remarks: *Hypnea pannosa* is the most common species of this genus in tropical and subtropical regions in the western Pacific and in the field is distinguished from other species by cartilaginous, iridescent, compactly tufted fronds with densely interwoven branches. It is also characterized by having branches with a thickness similar to that of the axes and uniform almost all the way to the apex (Tanaka 1941, Mshigeni 1978).

Tanaka (1941) distinguished *H. pannosa* from *H. nidulans* Setchell as follows: *Hypnea pannosa* has densely entangled plants and tetrasporangial sori generally borne on one side of branchlets (afterward gradually circling the branchlet), whereas *H. nidulans* has loosely entangled plants and saddle-shaped tetrasporangial sori. This finding strongly suggests that *H. nidulans* plants are younger individuals of *H. pannosa*. Dawson (1961, p. 236) concluded that the type specimens of these two species probably represented depauperate and well-developed examples, respectively, of the same species and reduced *H. nidulans* as a synonym of *H. pannosa*. Cribb (1983, p. 60) states, "The more compact, mat-like form, corresponding to *H. pannosa* as generally recognised, occurs on the reef rock rim; the laxer form, corresponding to plants generally referred in the past to *H. nidulans*, occurs mainly between coral branches lining pools in the outer reef flat." Tanaka (1941) and Tanaka and Pham (1962), however, report that these two species grow together. We have never obtained any specimens similar to *H. nidulans* circumscribed by Tanaka (1941) from Japanese waters.

Hypnea saidana Holmes, J. Linn. Soc. Bot. 31:256, pl. 2, figs. 3a and 3b, 1896.
(Figs. 26–29)

Type Locality: Enoshima, Kanagawa Prefecture, Japan.

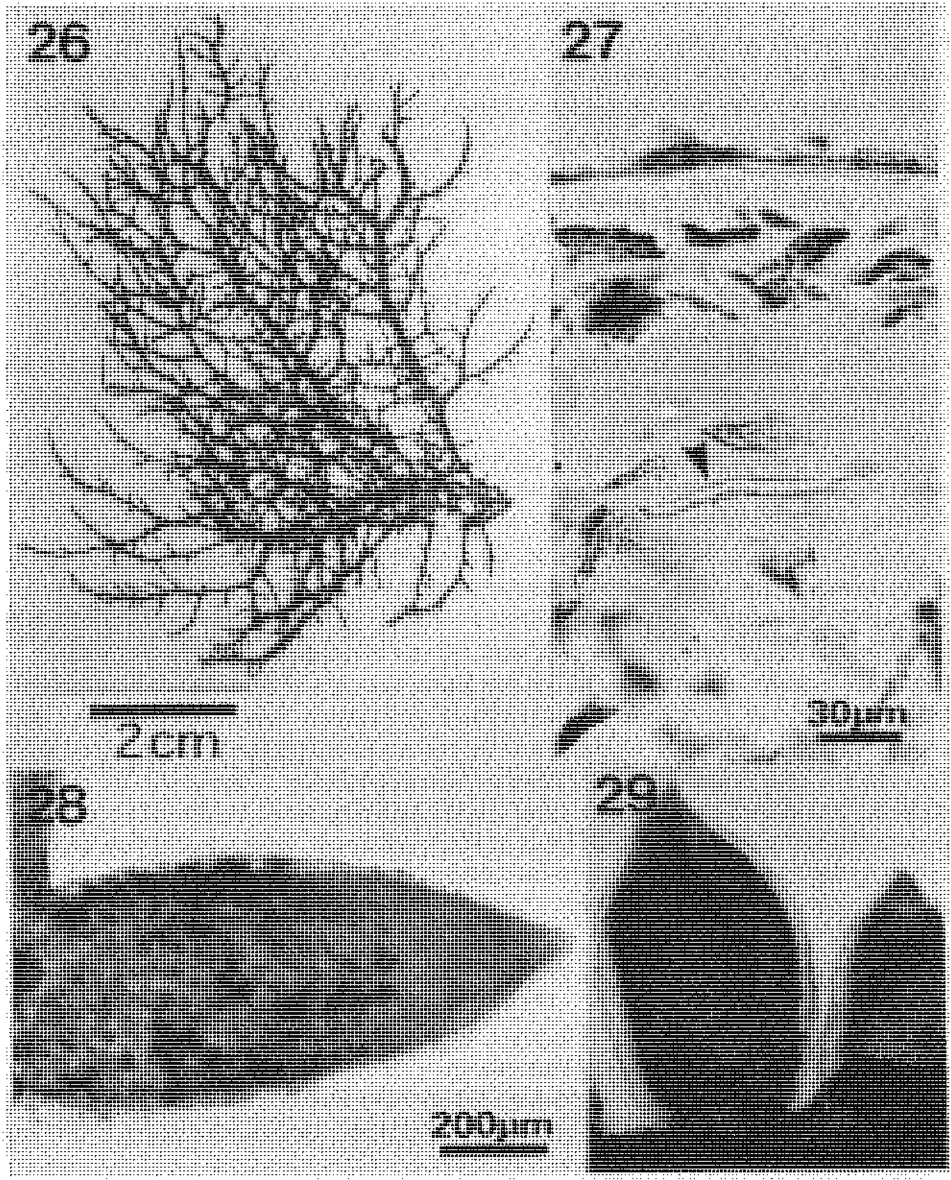
Holotype Specimen: BM (not examined).

Distribution: Pacific coast of central Japan from Fukushima Prefecture south to Mie Prefecture (Tanaka 1941), Korea, the Philippines, and Australia (northern New South Wales).

References: Okamura 1909, p. 24, 1936, p. 610; Tanaka 1941, p. 239; Kang 1966, p. 81; Silva et al. 1987, p. 50; Millar 1990, p. 351.

We have never examined living and liquid-preserved specimens of this species. The following description is based on pressed herbarium specimens and information from Okamura (1909) and Tanaka (1941).

Plants yellowish red or blood red, forming a roundish mass with branches entangled and attached at points to each other (Okamura 1909), up to 8 cm high,



Figs. 26–29. *Hypnea saidana*. Fig. 26, Cystocarpic specimen from Enoshima, Kanagawa Prefecture (SAP 059934). Fig. 27, Transverse section of lower axis showing lenticular thickening (arrowhead) of specimen from Shichirigahama, Kanagawa Prefecture, (SAP 059936). Fig. 28, Tetrasporangial branchlet of specimen collected at Enoshima, Kanagawa Prefecture, (SAP 059950). Fig. 29, Spermatangial branchlet of specimen from Sunosaki, Chiba Prefecture, (SAP 059958). Scale bar in Fig. 28 also applies to Fig. 29.

with percurrent main axes (Fig. 26); main axes compressed to flattened, 1.0–1.8 mm wide, issuing alternate, curved branches in a single plane; some branches growing indeterminately like the main axis. Branches forming short, often secund or sometimes alternate, spreading branchlets; branchlets arranged mostly in a single plane but sometimes in three dimensions, thornlike, up to 15 mm long and 0.6 mm wide, with sharply pointed apices; proliferations rare except at grazed ends; central part of axes (Tanaka 1941, fig. 12A) and branches (Okamura 1909, pl. 57, fig. 6) consisting of a few small cells; lenticular thickenings rarely present in the walls of medullary cells (Fig. 27). Tetrasporangia first formed on one side of the proximal to middle swollen parts (Fig. 28) of branchlets, later encircling them; fertile branchlets 0.8–7.8 mm long, 0.5–1.0 mm wide; zonately divided tetrasporangia 36–62 µm long, 18–26 µm wide; cystocarps hemispherical, 400–1100 µm in diameter on branchlets 0.4–10.0 mm long and 200–500 µm wide; spermatangia formed in chains over the entire branchlets (except for the apices) 0.5–2.0 mm long and 250–450 µm wide (Fig. 29), encircling the fertile parts, 3–5 µm in diameter.

Remarks: This species is characterized by having flattened to compressed axes branched in a single plane as do *H. variabilis* and *H. yamadae.* It is distinguished from these two species by having curved branches and secund branchlets, which are clearly shown in the original illustration (Holmes 1896, pl. 11, fig. 3a) and in Okamura's illustrations (1909, pl. 57, figs. 1–3). In Japan, the geographical range of *H. saidana* is restricted to warm temperate localities (the Pacific coast) of central Japan. However, this species has been reported from the tropical Philippines (Silva et al.) and also from a remote locality of northern New South Wales in Australia (Millar 1990).

Cribb (1983) suggests that *H. saidana* is a synonym of *H. pannosa.* However, *H. saidana* is essentially distinguished from *H. pannosa* by the flattened to compressed axes of the former, which are branched in a single plane. In addition, *H. saidana* is essentially a larger species.

Hypnea spinella (C. Agardh) Kützing, Bot. Zeit. 5:23, 1847.
(Figs. 30–32)

Basionym: *Sphaerococcus spinellus* C. Agardh, Sp. alg. 1(2):323, 1822.

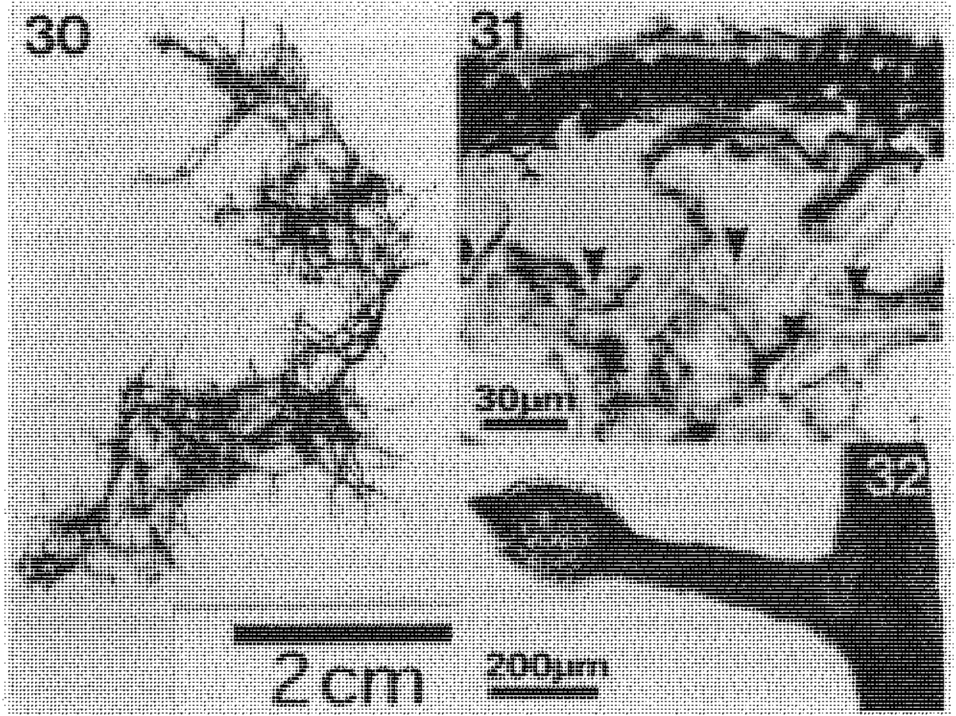
Type Locality: West Indies.

Lectotype Specimen: Herbarium AG 33888 in LD fide Haroun and Prud'homme van Reine (1993, p. 122) (not examined).

Synonym: *Hypnea cervicornis* J. Agardh, Sp. gen. ordines algarum, 2(2):451, 1852.

Distribution: Southern Japan from Wakayama Prefecture to Okinawa Prefecture, Vietnam, Malaysia, Indonesia, Hawaii, Pacific Mexico, and the West Indies. See Taylor (1960, p. 466) for distribution in the Caribbean and the Atlantic.

References: Weber-van Bosse 1928, p. 454; Tanaka 1941, p. 243 (as *H. esperi*); Taylor 1960, p. 465; Dawson 1961, p. 238; Pham 1969, p. 196; Mshigeni



Figs. 30–32. *Hypnea spinella*. Material from Okinawa Island (SAP 9863). Fig. 30, Tetrasporangial specimen. Fig. 31, Transverse section of lower axis showing lenticular thickenings (arrowheads). Fig. 32, Tetrasporangial proliferation.

1978, p. 876; Cribb 1983, p. 60; Millar 1990, p. 352; Verheiji and Prud'homme van Reine 1993, p. 462; Ismail 1995, p. 92.

Plants light red to scarlet, growing on other algae or rocks, gregarious, rather soft in texture, attached to the substratum by primary discoid holdfast and creeping branches with secondary discoid holdfasts, 1.5–3 cm high, loosely entangled at the basal part and forming small tufts, without percurrent axes (Fig. 30). Axes and branches terete, filiform, 0.3–0.5 mm thick, issuing short or long spinous branchlets with sharply pointed apices; proliferations usually present, not abundant; cells large in the inner layer around the axial cells, becoming smaller outward (Tanaka 1941, fig. 15A); lenticular thickenings sometimes present in the walls of medullary cells (Fig. 31). Tetrasporangia formed in the proximal, middle or distal (Fig. 32; also see Tanaka 1941, figs. 15C and 15D), swollen part of ultimate branchlets and proliferations 0.15–1.5 mm long by 100–200 μm wide, encircling the fertile part;

zonately divided tetrasporangia 28–44 µm long, 12–22 µm wide.

Remarks: This entity was first reported as *H. esperi* Bory de Saint-Vincent in Japan and adjacent regions by Tanaka (1941). According to Silva *et al.* (1987), however, *H. esperi* was superfluous when published, being a substitute name for *F. nootkanus* Esper, which is the basionym of *Bonnemaisonia nootkana* (Esper) Silva. The species was first given a valid name, at the varietal level, as *H. musciformis* (Wulfen) Lamouroux var. *esperi* by J. Agardh (1852), who made it clear that he was describing the material in Bory de Saint-Vincent's hands and excluding *F. nootkanus*. If this entity is recognized at the level of species, it must receive a different name. In describing *H. musciformis* (as variety α) and *H. musciformis* var. *esperi*, J. Agardh wrote, "ramis filiformibus infra apicem incrassatis circinato-incurvis" and characterized the variety *esperi* as "fronde firmior subcartilaginea corallino-rubra." The alga known as *H. esperi* in Japan has no such branches and has much more delicate fronds. It is entirely different from *H. musciformis* var. *esperi* and should be treated as a distinct species. Tanaka's (1941) identification may be based on an illustration given by Kützing (1868, pl. 26, fig. a). This illustration was from Tilesius's Pacific material (Kützing 1868, p. 26). Dawson (1961, p. 235) regarded this Kützing's alga as a small variant of *H. cervicornis.*

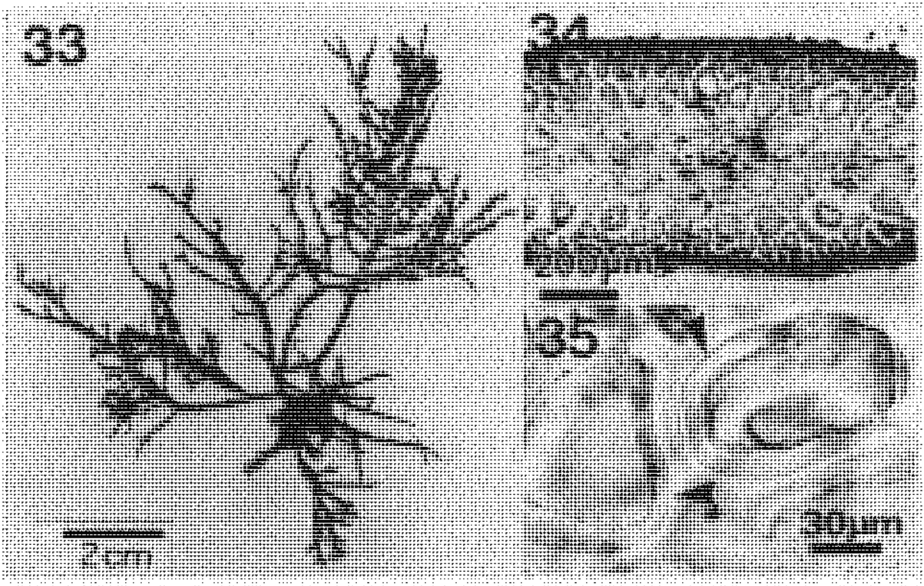
Mshigeni (1978) proposed a name, *H. spinella*, for the alga known as *H. esperi* in the western Pacific, including the Japanese one (Tanaka 1941). *Hypnea spinella* circumscribed by Mshigeni (1978) is characterized by slender axes (0.2–0.5 mm in diameter). In the original description of *S. spinellus*, Agardh (1822, p. 324) wrote, "Substantia cartilaginea, rigida." This is not the case of the alga under study. According to Cormaci et al. (1993) who examined the type material of *H. spinella*, the plant has a large axial cell with a size similar to that of periaxial cells. Kützing (1868, pl. 26, fig. f) illustrated a similar situation on the basis of material from West Indies. This is also not the case of the alga under study. However, Haroun and Prud'homme van Reine (1993, p. 121) described as "1 small axial [as central] cell surrounded by 5-(-6) large periaxial [as pericentral] cells" for their *H. spinella* from the Macaronesian region. We tentatively adopt Mshigeni's (1978) opinion, which was followed by Cribb (1983) and Millar (1990). However, further studies of the alga reported as *H. esperi* (Tanaka 1941; Dawson 1954, p. 436; Pham 1969, p. 194; Dinh et al. 1993, p. 272) or *H. musciformis* var. *esperi* (Silva et al. 1987, p. 49) from various Asian countries are needed to clarify their status.

Hypnea variabilis Okamura, Icon. Jpn. Alg. 2(2):21, pl. 56, figs. 1–18, 1909.
(Figs. 33–35)

Type Locality: Pacific coast of central Japan from Yotsukura, Fukushima Prefecture, to Owase, Mie Prefecture.

Holotype Specimen: Not in SAP; one of Okamura's illustrations (1909, pl. 56, fig. 1) is designated here as the lectotype.

Distribution: Pacific coast of central Japan (see "Type Locality") and southern California to Baja California.



Figs. 33–35. *Hypnea variabilis*. Fig. 33, Vegetative specimen from Enoshima, Kanagawa Prefecture (SAP 021714). Fig. 34, Transverse section of lower axis of specimen collected at Enoshima, Kanagawa Prefecture. Fig. 35, Transverse section of lower axis showing lenticular thickenings (arrowheads) of specimen from Enoshima, Kanagawa Prefecture.

References: Okamura 1936, p. 607; Tanaka 1941, p. 229; Dawson 1961, p. 240; Tazawa 1975, p. 127; Abbott and Hollenberg 1976, p. 490.

Plants dull red, growing on rocks, gregarious, not entangled even at the basal part, attached to the substratum by primary discoid holdfast and descending branches (Okamura 1909, pl. 56, figs. 1–5) with secondary discoid holdfasts, up to 9 cm high, with percurrent axes (Fig. 33), very rigid, cartilaginous; main axes flattened (Fig. 34), 1.0–2.5 mm wide, issuing irregularly arranged pinnate branches in a single plane; many branches growing indeterminately like the main axis. Branches forming toothlike spinous branchlets usually in a single plane, but sometimes in three dimensions; proliferations usually issuing from margins, sometimes from flat surfaces, not abundant; central part of the axis consisting of a few small cells (Fig. 34); lenticular thickenings often present in the walls of medullary cells (Fig. 35). Tetrasporangia formed in the proximal to middle swollen parts of branchlets and proliferations (Tanaka 1941, fig. 1B) 1.2–17.5 mm long by 0.4–1.4

mm wide, encircling the fertile parts; zonately divided tetrasporangia (Okamura 1909, pl. 56, fig. 18) 33–77 μm long, 12–25 μm wide.

Remarks: This species is characterized by having flattened to compressed axes branched in a single plane as do *H. saidana* and *H. yamadae*. *Hypnea variabilis* differs from these two species by its lack of entangling parts of plants. It is also distinguished from *H. saidana* by the absence of curved branches and secund branchlets and from *H. yamadae* by the purplish red color and the presence of small cells around the axial cell.

No voucher specimens of *H. variabilis* used by Okamura (1909) have been found in his herbarium housed in SAP. We designate an illustration (Okamura, 1909, pl. 56, fig. 1) as the lectotype. Unfortunately, its locality was not given by Okamura (1909).

Hypnea yamadae Tanaka, Mem. Fac. Fish. Kagoshima Univ. 9:94, pl. 2, fig. b, figs. 3 and 4, 1960.

(Figs. 36–38)

Type Locality: Uji Islands, Kagoshima Prefecture, Japan.

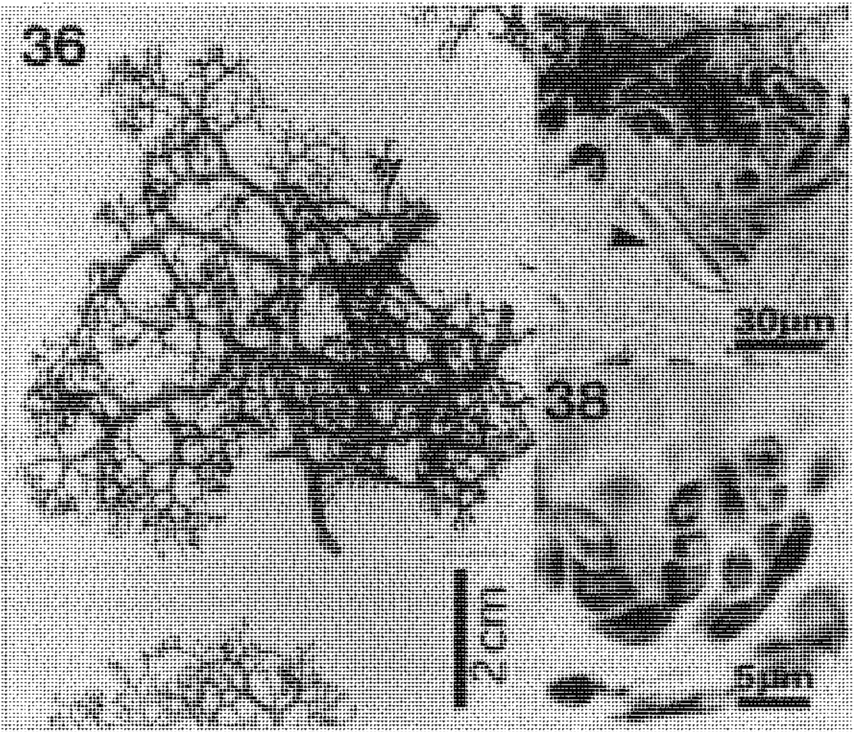
Holotype Specimen: SAP 052161, collected on May 30, 1953, by T. Tanaka (examined).

Distribution: Southern Japan from Wakayama Prefecture to Kagoshima Prefecture.

We have never examined living or liquid-preserved specimens of this species. The following description is based on pressed herbarium specimens and information from Tanaka (1960).

Plants cardinal red, entangling and caespitose (Tanaka 1960), up to 8 cm high, with percurrent main axes; axes flattened to compressed except at the uppermost part, 1–2 mm wide, alternately branched in a single plane, subterete to terete at the uppermost part, 140–500 μm in diameter, branched in an alternate-spiral manner. Branches spreading and many indeterminate branches similar to the main axis (Fig. 36); ultimate branchlets spinous, slender, 100–500 μm in diameter, in contrast to the wide main axis and branches; proliferations issuing from margins and flat surfaces, not abundant; cells large in the inner layer around the axial cells, becoming smaller outward (Tanaka 1960, fig. 4C); lenticular thickenings sometimes present in the walls of medullary cells (Fig. 37). Tetrasporangia formed in the proximal, middle, or distal swollen part of ultimate branchlets and proliferations (Tanaka 1960, fig. 4A), first on one side and later encircling the fertile part; fertile branchlets and proliferations 0.15–3.00 mm long, 100–500 μm wide; zonately divided tetrasporangia 34–68 μm long, 13–28 μm wide; spermatangia formed in two to three chains (Fig. 38) on one side of the middle swollen part (380–700 μm wide) of ultimate branchlets and proliferations 0.7–1.6 mm long, 3–6 μm in diameter.

Remarks. This species is characterized by having flattened to compressed axes branched in a single plane as do *H. saidana* and *H. variabilis*. It is distinguished from these two species by its cardinal red color and the absence of small



Figs. 36–38. ***Hypnea yamadae.*** **Fig. 36, Vegetative specimen from Ikata, Ehime Prefecture (SAP 035377). Fig. 37, Transverse section of lower axis showing lenticular thickening (arrowhead) of specimen collected at Ikata, Ehime Prefecture. Fig. 38, Transverse section of spermatangial branchlet showing spermatangia formed in chains on specimen from Arita, Kushimoto, Wakayama Prefecture.**

cells around the axial cell. Furthermore, *H. yamadae* has branchlets that are much more slender than its broad axes. Cormaci et al. (1993) adopted a feature (thickness of branches and branchlets with respect to that of axes) that distinguishes their new species, *H. furnariana* Cormaci, Alongi et Dinaro from closely related species. Their illustrations clearly show a conspicuous difference in thickness between the main axes and branchlets (Cormaci et al. 1993, fig. 2). In the original description, Tanaka (1960) mentions that lenticular thickenings are absent, but they are sometimes found in the walls of medullary cells.

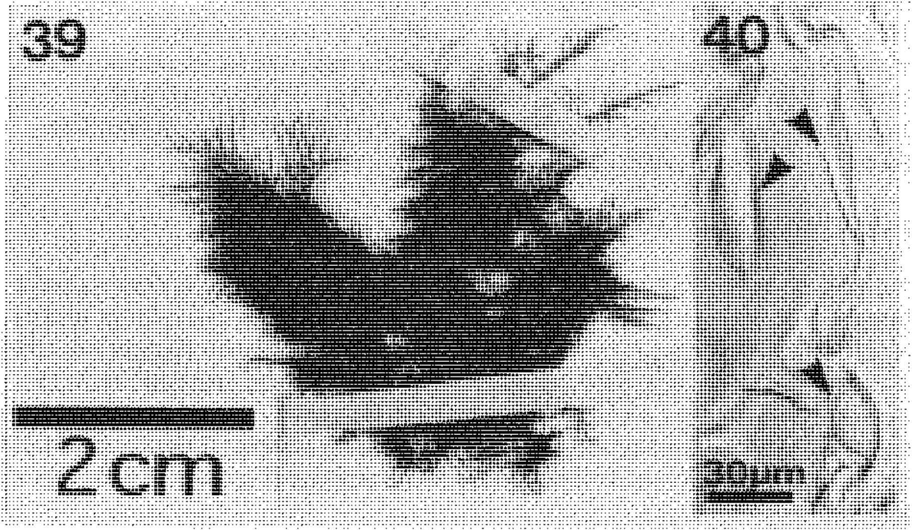
Hypnea species

(Figs. 39 and 40)

Distribution: Southern Japan (Bonin Islands) and probably tropical to subtropical countries in the western Pacific.

Reference: Tanaka (1941 as *H. cenomyce*).

Plants yellowish red to scarlet, growing on rocks, gregarious, attached to the substratum by primary discoid holdfast and creeping branches with secondary discoid holdfasts, entangling at the basal part and forming a rather small tuft, with percurrent axes (Fig. 39), 3–5 cm high; axes terete, 1.0–1.5 mm thick, alternate-spirally branched densely. Indeterminate branches growing like the main axis; branches issuing short, spinous branchlets often with terminal discoid attachments (Tanaka 1941, fig. 21A); spinous branchlets 0.15–3.00 mm long, 120–500 µm thick; proliferations present, sometimes abundant, often with terminal discoid attachments; cells large in the inner layer around the axial cells, becoming smaller outward (Tanaka 1941, figs. 21C and 21D); lenticular thickenings often present in the walls of medullary cells (Fig. 40). Reproductive structures not found.



Figs. 39 and 40. *Hypnea* sp. Material from Chichijima, Bonin Islands (SAP 021691). Fig. 39, Vegetative specimen. Fig. 40, Transverse section of lower axis showing lenticular thickenings (arrowheads).

Remarks: This species is characterized by short plants; conspicuously entangled basal systems; relatively slender axes and branches; and spinous branchlets and proliferations, both with terminal discoid attachments. Tanaka (1941) first identified this entity as *H. cenomyce* J. Agardh (1852), which was described on the basis of material from Australia. J. Agardh's specimens are characterized by having profusely branched, entangling plants with coherent branches and free branchlets (J. Agardh 1852). Although reproductive structures of *H. cenomyce* were not given by J. Agardh, some critical differences between *H. cenomyce* and the alga under study are found. J. Agardh (1852) wrote, "Rami subpaniculatim ramosi, ... apice subcorymbosi. Ramuli a basi latiore attenuati obtusiusculi, ... " The alga under study has neither branches with subcorymbose apices nor branchlets with somewhat obtuse apices; apices of branches are racemose and apices of branchlets are acute.

According to Womersley (1994), who examined the type material of *H. cenomyce*, it may be only a basal-mat form of young *H. ramentacea* (C. Agardh) J. Agardh growing under rough-water conditions, or some other species in Australia. *Hypnea ramentacea* produces numerous hamate branches, and some lower hamate branches function as secondary attachment organs (Womersley 1994). This finding is not the case in the alga under study. Furthermore, three species of *Hypnea* have been reported from Australia (Womersley 1994): *H. filiformis* (Harvey) Womersley differs from the alga in question by not having numerous, short, spinous branchlets covering the axes and branches; *H. charoides* and *H. valentiae* are much larger plants than the alga under discussion.

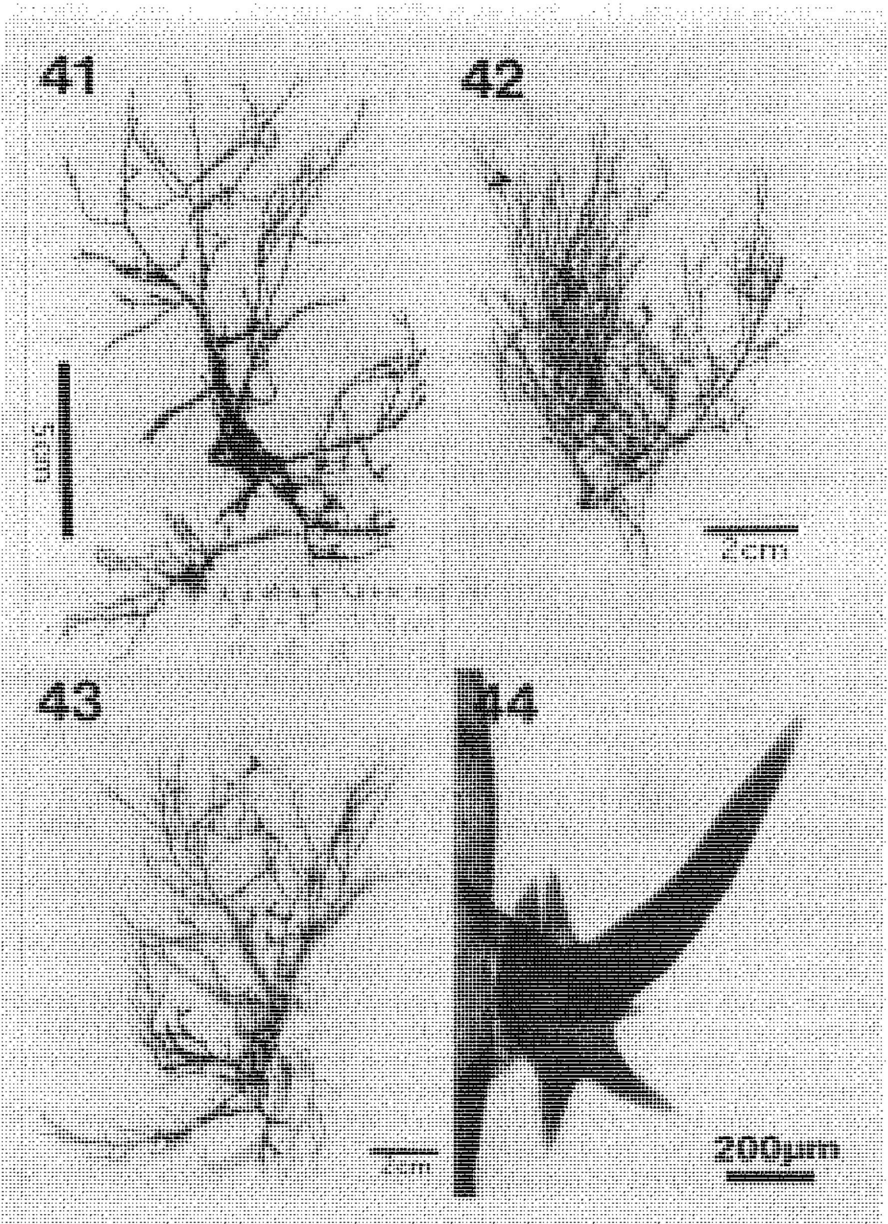
This alga will be described as a new species after examination of tetrasporangial specimens. The status of the algae reported as *H. cenomyce* (Børgesen 1950, p. 17, Pham 1969, p. 197; Silva et al. 1987, p. 48) and *H. cenomyce* var. *tenuis* Weber-van Bosse (1928, p. 456) from various countries should be clarified by further studies.

Hypnea cornuta sensu Tanaka

(Figs. 41–44)

Tanaka (1941, p. 242) reported *H. cornuta* (Kützing) J. Agardh from several localities in Japan and Taiwan. Tanaka's voucher specimens seem to be heterogeneous: (1) SAP 022254 (Shichigashima, prefecture unknown, August 24, 1926, leg. T. Kawasaki) (Fig. 41), SAP 022255 (Hyogo Prefecture) and SAP 022133 (Ooiso, Misumi, Nagato Province [Yamaguchi Prefecture]), are referable to *H. charoides-valentiae* complex; (2) SAP 013987 (Moan, Bokoto, Taiwan, April 1924, leg. Y. Yamada), which has a slender axis and branches (Fig. 42), is referable to another species.

Hypnea cornuta includes two varieties, *cornuta* and *stellulifera* J. Agardh (1852, p. 449). The type locality of the former variety is "ad oras Guinieae" in the Atlantic, and syntype localities of the latter variety are Manila and Vietnam (J. Agardh 1852, p. 449). J. Agardh distinguished these two entities as follows: "Var. *cornuta* fronde elongata gracili, spinulis stellulaeformibus sparssimis; var. *stellulifera* fronde breviori rigidiuscula, spinulis stellulaeformibus densis." We examined the following specimens: (1) pressed specimen collected from Loggerhead Key, Florida, on June 25, 1925, by W. R. Taylor (SAP 039733) (Fig. 43); this is one of Taylor's (1928, p. 156) voucher specimens; (2) liquid-preserved specimens collected at Tanjung Rhu, Pulau Langkawi, Malaysia, on February 9, 1986 (PSM 374); these are Phang's (1994, p. 127) voucher specimens.



Figs. 41–44. *Hypnea cornuta* sensu Tanaka and *Hypnea cornuta* (Kützing) J. Agardh. Fig. 41, Tetrasporangial specimen from Shichigashima, Japan (SAP 022254). Fig. 42, Vegetative specimen from Moan, Bokoto, Taiwan (SAP 013987). Fig. 43, Vegetative specimen from Loggerhead Key, Florida (SAP 039733). Fig. 44, Stellate branchlets on specimen from Tanjung Rhu, Pulau Langkawi, Malaysia (PSM 374).

The Florida specimen (Fig. 43) has a rather elongated frond and scattered stellate or cornuted branchlets and is referable to the variety *cornuta*. Børgesen (1920, p. 382) reported *H. cornuta* from the West Indies. His illustration of a plant (Børgesen 1920, fig. 382) is similar to that of Taylor (1928, pl. 22, fig. 12). On the other hand, Malaysian specimens have rather slender fronds and abundant stellate or cornuted branchlets (Fig. 44) throughout the frond and are similar to the specimen from Taiwan (SAP 013987). However, these specimens do not agree completely with the descriptions of two varieties of *H. cornuta* given by J. Agardh (1852). These specimens suggest that an entity similar to *H. cornuta* is present in the western Pacific outside Japan.

Acknowledgements

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Appendix

The following is a list of the representative specimens examined. The locations of the prefectures are shown in Figure 45. Numbers given refer to SAP.

Hypnea charoides-valentiae complex

Aoname, Okushiri Island, Hokkaido, October 11, 1943, leg. Y. Hasegawa (025153); Asamushi, Aomori Prefecture, August 1940, leg. S. Inoh (024191); Ayukawa, Miyagi Prefecture, date unknown, anonymous (021718); Fukura, Yamagata Prefecture, August 1951, leg. T. Kanamori (035356); Shigaki, Hakui, Ishikawa Prefecture, August 1938, leg. M. Kumazawa (021339); Oshima, Fukui Prefecture, August 7, 1942, leg. Y. Nakamura (023676); Amatsura, Chiba Prefecture, date unknown, leg. T. Muraoka (021717); Hinomisaki, Shimane Prefecture, August 2, 1942, leg. Y. Nakamura (023682); Shirahama, Shimoda, Shizuoka Prefecture, June 12, 1995, leg. Y. Yamagishi; Utsumi, Aichi Prefecture, August 1940, leg. T. Segi (024725); Wagu, Mie Prefecture, June 1942, leg. T. Segi (023065); Shionomisaki, Wakayama Prefecture, July 24, 1994, leg. H. Ebata; Ikata, Ehime Prefecture, August 1981, leg. H. Ishibashi (042098); Susaki, Kochi Prefecture, July 1941, leg. T. Tanaka (022216); Nomozaki, Nagasaki Prefecture, May 1932, leg. Y. Yamada (13181); Ebisubana, Tomioka, Kumamoto Prefecture, August 19, 1955, leg. T. Yoshida (049934); Ankyaba, Kakeroma Island, Kagoshima Prefecture, June 27, 1961, leg. T. Yoshida; Miyako-jima, Okinawa Prefecture, April 10, 1935, leg. Y. Yamada and T. Tanaka (022141); Sukuji, Ishigaki Island, Okinawa Prefecture, March 15, 1995, leg. M. Masuda.

Hypnea chordacea Kützing

Shirahama, Shimoda, Shizuoka Prefecture, June 12, 1995, leg. Y. Yamagishi; Yaizu, Shizuoka Prefecture, June 29, 1991, F. Hayashida (042625).

Hypnea flagelliformis J. Agardh

Fukaura, Aomori Prefecture, September 13, 1994, leg. M. Masuda & Y. Yamagishi; Kamo, Yamagata Prefecture, August 1956, leg. T. Kanamori (035028); Murakami, Niigata Prefecture, November 11, 1994, leg. M. Masuda & Y. Yamagishi; Takeno-hama, Hyogo Prefecture, August 1930, anonymous (021701); Kiwado, Heki, Yamaguchi Prefecture, September 4, 1994, leg. M. Masuda.

Fig. 45. Map of Japan showing prefectures.

Hypnea japonica Tanaka

Nemoto, Chiba Prefecture, August 1931, leg. T. Hirohashi (022138); Enoshima, Kanagawa Prefecture, May 1924, leg. Y. Yamada (022126); Hinomisaki, Shimane Prefecture, May 4, 1985, leg. T. Yamamoto (059590); Susaki, Shimoda, Shizuoka Prefecture, May 1941, leg. S. Inoh (022147); Shirahama, Shimoda, Shizuoka Prefecture, June 12, 1995, leg. Y. Yamagishi; Wagu, Mie Prefecture, April 1931, leg. K. Inagaki (10383); Taiji, Wakayama Prefecture, April 4, 1957, leg. Y. Tsuji (057378); Hiburijima, Uwajima, Ehime Prefecture, March 22, 1987, leg. H. Ishikawa (053404); Ashizuri-misaki, Kochi Prefecture, April 28, 1956, leg. N. Tazawa (057315); Shikano-shima, Fukuoka Prefecture, June 25, 1983, leg. K. Nanri (044783); Nomo, Nagasaki Prefecture, May 9, 1955, leg. M. Ichiki (058808); Kamiura, Saganoseki, Ooita Prefecture, June 20, 1986, leg. M. Kanda (048583); Uryuzako, Miyazaki Prefecture, April 8, 1974, M. Kurogi (058459); Hananose, Kagoshima Prefecture, April 12, 1963, leg. K. Matsunaga.

Hypnea pannosa J. Agardh

Yakomo, Okinoerabu-jima, Kagoshima Prefecture, July 25, 1979, leg. M. Baba (056101); Kunigami, Okinoerabu-jima, Kagoshima Prefecture, July 23, 1979, leg. M. Baba (056104); Cape Hedo, Okinawa Prefecture, September 27, 1995, leg. M. Masuda and Y. Yamagishi; Oohama, Ishigaki-jima, Okinawa Prefecture, March 16, 1995, leg. M. Masuda.

Hypnea saidana Holmes

Sunosaki, Chiba Prefecture, March 29, 1930, leg. K. Okamura (059958); Enoshima, Kanagawa Prefecture, April 1900, leg. K. Okamura (Okamura herbarium), May 24, 1932, leg. K. Okamura (059950), June 1927, leg. K. Okamura (059954); Shichirigahama, Kanagawa Prefecture, May 25, 1930, leg. K. Okamura (059956).

Hypnea spinella (C. Agardh) Kützing

Shiono-misaki, Wakayama Prefecture, September 11, 1952, leg. T. Yamamoto (043971); Okinoshima, Kochi Prefecture, August 1940, leg. Y. Yamada and T. Tanaka (022262); Imuta, Koshikijima, Kagoshima Prefecture, August 1940, leg. Y. Nakamura (023970); Okinawa Island, date unknown, leg. S. Inoh (9863).

Hypnea variabilis Okamura

Ooarai, Ibaraki Prefecture, July 22, 1933, anonymous (059967); Oohara, Chiba Prefecture, June 7, 1925, leg. Y. Yamada (021714); Enoshima, Kanagawa Prefecture, March 24, 1924, leg. Y. Yamada (021714), June 13, 1995, leg. Y. Yamagishi; Shirahama, Shimoda, Shizuoka Prefecture, June 12, 1995, leg. Y. Yamagishi; Omaezaki, Shizuoka Prefecture, May 23, 1993, leg. T. Sawada (060948).

Hypnea yamadae Tanaka

Arita, Kushimoto, Wakayama Prefecture, April 5, 1994, leg. H. Ebata; Ikata, Ehime Prefecture, July 2, 1958, leg. Y. Nomura (035377); Nomo, Nagasaki Prefecture, April 4, 1977, leg. T. Yoshida; Sato, Koshikijima, Kagoshima Prefecture, August 1923, leg. Y. Yamada (021689).

Hypnea species

Chichijima, Bonin Islands, Tokyo, date unknown, leg. S. Segawa (021691, 021695).

SPECIES OF *HYPNEA* LAMOUROUX (GIGARTINALES, RHODOPHYTA) FROM TAIWAN

Young-Meng Chiang

Abstract

Nine species of *Hypnea* from Taiwan are described on the basis of specimens described earlier by Tanaka and specimens in my collection. *Hypnea chordacea* Kützing forma *simpliciuscula* (Okamura) Tanaka and *H. saidana* Holmes sensu Chiang are excluded from the marine flora of Taiwan. *Hypnea spinella* (C. Agardh) Kützing is used in place of *H. esperi* sensu Tanaka. The distinction between *H. charoides* Lamouroux and *H. valentiae* (Turner) Montagne is ambiguous, so they are treated as *H. charoides-valentiae* complex. The occurrence of *H. cervicornis* J. Agardh sensu Yoshikawa et Yoshikawa in Taiwanese waters is questionable. Moreover, *H. cervicornis* itself has been placed in synonymy with *H. spinella*.

Introduction

Hypnea Lamouroux has numerous species of wide distribution in warmer waters of the world. In Taiwan, species of *Hypnea* can be found year-round growing on rocks, stones, shells, and dead corals or epiphytic on other algae in the lower intertidal to sublittoral zones. Notably, during the spring certain species of *Hypnea* such as *H. japonica* can be found growing luxuriantly on other algae that are growing on rocks in the lower intertidal zone.

The first record of species of *Hypnea* in Taiwan was *H. seticulosa* J. Agardh (synonym of *H. charoides* Lamouroux) published by Ariga (1920). Tanaka (1941) included 9 species and one form of *Hypnea* collected from Taiwan in his excellent study, "The genus *Hypnea* from Japan." Thereafter, *H. cervicornis* J. Agardh (Yoshikawa and Yoshikawa 1977), *H. spinella* (C. Agardh) Kützing (Chiang 1962), and *H. saidana* Holmes (Chiang 1973) were added to the marine flora of Taiwan. Among other species reported by Tanaka (1941), several have been placed in synonymy: *H. esperi* Bory with *H. spinella* (C. Agardh) Kützing, *H. hamulosa* (Turner) Montagne with *H. valentiae* (Turner) Montagne and *H. nidulans* Setchell with *H. pannosa* J. Agardh. Thus, 10 species are known in Taiwan. Among these 10, *H. cervicornis* J. Agardh was reported by Yoshikawa and Yoshikawa (1977), but no specimens with this identification belonging to them or to others are stored in Taiwan. Because the gross morphology of some closely related entities is extremely variable and the identification is difficult, the presence of *H. cervicornis* (sensu Yoshikawa and Yoshikawa 1977) in Taiwanese waters is questionable.

During this study, I had access to some of Tanaka's specimens of *Hypnea*, and I compared them with my own collections at the Kuala Lumpur workshop. In this chapter, nine taxa are recognized. More specimens need to be collected for future studies of the genus.

Materials and Methods

Herbarium specimens that had been collected in Taiwan and deposited in the herbarium of Hokkaido University (SAP) and liquid-preserved and dry specimens collected by me were examined. Sections made by hand were stained with 1% aniline blue and fixed with 1% hydrochloric acid. The sections were then mounted in a drop of undiluted corn syrup with phenol added as a preservative and examined with a light microscope.

Key to the Species of *Hypnea* from Taiwan

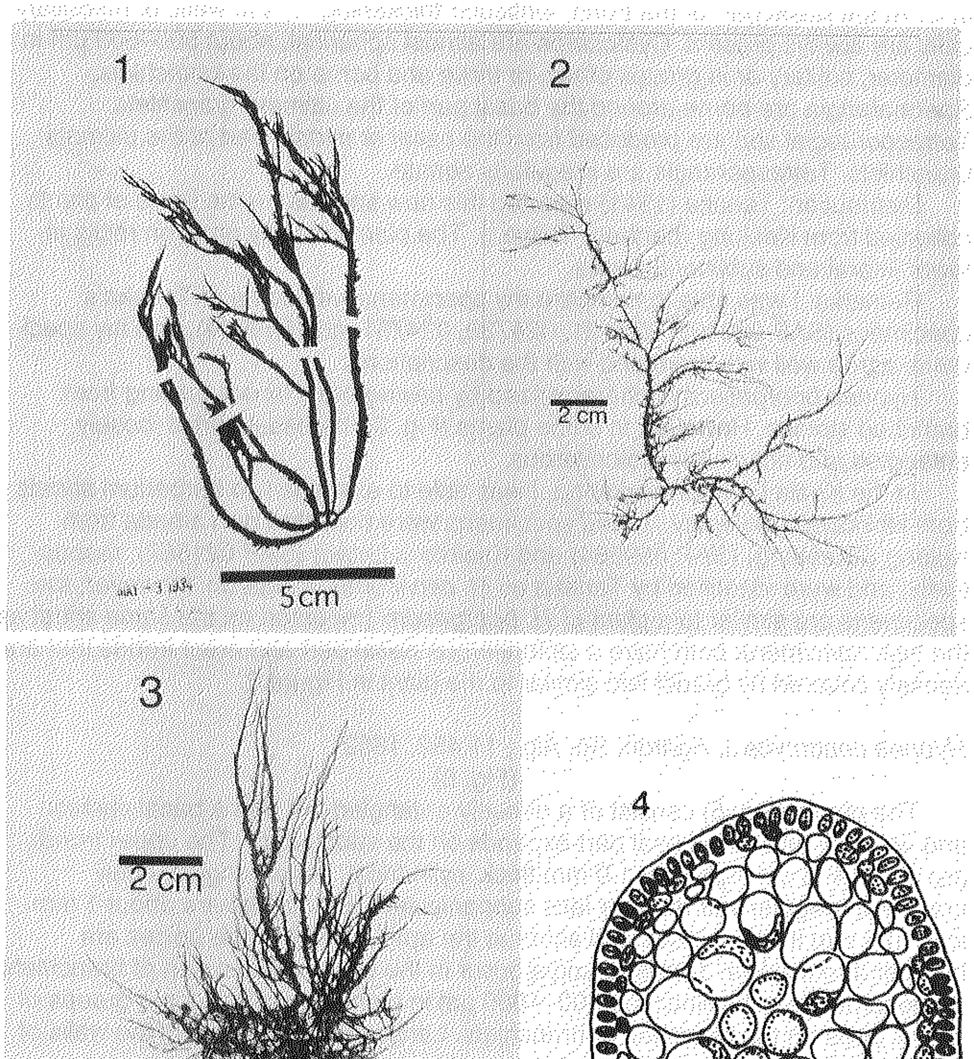
1. Plants with hooks at ends of branches .... *H. japonica*
1. Plants without hooks 2
    2. Plants with persistent axes 3
    2. Plants without persistent axes 6
3. Axes simple or sparsely branched, naked or covered with many branchlets from mid to apical parts .... *H. chordacea*
3. Axes profusely branched throughout 4
    4. Branches with many stellate, spiny processes .... *H. cornuta*
    4. Branches without stellate, spiny processes 5
5. Plants with densely branched, cushionlike basal part and erect fronds .... *H. cenomyce*
5. Plants with axes arising from branched stolons or more or less densely branched basal part .... *H. boergesenii*
    6. Plants large, spreading fronds filiform, loosely branched .... *H. charoides-valentiae* complex
    6. Plants small, less than 5 cm high, in form of prostrate mat 7
7. Plants easily separated into small parts .... *H. spinella*
7. Plants impossible to separate without causing damage .... *H. pannosa*

Description of the Species

Hypnea boergesenii Tanaka, Sci. Pap. Inst. Algol. Res. Fac. Sci. Hokkaido Univ. 2: 233–235, pl. 53, fig. 1, text figs. 6–8, 1941.

(Figs. 1–4)

Plants (Figs. 1–3) are tufted, erect, up to 17 cm high, 1–2 mm thick, cylindrical, basally with branched stolons or loosely entangled base. Erect axes are profusely branched four or five times and gradually attenuated at the apex. Fronds are densely covered with many lateral branchlets, 0.5–2.0 mm long, about 0.5 mm wide, single or divided, pointed or club-shaped at the apex. Branchlets are most profuse at the middle parts of the branches, rarely extending to the upper or lower parts. In cross sections (Fig. 4), the frond consists of the cortex, the medullary layer, and the central axis. The cortical layer is composed of one to two layers of pigmented small cells; the medullary layer consists of larger cells. At the central part of the frond, a central cell or a few smaller cells form a central



Figs. 1–4. ***Hypnea boergesenii.*** **Fig. 1, Type specimen (SAP 021721) collected at Keelung May 3, 1934. (Provided by M. Masuda). Fig. 2, Specimen collected at Patoutzu, Keelung, April 27, 1976. Fig. 3, Specimen collected at Tali, Taipei County, Apil 6, 1970, showing loosely entangled basal part. Fig. 4, Cross section through lower part of frond showing lenticular thickenings (arrows) on the walls of medullary cells.**

axis. At the basal part of the frond, lenticular thickenings in the walls of medullary cells are always present. Cystocarps are almost spherical, about 500–600 µm in diameter, solitary or in groups of two or three and borne on the branchlets. Spermatangia are borne around the basal part of the ultimate branchlets. Tetrasporangial sori are produced from the basal or middle part of the ultimate branchlets. Tetrasporangia are irregularly zonate.

Distribution: Tanaka (1941) reported this new species on the basis of plants collected from Keelung (northern Taiwan). The plants usually grow on rocks in lower littoral and sublittoral zones.

Remarks: I was able to compare my specimens with some of Tanaka's specimens (SAP 022130, 022131, 024739, 024731, and 059964), and my specimens agree well with them and with the descriptions.

Hypnea boergesenii is characterized by having erect fronds issuing from branched stolons. However, in some plants (Fig. 3) the basal part is loosely entangled and not clearly stoloniferous.

At the Kuala Lumpur workshop, I was able to examine two herbarium sheets from Hokkaido University. These specimens were collected by Yamada from Kelung (=Keelung) (SAP 059964) and Kasioto (=Lutao) (SAP 021692), respectively, and were identified by Tanaka as *H. cervicornis* J. Agardh. However, the specimens are similar to a plant of *H. boergesenii* (mounted on the same sheet as the type specimen): both have a stoloniferous basal part and erect fronds that are densely covered by branchlets similar to the plant in Figure 2.

Hypnea cenomyce J. Agardh, Sp. Alg., 11:452, 1852.

(Fig. 5)

The plants (Fig. 5) consist of a densely entangled tuft with a basal cushion and an erect part. The basal part expands on the substratum. The upper fronds are about 4–6 cm high, 0.5–1.0 mm thick, cylindrical, not entangled, richly branched irregularly or more or less subpaniculate. Branchlets are about 1 mm long, 0.5 mm thick, spinous and acute at the apex, but often the apices are broader and disklike. Tetrasporangia occur in the basal swollen part of branchlets. Cystocarps are subcylindrical, 600–1000 µm in diameter, solitary or in groups of two or three on the branches or branchlets. Lenticular thickenings in the walls of the medullary cells are often present.

Distribution: Widely distributed in Taiwan. During the spring, plants of this species can be found abundantly on pebbles, stones, and other surfaces in the upper subtidal zone in some places, such as Makang, on the northeast coast of Taiwan.

Remarks: At the Kuala Lumpur workshop, I had access to a specimen (SAP 059963) collected by Yamada at Tairi (=Tali) and identified by Tanaka. My specimens are almost the same as Yamada's specimen. Tanaka (1941, p. 250) pointed out that this species is close to *H. spinella* J. Agardh except in ramification and shape of branchlets. The upper branches of the frond of *H. cenomyce* are similar

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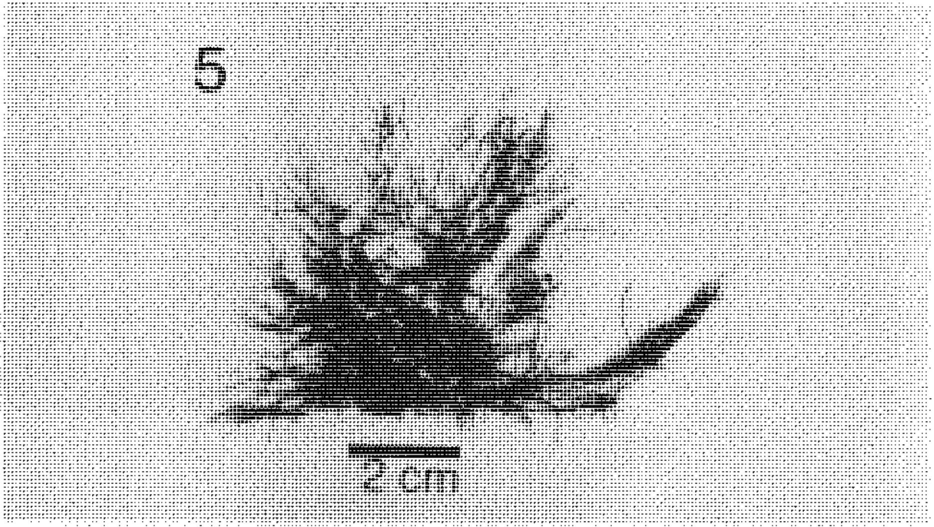


Fig. 5. *Hypnea cenomyce*. Specimen collected at Makang, Taipei County, March 6, 1985.

to those of *H. hamulosa* J. Agardh (=*H. valentiae*). The cushionlike mass at the base in *H. cenomyce* differs from that of *H. hamulosa*. From my observations in nature, I find that this species can be distinguished from *H. spinella* by differences in size and form. The erect axes of *H. cenomyce* are variable but on average taller (up to 10 cm high), whereas the fronds of *H. spinella* are only 1–2 cm high.

Hypnea charoides-valentiae complex

(Figs. 6–8)

Hypnea charoides Lamouroux, Ann. Mus. Natl. Hist. Nat. 20:132, pl. 10, figs. 1–3, 1813.

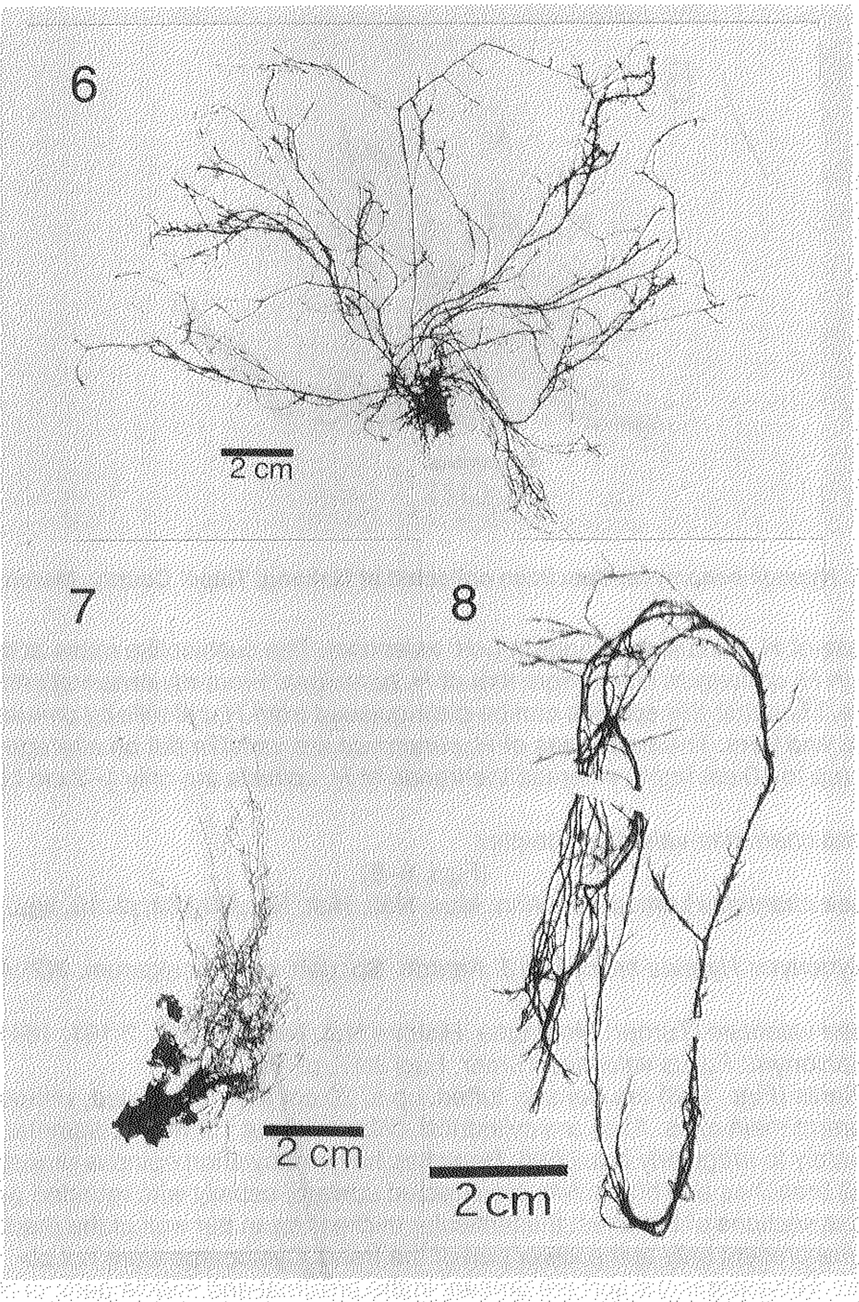
Synonym: *Hypnea seticulosa* J. Agardh, Sp. gen. ordines algarum, 2(2):446, 1852.

Hypnea valentiae (Turner) Montagne, Histoire Nat. Iles Canaries, 3:161, 1841.

Basionym: *Fucus valentiae* Turner, Fuci 2:17, pl. 78, 1809.

Plants (Figs. 6–8) are densely tufted, up to 20 cm high, entangled, without percurrent main axes. Axes are cylindrical, filiform, about 1.0 mm in diameter, alternately to irregularly branched. Branches have many short spinous branchlets, and all branches and branchlets are directed upward, usually with rounded axils. In cross sections of the axes, the lenticular thickenings in the wall of the medullary cells are present only at the lower part of the frond. Cystocarps were not observed. Tetrasporangial sori are present in the proximal and middle parts of the short branchlets, and tetrasporangia are zonately divided.

Distribution: Common in Taiwan. During the spring, this species grows



Figs. 6–8. *Hypnea charoides-valentiae* complex. Fig. 6, Specimen collected at Tanhai, Taipei County, May 28, 1981. Fig. 7, Specimen collected at Ch'uan-fan-shih, Pingtong County, March 13, 1978. Fig. 8, Specimen collected at Keelung May 3, 1934 (SAP 021719; provided by M. Masuda).

abundantly in the lower littoral to upper sublittoral zones and in tide pools in some places, such as Nanwan in southern Taiwan. It grows epiphytically and on stones and shells.

Remarks: Tanaka (1941) reported both *H. charoides* and *H. hamulosa* (Turner) Montagne[1] from Taiwan. However *H. hamulosa* is a misapplied name and currently is associated with *H. valentiae* (Turner) Montagne by Silva et al. (1987, p. 50).

The distinctions between *H. charoides* and *H. valentiae* are based on whether the plant has percurrent axes or not and the nature of branchlets. According to Womersley (1994), *H. charoides* is characterized by plants without percurrent axes, and all branches are covered with numerous, short spinous branchlets that are more or less at right angles to the bearing branch. *Hypnea valentiae* has percurrent main branches and has relatively few spinous branchlets that are directed upward rather than at right angles. Many intermediate forms are found in Taiwanese waters. Some specimens have numerous branchlets that are directed upward on percurrent main axes and branches, whereas other plants have relatively few branchlets issuing at right angles to the axes and branches. In some specimens, branchlets are irregularly directed, both upward and at right angles, in the same individual specimen. This kind of feature also can be found in Tanaka's specimens collected from Taiwan under the name of *H. charoides* (SAP 021719) and *H. hamulosa* (SAP 021703). At the Kuala Lumpur workshop, the members of the *Hypnea* group agreed to treat those algae as *H. charoides-valentiae* complex. In the future, these relationships may be clarified by studies with experimental cultures, examination of large collections, and a study of authentic specimens in European herbaria.

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[1] Turner's material, identified by him (Turner, 1809, vol. 2, pp. 19–20, pl. 79) with *F. hamulosus* Esper (Papenfuss, 1958, pp. 105–106), was later believed by various authors, including Kützing (1849, p. 758) and Børgesen (1943, p. 59), to be identical with *H. valentiae* (Turner) Montagne (1841), on the basis of *F. valentiae* Turner (1809, vol. 2, pp. 17–18, pl. 78). The two plates of Turner show plants that are much alike, each having percurrent axes; however, the specimen of *H. valentiae* is cystocarpic and that of *H. hamulosa* Montagne is tetrasporangial. When herbarium specimens bearing these specific names and these reproductive structures are compared, there are no features among many variable features shown by *Hypnea* species that distinguish these two. Montagne (1841) named *H. hamulosa* on the basis of Turner's descriptions and illustrations of a plant from the Red Sea. Esper's plant from the Malabar coast of India was placed by J. Agardh (1862) with a query in *H. nigrescens* (Silva et al., 1987), which has not been taken up again. In my opinion, *H. hamulosa* Montagne should be treated as a synonym of *H. valentiae* (Turner) Montagne. (See the more formal treatment of this nomenclatural problem in "Overview of *Hypnea* (Rhodophyta, Hypneaceae)," by Masuda et al., at the beginning of this section.)—Editor

Hypnea chordacea Kützing, Sp. alg., p. 760, 1849.

(Fig. 9)

Synonym: *Hypnea simpliciuscula* Okamura in De Toni, Sopra tre Nuo. Alg. Mar. Giap., p. 345, 1895; *Hypnea chordacea* var. *simpliciuscula* (Okamura) Tanaka, Sci. Pap. Inst. Algol. Res. Fac Sci. Hokkaido Imp. Univ. 2:232, pl. 53, fig. 2, 1941.

Plants (Fig. 9) consist of several erect percurrent axes attached to a branched fibrous base. The axes are up to 13 cm high, 1–2 mm thick, rarely dichotomously branched, usually acute at the apex. In the middle part, the axes and their lateral branches are densely covered with branchlets, which are short, 1.5–7.0 mm long, about 300 µm wide, simple or divided, often entangling with each other. In cross sections of the axis, the medullary layer is composed of parenchymatous cells that have no lenticular thickenings in the walls. The central part consists of small, rather thin-walled cells. Cystocarps were not observed. Tetrasporangia are formed around the middle or lower swollen part of the branchlets, irregularly zonate, 20–30 µm wide, and 40–55 µm long.

Distribution: Widely distributed in Taiwan and its offshore islands but more common in the north and northeast areas of the island. The plants usually grow on rocks in the lower intertidal to upper subtidal zone.

Remarks: Young plants of this species characteristically have erect, simple or sparsely branched, naked, cylindrical axes. On maturing, the axes become densely covered with short branchlets at the middle to upper parts.

On the basis of material with "a slender (ca. 1.5 mm thick) and a much ramified" axis, Tanaka (1941, p. 232) established *H. chordacea* forma *simpliciuscula* (Okamura) Tanaka. We (Drs. Masuda and Yamagishi and I) think that the differences attributed to this forma are due to environmental conditions. Therefore, the herbarium specimens collected from Taiwan and determined by Tanaka as *H. chordacea* forma *simpliciuscula* (SAP 024735 and 042625) and *H. simpliciuscula* Okamura (SAP 059962) should be merged with *H. chordacea* Kützing as synonyms.

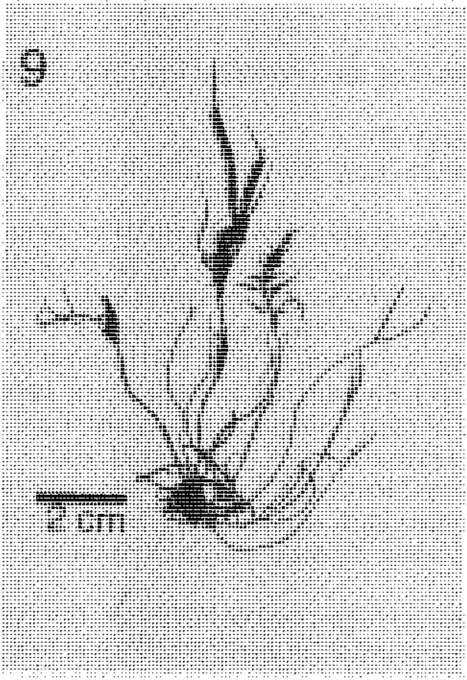
Hypnea cornuta (Lamouroux) J. Agardh, Sp. alg. 2:449, 1852.

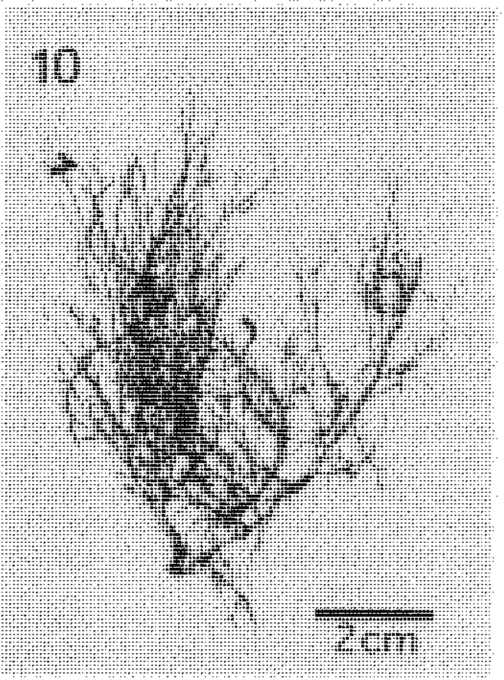
(Figs. 10 and 11)

The plants (Fig. 10) are erect, tufted, 4–11 cm high. Axes are subcylindrical, about 1 mm wide, alternately branched. Branches have both tiny, pointed branchlets and stellate, spiny processes. Stellate processes (Fig. 11) are small, with three to five rays and are peltately fixed to the branches. In cross sections, a central cell of the axis is surrounded by larger medullary cells with no lenticular thickenings in their walls. No cystocarps or tetrasporangia were observed.

Distribution: This species is not a common alga in Taiwan. The plants were collected from Penghu and southern Taiwan.

Remarks: The plants are characterized by having many conspicuous, small stellate spiny processes scattered on the branches.





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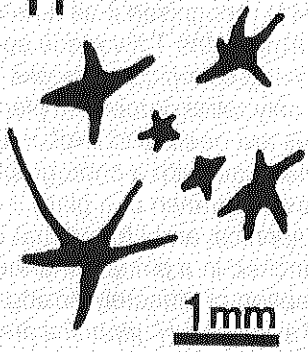


Fig. 9. *Hypnea chordacea*. Specimen collected at Keelung April 28, 1979.
Figs. 10 and 11. *Hypnea cornuta*. Fig. 10, Specimen collected at Wanan (=Moan), Penghu County, April 1924 (SAP 13987; provided by M. Masuda). Fig. 11, Stellate processes formed from arrangement of short branchlets.

Børgesen (1943, p. 59) pointed out that this species and *H. valentiae* are closely related forms, and their differences are most probably nothing but variations due to different external conditions. Whether this proposal is true or not needs to be proved by experimental study.

Hypnea japonica Tanaka, Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Imp. Univ. 2:236, pl. 54, figs. 9 and 10, 1941.

(Figs. 12 and 13)

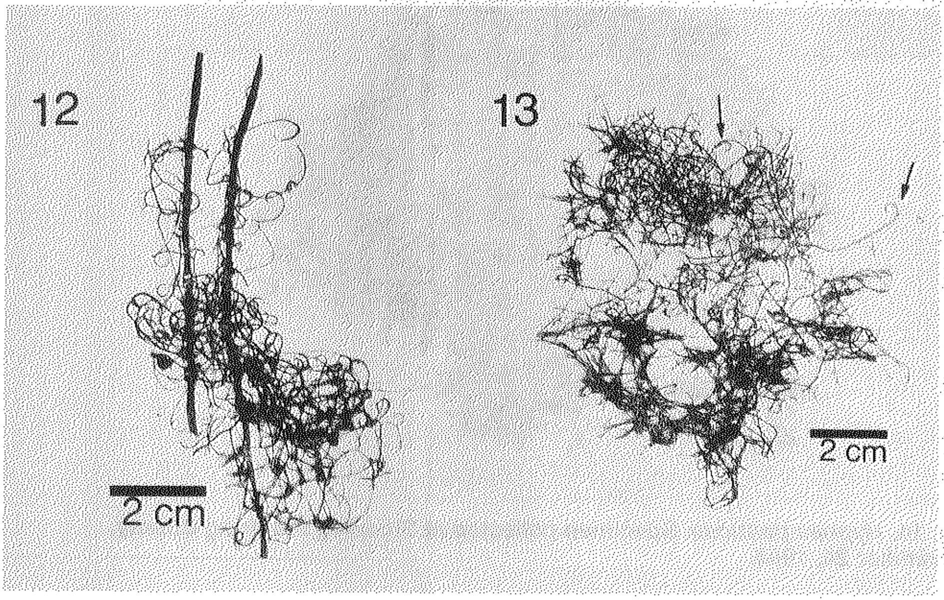
Synonym: *Hypnea musciformis* of Okamura, Icon. Jpn. Alg. 2:35, pl. 59, fig. 7, pl. 60, figs. 7–11, 1909.

Plants (Figs. 12 and 13) are always entangled with other algae to which they fix themselves by means of hooks or slender, curling branch tips. Fronds are about 1.0–2.0 mm in diameter, cylindrical, without percurrent axes, always loosely entangled to form a large mass. They branch three to five times in alternate, or rarely secund, manner, and often form hooks at their apices (Fig. 13). In cross sections, lenticular thickenings in the walls of medullary cells are often found here and there. The central axial strand consists of several cells that are smaller than those of the medullary layers and are rounded to polygonal, thick-walled, and usually 5 to 15 times longer than wide in longitudinal view. Gametophytes were not observed. Tetrasporangia are formed in swollen parts of the ultimate branchlets in sori. Tetrasporangia are ovoid to elliptical, divided zonately, 20–35 μm wide and 45–60 μm long.

Distribution: North, east, and, most often, northeast coasts of Taiwan. During early March, the plants can be found growing abundantly on other red algae that grow on rocks in the lower littoral and sublittoral zones along the coasts of some areas, such as Makang, in northeast Taiwan.

Remarks: This species was first reported as *H. musciformis* by Okamura (1909). However, Tanaka (1941) recognized it as a new species on the basis of its large and cartilaginous thalli. Among the Taiwanese species of *Hypnea*, this species is characterized by having conspicuous hooks at the apex of branches. It is curious that for a long time only tetrasporophytic plants of this species have been collected. Experimental studies are needed to explain this situation.

Recently, Dr. Abbott provided me with a photograph of Hawaiian *H. musciformis* that probably shows a branch of a plant. I compared this picture with Taiwanese specimens of *H. japonica*, and I found that the plant from Hawaii is more regularly and neatly branched in a pinnate manner and that almost all the tips of the branches, with the exception of pinnately arranged branchlets, turn into hooks. In contrast, plants of Taiwanese *H. japonica* are more irregularly and less branched. Most branches of *H. japonica* have straight or curved tips; thus, the presence of tendrils in this species is not as common as in *H. musciformis*. Apparently, these two species of *Hypnea* differ from each other in the feature of branching and the production of hooks, at least according to a comparison of the photograph of Hawaiian *H. musciformis*, which was introduced to Hawaii from Florida,



Figs. 12 and 13. *Hypnea japonica*. Fig. 12, Specimen collected at Tali, Ilan County, May 20, 1979, showing the plant epiphytic on branches of *Prionitis ramosissima* (Okamura) Kawaguchi. Fig. 13, Specimen collected at Patoutzu, Keelung, June 25, 1972, showing entangled mass of the plant and its tendrils (arrows) at the apices.

and the specimens of Taiwanese *H. japonica*. More specimens of *H. musciformis* are needed to make further comparisons of these two species.

Hypnea pannosa J. Agardh, Öfvers. Kongl. Vet. Akad. Forh. 4:14, 1847.
(Fig. 14)

Synonym: *Hypnea nidulans* Setchell, Calif. Acad. Sci. Proc. IV, 12:161, 1924.

Plants (Fig. 14) are densely entangled tufts, 2–5 cm high, consisting of a cushionlike mat up to 10 cm across on rocks, pebbles, or other substrata. Fronds are densely interwoven with axes about 1.5–2.5 mm thick, subterete, subcartilaginous, often irregularly densely branched at close intervals, the whole mat tightly interwoven and almost impossible to loosen. Live fronds are usually greenish or purplish red; dried specimens are black. In cross section, a single central axis is present at the center of the frond; lenticular thickenings in the walls of the medullary cells are rarely observed. Cystocarps are not observed. Tetrasporangia are borne on one side of the swollen ultimate branchlets.

Distribution: Common in Taiwan, but most common in the south and the

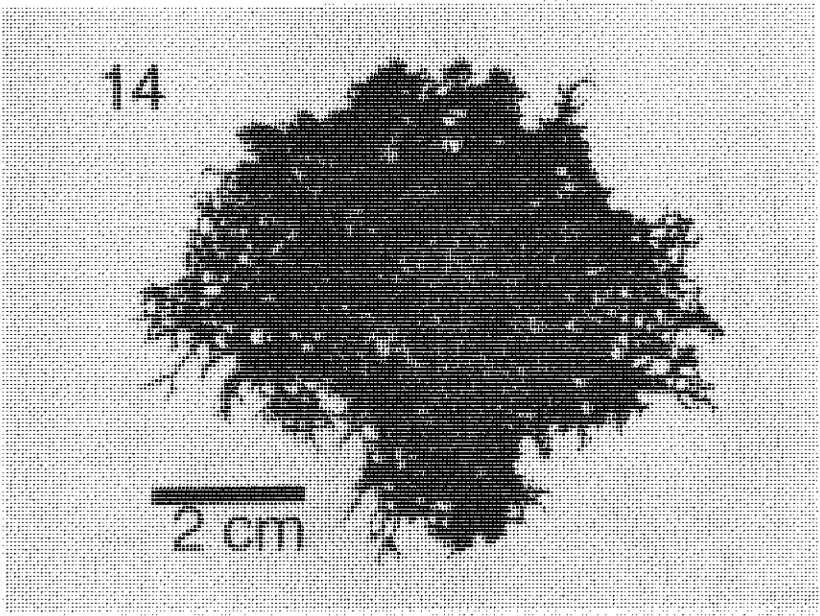


Fig. 14. *Hypnea pannosa*. Specimen collected at Shanhai, Pingtung County, November 24, 1984.

offshore islands, especially during the spring.

Remarks: I compared my specimens with a specimen (SAP 050708) identified by Tanaka from Tairi (=Tali), Taiwan and found that the two are almost alike. My plants also agree with the descriptions and figures of Hawaiian plants reported by Mshigeni (1978).

Tanaka (1941) reported *H. pannosa* and *H. nidulans* Setchell from Taiwan and distinguished them as follows: *Hypnea pannosa* has densely entangled plants and tetrasporangial sori usually growing on one side of branchlets, then gradually completely surrounding the branchlets. Plants of *H. nidulans* are loosely entangled, and tetrasporangial sori are saddle-shaped. In 1954, Dawson distinguished *H. pannosa* from *H. nidulans* by the small sizes and compact tufts of the first species, but later he (Dawson 1961, p. 236) concluded that the type specimens of the two species are the same and reduced *H. nidulans* to the synonymy of *H. pannosa*.

Plants of *H. pannosa* are most commonly found growing abundantly on stable rocks of middle to lower intertidal zones, but sometimes they can be found growing in tide pools.

The Taiwanese *H. pannosa* can be distinguished quite easily from *H. spinella* (C. Agardh) J. Agardh by the color and the texture of the plants. *Hypnea pannosa* is usually greenish red, whereas *H. spinella* is brownish or purplish red. The plants of *H. pannosa* are tough and cannot be separated easily, but break apart into fragments; plants of *H. spinella* are easily separated.

Hypnea spinella (C. Agardh) Kützing, Bot. Zeit. 5:23, 1847.

(Fig. 15)

Basionym: *Sphaerococcus spinellus* C. Agardh, Sp. alg. 1(2):323, 1822.

Synonym: *Hypnea cervicornis* J. Agardh, Sp. gen. ordines algarum, 2(2):451, 1852.

Plants (Fig. 15) form small concrescent rounded mats on rocks. The plants are without percurrent axes, about 3–6 cm across and 1.0–2.0 cm high, entangled with branches of 0.5–1.0 mm thick. Axes and branches are terete, filiform, with long or short branchlets that are pointed at the apices. Here and there, branches come together forming loose webs. In cross sections, lenticular thickenings are present in the walls of medullary cells. Tetrasporangia are formed in the proximal, middle, or distal swollen part of the ultimate branchlets.

Distribution: Growing on rocks of the lower intertidal to upper subtidal zones in

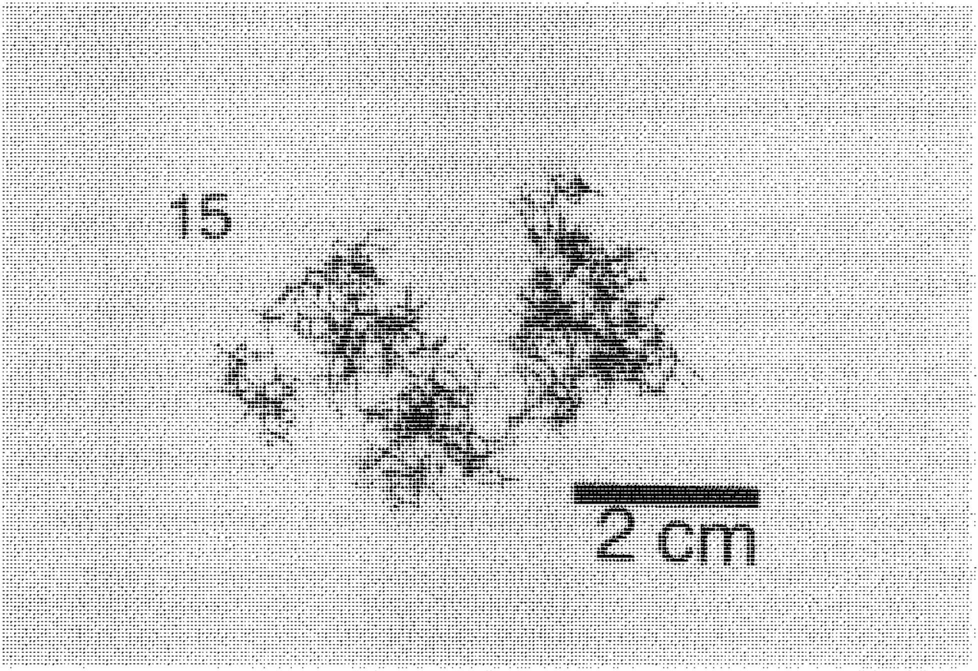


Fig. 15. *Hypnea spinella*. Specimen collected at Ch'uan-fan-shih, Pingtong County, March 13, 1978.

the north and northeastern parts of Taiwan.

Remarks: Mshigeni (1978) proposed that all algae known as *H. esperi* reported from the western Pacific, including Taiwan should be named *H. spinella*. I find that the pulvinate mats of *H. spinella* are easily separated into small intact specimens, whereas those of *H. pannosa* cannot easily be separated without causing damage to the specimens. In *H. pannosa*, the branchlets are thick almost all the way to the apex, and the branch tips are often divaricate. In *H. spinella*, the upper branches and branchlets are laterally branched, more slender, and narrowing at the tip. The tetrasporangia of *H. pannosa* are borne unilaterally on the fertile parts of ultimate branchlets, whereas those of *H. spinella* are borne all around the fertile axis.

The specimen of *H. spinella* (SAP 021704) collected from Taiwan is kept in the Hokkaido University herbarium and is either a small individual plant or a small part of a larger plant.

Acknowledgments

I thank Dr. Isabella Abbott for the invitation to participate in the sixth workshop and her critical corrections and editing of the manuscript. I also extend my appreciation to Dr. James Sullivan for assistance and to Dr. Phang Siew-Moi and her students for all the arrangements of this workshop and their hospitality. I am also deeply indebted to Drs. Michio Masuda and Yukimasa Yamagishi for bringing some Taiwanese *Hypnea* specimens from the Herbarium of Hokkaido University to the workshop and thereafter sending me photographs and material of other *Hypnea* species.

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SPECIES OF *HYPNEA* FROM THAILAND

Khanjanapaj Lewmanomont

Abstract

Forty-two specimens of the genus *Hypnea* previously collected from the Gulf of Thailand and Andaman Sea and deposited at the Faculty of Fisheries, Kasetsart University, Bangkok, were examined. Four species are discussed: *H. charoides-valentiae* complex, *H. cornuta* var. *stellulifera*, *H. pannosa* and *Hypnea* sp. for which no gametophytic material is yet available. There are approximately six additional species to be reexamined.

Introduction

In Thailand, *Hypnea* was first reported by Martens (1866) as part of the collections from the German expedition to eastern Asia. He reported *H. divaricata* R. Brown from Simaharadscha (Si Racha, Chon Buri). Reinbold (1901) reported *H. musciformis* (Wulfen) Lamouroux from Lem Ngob, Trat. Dawson (1954) found *H. cervicornis* J. Agardh at Saen Soek, Chon Buri, and Egerod (1971) collected *H. esperi* Bory from Koh Charn, Prachuap Khiri Khan. In 1981, Ogawa and Lewmanomont recorded six species from Si Racha, Chon Buri: *H. cenomyce* J. Agardh, *H. cervicornis* J. Agardh, *H. charoides* Lamouroux, *H. cornuta* (Lamouroux) J. Agardh, *H. esperi* Bory, and *H. hamulosa* (Turner) Montagne. Lewmanomont (1988) reported two species, *H. cenomyce* J. Agardh and *H. valentiae* (Turner) Montagne, from coral reef areas. Recently, Lewmanomont and Ogawa (1995) added *H. pannosa* J. Agardh to the records of this genus.

Materials and Methods

Materials used for this study were specimens collected from various parts of the Gulf of Thailand and the Andaman Sea from 1971 to 1996 and kept as herbarium specimens. Some were also preserved in formalin. All these specimens are deposited at the Faculty of Fisheries, Kasetsart University, Bangkok. Reference specimens were type material of *H. cornuta* and varieties loaned from the Agardh Herbarium (LD), Lund, Sweden.

Key to the Species of *Hypnea* from Thailand

1. Plants with more or less compressed branches .... *H. pannosa*
1. Plants with terete axes and branches 2
    2. Plants with small stellate spinous processes of three to six rays, peltately attached .... *H. cornuta* var. *stellulifera*
    2. Plants without small stellate spinous processes 3
3. Plants with or without percurrent axis, axis and branches covered with numerous branchlets mostly at right angles to plane of axes .... *H. charoides-valentiae* complex
3. Plants with percurrent axis, branch terminals hooklike .... *Hypnea* species

Description of the Species

Hypnea cornuta (Kützing) J. Agardh var. *stellulifera* J. Agardh, Sp. gen. ordines algarum, 2(2):449, 1852.

(Figs. 1–16)

Basionym: *Chondroclonium cornutum* Kützing, Sp. alg., p. 741, 1849.

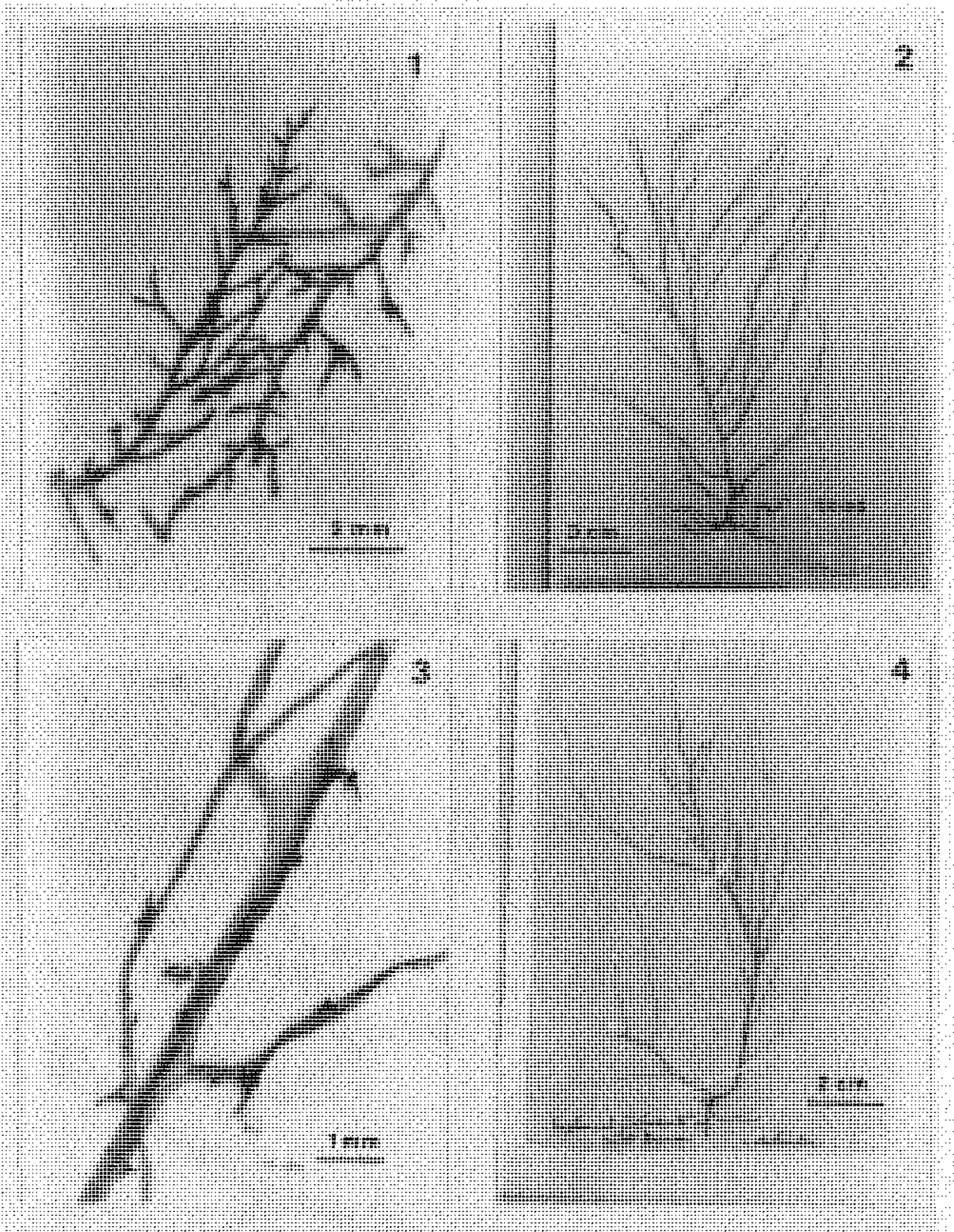
Type Locality: Original specimens listed from Manila and Vietnam.

Plant dark red to pale red, erect to caespitose, 5–16 cm high, with or without percurrent axes; branching freely alternate, lateral branch axes also percurrent, tapering to the extremities, ultimate branchlets long or short; small stellate spinous processes of three to six rays abundant, peltately attached and easily detached. Terasporangia forming small swellings encircling the basal and middle parts of the branchlets.

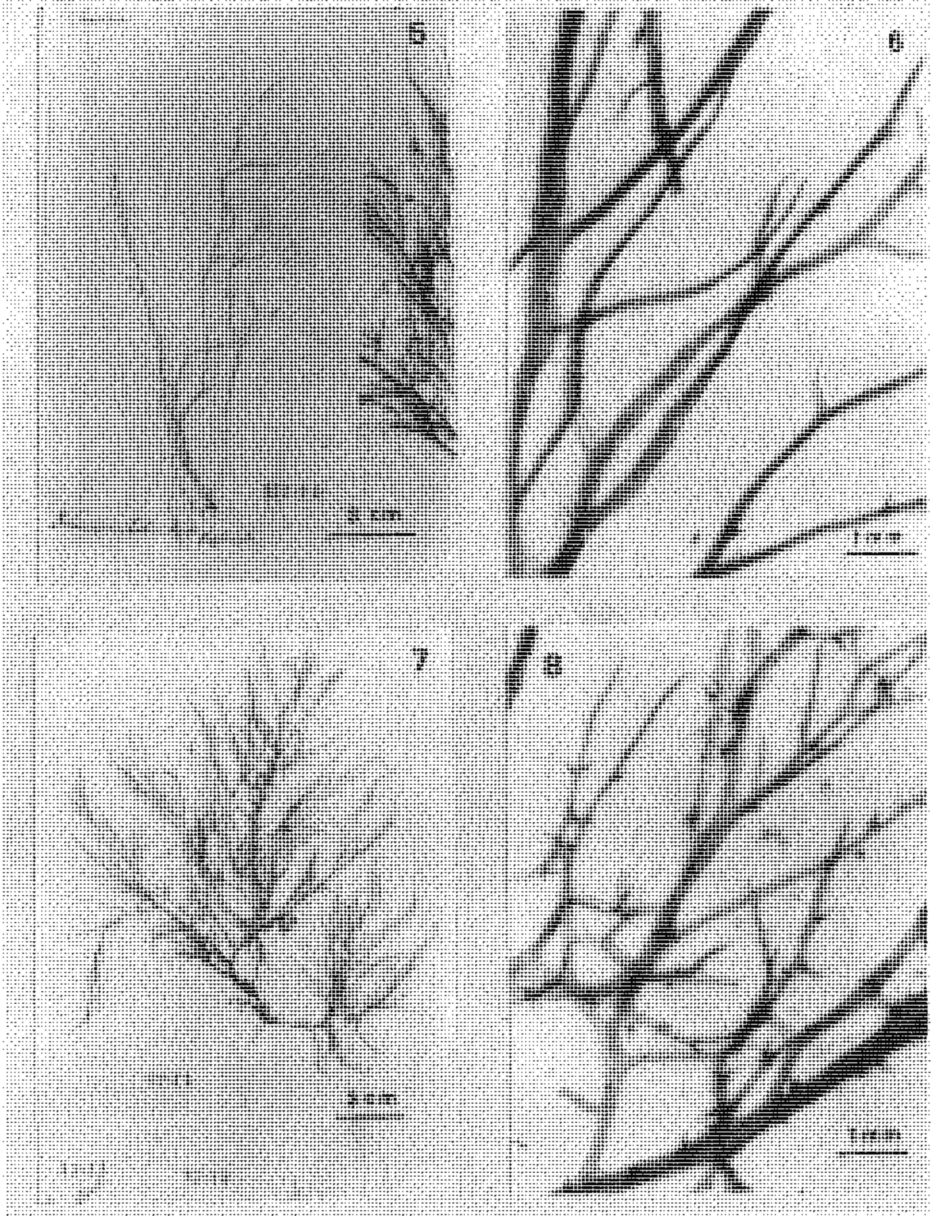
Remarks: *Hypnea cornuta* was first named *Gigartina cornuta* by Lamouroux but was not validly published as a new species. Afterward, the specific name was taken up and validly published by Kützing (1849) as *G. cornutum.* The type citation there is "*Gigartina cornuta* Lamour—Locus natalis ignotus (v.s. in herb. Lenormand)," meaning that Kützing saw a specimen without a locality named, in the herbarium of Lenormand, and evidently with Lamouroux's unpublished name on it. This specimen (in Lenormand's or Kützing's herbarium) is to be regarded as the lectotype of *C. cornutum,* later transferred to *H. cornuta* (Kützing) J. Agardh (1852). The specific character is as follows: "*H. cornuta* (Lamour. mscr.) caespitosa alterne ramosa, amis extra caespitem parum porrectis, per totam longitudinem laxe spinulosis apice subdenudato rectiusculis, spinulis quoquoversum egerdientibus patentibus, aliis simplicibus a basi latiore acuminatis rigidis, aliis stellulaeformibus vivide rubris, capsuligeris rectis spinulis simplicibus obsitis."

Material cited by J. Agardh for the variety α *cornuta* includes first "ad oras Guineae (Hb. Lamouroux!)," corresponding to the small fragments in specimen 33806 (Fig. 1), labeled in J. Agardh's handwriting as "*Gigartina cornuta* Lam./ex oris Guineae/pinnae." This specimen could be part of the same material that Kützing saw in Lenormand's herbarium and thus is an isotype that should be checked (Dr. Per Lassen's opinion, personal communication).

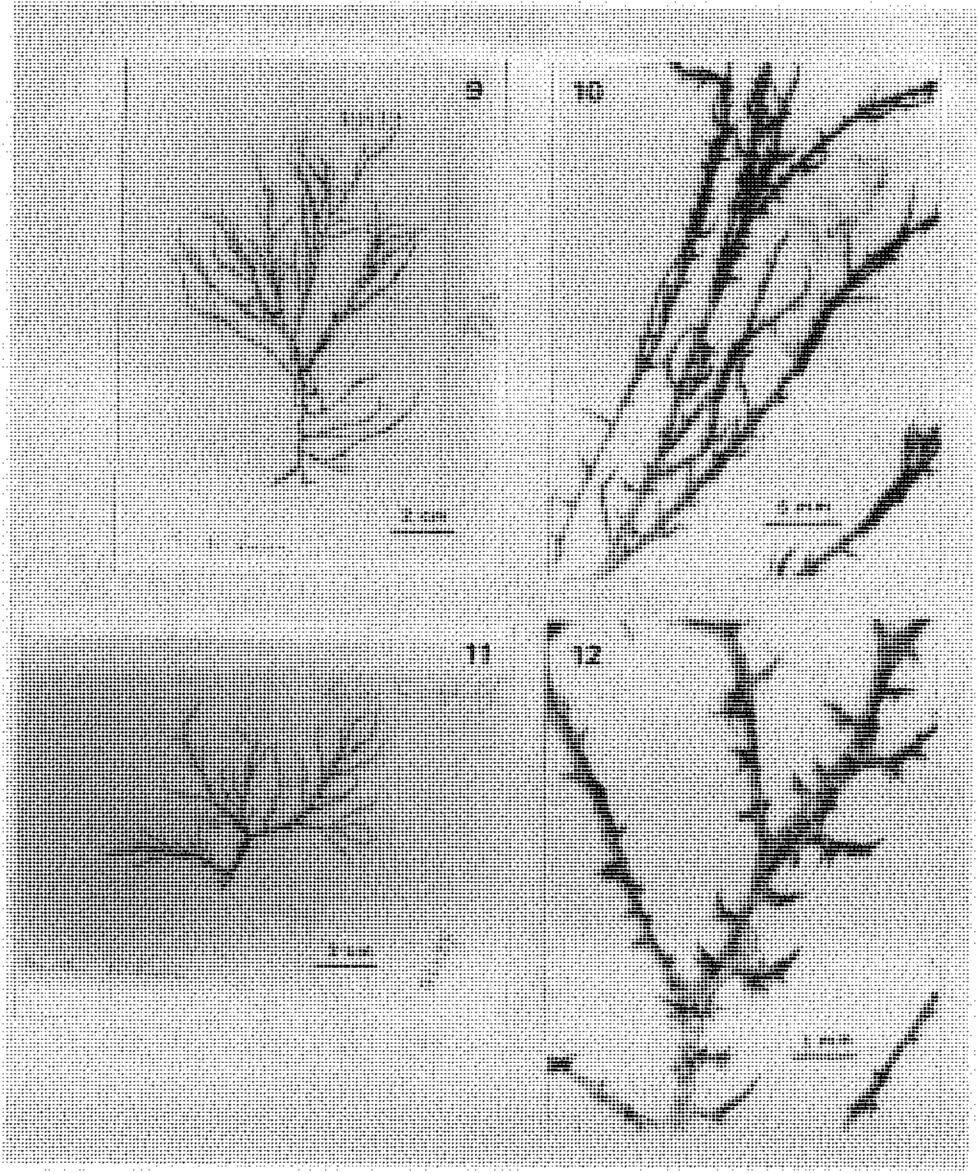
Specimens 33803–33805 correspond to J. Agardh's further citation "ad St. Thomas (Oersted!)" (33803, Figs. 2 and 3) or are just illustrative of his concept of the taxon (33804, Fig. 4, and 33805). They are of course not type specimens. *Hypnea cornuta* var. *stellulifera* J. Agardh (1852) materials cited "lin mari Chinensi ad Manillam (Hb. Binder!) and oras Cochinchinae (Busseui!)" are specimens 33812 (Figs. 9 and 10) from Manila and 33810 (Figs. 5 and 6) from Cochinchina or Vietnam. Both specimens are evidently syntypes of the variety *stellulifera,* even if they are not so inscribed. Specimen 33816 (Manila Hb. Binder) (Figs. 11 and 12) has a note, "var. β ut Hypn. hamulosam olim saepe determinavi," that means he identified it as *H. hamulosa* before the description of the variety *stellulifera.* It is probably a duplicate specimen of 33812 and thus another syntype.



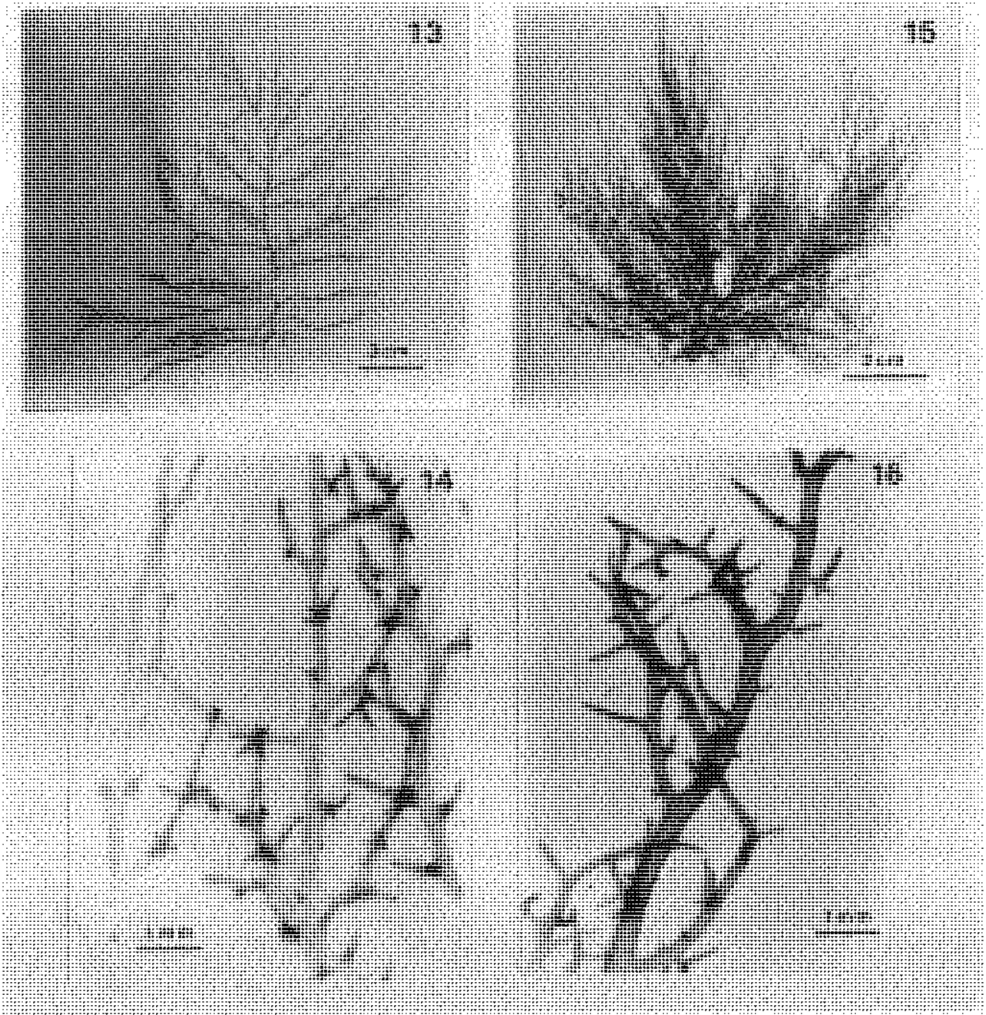
Figs. 1–4. Specimens of *Hypnea cornuta* var. *stellulifera* showing habit of plants and stellate spinous processes. Fig. 1, An isotype from Guineae (33806) Figs. 2 and 3, Specimen from St. Thomas, Virgin Islands (33803). Fig. 4, Specimen from St. Thomas, Virgin Islands (33804).



Figs. 5–8. Syntype specimens of *Hypnea cornuta* var. *stellulifera* showing habit of plants and stellate spinous processes. Figs. 5 and 6, Specimen from Vietnam (33810). Figs. 7 and 8, Specimen from Australia (33811).



Figs. 9–12. Syntype specimens of *Hypnea cornuta* var. *stellulifera* from Manila showing habit of plants and stellate spinous processes. Figs. 9 and 10, Specimen 33812. Figs. 11 and 12, Specimen 33816 previously identified as *Hypnea hamulosa.*



Figs. 13–16. *Hypnea cornuta* var. *stellulifera* from Thailand showing habit of plants and stellate spinous processes. Figs. 13 and 14, Specimen collected at Sattahip, Chon Buri, February 11, 1977. Figs. 15 and 16, Specimen collected at Ban Phe, Rayong, January 11, 1993.

J. Agardh distinguished these two entities as follows: "Var. α *cornuta* fronde elongata gracili, spinulis stellulaeformibus sparssimis; var. β *stellulifera* fronde breviori rigidiuscula, spinulis stellulaeformibus densis."

Examination of specimens 33803–33805 of the variety *cornuta* from the Caribbean showed that plants are rather elongate with filiform branchlets and sparse stellate spinous processes (Fig. 3). Specimen 33806 has only two fragments in which the branches are much shorter, simple to bifurcate, 0.5–2.0 mm long (Fig.1). Those of the variety *stellulifera* from the Pacific, specimen 33810 from Vietnam (Figs. 5 and 6) are also elongate, with a few stellate spinous processes, similar to findings in specimens 33803–33805 of the variety *cornuta* from the Caribbean. Other specimens, 33812, 33813, and 33816 from Manila, are rather rigid and erect with short upcurved branchlets and abundant stellate spinous processes (Figs. 9–12). Specimen 33811 from Australia (Fig. 7) has filiform or elongate branchlets (Fig. 8).

Specimens from Thailand that have small stellate spinous processes are variable in morphology. Some are similar to the type specimens, and some are different. If small stellate spinous processes are considered the characteristic of *H. cornuta*, many varieties and forms should be separated or completely put together as a single variable species. This group needs further study.

Specimens that correspond to the type specimens of *H. cornuta* var. *stellulifera* are those collected from Sattahip, Chon Buri, February 11, 1977 (Figs. 13 and 14); Prachuap Khiri Khan, February 11, 1983 (KL4025); and Ban Phe, Rayong, January 12, 1993, and March 24, 1996 (Figs. 15 and 16).

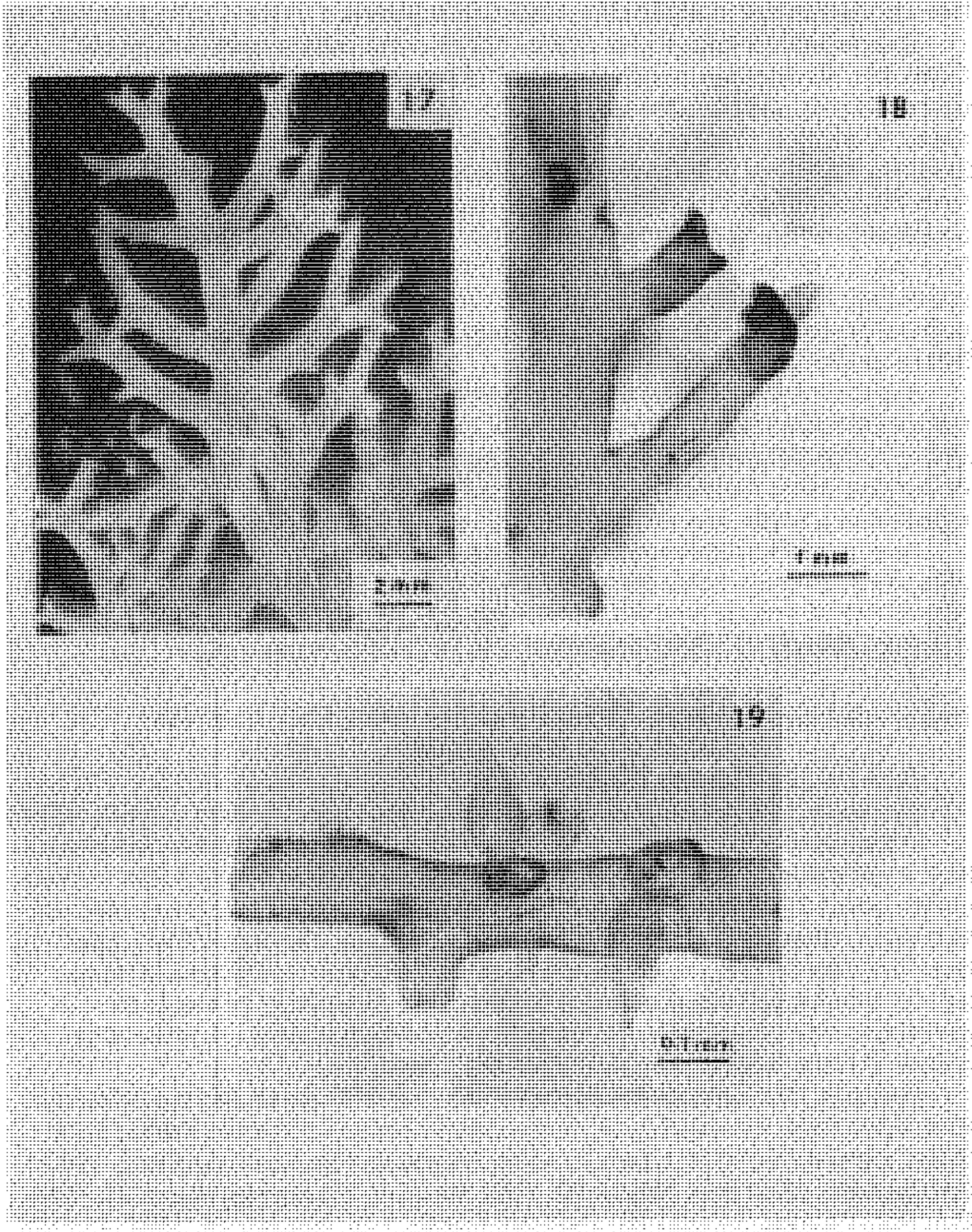
Hypnea pannosa J. Agardh, Öfvers Kongl. Vet. Akad. Förh. 4:14, 1847.
(Figs. 17–19)

Type Locality: Oaxaca, Pacific Mexico.

Synonym: *Hypnea nidulans* Setchell, Calif. Acad. Sci. Proc. IV, 12:161, 1924.

Plants dark brown or pale red, but submerged living plants iridescent grayish blue, subcartilaginous and brittle, forming a compact tuft or mat on rocks or dead corals, about 2–5 cm high and 4–12 cm wide, round or oval; branching alternate to irregular, lower branches terete and coalesced, 1–2 mm in diameter, upper branches slightly to highly compressed, branchlets short and stout with acute apices, transverse section showing a central cell surrounded by five to six pericentral cells. Tetrasporangia borne on one side or encircling the basal or middle or distal swollen part of ultimate branchlets.

Remarks: This species is common in the Gulf of Thailand and the Andaman Sea. Specimens identified as *H. pannosa* were collected from Ko Samui, Surat Thani, October 13, 1971; Laem Ta Tang, Prachuap Khiri Khan, August 9, 1980; Samae Sarn, Chon Buri, August 22, 1982; Ko Surin, Phangnga, March 23, 1986; Ban Phe, Rayong, January 26, 1991; Ko Kradat, Trat, January 26, 1991; and Nai Yang, Phuket, September 7, 1994.



Figs. 17–19. *Hypnea pannosa.* Fig. 17, Compressed upper branches. Figs. 18 and 19, Branchlets with tetrasporangial sori.

Hypnea charoides-valentiae complex

(Figs. 20–22)

Hypnea charoides Lamouroux, Ann. Mus. Natl. Hist. Nat. 20:132, pl. 10, figs. 1–3, 1813.

Synonym: *Hypnea seticulosa* J. Agardh, Sp. gen. ordines algarum, 2(2):446, 1852.

Type Locality: Australia.

Hypnea valentiae (Turner) Montagne, Histoire Nat. Iles Canaries 3:161, 1841.

Basionym : *Fucus valentiae* Turner, Fuci 2:17, pl. 78, 1809.

Type Locality: Red Sea.

Plants yellowish brown to pale red, cylindrical and soft to somewhat brittle thallus when living, erect to slightly decumbent, 8–15 cm high, with or without percurrent main axis. Branching alternate to subdichotomous with acute to wide and rounded angles, branches tapering to the extremities and covered with numerous short and long spinous branchlets coming out in all directions, mostly at right angles; five to six pericentral cells surrounding a small central cell, lenticular thickening in the medullary cell walls not found. Tetrasporangia in the middle or distal swollen parts of elongate penultimate and ultimate branchlets encircling the fertile parts.

Remarks: This species is rather common in the Gulf of Thailand, growing on rocks and shells and exposed during low tide. Examined specimens were collected from Ko Samui, Surat Thani, October 13, 1971, April 12, 1975, and August 11, 1978; Sattahip, Chon Buri, September 2, 1972, and February 12, 1977; Ban Phe, Rayong, August 8, 1976, and January 11, 1993; Panare, Pattani, April 9,1977; Laem Sok, Trat, January 16, 1981; and Samae Sarn, Chon Buri, August 22, 1982.

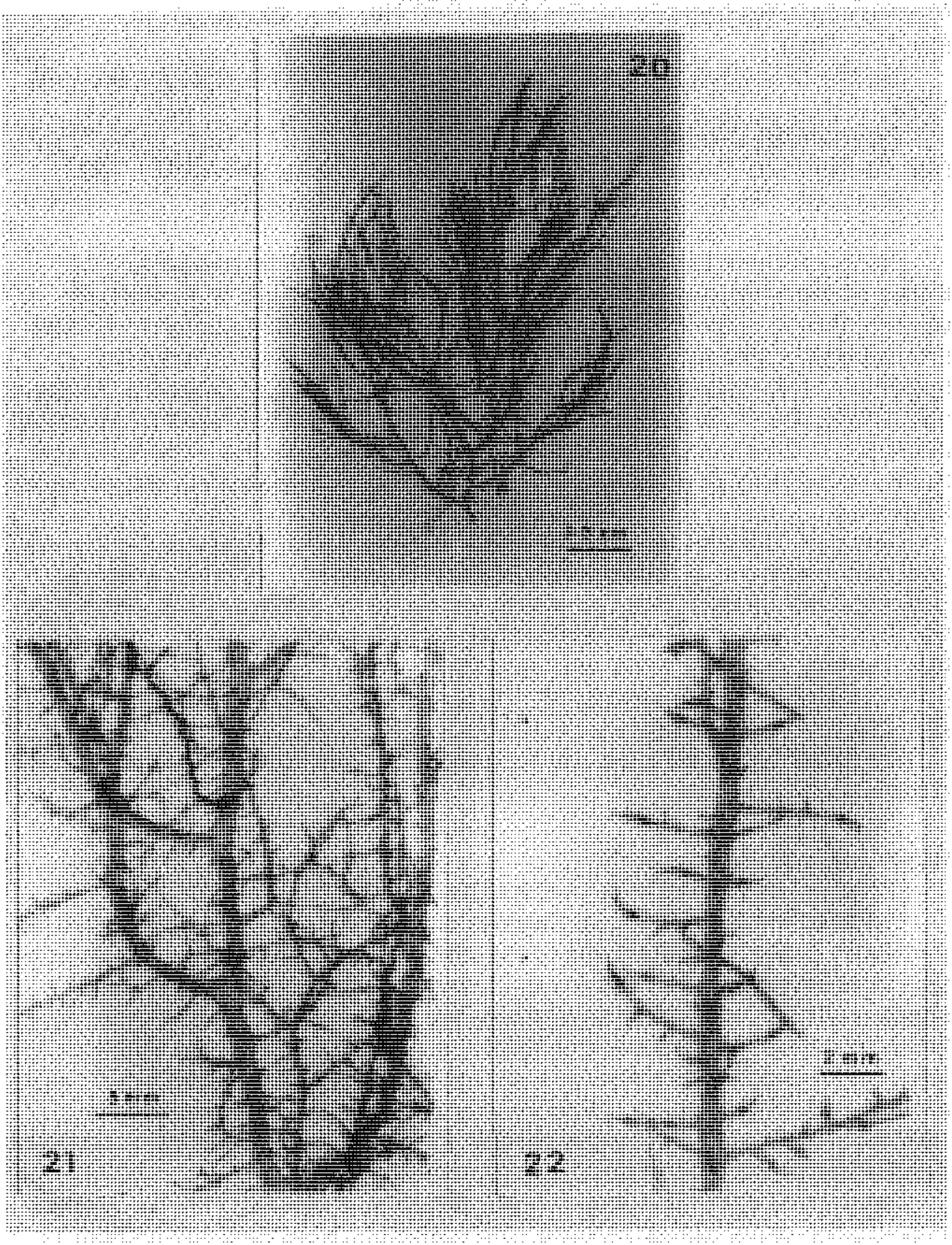
For details of this complex, see the chapter by Yamagishi and Masuda in this volume.

Hypnea species

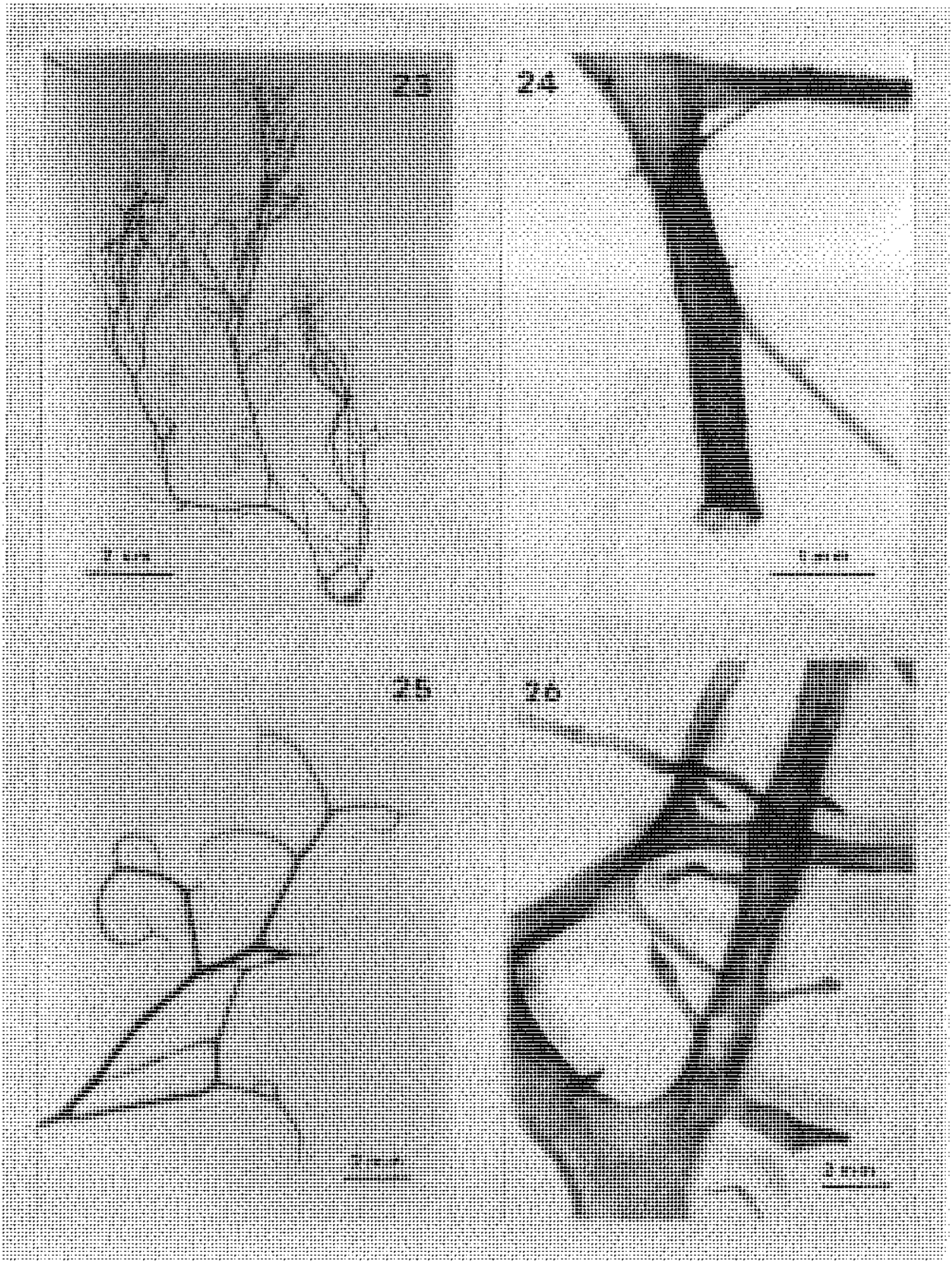
(Figs. 23–29)

Plants dark red, thallus erect, terete percurrent axis, 10–15 cm high, attached to rocks by a discoid holdfast. Branching alternate to subdichotomous; main axis cylindrical, less than 1 mm in diameter, branch terminal hooklike; branchlets slendar or filiform; transverse section with one small central cell surrounded by five to six pericentral cells with one layer of cortical cells. Tetrasporangial sori occur on one side of branchlets or encircling basal, middle, or distal part of simple or bifurcate short branchlets, occurring only at lower part of the main axis or branches; tetrasporangia zonately divided, 40–45 μm long, 16–18 μm in diameter; gametangial plants not found.

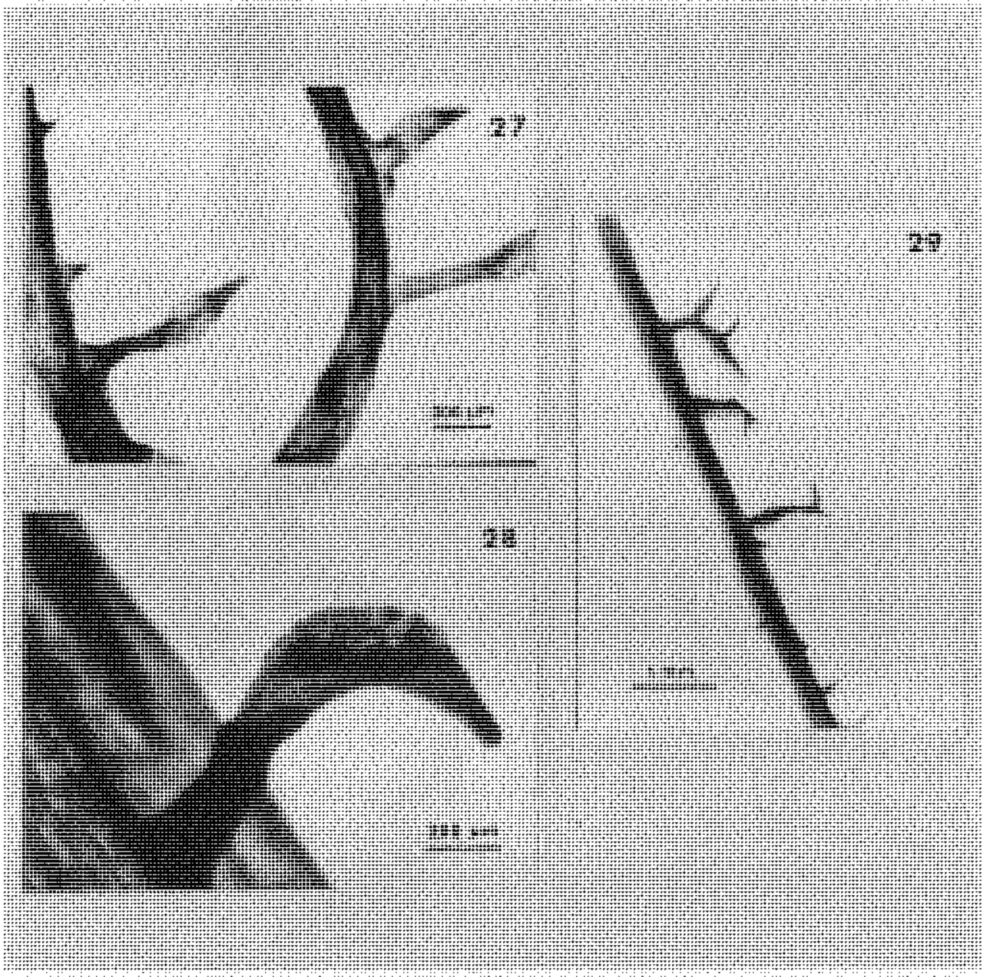
Remarks: Growing on rocks of intertidal habitat at Ao Cho, Trat, the easternmost location of the Gulf of Thailand. The specimens were collected on April 11, 1989.



Figs. 20–22. *Hypnea charoides-valentiae* complex. Fig. 20, Habit of plant. Figs. 21 and 22, Enlarged part of thallus showing filiform branchlets with tetrasporangial sori.



Figs. 23–26 *Hypnea* species. Fig. 23, Habit of plant. Fig. 24, A discoid holdfast. Fig. 25, Hooklike apices. Fig. 26, Basal part with tetrasporangial branchlets.



Figs. 27–29. *Hypnea* species. Fig. 27, Tetrasporangial sori on simple branchlets. Fig. 28, Tetrasporangial sori on one side of branchlets. Fig. 29, Tetrasporangial sori on bifurcate branchlets.

Acknowledgments

I thank Dr. Per Lassen, curator of the Herbarium Lund, for the loan of the type specimens of *H. cornuta* and Prof. Michio Masuda for his kind provision of some references. I also extend my appreciation to Dr. Virginia Harden and Prof. I. A. Abbott for reading and correcting the manuscript and to Dr. Phang Siew Moi and her students for their kind arrangements and hospitality during my stay in Malaysia.

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SOME SPECIES OF THE GENUS *HYPNEA* (GIGARTINALES, RHODOPHYTA) FROM CHINA

Xia Bangmei and Wang Yongqiang

Abstract

Herbarium specimens of *Hypnea* species from the Institute of Oceanology, Academia Sinica, Qingdao (AST) were examined, including species previously recorded. Three new records added here, of *H. chordacea*, *H. cornuta*, and *H. spinella*, common species in the western Pacific, bring the total known from China to eight species. Many other specimens in the institute's collections are sterile and cannot be identified at this time.

Introduction

Despite the wide distribution of *Hypnea* species in tropical and warm temperate waters of the world, only a small number have been identified in China; and although many specimens are available, they are sterile and difficult to understand. We hope that researchers will make an effort to collect more, and fertile, specimens so that *Hypnea* species might be better understood and identified in the future.

Tseng (1936) reported *H. cervicornis* J. Agardh as the first species of *Hypnea* for China from Xiamen (then known as Amoy), and four were recorded in 1962 by Tseng et al. These species were *H. cervicornis* J. Agardh, *H. japonica* Tanaka, *H. boergesenii* Tanaka, and *H. charoides* Lamouroux, for a total of five species for China. A study (Chang et al. 1963) that compared Atlantic specimens of *Hypnea musciformis* (Wulfen) Lamouroux and some specimens previously named as *H. musciformis* from the western Pacific led to the conclusion that there were two similar, but not identical, species: *H. musciformis* was reserved for Atlantic and Caribbean specimens, and *H. japonica* Tanaka for specimens from China, Japan, Vietnam, and the Philippines. A report on Hong Kong algae (Tseng et al. 1980) recorded two species: *H. cervicornis* and *H. japonica*. *Hypnea pannosa* was reported by Zhang and Xia (1983) from the Xisha Islands (Hainan Province). Finally, *Common Seaweeds of China* (Xia et al. 1983) lists the following five species for China: *H. boergesenii*, *H. cervicornis*, *H. charoides*, *H. japonica*, and *H. pannosa*.

This chapter adds *H. chordacea* Kützing, *H. cornuta* (Lamouroux) J. Agardh, and *H. spinella* (C. Agardh) Kützing, giving a total of eight species for China.[1]

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[1] Professor Xia and I discussed the conclusions of Yamagishi and Masuda (this volume) in their study of species from Japan, and she asked that the Chinese species be treated in the "old style" classification, because she lacks the large numbers of specimens necessary to evaluate the standings of Chinese material compared with material not only from Japan but elsewhere. I concur with her judgment, because common species with large numbers of species (whether *Hypnea*, *Polysiphonia*, *Gracilaria*, or *Sargassum*) need years of study and shifting around before the taxonomy is stabilized.—Editor

Hypnea boergesenii, H. cervicornis, H. charcides, H. japonica, and *H. pannosa* are well described by others in this book, and their descriptions are available in Chinese (Tseng et al. 1962, Chang et al. 1963) and English (Xia et al. 1983, Tseng et al. 1980, Zhang and Xia 1983). Therefore, their descriptions are not repeated here. However, descriptions of the three new records for China, a key that includes all species reported from China, and illustrations of the species are included.

Hypnea species are of interest in China because they are used as food and as raw material for production of phycocolloids.

Materials and Methods

Some of the herbarium specimens of *Hypnea* brought by Drs. Masuda and Chiang to the Kuala Lumpur workshop were examined, and the information on them was compared with specimens in our herbarium (AST). Microscope slides were prepared by using 1% aniline blue as a stain and 30% glucose as a mounting medium.

Key to the species of *Hypnea* from China

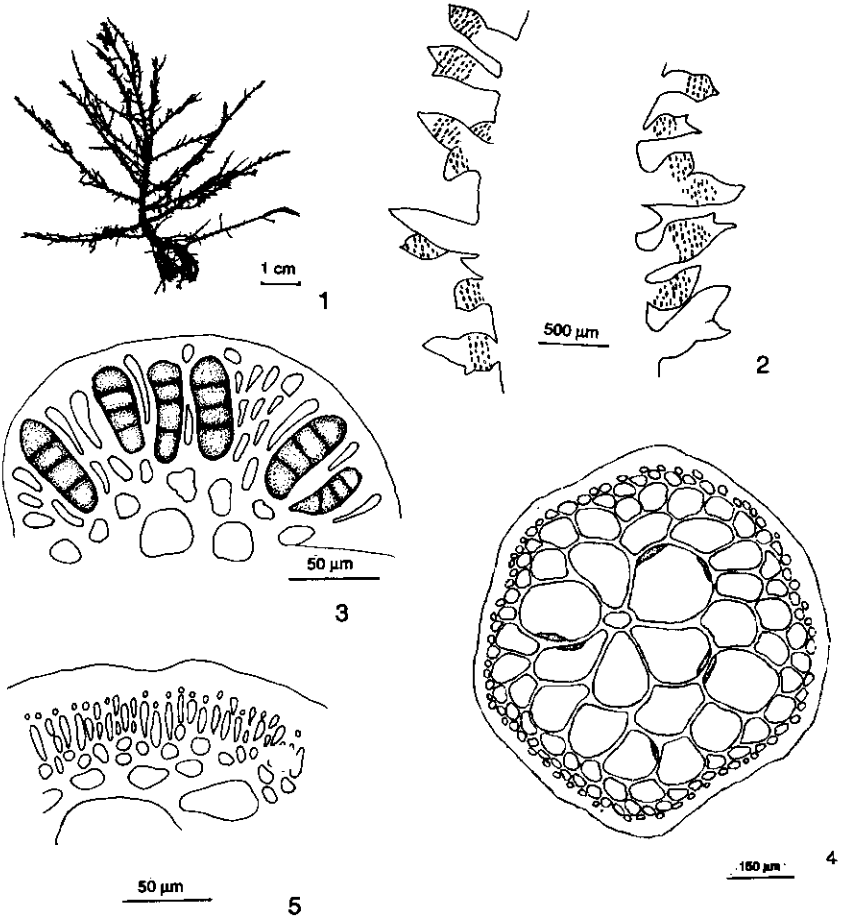
1\. Plants tufted, not entangled; main axes clearly percurrent 2
1\. Plants entangled basally or throughout; main axes not percurrent 3
    2. Lower axes often naked for one half their lengths, axes with rhizoidal filaments around central axial cell; cross sections showing no lenticular thickenings ..... *H. chordacea*
    2. All axes crowded throughout with determinate and indeterminate branches, no rhizoidal filaments around central axial cell; cross sections showing lenticular thickenings ..... *H. boergesenii*
3\. Some apices of branches showing an inflated hook (hamate) ..... *H. japonica*
3\. Apices of branches never hooklike; apices blunt or acuminate 4
    4. Plants erect, indeterminate branches few, primary axes percurrent 5
    4. Plants decumbent or spreading, indeterminate branches many, primary axes mostly not percurrent; cross sections showing occasional lenticular thickenings ..... *H. spinella*
5\. Indeterminate branches spreading, star-shaped processes (stellate branchlets) occasional to many ..... *H. cornuta*
5\. Indeterminate branches not spreading, lacking star-shaped processes; cross sections lacking lenticular thickenings 6
    6. Plants forming tight mats with branches difficult to disentangle without breaking branches ..... *H. pannosa*
    6. Plants not forming mats; branches easily disentangled without breaking 7
7\. Plants usually yellowish, forming an entangled mass of axes and branches, brittle when dried ..... *H. cervicornis*
7\. Plants usually reddish, irregularly branched but branches separable, not brittle when dried ..... *H. charoides*

Description of Some Chinese Species

Only distribution records within China are provided.

Hypnea boergesenii Tanaka, Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Univ. 2:233, figs. 6–8, pl. 53.1, 1941.

(Figs. 1–5)

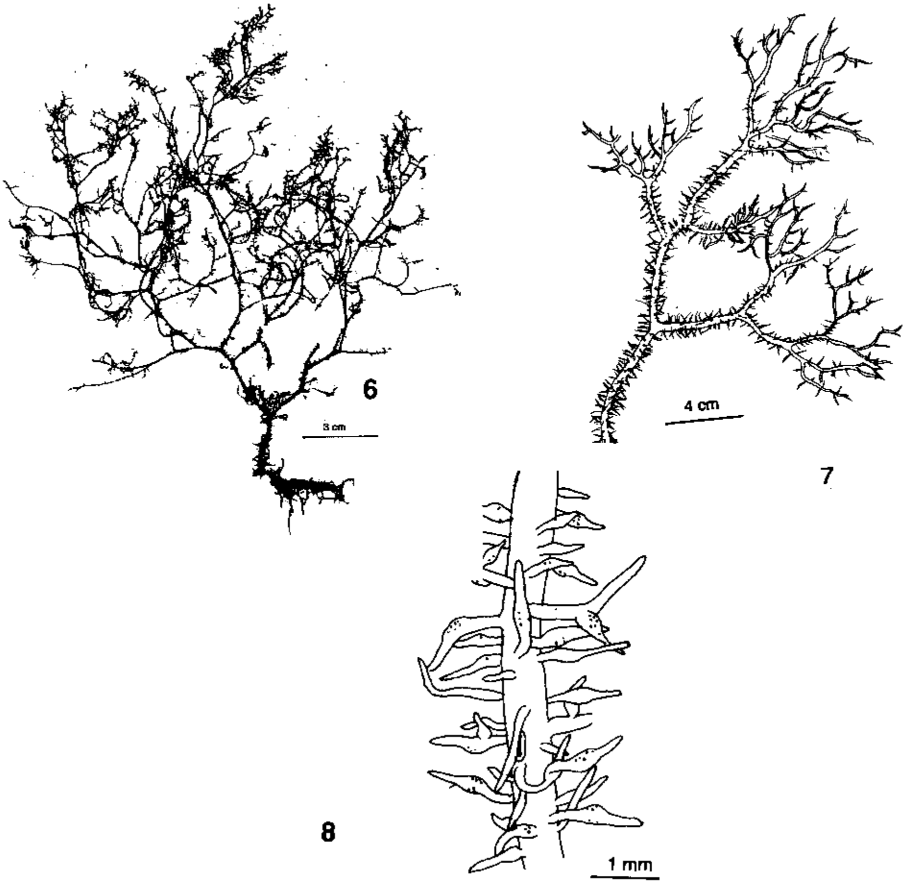


Figs. 1–5. *Hypnea boergesenii.* Fig. 1, Habit of plant. Fig. 2, Part of plant showing tetrasporangial branchlets. Fig. 3, Cross section of part of nemathecium showing zonately divided tetrasporangia. Fig. 4, Cross section of main axis showing central axial strand and a few lenticular thickenings in medullary cells. Fig. 5, Cross section of spermatangial branchlet showing spermatangia above modified cortex.

Chinese Distribution: Central to southern China at Zhejiang, Fujian, Guangdong, Hainan, and Taiwan.

References: Tseng et al. 1962, Xia et al. 1983.

Hypnea cervicornis J. Agardh, Sp. gen. ordines algarum 2(2):451, 1852.[2]
(Figs. 6–10)



Figs. 6–10. *Hypnea cervicornis*. Fig. 6, Habit of an entire plant showing spiny, loosely and irregularly arranged branches and branchlets. Fig. 7, Part of terminal part of plant with several orders of branching. Fig. 8, Detail of determinate branches, simple and divided, some bearing tetrasporangia.

---

[2] It is clear that what is identified as *H. cervicornis* in China (Tseng et al., 1983, p. 98, fig. 2) is the same plant that is given this name in widespread Pacific and Indian oceans as well as Caribbean localities. However, as is usual with widely distributed species, it is exceedingly difficult to draw limits for species recognition. Moreover, with common species, it is easy to give the same taxon many names, which apparently is the case for *H. cervicornis* (see chapter by Yamagishi and Masuda in this volume). This opinion in no way implies that Japanese specimens were not compared with other specimens, or that they were not studied adequately.—Editor.

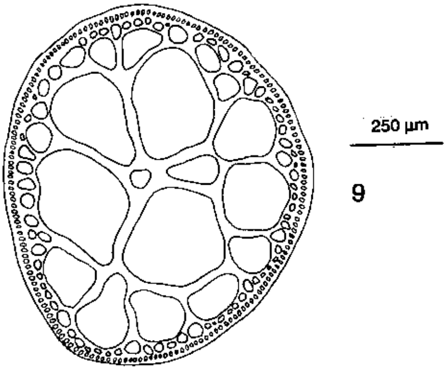


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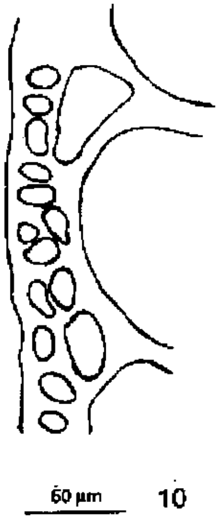
Fig. 9. Cross section of axis showing single axial strand surrounded by large medullary cells. Fig. 10, Part of cortex showing irregularly arranged cortical cells.



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Chinese Distribution: Southern China at Fujian, Guangdong, and Hainan provinces, and Hong Kong.

References: Tseng 1936, Tseng et al. 1962, Tseng et al. 1980, Xia et al. 1983, Zhang and Xia 1983.

Hypnea charoides Lamouroux, Ann. Mus. Natl. Hist. Nat. 20:132, pl. 10, figs. 1 and 2, 1813.

(Figs. 11–15)

Hypnea charoides-valentiae (as accepted by Yamagishi and Masuda, this volume, and Chiang, this volume, *pro parte*).

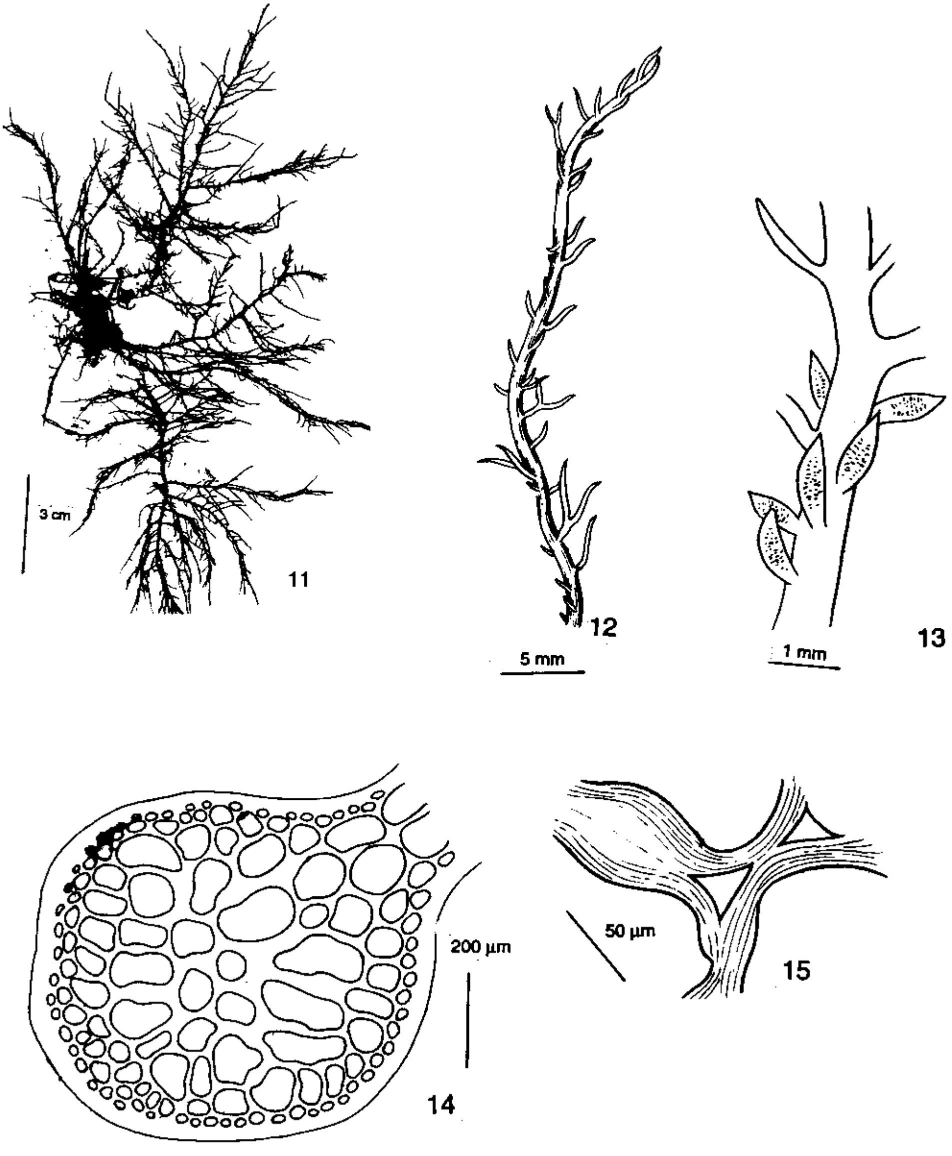
Chinese Distribution: Fujian, Guangdong, and Hainan provinces.

References: Tseng et al. 1962, Xia et al. 1983.

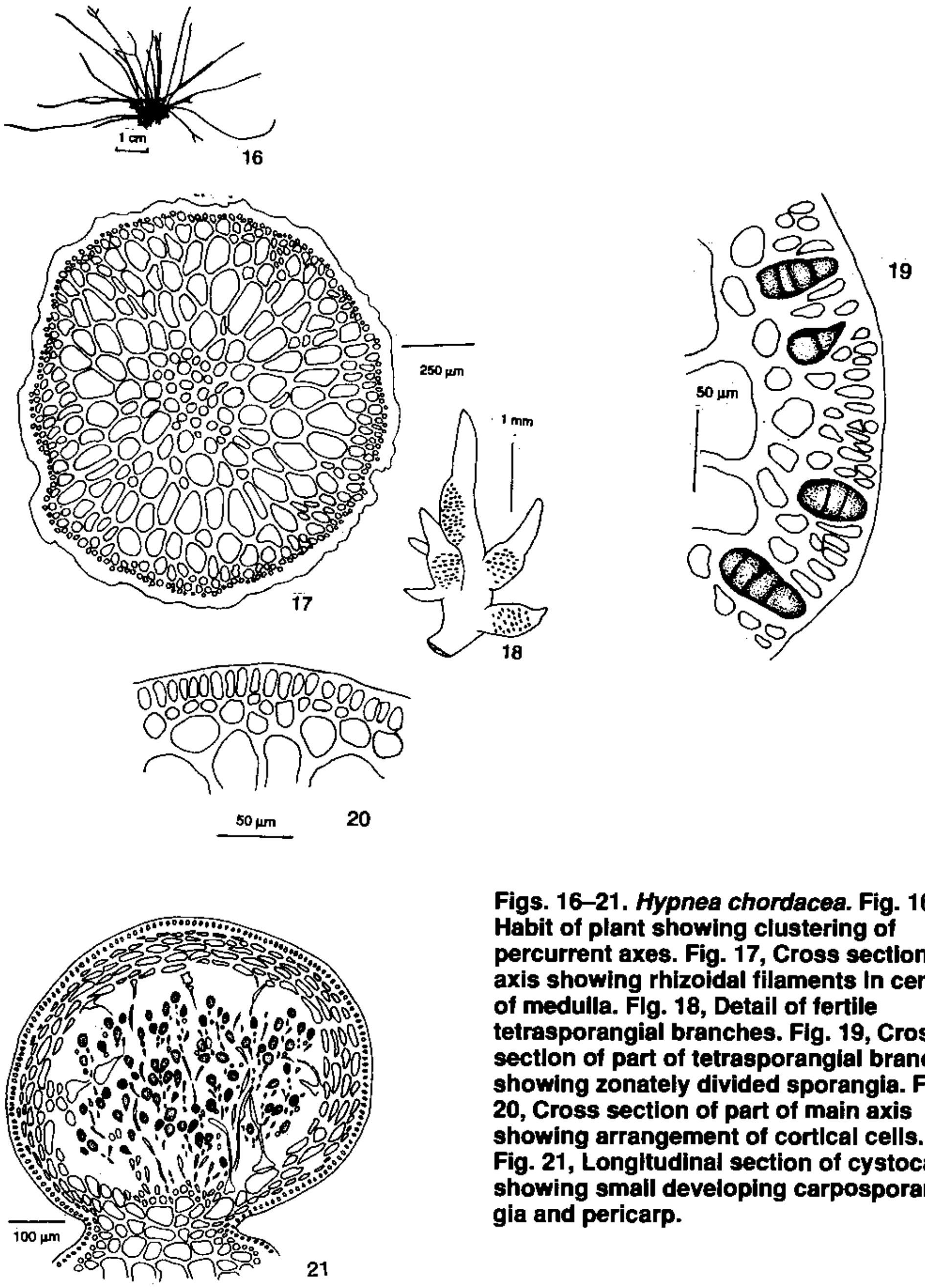
Hypnea chordacea Kützing, Species algarum, p. 760, 1849.

(Figs. 16–21)

Plants dark purplish red, tufted, 2.5–9.0 cm high, 1.0–1.5 mm thick, terete, with fibrous holdfast, erect axes percurrent, usually unbranched, conspicuously free of short branchlets for up to one half of length, then clothed with dense usually undivided branchlets to the apex; branchlets 3–6 mm long, 550–580 µm in diameter, simple or divided once; cartilaginous, adhering imperfectly to paper upon drying. Cross section of axis showing narrow, thin-walled cells at the center, 27–59 µm by 13–40 µm in diameter, surrounded by large medullary cells 116–166 µm in diameter; one to two layers of inner cortical cells, rounded to oblong, approximately 13–23 µm in diameter, superficial cortical cells small, obovoid or oblong 13.0–16.5 µm tall, by 5.0–6.6 µm wide; lenticular thickenings rare to



Figs. 11–15. ***Hypnea charoides.*** **Fig. 11, Habit of plant showing entangled base and irregularly branched axes and indeterminate branches. Fig. 12, Detail of indeterminate branch. Fig. 13, Swollen tetrasporangial branches with spreading nemathecia. Fig. 14, Cross section of axis with part of branch. Fig. 15, Thickened walls *of* medullary cells.**



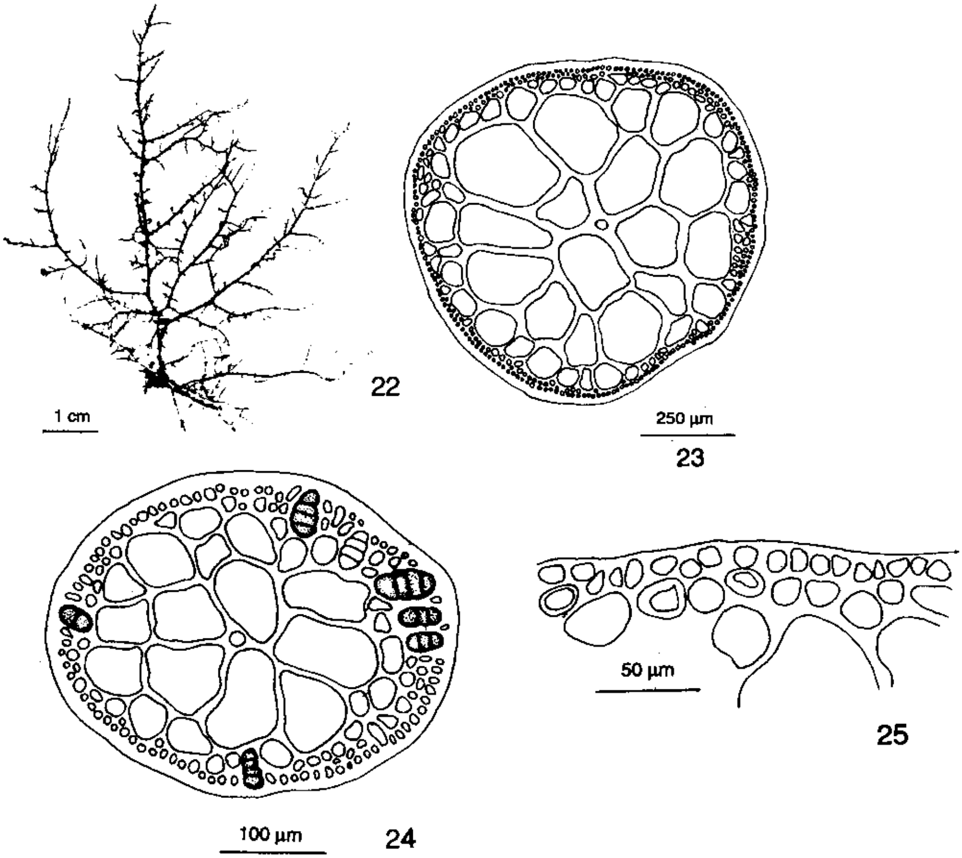
Figs. 16–21. *Hypnea chordacea*. Fig. 16, Habit of plant showing clustering of percurrent axes. Fig. 17, Cross section of axis showing rhizoidal filaments in center of medulla. Fig. 18, Detail of fertile tetrasporangial branches. Fig. 19, Cross section of part of tetrasporangial branch showing zonately divided sporangia. Fig. 20, Cross section of part of main axis showing arrangement of cortical cells. Fig. 21, Longitudinal section of cystocarp showing small developing carposporangia and pericarp.

absent in the walls of medullary cells. Tetrasporangia formed toward the mid or lower swollen part of ultimate branches, 50–60 µm tall, 17–30 µm wide; cystocarps prominently protruding, almost globose, sessile, 548–913 µm in diameter, carpospores roundish or ovoid, 23–33 µm in diameter, pericarp consisting of four to six layers of cells, 86–118 µm thick; spermatangia not seen.

Chinese Distribution: Growing on rocks, mid and low intertidal zones in central to southern China at Zhejiang, Fujian, Guangdong, Hainan, and Taiwan provinces.

Remarks. This species is a new record for China. Several specimens of this species are in our herbarium, but we did not know its identity before this study.

Hypnea cornuta (Kützing) J. Agardh, Sp. gen. ordines algarum 2(2):449, 1852.
(Figs. 22–25)



Figs. 22–25. *Hypnea cornuta*. Fig. 22, Habit of plant showing delicate percurrent axis with irregular indeterminate branches. Fig. 23, Cross section of main axis showing central axial cell among medullary cells. Fig. 24, Cross section of branchlet showing tetrasporangia. Fig. 25, Cross section of a part of cortex showing arrangment of cells.

Basionym: *Chondroclonium cornutum* Kützing, Sp. algarum, p. 741, 1849.

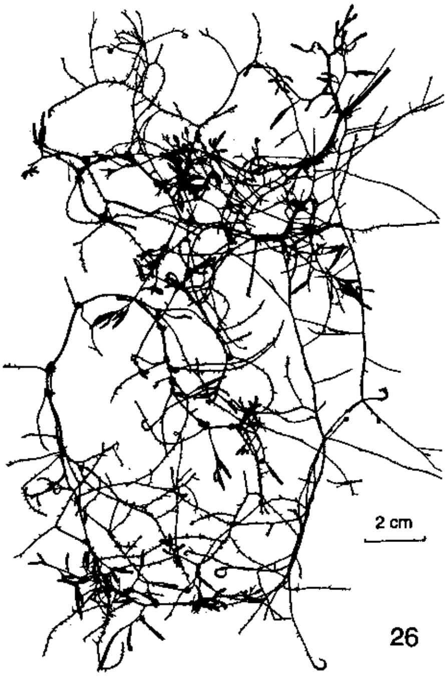
Plants light to dark red, tufted or loosely entangled on other algae, 6–20 cm high, delicate, nearly membranous, axis about 1.0–1.5 mm thick, subterete, alternately branched, loosely covered by spinous branchlets and stellate processes; spinous branchlets 1–2 mm long, 300–365 µm thick, stellate processes short, with three to five rays, the arms conical, up to 1 mm long, 380–415 µm thick; adhering well to paper upon drying. In cross sections, central axial cell distinct, roundish, 66–80 µm in diameter, surrounded by some large irregularly rounded or ovoid medullary cells, 215–500 µm in diameter, inner cortical cells roundish, 15–40 µm in diameter, superficial cortical cells ovoid or oblong, 7–10 by 5–10 µm; lenticular thickenings absent in walls of medullary cells. Tetrasporangia oblong, 45 µm long, 13 µm wide; cystocarps and spermatangia not seen.

Chinese Distribution: Growing on shells in tide pools or loosely entangled with other algae, Hainan Island.

Remarks: This is a new record for China. If following J. Agardh (1852, p. 449), the Chinese material should be identified with *H. cornuta* var. *cornuta* because of the slenderness of the plants with few stellate processes.

Hypnea japonica Tanaka, Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Univ. 2(2):236, pl. 54, figs. 9 and 10, 1941.

(Figs. 26–32)



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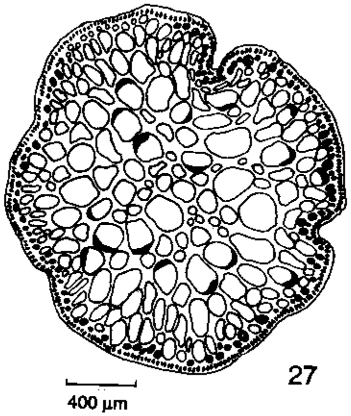

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Figs. 26–32. *Hypnea japonica*. Fig. 26, Habit of epiphytic plant showing branches irregular in both position and lengths, some with hooked tips. Fig. 27, Cross section of main axis showing small cells in the center of the medulla and loosely arranged medullary cells, some with lenticular thickenings (stippled).

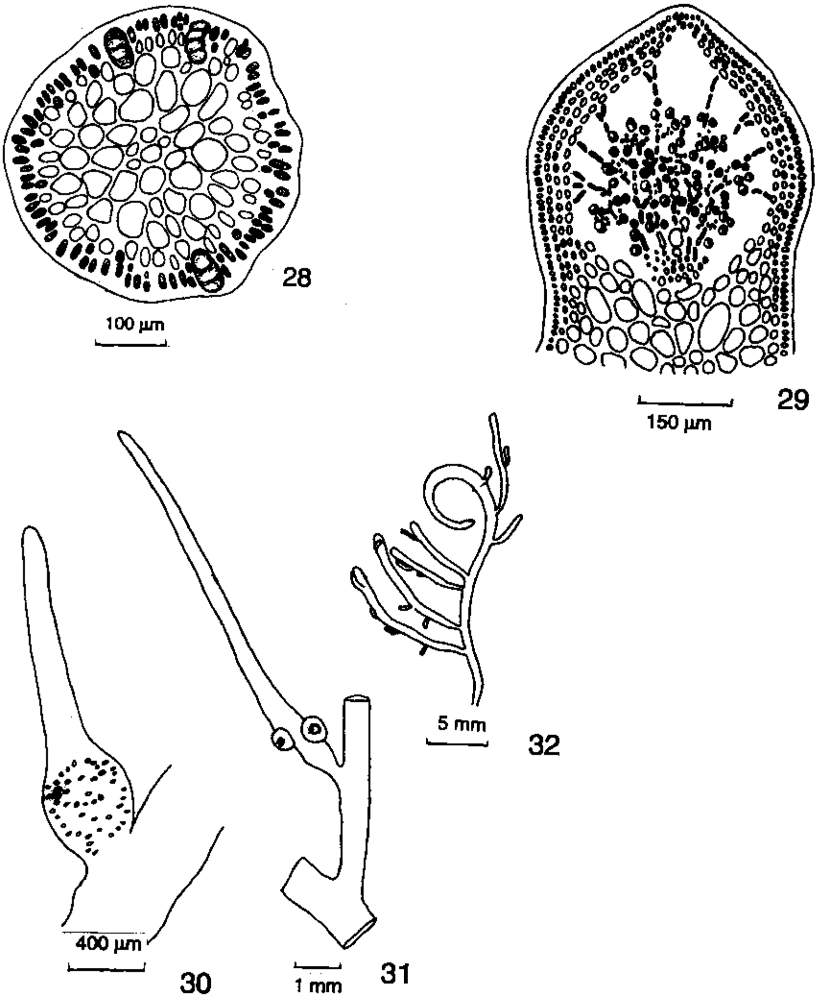


Fig. 28,Cross section of tetrasporangial branchlet, showing a few tetrasporangia. Fig. 29, Longitudinal section of a cystocarp. Fig. 30, Tetrasporangial branchlet with fertile swollen part at base. Fig. 31, Two cystocarps near the base of an ultimate branch. Fig. 32, Detail of branching in the region of a hooked (hamate) tip.

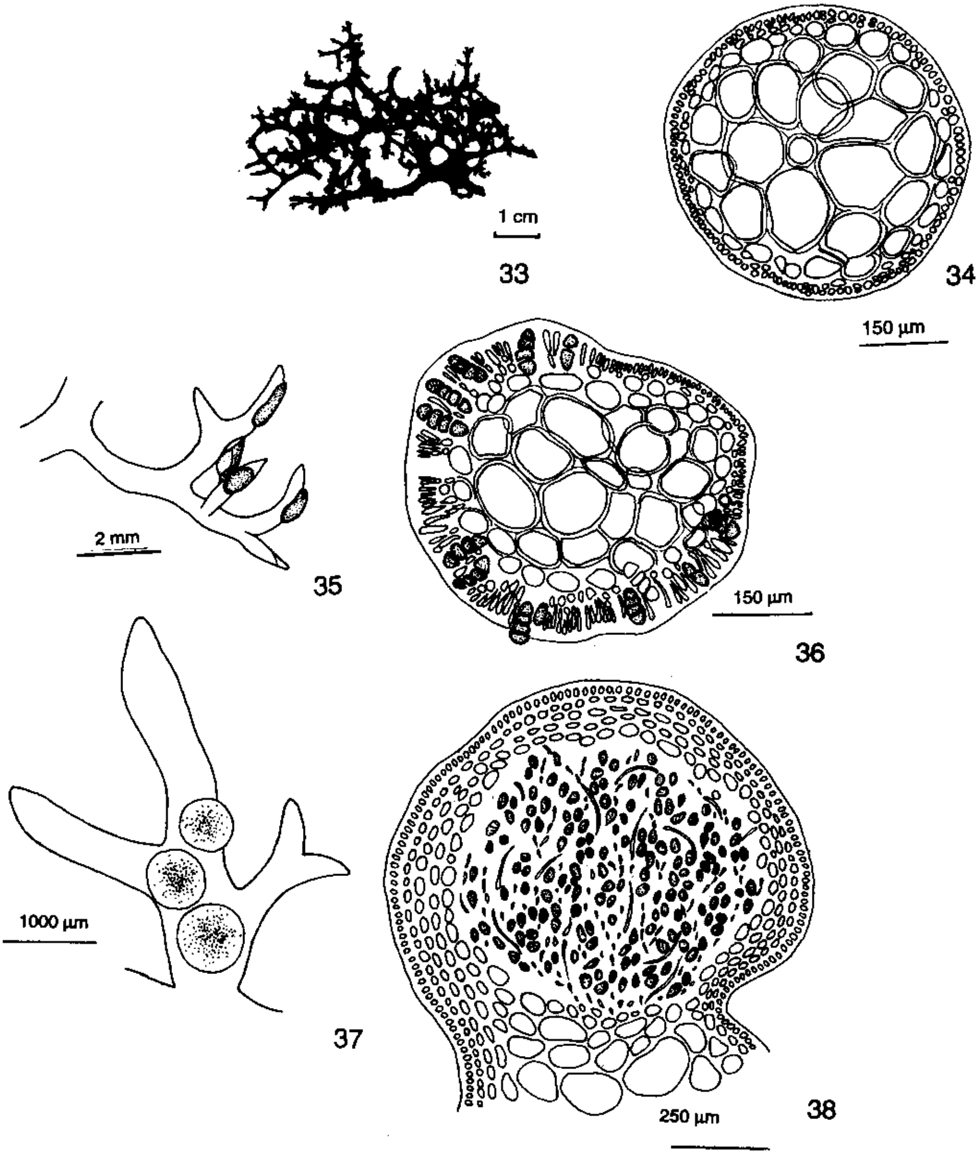
Chinese Distribution: Fujian, Guangdong, Hainan, Taiwan, and Hong Kong. In Hainan, on subtidal coral reefs or epiphytic on *Sargassum* species.

References: Tseng et al. 1962, Chang et al. 1963, Tseng et al. 1980, Xia et al. 1983.

Remarks: Figures 27–32, drawn by Xia Bangmei, first appeared in Tseng et al. 1962.

Hypnea pannosa J. Agardh, Öfvers. Kongl. Vet. Akad. Förh. 4:14, 1847.

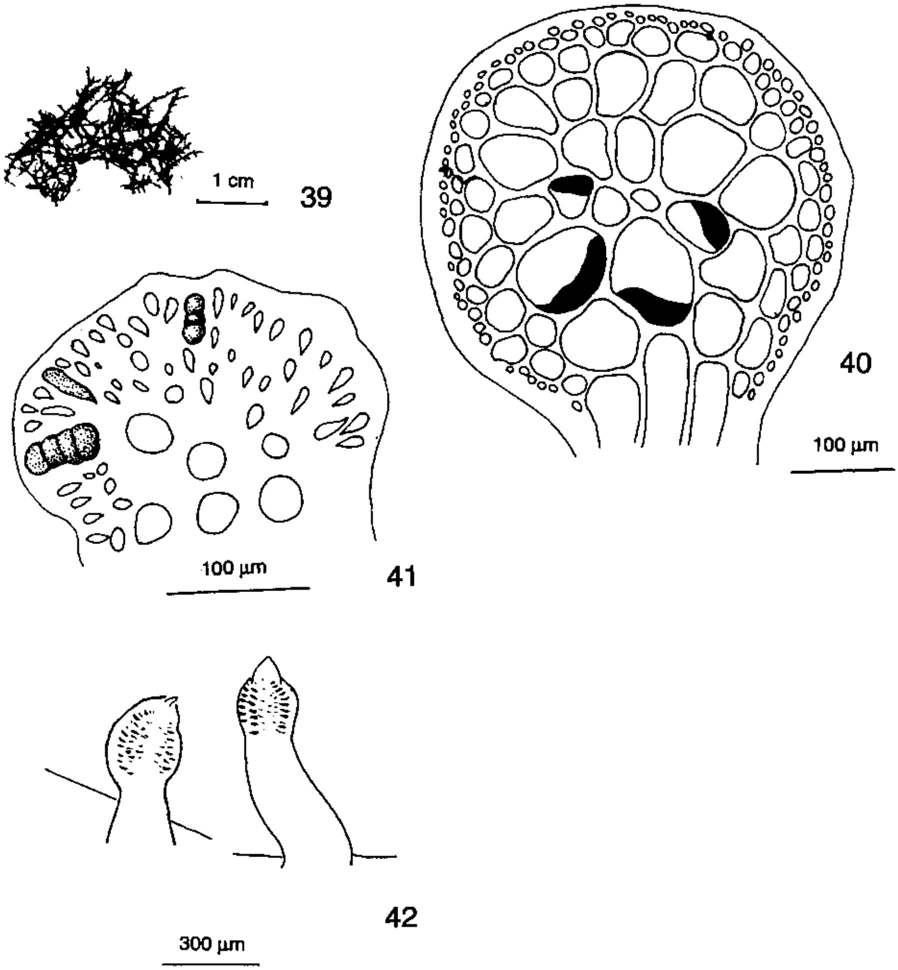
(Figs. 33–38)



Figures 33–38. *Hypnea pannosa*. Fig. 33, Habit of mat showing compressed branches, short branchlets, and small distances separating branchlets. Fig. 34, Cross section of axis showing a single axial cell surrounded by medullary cells. Fig. 35, Location of tetrasporangial nemathecia on ultimate branches. Fig. 36, Cross section through tetrasporangial nemathecium showing developing tetrasporangia. Fig. 37, Arrangements of cystocarps in surface view. Fig. 38, Longitudinal section of a cystocarp.

Chinese Distribution: Hainan Island and Taiwan.
References: Xia et al. 1983, Zhang and Xia 1983.

Hypnea spinella (C. Agardh) Kützing, Bot. Zeit. 5:23, 1847.
(Figs. 39–42)



Figs. 39–42. *Hypnea spinella*. Fig. 39, Habit of part of a plant. Fig. 40, Cross section through axis showing an axial cell and conspicuous lenticular thickenings in some cells of the medulla. Fig. 41, Cross section through part of a developing tetrasporangial nemathecium. Fig. 42, Two views of subterminal nemathecia on ultimate branchlets.

Basionym: *Sphaerococcus spinellus* C. Agardh, Sp. algarum 1(2):323, 1822.

Plants purplish red or yellow-brown to greenish, tufted, short and slender, rarely more than 3 cm high, loosely entangled at their bases, axes less than 500 µm thick, not percurrent, irregularly dichotomously or alternately branched; branches terete, filiform with sharply pointed apices; adhering to paper upon drying. In cross section, central axial cell distinct, 26–33 µm in diameter, surrounded by large medullary cells, irregularly ovoid, with cell walls up to 5 µm thick; lenticular thickening present in walls of medullary cells; inner cortical cells rounded or ovoid, 17–20 µm in diameter, superficial cells 6.6–10.0 µm long by 5.0–6.6 µm wide. Tetrasporangia formed in upper swollen parts of ultimate branchlets, oblong, 43–53 µm by 17–20 µm, surrounded by somewhat modified cortical cells. Cystocarps and spermatangia not seen.

Chinese Distribution: Growing on sandy mud flats at a depth of 10 m or on dead coral in intertidal zone at Hainan Island.

Remarks. This is a new record for China. As described, our specimens of *H. spinella* resemble material recently described by Millar (1990, pl. 23D) and Price and Scott (1992, figs. 10a–10e).

Acknowledgments

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Zhang Junfu and Xia Bangmei. 1983. Studies on some marine red algae of the Xisha Islands, Guangdong Province, China. IV. Stud. Mar. Sin. 20:123–140, figs. 1–12.

Section V. Taxonomic Index