TAXONOMY OF ECONOMIC SEAWEEDS

With reference to some Pacific species

Volume VIII

Isabella A. Abbott, Editor; Karla McDermid, Co-Editor

A Publication of the
California Sea Grant College Program

Sea Grant
California

Published by the California Sea Grant College Program, University of Calfornia, San Diego, La Jolla, California. Publication No. T-048. Additional copies are available for $15 (U.S. and territories), and $20 (international) each. Check or money order should be made payable to "UC Regents" and sent to California Sea Grant College Program, University of California, 9500 Gilman Drive, La Jolla, CA 92093-0232. (858) 534-4446; http://www-csgc.ucsd.edu.

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This work is sponsored in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA06RG0142, project number A/P-1. The views expressed herein are those of the authors and do not necessarily reflect the views of any of those organizations.

Publication: September, 2002.

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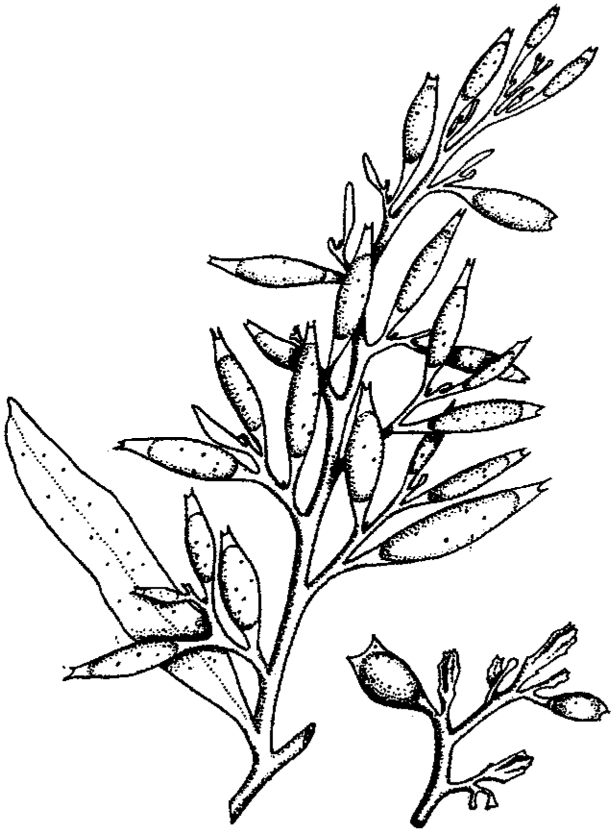
Results of an international workshop sponsored by the California Sea Grant College Program and hosted by the Oceanographic Institute, Nha Trang, Vietnam, April 1999.



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Report No. T-048
ISBN 1-888691-07-7

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Preface

James J. Sullivan
Former Director, California Sea Grant College Program

I am pleased to see the proceedings of the eighth international Workshop on the Economic Seaweeds of the Pacific, which was held at the Oceanographic Institute in Nha Trang, Vietnam in 1999. The workshop participants confirmed the many scientific and economic benefits to be derived from communicating and cooperating with colleagues from neighboring and distant countries on common problems. They pointed out how the commercial species of agar-producing *Gracilaria* were named in Thailand and Malaysia by Xia Bangmei from China, and Isabella Abbott from the United States. They recognized different species of *Sargassum* beyond their original geographical boundaries of China or Japan to Malaysia, Thailand, and Vietnam, and the fact that it took many of them working together to make this recognition possible. It was further recognized that stability in the taxonomy of eucheumoid and gelidioid algae was brought about by the contributions of leading workers in the field such as M.S. Doty on *Eucheuma*, and Bernabé Santelices on Gelidiales.

Against this successful background, the participants began planning for the ninth workshop, which was subsequently held at the end of May 2002 in Hilo, Hawaii. I was very pleased to have been invited to observe how it was conducted, and to meet again some participants who had been at previous workshops—people I had known and looked forward to seeing for over 16 years. In addition, there were many people at this workshop who were new to me, and I was interested to see how they participated in learning and sharing some of the taxonomic problems that were facing others, and how their interest and curiosity received warm responses from the "regulars." I am sure that everyone went home considerably enriched with information learned from others about many algal species. The workshop featured a specially invited guest, Dr. Paul C. Silva, of the University of California, Berkeley, who gave a talk on nomenclature and taxonomy, and on his life's research specialty, the genus *Codium*.

The participants of this particular workshop had a different "look"—they seemed much younger on average. Beginning with the hostess, Dr. McDermid, who shared convener duties with Dr. Abbott, and who will be assuming editorial duties after this volume is published, there were taxonomists from Japan, Korea, Thailand, Australia, and the U.S., who can continue the workshops and take advantage of the momentum that has been established. It would be well to keep the contacts that have been made with Chinese and Malaysian colleagues, and to enlarge the connections with Indonesia and other countries that have many economically important seaweeds, but few taxonomic researchers. While they may have the natural resources, we have the knowledge to help them identify, replicate, and market the species that are most profitable.

Dr. Roy Tsuda, the first person to name taxonomy of economic seaweeds as the subject of the first workshop held in Guam in 1985, has tentatively invited the group to celebrate the tenth workshop in Guam. I will be glad to see this successful enterprise come full circle, and I hope that I will once again be able to participate.

In closing, it is important to recognize that none of this would have been accomplished without the dedication and diversity of the participants and the continuing financial support from the Sea Grant programs of the University of California and the University of Hawaii. Collectively they have made these workshops truly a Pacific-wide Sea Grant program specializing in the economic seaweeds of that region.

A Special Introduction and An Explanation

Isabella A. Abbott, Workshop Convener and Editor

In 1985, we held our first Sea Grant workshop on the taxonomy of economic seaweeds in Agana, Guam, with the University of Guam Marine Laboratory and Dr. Roy Tsuda as hosts. Seven volumes of articles published by the California Sea Grant College Program on studies and expansion of articles from this first workshop and ensuing workshops have resulted in over 1600 pages of expertly edited, well-copyedited, first-class, prize-winning, and very useful contributions. We can be proud of these efforts.

So, I hope that the participants of the eighth workshop thought of that accomplishment when they were asked to prepare their manuscripts and illustrations once again and to submit the materials for review when everyone (especially I) thought that the next time you saw the materials, they would be in a bound volume. It was not to be. The U.S. Postal Service delivered an empty carton to the California Sea Grant office. All manuscripts, illustrations, and diskettes were gone—lost in the mail system that had served us so well for 14 years. With considerable dismay, and sighing, I notified all authors of the loss. For some, getting new pictures to that "strict" editor in Honolulu was the hardest. It seems that in many countries, it is now particularly difficult and expensive to get black-and-white film, and the original submissions that came with colored pictures were returned to the authors, meaning a big "to do" to furnish black-and-white pictures. We simply cannot publish colored pictures as they are prohibitively expensive.

Although some publications (journals) now accept digitized illustrations (which can start with a colored picture), most of us do not have the proper equipment, or if our institution has it, we do not know how to use it. For that reason, I insisted on black-and-white photographs. We understand black-and-white photographs: we know how to evaluate their quality, and editors will accept them. The luckiest people were those who still do old-fashioned black-and-white drawings, like those that adorn the pages of the chapters by C. K. Tseng and Lu Baoren, and by Xia Bangmei. Those drawings translate for publication very easily.

I thank all of you who came through this traumatic experience like the good colleagues you are. I also thank Dr. Gordon Grau, director of the Hawaii Sea Grant Program, for extra funds for clerical help to assist in getting the manuscripts in good shape to send the material once again for copyediting and printing at the

California Sea Grant Program communications office. Although I had to put 2 months into retrieving what had been mailed 3 months earlier, I think that this volume will look the same as the previous volumes. However, I thought I should explain why this volume may be late, and why perhaps we may have to postpone our next workshop until 2002. We have not had enough time to do what had to be done for this volume and at the same time prepare proposals for the next workshop if it is to be held in 2001—the second year after the last workshop. I ask for your understanding and your patience.

November 27, 2000

Thoughts on the Importance of Taxonomy

Karla J. McDermid, Co-Editor

Taxonomy is the science of interpretation of the basic patterns of the natural world. Taxonomists hold the key to understanding that world. Taxonomists are the people who can read nature's hieroglyphics. Only with taxonomy do we know the true scope of natural biodiversity, resources, services for humankind, fluctuations, and losses. Taxonomists recognize individualness, patterns, similarities, and anomalies. Taxonomists value uniqueness in living organisms that most persons would recognize only in other humans.

As I traveled across thousands of miles and through 3 nations to reach the Sea Grant workshop in Nha Trang, Vietnam, I was constantly reminded that names are necessary on passports, visas, invitations, reservations, tickets, and countless forms. Names show relatedness and membership and uniqueness. Names are just as important in the natural world.

People scoff at taxonomists because our basic tools are our eyes and minds. I have been called "old-fashioned," "low-tech," "just a list maker," and "only a seaweed presser." In response, I ask, could a health care practitioner examine a person and recognize signs and symptoms without knowing, in detail, the parts of the human body? Can a farmer raise and harvest crops without knowing exactly what is planted? Can a teacher teach well without learning the names of the students? Can a scientist work without finding out what equipment and supplies are in the laboratory? Can the world truly progress and advance without understanding itself? Our role as taxonomists is critical to the new millennium. We have so much work to do.

This eighth workshop on the taxonomy of economic seaweeds was a chance to work, to create, and to add to scientific knowledge. Certainly, the effectiveness of these workshops can be measured in the sum total of production, the number of articles, and the lists of species more clearly defined. Additionally, the cooperation among experts and international collaboration, which mark these workshops, are an even more meaningful measure of the effectiveness of our work to the world.

Acknowledgments

First, and foremost, we participants, especially the 6 of us who have been on board since the beginning of the workshops on taxonomy of economic seaweeds, acknowledge and deeply thank Dr. James J. Sullivan for his strong, consistent, far-reaching support in both financial and academic ways. The envy of our phycological colleagues, these workshops and their published results are known far beyond the Pacific, and beyond the confines of "economic algae." It has been a privilege and an honor to be part of this visionary Pacific-wide undertaking. That participation has shaped points of view, methods, and, yes, a wonderful chance to practice speaking and writing scientific English every 2 years, not to mention making friends and traveling to many interesting places. We owe these to Dr. Sullivan, too.

We are pleased to offer thanks to Dr. An, director of the Oceanographic Institute in Nha Trang, and his able and helpful staff, especially Mrs. Thu, for their hospitality during our 5-day stay in April 1999. We remember the personnel of the Institute as unfailingly helpful and friendly, always smiling; we hope that they will remember us that way also. Although Drs. Hunh Quang Nang and Nguyen Huu Dinh, who are attached to the Center of Science for Seaweed Production in Nha Trang, were participants in the previous 2 or 3 workshops, they were unable to serve as hosts for us for the eighth workshop and were away from the city when we visited. We were sorry to miss them, but we enjoyed seeing their home "habitat." The open marketplace in the city was full of interesting things to see; the fruits alone were a treat to see (and eat). As with many places we have visited, clearly, there is a lot more to see than seaweeds.

Isabella A. Abbott

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Notes

About Chinese Names

In accordance with the national change made in China in 1987, Chinese names are listed with surname first, no comma, and given name last, with a different spelling than before. 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. Because he is known in the West as C. K. Tseng, Dr. Tseng has asked us to list his name in this Western style.

About Vietnamese Names

Our visit to Vietnam and our uses of Vietnamese names were the object of many discussions. The upshot is that most (99%?) of the Vietnamese we met insisted that their given names were their proper names. I was equally insistent that as editor of their manuscript, which would be published in a Western publication, I had to take a standard way of citing their names, and the least acceptable way was to use their given names as the name to cite or retrieve in a bibliography. So, in this volume, we use whole names (all 3 pieces of the name) for Vietnamese authors at first mention in the text and in the Literature Cited (references) section. When we speak to them, we will use the last of the 3-name pieces as their "familiar" name. The reason our colleagues use the first names as their names is that Vietnam has only a very few family names, and the "familiar" name is the one that distinguishes each individual. I recognize this situation, but bibliographic retrieval situations would be in chaos if sometimes a given name is used and sometimes a family name is used. It is our intention to make the use uniform so all can understand. That is the reason for this seemingly arbitrary ruling. Please observe these niceties that bridge East and West. (You would be surprised to find Pham Hoang Ho listed as Ho about as many times as he was listed as Pham in a bibliography. But he never explained what the order of names meant. Now, we know; so please observe this usage.)

Listing Species Names

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

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

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

Literature Cited

In this volume, all references to volumes from the seven previous workshops are listed in nomenclature setups and in Literature Cited as "Tax. Econ. Seaweeds 1 (or 2, 3, 4, 5, 6, or 7)," 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 5 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.

Taxonomy of economic seaweeds: with reference to some Pacific species, vol. 6. I. A. Abbott, ed. [i–ii] + iii–xviii + 1–212, 1997. California Sea Grant College System, University of California, La Jolla, Calif. Report No. T-040; ISBN 1-888691-04-2.

Taxonomy of economic seaweeds: with reference to some Pacific species, vol. 7. I. A. Abbott, ed. [i–ii] + iii–xviii + 1–181, 1999. California Sea Grant College System, University of California, La Jolla, Calif. Report No. T-044: ISBN 1-888691-08-5.

Section I. *Sargassum* Species

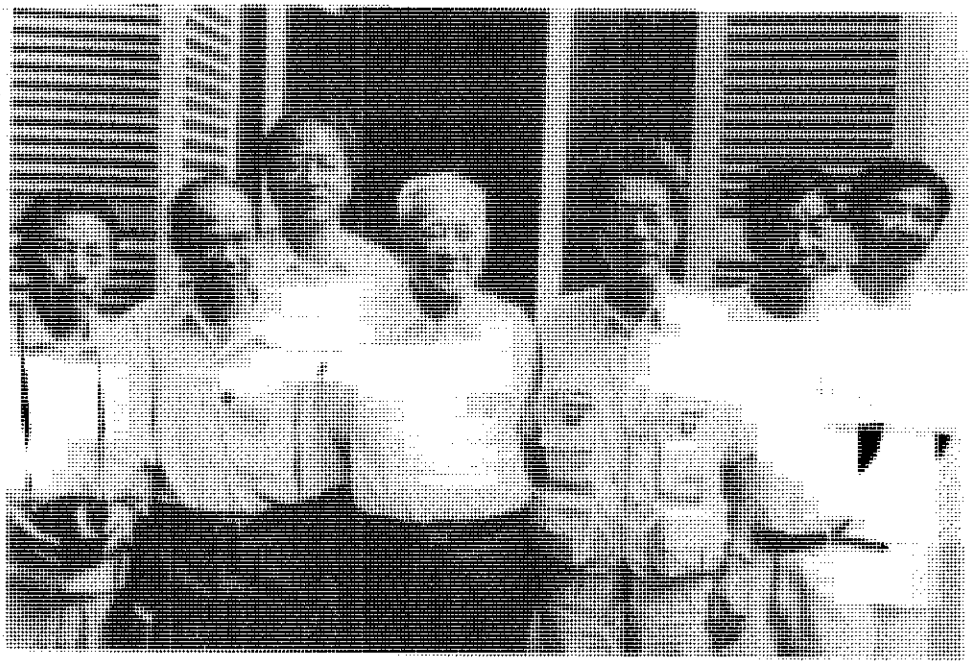
INTRODUCTION

Isabella A. Abbott

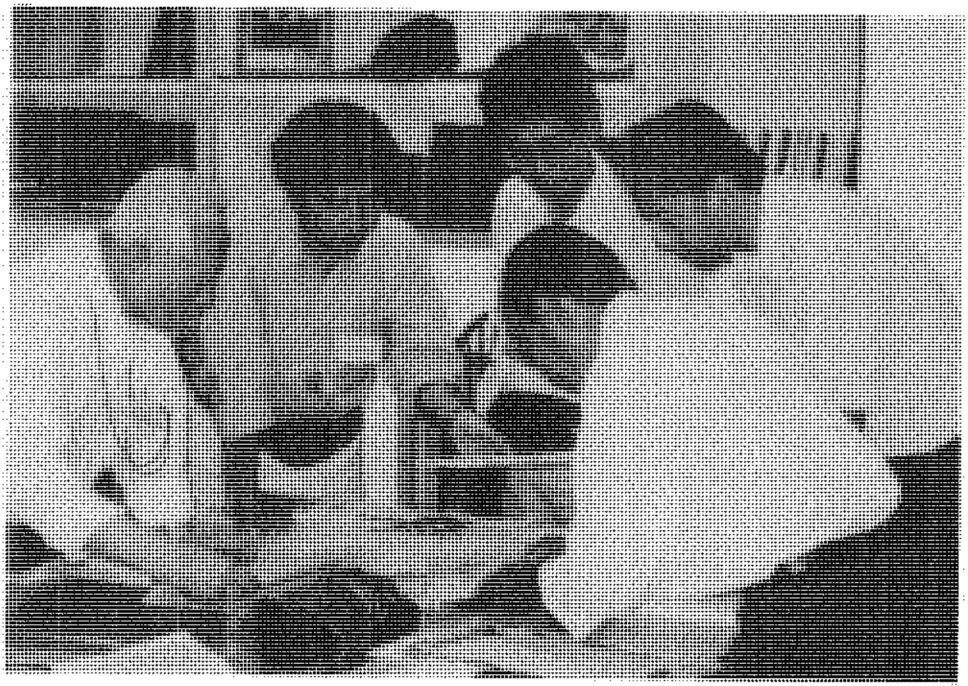
If you felt a ripple of excitement going through the *Sargassum* group as they were on the field trip, it was the Japanese members saying "hajimete omeni kakari masu" in response to what looked like an ordinary *Sargassum* specimen that was being passed around. For Dr. Yoshida, one of the world's *Sargassum* students, it was meeting a member of the section *Phyllocystae* for the first time in the field. *Sargassum mcclurei,* originally described from Hong Kong and with limited further distribution in the western Pacific, was the cause of the excitement. When I went to greet the collectors coming off the boat, it was clear that they were happy with their finds.

Three of the chapters in this section can be directly connected to the Vietnamese collections. Other chapters include drawings and photographs of structures in common in species, and 3 chapters by Tseng and Lu continue these authors' meticulous ("old-fashioned") classical taxonomic examination of many Chinese species. I am particularly pleased that Dr. Ajisaka was able to identify most of the dried herbarium specimens in the herbarium of the Bishop Museum of *Sargassum* species from Singapore and Malaysia, thus filling in the knowledge on species that he and others have collected in the field in those 2 places.

Like saving dessert to the last, I think it is especially noteworthy that molecular biological tools have been used in analyzing the section *Phyllocystae,* with results that support some but not all of the morphological studies that have gone before. This function is exactly the one we foresee for this technique that helps us predict or support (or both) the phylogenetic and evolutionary conclusions of our taxonomic studies.



The *Sargassum* Group. (Left to right): Zhou (Dr. Tseng's secretary), Nguyen Huu Dai, Tadahide Noro, C.K. Tseng, Tadao Yoshida, Lu Baoren, Tetsuro Ajisaka.



The Working *Sargassum* Group. (Left to right): C.K. Tseng, Tetsuro Ajisaka, Tadao Yoshida, Tadahide Noro, Nguyen Huu Dai (photo by Lu Baoren).

STUDIES ON THE BISERRULIC *SARGASSUM* OF CHINA: III. ON *SARGASSUM PARVIFOLIUM* (TURNER) C. AGARDH, WITH A NOTE ON THE CLASSIFICATION OF THE *BISERRULAE*

C.K. Tseng and Lu Baoren

Abstract

The status of *Sargassum parvifolium* (Turner) C. Agardh was reviewed. Plants with male receptacles were found for the first time in China. The receptacles are cylindrical, often furcate with a short cylindrical pedicel, mostly glabrous but occasionally with 1–2 short spines. Thus, *S. parvifolium* (Turner) C. Agardh should be removed from the series originally called *Parvifoliae* to the series *Ilicifoliae*. Hence, a new name, *Plagiophyllae*, centered on *S. plagiophyllum* C. Agardh, should take the place of *Parvifoliae*.

Introduction

Sargassum parvifolium (Turner) C. Agardh was based on *Fucus parvifolius* Turner, published in 1819. The species was based on a fragmentary specimen collected by Sir Joseph Banks, who "gathered it in the course of his voyage around the world but did not preserve any note on the spot in which he found it" (Turner, 1819, p. 34). Turner described a fragmentary specimen with a few branches with abundant small linear leaves and small globular vesicles in natural size, as shown in the illustration (Fig. a, c), and branches bearing leaves, a vesicle, and a few female receptacles. In the figure supplied by Turner, the branches are horizontal, alternate, cylindrical, filiform, usually flexuous in an irregularly spiral manner; the leaves on the branchlets are quite small, thin, short, narrow, and cartilaginous, about 7 mm long, 1.2 mm wide, acute at the apex, extremely attenuated with slightly oblique base, conspicuous midrib, deeply serrated at the margin, with numerous cryptostomata. The vesicles are solitary, about 1.2 mm in diameter, smooth at the surface, with short, filiform, cylindrical pedicels. The female receptacles are triquetrous, spinous, linear-elliptical, solitary, less than 2.3 mm long, sessile or with a very short petiole, externally uneven, and full of pores. Turner's figure is based on a part of the plant that has lanceolate leaves with a midrib that is conspicuous on the leaves of the primary and secondary branches and obscure on the younger ones. The vesicles are small and spherical.

C. Agardh in *Species Algarum* (1820, p. 30) established the genus *Sargassum* and transferred the species *Fucus parvifolius* Turner to it. *Fucus parvifolius* Turner became *S. parvifolium* (Turner) C. Agardh. This species was also described by J. Agardh (1848, 1889): branches filiform, subsmooth on the primary branches, leaves on the upper part of the branches linear-lanceolate, with midrib and cryptostomata, and leaves on the lower part usually broad lanceolate, with few cryptostomata; minute spherical vesicles with glandular dots, and cylindrical lower pedicel and clavate-edged female receptacles, spinous, racemosely arranged. J. Agardh put *Carpacanthus parvifolius* (Turner) Kützing as a synonym of *S. parvifolium* (Turner) C. Agardh. Grunow (1916) collected this species from the China Sea, including Cochin China, the Philippines, Singapore, Australia, Madagascar, Bangkok of Thailand, Muntok of Indonesia, and so forth, and described *S. parvifolium* (Turner) C. Agardh and 2 new varieties. Grunow's specimen of *S. parvifolium* (Turner) C. Agardh is mainly characterized by its subsmooth branches; somewhat rigid, lanceolate, small leaves, 4–20 mm long, 0.6–2 mm wide, mostly acuminate, sometimes obtuse at the apex, sharply dentate at the margin; small, spherical vesicles, 0.6–2 mm in diameter, without any mucron at the apex and with cryptostomata; and female spinous triquetrous receptacles. He suspected that *S. baccularia* (Merton) C. Agardh was the sexual state of *S. parvifolium* (Turner) C. Agardh and despite its glabrous female receptacles, placed *S. baccularia* (Merton) C. Agardh near *parvifolium* among the *Acanthocarpicae.*

Setchell (1936) discussed *S. parvifolium* (Turner) C. Agardh on the basis of the specimens with oogonial receptacles that he collected from Repulse and Stanley beaches, Hong Kong, in April to May 1929. He stated that these specimens "seem to answer fairly well to the description of *S. parvifolium* (Turner) C. Agardh, but there are a few differences, especially in that the vesicles are faintly and sparingly glandular dotted. Whether this character may, or may not, be present in the type specimen cannot, as yet, be verified." He found younger plants with broadly lanceolate leaves on the lower parts of the plants and female triquetrous spinous receptacles. Like Grunow, Setchell suspected that *S. baccularia* (Merton) C. Agardh was a "sex-state" of *S. parvifolium* (Turner) C. Agardh. However, he placed *S. baccularia* in the subsection *Racemosae* of the *Malacocarpicae.*

Recently, we studied our *S. parvifolium* specimens collected by Zhang Junfu and Xu Fali from the beach at Qinzhou Bay, Guangxi Province, on May 11, 1955, and by Lu Baoren and Wang Yongqiang from Weizhou Island, Guangxi Province, in May to June 1996. We found that some specimens are female plants of *S. parvifolium,* with main characters, particularly the branches on the upper part of the plant, closely corresponding to those in Turner's figures and descriptions. We found male plants mixed with the female plants, a situation that has never been described before.

Male Plants of *Sargassum parvifolium* (Turner) C. Agardh

The male plants of *S. parvifolium* are yellowish brown, slender, up to 30–65 cm in height. The holdfasts (Fig. 1) are small, conical, up to 7 mm in diameter, and 5 mm or more in height. The main axes are cylindrical, about 6 mm tall, 2 mm in diameter. The primary branches arise from the upper part of the axis and are slender, terete, glabrous, 29–60 cm long, 2 mm in diameter. The secondary branches are patently branched, alternate, glabrous, arising from the foliar axils of the primary branches, about 20–30 cm long, 1 mm in diameter, at intervals of

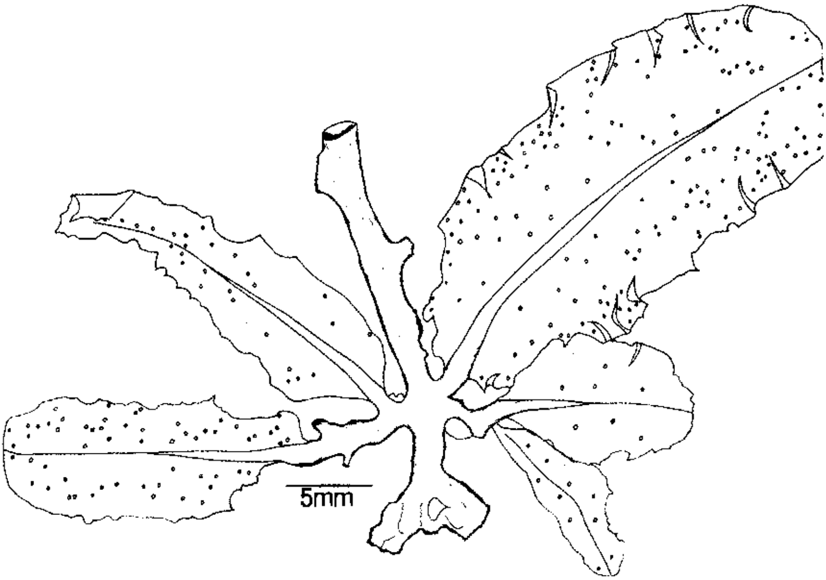


Fig.1. Basal part of *Sargassum parvifolium* (Turner) C. Agardh. Note conical holdfast, short axis, and 5 broad, cuneate basal leaves.

1.5–2 cm. The ultimate branchlets are small, short, slender, terete, with a few raised glandular dots on the surface, usually 2–4 cm long, less than 0.6 mm in diameter and beset with leaves, vesicles, and male receptacles.

The basal leaves are broad-lanceolate, up to 3 cm long, 10 mm wide, obtuse or slightly acute at the apex, obliquely cuneate at the base, with a conspicuously percurrent midrib, irregularly scattered cryptostomata on the surface, wavy or somewhat irregularly shallowly serrulate at the margins. The leaves on the primary and secondary branches are small, slender, lanceolate, acute at the apex, slightly oblique, asymmetrically cuneate at the base, with a conspicuous midrib percurrent or vanishing below the apex, with irregularly scattered cryptostomata on both sides of the midrib, and irregularly sharply dentate at the margins. The leaves on the primary branches are mostly deciduous; the remaining ones are about 4 cm long, 3 mm wide. The leaves on the secondary branches are 2.5–3 cm long, 2–2.5 mm wide. The leaves on the ultimate branchlets are small and narrow or linear-lanceolate, about 1.5–2 cm long, 1.5–2 mm wide, acute at the apex, cuneate at the base, with an obscure midrib and a few cryptostomata, irregularly and sharply dentate on the upper part of the margins, mostly wavy on the lower part.

The vesicles (Fig. 2) are small, spherical when mature, subspherical or ovate when young, up to 4 mm in diameter, with a few cryptostomata on the surface and cylindrical, glabrous pedicels usually 3–4 mm long, less than 1 mm in diameter. The male receptacles (Fig. 3) are rather long when mature, cylindrical, often

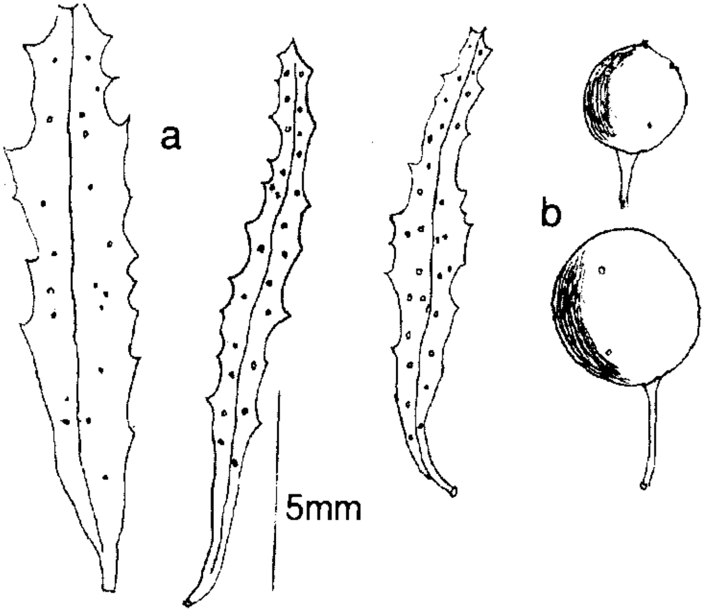


Fig. 2. Leaves (a) and vesicles (b) of *Sargassum parvifolium* (Turner) C. Agardh.

furcate, usually 10–20 mm long, 1 mm in diameter, mostly glabrous, sometimes with 1 or 2 spines. The receptacles are racemosely arranged on the fertile branches; each receptacle often has a cylindrical small pedicel.

On the Classification of the Biserrulae

We (Tseng et Lu 1997) discussed the taxonomy of the *Sargassum* subsection *Biserrulae* J. Agardh and promoted the species groups of J. Agardh and Grunow to series. Unfortunately, the series names were misspelled. They should be *Parvifoliae* instead of *Parvifolia*, *Iliicifoliae* instead of *Ililcifolia*, and *Coriifoliae* instead of *Coriifolia*.

We agreed with Grunow and accepted the classification of J. Agardh (1889) in Agardh's treatment of the species group *Parvifolia* of *Biserrulae*, which was based solely on the reproductive organs (Grunow 1915, p. 409), deviating entirely from J. Agardh's original definition of the *Parvifolia*, which was based on the vegetative characters. Unfortunately, Grunow still used vegetative characters to differentiate the other 2 series.

After studying hundreds of specimens during our research, we found that most of the specimens we classify as members of *Coriifoliae* are androgynous, and we

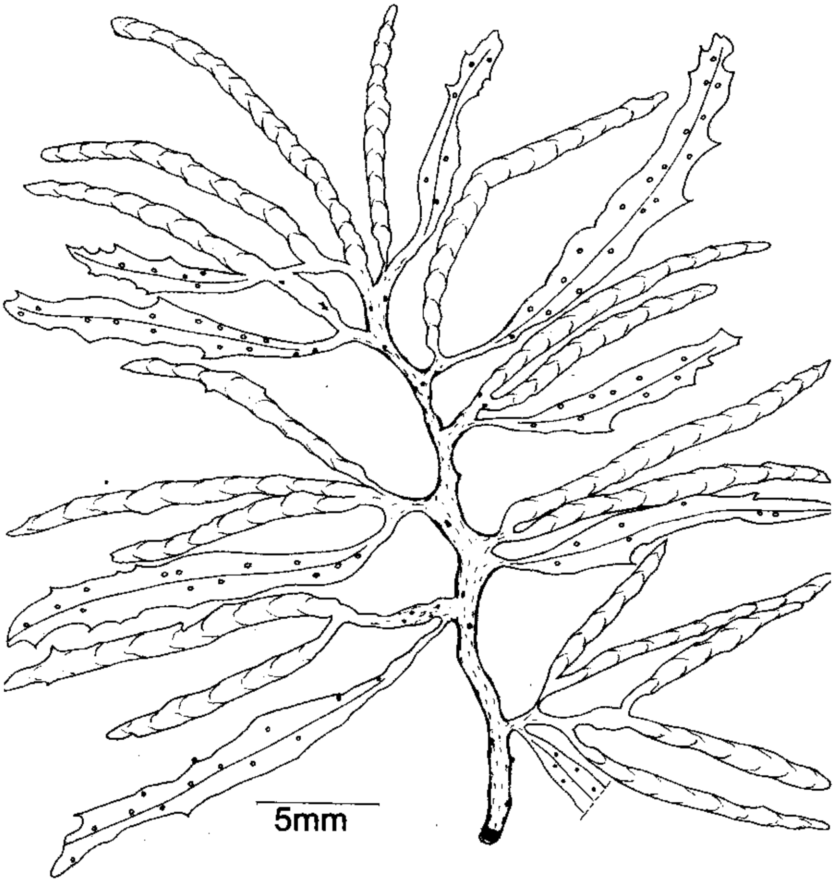


Fig. 3. Male receptacles of *Sargassum parvifolium* (Turner) C. Agardh.

realized that classification based solely on reproductive structure is possible and necessary. Therefore, in our chapter (Tseng and Lu 1997), we emphasize the reproductive structures. We still follow the J. Agardh and Grunow taxonomy of the *Biserrulae* by using the same series names.

Recently, we had a serious difficulty. We found several male specimens of *S. parvifolium*, originally the type species of the *Parvifolia* group of Grunow, who never saw a male plant of *S. parvifolium* and who assumed that male plants of this species had glabrous male receptacles. Our plants, which we think belong to *S. parvifolium*, have male receptacles, and although most of the receptacles are glabrous, a few have 1 or 2 short spines. If we insist that the series *Parvifoliae* consists of plants with spinous female receptacles and glabrous male receptacles and that the series *Ilicifoliae* consists of plants in which both female and male receptacles are spinous, we must move *S. parvifolium* to the series *Ilicifoliae*. But *S. parvifolium* is the type species of the series *Parvifoliae*; therefore, we must select another type species for the *Parvifoliae*. After serious consideration, we finally selected *S. plagiophyllum* (Mertens) J. Agardh, a widely distributed species of the Indo-West Pacific region, as the new type species, and concurrently changed the series name *Parvifoliae* to *Plagiophyllae* as follows:

Series *Plagiophyllae* Tseng et Lu, ser. nov.

Basionym: Series *Parvifolia* (J. Agardh amend Grunow) Tseng et Lu, Tax. Econ. Seaweeds 6, p. 5, 1997.

Planta dioica. Receptaculis feminibus spinulosis et receptaculis maribus glabellis. Foliis membranaceis, magnis vel pusillis, vulgo angustis, plerumque basibus obliquis vel non obliquis.

Type species: *Sargassum plagiophyllum* (Mertens) J. Agardh, Sp. gen. ordines algarum, vol. 1, p. 309, 1848; J. Agardh, Sp. Sargassorum Austr., p. 120, pl. 12, figs. 4–5, 1889.

According to Silva et al. (1996), the species name of *S. coriifolium* J. Agardh (1889) is an illegal name because the name *S. odontocarpum* was already given by Sonder in 1871. Accordingly the series name *Odontocarpae* should be adopted to take the place of *Coriifoliae*. It has also been considered that androgyny precedes dioecism, and therefore in the subsection *Biserrulae*, *Odontocarpae* should be the most primitive series, followed by *Plagiophyllae*, with *Ilicifoliae* as the most advanced series.

We offer a new key to the series of *Biserrulae*:

1. Receptacles androgynous, acanthocarpic .... *Odontocarpicae*
1. Receptacles dioecious, female receptacles acanthocarpic 2
   2. Male receptacles malacocarpic .... *Plagiophyllae*
   2. Male receptacles acanthocarpic .... *Ilicifoliae*

Acknowledgments

This chapter is contribution No. 3861 from the Institute of Oceanology, Chinese Academy of Science, Qingdao. We thank Dr. James J. Sullivan, former director, California Sea Grant College Program, and Dr. Isabella Abbott for their kind invitation to attend the wonderful workshop. We also thank Dr. Abbott for reading and editing our manuscript.

Literature Cited

Agardh, C. A. 1820. Species algarum...vol. 1. iv + 168 pp. Berling, Lund.

Agardh, J. G. 1848. Species, genera et ordines algarum...I. Algas fucoideas complectens. viii + 363 pp. Gleerup, Lund.

Agardh, J. G. 1889. Species Sargassorum Australiae descriptae et dispositae. Kgl. Svenska Vet.-Akad. Handl. 23:1–133, pls. 1–31.

Grunow, A. 1915. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 65:329–448.

Grunow, A. 1916. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 66:136–185.

Setchell, W. A. 1936. Hong Kong seaweeds, V. Hong Kong Nat. Suppl. 5:1–20.

Silva, P. C., Basson, P. W., and Moe, B. L. 1996. Catalogue of the Benthic marine algae of the Indian Ocean. University of California Press, Berkeley. 1259 pp.

Sonder, O. G. 1871. Die algen des tropischen Australiens. Abhandl. Gebiete Naturwissensch. Verein (Hamburg) 5(2):33–74, pls. 1–6.

Tseng, C. K., and Lu Baoren. 1997. Studies on the biserrulic *Sargassum* of China: I. Taxonomy of the subsection *Biserrulae.* In: Tax. Econ. Seaweeds 6, pp. 3–7.

STUDIES ON THE BISERRULIC *SARGASSUM* OF CHINA:
IV. THE SERIES *PLAGIOPHYLLAE* TSENG ET LU

C.K. Tseng and Lu Baoren

Abstract

The series *Plagiophyllae* is differentiated from the series *Odontocarpicae* (formerly *Coriifoliae*) on the basis of the former's dioecious receptacles with acanthocarpic female receptacles and malacocarpic male receptacles. The series is divided into 2 species groups: the *Rhizophora* and the *Plagiophylla*. In China, the *Rhizophora*, which has rhizoidal holdfasts, consists of 4 species, and the *Plagiophylla*, which has discoid holdfasts, consists of 3 species. The holdfasts of 2 species were not found, and these 2 species are therefore not grouped in any of the species groups. A species, its male plant still unknown, is provisionally placed in the series *Plagiophyllae* because of its linear-lanceolate leaves with rather equal basal parts. The series therefore has 10 species. The series *Plagiophyllae* is mostly distributed in the Indo-West Pacific region, especially the South China Sea. Of the 10 species presented, 6 species are new to science and are described.

Introduction

In the first chapter on the biserrulic *Sargassum* of China (Tseng and Lu 1997), we discussed the taxonomy of the subsection *Biserrulae* and differentiated 3 series on the basis of the receptacles. At that time, we were not sure whether the androgynous condition was more primitive or advanced and provisionally regarded the series *Parvifoliae*, now known as *Plagiophyllae*, as the most primitive and placed it as the first of the 3 series. In this chapter, we conclude that androgyny is more primitive and dioecism more advanced, and we therefore put the androgynous series *Odontocarpicae* (formerly *Coriifoliae*) as the most primitive series. For the other 2 dioecious series, we put the series *Plagiophyllae*, which has malacocarpic male receptacles, as the more primitive and the series *Ilicifoliae*, which has acanthocarpic receptacles in both males and females, as the most advanced series.

The Series *Plagiophyllae* Tseng et Lu

Of the 16 species of bisserulic *Sargassum* reported from China, the following 3 species were from the *Parvifoliae* (now *Plagiophyllae*) of Grunow (1915): *S. gracile* J. Agardh, *S. gaudichaudii* Montagne, and *S. baccularia* (Mertens) C. Agardh var. (?) *lantowensis* Grunow. *Sargassum heterocystum* Montagne was placed in *Ilicifolia* J. Agardh by Grunow (1915), but it has malacocarpic male receptacles and in our present system is placed in the series *Plagiophyllae.* Two more species in the series *Plagiophyllae*, both from Taiwan, are not included in the list, namely *S. plagiophyllum* C. Agardh, reported by Yamada (1942) and

Yoshida (1988), and *S. kasyotense*, reported by Yamada (1944). Because we lack more recent reports, we have put *S. gracile* and *S. gaudichaudii* as species inquirendae for the time being. We have evidence that *S. baccularia* var. *lantowensis* does not belong to the subsection *Biserrulae* and should be placed in *Malacocarpicae* because of its malacocarpic receptacles (Tseng et Lu 1992). Recently, we described a new species from Nansha Islands, Hainan Province, namely *S. longivesiculosum* Tseng, Lu, and Ding (1998). Thus, we have 4 species already reported to occur definitely in China. After studying the specimens we have collected from the South China Sea for more than 40 years, we have added 6 new species; thus, 10 species are described in this chapter.

The *Parvifoliae*, now known as the series *Plagiophyllae*, in the Grunowian system consists of 24 species and is divided into 2 groups, one with "ramis plus minueve hispidis, rariter sublaevitus" comprising 13 species and the other with "ramis parae muricalatis vel inermibus" comprising 11 species. From descriptions of the 24 species in Grunow's work, we think that this series is found mainly in the Indo-West Pacific area, especially the South China Sea. We do not agree with Grunow's division of the series on the basis of the hispidity of the branches. We think that the characteristic of the holdfast is more important.

We can differentiate members of this series into 2 species groups. The first group, *Rhizophora*, consists of plagiophyllic *Sargassum* with rhizoidal holdfasts and includes the following 4 species: *S. integerrimum*, *S. yinggehaiense*, *S. rhizophorum*, and *S. symphyorhizoideum*. These 4 species are described as new in the following section. The second group, *Plagiophylla*, consists of plagiophyllic *Sargassum* with discoid holdfasts and includes 3 species: *S. heterocystum*; *S. parvifolioides*, a new species; and *S. plagiophyllum*.

The series *Plagiophyllae* has 3 other species, but their positions remain undecided. Specimens of 2 new species, *S. fuscifolium* and *S. longivesiculosum*, were collected from the drift and do not have holdfasts. The specimen of 1 species, *S. kasyotense*, does not have a male gametophyte but does have elongated leaves with symmetrical bases.

All specimens examined were deposited at the herbarium of the Institute of Oceanology, Chinese Academy of Sciences, Qingdao (AST).

Key to the Chinese Species of *Plagiophyllae*

1. Holdfast rhizoidal (*Rhizophora*) 2
1. Holdfast discoid or conical or unknown 5
  2. Leaves thin, lanceolate, dentate at the margins .... 3. *S. rhizophorum*
  2. Leaves thick, elliptical or lanceolate, entire at the margins or sometimes with slightly serrulated upper parts 3
3. Leaves long-elliptical, wavy on the lower parts, irregular at the upper parts .... 2. *S. yinggehaiense*
3. Leaves lanceloate, entire or slightly serrulate in the upper parts 4

  4. Leaves entire, midrib percurrent, vesicles without earlike structure .... 1. *S. integerrimum*
  4. Leaves slightly serrulate in the upper parts, midrib not percurrent, vesicles with earlike structure at both sides .... 4. *S. symphyorhizoideum*
5. Holdfast conical, branches muricate .... 8. *S. kasyotense*
5. Holdfast discoid or unknown, branches smooth 6
  6. Holdfast discoid (*Plagiophylla*) 7
  6. Holdfast unknown 9
7. Leaves small, ellipsoidal, vesicles fusiform .... 5. *S. heterocystum*
7. Leaves large, not ellipsoidal, vesicles not fusiform 8
  8. Only one kind of leaves, leaves thick .... 7. *S. plagiophyllum*
  8. Two kinds of leaves, basal leaves broad-lanceolate, upper leaves small narrow-lanceolate, leaves thin .... 6. *S. parvifolioides*
9. Leaves elongately obovate or oblanceolate, margin wavy on lower parts, somewhat serrulate on upper parts, vesicles small, ovate .... 9. *S. fuscifolium*
9. Leaves lanceolate, entire at the margin, vesicles very large, ellipsoidal .... 10. *S. longivesiculosum*

Description of the Species

1. *Sargassum integerrimum* Tseng et Lu, sp. nov.

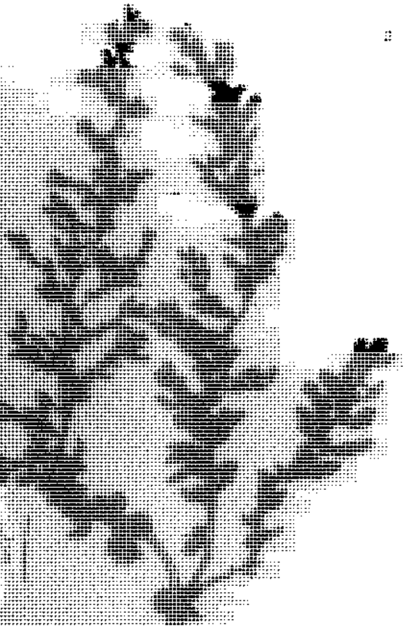
(Figs. 1 and 9)

Frons luteus brunneus, 112 cm alta. Hapteron scutellous rhizoidea. Ramis principalis cylindricis, laevibus, ad 111 cm longis, 2 mm diametro; ramis secundariis cylindricis, laevibus, ad 20 cm longis, 1 mm diametro; ramulis brevibus cylindricis, laevibus. Foliis basalum latis lanceolatis, 2 cm longis, 9 mm latis, apicibus acutis, basibus obliquis, costis percurrentibus conspicuus, marginibus integeris; foliis primariis 5–6 cm longis, 7–10 mm latis; foliis secundariis angustis, 3–4.5 cm longis, 2–3 mm latis; foliis ramulis linearibus, 1.5–2 cm longis, 1.5–2 mm latis, foliis totis integeris. Vesiculis sphaericis vel ovatis, 4 mm diametro, rotundatis vel acutis apicibus.

Planta dioica. Receptaculis feminibus triquetris, spinis, furcais, ad 5 mm longis, 1.5 mm diametro; receptaculis maribus cylindricis, furcatis, laevis, ad 6 mm longis, 1 mm diametro, racemosis.

Holotype: AST 55-1608, collected by Zhang Junfu and Xu Fali, April 6, 1955, from Naozhou Island, Guangdong Province.

Fronds yellow-brown, up to 112 cm tall. Holdfasts scutellate with rhizoids radiating and fusing with one another, forming a conical structure, up to 1.3 cm in diameter. Main axis cylindrical, 1 cm long, 2.5 mm in diameter. Branches all glabrous; several primary branches arising from the upper parts of the axis, up to



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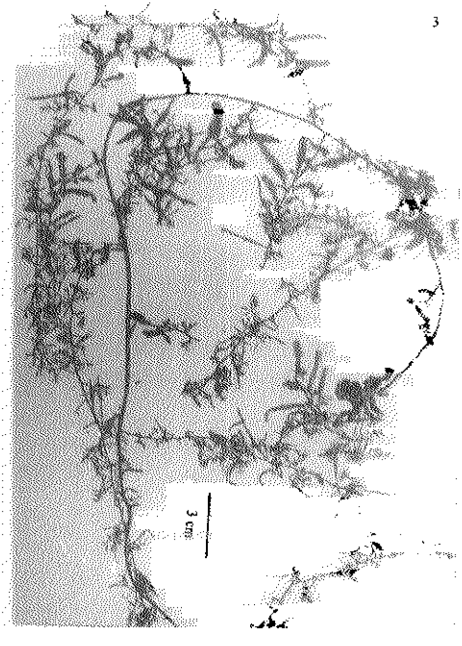

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Fig. 1. *Sargassum integerrimum* **Tseng et Lu.**
Fig. 2. *Sargassum yinggehaiense* **Tseng et Lu.**
Fig. 3. *Sargassum rhizophorum* **Tseng et Lu.**
Fig. 4. *Sargassum symphyorhizoideum* **Tseng et Lu.**

111 cm long, 2 mm in diameter; secondary branches arising alternately from foliar axils of the leaves, at intervals of 3–4 cm, up to 20 cm long, 1 mm in diameter; ultimate branches cylindrical, smooth, much shorter, up to 5 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves thick; basal leaves lanceolate, up to 2 cm long, 9 mm wide, acute at the apex, asymmetrical, oblique, and cuneate at the base, with conspicuous, percurrent midribs and scattered cryptostomata on both sides of the midrib, entire at the margins; primary leaves lanceolate, about 5–6 cm long, 7–10 mm wide, acute at the apex, asymmetrical, conspicuously oblique, cuneate at the base, with short stipes and percurrent midribs, with conspicuous cryptostomata scattered to both sides of the midrib, entire at the margins; secondary leaves narrow, narrow-lanceolate, or linear, about 3–4.5 cm long, 2–3 mm wide, acute at the apex, oblique and cuneate at the base, entire or wavy at the margins, cryptostomata obscure, scattered on both sides of the midrib; leaves on ultimate branches very narrow and short, about 1.5–2 cm long, 1.5–2 mm wide, acute at the apex, obliquely cuneate at the base, with conspicuous percurrent midrib and scattered cryptostomata on both sides of the midribs, entire at the margins. Vesicles spherical or ovate, up to 4 mm in diameter, sometimes with a sharp point at the apex, with a few raised cryptostomata on the surface and cylindrical, glabrous pedicels, about 2–3 mm long, and less than 1 mm in diameter.

Plants dioecious. Female receptacles triquetrous, furcate, up to 5 mm long, 1.5 mm in diameter, with spines on the surfaces and apices. Male receptacles cylindrical, glabrous, furcate, up to 6 mm long, 1 mm in diameter. All receptacles racemosely arranged in fertile branches.

Representative Material: AST 55-1588, 55-1589a, 55-1606, 55-1641, 55-1698, 55-1749, 55-2206, 55-2233, and 55-2235, collected April 6–23, 1955, from Naozhou Island, Guangdong Province.

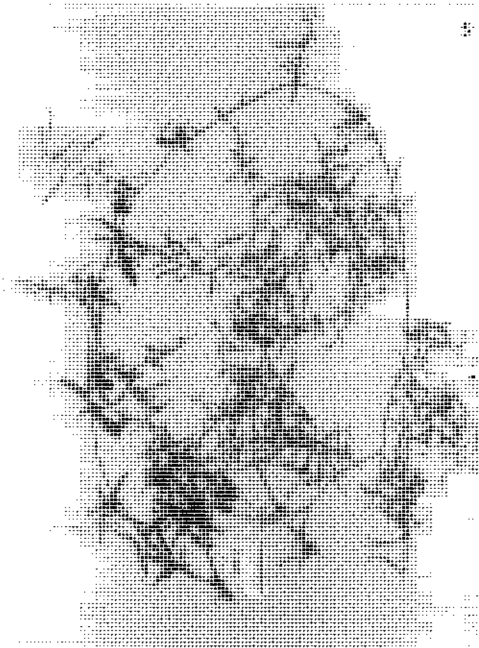
Habitat: Growing on lower intertidal rocks.

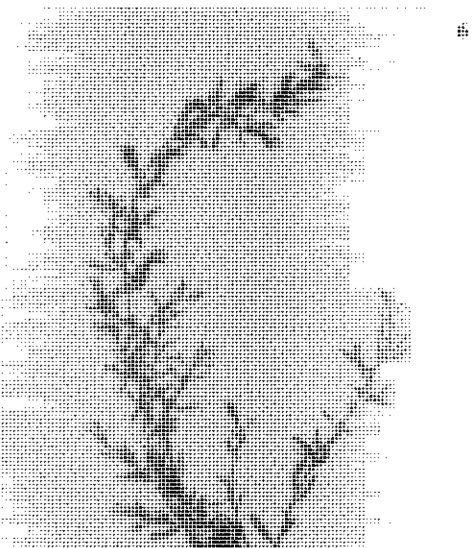
Remarks: *Sargassum integerrimum* is characterized by its dioecious receptacles with triquetrous and spinous female receptacles and cylindrical, glabrous male receptacles and by its scutellate rhizoidal holdfast. The leaves are entire at the margins, and the leaves on the secondary and ultimate branches are small and narrow. This species is related to *S. yinggehaiense* Tseng et Lu, but *S. integerrimum* has very narrow leaves that are entire at the margins and conical holdfasts.

2. *Sargassum yinggehaiense* Tseng et Lu, sp. nov.

(Figs. 2 and 10)

Frons atrofuscus, ca 40 cm altus. Hapteron rhizoidea formans discoidea. Ramis principalis cylindricis. Foliis primariis atrolabiis, longis ellipsoideis, 4 cm longis, 8–11 mm latis, multis rotundis, aliis acutis in apicibus, asymmetricis, obliquis ad basim, costis non percurrentibus, vel 2/3 infra apicalis evanida,





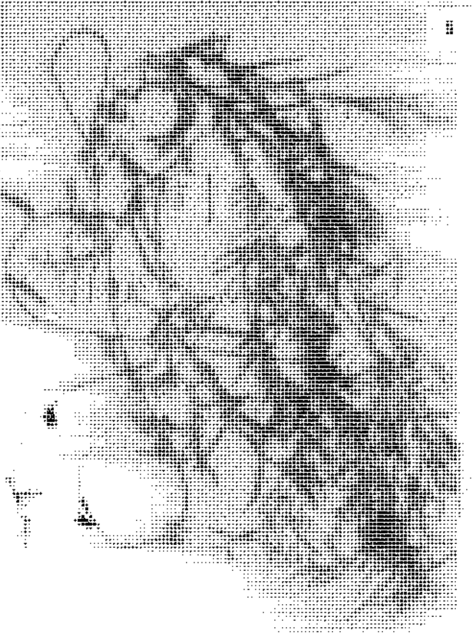


Fig. 5. *Sargassum parvifolioides* Tseng et Lu.
Fig. 6. *Sargassum plagiophyllum* Tseng et Lu.
Fig. 7. *Sargassum fuscifolium* Tseng et Lu.
Fig. 8. *Sargassum longivesiculosum* Tseng et Lu.

undulatibus vel acuminatibus ad margines; foliis secundariis et ramulis parvis, ellipsoideis, 1.5–2 cm longis, 5–8 mm latis, obtusis ad extremum, sine costibus vel obscure, 2/3 infra apicalis evanida. Vesiculis ellipsoideis, 5–7 mm longis, 4–5 mm diametro acutis in apicibus, vulgo foliaceis ad marginem.

Planta dioica. Receptaculis feminibus triquetris supra, furcatis, compressis vel cylindricis infra spinis, 5–6 mm longis, 1 mm diameter; receptaculis maribus cylindricis, vel subcylindricis, laevis vel undulatis, 6–7 mm longis, 0.7–0.8 mm diametro, racemosis.

Holotype: AST 73-0782, collected by Zhang Junfu, April 20, 1973, from Yinggehai Beach, Hainan Island.

Fronds dark brown, up to 40 cm tall. Holdfast discoid with rhizoids fusing with one another, forming a disc 1.5 cm in diameter. Main axes cylindrical, short, glabrous, up to 1 cm tall, 2 mm in diameter. Primary branches glabrous, cylindrical or subcylindrical, up to 39 cm long, 1.5–2 mm in diameter; secondary branches glabrous, cylindrical, arising from foliar axils at intervals of 0.5–1 cm, alternate, up to 8 cm long, 1 mm in diameter; ultimate branches terete, short, up to 2 cm long, less than 1 mm in diameter, with a few ordinary glandular dots on the surface, beset with leaves, vesicles, and receptacles. Leaves on primary branches thick, elongated-ellipsoidal, up to 4 cm long, 8–11 mm wide, mostly rounded, sometimes acute at the apex, asymmetrical, obliquely cuneate at the base, wavy or irregularly serrulate at the margins, particularly in the lower inside parts of the plant, with midribs usually vanishing at 2/3 of the distance to the top of the leaves; leaves on secondary and ultimate branches elongated-ellipsoidal, small, about 1.5–2 cm long, 5–8 mm wide, usually obtuse at the apex, asymmetrical, obliquely cuneate at the base, usually in its lower inside parts, wavy, other parts slightly serrulate at the margins, with midribs obscure or absent, generally vanishing at 2/3 of the tops of the leaves, cryptostomata scattered over the surfaces. Vesicles ellipsoidal, about 5–7 mm long, 4–5 mm in diameter, with sharp points at the apex, usually with narrow foliar appendages and a few cryptostomata on the surfaces and cylindrical pedicels, about 3–4 mm long, 1 mm in diameter.

Plants dioecious. Receptacles usually furcate, racemosely arranged. Female receptacles triquetrous above, sometimes compressed, cylindrical below, with a few spines, about 5–6 mm long, 1 mm in diameter. Male receptacles cylindrical or subcylindrical, about 6–7 mm long, 0.7–0.8 mm in diameter, glabrous.

Representative Material: Tseng 1465 and 2450; AST 55-0627, 55-0689, 55-0690, 58-5250, 58-5251, 58-5295, 62-2235, 62-2236, 73-0742, 73-0783, 80-2312, 80-2381, 82-0437, 92-0614, 93-0794, and 93-0795.

Habitat: Growing on lower intertidal and subtidal rocks, Yinggehai Beach, Hainan Island.

Remarks: *Sargassum yinggehaiense* Tseng et Lu is principally characterized by rhizoidal holdfasts. The primary branches are cylindrical or subcylindrical, and ultimate branches have glandular dots. The leaves are thick, ellipsoidal, mostly rounded at the apex, asymmetrical at the base, and wavy or serrulate at the margins. The female receptacles are spinuous, triquetrous above, and cylindrical below, and male receptacles are cylindrical or subcylindrical and glabrous with a wavy outline. The species is related to *S. symphyorhizoideum* Tseng et Lu, but unlike *S. symphyorhizoideum*, *S. yinggehaiense* has long-elliptical leaves and ellipsoidal vesicles.

3. *Sargassum rhizophorum* Tseng et Lu, sp. nov.
(Figs. 3 and 11)

Frons luteus brunneus, plus 1 m altus. Hapteron rhizoidea formans discoidea. Ramis principalis cylindricis, laevibus, ramulis brevibus cylindricis multis elevatis glandibus super paginis. Foliis basalum latis lanceolatis, 2.5–3 cm longis, 10 mm latis, vulgo apicibus obtusis, asymmetricis, obliquais ad basim, costa percurrens, cryptostomatibus irregularibus dispositis in costis utroque, acuminatibus ad margines supra, sinuatibus infra; foliis in ramis secundariis latis lanceolatis, 3 cm longis, 7 mm latis, vulgo multis acutis, aliis obtusis ad extremum, costis percurrentibus vel infra apices evanida, dentatibus ad margines; foliis in ramulis linearis, 2 cm longis, 2 mm latis, multis acutis, costis obscure, dentatibus ad margines. Vesiculis sphaericis, ovatis, 3 mm diametro rotundatis in apicibus, pedicellis cylindricis, 2–3 mm longis.

Planta dioica. Receptaculis feminibus triquetris, furcatis, spinis, 7 mm longis, 1.5 mm diametro; receptaculis maribus cylindricis, laevis, ad 10 mm longis, 1 mm diameter, racemosis.

Holotype: AST 55-1843, collected by Zhang Junfu and Xu Fali, April 26, 1955, from Weizhou Island, Beihai City, Guangxi Province.

Isotype: AST 55-1836, collected by Zhang Junfu and Xu Fali, April 26, 1955, from Weizhou Island, Beihai City, Guangxi Province.

Fronds yellow-brown, 1 m or more tall. Holdfast with rhizoids radiating and fusing with one another, forming a disc, up to 1.3 cm in diameter. Main axis cylindrical, glabrous, up to 8 mm tall, 2 mm in diameter, giving rise to several primary branches from its upper parts. Primary branches cylindrical, glabrous, up to 1 m or more long, 2 mm in diameter; secondary branches arising from foliar axils at intervals of 4–7 cm, alternate, cylindrical, glabrous, up to 25 cm long, 1.2 mm in diameter; ultimate branches short, cylindrical, about 1.5–2 mm long, 0.8 mm in diameter, with a few raised glandular dots, beset with leaves, vesicles, and receptacles. Basal leaves broadly lanceolate, about 2.5–3 cm long, 10 mm wide, obtuse at apex, asymmetrical and more or less oblique, cuneate at the base, sometimes serrulate at the upper parts of the margins, wavy on the lower parts of the margins, with conspicuous midrib, percurrent or vanishing at the apex, and cryptostomata irregularly scattered on both sides of the midrib; leaves on the primary branches broadly lanceolate, up to 3 cm long, 7 mm wide, acute or obtuse at the apex, more or less oblique, cuneate at the base, conspicuous percurrent midrib, dentate at the margins, with conspicuous cryptostomata irregularly scat-

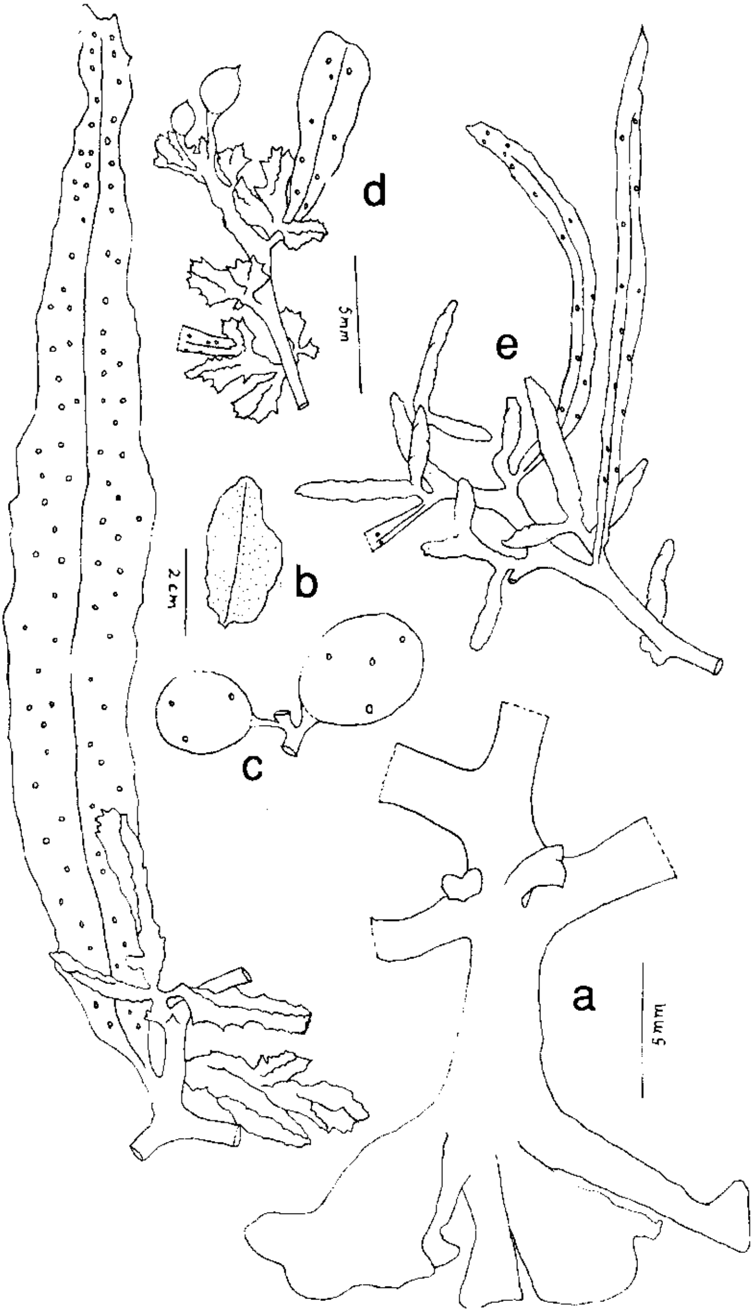


Fig. 9. *Sargassum integerrimum* Tseng et Lu. a, Rhizoidal holdfast. b, Basal leaves. c, Vesicles. d, Female receptacles. e, Male receptacles.

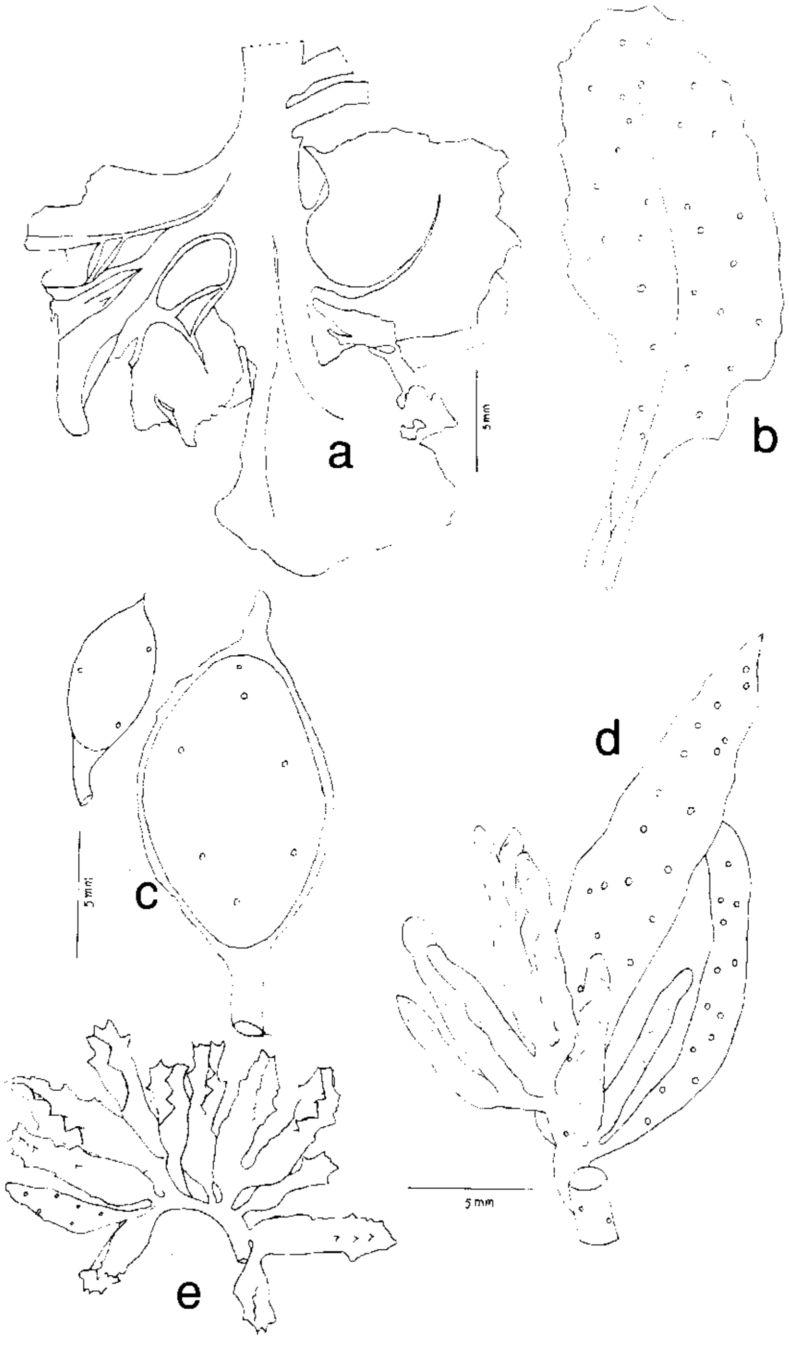


Fig. 10. *Sargassum yinggehaiense* Tseng et Lu, sp. nov. a, Rhizoidal holdfast. b, Leaves. c, Vesicles. d, Male receptacles. e, Female receptacles.

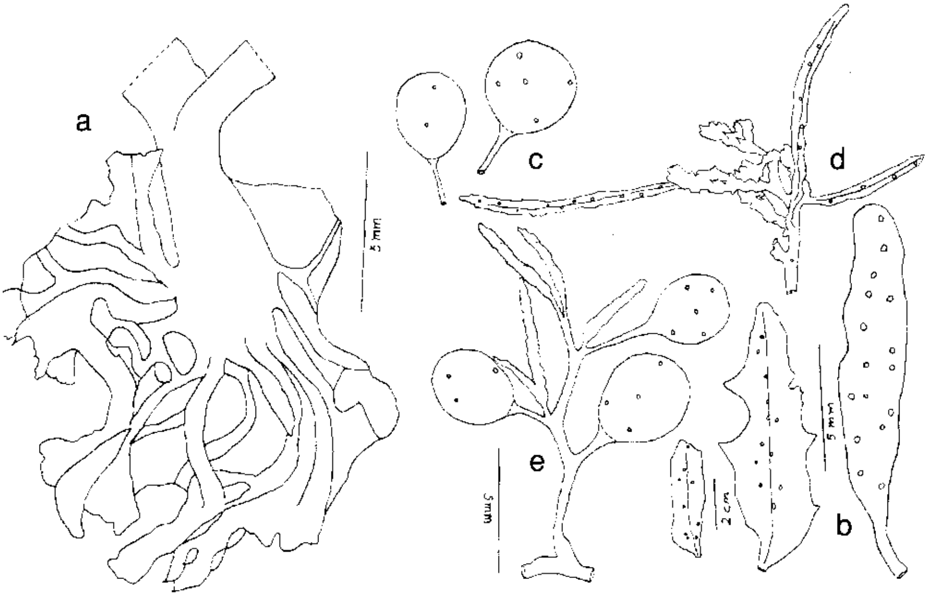


Fig. 11. ***Sargassum rhizophorum Tseng*** **et Lu, sp. nov. a, Rhizoidal holdfast. b, Leaves. c, Vesicles. d, Female receptacles. e, Male receptacles.**

tered on both sides of the midrib; leaves on secondary branches narrowly lanceolate, acute or obtuse at the apices; leaves on ultimate branchlets linear, up to 2 cm long, 2 mm wide, acute at the apex, irregularly dentate at the margins, with obscure midrib, usually vanishing below the apex, and usually short rows of cryptostomata scattered on both sides of the midrib, pedicels of the leaves filiform, up to 1.5 mm long. Vesicles small, spherical or obovate, 3 mm in diameter, mostly rounded, sometimes with sharp points at the apex, with a few cryptostomata, and cylindrical, filiform stipes, usually 2–3 mm, sometimes up to 5 mm, long.

Plants dioecious. Female receptacles triquetrous on upper parts, cylindrical on lower parts, spinous, up to 7 mm long, 1.5 mm in diameter. Male receptacles cylindrical, glabrous, up to 10 mm long, 1 mm in diameter. All receptacles furcate, racemosely arranged, particularly female receptacles when young.

Representative Material: AST 55-1877, collected by Zhang Junfu and Xu Fali, April 27, 1955, from Weizhou Island.

Habitat: Growing on subtidal rocks.

Remarks: *Sargassum rhizophorum* Tseng et Lu is principally characterized by its rhizoidal holdfast, with rhizoids radiating and fusing with one another, forming a disc. Branches are cylindrical, and ultimate branchlets have glandular dots. Basal leaves are broad-lanceolate, most of them obtuse at the apex, serrulate at the margins. Leaves on the primary branches are narrower than basal leaves and are dentate at the margins. Leaves on the ultimate branches are linear, mostly acute at the apex. This new species is related to *S. parvifolium* (Turner) C. Agardh. The main differences between the 2 species are the rhizoidal holdfast and much larger leaves of *S. rhizophorum*.

4. *Sargassum symphyorhizoideum* Tseng et Lu, sp. nov.
(Figs. 4 and 12)

Frons atrofuscus, ca 40 cm altus. Hapteron rhizoidea. Ramis primariis et secundariis cylindricis, laevibus; ramulis filiformis, elevatis glandibus. Foliis basalum latis lanceolatis, ad 6 cm longis, 8–12 mm latis, obtusis vel acutis ad extremum, obliquis basibus, costis conspicuus, vel infra apices evanida, undulatibus vel acuminatibus ad margines; foliis secundaris lanceolatis angustibus, 2.5–3.5 cm longis, 3–6 mm latis, acutis ad extremum, undulatibus vel acuminatibus ed supra margines; foliis ramulis linearibus, 2–2.5 cm longis, 2–2.5 mm latis, apicibus acutis, symmetricis ad basim, costis no percurrentibus vel infra 2/3 apices evanida, cryptostomatibus obscuris vel absenis, undulatibus vel acuminatibus ad margines. Vesiculis parvis, ovatis, 4–5 mm diametro, rotundatis vel acutis apicibus, interdum irregulatiler alatis, vulgo vel parvis foliis ad marginem, pedicellis compressis vel subcylindricis.

Planta dioica. Receptaculis feminibus compressis, interdum triquetris, spinis, furcatis, 4 mm longis, 2–3 mm latis; receptaculis maribus, cylindricis, furcatis, laevis, 5 mm longis, 2 mm diametro, racemosis.

Holotype: AST 60-8100, collected by Zheng Shudong and Zhou Xiantong, October 24, 1960, from Maling, Sanya City, Hainan Island.

Isotype: AST 60-8098, collected by Zheng Shudong and Zhou Xiantong, October 24, 1960, from Sanya City, Hainan Island.

Fronds dark brown, up to 40 cm tall. Holdfasts rhizoidal, up to 2 cm in diameter. Main axes cylindrical, smooth, up to 1 cm tall, 2 mm in diameter. Primary branches arising from the upper parts of the axis, cylindrical, smooth, up to 39 cm long, 2 mm in diameter; secondary branches arising from the foliar axils of the primary branches, at intervals of 2–2.5 cm, alternate, cylindrical, glabrous, about 10–15 cm long, 1.5 mm in diameter; ultimate branches filiform, about 2–3 cm long, 1 mm in diameter, with glandular dots on the surface. Leaves on primary branches broadly lanceolate, up to 6 cm long, about 8–12 mm wide, wavy or somewhat serrulate at the margins, obtuse or acute at the apex, oblique, cuneate at the base, with conspicuous midrib, often vanishing at the apex, with a few obscure cryptostomata, scattered on both sides of the midrib; leaves on secondary branches narrowly lanceolate, about 2.5–3.5 cm long, 3–6 mm wide, acute at the apex, symmetrical, cuneate at the bases, wavy or serrulate at the upper parts of the margins, with conspicuous midrib, usually vanishing at the apex, and with obscure cryptostomata, often scattered on both sides of the midrib; leaves on ultimate branches very narrow, narrow-lanceolate or linear, about 2–2.5 cm long, 2–2.5 mm wide, acute at the apex, cuneate at the base, wavy, smooth or slightly serrulate at the margins, with midrib usually vanishing in terminal third of the

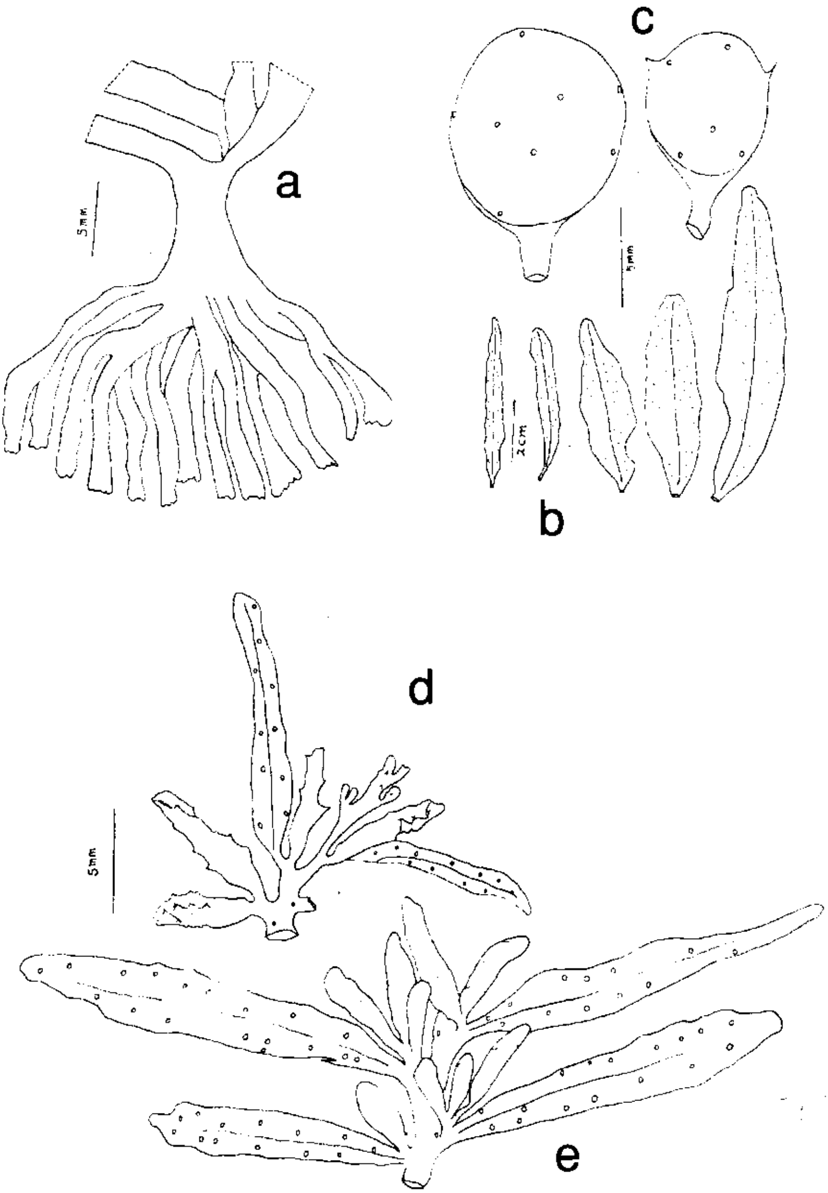


Fig. 12. *Sargassum symphyorhizoideum* Tseng et Lu, sp. nov. a, Rhizoidal holdfast. b, Leaves. c, Vesicles. d, Female receptacles. e, Male receptacles.

leaves, and obscure or no cryptostomata. Vesicles very small, ovate, rounded or sharply pointed at the apex, sometimes with earlike wings on both sides, sometimes with a narrow surrounding foliar structure, a few cryptostomata, about 4–5 mm in diameter, and compressed or subcylindrical pedicels, about 2–3 mm long.

Plants dioecious. Receptacles simple or furcate, several racemosely arranged in fertile branches. Female receptacles compressed, sometimes triquetrous, up to 4 mm long, 2–3 mm wide, spinous at upper parts. Male receptacles cylindrical, glabrous, wavy, up to 5 mm long, 2 mm in diameter.

Representative Material: AST 59-2863, 60-7225, 60-7287, 60-7693, 60-7695, 60-8019, 60-8093, 60-8153, and 81-0712.

Habitat: Growing on lower intertidal rocks.

Remarks: *Sargassum symphyorhizoideum* Tseng et Lu is principally characterized by its holdfast with fused rhizoids. The branches are cylindrical and glabrous, and ultimate branches have a few glandular dots on the surfaces. This species is related to *S. rhizophorum* Tseng et Lu. The main difference is the very large, lanceolate leaves of *S. symphyorhizoideum* Tseng et Lu, which are wavy or only slightly serrulate on the upper parts at the margins.

5. *Sargassum heterocystum* Montagne, Voy. Bonite, tab. 142, cent. III, p. 20, 1844.

Synonym: *Carpacanthus heterocystus* Kützing, Tabulae phycologicae, vol. XI, tab. 40, fig. 2, 1861.

Fronds dark brown, about 30 cm tall. Holdfast discoid. Main axes terete, verrucose, up to 1 cm long. Primary branches spirally arranged, on the upper part of the main axis, about 29 cm long; secondary and ultimate branches small, filiform, alternate. Leaves membranous, very small, ellipsoidal, coarsely dentate at the margins, usually 5–6 mm long, 3–4 mm wide, blunt at the apex, oblique, asymmetrical at the base, with inconspicuous midrib often vanishing at the middle part of the leaf, and a few, obscure cryptostomata on the surface. Vesicles ellipsoidal to fusiform, mucronate at the apex, with slightly winged, flattened pedicels, usually equal in length to the diameter of the vesicles.

Plants dioecious. Female receptacles flattened, verrucose, upper parts triquetrous, spinous on the surface. Male receptacles not certainly known according to Grunow (1915, p. 409); the male plant is perhaps the *Sargassum* known as *S. subspathulatum* Grunow, which has glabrous male receptacles (Grunow, 1916, p. 11).

Habitat: Growing on lower intertidal rocks.

Specimens Examined: Collected by K. C. Fan, August 20, 1949, from Tanshui, Taipei Hsien; Chiang 76108, collected by Y.M. Chiang, April 16, 1979, from Haikou, Taiwan. These specimens are deposited at the national herbarium of the National Taiwan University, Taipei, Taiwan.

Distribution: Vietnam, the Philippines, and Japan.

Remarks: The short description presented here is based entirely on the article by Chou and Chiang (1981). This species can be found in Vietnam on the west, the Philippines on the north, and Japan and Taiwan on the east of the mainland of China. Undoubtedly, it will eventually appear in China at the South China Sea coasts.

Sargassum heterocystum Montagne was studied previously by Grunow (1915, p. 409), Okamura (1936, p. 352), and Modelo and Umezaki (1995, p. 21, figs. 19–20).

6. *Sargassum parvifolioides* Tseng et Lu, sp. nov.
(Figs. 5 and 13)

Frons lutea brunnea, ad 1 m plus altus. Haptero disciformi, 1 cm diametro. Ramis primariis cylindricis, laevis, 1 m plus longis, 1.5 mm latis; ramis secundariis cylindricis, laevis, ad 10 cm longis, 1 mm diametro; ramulis parvis, 2 cm longis, 1 mm minus diametro. Foliis basalum oblongis, vel latis lanceolatis, 3 cm longis, 10 mm latis, obtusis vel acutis ad extremum costis conspicuus, non percurrentibus, vel 2/3 infra apicalis evanid, plerumque undulatibus ad margines, aliquot serrulatibus supra, foliis primariis lanceolatis, 3 cm longis, 6 mm latis, acutis ad extremum, leviter obliquiis ad basim, costis conspicuus, no percurrentibus, cryptostomatibus obscuris, bifariis, dentatibus ad margines; foliis secundariis et ramulis linearis, ad 3.5 cm longis, 2 mm latis, acutis ad extremum, irregularis acuminatis. Vesiculis sphaericis, 3–4 mm diametro.

Planta dioica. Receptaculis feminibus triquetriis supra, compressis infra, spinis, ad 6 mm longis, 1.5 mm diametro; receptaculis maribus cylindricis, laevis, 13 mm longis, 1 mm diametro, furcatis, racemosis.

Holotype: AST 87-1307a, collected by Lu Baoren and Dong Meiling, April 22, 1987, from Weizhou Island, Beihai City, Guangxi Province.

Isotype: AST 87-1307b, collected by Lu Baoren and Dong Meiling, April 22, 1987, from Weizhou Island, Beihai City, Guangxi Province.

Fronds yellowish brown, up to 1 m or more tall. Holdfast discoid, 1 cm in diameter. Main axis cylindrical, smooth, up to 1 m long, 1.5 mm in diameter. Several primary branches arising from the upper parts of the main axis, cylindrical, glabrous, up to 1 m or more long, 1.5 mm in diameter; secondary branches arising from the axils of the primary branches at intervals of 3 cm, short, alternate, cylindrical, smooth, up to 10 cm long, 1 mm in diameter; branchlets very short and slender, cylindrical, glabrous, up to 2 cm long, 1 mm or less in diameter, beset with leaves, vesicles, and receptacles. Basal leaves oblong or broadly lanceolate, up to 3 cm long, 10 mm wide, obtuse or acute at the apex, most of them wavy at the margins, only a few serrulate at the upper parts of the leaves, with conspicuous midrib, usually vanishing at 2/3 of the length of the leaves, and very few, obscure cryptostomata; leaves on primary branches narrow, lanceolate, up to 3 cm long, 6 mm wide, acute at the apex, slightly oblique, cuneate at the base,

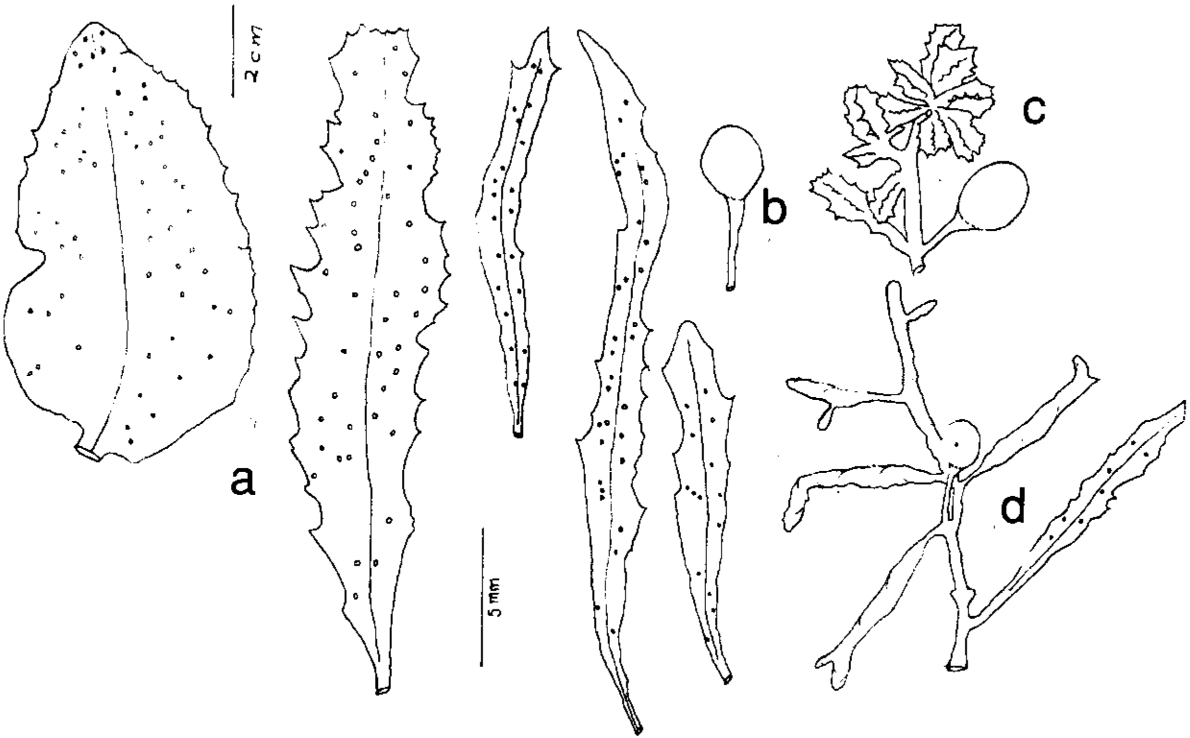


Fig. 13. *Sargassum parvifolioides* Tseng et Lu, sp. nov. a, Leaves. b, Vesicle. c, Female receptacles and vesicle. d, Male receptacles.

coarsely dentate at the margins, with conspicuous midribs, usually vanishing below the apex, with cryptostomata usually in 2 series on each side of the midrib; leaves on secondary and ultimate branches very narrow, linear, up to 3.5 cm long, 2 mm wide, acute at the apex, serrulate at the margins, with obscure midribs. Vesicles spherical, rounded at the apex, about 3–4 mm in diameter, with a few cryptostomata and cylindrical slender pedicels, various in size, often 2–3 mm long, 0.5 mm in diameter, sometimes up to 5 mm long, less than 0.5 mm in diameter.

Plants dioecious. Female receptacles compressed on lower parts, triquetrous on upper parts, spinous, up to 6 mm long, 1.5 mm in diameter. Male receptacles cylindrical, glabrous, up to 13 mm long, 1 mm in diameter. Both female and male receptacles often furcate, racemosely arranged on the fertile branches.

Representative Material: AST 87-1309, collected April 22, 1987, from Weizhou Island, Beihai City, Guangxi Province.

Habitat: Growing on the subtidal rocks.

Remarks: *Sargassum parvifolioides* Tseng et Lu is characterized by a discoid holdfast; large, oblong or broadly lanceolate basal leaves that are mostly wavy at the margins; lanceolate leaves on the primary branches that are coarsely dentate at the margins; and linear leaves on secondary and ultimate branches that are serrulate at the margins. The vesicles are spherical and rounded at the apex. The female receptacles are acanthocarpic, triquetrous on the upper parts, and compressed on the lower parts. Male receptacles are cylindrical and glabrous. Both female and male receptacles are usually furcate and racemosely arranged on the fertile branches. *Sargassum parvifolioides* is related to *S. parvifolium* (Turner) C. Agardh. The main differences are the discoid holdfast, larger basal leaves, and glabrous males receptacles of *S. parvifolioides.*

7. *Sargassum plagiophyllum* C. Agardh, Syst. algarum, p. 309, 1824.

(Fig. 6)

Fronds cinereous brown, glabrous, up to 50 cm or more tall. Holdfasts discoid, up to 5 mm in diameter. Main axes cylindrical, up to 5 mm long, 2 mm in diameter. Primary branches up to 49.5 cm long, 2 mm in diameter; secondary branches arising from the axils of the primary branches, at intervals of 1.5–2 cm, cylindrical, up to 11 cm long, 1–1.5 mm in diameter; ultimate branches small and short, cylindrical, 2 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves lanceolate, oblanceolate, or ellipsoidal, up to 3 cm long, 6 mm wide, mostly obtuse, occasionally acute at the apex, asymmetrical, oblique, cuneate at the base, usually outside leaves on older (outside) fronds larger than iinner leaves, entire at the margins, with obscure cryptostomata in 2 series arranged on both sides of the midrib. Vesicles ellipsoidal, ovate or obovate, up to 6 mm long, 5 mm in diameter, rounded or acute at the apex, fusiform when young, with a few cryptostomata and cylindrical or compressed pedicels, up to 2 mm long, less than 1 mm in diameter.

Habitat: Growing on lower intertidal and subtidal rocks.

Specimens Examined: AST 55-1161 and 55-1204, collected March 7, 1955, from Hailing Island, Guangdong Province.

Distribution: Singapore, Sri Lanka, India, Indonesia, Australia, and China (Taiwan; Hailing Island, Guangdong Province).

Remarks: We have 2 numbers of specimens credited to this species, but the specimens are too young and lack receptacles. Our specimens agree well with descriptions of various authors. According to Modelo and Umezaki (1995), *S. plagiophyllum* C. Agardh has "male and female receptacles almost similar in external morphology"; the receptacles are "2.6 mm long, 0.2–0.4 mm wide, terete, cylindrical, filiform, smooth, shortly stipitate, arranged in racemose cymose manner." However, Grunow (1916) described this species as having receptacles "feminea juvenile subspinuosa, mascula inermia, 5 mm longa." Our specimens are too young for us to comment.

Sargassum plagiophyllum was studied previously by J. Agardh (1848, p. 309; 1889, p. 120, pl. 12, figs. 4–5), Reinbold (1913, p. 166), Grunow (1916, p. 9), Yamada (1942, p. 516, figs. 20–21),Yoshida (1988, p. 15, fig. 13), and Modelo and Umezaki (1995, p. 33, fig. 26a–26c).

8. *Sargassum kasyotense* Yamada, Sci. Jpn. Inst. Algol. Res. Fac. Sci. Hokkaido Imp. Univ. 3(1):6, 1944.

Fronds yellowish brown, slender, up to 40 cm tall. Holdfasts conical, 1 cm in diameter. Main axes cylindrical, verrucose, about 2 cm long, 3 mm in diameter. Primary branches arising from the upper parts of the main axis in all directions, cylindrical, angulate, muricate; secondary branches arising at the axils of the primary branches, up to 10 cm long, very similar to the primary branches, only narrower and more slender. Small leaves linear or linear-lanceolate, 4 cm long, 6 mm wide, nearly sessile, obtuse at the apex, finely serrate at the margins, with percurrent midrib, with conspicuous cryptostomata irregularly arranged on both sides of the midrib. Vesicles ovate or pyriform, muticus or tipped with small points at the apex, with short and flattened pedicels and marginal wings, often dentate.

Plants dioecious. Female receptacles very thin, linear, slightly compressed, repeatedly furcate, blunt and distantly spinous in the upper parts of the receptacles, warty on the surface because of the verrucosely or hemispherically elevated female conceptacles. Several receptacles racemosely arranged in fertile branches.

Habitat: Growing on subtidal rocks.

Remarks: The species *S. kasyotense* Yamada is defined on the basis of specimens collected by T. Tanaka from Kasyoto, Taiwan, August 1939. The original description was published by Yamada, first in Japanese (1942) and 2 years later in Latin and English (1944). This species is characterized by a conical holdfast, verrucose main axis, muricate primary branches, and slender and short secondary branches. Male receptacles are as yet unknown, and the placement of the species in the *Plagiophyllae* series is therefore provisional.

Sargassum kasyotense is known only from the type collection, and the short description given here is based entirely on the work of Yoshida (1988, p. 15).

9. *Sargassum fuscifolium* Tseng et Lu, sp. nov.

(Figs. 7 and 14)

Frons lutea brunnea. Ramis primariis cylindricis, laevibus, ad 36 cm longis, 1.5 mm diametro; ramis secundariis ad 18 cm longis, 1 mm diametro; ramulis brevibus, ad 5 cm longis, 1 mm diametro, elevatis glandibus. Foliis primariis ramis parvis et angustis, 1.5–2 cm longis, 2.5 mm latis, obovatis vel oblanceolatis, obtusis ad extremum, serrulatibus supra, undulatibus infra ad margines, costis conspicuus, percurrentibus vel infra apices evanida, cryptostomatibus irregularis, dispersis ad utroque costalis; foliis supra 1.5 longis, 2.5 mm latis, costis obscuris vel absenis, undulatibus ad margines. Vesiculis ovatis, rotundatis vel acutis apicibus, 2 mm longis, 1.5 mm diametro.

Planta dioica. Receptaculis feminibus, dilatis supra, compressis infra, spinis, 2.5 mm longis, 1.5 mm diametro, receptaculis maribus, cylindricis, laevis, 8 mm longis, 0.5 mm diametro, racemosis.

Holotype: AST 55-2297, collected by Zheng Shudong, June 6, 1955, from Naozhou Island, Guangdong Province.

Isotype: AST 55-2296, collected by Zheng Shudong, June 6, 1955, from Naozhou Island, Guangdong Province.

Fronds yellowish brown. Primary branches cylindrical, glabrous, up to 36 cm long, 1.5 mm in diameter; secondary branches arising from the foliar axils of the primary branches, at intervals of 2–5 cm, cylindrical, glabrous, up to 18 cm long, 1 mm in diameter, alternate; ultimate branches short, up to 5 cm long, less than 1 mm in diameter, with a few glandular dots, beset with leaves, vesicles, and receptacles. Leaves on primary branches small, narrow, about 1.5–2 cm long, 2.5 mm wide, obovate or oblanceolate, obtuse at the apex, usually the upper parts of the leaves larger than the lower parts, more or less oblique, cuneate at the base, margins dentate at the upper part of the leaves, wavy or entire at the base, with conspicuous midrib, percurrent or vanishing at the apex, and irregularly scattered cryptostomata on both sides of the midrib; leaves on the secondary and ultimate branches very similar to the primary leaves in shape, but smaller, up to 1.5 cm long, 2.5 mm wide, rounded at the apex, cuneate at the base, entire or wavy at the margins, with obscure or no midrib, and irregularly scattered cryptostomata. Vesicles ovate, often rounded or sharp at the apex, up to 2 mm long, 1.5 mm in diameter, with a few cryptostomata and cylindrical, smooth pedicels, up to 1.5 mm long, 0.5 mm in diameter.

Plants dioecious. Female receptacles dilated and spinous in the upper parts of the receptacles, compressed in the lower parts, up to 2.5 mm long, 1.5 mm in

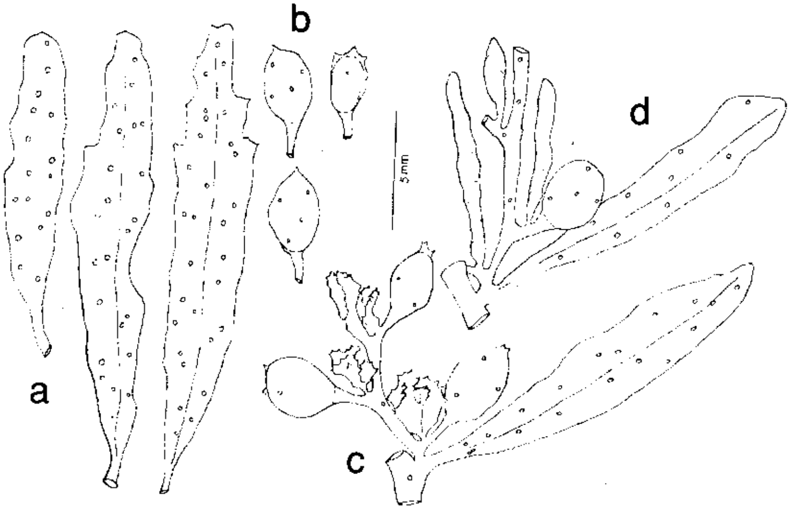


Fig. 14. ***Sargassum fuscifolium*** **Tseng et Lu, sp. nov. a, Leaves. b, Vesicles. c, Female receptacles. d, Male receptacles.**

diameter. Male receptacles cylindrical, glabrous, obtuse or acute at the apex, up to 8 mm long, 0.5 mm in diameter. Both male and female receptacles racemosely arranged in fertile branches.

Representative Material: AST 55-2301, collected June 6, 1955, from Naozhou Island.

Habitat: Growing on lower intertidal and subtidal rocks.

Remarks: S*argassum fuscifolium* Tseng et Lu is somewhat serrulate above and is characterized by very narrow and small, obovate or oblanceolate leaves that are wavy in the lower parts of the margins. This species has spinous female receptacles that are dilated in the upper parts of the receptacles and compressed in the lower parts. and male receptacles that are cylindrical and glabrous. Both male and female receptacles are racemosely arranged.

Sargassum fuscifolium is related to *S. dotyi* Trono. The main differences are the very narrow and small leaves, ovate vesicles, and dilated female receptacles of *S. fuscifolium.*

10. *Sargassum longivesiculosum* Tseng et Lu, Stud. Mar. Fauna Flora Biogeogr. Nansha Islands, Neighb. Waters III, p. 8, fig. 5, pl. 2:3, 1998.

(Figs. 8 and 15)

Fronds dark brown, very large. Primary branches subcylindrical, glabrous, up to 105 cm long, 2.5 mm in diameter, secondary branches arising from foliar axils of the primary branches at intervals of 4–5 cm, alternate, subcylindrical, glabrous, about 23–45 cm long, 1.5–2 mm in diameter; ultimate branches short and slender, cylindrical, glabrous, about 4–5 cm long, 1.5 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on the primary branches very thick, large, coriaceous, elongatedly lanceolate, about 6–7 cm long, 10–12 mm wide, obtuse at the apex, obliquely cuneate at the base, with conspicuous, raised midrib vanishing toward the leaf base; leaves on the secondary branches narrowly lanceolate, about 4–5 cm long, 4–5 mm wide, acute at the apex, obliquely cuneate at the base, with conspicuous, slightly raised midrib, usually vanishing below the apex, and a few obscure cryptostomata scattered on both sides of the midribs; leaves on the ultimate branches small, linear, about 1–2 cm long, 1–2 mm wide, acute at the apex, cuneate at the base, midrib obscure or absent. Vesicles very large, ellipsoidal, 12–13 mm long, 7–9 mm in diameter, usually with 2–3 cryptostomata on the surface, rounded at the apex, often with a sharp point when young, and cylindrical pedicels, sometimes flattened with midribs, 5–6 mm long, sometimes with elongated flattened pedicel, up to 21 mm long in young stage.

Plants dioecious. Female receptacles compressed, sometimes triquetrous, spinous on the upper parts, 2–3 mm long, 1.2–1.3 mm wide. Male receptacles subcylindrical, compressed at the upper parts, glabrous, 2–3 mm long, 1 mm in diameter, simple or furcate, a few receptacles racemosely arranged on the fertile branches.

Habitat: Drifted ashore.

Specimens Examined: AST 94-0059 and 94-0060, collected by Yingqiang Wang, March 30, 1994, at Banyuejiao, Nansha Islands, Hainan Province.

Distribution: So far, endemic in China.

Remarks: Two specimens, both without a holdfast and main axis, were collected from Banyuejiao, Nansha Islands, Hainan Province. The receptacles are small and young. The female receptacles are compressed, sometimes triquetrous, with a few spines, and the male receptacles are subcylindrical, smooth, and racemose. The leaves are very large and thick, coriaceous, rounded or obtuse at the apex, and wavy at the margins. The vesicles are very large and ellipsoidal.

Acknowledgments

This chapter is contribution No. 3862 from the Institute of Oceanology, Chinese Academy of Sciences, Qingdao. We thank Drs. James Sullivan and Isabella Abbott for inviting us to the splendid workshop in Vietnam and Dr. Abbott for reading and editing our manuscript. Thanks also to Ms. Li Shiling for her help in our drawings and Mr. Zhou Xiantong for his help in preparing the manuscript.

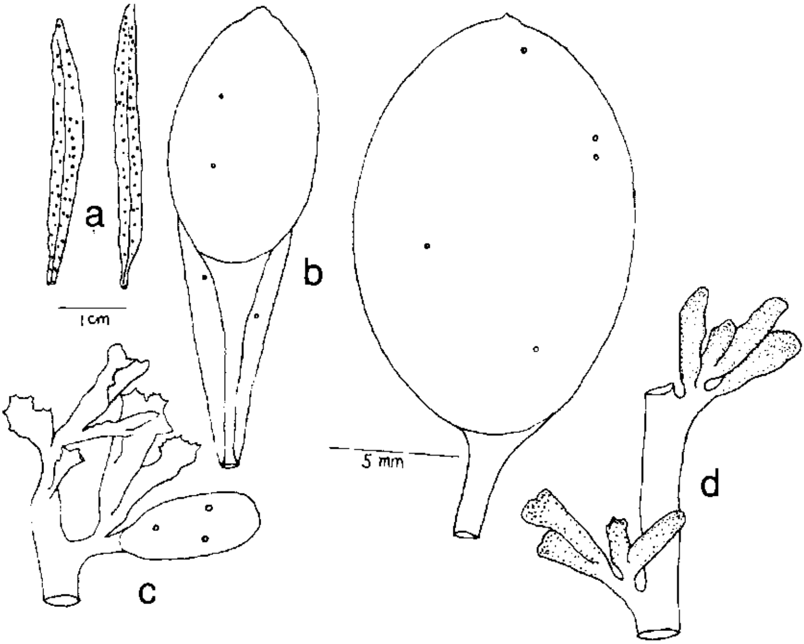


Fig. 15. ***Sargassum longivesiculosum*** **Tseng et Lu, sp. nov. a, Leaves. b, Vesicles. c, Female receptacles. d, Male receptacles.**

Literature Cited

Agardh, C. A. 1820. Species algarum, vol. 1. iv + 168 pp. Berling, Lund.

Agardh, C. A. 1824. Systema algarum, xxxviii + 312 pp. Berling, Lund.

Agardh, J. G. 1848. Species, genera et ordines algarum I. Species genera et ordines fucoidearum. I. viii + 363 pp. Gleerup, Lund.

Agardh, J. G. 1889. Species Sargassorum Australiae descriptae et dispositae. Kgl. Svenska Vet.-Akad. Handl. 23:1–133, pls. 1–31.

Chou, H. N., and Chiang, Y. M. 1981. The *Sargassum* of Taiwan. Acta Oceanogr. Taiwanica 12:132–149, pl. I, figs. 1–9; pl. II, figs. 1–6; pl. III, figs. 1–6.

Grunow, A. 1915. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 65:329–448.

Grunow, A. 1916. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 66:1–48, 136–185.

Modelo, R. B., Jr., and Umezaki, I. 1995. Contribution to the study of the genus *Sargassum* (Fucales, Phaeophyceae) of the Philippines. Philipp. J. Sci. Special issue, pp. 1–50, pls. 1–37.

Okamura, K. 1936. Nippon Kaiso-shie (Manual of Japanese seaweeds). Uchida Aokakaho, Tokyo (in Japanese).

Reinbold, T. 1913. Sargassum. In: Weber-van Bosse, A. Myxophyceae, Chlorophyceae, Phaeophyceae. Siboga Exped. Monogr. 59a:150–174.

Tseng, C. K., and Lu Baoren. 1992. Studies on the malacocarpic *Sargassum* of China: II. Racemosae J. Agardh. Tax. Econ. Seaweeds 3, pp. 11–34, figs. 1–28.

Tseng, C. K., and Lu Baoren. 1997. Studies on the biserrulic *Sargassum* of China: I. Taxonomy of the subsection *Biserrulae.* Tax. Econ. Seaweeds 6, pp. 3–7.

Yamada, Y. 1942. Notes on *Sargassum* from the southern parts of Japan: I. J. Jpn. Bot. 18:503–519, figs. 13–21.

Yamada, Y. 1944. Diagnoses of new *Sargassums* from Japan. Sci. Pap. Inst. Algol. Res. Fac. Sci., Hokkaido Univ. 3:1–10.

Yoshida, T. 1988. Japanese and Taiwanese species of *Sargassum* subgenus *Sargassum.* Tax. Econ. Seaweeds 2, pp. 5–21.

STUDIES ON THE BISERRULIC *SARGASSUM* OF CHINA: V. THE SERIES *ILICIFOLIAE* (J. AGARDH) TSENG ET LU

C.K. Tseng and Lu Baoren

Abstract

The series *Ilicifoliae* (J. Agardh) Tseng et Lu is differentiated from the series *Plagiophyllae* by the former's dioecious receptacles with acanthocarpic female and male receptacles. Fifteen species in the series *Ilicifoliae* are present in China; of these, 6 are new to science and are described: *Sargassum tenuifolioides, S. biserrulioides, S. pseudolanceolatum, S. siliculosoides, S. fujianense,* and *S. subdroserifolium*. Four species, *S. biserrula* J. Agardh, *S. dotyi* Trono, *S. squarrosum* Greville, and *S. subspathulatum* (Grunow) Grunow, are recorded here for the first time in China. Five other species and 2 varieties have previously been reported for China, namely, *S. cinctum* J. G. Agardh, *S. cystophyllum* Montagne var. *parcespinosa* Grunow, *S. ilicifolium* (Turner) C. Agardh, *S. ilicifolium* var. *conduplicatum* Grunow, *S. parvifolium* (Turner) C. Agardh, and *S. sandei* Reinbold.

Introduction

In his classification of *Sargassum*, J. Agardh (1889) proposed *Ilicifolia* as the first group under the tribe (now section) *Biserrulae*; the group consisted of 9 species. Grunow in his posthumous work on *Sargassum* (1915) accepted J. Agardh's *Ilicifolia* as a group consisting of 29 species. *Ilicifolia* is characterized by leaves with a conspicuously oblique basal part, an inner leaf margin that is entire or slightly excised, and an outer leaf margin that is distinctly dentate. Recently, we (Tseng and Lu 1997a) used the names suggested by J. Agardh and supported by Grunow but changed the basis for the classification, from depending almost entirely on the leaf characteristics to including sexual differences. We put the *Parvifoliae* as the lowest series and the *Coriifoliae* as the highest. More recently, after serious consideration, we decided that androgyny is more primitive than is dioecism, and we placed the *Coriifoliae* as the most primitive series.

The discovery of 1 or 2 spines on some of the male receptacles in *S. parvifolium* forced us to move the species to *Ilicifoliae* and to use a new name, *Plagiophyllae*, to replace *Parvifoliae* as originally proposed. At the same time, we found that *S. coriifolium* J. Agardh is an illegal name. The plant should be called *S. odontocarpum* Sonder, and the original series name should be changed to *Odontocarpae* (Tseng and Lu 1999).

Series *Ilicifoliae* (J. Agardh) Tseng et Lu

Ilicifoliae, as we interpret it now, is a series with acanthocarpic male and female receptacles. The species in this series have leaves with unequal basal parts, but the parts are not so unequal that the basal parts of the leaves always have inner margins that are entire and outer margins that are strongly dentate, as emphasized by J. Agardh and Grunow. The male receptacles have spines, but in some instances, most of the receptacles are glabrous and only a few have 1 or 2 spines.

This presence or absence of spines was neglected by previous investigators, including J. Agardh and Grunow. For instance, in *S. subspathulatum* Grunow, they took it for granted that the male receptacles were lacking spines. In our study of the plant we call *S. subspathulatum*, we found that a few receptacles had 1 or 2 spines. We think the presence of spines on some receptacles represents the earlier indication of evolution of spinous receptacles. We thus must put this species, as well as other similar species, in the series *Ilicifoliae*.

In the first installment of chapters on the biserrulic *Sargassum* (Tseng et Lu 1997a), 16 species were reported from China, including the following 3 species from the *Ilicifoliae* as elucidated by J. Agardh and interpreted by Grunow: *S. ilicifolium* Grunow; *S. parvifolium* (Turner) C. Agardh; and *S. sandei* Reinbold. In this chapter, we (Zeng, Lu, and Ding 1998) have already reported from Nansha Islands *S. squarrosum* Greville, and add 6 new species in this paper: *S. biserrulioides*, *S. fujianense*, *S. pseudolanceolatum*, *S. siliculosoides*, *S. subdroserifolium*, and *S. tenuifolioides*. Included are 4 new records for China, namely, *S. biserrula* J. Agardh, *S. cinctum* J. Agardh, *S. dotyi* Trono, and *S. subspathulatum* Grunow, making a total of 15 species and 1 variety. Another species, *S. granuliferum* C. Agardh, in the list of 16 species, has been moved from *Biserrulae* to *Holozygocarpicae*. *Sargassum cinctum* J. Agardh was listed with a question mark by Setchell (1931) in his preliminary study of Hong Kong *Sargassum*, and in his final study in 1936, he removed the species from the list of *Sargassum* species from Hong Kong.

All the specimens examined, including type specimens, are deposited at the herbarium of the Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China (AST).

Key to the Chinese Species of the Series *Ilicifoliae*

1. Leaves of the secondary branches lanceolate or linear, acute at the apex 2
1. Leaves of the secondary branches ovate, obovate, elongated obovate, or ellipsoidal, obtuse at the apex 10
    2. Leaves on the secondary branches linear, upper parts of most leaves and whole terminal leaves mostly flexuous .... 2. *S. tenuifolioides*
    2. Leaves on the secondary branches and upper leaves not flexuous 3
3. Leaves of the secondary branches smaller, narrow, less than 3 mm wide 4
3. Leaves larger, broad, more than 4 mm wide 5
    4. Leaves long and narrow, 2 cm long, 2 mm wide, female receptacles triquetrous .... 3. *S. parvifolium*

4. Leaves short and broad, 1.2 cm long, 3 mm wide, female receptacles compressed .... 1. *S. subspathulatum*
5. Leaves thin and membranous 6
5. Leaves very thick and coriaceous 9
6. Female receptacles compressed to flattened 7
6. Female receptacles triquetrous 8
7. Bulbs at the basal parts, vesicles spherical .... 5. *S. siliculosoides*
7. Without bulbs at the basal parts, vesicles ovate or obovate .... 6. *S. pseudolanceolatum*
8. Leaves on primary branches 4 cm long, 7 mm wide, vesicles ovate or obovate .... 7. *S. cinctum*
8. Leaves on primary branches 2.5 cm long, 4 mm wide, vesicles spherical .... 4. *S. biserrulioides*
9. Basal leaves very large, up to 9 cm long, 27 mm wide, wavy at the margins .... 9. *S. subdroserifolium*
9. Basal leaves smaller, up to 6 cm long, 8 mm wide, irregularly dentate at the margins .... 8. *S. fujianense*
10. Leaves elongated ellipsoidal, dentate at the margins 11
10. Leaves obovate, ovate, elongated obovate, or spatulate 13
11. Vesicles spherical, usually with earlike structure on both sides, female receptacles compressed 12
11. Vesicles obovate or fusiform, mucronate at the apex, without earlike structure on both sides, female receptacles triquetrous .... 11. *S. dotyi*
12. Apex of the leaves not duplicate .... 15. *S. ilicifolium*
12. Apex of the leaves usually duplicate .. 15a. *S. ilicifolium* var. *conduplicatum*
13. Leaves very small, usually spatulate, often duplicate at the apex 12. *S. sandei*
13. Leaves not spatulate, not duplicate at the apex 14
14. Vesicles usually with earlike structure on both sides .... 10. *S. cystophyllum* var. *parcespinosa*
14. Vesicles without earlike structure on both sides 15
15. Female receptacles compressed .... 13. *S. squarrosum*
15. Female receptacles triquetrous .... 14. *S. biserrula*

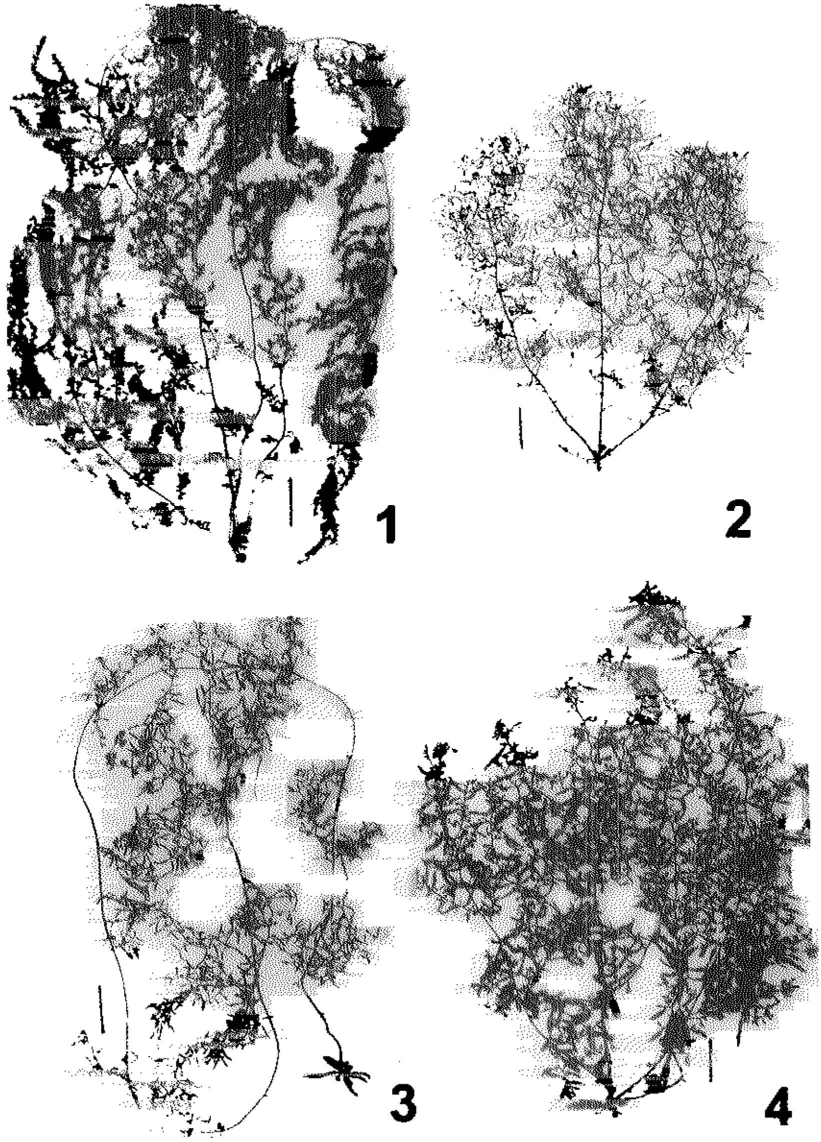
Description of the Species

1. *Sargassum subspathulatum* (Grunow) Grunow, Verh. K.-K. Zool.-Bot. Gesell. Wien 66:10, 1916.

(Figs. 1 and 17)

Basionym: *Sargassum pulchellum* var. *subspathulata* Grunow, in E. Askenasy, Forschungsreise. S.H.S "Gazelle". IV. Botanik. p. 25, tab. 6, figs. 5 and 6, 1888.

Fronds yellow-brown, slender, up to 90 cm tall. Holdfast rizhoidal forming



Figs. 1–4. Fig. 1, *Sargassum subspathulatum* (Grunow) Grunow. Fig. 2, *Sargassum tenuifolioides* Tseng et Lu. Fig. 3, *Sargassum parvifolium* (Turner) C. Agardh. Fig. 4, *Sargassum biserrulioides* Tseng et Lu.

scutellate plate, 8 mm in diameter. Main axes cylindrical, glabrous, up to 6 mm long, 2 mm in diameter. Primary branches subcylindrical, glabrous, arising from upper parts of the main axis, up to 89 cm long, 1.5 mm in diameter; secondary branches shorter and denser, arising from the foliar axil of the primary branches, alternate, glabrous, up to 18 cm long, 1.2 mm in diameter, at intervals of 1–2.5 cm; ultimate branchlets slender and short, with glandular dots on the surface, up to 2 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles. Basal leaves lanceolate, 2.3 cm long, 6 mm wide, acute at the apex, slightly obliquely cuneate at the base, with conspicuous, elevated midrib percurrent and vanishing below the apex, conspicuous cryptostomata, irregularly scattered on both sides of the midrib, wavy or irregularly dentate; leaves on the primary branches mostly deciduous; leaves on the secondary and ultimate branches very small and narrow, varied in shape and irregular, subspathulate or lanceolate, about 4–12 mm long, 1–3 mm wide, acute at the apex, asymmetrically obliquely cuneate at the base, with conspicuous midrib mostly percurrent or vanishing below the apex, and conspicuous cryptostomata scattered on both sides of the midrib. Vesicles spherical, very small, about 1.5–2 mm in diameter, rounded at the apex, with a few cryptostomata and cylindrical slender pedicels up to 1.5 mm long, 0.5 mm in diameter.

Plants dioecious. Female receptacles mostly compressed, 1–2 times furcate, spinulose, up to 2.5 mm long, 1 mm wide; male receptacles conical to cylindrical, mostly verrucose, sometimes with 1 or 2 spinules on the surface, 3 mm long, 0.5–0.7 mm in diameter; receptacles with short pedicels, racemosely arranged on fertile branches.

Specimen Examined: AST 70-0028. Collected April 18, 1970, from beach of Haikang County, Guangdong Province.

Habitat: Growing on the lower intertidal rocks.

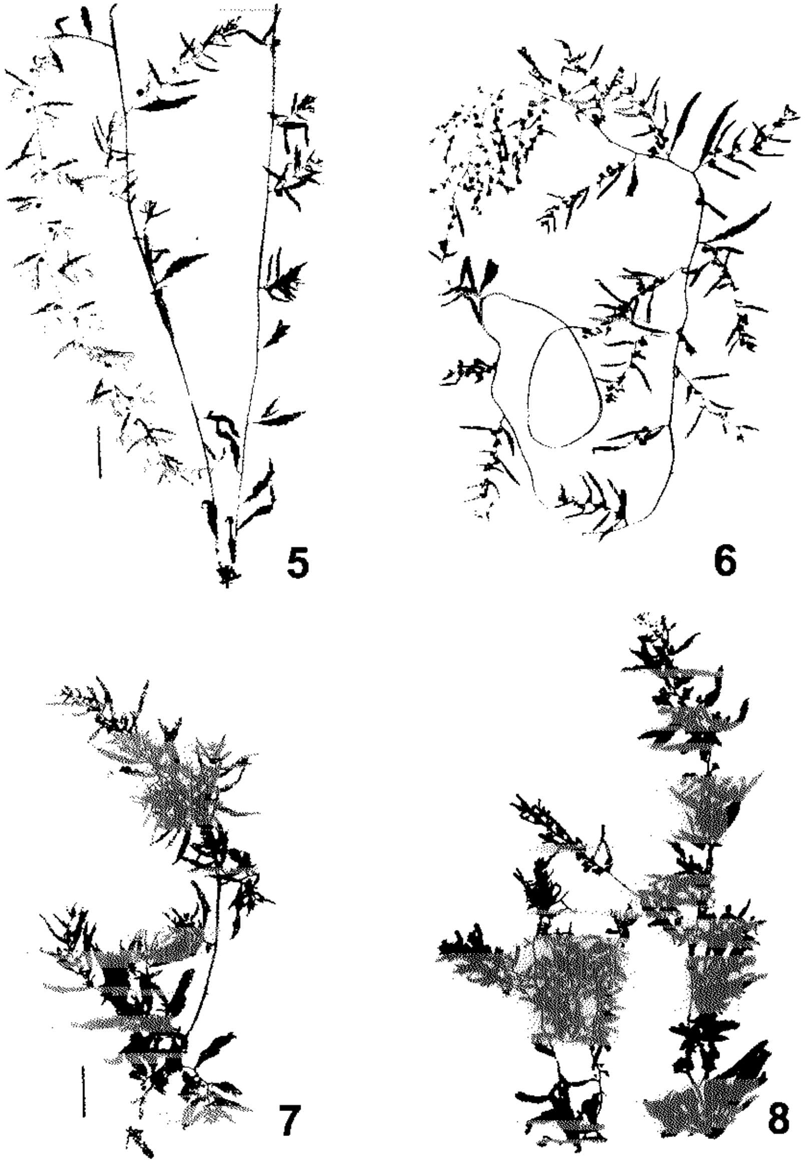
Distribution: Papua New Guinea.

Remarks: Our specimen agreed with the description of Grunow (1916, p. 10), but Grunow described only a male frond. We collected a female plant of this species for the first time.

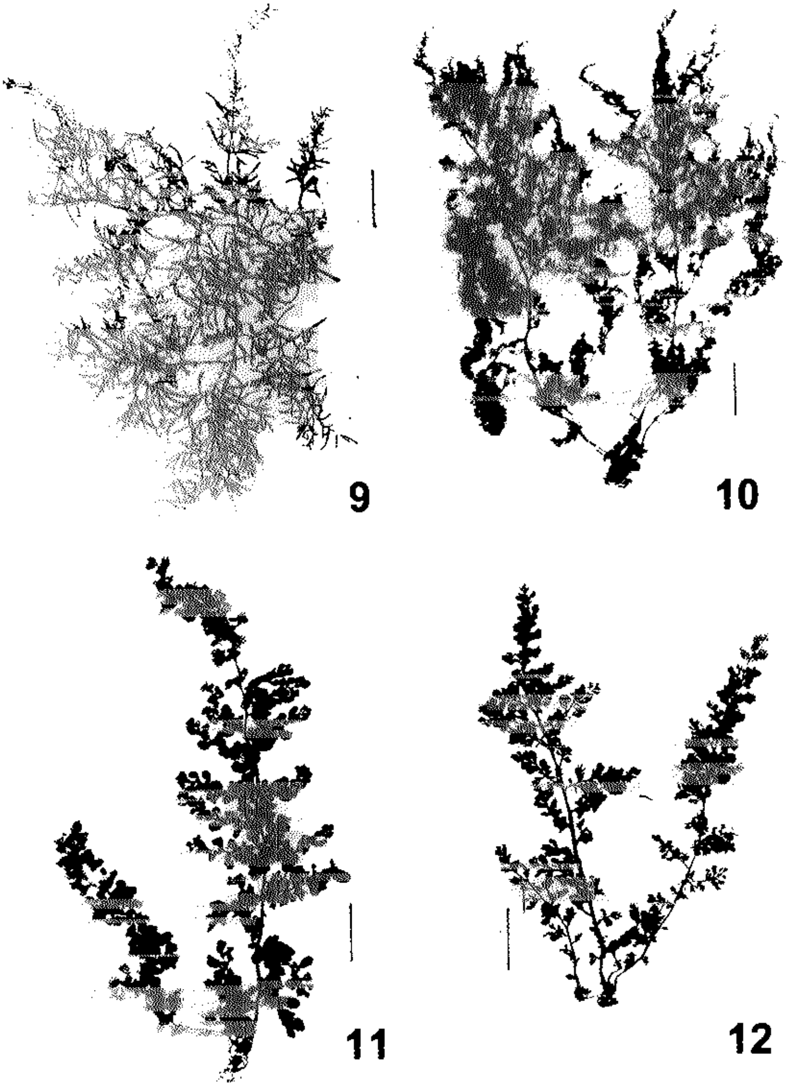
2. *Sargassum tenuifolioides* Tseng et Lu, sp. nov.

(Figs. 2 and 18)

Frons lutea brunnea, 46 cm alta. Haptero disciformi, 8 mm diametro. Ramis primariis cylindricis, laevibus, ad 45 cm longis, 1 mm diametro; ramis secundariis brevibus, quasi 6–8 cm longis, minis quam 1 mm diametro; ramulis parvis, conspicuus elevatis glandibus. Foliis basalum lanceolatis, quasi 2.5 cm longis, 10 mm latis, acutis ad extemum cuneatis ad basim, costis percurrentibus, undulatibus ad margines; foliis secundariis angustibus, linearis, interdum flexilis, 2 cm longis, 0.8–1 mm latis, acutis ad extremum, cuneatis ad basim, costis obscuribus vel 2/3 infra apicalis evanida, dentatibus supra, undulatibus infra ad margines; foliis



Figs. 5–8. Fig. 5, *Sargassum siliculosoides* Tseng et Lu. Fig. 6, *Sargassum pseudolanceolatum* Tseng et Lu. Fig. 7, *Sargassum cinctum* J. G. Agardh. Fig. 8, *Sargassum fujianense* Tseng et Lu.



Figs. 9–12. Fig. 9, *Sargassum subdroserifolium* Tseng et Lu. Fig. 10, *Sargassum cystophyllum* Montagne var. *parcespinosa* Grunow. Fig. 11, *Sargassum dotyi* Trono. Fig. 12, *Sargassum sandei* Reinbold.

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Figs.13–16. Fig. 13, *Sargassum squarrosum* Greville. Fig. 14, *Sargassum biserrula* J. Agardh. Fig. 15, *Sargassum ilicifolium* (Turner) C. Agardh. Fig. 16, *Sargassum ilicifolium* (Turner) C. Agardh var. *conduplicatum* Grunow.

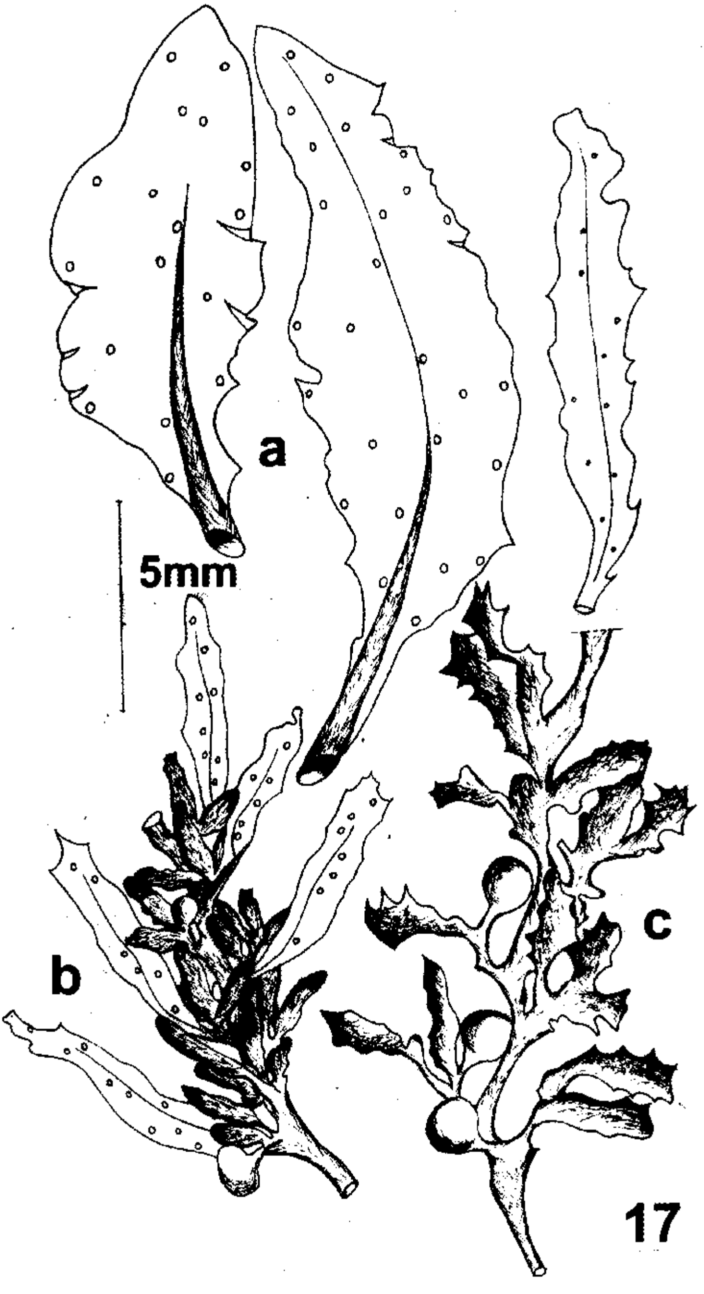

Fig. 17. *Sargassum subspathulatum* (Grunow) Grunow. a, Leaves. b, Male receptacles. c, Female receptacles and vesicles.

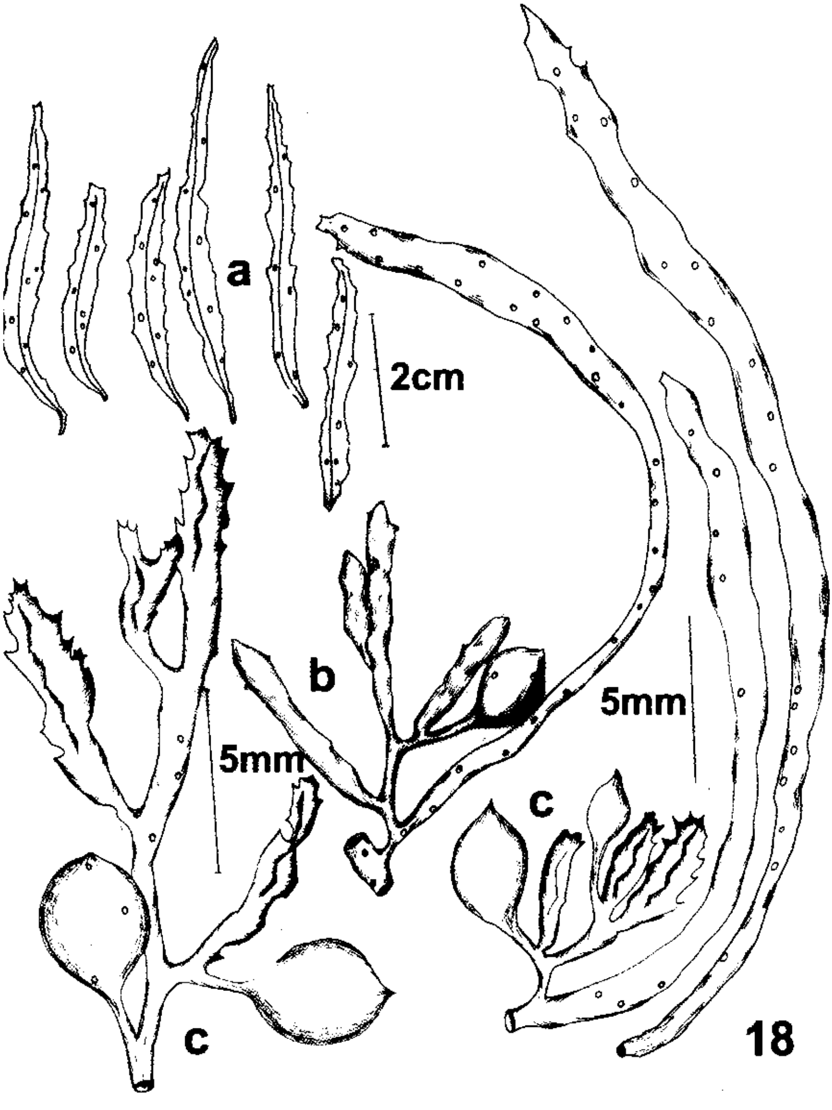

Fig. 18. *Sargassum tenuifolioides* Tseng et Lu. a, Leaves. b, Vesicles and male receptacles. c, Leaves, vesicles, and female receptacles.

ramulis filiformis, interdum flexilis, 1.5 cm longis, 0.5 mm latis, undulatibus ad margines, non costis, cryptostomatibus conspicuus, elevatis. Vesiculis parvis, sphaericis, ovatis, acutis vel rotundatis in apicibus, 2 mm diametro, pedicellis cylindricis, 3 mm longis.

Planta dioica. Receptaculis feminibus triquetris supra, cylindricis infra, spinis, quasi 5–8 mm longis, 1–1.2 mm diametro; receptaculis maribus cylindricis, vulgo laevis, interdum aliquot spinis quasi 10–13 mm longis, 0.5–0.6 mm diametro; racemosis.

Holotype: AST 55-1924a, collected by Zhang Junfu, April 28, 1955, at Weizhou Island, Beihai City, Guangxi Province.

Isotype: AST 55-1925. Collected by Zhang Junfu, April 28, 1955, at Weizhou Island, Beihai City, Guangxi Province.

Fronds yellow-brown, up to 46 cm tall. Holdfast small, discoid, 8 mm in diameter. Main axes cylindrical, glabrous, up to 5 mm long, 2 mm in diameter. Primary branches 45 cm long, 1 mm in diameter, cylindrical, glabrous; secondary branches short, arising from foliar axils of primary branches, cylindrical, about 6–8 cm long, less than 1 mm in diameter, with a few glandular dots, at intervals of 1.5–2 cm; ultimate branchlets shorter and more slender, with glandular dots, beset with leaves, vesicles, and receptacles. Basal leaves large, lanceolate, up to 2.5 cm long, 10 mm wide, undulate at the margins, acute at the apex, cuneate at the base, with percurrent midribs; leaves on the primary branches often deciduous; leaves on secondary branches very narrow, linear, usually flexuous, up to 2 cm long, 0.8–1 mm wide, acute at the apex, cuneate at the base, leaves on secondary branches irregularly serrate above and undulate below at the margins; with obscure midribs, often vanishing at 2/3 of the distance to top of the leaves, and conspicuous, elevated cryptostomata; leaves on the ultimate branchlets very narrow and short, filiform, flexuous, up to 1.5 cm long, 0.5 mm wide, acute at the apex, cuneate at the base, ecostate, with conspicuous, irregularly scattered, elevated cryptostomata. Vesicles very small, spherical or ovate, usually with a sharp point at the apex, sometimes rounded, 2 mm in diameter, with a few cryptostomata, and slender, cylindrical pedicels up to 3 mm long.

Plants dioecious. Receptacles racemosely arranged in fertile branches, simple or furcate. Female receptacles triquetrous above, cylindrical below, spinous, about 5–8 mm long, 1–1.2 mm in diameter. Male receptacles cylindrical, often wavy on the surface, occasionally slightly spinulose, about 10–13 mm long, 0.5–0.6 mm in diameter.

Other Material Examined: Qinzhou Bay: AST 55-1871, 55-2050, 55-2052, 55-2053, 55-2054, 55-2058, 55-2060, 55-2061, 55-2073, 55-2074, 55-2076, 55-2080, and 55-2151; Weizhou Island: 55-1871, 55-1879, 55-1925, 55-1927a, 55-1932, 55-1972, and 55-2049.

Etymology: Named for shape of the leaves on the upper part of the plant.

Habitat: Growing on lower intertidal and subtidal rocks.

Remarks: *Sargassum tenuifolioides* is characterized by the very narrow, slender, and usually flexuous leaves of the secondary and ultimate branches. The ultimate branches are slender, with a few glandular dots and very small spherical or ovate vesicles, usually with a sharp point at the apex. The male receptacles are mostly glabrous, sometimes with 1–2 spinules. This species is related to *S. parvifolium* (Turner) C. Agardh; the main difference is the filiform, usually flexuous leaves of *S. tenuifolioides.*

3. *Sargassum parvifolium* (Turner) C. Agardh, Species algarum, p. 30, 1820. (Figs. 3 and 19)

Basionyms: *Fucus parvifolius* Turner, Fuci, 4, p. 34, pl. 211, 1819;

Synonym: *Carpacanthus parvifolius* Kützing, Tabulae phycologicae, vol. XI, p. 12, tab. 38, fig. 1, 1861.

Fronds yellowish-brown, up to 65 cm tall. Holdfast scutellate, 5 mm tall, about 10 mm in diameter, with cylindrical, glabrous main axis, up to 6 mm long, 2 mm in diameter. Primary branches slender, cylindrical, glabrous, arising from upper parts of the main axis, about 29–60 cm long, 2 mm in diameter; secondary branches arising patently from the axils of the leaves, about 20–25 cm long, 0.66–1 mm in diameter, at intervals of 1.5–2 cm, alternate, terete, glabrous; ultimate branchlets short, about 2–4 cm long, less than 1 mm in diameter, with a few glandular dots, beset with leaves, vesicles, and receptacles. Basal leaves broadly lanceolate, about 2.5–4 cm long, 5–10 mm wide, obtuse at the apex, cuneate at the base, wavy or serrulate at the margins, with conspicuous, slightly raised, percurrent midribs and sparsely obscure cryptostomata; leaves on primary branches narrowly lanceolate, up to 6 cm long, 4 mm wide, acute at the apex, asymmetrically obliquely cuneate at the base, serrulate at the margins, with conspicuous midrib usually vanishing below the apex of the leaves, and conspicuous cryptostomata scattered on both sides of the midrib; leaves on secondary and ultimate branches narrowly lanceolate, about 1.5–2 cm long, 1.5–2 mm wide, acute at the apex, cuneate at the base, with midrib obscure or absent, cryptostomata in 2 series, scattered on both sides of the midrib, the leaves serrulate above and entire below. Vesicles small, spherical when mature, subspherical or ovate when young, rounded or mucronate at the apex, smooth or with a few cryptostomata on the surface, up to 2 mm in diameter, with cylindrical pedicels about 3–4 mm, sometimes up to 6 mm long.

Plant dioecious. Receptacles solitary or furcate, each with a cylindrical pedicel, racemosely arranged. Female receptacles triquetrous, about 3–5 mm long, 1.5 mm in diameter, spinous; male receptacles cylindrical, 10–20 mm long, 2–2.5 mm in diameter, with a few spinules.

Specimens Examined: Tseng 2776, collected May 12, 1940, from Hong Kong. AST 96-0011, 96-0013, 96-0023, 96-0041, 96-0042, and 96-0128, collected from Weizhou Island, Guangxi Province.

Habitat: Growing on lower intertidal to subtidal rocks.

Distribution: Vietnam, Singapore, and the Philippines.

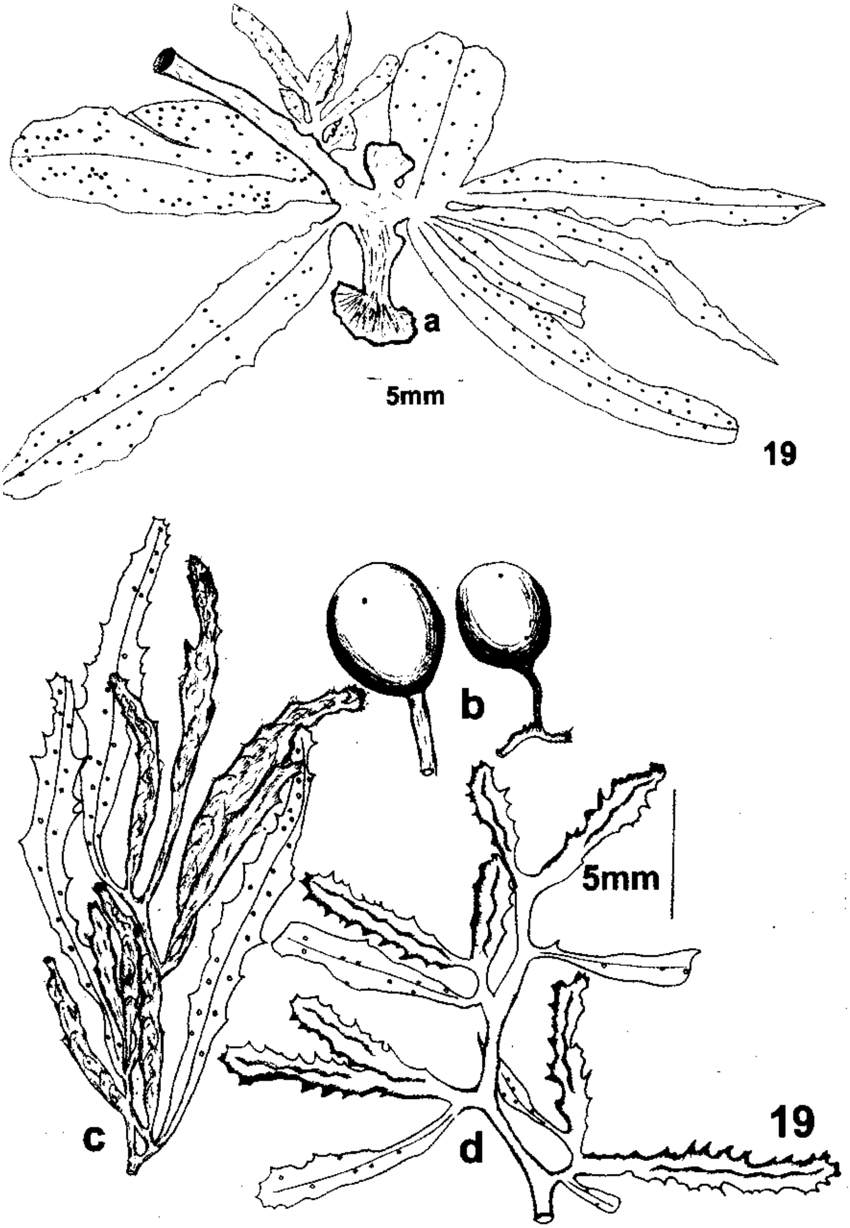

Fig. 19. *Sargassum parvifolium* (Turner) C. Agardh. a, Holdfast and basal leaves. b, Vesicles. c, Male receptacles and leaves. d, Female receptacles and vesicles.

Remarks: *Sargassum parvifolium* (Turner) C. Agardh is characterized by its scutellate holdfast; broad, lanceolate basal leaves; deeply serrulated leaves on the upper part of the plant; and very small, narrow, lanceolate, short, linear leaves on the upper part of the plant that are mostly entire, only occasionally serrulated at the margins. The vesicles are very small, spherical, usually mucronate at the apex, with cryptostomata. The female receptacles are triquetrous and spinous. The male receptacles are cylindrical, usually with 1–2 spinules.

This species was previously studied by C. Agardh (1824, p. 304), J. Agardh (1848, p. 313; 1889, p. 99, tab. 27, fig. 2), Grunow (1916, p. 13), Setchell (1936, p. 9, pl. 2, figs. 1–3), and Pham (1967, p. 313, fig. 26).

4. *Sargassum biserrulioides* Tseng et Lu, sp. nov.

(Figs. 4 and 20)

Frons lutea brunnea, 100 cm alta. Haptero disciformi, 1 cm diametro. Ramis primariis cylindricis, laevibus, ad 100 cm longis, 1.5 mm diametro; ramis secundariis cylindricis, ad 18 cm longis, 1.2 mm diametro; ramulis parvis, ad 4 cm longis, 1 mm diametro, conspicuus elevatis glandibus. Foliis basslum oblanceolatis, ad 2 cm longis, 8 mm latis, obtusis ad extremum, asymmetricis, obliquis cuneatis ad basim, costis conspicuus, percurrentibus, non elevatis, cryptostomatibus dispersis ad utroque costalis, undulatibus vel dentatibus ad margines; foliis primariis latis lanceolatis, ad 2.5 cm longis, 4 mm latis, acutis ad extremum, cuneatis ad basim, costis no percurrentibus conspicuus infra apices evanida, cryptostomatibus dispersis ad utroque costalis, acuminatibus ad margines; foliis secundariis maximon partem lanceolatis, acutis ad extremum aliquot obovatis, obtusis ad extremum, irregularis grosse dentatibus ad margines, 2.5 cm longis, 4 mm latis, foliis ramulis parvis, obovatis, 1.5 cm longis, 3 mm latis, ovulgo acutis ad extremum, asymmetricis, obliquis ad basim, costis obscuris, irregularis grosse dentatibus supra margines, undulatibus vel aliquot dentatibus infra margines. Vesiculis sphaericis vel ovatis, laevis vel acutis apicibus, 4 mm diametro.

Planta dioica. Receptaculis feminibus triquetris, spinis, furcatis, 7 mm longis, 1.5 mm in diametro; receptaculis maribus cylindricis, aliquot spinis, 10–14 mm longis, 1 mm diametro, racemosis.

Holotype: AST 96-0068, collected by Lu Baoren and Wang Yongqiang, May 23, 1996, at Weizhou Island, Beihai City, Guangxi Province.

Isotype: AST 96-0072, collected by Lu Baoren and Wang Yongqiang, May 23, 1996, at Weizhou Island, Beihai City, Guangxi Province.

Other Materials Examined: AST 87-1265, 96-0012, 96-0018, 96-0067, 96-0124, and 96-0131a.

Etymology: Named for the shape of the leaves, which are similar to those of *S. biserrula.*

Habitat: Growing on subtidal rocks.

Fronds yellow-brown, up to 100 cm or more tall. Holdfast discoid, 1 cm in

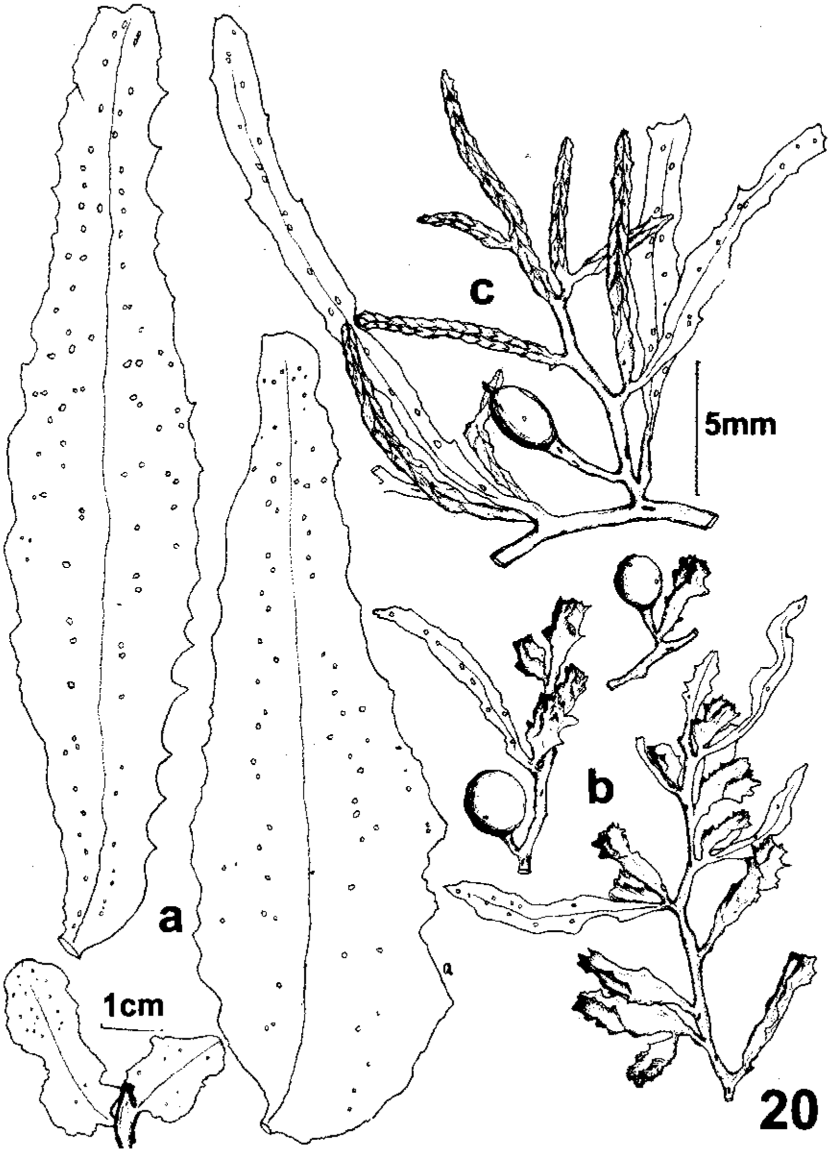

Fig. 20. *Sargassum biserrulioides* Tseng et Lu, sp. nov. a, Leaves. b, Vesicles and female receptacles. c, Male receptacles and leaves.

diameter. Main axis terete, smooth, 5 mm long, 3 mm in diameter. Primary branches arising from upper part of the main axis, cylindrical, glabrous, up to 100 cm or more long, 1.5 mm in diameter; secondary branches arising from the axils of the primary branches, up to 18 cm long, 1.2 mm in diameter, alternate, cylindrical, glabrous; ultimate branchlets small, slender, up to 4 cm long, less than 1 mm in diameter, with raised glandular dots, beset with leaves, vesicles, and receptacles. Basal leaves oblanceolate, up to 2 cm long, 8 mm wide, obtuse at the apex, slightly obliquely cuneate at the base, wavy or slightly dentate at the margins; midribs conspicuous, percurrent, with cryptostomata scattered on both sides of the midrib; leaves on primary branches broadly lanceolate, up to 2.5 cm long, 4 mm wide, slightly acute at the apex, cuneate at the base, shallowly serrulate at the margins; with conspicuous midribs, usually vanishing at the apex, and cryptostomata irregularly scattered on both sides of the midrib; leaves on secondary branches variable in shape, mostly lanceolate, acute at apex, some elongated obovate, rounded at the apex, coarsely dentate at middle and upper parts of the margins, up to 2.5 cm long, up to 4 mm wide; leaves on branchlets small, oblanceolate, upper and middle parts of leaves broader than lower parts, up to 1.5 cm long, 3 mm wide, acute at the apex, slightly oblique at the base, irregularly coarsely dentate at upper and middle parts of the leaves, with obscure midribs. Vesicles spherical, rounded or with sharp dots at the apex, up to 4 mm in diameter, with cryptostomata on the surface, and cylindrical or compressed pedicels, smooth, 3 mm long, 0.5 mm in diameter.

Plants dioecious. Female receptacles long, with spinules, up to 7 mm long, 1.5 mm in diameter, triquetrous. Male receptacles cylindrical, usually furcate, racemosely arranged on the fertile branches, with a few spinules, usually 10 mm, sometime 14 mm, long, 1 mm in diameter.

Remarks: *Sargassum biserrulioides* Tseng et Lu, sp. nov. is mainly characterized by its discoid holdfast, oblanceolate basal leaves, lanceolate leaves on the upper part of the plant, and small spherical or ovate vesicles. The species is dioecious, and the receptacles are long and spinulose. Female receptacles are triquetrous; male receptacles are cylindrical. *Sargassum biserrulioides* is clearly related to *S. biserrula* J. Agardh; the 2 species differ mainly in the characteristics of the leaves. Those of *S. biserrulioides* are mainly lanceolate and narrow, whereas those of *S. biserrula* are long and obovate.

5. *Sargassum siliculosoides* Tseng et Lu, sp. nov.

(Figs. 5 and 21)

Frons lutea cinereus, 80 cm alta. Haptero disciformi, 1 cm diametro. Axes cylindricis, multis verrucosis, 1 cm longis, 2.5 mm diametro. Bulbis 1 cm longis, 2 mm latis. Ramis cylindricis, laevis, 79 longis, 2 mm diametro; ramis secundariis parvibus, brevibus, cylindricis, laevis 30 cm longis, 1 mm diametro; ramulis brevibus, filiformis, 1 cm longis, 0.8 mm diametro. Foliis lanceolatis, acutis ad extremum, asymmetricis, obliquis ad basim, costis conspicuus, infra apices

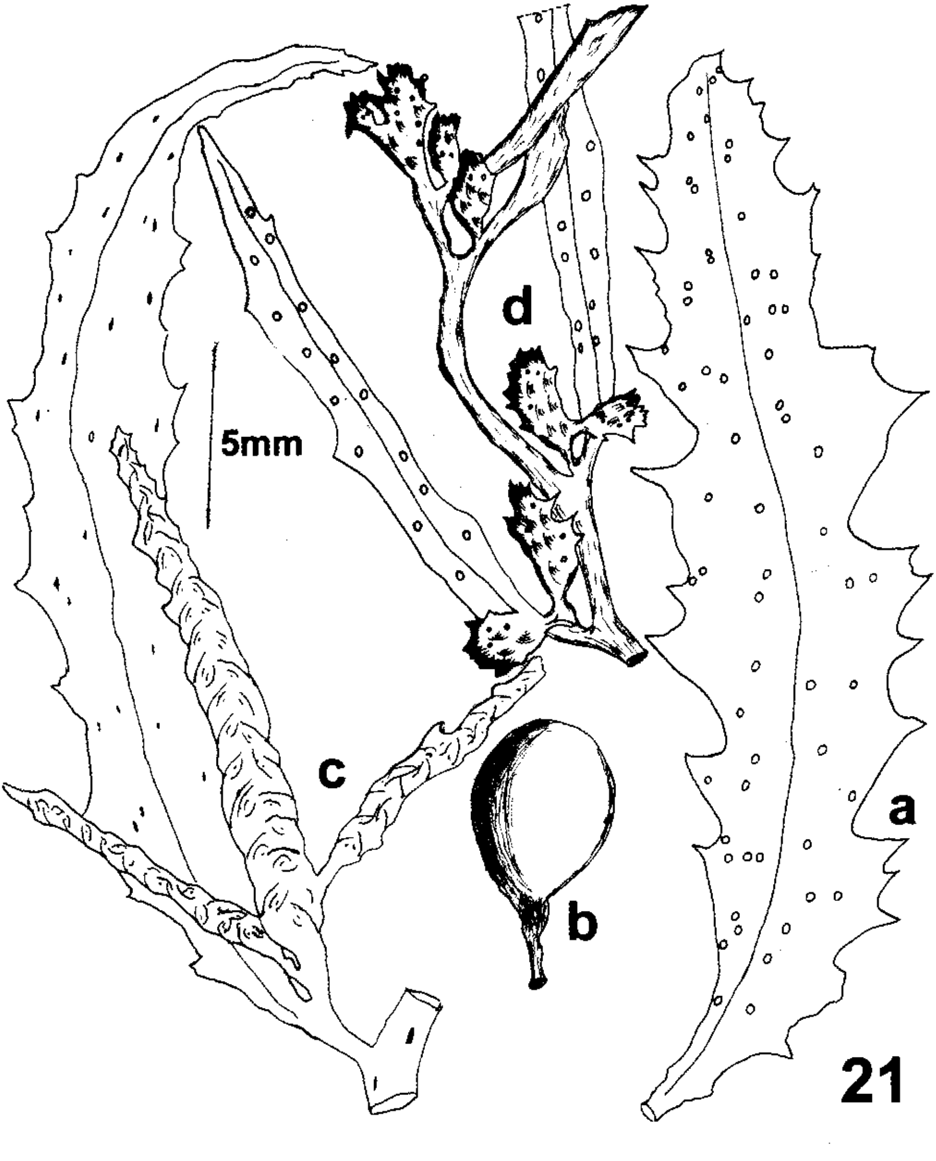

Fig. 21. *Sargassum siliculosoides* **Tseng et Lu. a, Leaves. b, Vesicles. c, Male receptacles. d, Female receptacles with leaves.**

evanida, cryptostomatibus conspicuus, regularis, dispersis ad utroque costalis, grossibus dentatibus ad margines; foliis primariis ca 4–5 cm longis, 5–8 mm latis; foliis secundariis ca 2–3 cm longis, 3–4 mm latis, foliis ramulis parvis, ca 1.5–2 cm longis, 2 mm latis, serrata ad margines. Vesiculis sphaericis, spellug 5 mm diametro, pedicellis cylindricis, laevis, 4 mm longis, 0.5 mm diametro.

Planta dioica. Receptaculis feminibus compressis vel complanatis, spinis, 6 mm longis, 2 mm latis; receptaculis maribus cylindricis, aliquot spinis, 18 mm longis, 1 mm diametro, furcatis, racemosis.

Holotype: AST 55-2024, collected by Zhang Junfu and Xu Fali, May 10, 1955, at Longmen Beach, Qinzhou City, Guangxi Province.

Other Materials Examined: AST 55-1983, 55-1985, 55-2011, 55-2015, 55-2017, 55-2019, 55-2020, 55-2024, 55-2025, 55-2026, 55-2045, and 55-2071.

Habitat: Growing on subtidal rocks.

Fronds cinereous, up to 80 cm tall. Holdfast discoid, 1 cm in diameter. Main axis cylindrical, verrucose on surface, 1 cm long, 2.5 mm in diameter. Several primary branches radially arising from the upper part of the glabrous axis, up to 79 cm long, 2 mm in diameter, with several bulbs at the basal parts of the primary branch, oblong, verrucose, thick, about 1 cm long, 2 mm wide; secondary branches arising from the axils of the primary branch, cylindrical, glabrous, up to 30 cm long, 1 mm in diameter, alternate, at intervals of 3–4 cm; ultimate branchlets short, filiform, with glandular dots, up to 1 cm long, up to 0.8 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on the primary branches large, cinereous, lanceolate, 4–5 cm long, 5–8 mm wide, acute at the apex, asymmetrical, obliquely cuneate at the base, coarsely dentate at the margins, with conspicuous midrib, usually vanishing below the apex, and conspicuous cryptostomata, scattered on both sides of the midrib; leaves on secondary branches very similar to those on primary branches, only shorter and narrower, about 2–3 cm long, 3–4 mm wide; leaves on ultimate branchlets small, about 1.5–2 cm long, 2 mm wide, irregularly serrulate at the margins. Vesicles spherical, rounded, or sometimes with sharp dot at the apex, small, up to 5 mm in diameter, with a few cryptostomata and cylindrical, glabrous pedicels, up to 4 mm long, less than 0.5 mm in diameter.

Plants dioecious. Receptacles furcate, racemosely arranged on the fertile branches. Female receptacles compressed to flattened, spinulose, up to 6 mm long, 2 mm wide. Male receptacles cylindrical, with a few spinules on the upper part, up to 18 mm long, 1 mm in diameter.

Remarks: *Sargassum siliculosoides* Tseng et Lu, sp. nov. is mainly characterized by short, thick, bulbous structures; lanceolate leaves, coarsely dentate at the margins, with spherical vesicles, rounded or with a sharp dot at the apex; and compressed to flattened, spinulose female receptacles. It is related to *S. pseudolanceolatum* Tseng et Lu. The 2 species have similarly shaped leaves and receptacles, but *S. siliculosoides* has bulbous structures and coarsely dentate leaves at the margins, whereas *S. pseudolanceolatum* does not.

6. *Sargassum pseudolanceolatum* Tseng et Lu sp. nov.
(Figs. 6 and 22)

Frons lutea brunnea, tenuis, 90 cm alta. Ramis cylindricis, laevis, non glandibus. Foliis lanceolatis acutis ad extremum, costis percurrentibus, asymmitricis, obliquis ad basim, cryptostomatibus conspicuus, irregularlis dispersis ad utroque costalis; foliis primariis ca 4–5 cm longis, 6–8 mm latis, dentatibus ad margines; foliis secundariis ca 2.5 cm longis, 4 mm latis, denticulatibus ad margines; foliis ramulis aliquot, parvis, 1 cm longis, 2 mm latis, undulatibus vel aliquot denticulatibus ad margines. Vesiculis sphaericis vel ovatis, 4 mm diametro, pedicellis cylindricis, laevis, 2 mm longis, 1 mm diametro.

Planta dioica. Receptaculis feminibus compressis vel applanatis, spinis in superibus, 5 mm longis, 2.5 mm latis; receptaculis maribus cylindricis, 7.5 cm longis, 1 mm diametro, aliquot spinis in superibus, racemosis.

Holotype: AST 92-0620. collected by C. K. Tseng, July 17, 1992, at Dadonghai, Sanya City, Hainan Island.

Etymology: Named for the shape of the leaves.

Habitat: Drifted ashore.

Fronds yellow-brown, slender, up to 90 cm or more tall. Primary branches cylindrical, smooth, up to 90 cm long, 1.2 mm in diameter; secondary branches arising from axils of the leaves of primary branches, smooth, alternate, up to 12 cm long, less than 1 mm in diameter, at intervals of 3–3.5 cm; ultimate branchlets glabrous, slender, and small, alternate, up to 3 cm long, less than 0.5 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on primary branches broadly lanceolate, membranous, about 4–5 cm long, 6–8 mm wide, acute at the apex, asymmetrical, obliquely cuneate at the bases, dentate at the margins, with conspicuous percurrent midribs and elevated cryptostomata, irregularly scattered on both sides of the midrib; leaves on secondary branches smaller and shorter, up to 2.5 cm long, 4 mm wide, acute at the apex, obliquely cuneate at the base, serrulate at the margins, with conspicuous percurrent midrib and conspicuous cryptostomata, regularly scattered on both sides of the midrib; leaves on ultimate branchlets sparse, small, and narrowly lanceolate, up to 1 cm long, 2 mm wide, undulate or occasionally serrulate at the margins. Vesicles spherical or ovate, variable in size, up to 4 mm in diameter, rounded at the apex, with a few cryptostomata on the surface, pedicels short, cylindrical, smooth, up to 2 mm long, less than 1 mm in diameter.

Plants dioecious. Receptacles furcate, racemosely arranged on the fertile branches. Female receptacles compressed, sometimes flattened, broader at apex, with sharp spinules mainly on the upper parts, up to 5 mm long, 2.5 mm wide. Male receptacles cylindrical, up to 7.5 mm long, 1 mm in diameter, with a few spinules on the upper parts.

Remarks: *Sargassum pseudolanceolatum* Tseng et Lu is mainly characterized by its cylindrical, glabrous branches with lanceolate leaves, which are larger on

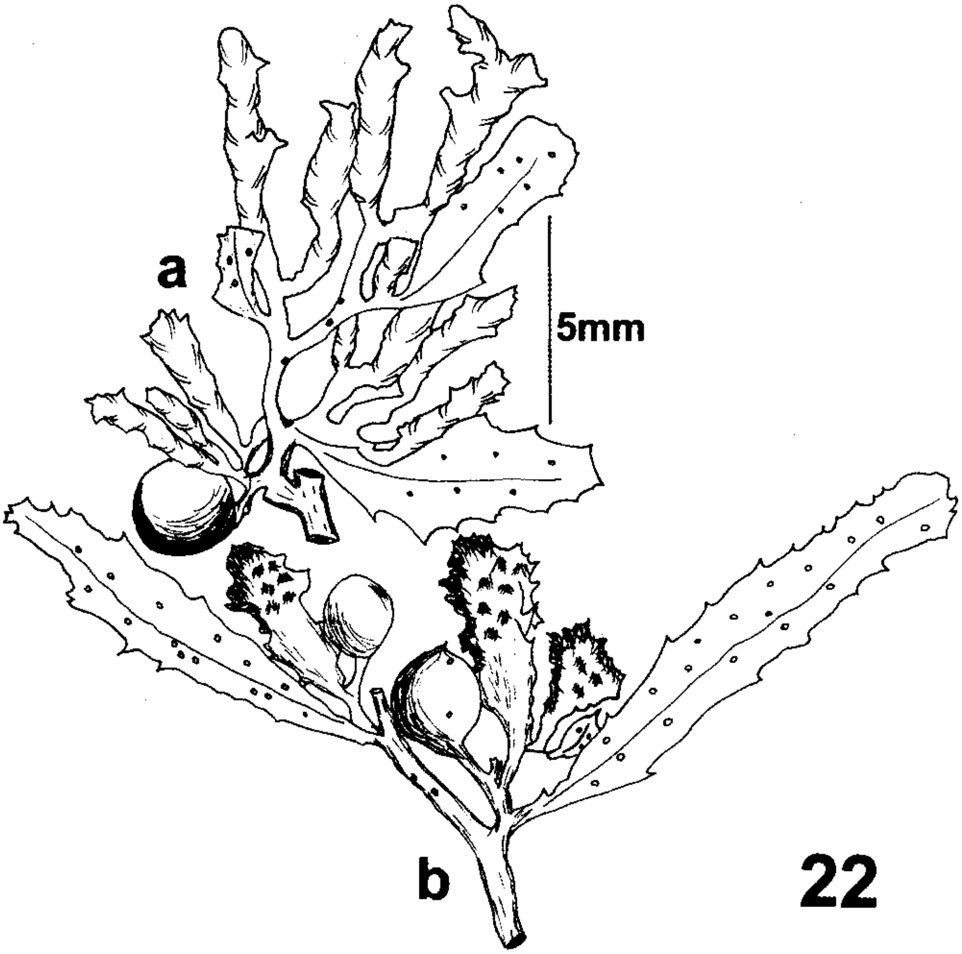

Fig. 22. *Sargassum pseudolanceolatum* Tseng et Lu. a, Male receptacles with leaves and vesicles. b, Female receptacles with leaves and vesicles.

the primary branches and smaller on the secondary branches. It has spherical to ovate vesicles, compressed female receptacles, which are sometimes flattened, broader at the apex, with many sharp spines on upper parts, and cylindrical male receptacles, which have a few spinules on the upper parts. This species is related to *S. parvifolium* (Turner) C. Agardh, but unlike *S. parvifolium*, it has glabrous branches with larger leaves with obliquely asymmetrical bases and compressed to flattened female receptacles, usually broader at the apex.

7. *Sargassum cinctum* J. Agardh, Sp. gen. ordines algarum, vol. 1, p. 324, 1848.

(Figs. 7 and 23)

Fronds dark brown, up to 60 cm tall. Holdfast discoid, 1 cm in diameter. Main axis cylindrical, smooth, 1 cm long, 2 mm in diameter. Several primary branches arising from upper parts of the axis, up to 59 cm long, 2 mm in diameter, cylindrical, glabrous; secondary branches short, arising from the axils of the primary branches, terete, smooth, alternate, up to 11 cm long, 1.5 mm in diameter, at intervals of 2–4 cm. Ultimate branches very short and small, filiform, about 1.5–2 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles. Basal leaves small, oblong, about 1.5–2 cm long, 5–6 mm wide, slightly acute at the apex, cuneate at the base, irregularly dentate or undulate at the margins, with percurrent midribs and conspicuous cryptostomata; leaves on primary branches larger, lanceolate, 4 cm long, 7 mm wide, acute at the apex, usually with conspicuous cryptostomata arranged on both sides of the midribs; leaves on secondary branches similar to those on the primary branches in shape, but narrower and shorter, usually 1.5–2 cm long, 2–3 mm wide, acute at the apex, conspicuously obliquely cuneate at the base, with midribs usually vanishing in distal 1/3 of the leaves. Vesicles variable in size, ovate or obovate, usually up to 4 mm long, 3 mm in diameter, usually with a few elevated cryptostomata on the surface, pedicels cylindrical or compressed, about 2–3 mm long, less than 0.5 mm in diameter.

Plants dioecious. Receptacles furcate, racemosely arranged on the fertile branches. Female receptacles triquetrous, spinulose, about 6–7 mm long, 1.5 mm in diameter. Male receptacles cylindrical, very long, spinulose on the apices and surfaces, about 15–18 mm long, 0.8–1.0 mm in diameter.

Specimens Examined: AST 96-0129 and 96-0131, collected May 30, 1996, from Naozhou Island, Zhanjiang City, Guangdong Province; AST 62-1535 collected between May and July 1962 and 96-0057 between May and July 1996 from Weizhou Island, Beihai City, Guangxi Province; AST 57-6738, collected July 30, 1957, from Hainan Island.

Habitat: Growing on subtidal rocks.

Distribution: The Philippines, India, and Australia.

Remarks: Setchell (1931) reported "*S. cinctum* J. Agardh?" from Hong Kong, but in 1936, he finally rejected it, unsure of his determination. We agree with Setchell that *S. cinctum* J. Agardh is related to *S. biserrula* J. Agardh and *S. glaucescens* J. Agardh. However, unlike *S. biserrula*, *S. cinctum* has lanceolate leaves, acute at the apex, and receptacles closely racemosely arranged. In addition, the leaves of *S. cinctum* differ from those of *S. glaucescens* in shape and have midribs that are usually percurrent or vanishing below the apex.

Sargassum cinctum J. Agardh has been previously studied by J. Agardh (1889, p. 95, pl. 27, fig. 3); Reinbold (1913, p. 161), Grunow (1915, p. 418), and Setchell (1936, p. 6).

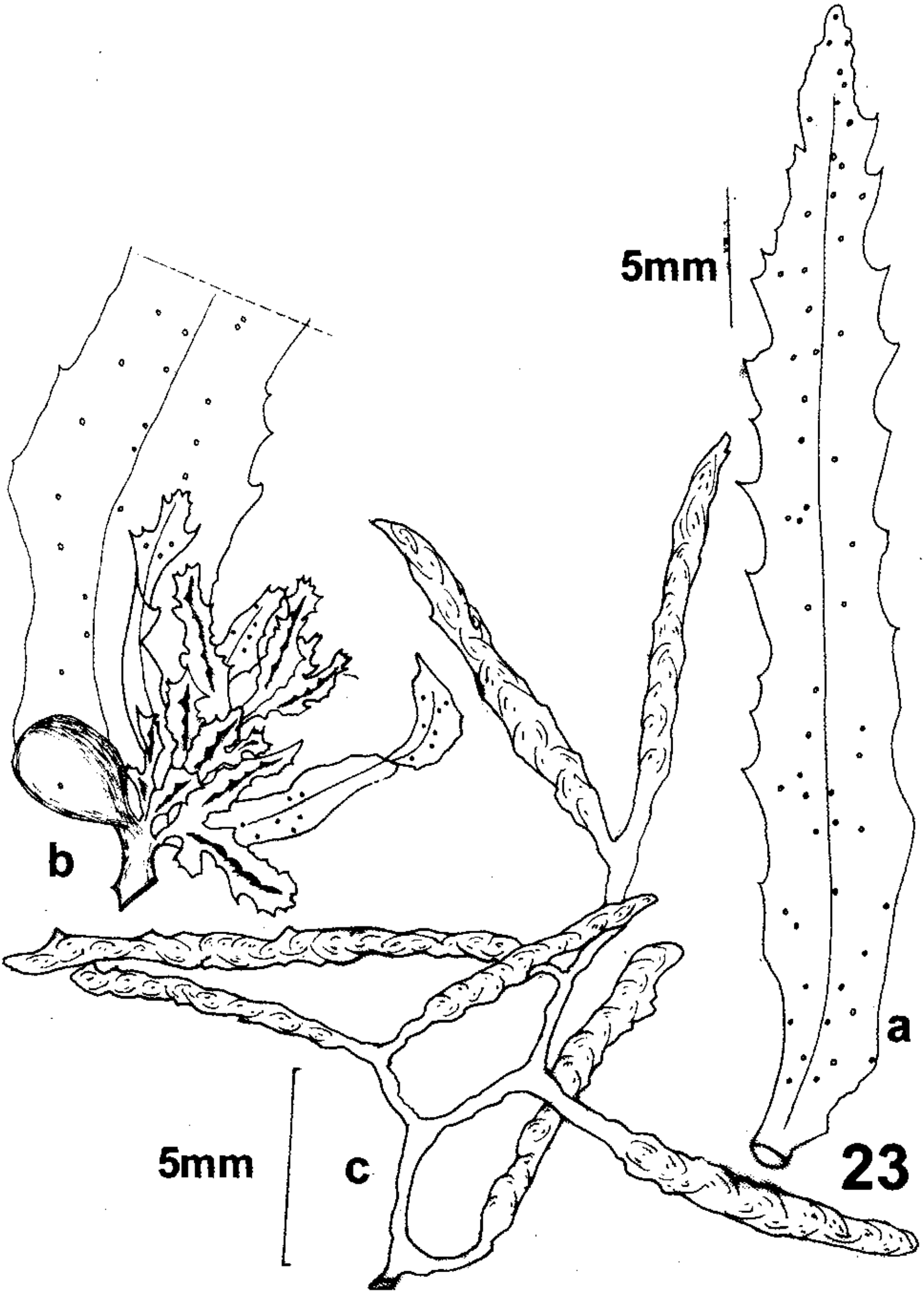

Fig. 23. *Sargassum cinctum* J. Agardh. a, Leaves. b, Vesicles and female receptacles. c, Male receptacles.

8. *Sargassum fujianense* Tseng et Lu, sp. nov.

(Figs. 8 and 24)

Frons lutea brunnea, 35 cm altas. Haptero disciformi, 1 cm diametro. Ramis primariis cylindricis vel subcylindricis, laevibus, 33 cm longis, 1.5 mm diametro; ramis secundariis et ramulis parvis, cylindricis. Foliis crassis, costis conspicuus, non percurrentibus, 2/3 infra apices evanida, obtusis vel acutis ad extremum, cuneatis ad basim, foliis basalum oblongis vel latis lanceolatis, ad 6 cm longis, 8 mm latis, dentatibus ad margines; foliis primariis lanceolatis, ad 5 cm longis, 6 mm latis dentatibus ad supra margines, undulatibus infra; foliis secondariis lanceolatis-linearis, grosse serratibus ad supra margines, aliquot dentatibus infra. Vesiculis sphaericis, ovatis, 3–4 mm diametro, rotundatis vel acutis ad extremum, pedicellis cylindricis, 3–4 mm longis, 1 mm diametro.

Planta dioica. Receptaculis feminibus compressis, 3 mm longis, 2 mm diametro, spinis; receptaculis maribus cylindricis, quasi 8–10 mm longis, 1 mm diametro, aliquot spinis, racemosis.

Holotype: AST 54-2410, collected by Zhang Junfu, June 14, 1954, at Dongshang, Fujian Province.

Other Materials Examined: AST 54-2366, 54-2440, 54-2659, and 54-2695b. Collected at Dongshan Beach, Fujian Province.

Etymology: Named after the Fujian Province.

Fronds yellow-brown, up to 35 cm tall. Holdfast discoid, 1 cm in diameter, usually giving rise to 3–4 axes. Axis cylindrical, verrucose, up to 2 cm long, 2 mm in diameter, bearing several primary branches from the upper part of the axis. Primary branches cylindrical to slightly compressed, glabrous, up to 33 cm long, 1.5 mm in diameter; secondary branches short, cylindrical, glabrous, arising from axils of the primary branches, alternate, about 4–5 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles at intervals of 1–1.5 cm. Basal leaves very thick, oblong or broadly lanceolate, up to 6 cm long, 8 mm wide, obtuse or slightly acute at the apex, cuneate at the base, irregularly dentate at the margins, with conspicuous midrib, usually vanishing in the distal third of the leaves, and inconspicuous cryptostomata scattered on both sides of the midrib; leaves on the primary branches lanceolate, up to 5 cm long, 6 mm wide, slightly acute or obtuse at the apex, slightly asymmetrical, obliquely cuneate, dentate at the margins, with midribs usually vanishing below the apex, and conspicuous cryptostomata irregularly scattered on the both sides of the midrib; leaves on secondary branches small and narrow, lanceolate or linear, up to 2–3 cm long, 2–3 mm wide, slightly acute or obtuse, symmetrically cuneate at the base, coarsely dentate at the margins, with midrib and cryptostomata similar to those of leaves of primary branches. Vesicles small, spherical or ovate, about 3–4 mm in diameter, rounded, sometimes with sharp tips at the apex, with several cryptostomata and cylindrical, smooth pedicels, about 3–4 mm long, less than 1 mm in diameter.

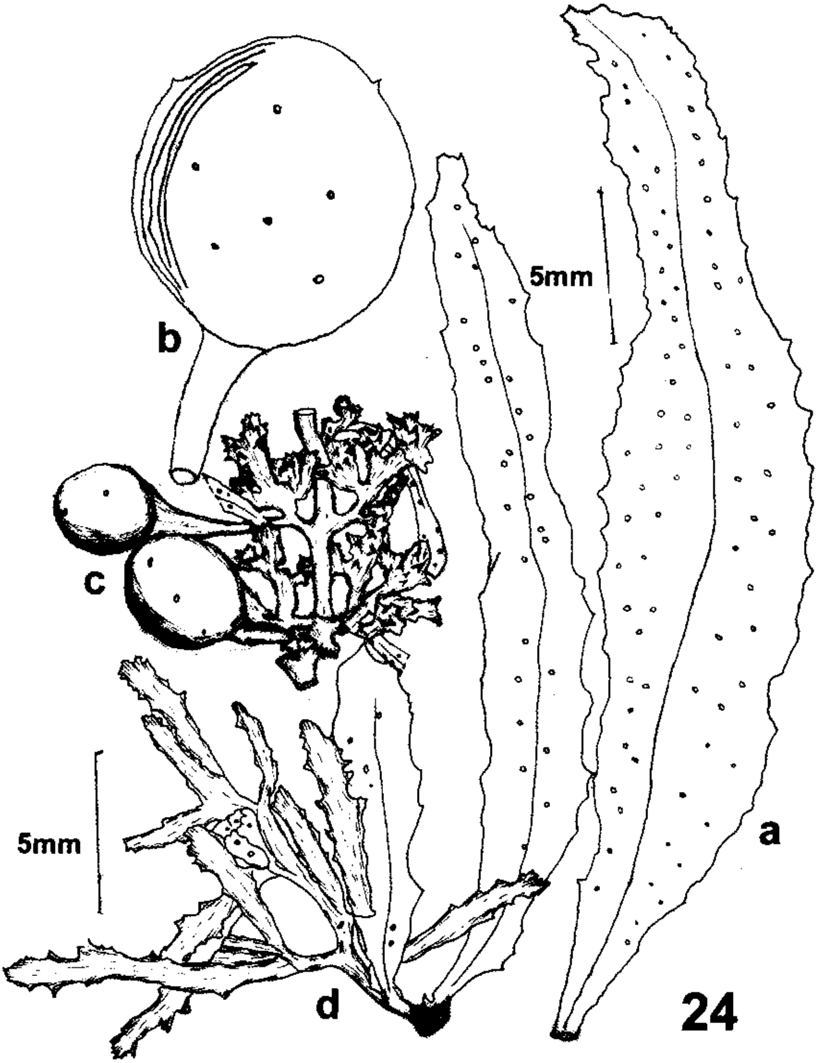

Fig. 24. *Sargassum fujianense* Tseng et Lu. a, Basal leaves. b, Vesicle. c, Female receptacles with vesicles. d, Male receptacles with leaves.

Plants dioecious. Receptacles furcate, irregularly racemosely arranged on the fertile branches. Female receptacles compressed, up to 3 mm long, 2 mm wide, with many sharp spinules. Male receptacles cylindrical, about 8–10 mm long, less than 1 mm in diameter, with a few spinules.

Habitat: Growing on lower intertidal rocks.

Remarks: *Sargassum fujianense* Tseng et Lu, sp. nov. is mainly characterized by its discoid holdfast, thick leaves in which the upper parts of the margins are dentate or coarsely dentate, and male receptacles with a few spinules. The branches are cylindrical to slightly compressed and glabrous. The leaves have conspicuous midribs. Basal leaves are oblong or broadly lanceolate and dentate at the margins. Leaves on the primary branches are lanceolate; the upper parts of the margins are dentate, and the lower parts are wavy. Leaves on the secondary branches are small and narrow, lanceolate or linear, and have spherical or ovate small vesicles. The female receptacles are compressed and spinulose; the male receptacles are cylindrical and have a few spinules.

9. *Sargassum subdroserifolium* Tseng et Lu, sp. nov.

(Figs. 9 and 25)

Frons atrofuscus, plus 50 cm altas. Haptero disciformis, 1.5 cm diametro. Axe cylindricis, laevis, 5 mm longis, 3 mm diametro. Ramis primariis subcylindricis, laevis, 50 cm longis, 2 mm diametro; ramis secundariis cylindricis, alternis, laevis, 15 cm longis, 1.5 mm diametro; ramulis brevibus, cylindricis, 4 cm longis, minus 1 mm diametro. Foliis basalum magnis, crassis, lanceolatis, coriaceis, 9 cm longis, 2.7 cm latis, obtusis vel interdum acutis ad extremum, leviter obliquis ad basim, costis conspicuus, elevatis, percurrentibus, cryptostomatibus obscure undulatibus ad margines; foliis primariis parvis, 5 cm longis, 10 mm latis; foliis secundariis linearifoliis, 2–3 cm longis, 4–5 mm latis, obtusis ad extremum, cuneatis ad basim dentatibus ad magines. Vesiculis parvis, ovatis, 3.5 mm longis, 3 mm diametro, pedicellis cylindricis, laevis, 2 mm longis, minus 1 mm diametro.

Planta dioica. Receptaculis magnis, vulgo furcatis, spinis, racemosis; receptaculis feminibus triquetris, 16 mm longis, 3 mm diametro; receptaculis maribus cylindricis, leviter compressis ad extremum, 20 mm longis, 1.2 mm diametro.

Holotype: AST 73-0629a, collected by Lu Baoren, Xia Enzhan, and Xu Fali, May 17, 1973, at Naozhou Island, Guangdong Province.

Isotype: AST 73-0629b, collected by Lu Baoren, Xia Enzhan, and Xu Fali, May 17, 1973, at Naozhou Island, Guangdong Province.

Etymology: Named for the similarity of the frond to *Drosera*.

Habitat: Growing on subtidal rocks.

Fronds dark brown, up to 50 cm or taller. Holdfast discoid, up to 1.5 cm in diameter. Axis short, terete, glabrous, up to 5 mm long, 3 mm in diameter. Primary branches arising from the upper part of the axis, subcylindrical, glabrous, up to 50

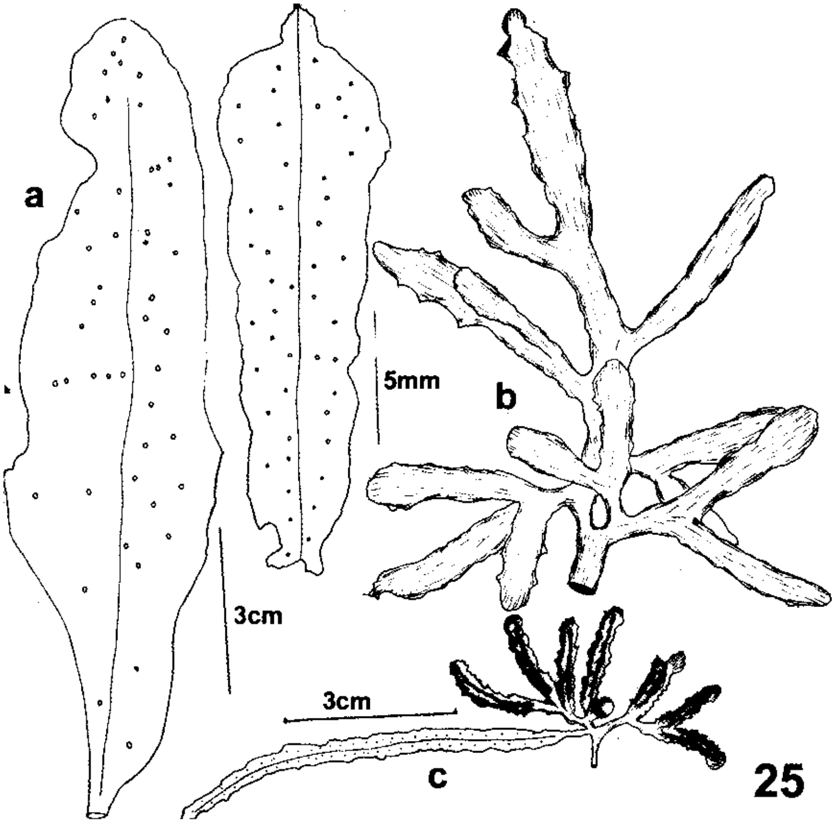

Fig. 25. ***Sargassum subdroserifolium*** **Tseng et Lu. a, Leaves. b, Male receptacles. c, Female receptacles with leaves and vesicles.**

cm long, 2 mm in diameter; secondary branches arising from the axils of the primary branches, alternate, short, terete, glabrous, up to 15 cm long, 1.5 mm in diameter, at intervals of 1–2 cm; ultimate branchlets short, terete, up to 4 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Basal leaves very large and thick, lanceolate, coriaceous, up to 9 cm long, 2.7 cm wide, obtuse, sometimes slightly acute at the apex, slightly obliquely cuneate at the base, wavy at the margins, with conspicuous percurrent, elevated midrib and obscure cryptostomata, irregularly scattered on both sides of the midrib; leaves on the primary branch very similar to the basal leaves, only smaller, up to 5 cm long, 10 mm wide, obtuse, sometimes slightly acute at the apex, slightly obliquely cuneate at the base, wavy at the margins, with percurrent, conspicuous midribs; leaves on secondary branches slender, small, broadly linear, about 2–3 cm long, 4–5 mm wide, obtuse at the apex, cuneate at the base, irregularly slightly dentate at the margins, with conspicuous midribs usually vanishing below the apex. Vesicles very small, ovate, 3.5 mm long, 3 mm in diameter, usually with 1–2 cryptostomata and cylindrical, short, glabrous pedicels, up to 2 mm long, less than 1 mm in diameter.

Plants dioecious. Receptacles very large, usually furcate, racemosely arranged on the fertile branches. Female receptacles triquetrous, usually slightly flexuous, with many spinules, up to 16 mm long, 3 mm in diameter. Male receptacles cylindrical, slightly compressed at the apex, spinulose on the upper parts, up to 20 mm long, 1.2 mm in diameter.

Remarks: The main characteristics of *S. subdroserifolium* Tseng et Lu include its *Drosera*-like frond; large triquetrous spinulose female receptacles; cylindrical, spinulose male receptacles slightly compressed at the apex; and very large, lanceolate, thick, coriaceous basal leaves, which are wavy at the margins. Its holdfast is discoid. The leaves on the primary branches had fallen off the specimen we examined, but the leaves on the secondary branches were broadly linear and irregularly dentate at the margins. This species is similar to *S. droserifolium* Bory. However, *S. droserifolium* has much smaller duplicate-margined leaves, glabrous or slightly spinulose female receptacles, and glabrous male receptacles.

10. *Sargassum cystophyllum* Montagne var. *parcespinosa* Grunow, Verh. K.-K. Zool.-Bot. Gesell. Wien 65:414, 1915.

(Figs. 10 and 26)

Fronds yellow-brown, up to 40 cm tall. Holdfast discoid, 1 cm in diameter. Axes cylindrical, glabrous, up to 1 cm tall, 3 mm in diameter. Primary branches arising from the upper part of the axes, subcylindrical, up to 39 cm long, 2 mm wide. Secondary branches arising from slightly compressed foliar axils of the primary branches, cylindrical, glabrous, up to 11 cm long, 1.2 mm in diameter, at intervals of 1–3 cm. Ultimate branches arising from foliar axils of the secondary branches, shorter, cylindrical, with a few glandular dots, up to 2 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves small and stiff, obovate or elongate-ovate, variable in shape and size. Basal leaves up to 2 cm long, 5 mm wide, obtuse at the apex, with conspicuous midrib, not percurrent, wavy, sometimes serrulate; leaves on primary branches mostly fall off; only a few leaves on ultimate branchlets, usually elongate-obovate or obovate, usually 0.8–1.0 cm long, 4 mm wide, occasionally up to 1.4 cm long, 5 mm wide, acute or obtuse at the apex, obliquely cuneate at the base, wavy or slightly dentate at the margins, midrib usually vanishing below the apex, cryptostomata conspicuous, irregularly scattered on both sides of the midrib. Vesicles small, generally spherical or ovate, 3 mm in diameter, often with earlike protuberances on both sides, a few cryptostomata, and cylindrical or slightly compressed pedicels, up to about 2 mm long.

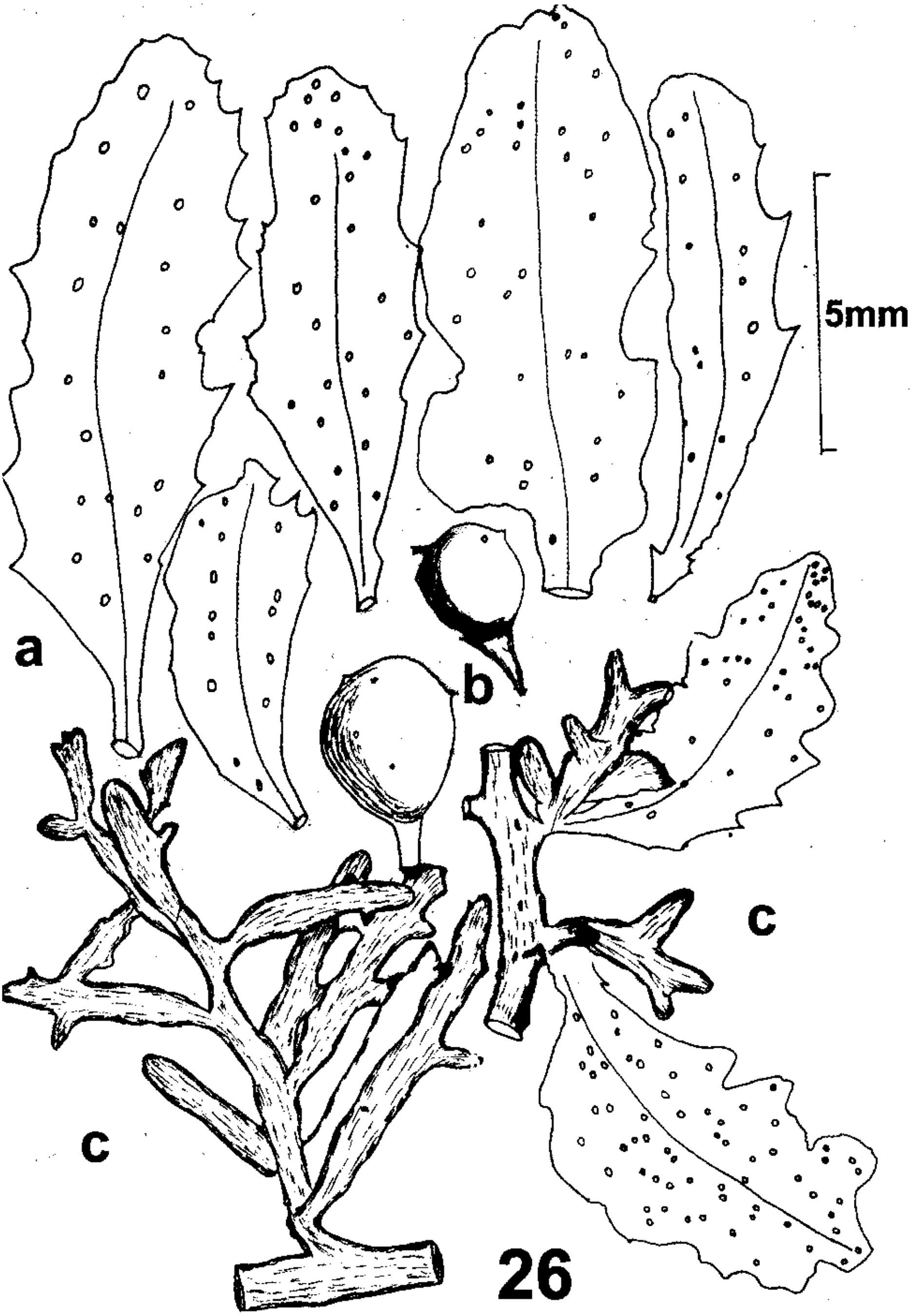

Fig. 26. *Sargassum cystophyllum* Montagne var. *parcespinosa* Grunow. a, Leaves. b, Vesicles. c, Male receptacles.

Plants dioecious. Male receptacles cylindrical, usually divided at the apex, up to 6 mm long, 1 mm in diameter, with a few spines. Female plant not collected.

Specimen Examined: AST 55-0717, collected March 25, 1955, from Wenchang, Hainan Island.

Habitat: Growing on lower intertidal rocks.

Distribution: China Sea.

Remarks: *Sargassum cystophyllum* Montagne var. *parcespinosa* Grunow is characterized by its very small, obovate to elongate-ovate leaves, very small spherical or ovate vesicles, cylindrical or compressed pedicels, short, linear female receptacles with spinules, and cylindrical male receptacles, usually with a few spinules. We collected only a single male plant, which has somewhat larger leaves than those described by Grunow. According to Grunow, *S. cystophyllum* Montagne has linear, spinulose female receptacles.

11. *Sargassum dotyi* Trono, Tax. Econ. Seaweeds 3, p. 66, figs. 46–48, 98, 1992 and Tax. Econ. Seaweeds 4, p. 3, 1994.

(Figs. 11 and 27)

Fronds yellow-brown. Holdfast conical. Axis short. Primary branches cylindrical, slender, smooth, up to 70 cm long, 1–1.5 mm in diameter; secondary branches shorter, slender, cylindrical, glabrous, alternate, about 5–7 cm long, 1 mm in diameter, at intervals of 2.5–5 cm; ultimate branches shorter and more slender, cylindrical, about 1–2 cm long, less than 1 mm in diameter, with a few elevated glandular dots, beset with leaves, vesicles, and receptacles. Leaves on primary branches long, ellipsoidal, sometimes obovate, about 1.5–2 cm long, 5–7 mm wide, obtuse at the apex, asymmetrical, obliquely cuneate at the base, with the outside part often larger than the inside part, dentate at the upper part of the margins, entire or slightly dentate at the lower parts of the margins, midribs usually disappearing midway or two thirds below the apex, cryptostomata few, not distinct, irregularly scattered; leaves on secondary and ultimate branches obovate, small, 1–1.2 cm long, 4–5 mm wide, similar to those on primary branches in shape, smaller, pedicels cylindrical or compressed, about 2–3 mm long, 1 mm in diameter. Vesicles obovate or fusiform, up to 10 mm long, 5–8 mm in diameter, some small, others large, sometimes with thin fringing margin, rounded at the apex, mostly mucronate, with a few elevated cryptostomata on the surface and cylindrical pedicels, with upper parts usually larger than the lower parts, mostly 3–5 mm long, some up to 7 mm long, 2–2.5 mm in diameter.

Plants dioecious. Receptacles racemosely arranged on fertile branches. Female receptacles triquetrous above, compressed below, spinulose, small, about 2–3 mm long, 1–1.2 mm wide. Male receptacles cylindrical, 5 mm long, 1 mm in diameter, mostly glabrous, in some cases with few spinules.

Specimens Examined: AST 75-1308, 75-1311a, and 75-1312a, collected April 11, 1975, from Yulin Harbor, Sanya City, Hainan Province.

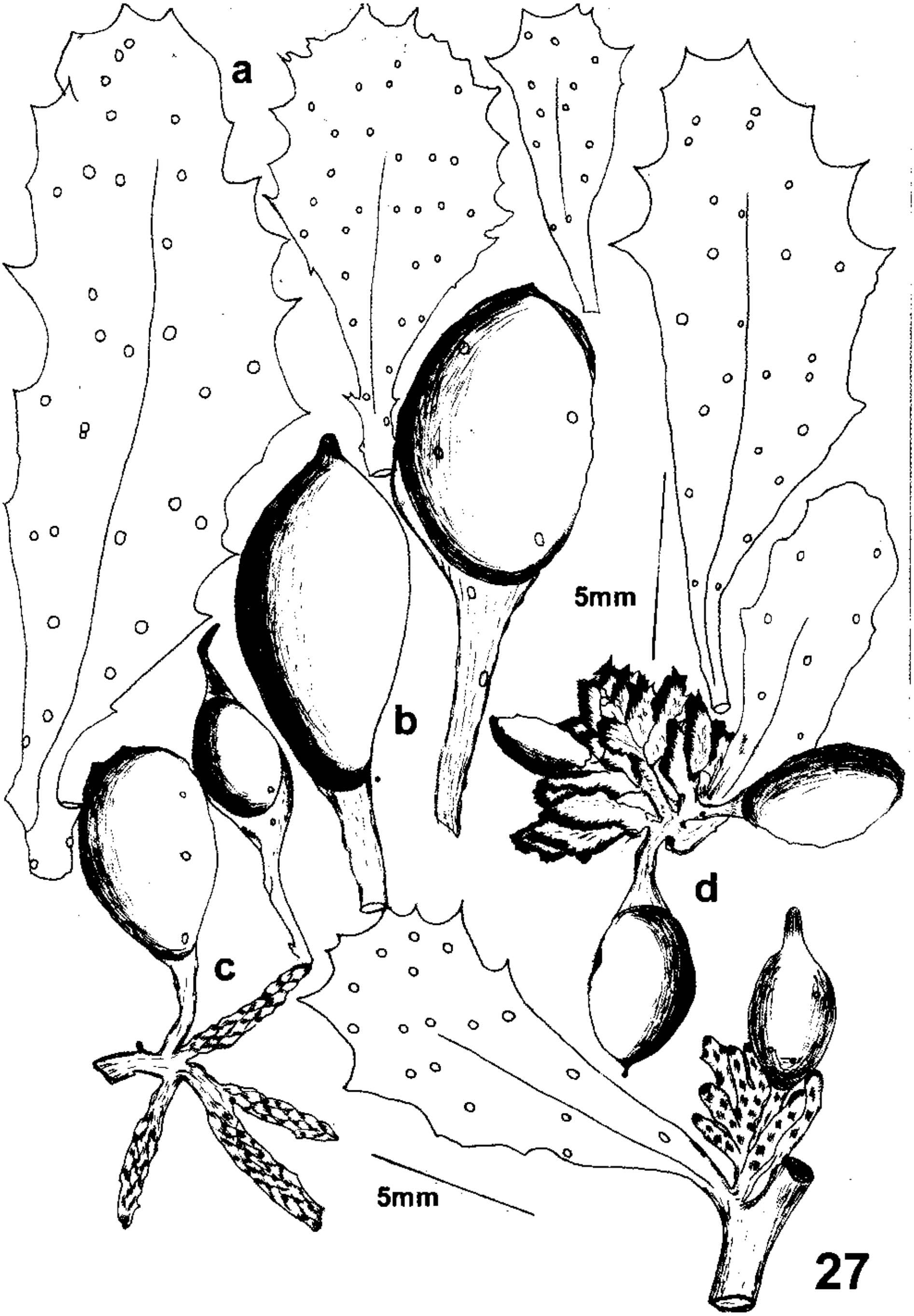

Fig. 27. *Sargassum doyti* Trono. a, Leaves. b, Vesicles. c, Fertile branches with leaves, vesicles and male receptacles. d, Fertile branches with leaves, vesicles, and female receptacles.

Habitat: Growing on lower intertidal and subtidal reefs.

Distribution: The Philippines (type locality).

Remarks: Three specimens were collected from Yulin Harbor, some male plants and others female. The main characteristics of *S. dotyi* Trono are ultimate branchlets with a few elevated glandular dots; leaves that are elongated ellipsoidal, obovate, and mainly dentate at the upper margins; vesicles that are obovate, fusiform, mostly mucronate; female receptacles that are triquetrous above and compressed below, with spinules; and male receptacles that are cylindrical with a few spinules. This record is a new one for China.

12. *Sargassum sandei* Reinbold In: Weber-van Bosse, Siboga Exped. 59a, p. 158, pl. 4, 1913.

(Figs. 12 and 28)

Fronds yellow-brown, 50 cm tall. Holdfast with radiating rhizoids fusing with one another forming a disc, up to 1 cm in diameter. Axes short, cylindrical, glabrous, up to 1 cm long, 2.5 mm in diameter. Several primary branches arising from upper part of the axis, subcylindrical, glabrous, up to 49 cm long, 1.5 mm in diameter; secondary branches cylindrical, alternate, glabrous, arising from the foliar axil of the primary branches, up to 10 cm long, 1 mm in diameter, at intervals of 2–3 cm, ultimate branches slender, with glandular dots, 3 cm long, 0.8 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves spatulate or oblong, obtuse at the apex, asymmetrical, obliquely cuneate at the base, usually larger outside than inside, irregularly dentate at the margins; midrib conspicuous, usually vanishing at middle parts of the leaves, cryptostomata conspicuous, irregularly scattered on both sides of the midrib; leaves on primary branches larger than leaves on other branches, up to 2 cm long, 10 mm wide, sometimes doubly dentate or duplicate, forming a very narrow cuplike structure at the apex; leaves on secondary branches small, up to 1.5 cm long, 6 mm wide, sometimes doubly serrulate at the apex; leaves on ultimate branchlets smaller, up to 1 cm long, 4 mm wide, serrulate at the margins. Vesicles elongated ovate or obovate, up to 6 mm long, 4 mm in diameter, variable in size, acute at the apex, glabrous or sometimes surrounded by small, narrow leaflike structure at the margin, cryptostomata elevated, pedicels cylindrical, about 2–3 mm long, 1 mm in diameter, sometimes compressed or flattened, up to 3 mm long, 2 mm wide.

Plants dioecious. Receptacles furcate, racemosely arranged on the fertile branches. Female receptacles compressed or flattened, 4 mm long, 2 mm wide, spinulose, upper parts mainly gathered. Male receptacles cylindrical, up to 6 mm long, 1 mm in diameter, with 1–2 spinules.

Specimens Examined: Collected from Yulin, Sanya City Hainan Island: AST 62-2558, on March 21, 1962; 75-1306, on April 11, 1975; and 82-0454 on April 24, 1982.

Habitat: Growing on subtidal reefs.

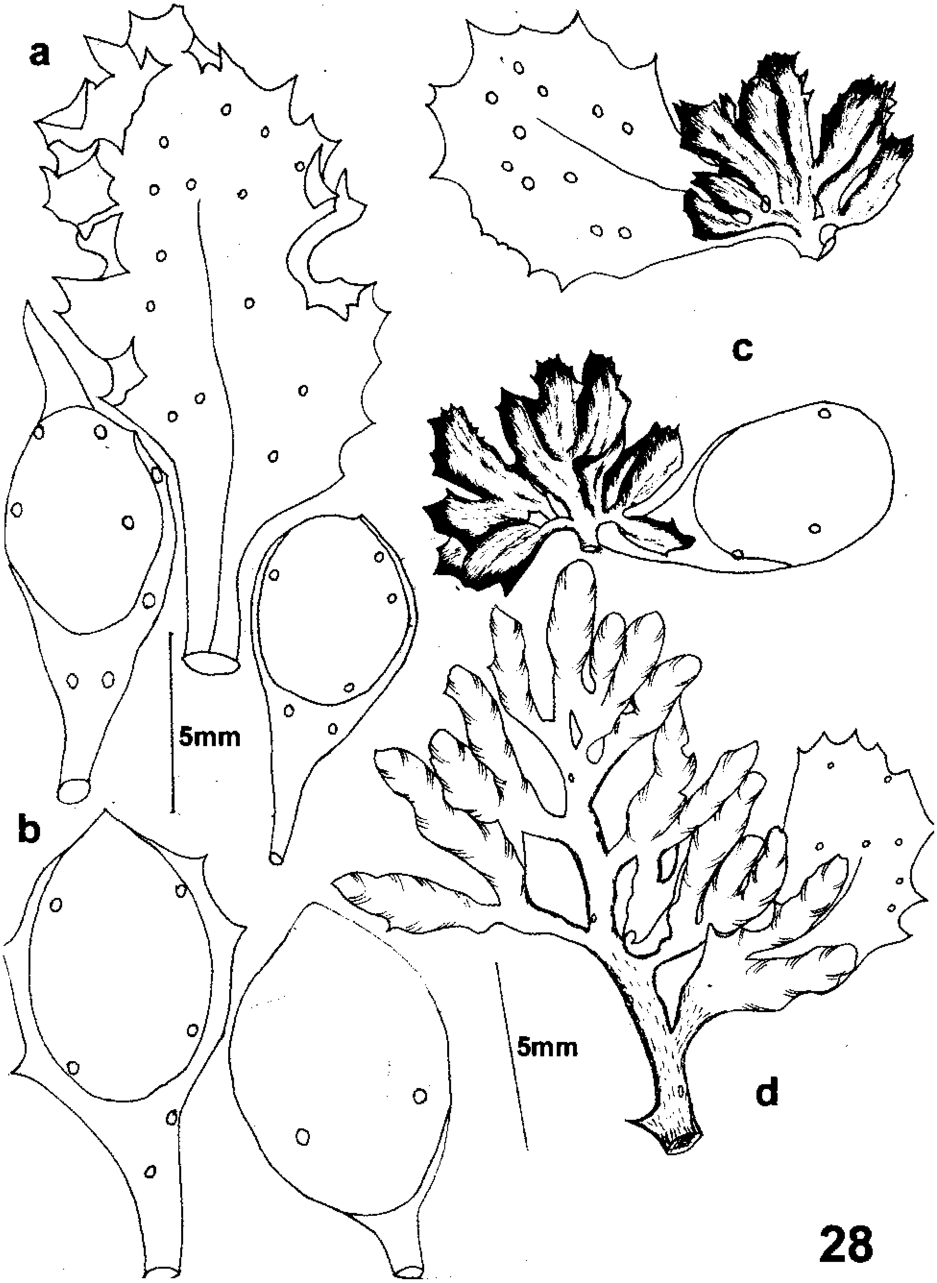

Fig. 28. *Sargassum sandei* Reinbold. a, Leaves. b, Vesicles. c, Female receptacles with leaves or vesicles. d, Male receptacles.

Distribution: Vietnam, Indonesia, and Japan.

Remarks: Noro et al. (1994, p. 30) examined the type specimens of *S. sandei* Reinbold, which have small duplicate leaves and narrow primary leaves, characteristics included in the range of morphological variation of *S. ilicifolium*. They stated, "We believe *S. sandei* should be a synonym of *S. ilicifolium*." Ajisaka et al. (1997, p. 28) emphasized further that there is "no difference between *S. duplicatum* and *S. sandei*, and the latter will be a synonym of *S. duplicatum*."

After studying our Chinese specimens of *S. sandei* Reinbold, *S. duplicatum* Bory, and *S. ilicifolium* (Turner) C. Agardh, we came to believe that they are 3 distinct species. *Sargassum duplicatum* has glomerulate receptacles, and *S. ilicifolium* and *S. sandei* have biserrulic receptacles. *Sargassum ilicifolium* and *S. sandei* can be differentiated from each other by some of their characteristics. For example, *S. sandei* has leaves with a cup-shaped structure at the apex and scutellate rhizoidal holdfasts, whereas *S. ilicifolium* does not.

Sargassum sandei Reinbold was previously studied by Yamada (1950, p. 191, fig. 8), Chou and Chiang (1981, p. 137, pl. I, fig. 6; pl. II, fig. 5), Noro et al. (1994, p. 30), Modelo and Umezaki (1995, p. 37, figs. 28a–28c, 34), and Ajisaka et al. (1997, p. 28).

13. *Sargassum squarrosum* Greville, Ann. Mag. Nat. Hist. (Ser. 2) 3:97, pl. 10, figs. 1–4, 1849.

(Figs. 13 and 29)

Fronds yellowish brown, small, up to 27 cm tall. Holdfast discoid, up to 8 mm in diameter. Axis cylindrical, glabrous, up to 5 mm long, 2.5 mm in diameter. Several primary branches arising from the upper part of the axis, cylindrical, glabrous, up to 26 cm long, 1.5 mm in diameter; secondary branches arising from the axils of the primary branches, alternate, up to 19 cm long, 1.2 mm in diameter, glabrous on the surface, at intervals of 1–1.5 cm; ultimate branches smaller, glabrous, alternate, with glandular dots on the surface, up to 3.5 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves stiff, elongate-obovate, usually upper part larger than lower part, mostly obtuse, sometimes slightly acute at the apex, obliquely cuneate at the base, irregularly serrulate at the margins, midrib conspicuous, generally vanishing in middle of leaf or top one third, cryptostomata conspicuous, irregularly arranged on both sides of the midrib; leaves on primary branches 1.6 cm long, 5 mm wide; leaves on secondary branch smaller, 1.2 cm long, 4 mm wide; leaves on ultimate branchlets variable in shape, usually up to 1 cm long, 3 mm wide, some linear, about 1.8–2 cm long, 1.5–2 mm wide, obtuse at the apex, obliquely cuneate at the base, dentate at the margins, with obscure midrib and cryptostomata. Vesicles small, subspherical, or ovate with a few cryptostomata, up to 3 mm in diameter, pedicels cylindrical, up to 1.5 mm long, 0.6 mm in diameter.

Plants dioecious. Receptacles furcate, racemosely arranged on the fertile

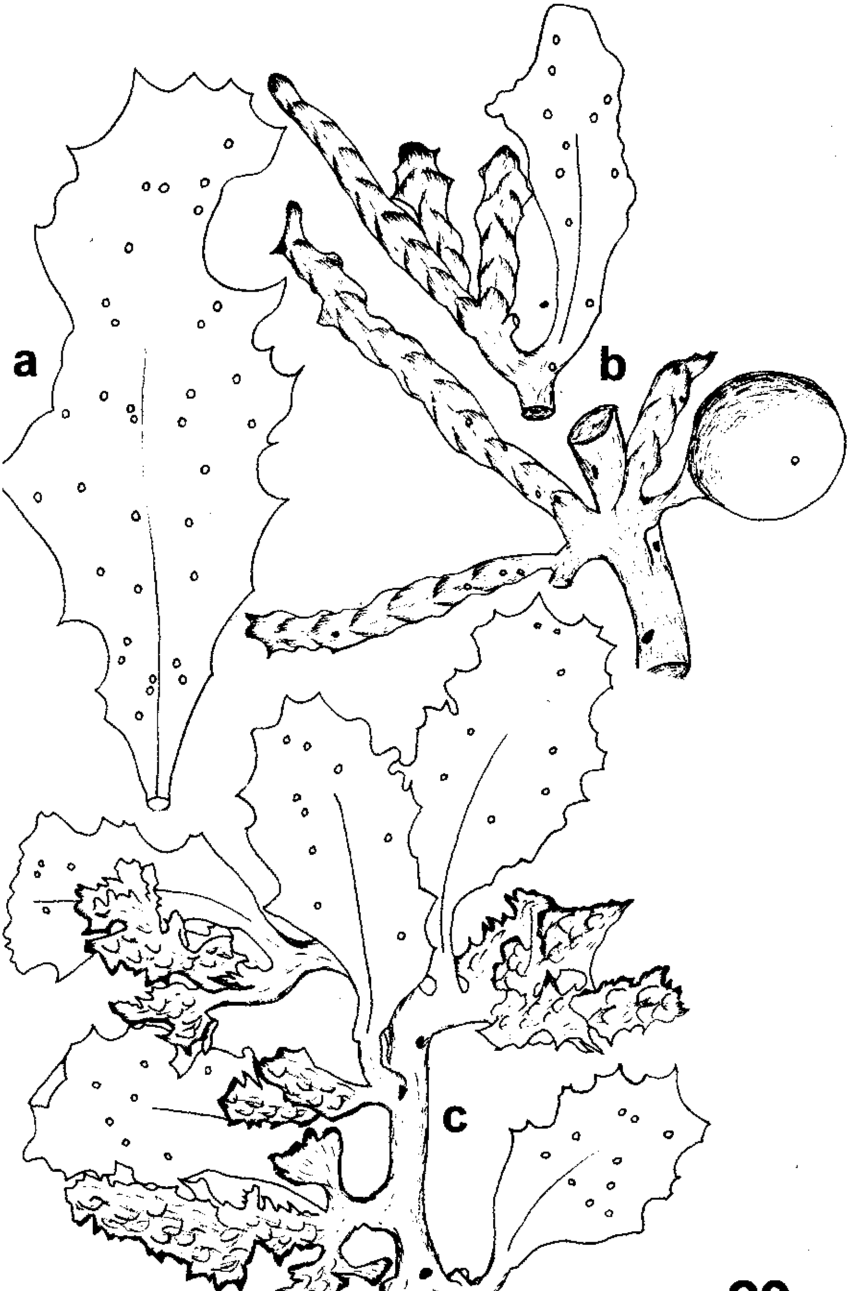

Fig. 29. *Sargassum squarrosum* Greville. a, Leaves. b, Vesicle and male receptacles. c, Female receptacles and leaves.

branches. Female receptacles irregularly compressed, ancipital, very spinulose, up to 7 mm long, 2 mm wide. Male receptacles cylindrical, up to 10 mm long, less than 1 mm in diameter, undulate, usually with 2–3 spinules on the upper part.

Specimens Examined: AST 96-0022 and 96-0074, collected in May 1996 from Weizhou Island, Beihai City, Guangxi Province.

Habitat: Drifted ashore, Nansha Islands, Hainan Province, and growing on subtidal rocks, Weizhou Island, Guangxi Province.

Distribution: Singapore, India, and Sri Lanka.

Remarks: The main characteristics of *S. squarrosum* Greville are very small, elongated-obovate leaves that are usually larger at the upper part than at the lower part; spinulose, compressed female receptacles; and cylindrical male receptacles with few spinules. This species was previously recorded for China from Nansha Islands (Tseng et al. 1998).

14. *Sargassum biserrula* J. Agardh, Sp. gen. ordines algarum, vol. 1, p. 318, 1848. (Figs. 14 and 30)

Fronds yellow-brown, up to 23 cm tall. Holdfast discoid, up to 8 mm in diameter. Main axis cylindrical, smooth, 5 mm long, 2 mm in diameter. Several primary branches arising from the upper parts of the main axis, cylindrical, glabrous, up to 22.5 cm long, 1.5 mm in diameter; secondary branches arising from the axils of the primary branches, with a few glandular dots, up to 10 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles, at intervals of 0.5–1 cm. Leaves small, elongated obovate, up to 2.5 cm long, 7 mm wide, upper parts of leaves broader than basal parts, obtuse at the apex, sometimes acute, slightly oblique cuneate at the base, with conspicuous midribs, usually vanishing below the apex, and cryptostomata, often in 2 series, scattered on both sides of the midribs. Vesicles small, spherical or subspherical, 3 mm in diameter, often rounded at the apex, slightly mucronate at the apex when young, with slightly raised cryptostomata, terete or compressed pedicels, about 2–3 mm long.

Plants dioecious. Receptacles furcate, arranged on fertile branches in racemes. Female receptacles triquetrous above and compressed or terete below, spinulose in upper parts, usually up to 3 mm long, 1.2 mm in diameter. Male receptacles cylindrical, with a few spinules at upper parts, up to 4.5 mm long, less than 1 mm in diameter.

Specimens Examined: AST 55-1975, collected April 28, 1955, from Weizhou Island, Beihai City; AST 55-3102, collected November 3, 1955, from Qinzhou.

Habitat: Growing on lower subtidal rocks.

Distribution: Sri Lanka, Indonesia, Singapore, and India.

Remarks: This record of *S. biserrula* J. Agardh, with 2 specimens, is a new one for China. The vesicles on the Chinese specimens seem to be less variable than on specimens from the Indian Ocean. Grunow (1915, p. 414) published 3 varieties and 6 forms, some androgynous, and others dioecious. We doubt

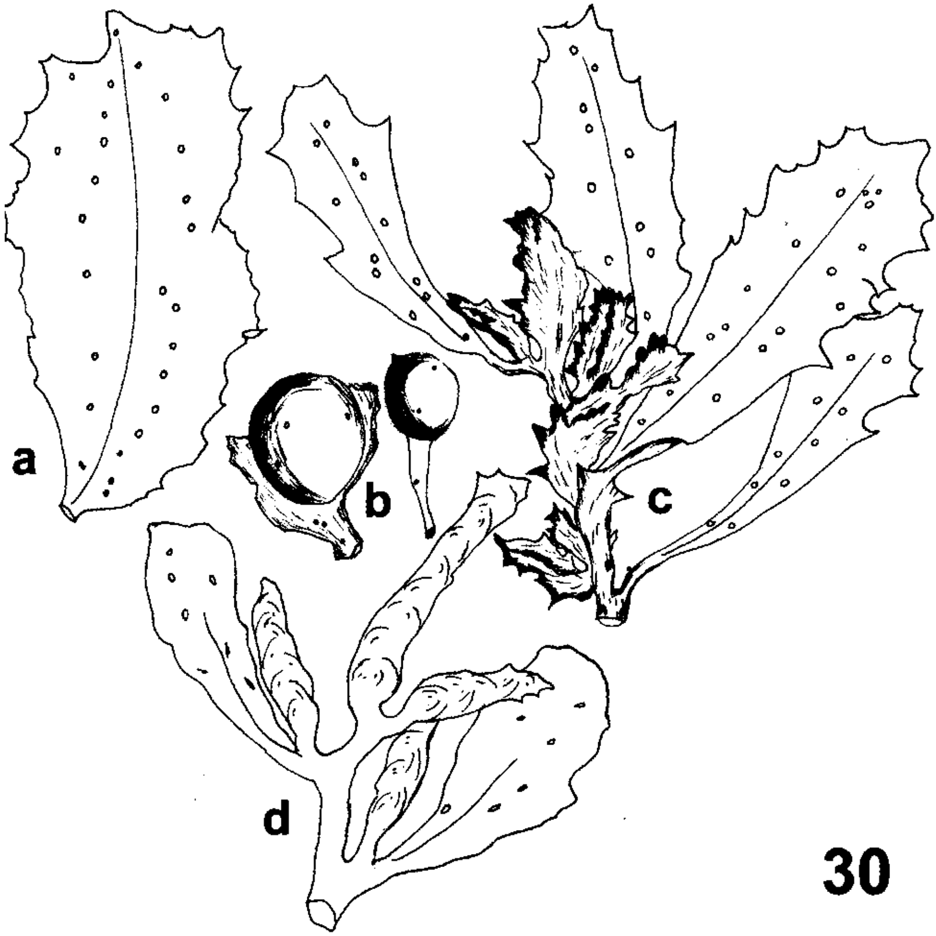

Fig. 30. ***Sargassum biserrula*** **J. Agardh. a, Leaves. b, Vesicles. c, Female receptacles. d, Male receptacles.**

whether all these varieties or forms belong to the same species.

Sargassum biserrula J. Agardh was previously studied by J. Agardh (1889, p. 94, pl. 27, figs. 16–23), Grunow (1915, p. 414), and Biswas (1950, p. 90).

15. *Sargassum ilicifolium* (Turner) C. Agardh, Species algarum, p. 11, 1820.
(Figs. 15 and 31)

Basionym: *Fucus ilicifolius* Turner, Fuci . . . , vol. 1, p. 113, pl. 51, 1808.

Fronds yellow-brown, up to 90 cm tall. Holdfast discoid, up to 1 cm in diameter. Main axis cylindrical, about 5 mm long, 3 mm in diameter, with glabrous surface. Primary branches arising from upper part of the axis, up to 89 cm long, 2 mm in diameter, cylindrical, glabrous; secondary branches arising from the axils of the primary branches, alternate, similar to primary branches, only shorter and slender, up to 20 cm long, 1.5 mm in diameter, at intervals of 2–3 cm; ultimate branches short and small, about 5–7 cm long, 1 mm in diameter, with glandular dots on the surface. Leaves elongated, ellipsoidal, sometimes undulate, about 2–3 cm long, 12 mm wide, rounded at the apex, conspicuously asymmetrical, obliquely cuneate at the base, usually broader and more dentate teeth abaxially than adaxially, midribs conspicuous, usually vanishing at middle parts of the leaves, cryptostomata conspicuous, scattered on the surface. Vesicles spherical, 5 mm in diameter, a few cryptostomata on the surface, with earlike structure on both sides and short subcylindrical pedicels, about 2–3 cm long.

Plants dioecious. Receptacles racemosely arranged on fertile branches. Female receptacles compressed, furcate, about 3–4 mm long, 2 mm wide, somewhat club-shaped and expanded at the apex, with acute spinules. Male receptacles subcylindrical, slightly compressed at the apex, up to 10 mm long, 1 mm wide, with acute spinules.

Specimens Examined: AST 92-0354 and 60-7841, collected from Wenchang Beach; AST 76-0200, 58-5038, 60-7751, 59-2696, 60-8276, and Tseng 394, from Sanya Beach, from Hainan Island, and AST 96-0078a from Weizhou Island, Beihai City, Guangxi Province.

Habitat: Growing on lower intertidal to subtidal rocks.

Distribution: Indonesia, Malaysia, Sri Lanka, India, and Australia.

Remarks: Tseng and Lu (1978) published "*S. ilicifolium*" on the basis of specimens that had compressed acanthocarpic androgynous receptacles, were branched once or twice, and had elevated glandular dots on secondary and ultimate branches. Our identification was based entirely on the description of Grunow: "receptaculis ancipitibus, androgynis racemosis vel racemoso-cymosis, masculs hinc inde longioribus, omnibus acute spinosis." Japanese phycologists, including Dr. Yoshida, also reported this species from Taiwan, but they told us that *S. ilicifolium* is dioecious. They examined our specimens and agreed with our determination. Yoshida (1988) reported only male receptacles.

In recent years, the more we work with taxonomy of the *Sargassum* subgenus, especially the *Biserrulae* subsection, the more we have come to believe that algae, although very primitive plants, clearly have different sexual stages and that a single species cannot be both androgynous and dioecious. Therefore, we studied the problem more carefully. Finally, we found real female gametophytes of *S. ilicifolium* and compared them with those of the "*S. ilicifolium*" or *S. ilicifolioides* as we call it now, and we discovered some differences. First, in *S. ilicifolioides*, the leaves on the upper parts of the plant are lanceolate and are smaller than the leaves on the lower parts of the plant, which are ellipsoidal. In *S. ilicifolium*, the leaves are obovate or ellipsoidal throughout the whole plant. Second, the glandular dots of *S. ilicifolioides* are evidently elevated, whereas those of *S. ilicifolium* are more or less plane.

Fig. 31. *Sargassum ilicifolium* (Turner) C. Agardh. a, Leaves. b, Fertile branches with leaves, vesicles, and female receptacles. c, Male receptacles.

Sargassum ilicifolium (Turner) C. Agardh was previously studied by C. Agardh (1824, p. 296), J. Agardh (1848, p. 318; 1889, p. 94), Reinbold (1913, p. 160), Grunow (1915, p. 402), Yamada (1925, p. 246), Chou and Chiang (1981, p. 137), Modelo and Umezaki (1995, p. 23, figs. 4a–d, 21), and Nguyen Huu Dai (1997, p. 116, fig. 46).

15a. *Sargassum ilicifolium* var. *conduplicatum* Grunow, Verh. K.-K. Zool.-Bot. Gesell. Wien 66:405, 1915.

(Figs. 16 and 32)

Fronds yellow-brown, more than 1 m tall. Holdfast discoid, 1 cm in diameter. Axis short, cylindrical, glabrous, 5 mm long. Primary branches subcylindrical, slightly compressed, glabrous, 1 m long, 2 mm in diameter; secondary branches arising from the axils of the primary branches, similar to the primary branches in shape, alternate, up to 20 cm long, 1–1.5 mm in diameter, at intervals of 3–4 cm; ultimate branchlets shorter and slender, about 5–7 cm long, 1 mm in diameter. Leaves elongated-ellipsoidal, up to 3 cm long, 12 mm wide, rounded at the apex, usually duplicate, but not forming cuplike structure, asymmetrical, with conspicuously oblique bases, thick, elevated midribs, not percurrent, usually vanishing at middle parts of the leaves, denticulate at the margins, with cryptostomata irregularly scattered on both sides of the midrib. Vesicles mostly spherical, 7 mm in diameter, some small, obovate with earlike wings on both sides.

Plants dioecious. Receptacles furcate, racemosely arranged on fertile branches. Female receptacles spinulose, compressed, up to 3 mm long, 2 mm wide. Male receptacles compressed, up to 4 mm long, 1.5 mm wide, with some spinules.

Specimens Examined: Tseng 1063, AST 55-0665, 58-5340, 58-5342, 73-0402, 73-0495, 73-0688, 75-0854, and 80-2049, collected from Sanya Beach, Hainan Island.

Habitat: Growing on lower intertidal to subtidal rocks.

Distribution: Japan and Sri Lanka.

Remarks: *Sargassum ilicifolium* var. *conduplicatum* Grunow was studied by Yamada (1942, p. 556, fig. 27) and Yoshida (1988, p. 15, fig. 12; 1998, p. 387).

Acknowledgments

This chapter is contribution No. 3863 from the Institute of Oceanology, Chinese Academy of Sciences, Qingdao. We thank Dr. James J. Sullivan, former director, California Sea Grant College Program, and Dr. Isabella A. Abbott for their kind invitation to attend the wonderful meeting in Vietnam. We thank Dr. Abbott for reading and editing our manuscript. Thanks also to Ms. Li Shiling for her help with our drawings and to Mr. Zhou Xiantong for his help in preparing the manuscript.

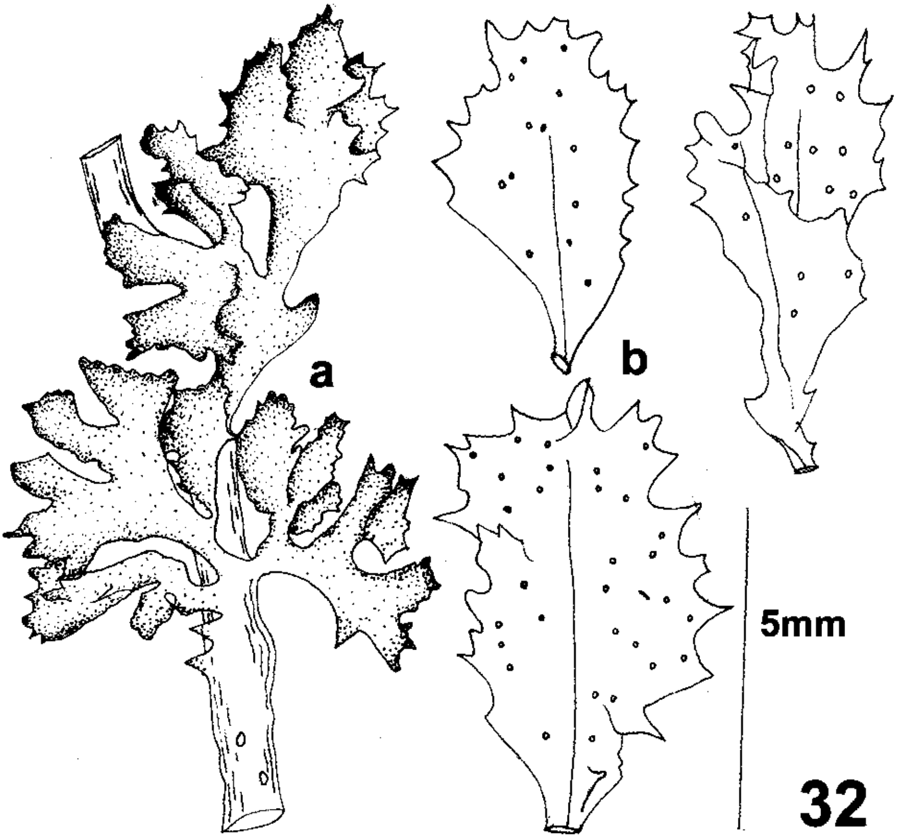

Fig. 32. *Sargassum ilicifolium* var. *conduplicatum* Grunow. a, Female receptacles. b, Duplicate leaves.

Literature Cited

Agardh, C. A. 1820. Species algarum, vol. 1. iv + 168 pp. Berling, Lund.

Agardh, C. A. 1824. Systema algarum. xxxviii + 312 pp. Berling, Lund.

Agardh, J. G. 1848. Species, genera et ordines algarum I. Species genera et ordines fucoidearum. I. vii + 363 pp. Gleerup, Lund.

Agardh, J. G. 1889. Species Sargassorum Australiae descriptae et dispositae. Kgl. Svenska Vet.-Akad. Handl. 23:1–133, pls. 1–31.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Ang, P., Jr., Phang, S. M., Noro, T., and Yoshida, T. 1997. Taxonomic and nomenclatural study of *Sargassum duplicatum* Bory and related species. In: Tax. Econ. Seaweeds 6, pp. 27–36, figs. 1–12.

Biswas, M. A. 1950. *Sargassum* of Indian seas. J. R. Asiat. Soc. Bengal. Sci. 16:79–97, figs. 1–5.

Chou, H. N., and Chiang, Y. M. 1981. The *Sargassum* of Taiwan. Acta Oceanogr Taiwanica 12:132–149, pl. I, figs. 1–9; pl. II, figs. 1–6; pl. III; figs. 1–6.

Grunow, A. 1915. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 65:329–448.

Grunow, A. 1916. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 66:1–48; 136–185.

Kützing, F. T. 1861. Tabulae phycologicae. Vol. 11, pp. 1–31, pls. 1–100. W. Koehne and author, Nordhausen.

Modelo, R. B., Jr., and Umezaki, I. 1995. Contribution to the study of the genus *Sargassum* (Fucales, Phaeophyceae) of the Philippines. Philipp. J. Sci. Special issue, pp. 1–50, pls. 1–37.

Nguyen Huu Dai. 1997. Sargassaceae in Vietnam. Agriculture Publishing House, Ho Chi Minh City, 199 pp. (in Vietnamese).

Noro, T., Ajisaka, T., and Yoshida, T. 1994. Species of *Sargassum* subgenus *Sargassum* (Fucales) with compressed primary branches. In: Tax. Econ. Seaweeds 4, pp. 23–31, figs. 1–6.

Pham Hoang Ho. 1967. Contribution à l'étude des algues littorales du Vietnam: le genre *Sargassum*. Ann. Fac. Sci. Saigon, pp. 259–332, figs. 1–32 (in French).

Reinbold, T. 1913. *Sargassum*. In: Weber-von Bosse, A. Myxophyceae, Chlorophyceae, Phaeophyceae. Siboga Exped. Monogr. 59a:150–174.

Setchell, W. A. 1931. Hong Kong seaweeds: II. Hong Kong Nat. Suppl. 2: 237–253, 40 figs.

Setchell, W. A. 1936. Hong Kong seaweeds: V. Sargassaceae. Hong Kong Nat. Suppl. 5:1–20, pls. 1–8.

Silva, P. C., Basson, P. W., and Moe, R. L. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Press, Berkeley, xi + 1259 pp. Publ. Bot. 7.

Tseng, C. K., and Lu Baoren. 1978. Studies on the Sargassaceae of the Xisha Islands, Guangdong Province, China: I. Stud. Mar. Sin. 12:1–11, pls. 1–5.

Tseng, C. K., and Lu Baoren. 1997a. Studies on the biserrulic *Sargassum* of China: I. Taxonomy of the subsection Biserrulae. In: Tax. Econ. Seaweeds 6, pp. 3–6.

Tseng, C. K., and Lu Baoren. 1997b. Studies on the glomerulate *Sargassum* of China: V. Series of Platycarpae. In: Tax. Econ. Seaweeds 6, pp. 9–25, figs. 1–14.

Tseng, C. K., and Lu Baoren, 1999. Studies on the biserrulic *Sargassum* of China: II. The Series Coriifoliae J.G. Agardh. In: Tax. Econ. Seaweeds 7, pp.3–22, figs. 1–17.

Turner, D. 1819. Fuci sive pllantarum fucorum generia botanicis ascriptarum icones descriptriones et historia. Vol. IV, pp. 1–153, pls. 1–153. M'Creery, London.

Yamada, Y. 1925. Studien über die Meeresalgen von der Insel Formosa: 2. Phaeophyceae. Bot. Mag. Tokyo 39(465):239–254.

Yamada, Y. 1942. Notes on *Sargassum* from the southern parts of Japan. Jpn. Bot. 18; pp. 369–381; 503–519; 553–562 (in Japanese).

Yamada, Y. 1950. A list of marine algae from Ryukyusho, Taiwan. Sci. Pap. Inst. Algal. Res. Fac. Sci. Hokkaido Imp. Univ. 3:173–194.

Yoshida, T. 1988. Japanese and Taiwanese species of *Sargassum* subgenus *Sargassum*. In: Tax. Econ. Seaweeds 2, pp. 5–21.

Yoshida, T. 1998. Marine algae of Japan. Uchida Rokakuho Publishing, Tokyo, 1222 pp. (in Japanese).

Zeng (Tseng), C. K., Lu Baoren, and Ding Lanping. 1998. Some non-zygocarpic *Sargassum* from Nansha Islands, South China Sea. Stud. Mar. Fauna Flora Biogeogr. Nansha Islands Neighb. Waters 3:1–18, pls. 1–3.

SARGASSUM SPECIMENS FROM SINGAPORE AND MALAYSIA IN THE HERBARIUM OF THE BISHOP MUSEUM

Tetsuro Ajisaka

Abstract

Sargassum specimens from Singapore and Malaysia (Sabah and Pinang islands) deposited by the late Dr. M. S. Doty at the Bishop Museum herbarium in Honolulu were examined. Morphological characteristics were studied and compared, and 7 species were identified: *Sargassum siliquosum, S. binderi, S. oligocystum, S. baccularia, S. polycystum, S. stolonifolium,* and *S. swartzii. Sargassum swartzii* and 2 unidentifiable specimens are described in detail. Three localities beyond the type locality of Batu Ferringhi on Pinang Island were established for *S. stolonifolium. Sargassum swartzii* is a new record from Malaysia.

Introduction

Many *Sargassum* specimens from the herbarium of the late Dr. M. S. Doty were deposited in the Bishop Museum, Honolulu, Hawaii, U.S.A. Dr. Doty collected many useful species of colloid-bearing taxa (*Gracilaria* and *Eucheuma*) and alginic acid-bearing taxa (*Sargassum*). Most of the *Sargassum* specimens that he collected in Singapore and Malaysia[1] (Sabah and Pinang islands) from 1960 to 1980 were not identified by anyone.

In volume 7 of this series of books on the taxonomy of economic seaweeds, 8 species of *Sargassum* from Malaysian coasts (peninsular Malaysia and Sabah Province in Borneo) were reported (Ajisaka et al. 1999).

Most of the Doty specimens could be identified within the species reported in volume 7. However, *S. swartzii* (Turner) C. Agardh is new from Pinang Island, Malaysia. In the following list, some specimens were represented by a part of plant; these specimens are designated by question mark (?). For instances in which several individual plants of different species are on the same sheet, an asterisk (*) is used for some specimens. Two specimens were not recognized as species known to me, so I composed descriptions for them.

Identified Specimens

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

(Figs. 1–7)

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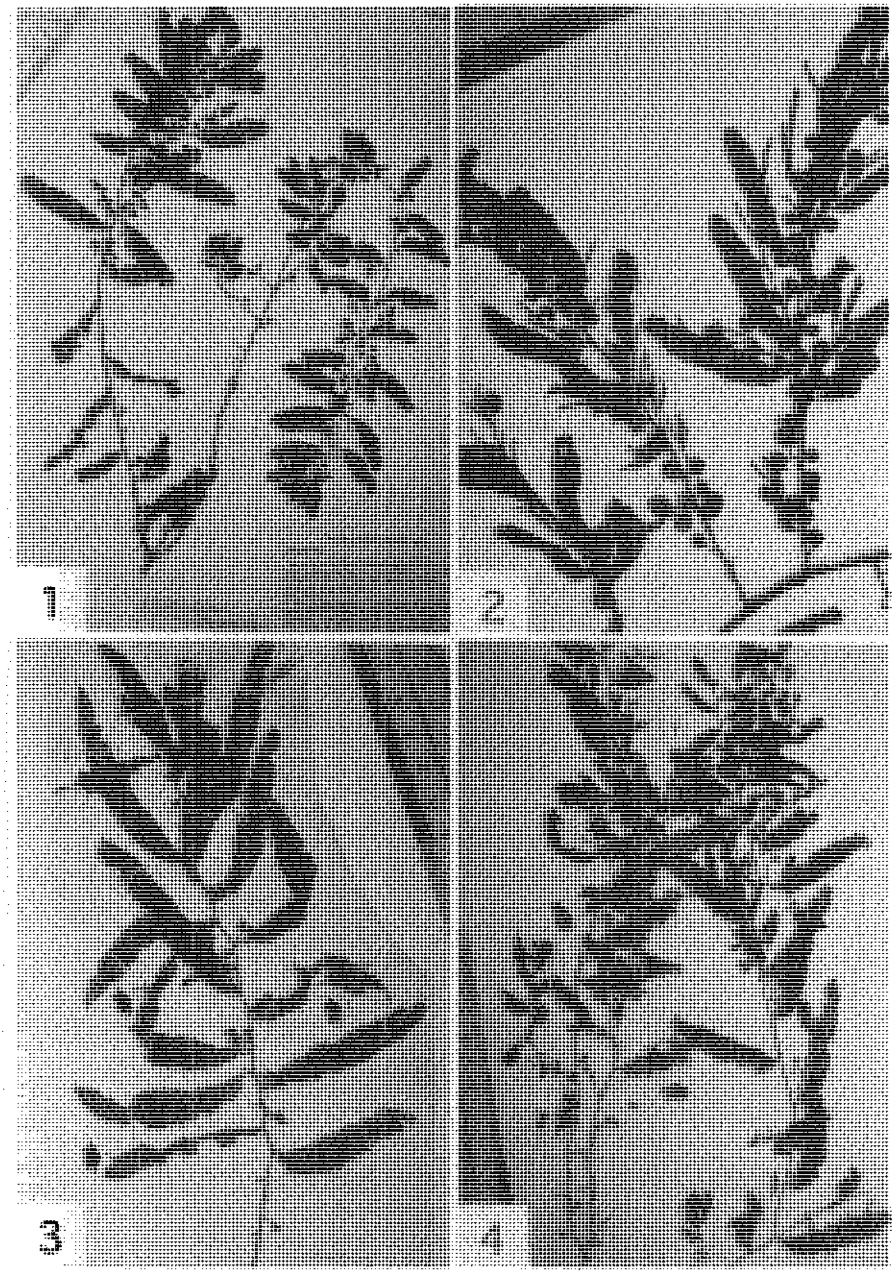
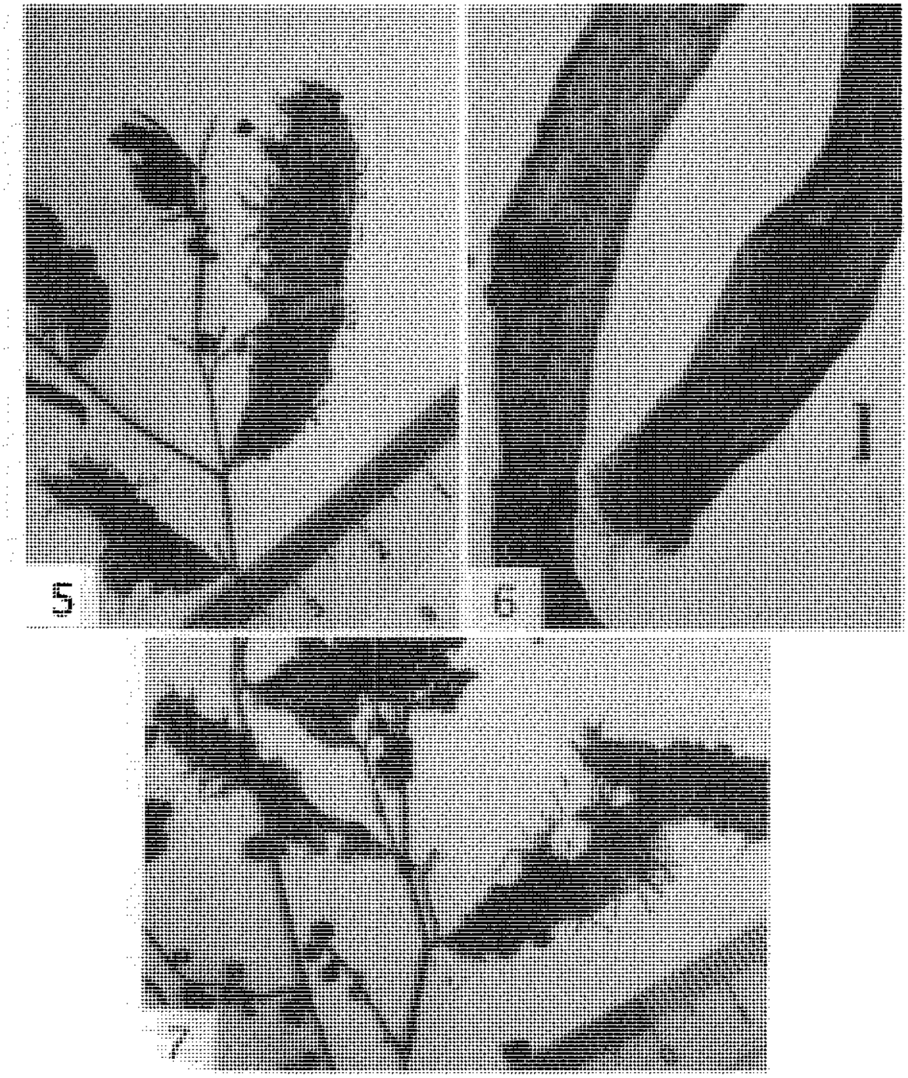
[1] Editor's note: In the Malay language, pasir means sand or sandy. The word pulau means island, and Hantu, Saltra, Sabar-Darat, and Sudong are names of islands mentioned in this chapter. The word tanjong means point or peninsula, teluk means bay, and kota means castle or city. I thank Jack Fisher for this translation help. I. Abbott



Figs. 1–4. *Sargassum siliquosum* J. G. Agardh. Fig. 1, Habit of whole juvenile plant (BISH 559779). Fig. 2, Upper branchlets with leaves, vesicles, and male receptacles (BISH 559778). Fig. 3, Main branch with developing juvenile (arrows; BISH 559820). Fig. 4, Main branches with developing juveniles (arrow; BISH 570094).



Figs. 5–7. ***Sargassum siliquosum*** **J. G. Agardh (BISH 570094). Figs. 5 and 7, Magnification of leaves with many developing juveniles. Fig. 6, Juvenile plants with rhizoidal filaments (scale bar = 1 mm).**

Specimens From Singapore: From Pulau Sudong, BISH 559776* and 559832; from Pulau Hantu, BISH 559820; from Raffles Light House, BISH 57006; from Pulau Saltra, BISH 41616 and 41618; from Tanjong Berlayear ("Labrador"), BISH 559715, 570094, 41619, 41620, and 41621; and from Pulau Sabar-Darat, BISH 41624 and 41625.

Specimens From Sabah, Malaysia: From Semporna, BISH 559778 and 559779; from Kota Kinabaru, BISH 560598 and 560616; and from Pulau Gaya, BISH 560263.

Remarks: *Sargassum siliquosum* J. G. Agardh is a widely distributed species in the tropical western Pacific. The leaves of 2 specimens (BISH 559820 and 570094) had crowded filaments (Figs. 3–5, 7). Microscopic examination revealed that the filaments were the juvenile plants developing from the embryos (Fig. 6). Mature embryos (fertilized eggs) dropped on the basal leaves of mother plants in calm conditions and developed into juvenile plants.

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

Specimens From Singapore: From Johore Strait, BISH 560691 and 560835*.

Remarks: Malaysian specimens were identified as *S. binderi* Sonder on the basis of sharply dentate receptacles. However, Womersley and Bailey (1970) synonymized this species with *S. oligocystum* Montagne, which lacks dentate margins on receptacles and instead has a few spines or lacks spines entirely. As distinguished by J. G. Agardh (1848) and supported by Tseng and Lu (1995), *S. binderi* should be recognized as a species separate from *S. oligocystum*.

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

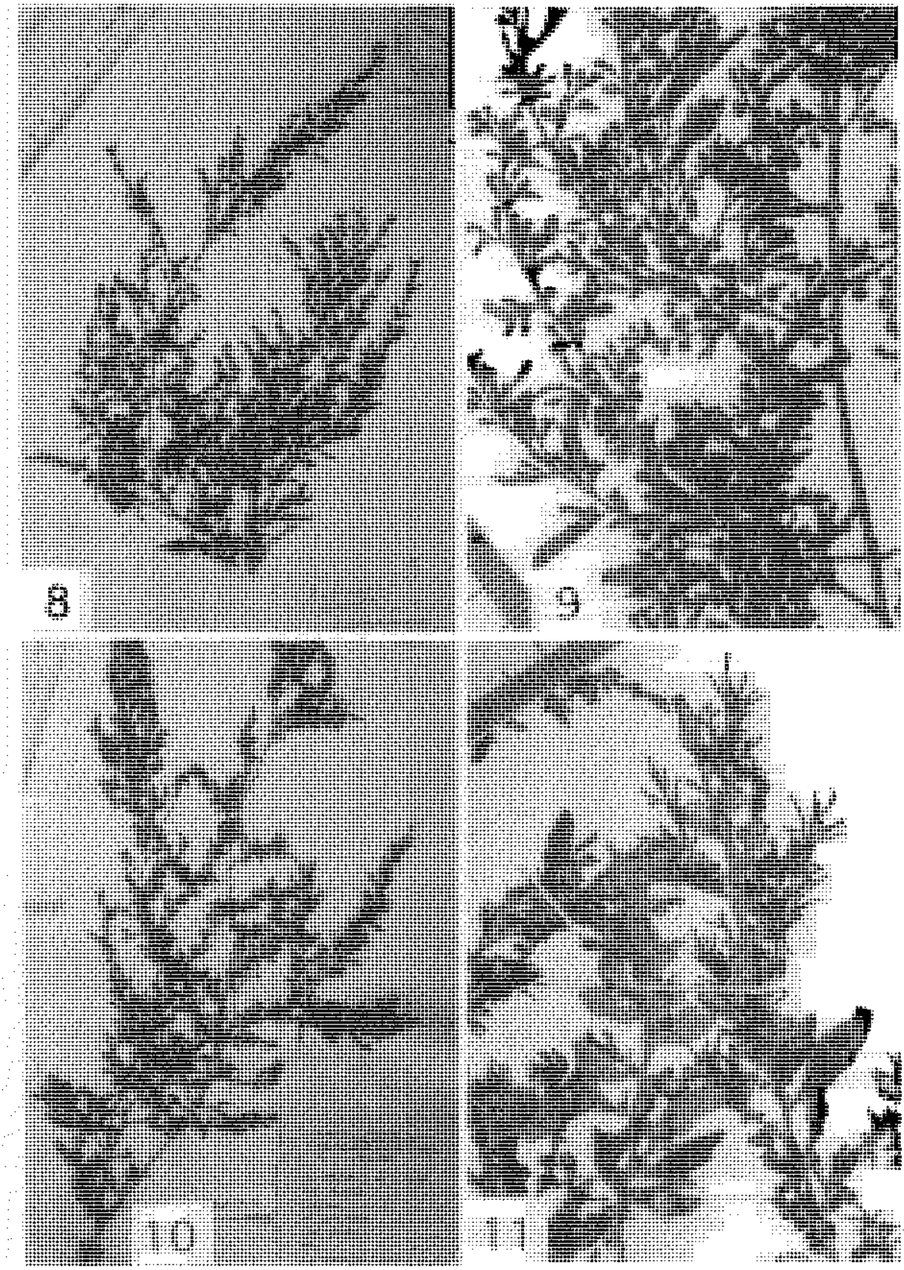
Specimens From Singapore: From Pulau Hantu, BISH 560800; from Pulau Saltra, BISH 41617.

Specimens From Sabah, Malaysia: From Creagh Reef, BISH 559773.

Remarks: *Sargassum oligocystum* Montagne is also a widely distributed species in the tropical western Pacific. In Sabah, Malaysia, many specimens were collected around Tawau and Kota Kinabaru (Ajisaka et al. 1999); the species is rare in peninsular Malaysia.

Sargassum baccularia (Mertens) C. A. Agardh, Syst. algarum, p. 304, 1824.
(Figs. 8–11)

Specimens From Singapore: From Tanjong Pasir Laba, BISH 490772, 560833, and 560250; from Tanjong Gul, BISH 559818; from Tanjong Berlayear ("Labrador"), BISH 41614; from Pulau Hantu, BISH 41622; from Pulau Sabar-Darat, BISH 41623; from "Singapore;" BISH 490772.



Figs. 8–11. *Sargassum baccularia* (Mertens) C. A. Agardh. Fig. 8, Habit of whole female plant (BISH 490772). Fig. 9, Plant shown in Fig. 8 enlarged to show leaves, vesicles, and female receptacles. Fig. 10, Habit of whole male plant (BISH 41614). Fig. 11, Plant shown in Fig. 10 enlarged to show upper branchlets with leaves, vesicles, and male receptacles.

Remarks: *Sargassum baccularia* (Mertens) C. A. Agardh was recently collected from Port Dickson, western coast of Malaysia (Ajisaka et al. 1999), in peninsular Malaysia and was not collected from Sabah (Borneo).

Sargassum polycystum C. A. Agardh, Syst. algarum, p. 304, 1824.

Specimens From Singapore: From Pulau Sudong, BISH 559776(?)* and 560856*; from Johore Strait, BISH 559870(?) and 560835(?)*; from Tanjong Berlayear ("Labrador"), BISH 570007(?) and 559707; from Pulau Sabar-Darat, BISH 41623(?)*.

Specimens From Sabah, Malaysia: From Pulau Gaya, BISH 559780.

Remarks: *Sargassum polycystum* is one of the most widely distributed species in the western Pacific and Indian oceans and as such can be expected to have large variations in morphology. The species is characterized by secondary holdfasts (rhizoids) formed on the stem and heavily muricate main branches.

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

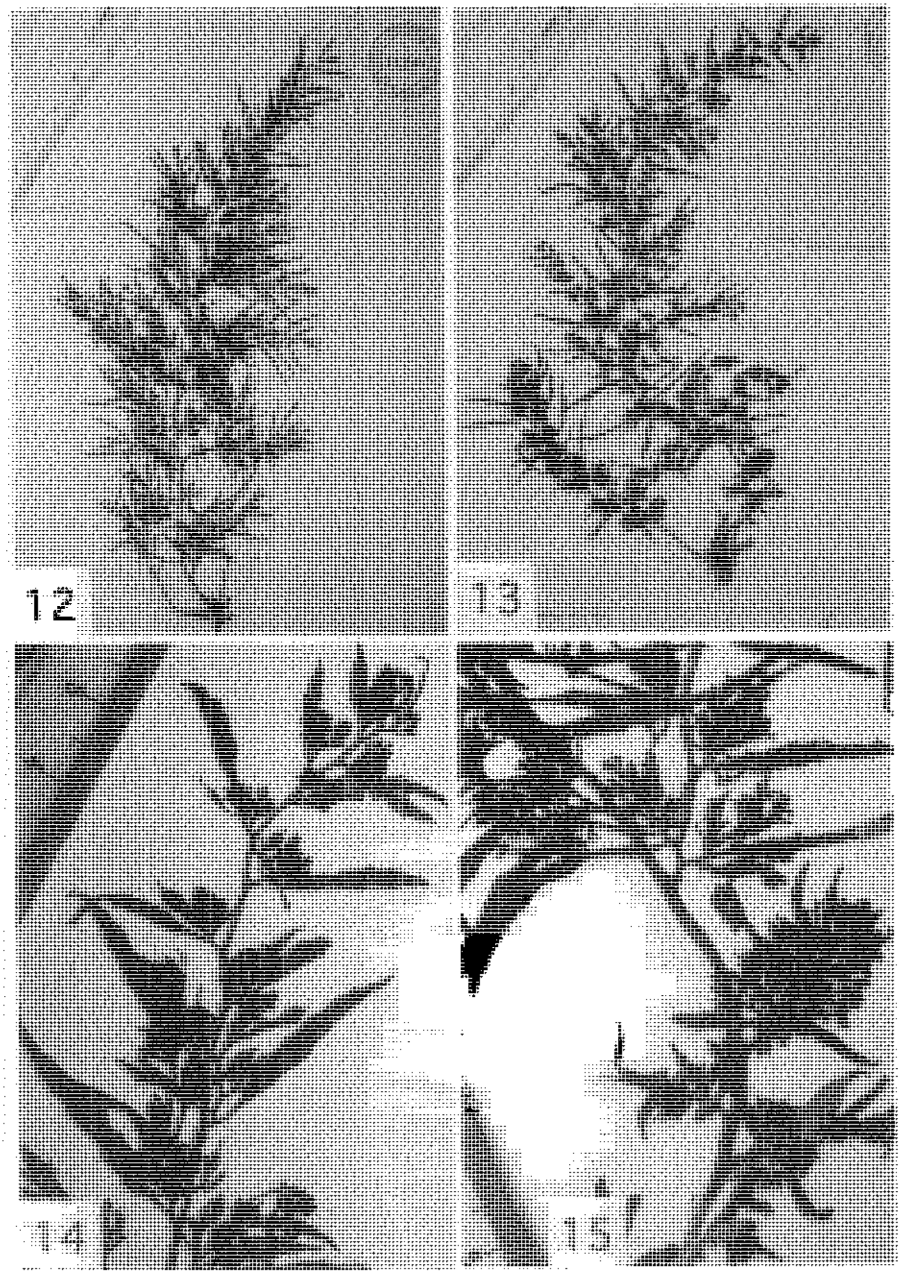
Specimens From Malaysia: From Pinang Island, Teluk Bayu, BISH 559789 and 559790; from Tanjong Chut, BISH 560631, 560633, and 560635; from "Sunshine Beach," BISH 570003.

Remarks: The type locality of *S. stolonifolium* Phang et Yoshida is Batu Ferringhi on Pinang Island (Phang and Yoshida 1997), which is in the neighborhood of the new sites. This species may be widely distributed along the Andaman Sea. I have collected this species along the western coasts of Thailand. It is characterized by secondary holdfast (rhizoids) transformed from the cauline leaves on the stem.

Sargassum swartzii (Turner) C. A. Agardh, Syst. algarum, p. 296, 1824.
(Figs. 12–15)

Specimens From Malaysia: From Pinang Island, Tanjong Chut, BISH 559786, 560627, and 560632.

Holdfast discoid, up to 12 mm in diameter. Stem terete, up to 10 mm long, up to 2.5 mm in diameter, smooth on the surface, issuing main branches radially. Main branches up to 80 cm long, compressed, 3–3.5 mm wide, 1–1.5 mm thick, issuing secondary branches distichously: secondary branches also compressed, branched distichously. Leaves of the basal parts of main branches elongated lanceolate, up to 4.7 cm long, up to 7 mm wide, asymmetrical at the base, acute at the apex, margin entire or slightly dentate, midrib obscure and immersed at the apex, cryptostomata small and scattered; leaves of the distal parts of secondary branches linear lanceolate to linear, up to 5.5 cm long, up to 3 mm wide, asymmetrical at the base, acute toward the apex, margin entire, midrib obscure and vanishing near the apex, cryptostomata arranged on each side of the midrib;



Figs. 12–15. *Sargassum swartzii* (Turner) J. G. Agardh. Fig. 12, Habit of whole young plant (BISH 560627). Fig. 13, Habit of whole mature plant (BISH 560632). Figs. 14 and 15, Plant in Fig. 13 enlarged to show upper branchlets with leaves, vesicles, and receptacles (Fig. 14), and middle branchlets with leaves and receptacles (Fig. 15).

vesicles elliptical, up to 8 mm long, up to 4 mm wide, pointed at the apex or 1–4 mm mucronate; petioles of vesicles cuneate, 8–12 mm long, sometimes longer than the vesicles.

Plants monoecious. Receptacles androgynous, compressed, up to 7 mm long, up to 1.5 mm wide, margin dentate with sharp spines, closely clustered and forked 2–3 times, holozygocarpic with small leaves and vesicles.

Remarks. This record is the first one of *S. swartzii* (Turner) C. A. Agardh from Malaysia. This species may be widely distributed along the Andaman Sea, as is *S. stolonifolium*. I have collected this species in the southern area of Pinang Island and along the western coasts of Thailand. *Sargassum swartzii* has compressed main branches, but it can be distinguished from *S. binderi* and *S. oligocystum* on the basis of its slender leaves and smaller vesicles with mucronate and closely clustered receptacles.

Unidentifiable Specimens

Sargassum sp. 1.

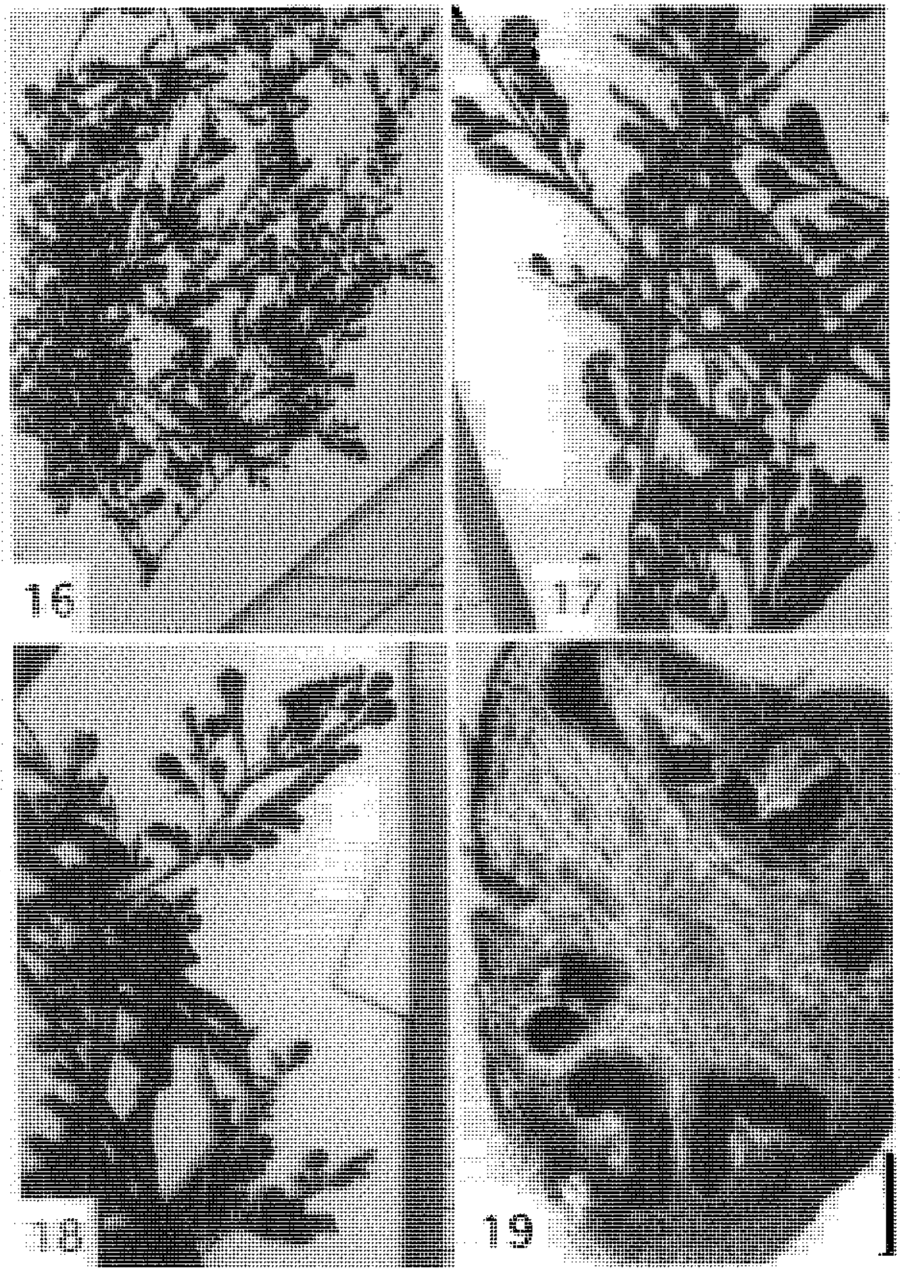
(Figs. 16–19)

Holdfast discoid, about 9 mm in diameter. Stem short, terete, up to 3 mm long, up to 2 mm in diameter, with smooth surface, forming 3 or more main branches radially. Main branches terete, up to 1.5 mm in diameter, up to 45 cm long, with smooth surface, issuing secondary branches spirally; secondary branches terete, up to 10 cm long, with smooth surface. Leaves lanceolate, up to 2.5 cm long, up to 7 mm wide, with round apex, margin with small to coarse dentations, midrib distinct and vanishing below the apex; cryptostomata scattered; vesicles variable in shape, spherical to elliptical, up to 5 mm in diameter, but sometimes smaller, usually entire at the apex; petioles of vesicles variable in shape, cylindrical, cuneate to leafy, usually longer than the vesicles.

Plants dioecious (?). Female receptacles slightly compressed, fusiform, up to 3 mm long, up to 0.5 mm wide, forked 2–3 times, with coarse spines on the margin, pseudozygocarpic with small vesicles.

Specimen Examined: BISH 560678. This single specimen, which has female receptacles, was collected by M. S. Doty, January 23, 1965, from Tanjong Berlayear ("Labrador"), Singapore.

Remarks: In general morphology and features of the leaves, this specimen resembles the female plants of Malaysian *S. baccularia* (Ajisaka et al. 1999 and this chapter). Although the leaves of this specimen are larger, they are similar to the lower leaves of the female plants of *S. baccularia*. However, the vesicles are 4–5 times larger (up to 5 mm in diameter) than those of *S. baccularia*, and the petioles of the vesicles are longer than the vesicles; in *S. baccularia*, the petioles are shorter than the vesicles. The receptacles of this specimen are compressed to fusiform with coarse spines at the margins, but the female receptacles of *S. baccularia* are short, conical and with warty surfaces and sometimes with spines



Figs. 16–19. *Sargassum* sp. 1 (BISH 560678). Fig. 16, Habit of whole plant. Figs. 17 and 18, Upper branchlets with leaves, vesicles, and female, holozygocarpic receptacles. Fig. 19, Transection of female receptacle (scale bar = 100 µm).

at the apex. Because only a single female plant was collected, I cannot be certain whether these features are normal morphological variations from *S. baccularia* or not.

Sargassum sp. 2.

(Figs. 20–23)

Holdfast discoid, flattened, up to 12 mm in diameter. Stem terete, up to 5 mm long, 3 mm in diameter, warty on the surface, issuing main branches radially. Main branches up to 35 cm long, terete, up to 2 mm in diameter, with smooth surface, forming secondary branches spirally; secondary branches terete, up to 7 cm long, up to 1 mm in diameter, with smooth surface. Leaves lanceolate, up to 16 mm long, up to 4.5 mm wide, with acute apex, margin coarsely dentate, midrib distinct and vanishing below the apex, cryptostomata scattered or arranged in 2 rows along the midrib; most vesicles had fallen off; vesicles elliptical, up to 1 mm in diameter, usually entire at the apex, sometimes with earlike appendages; petioles of vesicles cylindrical, the same size or slightly longer than the vesicles.

Plants dioecious (?). Male receptacles cylindrical to fusiform, up to 5 mm long, up to 0.5 mm in diameter, forked 1–2 times, with smooth surface.

Specimen Examined: BISH 560664. This single specimen, which has male receptacles, was collected by H. M. Burkill, October 8, 1960, Singapore, from a coral reef in the lower littoral at Raffles Light.

Remarks: This specimen is similar to male plants of Malaysian *S. baccularia* (Ajisaka et al. 1999 and this chapter). The leaves on the upper part of the plant are similar to but smaller than those in *S. baccularia*. Vesicles have the same dimensions of those of *S. baccularia* but are elliptical rather than spherical and the petioles are longer. Male receptacles in this specimen are up to 5 mm long, whereas they are up to 3 mm long in *S. baccularia*. I hope to examine more materials in order to determine the variations between the 2 Bishop specimens that could not be identified and between those 2 specimens and *S. baccularia*.

Acknowledgments

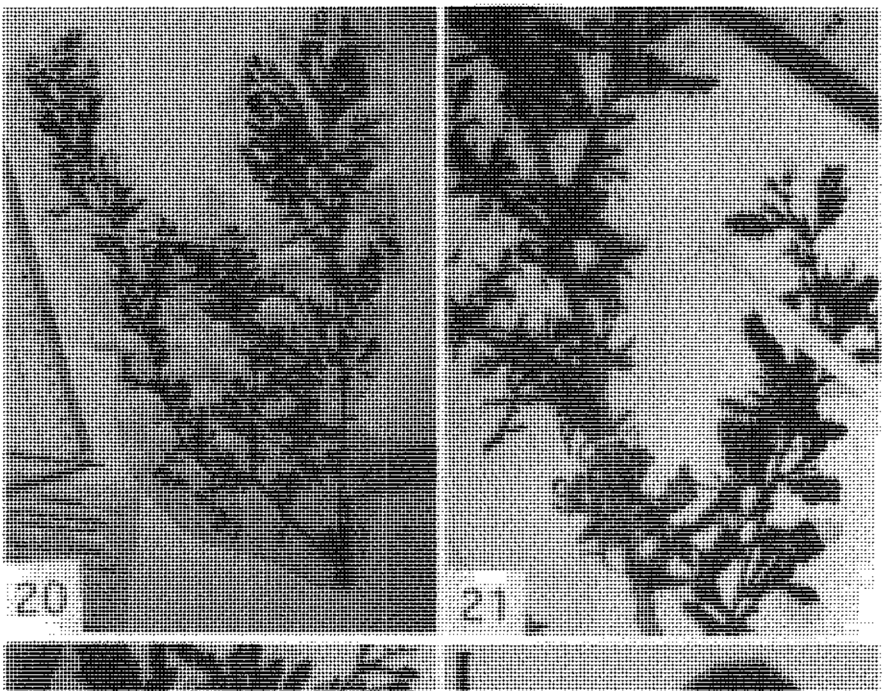
I thank Dr. Isabella Abbott, the University of Hawaii, and Jack Fisher, the Bishop Museum, for their kindness in sending me this collection of *Sargassum* specimens to study. I am grateful for the corrections that Dr. Abbott made to the original manuscript.

Literature Cited

Agardh, J. G. 1848. Species, genera et ordines algarum I. Species genera et ordines fucoidearum. I. viii + 363 pp. Gleerup, Lund.

Ajisaka, T., Phang, S. M., and Yoshida, T. 1999. Preliminary report of *Sargassum* species collected from Malaysian coasts. In: Tax. Econ. Seaweeds 7, pp. 23–41, figs. 1–8.

Phang, S. M., and Yoshida, T. 1997. *Sargassum stolonifolium* Phang et Yoshida sp. nov.



Figs. 20–23. ***Sargassum*** **sp. 2 (BISH 560664). Fig 20, Habit of whole male plant. Figs. 21 and 22, Upper branchlets with leaves, vesicles, and male receptacles. Fig. 23, Transection of male receptacle (scale bar = 100 μm).**

from Pinang Island, Peninsular Malaysia. In: Tax. Econ. Seaweeds 6, pp. 61–73, figs. 1–9.

Tseng, C. K., and Lu Baoren. 1995. Studies on the glomerulate *Sargassum* of China: III. The species group *Binderia*. In: Tax. Econ. Seaweeds 5, pp. 93–106, figs.1–13.

Womersley, H.B.S., and Bailey, A. 1970. Marine algae of the Solomon Islands. Phil. Trans. R. Soc. 259:257–352.

A MOLECULAR STUDY OF SECTION-LEVEL CLASSIFICATION OF *SARGASSUM* SUBGENUS *BACTROPHYCUS* (SARGASSACEAE, PHAEOPHYTA)

Tadao Yoshida, Valerie Stiger, Tetsuro Ajisaka, and Tadahide Noro

Abstract

A group of species of *Sargassum* with distinctive morphology of vesicles designated as the section *Phyllocystae* is currently attributed to the subgenus *Bactrophycus*. In addition to morphological study, molecular systematics has provided a basis for phylogenetic evaluation of characters. Comparison of partial 5.8S gene and internal transcribed spacer 2 sequences of nuclear ribosomal DNA indicated that the section *Phyllocystae* should be transferred to the subgenus *Sargassum*.

Introduction

A group of *Sargassum* species has vesicles with a distinctive morphology. The vesicles as a whole are similar to ordinary leaves, and the central part of the leaf becomes inflated and hollow. For this kind of vesicles, the term *phyllocyst* was proposed by Tseng and Lu (1978) when they described the Chinese species *S. phyllocystum* and *S. emarginatum*, both from Xisha Islands, South China Sea. *Sargassum mcclurei* Setchell and *S. herklotsii* Setchell from Hong Kong have similar kinds of vesicles. Setchell (1936) recognized this peculiar characteristic and gave the name "*Sargassa asiatica* group" to plants with this characteristic, which included *S. mcclurei* and *S. herklotsii*.

Tseng (1985) proposed a new section, *Phyllocystae*, with the type species *S. phyllocystum*, and included this section in the subgenus *Bactrophycus*, although the receptacles are generally compound, sometimes triquetrous, and the leaves are without retroflexed petioles even in the lower parts of main branches. The section *Phyllocystae* was composed of *S. emarginatum*, *S. herklotsii*, *S. mcclurei*, and *S. phyllocystum*. Nguyen (1992) described from Vietnam *S. quinhonense*, which shares the characteristic phyllocysts.

Recent progress in molecular systematics has provided a basis for phylogenetic evaluation of morphological characters and relationships of subgeneric taxa. Comparison of partial 5.8S gene and internal transcribed spacer 2 (ITS-2) sequences of nuclear ribosomal DNA (nrDNA) is useful for this purpose (Stiger et al. 2000). The results indicate that the section *Phyllocystae* should be transferred to the subgenus *Sargassum*.

Materials and Methods

Specimens of *Myagropsis myagroides* and specimens of 18 species of *Sargassum*, belonging to 3 subgenera, collected from various localities were used in the study (Table 1). Specimens of *S. crassifolium* were collected from 2 locations. Specimens of *S. mcclurei* (Fig. 1) were collected near the Institute of Oceanography, Nha Trang, Vietnam, during the eighth workshop on the taxonomy of seaweeds. Dried material of *S. quinhonense* was supplied by Nguyen Huu Dai.

The protocols used for DNA extraction, polymerized chain reaction, and sequencing have been described (Stiger et al. 2000). Partial 5.8S gene and ITS-2 sequences were directly sequenced by using an autosequencer (ABI PRISM 3100 Genetic Analyzer, Applied Biosystems/Hitachi, Foster City, Calif.). Both DNA strands were sequenced. Sequences were aligned in accordance with common secondary structure by using the methods of Mai and Coleman (1997) and the mfold program (Zuker 1989). Data were analyzed by using neighbor-joining, maximum-likelihood, and most-parsimonious algorithms.

Table 1. List of Species Studied and Their Location and Date of Collection

Species	Collection Site	Date
Myagropsis myagroides (Turner) Fensholt	Nagasaki Prefecture, Japan	May 15, 1999
Sargassum binderi Sonder	Port Dickson, Malaysia	January 6, 1998
S. boryi C. Agardh	Larengniere, New Caledonia	May 1999
S. carpophyllum J. Agardh	Nagasaki Prefecture, Japan	June 3, 1999
S. confusum C. Agardh	Rishiri, Hokkaido, Japan	July 26, 1999
S. crassifolium J. Agardh	Nha Trang, Vietnam	May 6, 1999
S. crassifolium J. Agardh	Okinawa Prefecture, Japan	June 1, 1999
S. duplicatum Bory	Port Dickson, Malaysia	May 1999
S. filicinum Harvey	Kumamoto Prefecture, Japan	January 23, 1999
S. horneri (Turner) C. Agardh	Kumamoto Prefecture, Japan	January 23, 1999
S. mangarevense Setchell	Tahiti, French Polynesia	1998
S. mcclurei Setchell	Nha Trang, Vietnam	April 28, 1999
S. miyabei Yendo	Rishiri, Hokkaido, Japan	July 26, 1999
S. myriocystum J. Agardh	Okinawa Prefecture, Japan	June 1, 1999
S. nigrifolium Yendo	Chiba Prefecture, Japan	May 18, 1999
S. polycystum C. Agardh	Nha Trang, Vietnam	May 6, 1999
S. quinhonense Nguyen Huu Dai	Nha Trang, Vietnam	May 6, 1999
S. siliquastrum (Turner) C. Agardh	Nagasaki Prefecture, Japan	May 15, 1999
S. sociale (Grunow) Setchell	Tahiti, French Polynesia	March 23, 1999
S. yamamotoi Yoshida	Wakayama Prefecture, Japan	March 4, 1999

Fig. 1. Herbarium specimen of *Sargassum mcclurei*. Collected by T. Yoshida April 28, 1999, at Nha Trang, Vietnam.

Results

The results of maximum-likelihood, most-parsimonious, and neighbor-joining analyses of the partial 5.8S gene and ITS-2 nrDNA sequences are shown in Figure 2. Trees obtained by using the 3 different phylogenetic analyses were congruent.

The analyses revealed 3 monophyletic lineages corresponding to 3 subgenera. *Phyllotrichia* is the early diverging subgenus and is a sister group of *Bactrophycus* and *Sargassum* clades. The branch defining the 2 monophyletic lineages *Bactrophycus* and *Sargassum* is supported by bootstrap values of 100% (maximum-likelihood and most-parsimonious analyses) and 98% (neighbor-joining analyses).

Determination of phylogenetic trees positioned *S. mcclurei* and *S. quinhonense* as sister groups of the clade *S. myriocystum* and *S. polycystum*. The presence of a gap of more than 90 bp at the end of the ITS-2 sequence in *S. mcclurei* and *S. quinhonense* indicates that these 2 species are much closer to the subgenus *Sargassum* than to *Bactrophycus*.

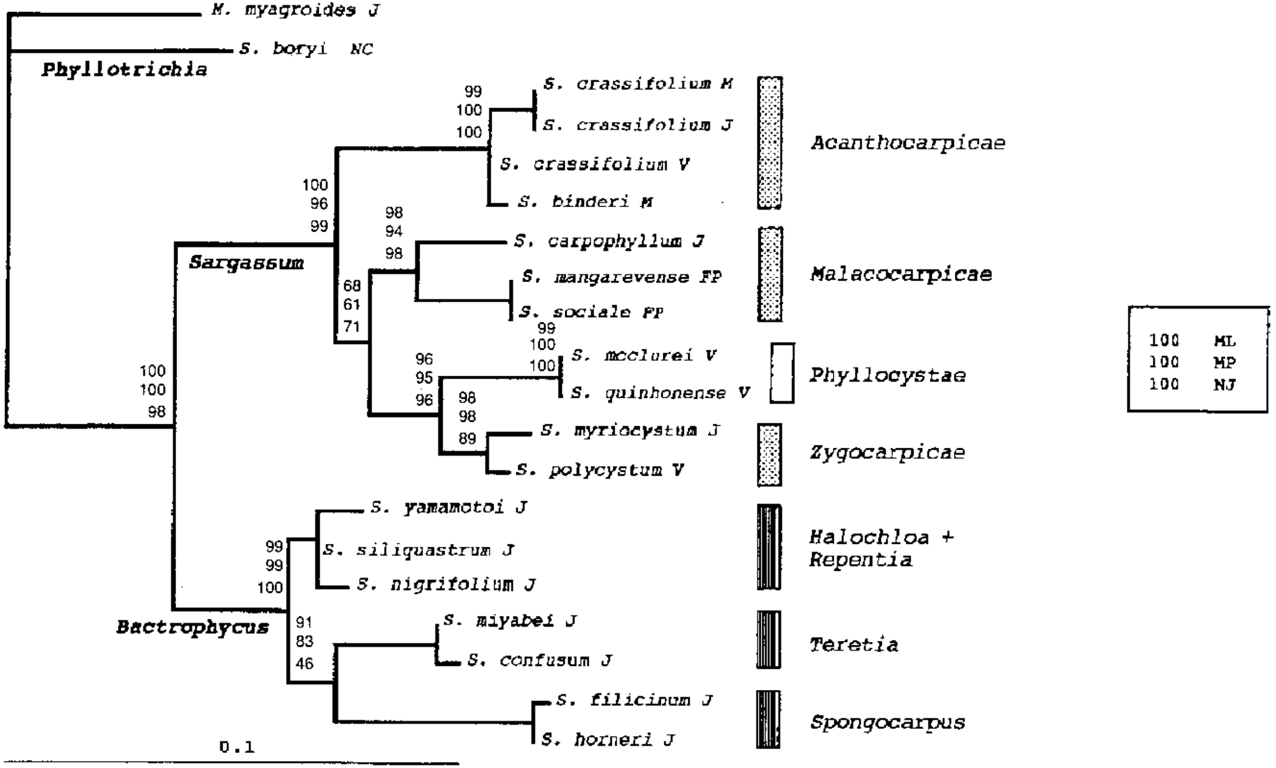


Fig. 2. Phylogenetic analysis of the partial 5.8S gene and internal transcribed spacer 2 sequences of nuclear ribosomal DNA of *Sargassum* species inferred by using the maximum-likelihood (ML) method. Numbers at internal nodes indicate statistical support values obtained by using the bootstrap method with the maximum-parsimony (MP), neighbor-joining (NJ), and quartet-puzzling (ML) analyses. *Myagropsis myagroides* was used as an outgroup. The letter after each species name is the country of collection: J indicates Japan; NC, New Caledonia; M, Malaysia; V, Vietnam; FP, French Polynesia.

Discussion

Our results do not support attribution of *Phyllocystae* within the subgenus *Bactrophycus* (Tseng 1985). According to comparisons of the ITS-2 sequences, *S. mcclurei* and *S. quinhonense* have closer affinities with the species of the subgenus *Sargassum* than with the species included in the subgenus *Bactrophycus*. Exclusion of the section *Phyllocystae* from the subgenus *Bactrophycus* by using the cladistic method is substantiated here, as suggested earlier by Ajisaka (1997).

Currently, 3 sections are recognized in the subgenus *Sargassum*: *Acanthocarpicae*, *Malacocarpicae*, and *Zygocarpicae* (Abbott et al. 1988). The characteristics that distinguish these sections from one another are differences in the morphology of receptacles, whether the receptacles are mixed with vesicles or leaves or have spinous processes. In contrast, the main characteristic of the *Phyllocystae* is the presence of phyllocysts.

Classification at the section level in the subgenus *Sargassum* must be reconsidered in view of molecular data, and morphological characteristics must be reevaluated, taking into account the result of molecular studies with ITS-2 and other regions of DNA. However, at this time, only a few species have been examined by using molecular tools, and it is too early to make profound changes in the genus-level categories that would affect phylogenetic as well as taxonomic relationships. Examination of large numbers of species now divided into 3 sections of subgenus *Sargassum* in order to evaluate where *Phyllocystae* should be placed is a necessary step before the actual transfer is made into subgenus *Sargassum*.

Phillips (1998) did not recommend using ITS regions to determine the phylogeny of *Sargassum* because of the great size differences among *Sargassum* species. Instead she relied on the intergenic spacer in *rbcL* and *rbcS* genes in the chloroplast genome in which the intergenic spacer separates the larger (*rbgL*) from the smaller (*rbcS*) genes in the chloroplast genome. The size differences can be overcome by using the secondary structure of the RNA transcript of ITS-2 sequences, and doing so allows an appropriate primary sequence alignment. Then, the sequences of the partial 5.8S gene and ITS-2 appear to be the best markers to show differences between subgenera and sections within the genus *Sargassum*.

Acknowledgments

Thanks to Nguyen Huu Dai, Institute of Oceanography, Nha Trang, who provided the material of *Sargassum quinhonense*. We acknowledge with sincere thanks Dr. T. Horiguchi, Hokkaido University, for technical support for DNA analysis.

Literature Cited

Abbott, I. A., Tseng, C. K., and Lu Baoren. 1988. Clarification of some subgeneric nomenclature in *Sargassum* subgenus *Sargassum*. In: Tax. Econ. Seaweeds 2, pp. 55–57.

Ajisaka, T. 1997. Cladistic studies in the Fucales and the genus *Sargassum*

(Phaeophyceae) from their morphological and anatomical characters [Abstract]. Phycologia 36(Suppl.):1.

Mai, J. C., and Coleman, A. W. 1997. The internal transcribed spacer 2 exhibits a common secondary structure in green algae and flowering plants. J. Mol. Evol. 44:258–271.

Nguyen Huu Dai. 1992. Mot so loai rong mo (*Sargassum* C. Ag) moi tim thay o Viet Nam. Tap chi Shin Hoc. 14:1–7 (in Vietnamese).

Phillips, N. 1998. Molecular phylogenetic analysis of the Pan-Pacific genus *Sargassum* [Ph.D. dissertation]. University of Hawaii, Honolulu.

Setchell, W. A. 1936. Hong Kong seaweeds: V. Sargassaceae. Hong Kong Nat. Suppl. 5:1–20.

Stiger, V., Horiguchi, T., Yoshida, T., Coleman, A. W., and Masuda, M. 2000. Phylogenetic relationships of *Sargassum* (Sargassaceae, Phaeophyceae) with reference to a taxonomic revision of the section *Phyllocystae* based on ITS-2 nrDNA sequences. Phycol. Res. 48:251–260.

Tseng, C. K. 1985. *Sargassum* sect. *Phyllocystae* sect. nov., a new section of *Sargassum* subgenus *Bactrophycus*. In: Tax. Econ. Seaweeds 1, p. 15.

Tseng, C. K., and Lu Baoren. 1978. Studies on the Sargassaceae of the Xisha Islands, Guandong Province, China: I. Stud. Mar. Sinica 12:1–11. pls. 1–5.

Zuker, M. 1989. On finding all suboptimal foldings of an RNA molecule. Science 244:48–52.

VERIFICATION OF *SARGASSUM* SPECIES IDENTIFIED WITH SUBGENERA *BACTROPHYCUS, PHYLLOTRICHIA*, AND *SCHIZOPHYCUS* IN VIETNAM*

Tadao Yoshida, Nguyen Huu Dai, Tetsuro Ajisaka, and Tadahide Noro

Abstract

Voucher specimens of *Sargassum* species belonging to the subgenera *Phyllotrichia, Schizophycus*, and *Bactrophycus* previously reported by Pham Hoang Ho and Nguyen Huu Dai were examined during the eighth workshop on taxonomy of seaweeds, held in Nha Trang, Vietnam. Among the species reported, *Sargassum piluliferum* (Turner) C. Agardh, *S. horneri* (Turner) C. Agardh, and *S. hemiphyllum* var. *chinense* J. Agardh were confirmed for the coast of Vietnam. Other records previously listed in these subgenera were not verified.

Introduction

According to the Agardhian system of distinguishing subgenera in the genus *Sargassum*, subgenera *Phyllotrichia* and *Schizophycus* are characterized by main branches that emerge as foliar expansions and leaves that expand in the same plane as the flattening of the main branch. *Schizophycus* differs from *Phyllotrichia* in having vesicles with a coronal leaf. Most species of *Phyllotrichia* are distributed in the Southern Hemisphere around Australia. On the other hand, species of *Schizophycus* are known from the temperate region of the Northern Hemisphere.

According to Womersley (1954), separation of the 2 subgenera on the basis of the coronal leaf was not worthy of subgeneric consideration. Subgenus *Bactrophycus* has horizontally expanded, often retroflexed, leaves and usually simple receptacles. Distribution of species of this subgenus is confined to the Northern Hemisphere, especially temperate regions around Japan (Yoshida 1983) and Korea (Lee and Yoo 1992), with a number of species from China.

Pham Hoang Ho (1967) recorded several species of subgenera *Bactrophycus* and *Phyllotrichia* from Vietnam. Later, Nguyen Huu Dai (1997) added more species, including the subgenus *Schizophycus*, to the Vietnamese flora. Because the species of subgenera *Bactrophycus* and *Schizophycus* are mostly distributed in the temperate region around Japan, Korea, and China, extension of the distribution area south to the coast of Vietnam needed to be verified by examination of relevant specimens.

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*Editor's note: All references for the misidentifications mentioned in this chapter have been removed. If the identifications (names used) are incorrect, they should not be perpetuated, and if incorrect, they are certainly not the species described by the author(s) of the name(s). I. Abbott

At the eighth workshop on taxonomy of economic seaweeds, held at the Institute of Oceanography, Nha Trang, Vietnam, we examined the collections of Pham and Nguyen, with special attention to these subgenera. Examination of relevant specimens and the results of previous workshops confirmed the presence of *S. piluliferum* and *S. hemiphyllum* var. *chinense* in the northern part of the Vietnamese coast. Specimens of *S. horneri* (Turner) C. Agardh (subgenus *Bactrophycus*) were confirmed, but because the specimens collected were floating, we cannot be certain that the species is present in Vietnam. The nearest specimens of this species that were collected from rocks were from Hong Kong. Other records were not verified. Species belonging to section *Phyllocystae* of subgenus *Bactrophycus* are considered in a separate chapter.

Confirmed Species

Subgenus *Phyllotrichia*

Sargassum piluliferum (Turner) C. Agardh, Species algarum, p. 27, 1820.

Ajisaka et al. (Ajisaka, Huynh, Nguyen, and Yoshida 1997) reported *S. piluliferum* var. *serratifolium* Yamada (subgenus *Phyllotrichia*) from Hon Nom, Quang Binh Province, north of latitude 17°N. Earlier, Pham (1967) described *S. piluliferum* var. *nhatrangense*. Examination of type material of this variety revealed that this entity belongs to *S. carpophyllum* J. Agardh (subgenus *Sargassum*). Ajisaka et al. (Ajisaka, Huynh, Nguyen, and Yoshida 1997) have already transferred this variety to *S. carpophyllum*. The report of *S. piluliferum* var. *serratifolium* Yamada from Vietnam was the first report of this variety outside of Japan and the first report of the distribution of the species south of Hong Kong.

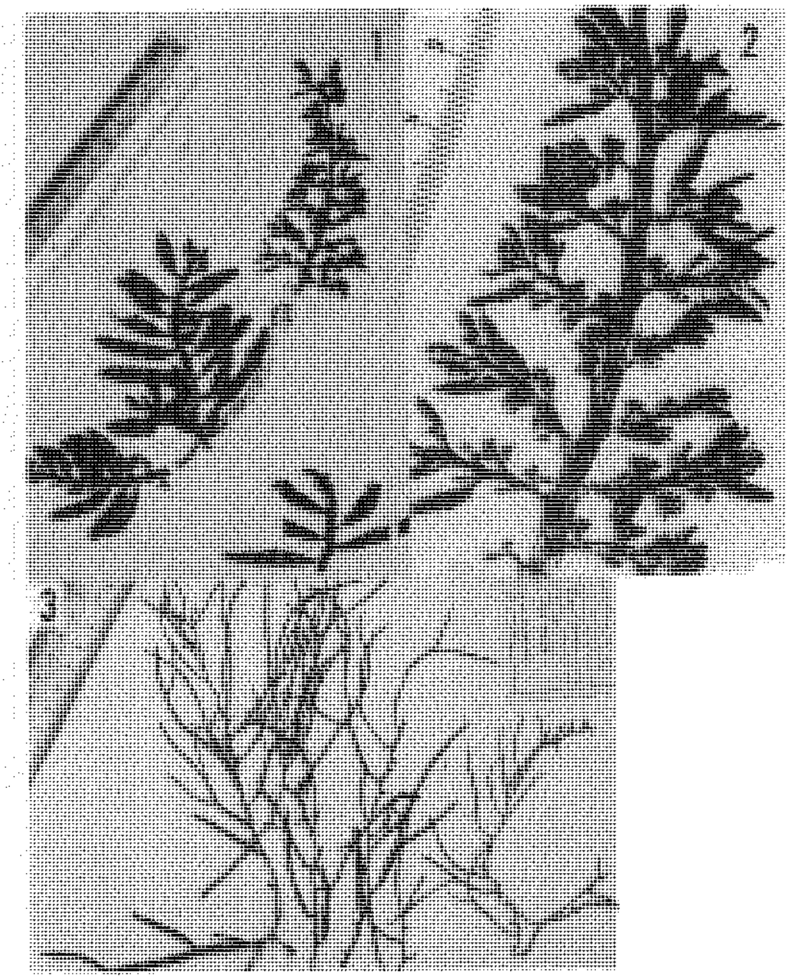
Subgenus *Schizophycus*

Sargassum patens C. Agardh (Figs. 1–2)

Nguyen (1992, p. 1, fig. 1; 1997, p. 44, fig. 11) described *S. patens* var. *vietnamense*. The plant (Figs. 1 and 2) has flat main branches, leaves distichously arranged, and spherical vesicles without coronal leaves. These characters indicate that this entity does not belong to the subgenus *Schizophycus*. After examination of the specimens concerned, we concluded that they are identifiable as *S. oligocystum* Montagne (subgenus *Bactrophycus*). This confirmation eliminates the record of a species of subgenus *Schizophycus* from Vietnam.

Sargassum tosaense Yendo (Fig. 3)

Nguyen (1992, p. 2, fig. 2) applied the name *S. tosaense* Yendo to specimens (numbers 78273–78275, Fig. 3) from Quang Binh Province. The specimens have narrow leaves, branched once or twice, and seem to be very young plants of some other (unidentifiable) species. This observation also eliminates another species in subgenus *Schizophycus* from the Vietnamese flora. With this omission, the subgenus *Schizophycus* has no Vietnamese specimens.



Figs. 1–3. Fig. 1. *Sargassum oligocystum* Montagne, the correct identification for *Sargassum patens*. Fig. 2. *Sargassum oligocystum*, receptacles and "leaves." Fig. 3. *Sargassum tosaense* Yendo, an incorrect name for these unidentifiable specimens, which are too young to show important features for identification.

Subgenus *Bactrophycus*

Sargassum confusum C. Agardh

Although the name *S. confusum* C. Agardh was reported by Pham (1967), he did not collect this species himself from Vietnamese coasts but rather depended on a specimen in the herbarium of Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle, Paris (PC). We did not examine Nguyen's collection of this species (Nguyen 1997, fig. 18). The presence of this species on the Vietnamese coast is highly doubtful.

Sargassum hemiphyllum (Turner) C. Agardh, Species algarum, p. 39, 1820.
Sargassum hemiphyllum var. *chinense* J. Agardh, Kgl. Svenska Vet.-Akad. Handl. 23:1–133, pls. 1–31, 1889. (Figs. 5–7)

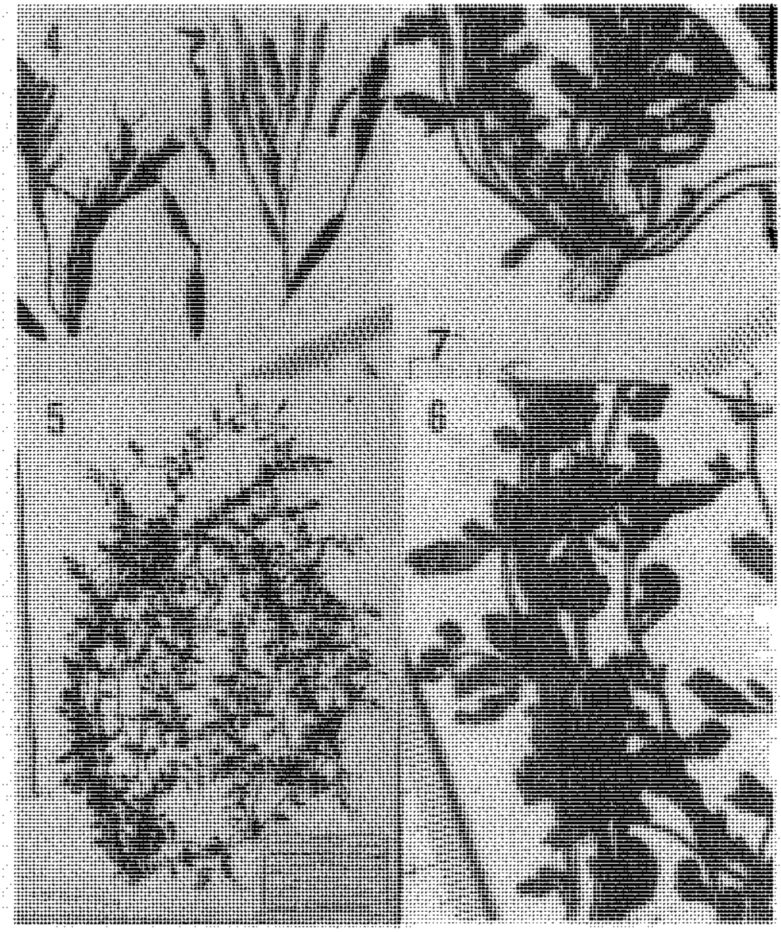
Pham (1967) identified his specimen 3242 from Hong Chong (Nha Trang) and specimen 3032 from Quam Duoi (Nha Trang) as *S. hemiphyllum* (Turner) C. Agardh and described them as representing a new form: *serrata* Pham Hoang Ho. We selected his specimen 3242 as the lectotype of the form (Fig. 5). Examination of the specimens revealed that they have compound receptacles which are not found in *S. hemiphyllum (*subgenus *Bactrophycus),* but in subgenus *Sargassum.* Ajisaka et al. (Ajisaka, Huynh, Nguyen, Lu, Chiang, and Yoshida1997) examined specimens of *S. hemiphyllum* collected from Vietnam, the mainland of China, Hong Kong, and Taiwan. The Vietnamese specimens they examined have larger leaves than those of typical *S. hemiphyllum* and can be called *S. hemiphyllum* var. *chinense* J. Agardh. Distribution of this variety is confined to the central part of Vietnam at Nighi Son (Thang Hoa Province) and Thoson (Quang Binh Province), about 18°N latitude (Ajisaka, Huynh, Nguyen, Lu, Chiang, and Yoshida 1997, fig. 1). *Sargassum hemiphyllum* (Turner) C. Agardh is the only species of subgenus *Bactrophycus* confirmed to be distributed from the Japanese coast southward to central and north Vietnam.

Sargassum horneri (Turner) C. Agardh, Species algarum, p. 38, 1820. (Fig. 4)

A sheet of specimens at the Institute of Oceanography in Nha Trang is labeled *S. horneri* (Turner) C. Agardh. The sheet contains several leaves, vesicles, and a tip of a branch. The identification of the specimens as *S. horneri* is correct. The specimens (Fig. 4) were collected as floating fragments (Nguyen 1997, fig. 13). Pham (1967) wrote, "Je n'ai pas retrouve cette espèce dans les regions de Nha-Trang et de Ha-Tien." His figure (fig. 2 on p. 275) was based on a specimen in the herbarium of Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle, Paris (PC). There is no record of this species growing on the coast of Vietnam.

Sargassum kjellmanianum Yendo

A specimen (3134) from Hon Chong, Nha Trang, was attributed by Pham (1967) to *S. kjellmanianum.* It is difficult to determine whether or not the specimen is the same as *S. kjellmanianum* reported from northern parts of Japan and China,



Figs. 4–7. Fig. 4, *Sargassum horneri* (Turner) C. Agardh is the correct name for these specimens, which were found floating and so are of unknown origin. No attached specimens have been found in Vietnam. Figs. 5–7, Lectotype specimen of *Sargassum hemiphyllum* f. *serratum* Pham Hoang Ho. This form belongs to the subgenus *Sargassum*, but *S. hemiphyllum* is placed in the subgenus *Bactrophycus*.

and identification of the species of the specimen is not possible at present because of insufficient material. Most probably, *S. kjellmanianum* is not found in Vietnam, because this species is not known in the tropics.

Earlier, Yoshida (1978) indicated that *S. miyabei* Yendo and *S. kjellmanianum* are heterotypic synonyms and chose the former name for this species. *Sargassum kjellmanianum* f. *muticum* described by Yendo (1907) was raised to specific rank as *S. muticum* (Yendo) Fensholt. *Sargassum muticum* (Yendo) Fensholt is monoecious and has spherical to obovoid vesicles; it also differs from the Vietnamese specimen.

Sargassum nigrifolium Yendo

Nguyen (1997) assigned several specimens (702502, 82034-6) from Da Nang, central Vietnam, to *S. nigrifolium* Yendo. The plants have an erect stem and very narrow linear leaves (Nguyen 1997, fig. 19). The plants differ from *S. nigrifolium* from Japan, which is characterized by a creeping stem and obovoid to broad lanceolate leaves. We removed *S. nigrifolium* from the Vietnamese *Sargassum* flora.

Sargassum nipponicum Yendo (Figs. 8–9)

Pham (1967) reported *S. nipponicum* Yendo on the basis of a specimen (E 3348) from Da Nang, central Vietnam. The specimen (Figs. 8–9) is fragmentary and without basal parts. It differs from Japanese plants that are identified as *S. nipponicum*. A record of *S. nipponicum* in Vietnam was not verified by the material available to us at the workshop.

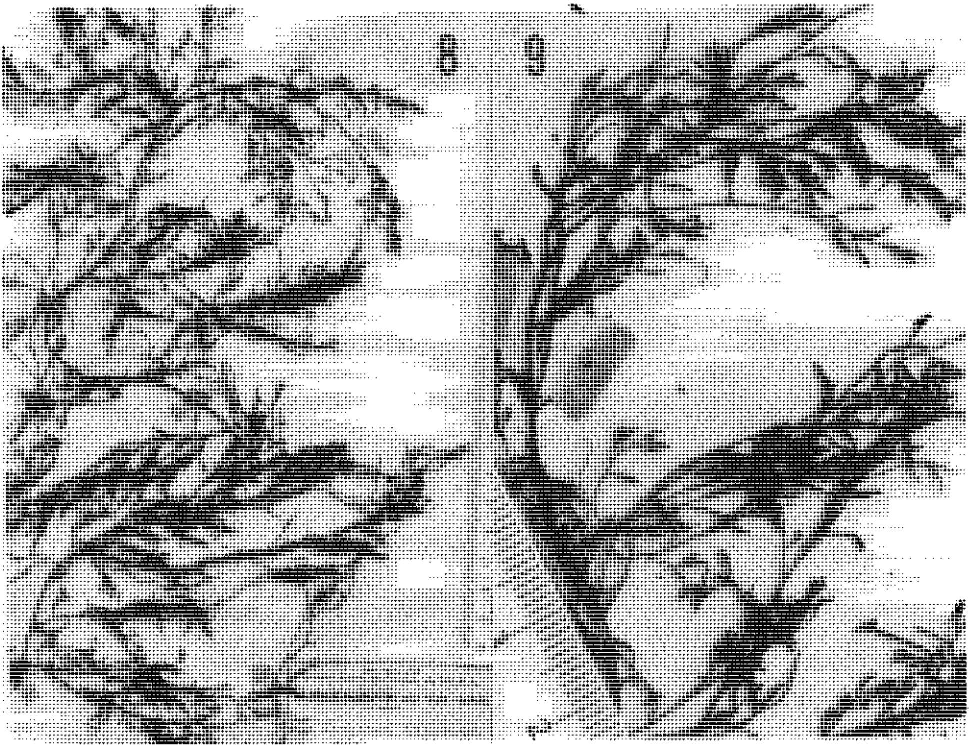
Sargassum tortile (C. Agardh) C. Agardh

Sargassum tortile (C. Agardh) C. Agardh was first reported by Pham (1967), and he cited his figure 3 (on p. 275) on the basis of a specimen in the herbarium in Paris (PC). The herbarium at the Institute of Oceanography does not have any specimen assigned by Pham to this species. Nguyen (1997) reported materials from Quang Ninh as *S. tortile*, but the specimens (Nguyen 1997, fig. 14) were shown to be *S. graminifolium* (Turner) C. Agardh.

We could not verify the presence of *S. tortile* in Vietnam. The name *S. tortile*, moreover, is a heterotypic synonym of *S. siliquastrum* (Mertens ex Turner) C. Agardh (Yoshida, 1983).

Discussion

When Ajisaka and his Vietnamese colleagues, Huynh Quang Nang and Nguyen Huu Dinh, found *S. piluliferum* var. *serratifolium* Yamada in Vietnam, it was very exciting news for phycologists in Japan, because this collection was the first outside of Japan. Therefore, we were eager to see specimens of *S. piluliferum* var. *nhatrangense* Pham Hoang Ho, which Ajisaka had removed to



Figs. 8–9. *Sargassum nipponicum* Yendo from Vietnam was not recognized by the Japanese *Sargassum* students. Because they lacked basal parts, the specimens could not be further identified.

S. carpophyllum in 1997. (We also collected materials of these taxa, and we present some of our conclusions elsewhere in this volume.)

Among the species of the subgenus *Bactrophycus*, *S. hemiphyllum* var. *chinense* is the only one that we verified is distributed from Japan south to Vietnam. However, this distribution, in itself, is worthy of note because species in the subgenus *Bactrophycus* are more common in colder waters of Japan, mainland China, and Korea. We found that specimens identified as *S. horneri*, which were collected floating off the Vietnamese coast, were correctly identified. However, because the origin of the specimens is unknown, we prefer to list this occurrence as provisional.

In the subgenus *Schizophycus*, we removed the 2 species previously reported as members of that subgenus. Thus, no plants of the subgenus *Schizophycus* species are present in Vietnam.

In summary, we found that 6 taxa had been misidentified previously, or that the material was too limited to identify.

The taxonomic position of the section *Phyllocystae* is treated in a separate chapter.

Acknowledgments

We thank Nguyen Huu Dai for his cooperation in opening his herbarium to us for study, and Dr. Isabella A. Abbott for editing our English and improving our manuscript.

Literature Cited

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Chiang, Y.-M., and Yoshida, T. 1997. *Sargassum hemiphyllum* (Turner) C. Agardh var. *chinense* J. Agardh from Vietnam, the Chinese mainland, and Taiwan. In: Tax. Econ. Seaweeds 6, pp. 37–49.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, and Yoshida, T. 1997. *Sargassum carpophyllum* J. Agardh var. *nhatrangense* (Pham) Ajisaka comb. nov. and *S. piluliferum* (Turner) C. Agardh var. *serratifolium* Yamada from Vietnam. In: Tax. Econ. Seaweeds 6, pp. 51–60.

Lee, I. K., and Yoo, S.-A. 1992. Korean species of *Sargassum* subgenus *Bactrophycus* J. Agardh (Sargassaceae, Fucales). In: Tax. Econ. Seaweeds 3, pp. 139–147.

Nguyen Huu Dai. 1992. Mot so loai rong mo (*Sargassum* C. Ag.) moi tim thay o Viet Nam. Tap chi Sinh Hoc 14:1–7 (in Vietnamese).

Nguyen Huu Dai. 1997. Sargassaceae in Vietnam: resources and utility. Agriculture Publishing House, Ho Chi Minh City (in Vietnamese).

Pham Hoang Ho. 1967. Contribution à l'étude des algues littorales du Vietnam: le genre *Sargassum*. Ann. Fac. Sci. Saigon, pp. 259–332, figs. 1–32 (in French).

Womersley, H. B. S. 1954. Australian species of *Sargassum*, subgenus *Phyllotrichia*. Aust. J. Bot. 2:337–354.

Yendo, K. 1907. The Fucaceae of Japan. J. Coll. Sci. Tokyo Imp. Univ. 21:1–174.

Yoshida, T. 1978. Lectotypification of *Sargassum kjellmanianum* and *S. miyabei* (Phaeophyta, Sargassaceae). Jpn. J. Phycol. 26:121–124 (in Japanese).

Yoshida, T. 1983. Japanese species of *Sargassum* subgenus *Bactrophycus* (Phaeophyta, Fucales). J. Fac. Sci. Hokkaido Univ. Ser. V (Bot.) 13:99–246.

THREE NEW SPECIES OF *SARGASSUM* (SARGASSACEAE, FUCALES) FROM VIETNAM

Nguyen Huu Dai

Abstract

Three new species of *Sargassum* from Vietnam, descriptions of which were previously published in Vietnamese, are redescribed in English, including collections of the species added since 1997. *Sargassum cotoense* has slender thalli, thick leaves, and very narrow, nearly terete, solitary, and monoecious receptacles. *Sargassum phamhoangii* has long leaves, longer than its lateral branches, and solitary and dioecious receptacles. *Sargassum quinhonense* is special because of its phyllocysts and vesicles with earlike expansions. It differs from *S. herklotsii* Setchell, first described from Hong Kong, in the shape of the leaves and receptacles.

Introduction

In the mid-19th century, species of *Sargassum* from Vietnamese waters were collected and identified by European researchers such as Gaudichaud and Busseuil. Almost all of those collections were deposited in the Muséum National d'Histoire Naturelle (Paris, PC). More than 100 years passed before Dawson (1954) published an extensive article on the marine flora in the vicinity of the Institute of Oceanography in Nha Trang, central Vietnam. Pham Hoang Ho (1969), who also studied at the Institute of Oceanography, published an article on the general flora, similar to that of Dawson's and describing more species. In 1993, Nguyen Huu Dinh et al. published a book on the marine algae of North Vietnam that contains descriptions of some species of *Sargassum* not previously listed.

Publications on *Sargassum* in Vietnam are nearly as numerous as those that deal with all other elements of the marine flora. Vietnamese authors are led by Pham Hoang Ho (1967), who contributed a very comprehensive article on the species in Vietnam. More recently, Nguyen Huu Dai (1997), Nguyen Huu Dinh, and Huynh Quang Nang were coauthors of articles on Vietnamese *Sargassum* published in 1995 (Ajisaka et al.), 1997 (Ajisaka, Huynh, Nguyen, Lu, Chiang, and Yoshida 1997; Ajisaka, Huynh, Nguyen, Lu, Put, et al. 1997; Ajisaka, Huynh, Nguyen, and Yoshida 1997); and 1999 (Nguyen and Huynh). The 1995, 1997, and 1999 contributions were published in the *Taxonomy of Economic Seaweeds* series. Because of the difficulties of exchanges and loans for comparison of specimens with materials in other herbaria of the world, progress was very slow. The eighth Sea Grant workshop on taxonomy of economic seaweeds was the best opportunity for reexamination and discussion of our specimens.

The following material is based on the publication *Sargassaceae in Vietnam: Resources and Utility* by Nguyen Huu Dai (1997). New materials of *Sargassum* have been collected since 1968 by Huynh Quang Nang in Quang Ninh Province in the north and since 1982 by Nguyen Huu Dai in Quang Nam, Quang Ngai, and Binh Dinh provinces in central Vietnam (Fig. 1).

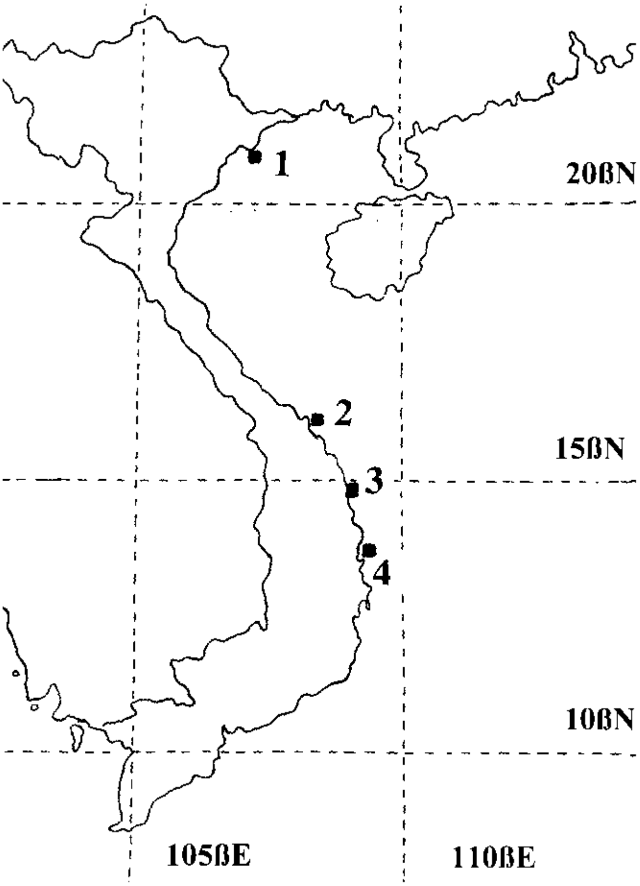


Fig. 1. Map of Vietnam with collecting places numbered. 1 indicates Quang Ninh Province (Co To Island); 2, Quang Nam Province, Da Nang City (Nam O); 3, Quang Ngai Province (Ly Son Island); 4, Binh Dinh Province, Quy Nhon City (Ganh Rang).

Description of the Species

Sargassum cotoense Nguyen Huu Dai, sp. nov.
(Figs. 2–4)

Planta flavobrunnea in sicco. Thallus plerumque ad 30–40 cm altus, filiformis; haptero discoidea-conico circa 1 cm diametro. Caulis brevis, teres, 3 mm longus, 2–4 primariis ramis cylindricis, levibus, circa 1 mm diametro. Folia brevia, crassa, folia prope basim 3 cm longa, 0.7 mm lata, folia ramulorum breviora circa 0.4 mm lata, cylindriforma, margine integro, cyptostomatibus non conspicuibus, costa conspicua. Vesiculae obovatae 2–5 mm diametro, aliquando spina longa obtusa acuta ad apicem, petiolo cylindricae tam longo quam vesicula.

Planta monoica. Receptacula fusiformia, minuta, solitaria ad folii axillam, circa 2 mm longa.

Holotype: 68550, collected by Huynh Quang Nang, April 30, 1968, from Co To Island, Quang Ninh Province. Deposited in the herbarium of the Institute of Oceanography, Nha Trang, Vietnam.

Plants yellow-brown, filiform, up to 30–40 cm tall, attached to substratum by conical discoid holdfast about 1 cm in diameter. Stem very short, terete, 3 mm long, usually bearing 2 to 4 primary branches from its upper part; secondary branches terete, smooth, alternately arising from the foliar axil of primary branches, up to 20 cm long. Leaves thick and very narrow, nearly cylindrical, up to 3 cm long, 0.7 mm wide on primary branches, only 0.4 mm wide on branchlets, margins entire, midrib not apparent, cryptostomata conspicuous, vesicles obovate, 2–5 mm in diameter, sometimes with an obtuse and long spine at the apex, petioles cylindrical, as long as vesicles.

Plants monoecious. Receptacles small, fusiform, solitary at the base of small leaves, warty, about 2 mm long.

Other Specimens Examined: 68053, 68054, and 68055, collected by Huynh Quang Nang, May 30, 1968, from Co To Island, Quang Ninh Province.

Habitat: Growing on intertidal and subtidal rocks.

Etymology: Named for the type locality, Co To Island.

Sargassum phamhoangii Nguyen Huu Dai, sp. nov.
(Figs. 5–6)

Planta atrobrunnea in sicco. Thallus plerumque ad 0.5–1 m altus, colligatus ad substratum, haptero discoideo-conico circa 1 cm diametro. Caulis cylindricus, brevis, circa 5 mm altus. Principalis ramus cylindricus, levis, circa 1 mm diametro. Secundarius ramus teres et levis. Folia principalium ramorum lanceolata, crassa 5 mm lata, 12 cm longa, aliquando usque 20 cm, longiora quam secundarii rami, margine integro aut pouches spinis obtusis, costa non conspicua, cyptostomatibus non conspicuus. Folia ramorum secundariorum, et terminalium angusta, 2–4 mm

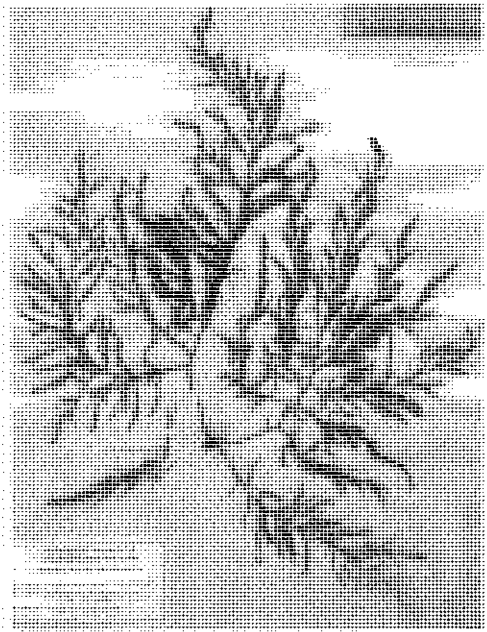


Fig. 2. ***Sargassum cotoense*** **sp. nov. Habit of plant showing several erect axes with spiraling branching pattern.**

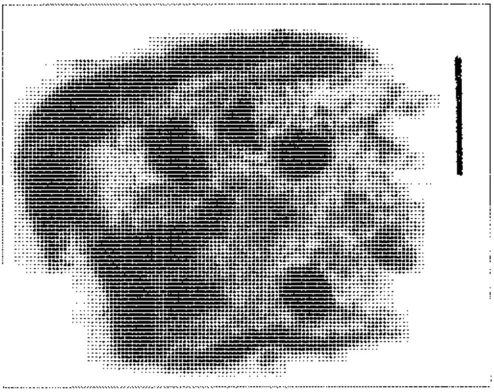


Fig. 3. ***Sargassum cotoense*** **sp. nov. Cross section of female receptacle. Scale bar = 20 µm.**

lata. Vesiculae obovatae aut ovato-oblongae, 2–3 mm diametro, aliquando spina longa ad apicem, petiolo cylindrico et brevi.

Planta dioica. Receptacula fusiformia, solitaria ad folii axillam, dura, aliquando furcata, 3–5 mm longa.

Holotype: 82107, collected by Nguyen Huu Dai, May 4, 1982, from Nam O, Da Nang. Deposited in the herbarium of the Institute of Oceanography, Nha Trang.

Plants dark brown, up to 0.5–1 m tall. Holdfast small, conical, discoid, about 1 cm in diameter, with a short stem, 5 mm tall. Primary branches terete, filiform, smooth, cylindrical, and erect, about 1 mm diameter; secondary branches terete, smooth, arranged alternately along primary branches at irregular intervals. Leaves linear-lanceolate, relatively thick, leaves on primary branches 5 mm wide, 12 cm long, sometimes up to 20 cm or more long, longer than the secondary branches, petiole long and slender, margins entire or with few obtuse spines; midrib and cryptostomata not clearly visible; leaves on secondary and terminal branches narrow, 2–4 mm wide. Vesicles obovate to ovate-oblong, 2–3 mm in diameter, sometimes with a long spine at the apex, petiole short, cylindrical.

Plants dioecious. Receptacles fusiform, warty, solitary at the base of small leaves, sometimes forked, 3–5 mm long.

Other Specimens Examined: Female plants collected at Nam O, Da Nang, by

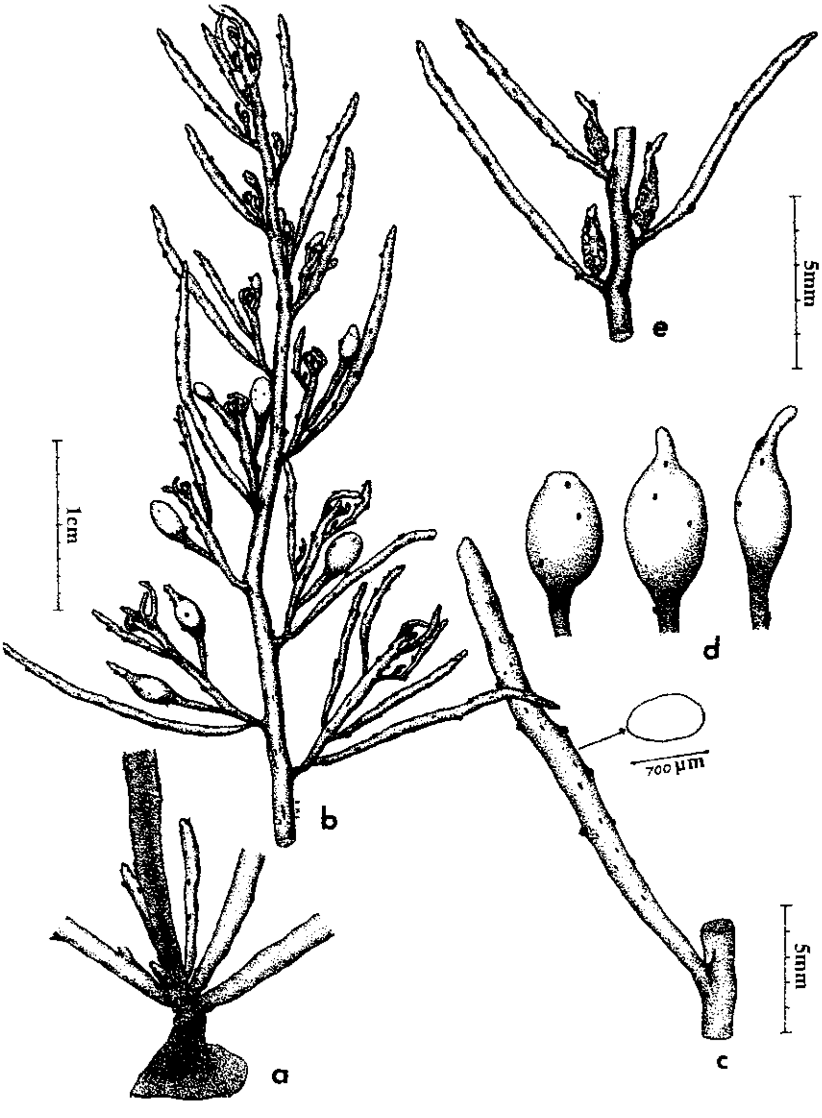


Fig. 4. ***Sargassum cotoense*** **sp. nov. a, Holdfast. b, Habit. c, Terete to slightly compressed stems. d, Vesicles. e, Small monoecious receptacles at bases of leaves.**

Nguyen Huu Dai: 82109, 82110, and 82114, collected May 4, 1982, and 83111, collected May 15, 1983.

Habitat: Growing on subtidal rocks.

Etymology: Named for Dr. Pham Hoang Ho, the first Vietnamese botanist who

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Fig. 5. *Sargassum phamhoangii* sp. nov. Habit of plant showing very long leaves, longer than lateral branches.

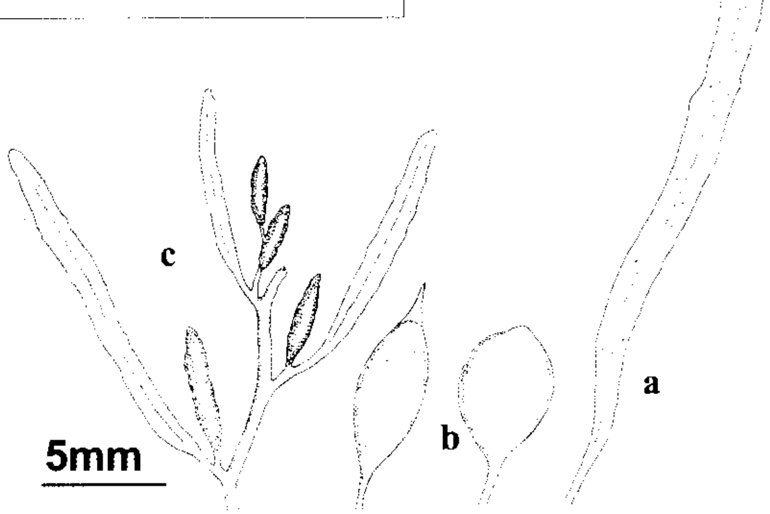

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Fig. 6. *Sargassum phamhoangii* sp. nov. a, Shape of very long leaf. b, Shape of vesicles. c, Branchlet with female receptacles.

left a rich legacy of studies of both the flowering plants of Vietnam and marine algae.

Sargassum quinhonense Nguyen Huu Dai, sp. nov.
(Figs. 7–9)

Planta brunnea vel atrobrunnea in sicco. Thallus plerumque ad 0.8–1 m altus, colligatus ad substratum haptero discoidea circa 1.5 cm diametro. Caulis cylindricus, brevis, 2–3 mm longus. Principalis ramus cylindricus, levis, 1 mm diametro. Secundarius ramus ex axillis foliaribus rami principalis, alternatus, cylindricus et levis, ad 20 cm longus. Folia principalis rami lanceolata, usque 5–8 cm longa, 0.5–1.0 cm lata, apice obtuso, margine integro, vel parce denticulatato, petiolo longo et gracili. Vesiculae obovatae aut ovato-oblongae, 0.5–1 cm diametro, biauriculatae.

Planta dioica. Receptacula solitaria, aut racemosa ad axillam locata; feminea receptacula triquetra, 3.5 mm long, spinulis obtusis ad margines et apicem.

Holotype: 83243, collected by Nguyen Huu Dai, April 10, 1983, from Ganh Rang, Quy Nhon, Binh Dinh Province. Deposited at the herbarium of Institute of Oceanography, Nha Trang.

Plants brown to dark brown, up to 0.8–1 m tall, attached strongly to substratum by a discoid holdfast about 1.5 cm in diameter. Stem very short, 2–3 mm long, usually 2–4 primary branches arising from its upper part. Primary branches filiform, terete, smooth, about 1 mm in diameter; secondary branches arising from the foliar axils of primary branches, alternate, cylindrical, smooth, up to 20 cm long. Leaves relatively thick, lanceolate; leaves on primary branches 5–8 cm long, 0.5–1 cm wide; leaves on branchlets 3–4 cm long, 0.3–0.5 cm wide, obtuse at the apex, margins entire or very slightly and sparsely denticulate, petiole long and slender, midrib apparent, cryptostomata scattered irregularly, arranged on both sides of the midrib. Vesicles obovate to oblong-ovate, 0.5–1 cm in diameter; phyllocysts expanded into earlike appendages, often located at the apex of leaves, phyllocysts in branchlets smaller and usually earlike.

Plants dioecious. Receptacles solitary or 2–3 racemosely arranged; female receptacles triquetrous, 3–5 mm long, with some obtuse spinules at the apex and margins. Male plants not found.

Other Specimens Examined: All collected by Nguyen Huu Dai. From Quang Ngai, Ly Son Island: 82189 and 82190, female plants, collected May 18, 1985. From Ganh Rang, Binh Dinh: 82060, female plant, collected May 10, 1982; 83247, female plant, collected April 25, 1983; 83246, female plant, collected May 10, 1983; 8507, female plant, collected May 14, 1985; 83247 and 83248, nonfertile plants, collected April 25, 1983; and 85073, nonfertile plant, collected May 14,1985.

Habitat: Growing on subtidal rocks from February to May in areas of strong waves.

Fig. 7. *Sargassum quinhonense* sp. nov. Habit of plant.

Fig. 8. *Sargassum quinhonense* sp. nov. Cross section of female receptacle. Scale bar = 20μm.

Etymology: Named for Quy Nhon City, near the type locality.

Acknowledgments

I thank Dr. Isabella Abbott, University of Hawaii, for reading and carefully editing this manuscript, and Dr. Karla McDermid, University of Hawaii, Hilo, for correcting the Latin descriptions. I am grateful to Dr. Hoang Quoc Truong, Faculty of Biology, Saigon University, for the Latin that describes these new species. Thanks to Dr. C. K. Tseng, Mr. Lu Baoren, Dr. T. Yoshida, Dr. T. Noro, and Dr. T. Ajisaka for reexamination of our specimens and for helping me with the characterization.

Literature Cited

Ajisaka, T., Huynh Quang Nang, and Nguyen Huu Dinh. 1995. Studies of two zygocarpic species of *Sargassum* (subgenus *Sargassum*) from Vietnam. Tax. Econ. Seaweeds 5, pp. 45–54.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Chiang, Y. M., and Yoshida, T. 1997. *Sargassum hemiphyllum* (Turner) C. Agardh var. *chinense* J. Agardh from Vietnam, the Chinese mainland, and Taiwan. Tax. Econ. Seaweeds 6, pp. 37–50.

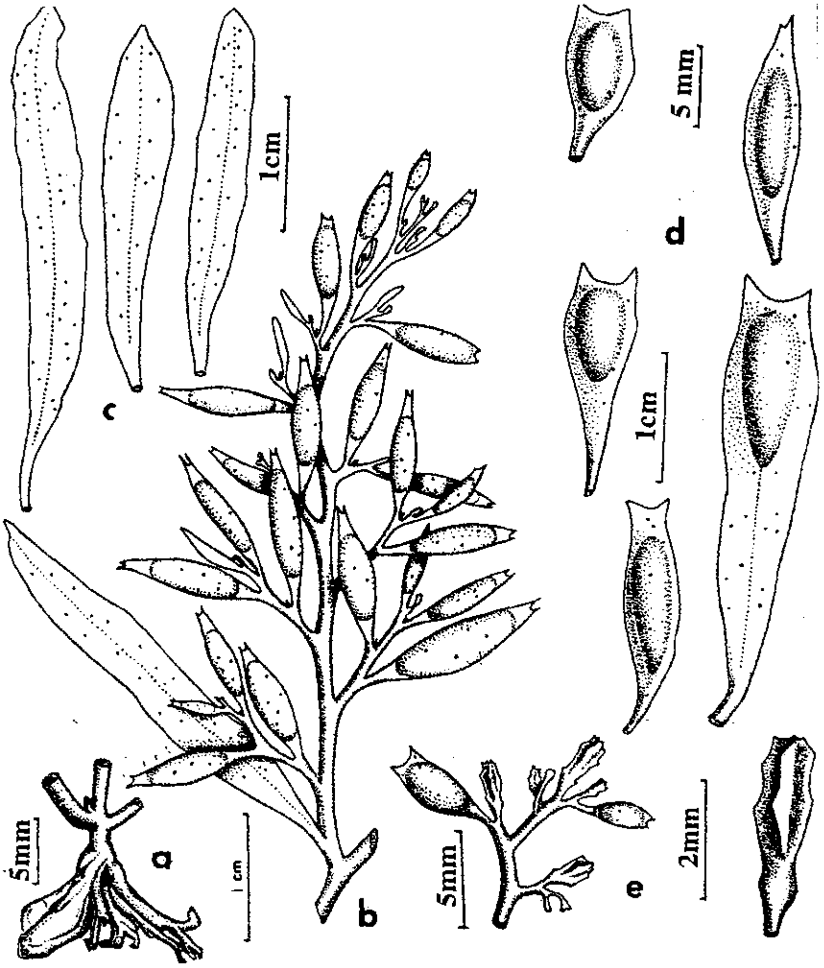


Fig. 9. *Sargassum quinhonense* sp. nov. a, Holdfast. b, Young secondary branches. c, Leaves. d, Vesicles with expanded margins. e, Female receptacle.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Put, A., Jr., Phang, S.-M., Noro, T., and Yoshida, T. 1997. Taxonomic and nomenclatural study of *Sargassum duplicatum* Bory and related species. Tax. Econ. Seaweeds 6, pp. 27–36.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, and Yoshida, T. 1997. *Sargassum carpophyllum* J. Agardh var. *nhatrangense* (Pham) Ajisaka comb. nov. and *S. piluliferum* (Turner) C. Agardh var. *serratifolium* Yamada from Vietnam. Tax. Econ. Seaweeds 6, pp. 51–60.

Dawson, E. Y. 1954. Marine plants in the vicinity of Nha Trang, Viet Nam. Pac. Sci. 8:373–469.

Nguyen Huu Dai. 1997. Sargassaceae in Vietnam: resources and utility. Agriculture Publishing House, Ho Chi Minh City.

Nguyen Huu Dinh and Huynh Quang Nang. 1999. Some new taxa of *Sargassum* (Phaeophyta) from Vietnam. In: Tax. Econ. Seaweeds 7, pp., 43–51, figs. 1–14.

Nguyen Huu Dinh, Huynh Quang Nang, Tran Ngoc But, and Nguyen van Tien. 1993. Marine algae of North Vietnam. Nha Xuat, Bankhoa (in Vietnamese).

Pham Hoang Ho. 1967. Contribution à l'étude des algues littorales du Vietnam: le genre *Sargassum*. Ann. Fac. Sci. Saigon, pp. 259–332 (in French).

Pham Hoang Ho. 1969. Marine algae of South Vietnam. Ministry of Education and Youth, Saigon (in Vietnamese).

SARGASSUM SPECIMENS WITH BULBOUS STRUCTURES FROM CHINA,VIETNAM, AND BAHRAIN

Tetsuro Ajisaka, C.K. Tseng, Lu Baoren, Nguyen Huu Dai, and Tadao Yoshida

Abstract

Several *Sargassum* specimens with bulbous structures from China, Vietnam (the South China Sea), and Bahrain (the Arabian Sea) were examined and their morphological characters compared. The function of bulbous structures is discussed, and a temporary name, "*perennis*," is given to distinguish these plants. A new variety name will be required.

Introduction

Sargassum bulbiferum Yoshida has been described on the basis of specimens collected in the Sea of Japan (Yoshida 1994). This species grows on rocks at a depth of 15–18 m and is characterized by the formation of short, thick bulbous structures, which were found for the first time in the genus *Sargassum*.

However, several *Sargassum* specimens with bulbous structures from China, Vietnam (the South China Sea), and Bahrain (the Arabian Sea) were recently found. The bulbous structure, also called "fusiform structure" (Yendo 1907) and "tophulose structure" (= tophule) (Roberts 1977), is well known in several species of the genus *Cystoseira* (e.g., *C. hakodatensis*, *C. elegans*, *C. spinosa*, *C. zosteroides*, and *C. nodicaulis*), but it has been reported only in *S. bulbiferum* in the genus *Sargassum*.

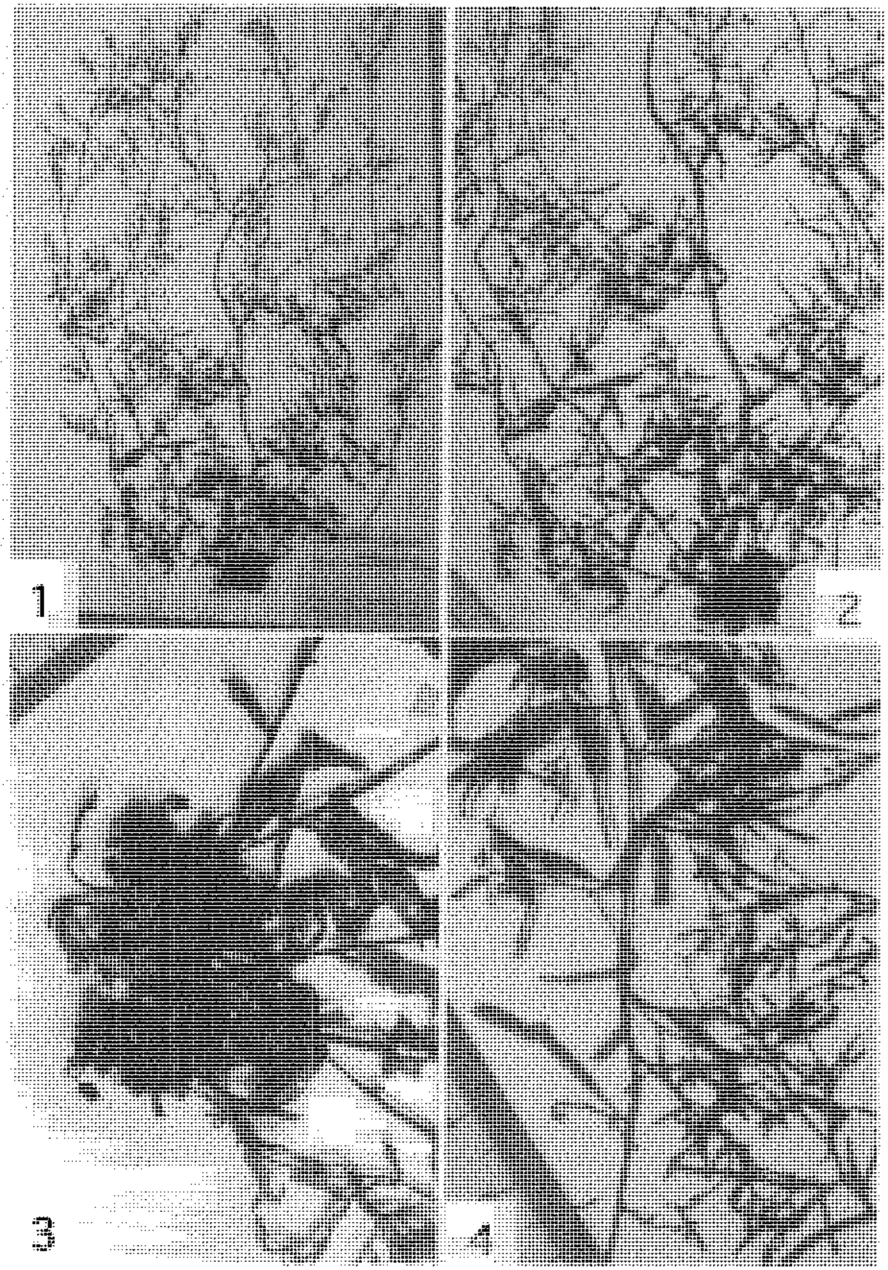
In this chapter, we provide morphological descriptions of the *Sargassum* specimens with bulbous structures from China, Vietnam, and Bahrain and compare their characters with those of the type specimens of *S. bulbiferum*. We also discuss the function of bulbous structures and the taxonomic treatment of the specimens that bear bulbous structures. The terminology for various parts follows that of Yoshida (1983).

Specimens From China

Specimen AST 55-1830. Collected April 28, 1955, from Weizhou Island, Guangxi Province, China.

(Figs. 1–4)

Holdfast discoid, up to 8 mm in diameter. Stem cylindrical, 5 mm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 40 cm or more long, slightly compressed, up to 2 mm wide in the basal part, cylindrical distally, smooth on the surface, with alternate leaves; secondary branches 8 cm or more long; short, thick bulbous structures formed from the stem, about 6 mm long, 3 mm in diameter. Leaves on the lower parts of main branches lanceolate, up to 3



Figs. 1–4. *Sargassum bulbiferum* from China (AST 55-1830). Fig. 1, Whole plant. Fig. 2, Basal part of plant. Fig. 3, Holdfast with bulbous structures (arrows). Fig. 4, Upper branchlets with leaves and receptacles.

cm long, 5 mm wide, entire or with sparse and small denticulations on the margin, midrib reaching the apex; leaves on the distal parts of main and secondary branches linear, becoming narrower and shorter; leaves often 1–3 times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex, without appendages, 4 mm in diameter, with cylindrical petioles up to 5–8 mm long.

Plant monoecious. Receptacles androgynous, slender, cylindrical to fusiform, up to 5 mm long, up to 0.8 mm in diameter, 1–2 times forked, without spines, pseudozygocarpic.

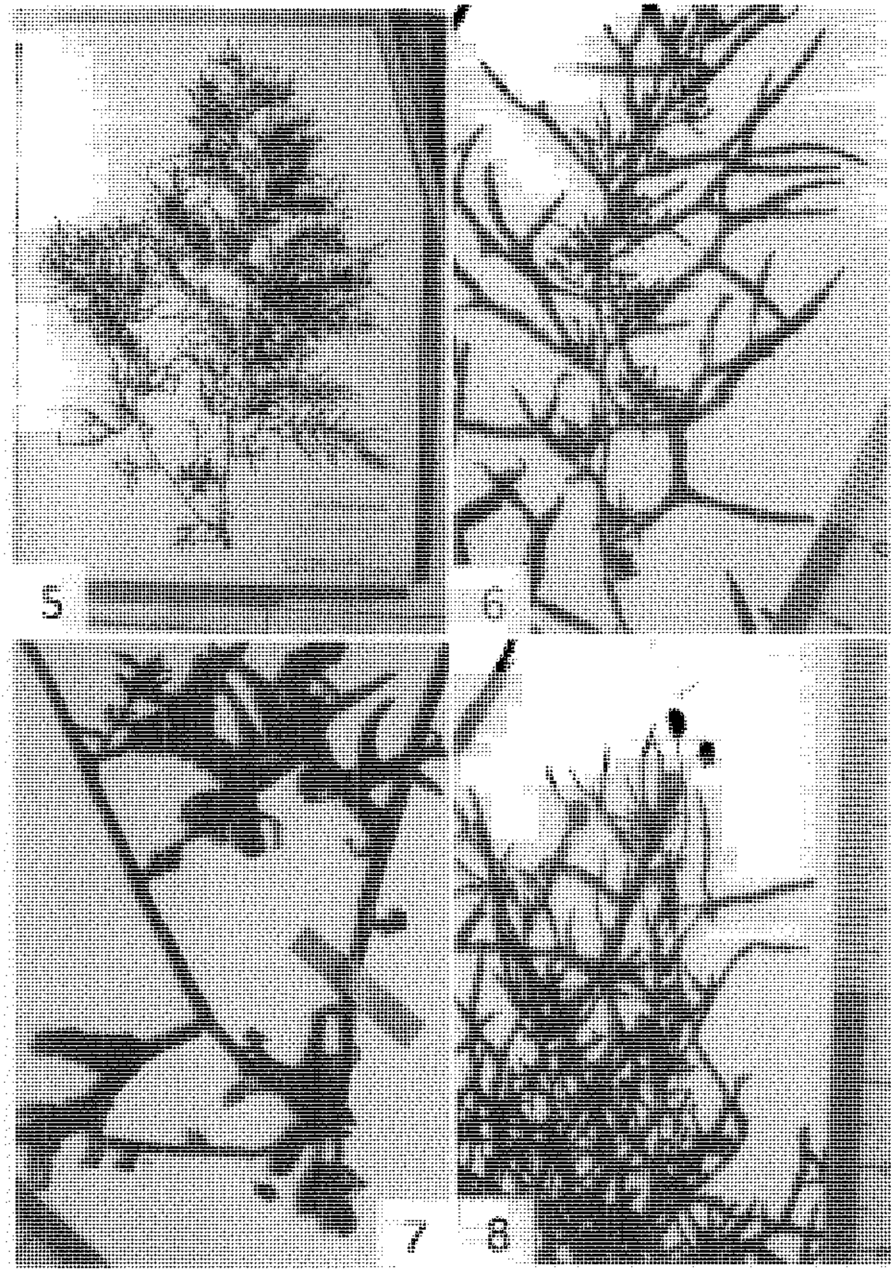
Specimen AST 55-1922. Collected April 28, 1955, from Weizhou Island, Guangxi Province, China. [*Sargassum bulbiferum* Yoshida]
(Figs. 5–8)

Holdfast discoid, up to 5 mm in diameter. Stem cylindrical, 6 mm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 37 cm or more long, slightly compressed, up to 2 mm wide in the basal part, cylindrical distally, smooth on the surface, with alternate leaves; secondary branches 14 cm or more long; short, thick bulbous structures formed from the stem, about 5 mm long, 2 mm wide. Leaves on the lower parts of main branches lanceolate, up to 5 cm long, 5 mm wide, entire or with sparse and small denticulations on the margin, papyraceous, midrib reaching the apex; leaves on the distal parts of main and secondary branches finer in texture, becoming narrower and shorter; leaves often 1–4 times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex, without appendages, 3 mm in diameter, with cylindrical petioles up to 5–8 mm long, sometimes longer, up to 17 mm.

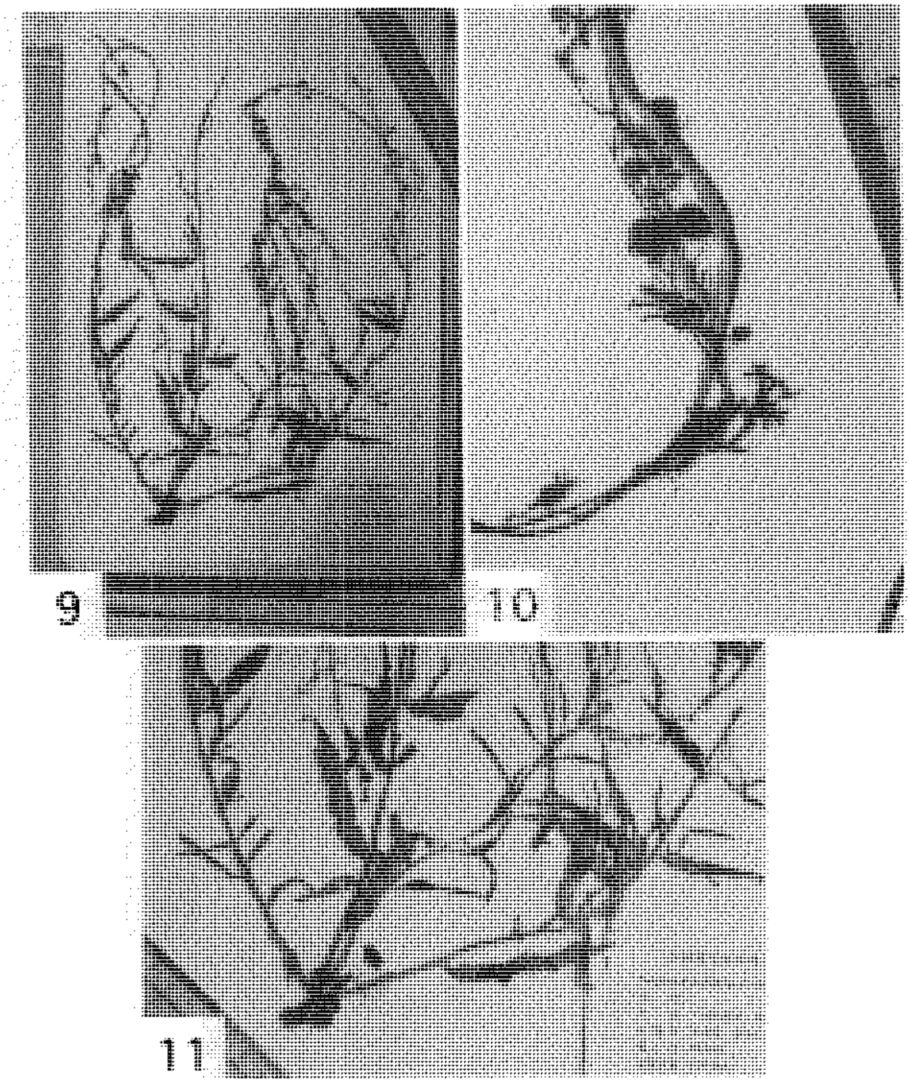
Plant monoecious. Receptacles androgynous, slender, cylindrical to fusiform, up to 6 mm long, up to 0.8 mm in diameter, 1–3 times forked, without spines, pseudozygocarpic.

Specimen AST 55-2041. Collected May 11, 1955, from Qinzhou Bay, Guangxi Province, China. [*Sargassum bulbiferum* Yoshida]
(Figs. 9–11)

Holdfast discoid, up to 5 mm in diameter. Stem cylindrical, 15 mm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 40 cm or more long, slightly compressed, up to 3 mm wide in the basal part, cylindrical distally, smooth on the surface, with alternate leaves; secondary branches 5 cm or more long; short, thick bulbous structures formed from the stem, about 10 mm long, 4 mm in diameter. Leaves on the lower parts of main branches linear to linear-lanceolate, up to 7 cm long, 9 mm wide, entire or with sparse and small denticulations on the margin, midrib reaching the apex; leaves on the distal parts of main and secondary branches linear, becoming narrower and shorter; leaves often 1–3



Figs. 5–8. *Sargassum bulbiferum* from China (AST 55-1922). Fig. 5, Whole plant. Fig. 6, Upper branchlet with furcate leaves and receptacles. Fig. 7, Holdfast with bulbous structure (arrow). Fig. 8, Vesicles with long cylindrical petioles (arrow).



Figs. 9–11. *Sargassum bulbiferum* from China (AST 55-2041). Fig. 9, Whole plant. Fig. 10, Upper branchlets with vesicles and receptacles. Fig. 11, Holdfast with bulbous structures (arrow).

times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex, without appendages, 4.5 mm in diameter, with cylindrical petioles up to 4–6 mm long.

Plant monoecious. Receptacles androgynous, slender, cylindrical to fusiform, up to 6 mm long, up to 0.8 mm in diameter, 1–4 times forked, without spines, pseudozygocarpic.

Specimen AST 87-1329; named *S. weizhouense* by Tseng and Lu, (pp. 135–138, this volume). Collected April 23, 1987, from Weizhou Island, Guangxi Province, China.

(Figs. 12–14)

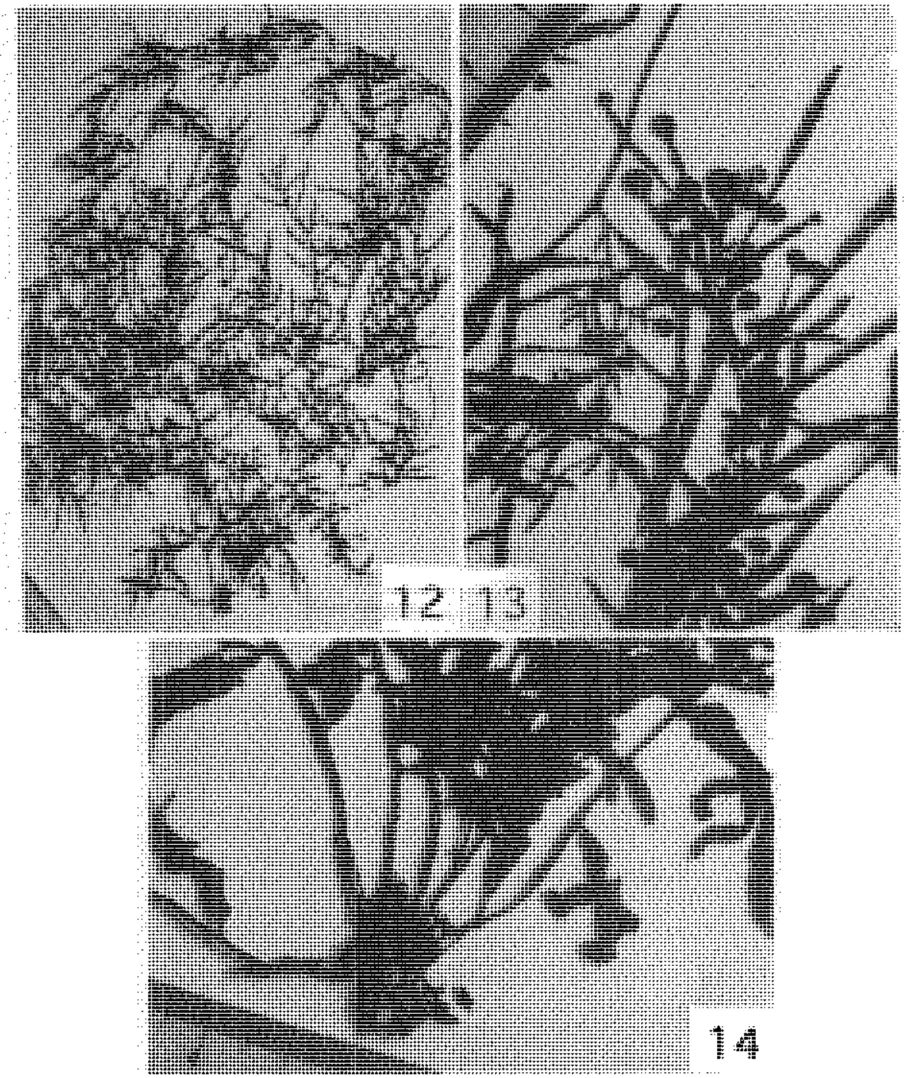
Holdfast discoid, up to 8 mm in diameter. Stem cylindrical, 5 mm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 70 cm or more long, cylindrical, up to 1 mm wide in the basal part, smooth on the surface, with alternate leaves; secondary branches 15 cm or more long; short, thick bulbous structures formed from the stem, about 5 mm long, 1.5 mm in diameter. Leaves on the lower parts of main branches linear to linear-lanceolate, up to 4 cm long, 4 mm wide, entire or with sparse and small denticulations on the margin, midrib reaching the apex; leaves on the distal parts of main and secondary branches linear, becoming narrower and shorter; leaves often 1–3 times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex, without appendages, 3 mm in diameter, with cylindrical petioles up to 3 mm long or leafy petioles up to 13 mm long.

Plant monoecious. Receptacles androgynous, slender, cylindrical to fusiform, up to 4 mm long, up to 1 mm in diameter, 1–3 times forked, without spines, pseudozygocarpic.

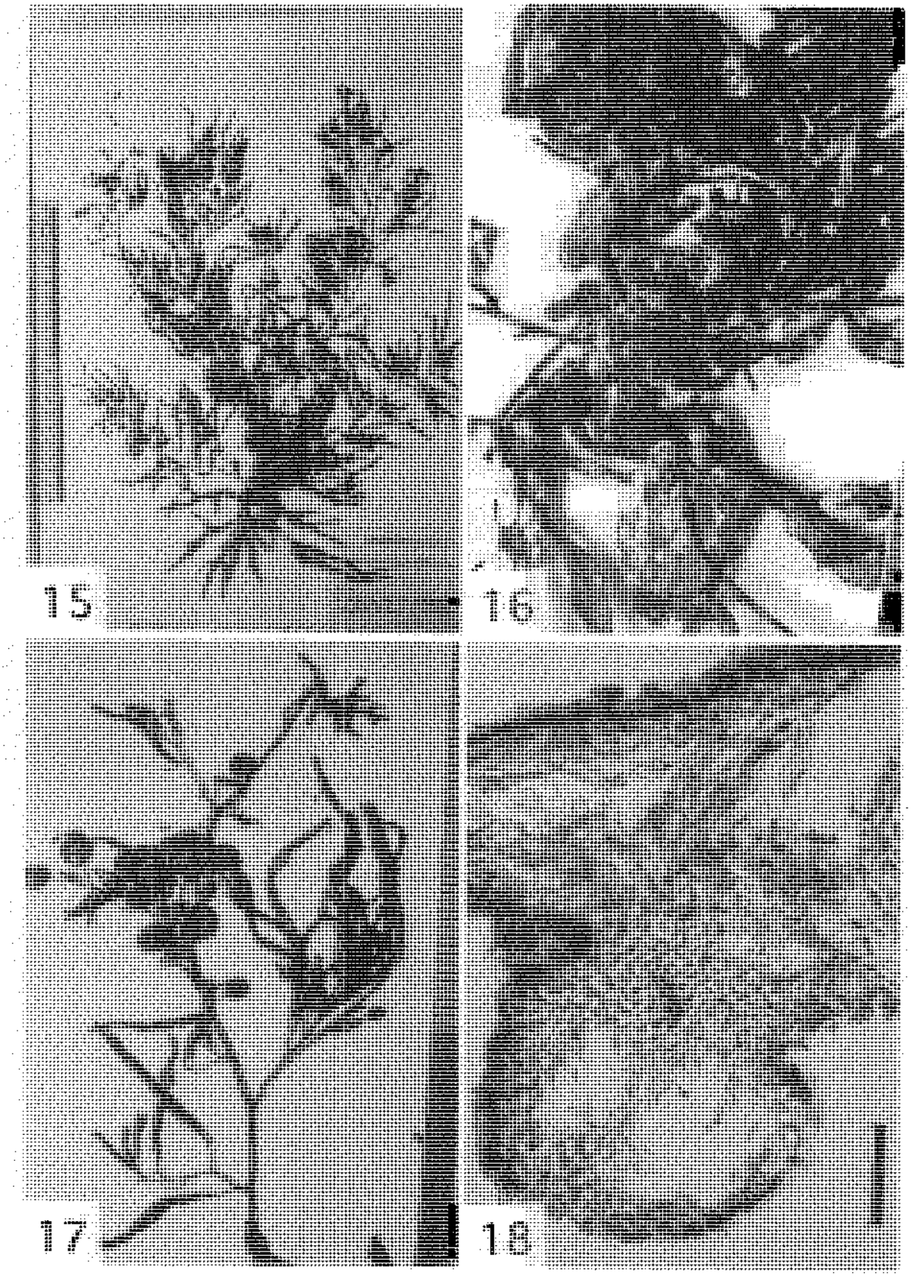
Specimen AST 55-2112 (male and female, 2 sheets); temporarily named "*S. gemmipherum*" by Tseng and Lu. Collected May 11, 1955, from Fang Cheng, Guangxi Province, China.

(Figs. 15–22)

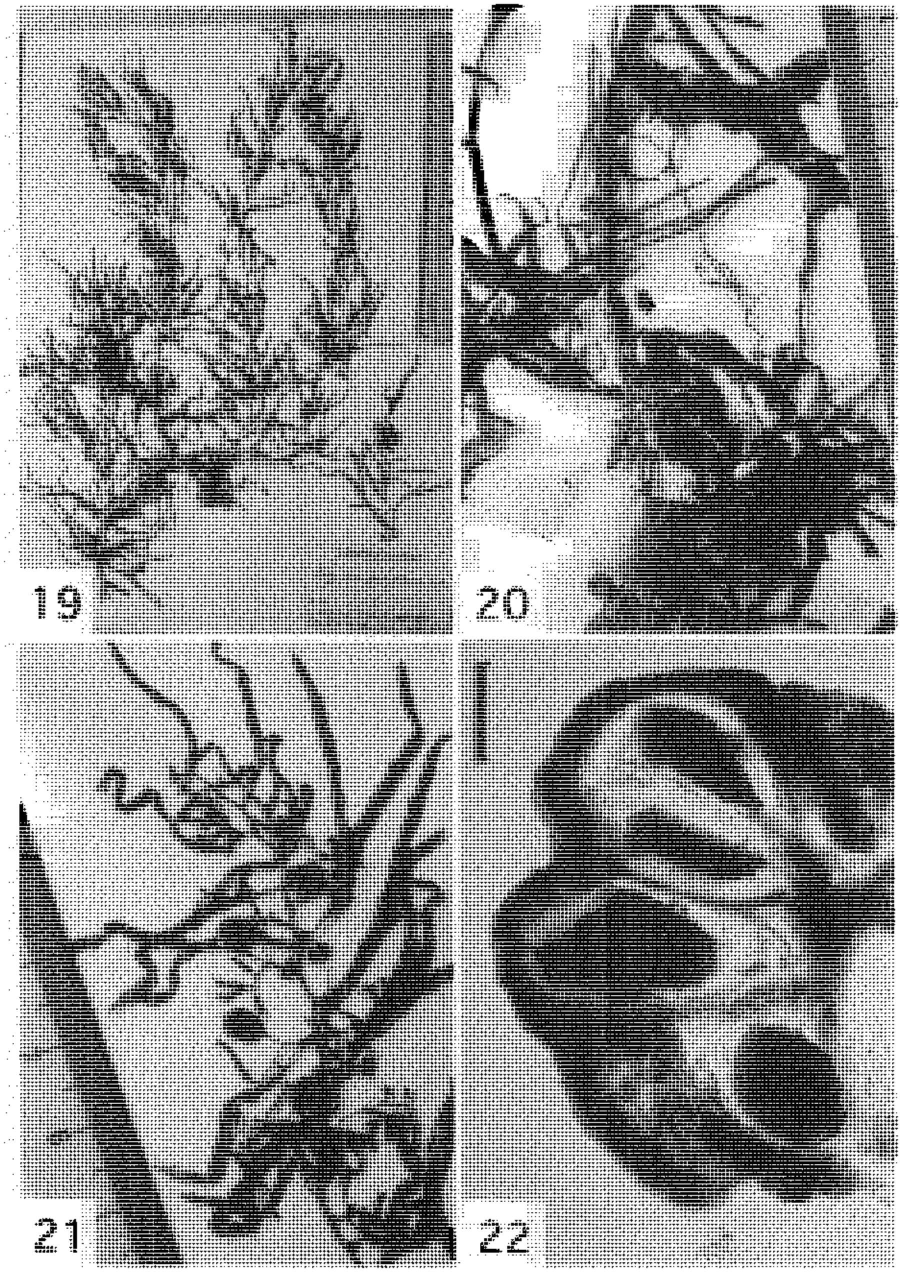
Holdfast discoid, up to 10 mm in diameter. Stem cylindrical, 8 mm tall, 2 mm in diameter. Main branches radially arising from the apex of the stem, 30 cm or more long, cylindrical, up to 1 mm wide in the basal part, smooth on the surface, with alternate leaves; secondary branches 7 cm or more long; short, thick bulbous structures formed from the stem, about 5 mm long, 2 mm in diameter. Leaves on the lower parts of main branches linear to linear-lanceolate, up to 7 cm long, 4 mm wide, entire or with sparse and small denticulations on the margin, midrib reaching the apex; leaves on the distal parts of main and secondary branches linear, becoming narrower and shorter; leaves often 1–3 times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex,



Figs. 12–14. *Sargassum weizhouense* from China (AST 87-1329). Fig. 12, Whole plant. Fig. 13, Upper branchlets with leaves, vesicles with leafy petioles, and receptacles. Fig. 14, Holdfast with bulbous structures (arrow).



Figs. 15–18. *Sargassum* specimen (male) from China (AST 55-2112). Fig. 15, Whole plant. Fig. 16, Holdfast with bulbous structures (arrow). Fig. 17, Upper branchlets with leaves, vesicles, and receptacles. Fig. 18, Transection of male receptacle; scale bar = 100 μm.



Figs. 19–22. *Sargassum* specimen (female) from China (AST 55-2112). Fig. 19, Whole plant. Fig. 20, Holdfast with bulbous structures (arrow). Fig. 21, Upper branchlets with leaves, vesicles, and receptacles. Fig. 22, Transection of male receptacle; scale bar = 100 µm. Note: Figs. 15–22 show separate sexes on separate plants (= dioecious) and therefore are not *S. bulbiferum* or *S. weizouense*.

without appendages, 3 mm in diameter, with cylindrical petioles up to 5 mm long. Plants dioecious. Male receptacles slender, cylindrical to fusiform, up to 7 mm long, up to 0.5 mm in diameter, sometimes forked, without spines, pseudozygocarpic; female receptacles cylindrical to fusiform, up to 4 mm long, up to 0.5 mm in diameter, without spines, pseudozygocarpic.

Specimens From Vietnam

Specimens Dai 81174 and 81175. Collected April 24, 1981, from Ninh Thuan (Son Hai), Vietnam; drifted.

(Figs. 23–28)

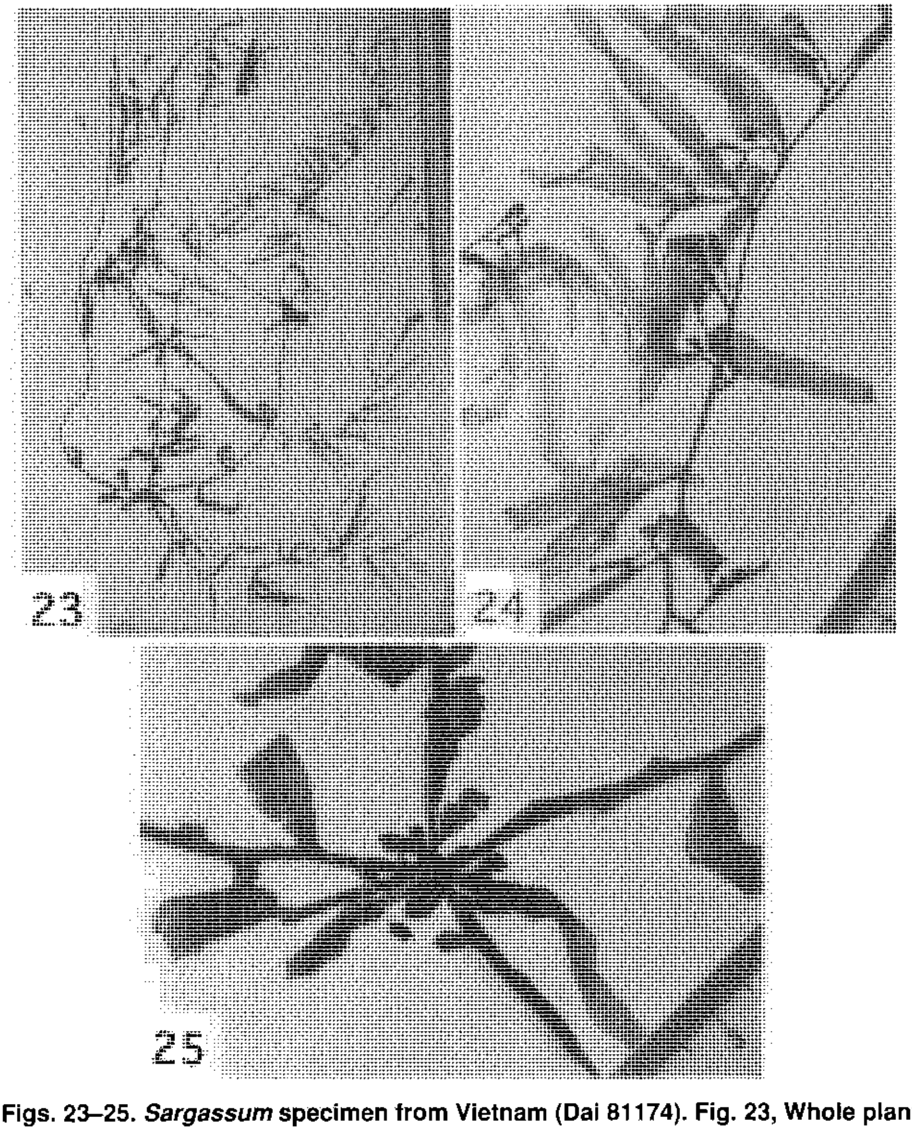
Holdfast lacking (drifted specimens). Stem cylindrical, 5 mm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 40 cm or more long, slightly compressed, up to 2 mm wide in the basal part, cylindrical distally, 1 mm wide, smooth on the surface; secondary branches 10 cm or more long; short, thick bulbous structures formed from the stem, about 8 mm long, 3 mm in diameter on the surface. Leaves on the lower parts of main branches lanceolate, up to 7 cm long, 10 mm wide, entire or with sparse and small denticulations on the margin, papyraceous, midrib reaching the apex; leaves on the distal parts of main and secondary branches finer in texture, becoming narrower and shorter, 5.5 cm long, 7 mm wide; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, with round apex, without appendages, 5 mm in diameter, with short cylindrical petioles up to 3 mm long.

Plants monoecious. Receptacles androgynous, slender, cylindrical to fusiform, up to 12 mm long, up to 1 mm in diameter, 1–2 times forked, without spines, holozygocarpic.

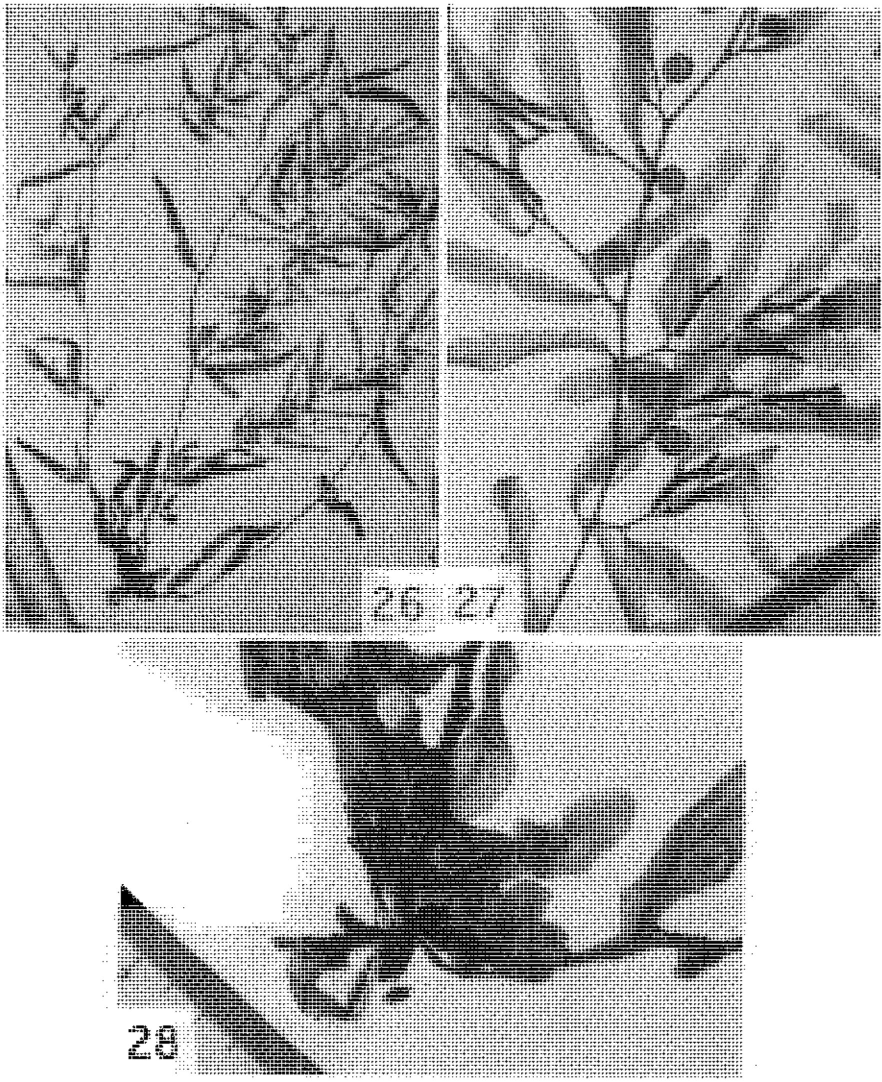
Specimens AJI 01–04 (4 sheets). Collected February 28, 1994, from Ganh Cao, Tien Yen Bay, Quang Ninh Province, Vietnam.

(Figs. 29–36)

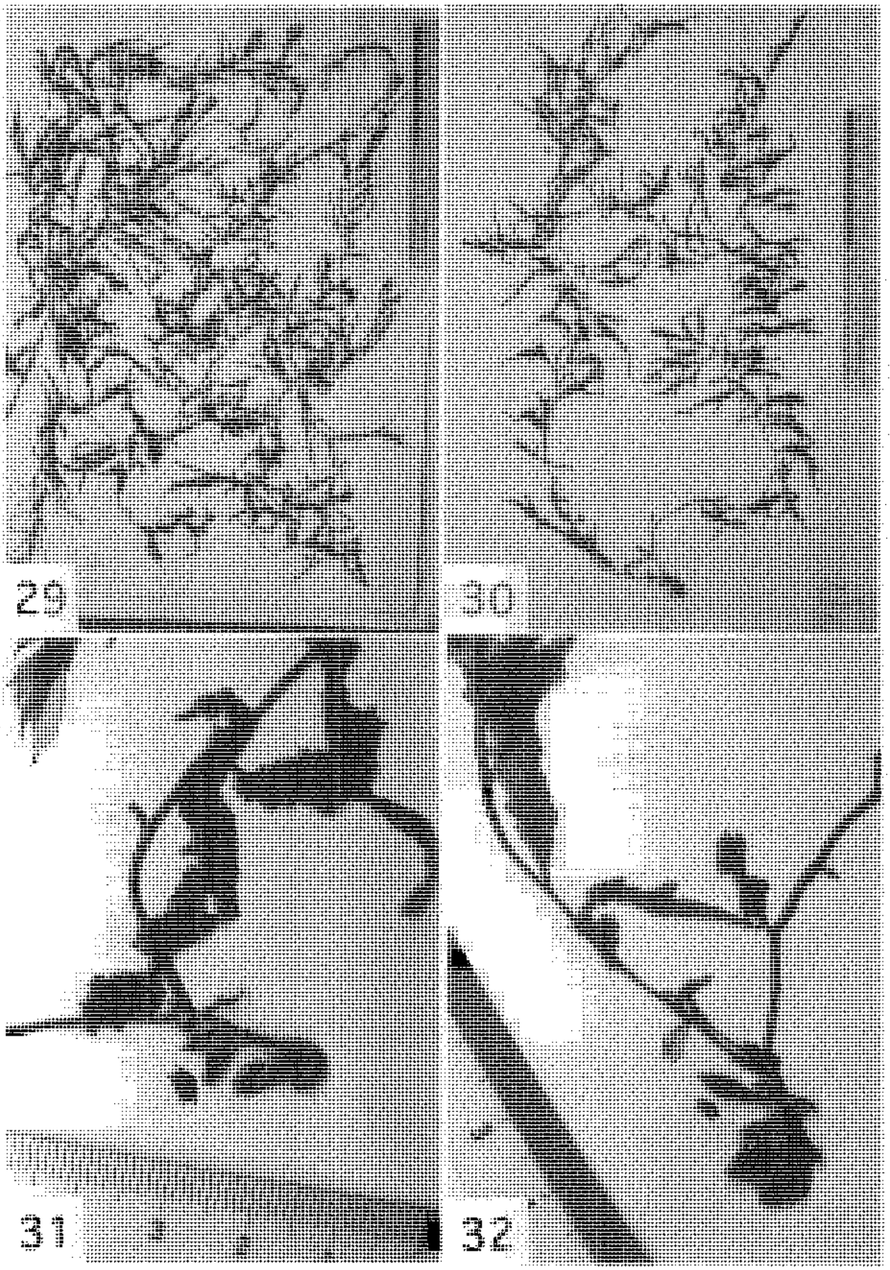
Holdfast discoid, up to 8 mm in diameter. Stem cylindrical, 1 cm tall, 2 mm in diameter. Main branches arising radially from the apex of the stem, 50 cm or more long, slightly compressed, up to 2 mm wide in the basal part, cylindrical distally, smooth on the surface, with alternate leaves; secondary branches 10 cm or more long; short, thick bulbous structures formed from the stem, about 5 mm long, 2 mm in diameter. Leaves on the lower parts of main branches linear to linear-lanceolate, up to 10 cm long, 10 mm wide, entire or with sparse and small denticulations on the margin, papyraceous, midrib reaching the apex; leaves on the distal parts of main and secondary branches finer in texture, becoming narrower and shorter; leaves often 3–4 times forked; cryptostomata very small, scattered on the surface of leaves; vesicles spherical to obovate, with round apex, without



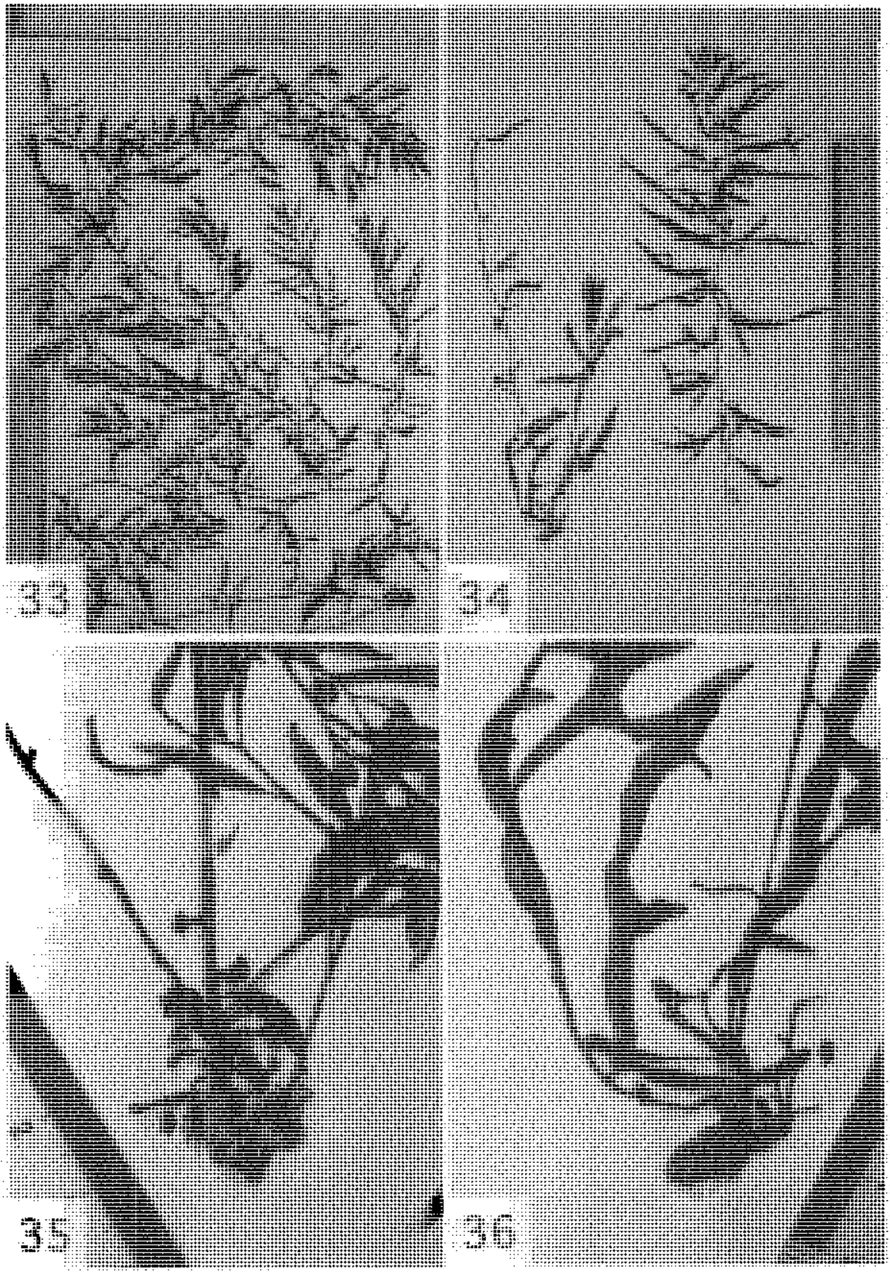
Figs. 23–25. ***Sargassum*** **specimen from Vietnam (Dai 81174). Fig. 23, Whole plant. Fig. 24, Upper branchlets with leaves and holozygocarpic receptacles. Figs. 25, Holdfast with bulbous structure (arrow).**



Figs. 26–28. *Sargassum* specimen from Vietnam (Dai 81175). Fig. 26, Whole plant. Fig. 27, Upper branchlets with leaves, vesicles, and holozygocarpic receptacles. Fig. 28, Holdfast with bulbous structures (arrow).



Figs. 29–32. *Sargassum* specimens from Vietnam (Figs. 29 and 31, AJI 01; Figs. 30 and 32, AJI 02). Figs. 29 and 30, Whole plants. Figs. 31 and 32, Holdfasts with bulbous structures (arrows).



Figs. 33–36. *Sargassum* specimens from Vietnam (Figs. 33 and 35, AJI 03; Figs. 34 and 36, AJI 04). Figs. 33 and 34, Whole plants. Figs. 35 and 36, Holdfasts with bulbous structures (arrows).

appendages, 3 mm in diameter, with cylindrical petioles up to 3 mm long.

Remarks: These plants with bulbous structures are immature plants without reproductive structures.

Specimens From Bahrain

Specimens ARAI 01–08 (8 sheets) and 09–12 (4 sheets). Collected February 6, 1999 (ARAI 01–08), and December 22, 1998 (ARAI 09–12), from Bahrain, Arabian Sea; drifted.

(Figs. 37–47)

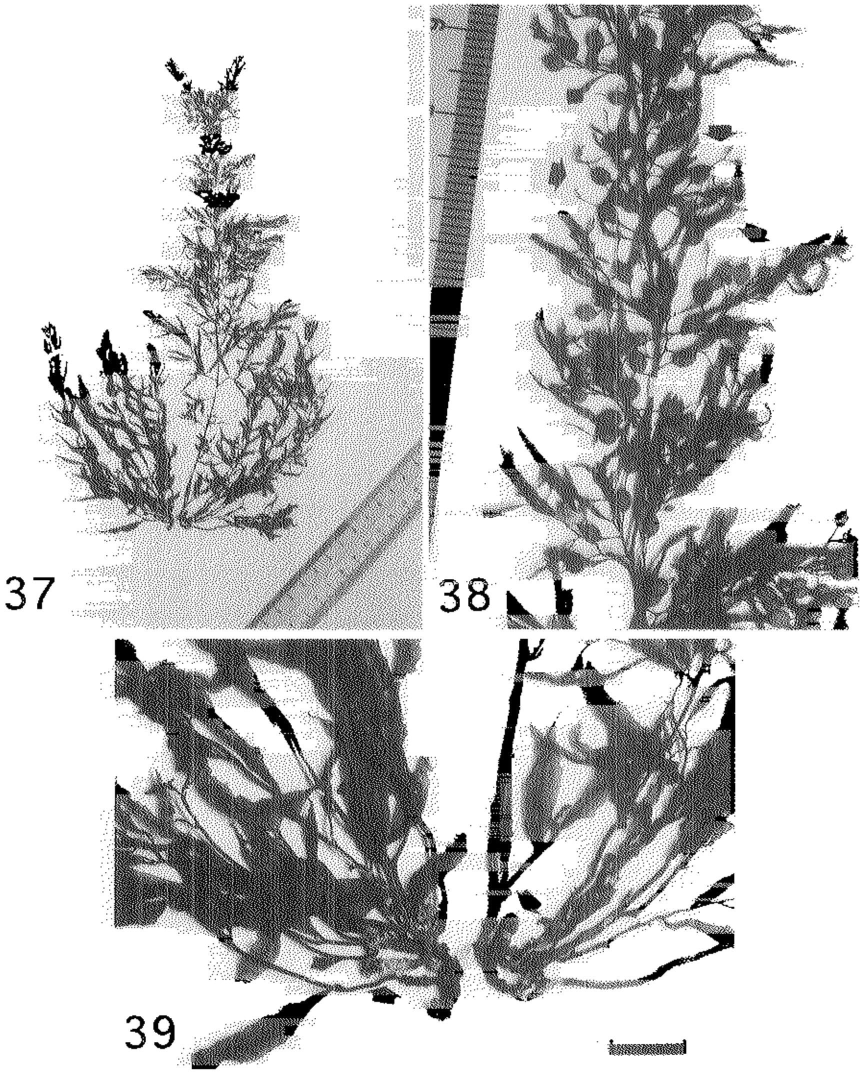
Holdfast discoid, up to 7 mm in diameter. Stem cylindrical, 5 mm tall, 1 mm in diameter. Main branches arising radially from the apex of the stem, 40 cm or more long, cylindrical, up to 1 mm wide, smooth on the surface, with alternate leaves; secondary branches 5 cm or more long; short, thick bulbous structures formed from the stem, about 6 mm long, 2 mm in diameter. Leaves on the lower parts of main branches lanceolate, up to 3.5 cm long, 4 mm wide, entire or with sparse and small denticulations on the margin, papyraceous, midrib reaching the apex; leaves on lower parts often 1–4 times forked; leaves on the distal parts of main and secondary branches finer in texture, becoming narrower and shorter; cryptostomata very small, scattered on the surface of leaves; vesicles spherical, 3 mm in diameter, usually with round apex, sometimes crowned with a linear leaf, 3 mm long; cylindrical petioles up to 5–8 mm long, sometimes longer, up to 10 mm, on secondary branches.

Plants monoecious. Receptacles androgynous, variable in shape and length, slender, cylindrical to short fusiform, up to 5–10 mm long, up to 0.8 mm in diameter, 1–2 times forked, without spines, sometimes holozygocarpic.

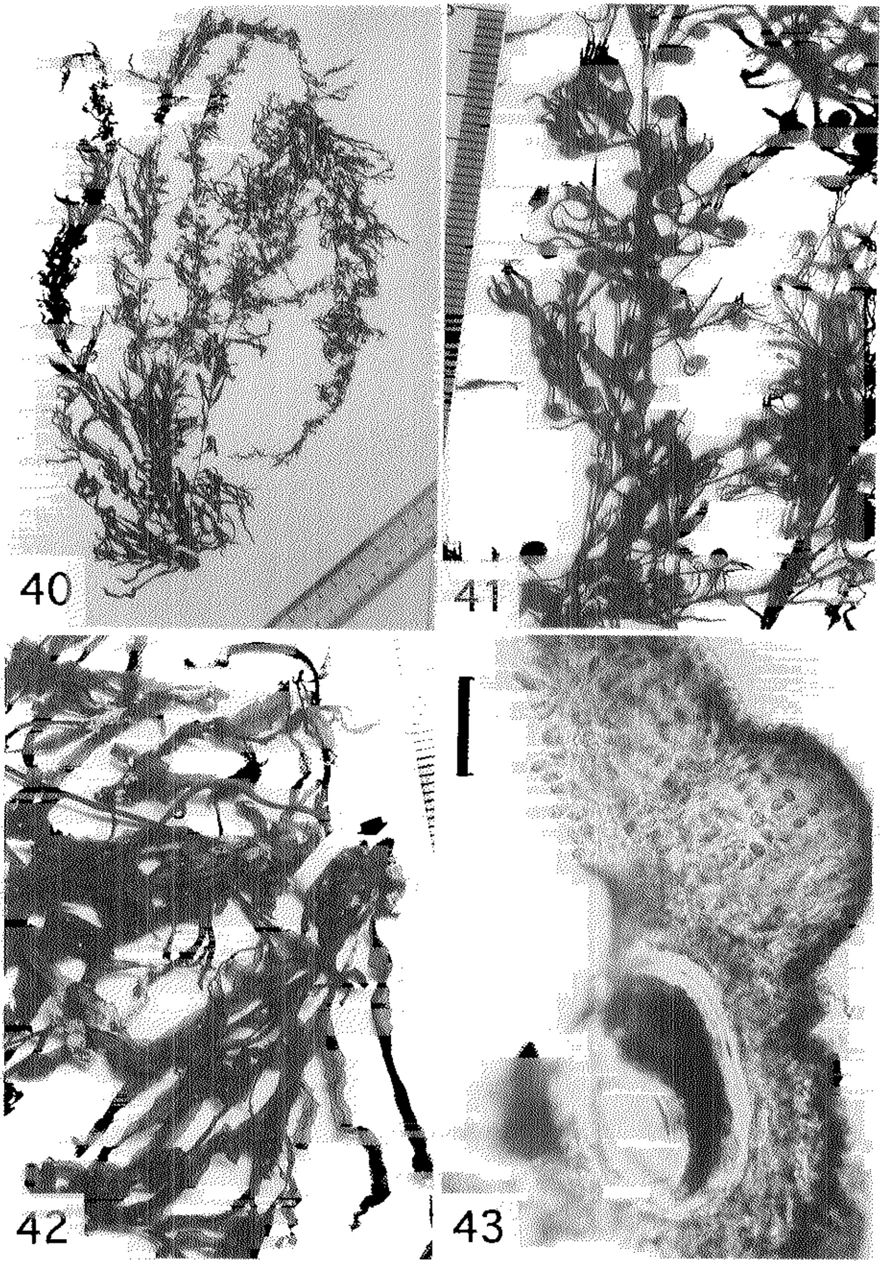
Discussion

Sargassum bulbiferum described by Yoshida (1994) can be easily distinguished from other *Sargassum* species by 2 characteristics: furcate leaves on the basal part of the plant and bulbous structures. The other morphological characters of *S. bulbiferum* are clearly similar to those of *S. carpophyllum* J. Agardh. However, Ajisaka et al. (1997) reported *S. carpophyllum* var. *nhatrangense* Ajisaka from Vietnam, which has furcate leaves on the basal parts of the plant. Nguyen and Huynh (1999) also reported a new variety from Vietnam, *S. carpophyllum* var. *honomense* Nguyen et Huynh, which also has furcate leaves on the basal part of the plant. The occurrence of these furcate leaves on the basal parts of the plant in *S. carpophyllum* may be common in Vietnamese populations. Sometimes basal furcate leaves are present even on the secondary branches of Vietnamese plants. On the other hand, basal furcate leaves have not been observed in Japanese specimens of *S. carpophyllum* (Ajisaka et al. 1995).

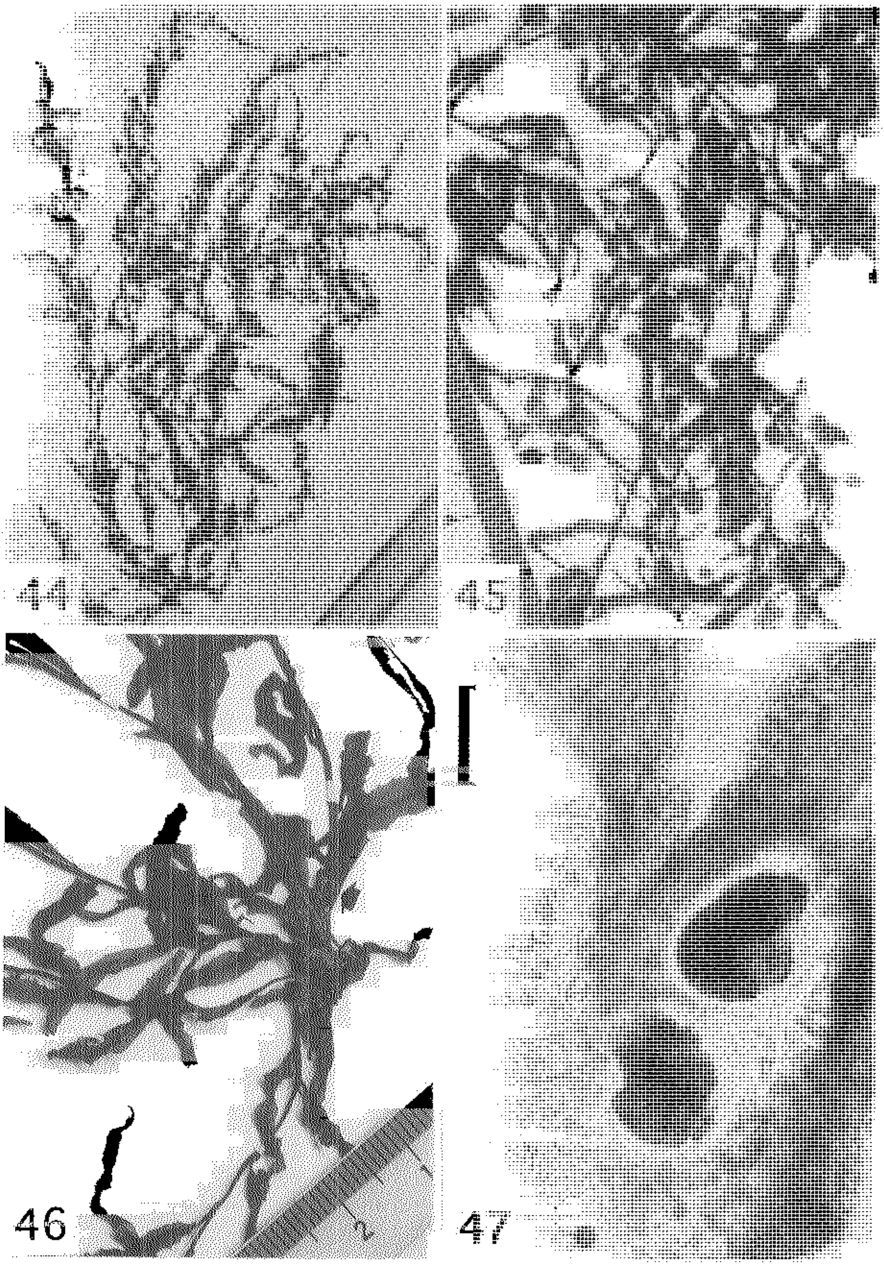
In her description of *C. nodicaulis* (Withering) M. Roberts, Roberts (1977)



Figs. 37–39: *Sargassum* specimen from Bahrain (ARAI 09). Fig. 37, Whole plant. Fig. 38, Upper branchlets with leaves, vesicles with crown leaves (arrows). Fig. 39, Holdfast with bulbous structures (arrows); scale bar = 1 cm.



Figs. 40–43. Sargassum specimen from Bahrain (ARAI 03). Fig. 40, Whole plant. Fig. 41, Upper branchlets with leaves, vesicles, and long holozygocarpic receptacles (arrow). Fig. 42, Holdfast with bulbous structures (arrow). Fig. 43, Transection of androgynous receptacle; scale bar = 100 µm.



Figs. 44–47. *Sargassum* specimen from Bahrain (ARAI 06). Fig. 44, Whole plant. Fig. 45, Upper branchlets with leaves, vesicles, and holozygocarpic receptacles (arrow). Fig. 46, Holdfast with bulbous structures (arrow). Fig. 47, Transection of androgynous receptacle; scale bar = 100 µm.

stated, "The basal tophules [the bulbous structures] form around the apex of the axis . . . and form a conspicuous feature of the denuded resting axis." She characterized the basal tophules of *Cystoseira nodicaulis* as "ovoid, about 1.5 cm long and the surface may be smooth or covered with tubercles." She reported that "after the period of dormancy, slender cylindrical outgrowths arise from the tips of the tophules, elongate rapidly, and divide to form the lateral branch system." After the plants were actively growing, these characteristic tophules disappeared. However, the morphological nature and the cause of their development are unknown. Yendo (1907) described similar structures of *C. hakodatensis* (Yendo) Fensholt as "fusiforme structures."

Bulbous structures of *Sargassum* and *Cystoseira* specimens have a similar morphology: ovoid to short, thick and fusiform, 5–10 mm long, 2–4 mm in diameter, with a very smooth surface. The bulbous structure may be an arrested stage of the main branch on the stem. After a period of dormancy, slender main branches may arise from the tip of bulbous structures, as with the tophules in *Cystoseira*. Bulbous structures may be produced on 1-year-old plants and may issue a new main branch for the next season in perennial specimens.

In North Vietnam (Quang Ninh Province), the *Sargassum* plants were growing in shallow coastal waters, only about 1 m deep. Juvenile plants with furcate leaves usually have no bulbous structures, but the juvenile and young main branches from the stout stem, which seems to be perennial, have bulbous structures (Figs. 29–36). These findings suggest that bulbous structures are formed only on perennial plants. At this time, mature plants with receptacles have not been collected from this location. When the juvenile and immature plants without bulbous structures are identified, they are easily recognized as *S. carpophyllum* J. Agardh because they have somewhat thin, papyraceous leaves and have furcate leaves on the basal parts of the plant, the same as does *S. carpophyllum.*

The Japanese specimens of *S. bulbiferum* were found in comparatively deeper water, about 15–18 m deep (Yoshida 1994). Because the type locality is located near the Tsushima Current (warm current, a branch of the Kuroshio Current), the deeper area may be warmer than the shallow/surface waters, even at the high latitude. On the other hand, in the tropical region, Vietnam, the plants were growing along a shallow coast, in water about 1 m deep. The plants of subgenus *Sargassum* usually grow in subtropical/tropical areas, so perhaps the plants of the Japanese population can survive only in deeper (warmer and calmer) conditions in the temperate region. The Japanese specimens have slightly larger holdfasts than do the specimens from other localities (Table 1). The larger holdfasts and bulbous structures may enable the population to persist in the deeper habitat.

Because the specimens from Bahrain and Ninh Thuan, Vietnam, were drifted specimens, we cannot discuss their habitats. However, the collector, Mr. Shogo Arai, observed that these plants were growing along the shallow coast (about 1 m deep) in Bahrain. We have no information about the habitats of the specimens from China.

A comparative study of the morphological characters among the type speci-

Table 1. A Comparative Study of Morphological Characters in *Sargassum bulbiferum* and Specimens With Bulbous Structures*

	Locality and Specimens						
Character	**Japan *S. bulbiferum***	**China AST 55-1830**	**China AST 55-1922**	**China AST 55-2041**	**Vietnam Dai 81174 and 81175**	**Vietnam AJ 101–04**	**Bahrain ARA 101–15**
Holdfast							
Diameter, mm	20	8	5	5	(None)	8	7
Stem							
Height, mm	10	5	6	15	5	10	5
Diameter, mm	2	2	2	2	2	2	1
Bulbous structure							
Height, mm	8	6	5	10	8	5	6
Diameter, mm	3	3	2	4	3	2	2
Main branch							
Length, cm	40	40	37	40	40	50	40
Width, mm	2	2	2	3	2	2	1
Secondary branches							
Length, cm	10	8	14	5	10	10	5
Leaves							
Length, cm	10	3	5	7	7	10	3.5
Width, mm	10	5	5	9	10	10	4
Tines, forked	0–1	0–3	0–4	0–3	0	0–4	0–4
Vesicles							
Diameter, mm	3	4	3	4.5	5	3	3
Petioles							
Length, mm	3	8	8 (17)	6	3	3	8
Receptacles	Monoecious	Monoecious	Monoecious	Monoecious	Monoecious	NA	Monoecious
Length, mm	7	5	6	6	12	NA	10
Diameter, mm	0.8	0.8	0.8	0.8	1.0	NA	0.8
Tines, forked	1–2	1–2	1–3	1–4	1–2	NA	1–2
Zygocarpic	Pseudo-	Pseudo-	Pseudo-	Pseudo-	Holo-	NA	Holo-

*Data for *S. bulbiferum* are from the type description (Yoshida 1994). Values for diameters, heights, lengths, and widths are maximums. NA indicates not applicable.

mens of *S. bulbiferum* and other *Sargassum* specimens with bulbous structures from China, Vietnam, and Bahrain is shown in Table 1. From the morphological characters, we conclude that Vietnamese and Arabian specimens seem to belong to the same species, which may be temporarily included in the name of *S. carpophyllum* "*perennis*," because it is difficult to recognize the characteristics (furcate leaves on the basal parts of the plants and bulbous structures) as taxonomic criteria at the species level.

Some morphological characteristics of the leaves, vesicles, and receptacles differ among these specimens. For example, some specimens from Bahrain have vesicles with linear crown leaves and receptacles that vary in shape and length (Figs. 38, 41, and 45). Receptacles of the plants from Bahrain and Vietnam (Ninh Thuan) have holozygocarpic receptacles, but specimens from other localities have pseudozygocarpic receptacles. These morphological differences might be caused by some geographic, physical, and ecological factors. A DNA analysis of the 2 species, *S. bulbiferum* and *S. carpophyllum*, is required for a clear conclusion about the taxonomic distinction between them.

The Chinese specimens present a somewhat different case in terms of the morphological characters. Some of the Chinese specimens might be included in *S. carpophyllum* "*perennis*," but some might be included in other species. The specimen AST 87-1329 (given the temporary name "*S. weizhouense*" by Tseng and Lu) is similar in morphological characters to other specimens from China, but Chinese specimens sometimes have very long, leafy petioles of the vesicles (Fig. 13). We also found some specimens (e.g., AST 55-2112) from China that have the same characteristics as those of *S. carpophyllum* "*perennis*," but the specimens have dioecious receptacles (Figs. 18 and 22); Tseng and Lu gave these specimens the tentative herbarium name "*S. gemmipherum*" (unpublished). This situation calls for a more critical survey of the morphological variations in these Chinese specimens, especially at the population level.

Acknowledgments

We thank Dr. Isabella Abbott, University of Hawaii, Manoa, and Dr. Karla McDermid, University of Hawaii, Hilo, for their careful help in improving the manuscript. Also, special thanks to Dr. James Sullivan, former director, California Sea Grant, for the workshops on taxonomic seaweeds for many years. Thanks also to Mr. Shogo Arai, Ltd. Algal Institute, for his kindness in contributing the specimens from Bahrain.

Literature Cited

Ajisaka, T., Noro, T., and Yoshida, T. 1995. Zygocarpic *Sargassum* species (subgenus *Sargassum*) from Japan. In: Tax. Econ. Seaweeds 5, pp. 11–44, figs. 1–24.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, and Yoshida, T. 1997. *Sargassum carpophyllum* J. Agardh var. *nhatrangense* (Pham) Ajisaka comb. nov. and *S. piluliferum* (Turner) C. Agardh var. *serratifolium* Yamada from Vietnam. In: Tax. Econ. Seaweeds 6, pp. 51–60, figs. 1–23.

Nguyen Huu Dinh and Huynh Quang Nang. 1999. Some new taxa of *Sargassum* (Phaeophyta) from Vietnam. In: Tax. Econ. Seaweeds 7, pp. 43–51, figs. 1–14.

Roberts, M. 1977. Studies on marine algae of the British Isles: 9. *Cystoseira nodicaulis* (Withering) M. Roberts. Br. Phycol. J. 12:175–199, figs. 1–23.

Yendo, K. 1907. The Fucaceae of Japan. J. Coll. Sci. Tokyo Imp. Univ. 21:1–174.

Yoshida, T. 1983. Japanese species of *Sargassum* subgenus *Bactrophycus* (Phaeophyta, Fucales). J. Fac. Sci. Hokkaido Univ. Ser V (Bot.) 13:99–246.

Yoshida, T. 1994. Three new species of *Sargassum* from Japan. Jpn. J. Phycol. 42:43–51, figs. 1–13.

SOME NEW SPECIES AND RECORDS OF *SARGASSUM* (SARGASSACEAE, PHAEOPHYTA) FROM THE CHINA SEA

C.K. Tseng and Lu Baoren

Abstract

Three new species of *Sargassum*, namely *S. weizhouense* Tseng et Lu, *S. capitatum* Tseng et Lu, and *S. ilicifolioides* Tseng et Lu, are discussed, and a new combination is made, namely *S. euryphyllum* (Grunow) Tseng et Lu. These 4 and *S. bulbiferum* Yoshida are all new records for China.

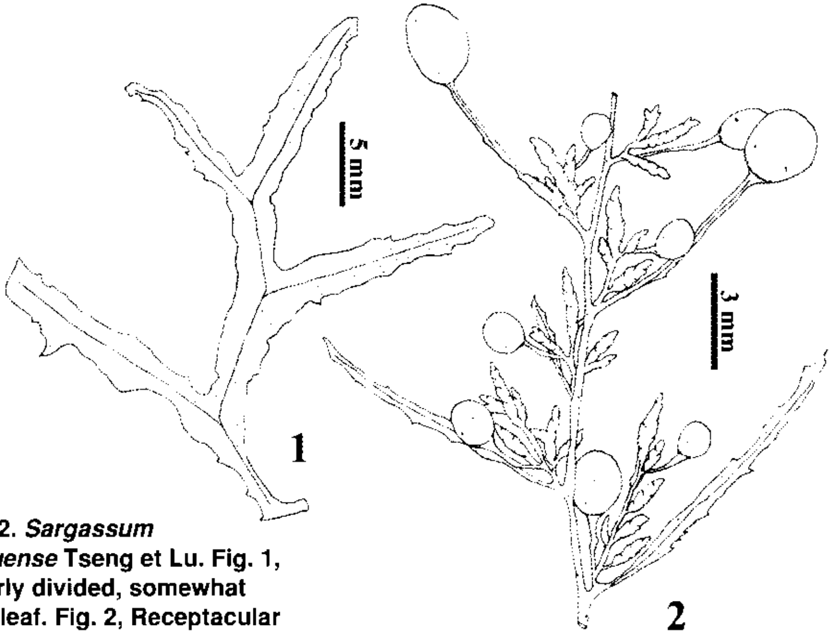
Introduction

Sargassum, especially the subgenus *Sargassum*, is a predominantly tropical and strongly subtropical genus and is very well represented in the Indo-Pacific region. When W. A. Setchell came to Hong Kong in 1929, he was surprised at the wealth of *Sargassum* species of this island; in a single drift on the beach, he found more than 10 species. He asked 2 young botanists in the area, Dr. Herklots of Hong Kong University and Prof. McClure of Lingnan University, to keep on searching for *Sargassum* specimens, and he finally published several articles enumerating 13 species (Setchell 1931a, 1931b, 1933, 1935, 1936). In the summer of 1942, a few months before his death, Setchell encouraged one of us (Tseng) to keep on with *Sargassum* studies because Setchell believed that many more species were present in this region. Although I (Tseng) returned to China in late 1946, I was unable to take up this study. I began to concentrate on *Sargassum* in 1965–1966, was interrupted by the "Cultural Revolution," and resumed the studies in 1970. Since then, Lu Baoren and I have written 36 articles or chapters describing 7 new species of *Sargassum*: 16 published in Chinese, 16 published in English, and 4 in press. In this chapter, we publish 4 more new species from China. Together with the published species, China has now 130 species of *Sargassum*.

Descriptions of the Species

Sargassum weizhouense Tseng et Lu, sp. nov.
(Figs. 1–5)

Frons lutea brunnea, 100 cm ultra alta. Haptero disciformi, 1 cm diametro. Ramis primariis et secundariis complanatas ad subcylindricis, cum aliquando spinis. Foliis primariis lanceolatis aliquando divisis pinnatim, 5–7 cm longis, 4–6 mm latis, acutis ad extremum, cuneatis vel oblique at basim, costis conspicuus percurrentibus, cryptostomatibus disperses ad utroque costalis, dentatibus ad margines; foliis secundariis similitudo ad foliis primariis, solum brevis, aliquando divisis, 4–5 cm longis, 3–5 mm latis; foliis ramulis angustis lanceolatis ad linearis,



Figs. 1–2. *Sargassum weizhouense* Tseng et Lu. Fig. 1, Irregularly divided, somewhat pinnate leaf. Fig. 2, Receptacular branchlets with receptacles, "leaves," and vesicles.

Fig. 3. Habit of *Sargassum weizhouense* Tseng et Lu. Note radial branching pattern.

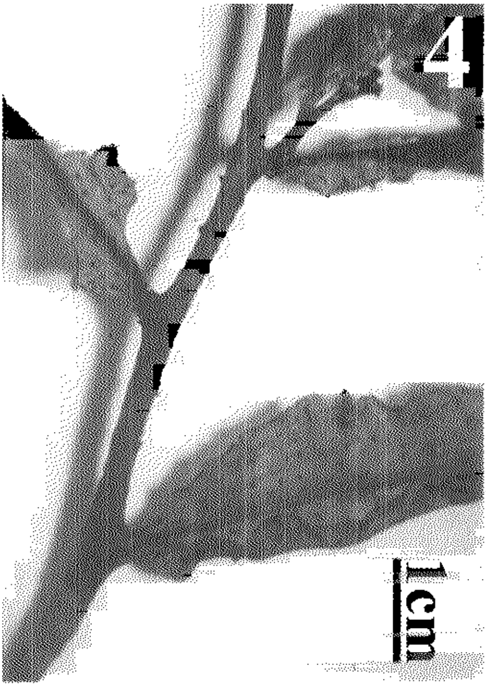


Fig. 4. Small spines on stem of *Sargassum weizhouense* Tseng et Lu. Fig. 5. Holdfast, stem, and main axis at base of plant of *Sargassum weizhouense* Tseng et Lu.

non lobatis, 3–6 cm longis vel plus, 1.5–2 cm latis. Vesiculis sphaeris vel ovatis, 1.5–3 mm diametro.

Planta androgyna. Receptaculis conicis, verrucosis, 1.5–2 mm longis, 0.8–1 mm diametro. Holozygocarpicae.

Holotype. AST 55-1828, collected by Zhang Junfu and Xu Fali, April 26, 1955, at Weizhou Island, Guangxi Province.

Fronds yellowish brown, more than 100 cm tall. Holdfast discoid, 1 cm in diameter. Main axis cylindrical, short, glabrous, about 5 mm long, 4 mm in diameter. Several primary branches arising from the upper part of the axis, compressed to subcylindrical, usually spinous, about 100 cm long, 2 mm in diameter. Secondary branches cylindrical, about 18–30 cm long, 1.5 mm in diameter, arising from leaf axils of the primary branches, similar to primary branches in shape, only shorter, slightly spinous on the surface, alternate, at intervals of 2–3 cm. Ultimate branchlets cylindrical with a few cryptostomata, 10–15 cm long, 1–1.5 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on primary branches with short compressed leaf stalk, about 1–2 mm long, lanceolate, 1–2 times pinnately divided, 5–7 cm long, 4–6 mm wide, acute at the apex, cuneate or slightly oblique at the base, dentate at the margins, with distinct, percurrent midrib and conspicuous cryptostomata irregularly scattered on both sides of the midrib. Leaves on secondary branches similar to those on the primary branches in shape, shorter and more slender, sometimes divided, 4–5 cm long, 3–5 mm wide. Leaves on ultimate branchlets narrowly lanceolate to linear, 3–6 cm or more long, 1.5–2 mm wide, usually 20–30 times as long as wide, dentate at the margins, with percurrent midrib and cryptostomata arranged on both sides of the midrib. Vesicles spherical or ovate, 1.5–3 mm in diameter, with some cryptostomata, stalks mostly cylindrical, 3–9 mm long, 0.3–0.5 mm in diameter, sometimes flattened or foliaceous, with midribs and cryptostomata, denticulate at the margins, 15–20 mm long.

Plants androgynous. Receptacles conical, simple, 1–2 times furcated, verrucose on the surface, about 1.5–2 mm long, 0.8–1 mm in diameter, sometimes holozygocarpic.

Holotype: AST 55-1828, collected by Zhang Junfu and Xu Fali, on April 26, 1955, at Weizhou Island, Guangxi Province.

Other Material Examined: From Weizhou Island: AST 55-1829, 55-1893, 55-1896, 55-1922a, 55-1923, 55-1935, 87-1260, 87-1329, 87-1330, 96-0002, 96-0003, 96-0043, 96-0051, 96-0052, 96-0053, 96-0065, 96-0076, and 96-0077.

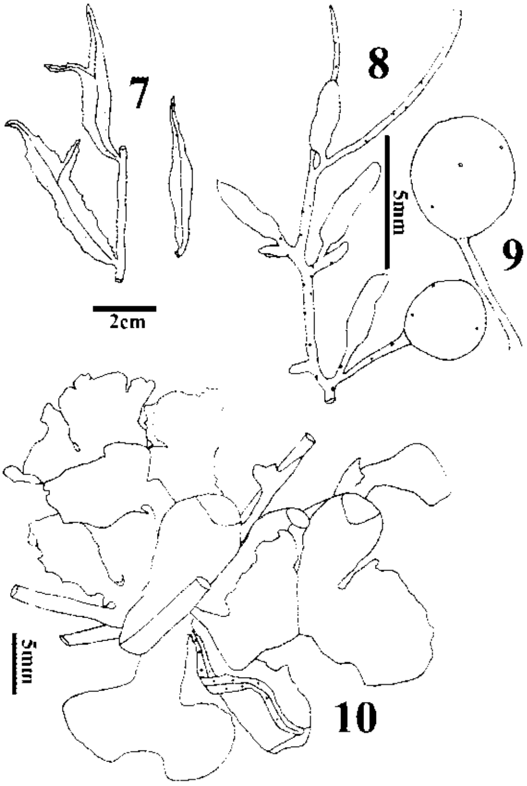
Habitat: Growing on subtidal rocks, usually 1–2 m under water.

Remarks: *Sargassum weizhouense* Tseng et Lu is characterized by its discoid holdfast; compressed to subcylindrical primary branches, usually spinous on the surface; leaves usually divided 1–2 times; and androgynous, holozygocarpic, conical receptacles, usually with a small leaf or vesicle. This species is related to *S. bulbiferum* Yoshida, but *S. weizhouense* does not have bulbs on the basal parts of the primary branches, and its primary and secondary branches usually have a spinous surface.

Sargassum bulbiferum Yoshida, Jpn. J. Phycol. 42:48, figs. 9–11.
(Figs. 6–10)

Fronds yellow-brown, attaining a height of more than 100 cm, holdfast discoid, verrucose on the surface, up to 1.2 cm in diameter. Axis cylindrical, glabrous or somewhat warty, up to 10 mm long, 2 mm in diameter. Primary branches thick and compressed, about 8–10 mm long, 3–5 mm wide, 3–5 arising radially from upper parts of the axis, lower parts of branches compressed, upper parts cylindrical, glabrous, up to 100 cm or more long, 2 mm wide, often with several bulbs at the base of the primary branches. Secondary branches arising from foliar axils of the primary branches, at intervals of 2–4 cm, alternate, cylindrical, glabrous, about 10–14 cm long, 1–1.2 mm in diameter. Ultimate branches short and slender, glandular, about 3–4 cm long, less than 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on primary branches elongatedly lanceolate, sometimes linear, once forked, about 3–7 cm long, 3–8 mm wide, acute at the

Fig. 6. Habit of Chinese specimen of *Sargassum bulbiferum* Yoshida, originally described from central Japan in the Sea of Japan.



Figs. 7–10. *Sargassum bulbiferum* Yoshida. Fig. 7, Shapes of 3 "leaves." Fig. 8, Elongate receptacles with "leaves" and vesicles. Fig. 9, Vesicle with nearly spherical shape and a few cryptostomata. Fig. 10, A group of bulbs (stunted structures) at the base of a primary branch.

apex, cuneate at the base, with conspicuous percurrent midrib and a few cryptostomata scattered throughout the surface, irregularly dentate or entire at the margins. Leaves on secondary branches similar to those on primary branches in shape, but smaller, about 4–5 cm long, 2–3 mm wide. Leaves on ultimate branchlets linear or narrowly lanceolate, not forked, about 2–3 cm long, 1–2 mm wide, acute at the apex, slightly obliquely cuneate at the base. Vesicles spherical or obovate-rounded at the apex, up to 3 mm in diameter, with a few cryptostomata and slender, terete, filamentous stalks, up to 8 mm long, less than 0.5 mm in diameter.

Plants androgynous. Receptacles cylindrical, glabrous, verrucose on the surface, oogonia mainly gathered on the upper parts of the receptacles, spermantagia mainly on the lower parts, about 7–8 mm long, 0.8–1 mm in diameter, once or twice forked, pseudozygocarpic.

Habitat: Growing on subtidal rocks.

Distribution in China: AST 55-1830 and 55-1922, collected by Zhang Junfu and Xu Fali, April 1955, at Weizhou Island, Guangxi Province; AST 55-2041, collected by Zhang Junfu and Xu Fali, May 1955, at Weizhou Island, Guangxi Province.

Geographical Distribution. Japan and China.

Remarks: Our specimens collected at Weizhou Island were carefully compared with the description and figures of *S. bulbiferum* published by Yoshida (1994, p. 48, figs. 9–11), particularly the bulbs at the base of the primary branches and the forked leaves. In 1999, at the workshop meeting in Vietnam, we showed a specimen (AST 55-2041) to Dr. Yoshida, and he agreed with our determination. We are grateful to Dr. Yoshida for his help. This species is recorded for the first time from China.

Sargassum capitatum Tseng et Lu, sp. nov.
(Figs. 11, 12, 15–17)

Frons cinerea, 24 cm alta, haptero disciformi, 1.5 cm diametro. Axes cylindricis, furcatis. Ramis primariis complanatis, glabris, bulbis, 23 cm longis, 2 mm latis. Ramulis brevibus, cylindricis, 1–1.5 mm longis, 1 mm diametro. Foliis cineris, elongatis lanceolatis, crassiusculis, aliquando divisis, 8 cm longis, 10 mm latis, acutis apicibus, obliques cuneatis ad basim, costis conspicuus, percurrentibus, cryptostomatibus dispersim ad utroque costalis, maximum partem undulatibus ad margines. Vesiculis sphaericis vel ovatis, 3–4 mm diametro, aliquot cryptostomatibus.

Planta androgyna. Receptaculis cylindricis furcis at apicibus, 5 mm longis, 1 mm diametro. Pseudozygocarpicae.

Holotype: AST 59-3586, collected by Yang Zondai and Li Xiaoyi, July 5, 1959, at Dacheng Island, Zhejiang Province.

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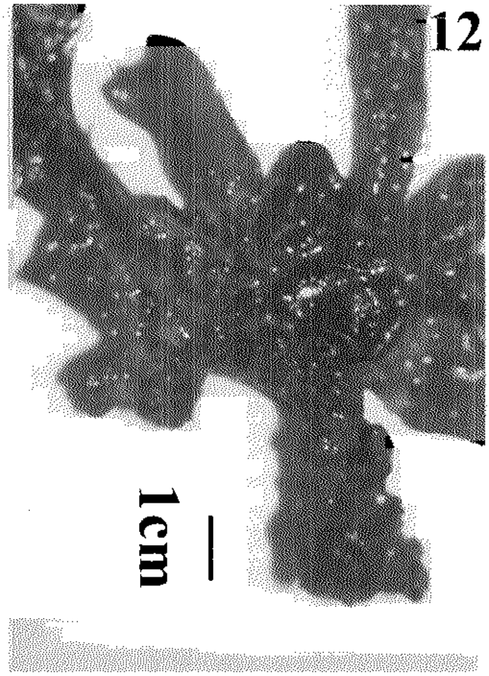
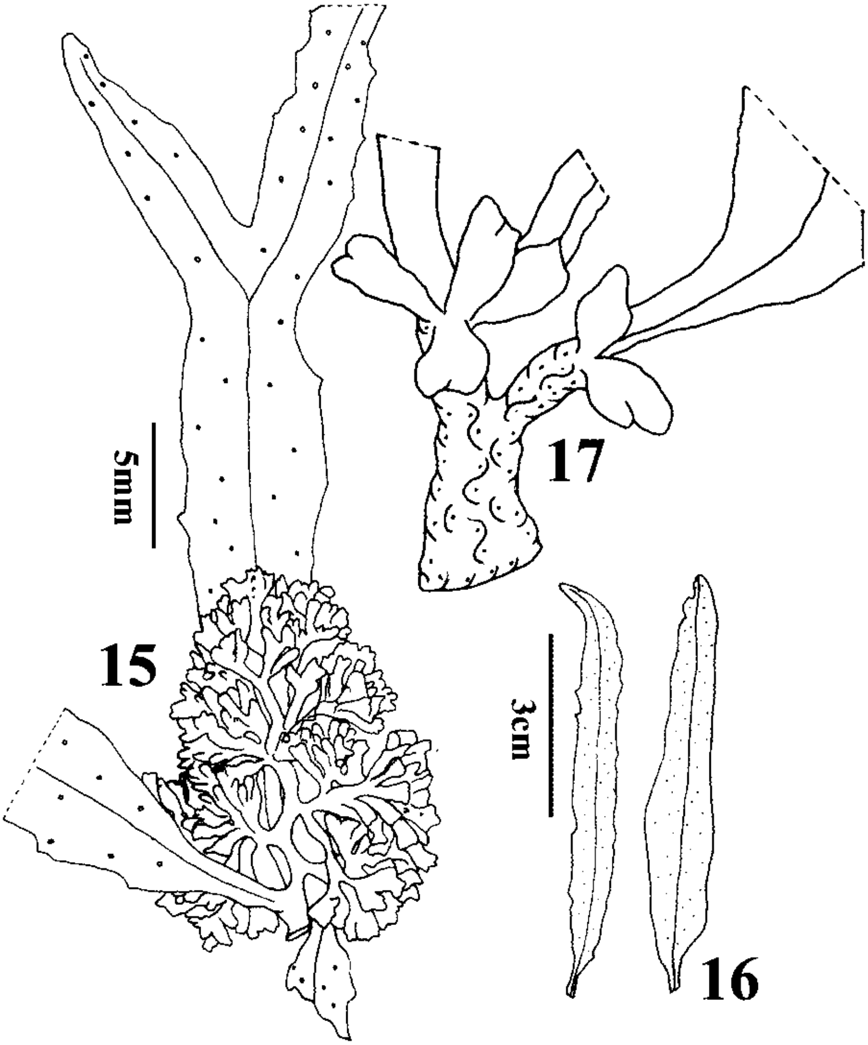


Fig. 11. Habit of holotype specimen of *Sargassum capitatum* Tseng et Lu. Fig. 12. Basal part of *Sargassum capitatum* Tseng et Lu, including holdfast, divided main axis, and bulbs.

Fronds with blue-gray cast, up to 24 cm tall. Holdfast discoid, 1.5 cm in diameter. Main axis cylindrical, usually divided at the top, up to 1.5 cm long, 3 mm in diameter, with warty surface. Primary branches arising from the upper parts of the main axis, compressed, glabrous on the surface, up to 23 cm tall, 2 mm wide, with several bulbs at the base. Fertile branchlets very short, arising from foliar axils of the primary branches, 1–1.5 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves with blue-gray cast, thick and large, elongatedly lanceolate, sometimes divided, up to 8 cm long, 10 mm wide, acute at the apex, slightly obliquely cuneate at the base, with conspicuous percurrent midribs and a few cryptostomata irregularly arranged on both sides of the midribs; leaves mostly entire at the margins, or denticulate at the middle and upper parts of the margins, generally leaves on lower parts of plant larger than leaves on upper parts, similar to each other in shape. Vesicles spherical or ovate, rounded at the apex, 3–4 mm in diameter, with compressed and glabrous stalks 3 mm long, and a few cryptostomata.

Plants androgynous. Receptacles cylindrical, verrucose on the surface, usually forked, particularly at the apex, 5 mm long, less than 1 mm in diameter, several receptacles compound, racemosely arranged, pseudozygocarpic.



Figs. 15–17. *Sargassum capitatum* Tseng et Lu. Fig. 15, Furcate "leaf" and densely branched receptacular branch. Fig. 16, Two lanceolate "leaves." Fig. 17, Divided main axis with bulbs.

Holotype: AST 59-3586, collected by Yang Zondai and Li Xiaoyi, July 5, 1959, at Dacheng Island, Zhejiang Province.

Other Material Examined: AST 59-3454, collected at Beiji Island, Weizhou City; AST 59-3850, collected at Beiyushan Island, Xiang County; and AST 63-4497, collected at Nanji Islands.

Habitat: Growing on lower intertidal to subtidal rocks.

Remarks: *Sargassum capitatum* is characterized by its usually divided main axis; compressed primary branches with thick, large, elongately lanceolate, sometimes forked, blue-gray leaves; the presence of bulbous structures at the base of primary branches; and androgynous, pseudozygocarpic, cylindrical, verrucose receptacles that are compound and arranged in a panicle. It is closely related to *S. bulbiferum* Yoshida. However, *S. bulbiferum* does not have a divided main axis; large and thick leaves, mostly entire at the margins; or paniculate receptacles.

Sargassum euryphyllum (Grunow) Tseng et Lu, comb. nov.
(Figs. 13, 18–20)

Basionym: *Sargassum ilicifolium* (Turner) C. Agardh var. *euryphylla* Grunow, Verh. K.-K. Zool.-Bot. Gesell. Wien 65:404, 1915.

Fronds yellow-brown, reaching a height of more than 100 cm. Holdfast discoid. Axis cylindrical, very short, up to 5 mm tall, glabrous. Primary branches arising radially from the upper parts of the axis, subcylindrical, more than 100 cm long, 3 mm in diameter, glabrous on the surface. Secondary branches arising from foliar axils of the primary branches, at intervals of 4–6 cm, alternate, cylindrical, glabrous, up to 20 cm long, 2 mm in diameter. Ultimate branchlets shorter and more slender, cylindrical, with a few plain glandular dots on the surface, up to 6 cm long, 1 mm in diameter, beset with leaves, vesicles, and receptacles. Leaves on primary branches large, oblong, up to 4.5 cm long, 16 mm wide, rounded at the apex, obliquely asymmetrically cuneate at the base, usually larger abaxially than adaxially, without conspicuous midrib, midrib vanishing on lower parts of the leaves, slightly raised conspicuous cryptostomata, irregularly arranged on both sides of the midrib, dentate at the margins. Leaves on secondary branches oblong, slightly shorter, up to 4 cm long, 10 mm wide. Leaves on ultimate branches usually obovate, upper parts larger than lower parts, about 2–3 cm long, 4–5 mm wide, with conspicuous cryptostomata arranged on both sides of the midrib. Vesicles spherical, sometimes opposite, up to 6 mm in diameter, generally 4 mm in diameter when young, with a few slightly raised cryptostomata on the surface, and cylindrical stalks, 3 mm long, 1 mm in diameter.

Plants dioecious. Female receptacles when very young and male receptacles cylindrical, glabrous, up to 4 mm long, 1 mm in diameter, usually forked, racemosely arranged on the fertile branches, pseudozygocarpic.

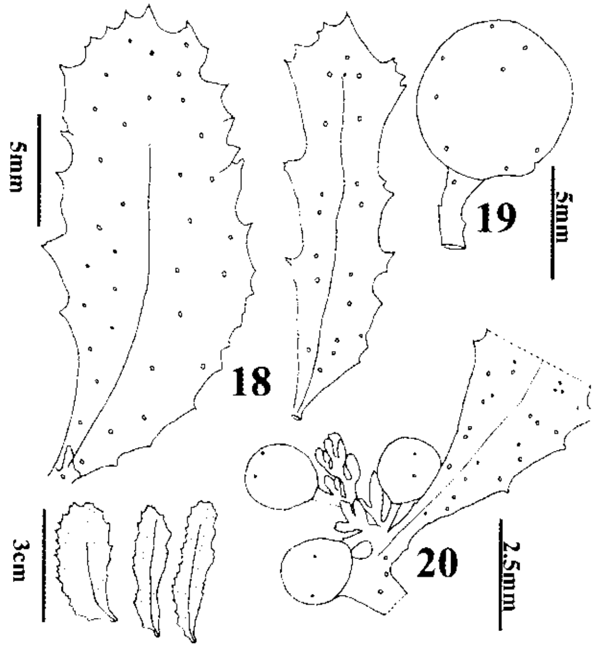
Distribution in China: Qinglanglang, Xinying, and Sanya, Hainan Island.

Geographical Distribution: Red Sea, China

Habitat: Growing on lower intertidal rocks.

Remarks: Some specimens of *Sargassum* collected from Hainan Island (AST 57-5897, 57-5898, 57-5920, 63-2383, and 92-0247) agree with the description of *S. ilicifolium* (Turner) C. Agardh var. *euryphylla* Grunow (Grunow 1915, p. 404). We carefully compared specimens from Hainan Island with *S. ilicifolium* (Turner)

Fig. 13. Habit of Chinese specimen of *Sargassum euryphyllum* (Grunow) Tseng et Lu.



Figs. 18–20. *Sargassum euryphyllum* (Grunow) Tseng et Lu. Fig. 18, "Leaves" on primary (2 at top of figure) and secondary (3 at bottom of figure) branches. Fig. 19, Vesicle with rather stout cylindrical stalk. Fig. 20, Vesicles mixed with male receptacles.

C. Agardh and found marked differences. Our specimens have large, oblong leaves, spherical vesicles, and no earlike structures on both sides. Female receptacles are very young; male receptacles are glabrous, cylindrical, and pseudozygocarpic. *Sargassum ilicifolium*, however, has small elongated, ellipsoidal leaves, spherical vesicles with an earlike structure on both sides, and very simple receptacles: "receptaculis femineis brevibus, fastigiato racemosis, minute denticulatis." Therefore, we decided to elevate the variety *euryphylla* Grunow of *S. ilicifolium* (Turner) C. Agardh to *S. euryphyllum* (Grunow) Tseng et Lu.

Sargassum ilicifolioides Tseng et Lu, sp. nov.

(Figs. 14, 21–24)

Misapplied Name: *Sargassum ilicifolium* of Tseng et Lu, Stud. Mar. Sinica 12:5, pl. 3, 1978.

Frons lutea brunnea, ramis primariis subcylindricis, 45 cm longis, 2 mm diametro; ramis secundariis cylindricis, 12 cm longis, 1.5 mm diametro, elevatis glandibus; ramulis parvis, elevatis glandibus, 5 cm longis, 1 mm latis; foliis ramulis lanceolatis, 1.5 cm longis, 4 mm latis. Vesiculis sphaericis, elevatis cryptostomatibus, structuris auriculatibus utroque.

Planta androgyna. Receptaculis complanatibus, spinis, furcatis saepe, 2–4 mm longis, 1–1.5 mm latis.

Holotype: AST 76-1239, collected by Lu Baoren, March 20, 1976, at Chenhang Island, Xisha Islands.

Fronds yellow-brown. Primary branches subcylindrical, glabrous, arising radially from upper parts of the axis, up to 45 cm long, 2 mm in diameter. Secondary branches cylindrical, up to 12 cm long, 1.5 mm in diameter, arising from foliar axils of primary branches, with a few raised glandular dots, at intervals of 2–4 cm, alternate. Ultimate branchlets cylindrical, slender and shorter, up to 5 cm long, 1 mm in diameter, with dense, raised glandular dots, beset with leaves, vesicles, and receptacles. Leaves on primary and secondary branches obovate or ellipsoidal, rounded at the apex, obliquely asymmetrically cuneate at the base, up to 2 cm long, 10 mm wide, with nonpercurrent, conspicuous midrib, midrib usually vanishing in the middle parts of the leaves, and conspicuous cryptostomata, slightly raised on the surface, dentate at the margins. Leaves on ultimate branchlets lanceolate, smaller, up to 1.5 cm long, 4 mm wide, acute at the apex, symmetrical, cuneate at the base, with conspicuous midrib, midrib usually vanishing below the apex, with conspicuously raised cryptostomata, irregularly arranged on both sides of the midrib, sharply dentate at the margins, with filamentous stalks with a few raised cryptostomata. Vesicles spherical and small, 3–5 mm in diameter, with a few raised cryptostomata, rounded at the apex, with earlike structures on both sides, and mostly cylindrical, sometimes compressed or flattened, stalks.

Plants androgynous. Receptacles compressed, spinous at the apex and

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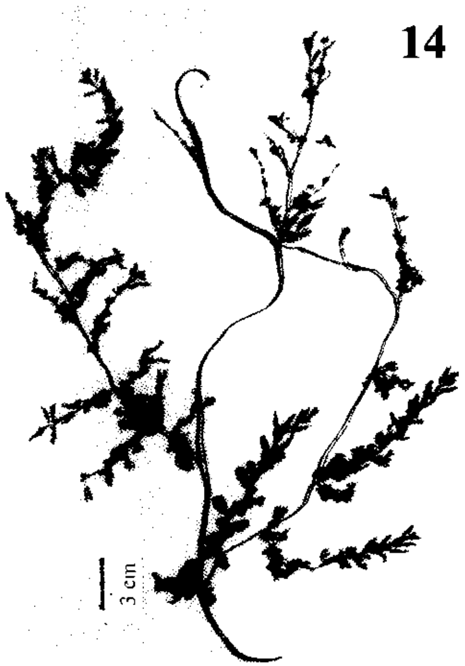
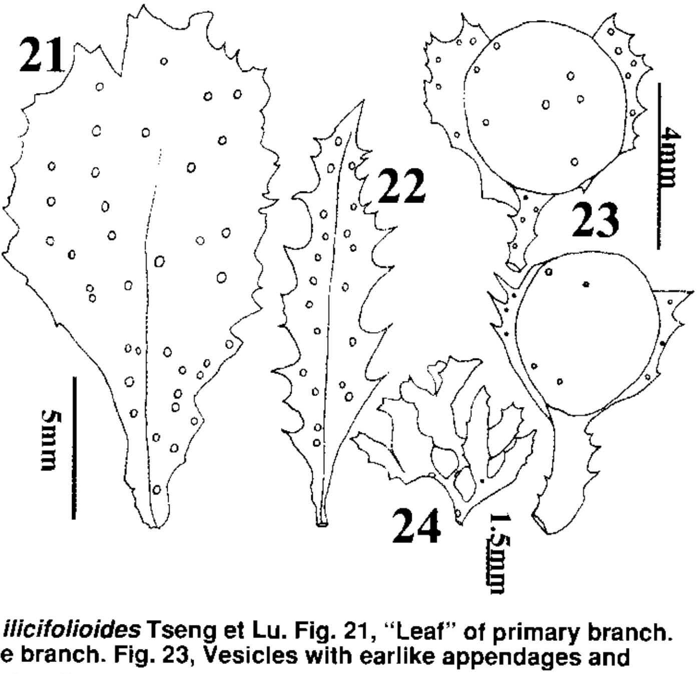


Fig. 14. Habit of the holotype of *Sargassum ilicifolioides* Tseng et Lu.



Figs. 21–24. *Sargassum ilicifolioides* Tseng et Lu. Fig. 21, "Leaf" of primary branch. Fig. 22, "Leaf" of ultimate branch. Fig. 23, Vesicles with earlike appendages and cylindrical to compressed stalks. Fig. 24, Compressed, branched vesicles.

laterally, often once to twice forked, about 2–4 mm long, 1–1.5 mm wide, several receptacles racemosely arranged on the fertile branches, odontocarpic.

Holotype: AST 76-1239, drifted ashore, collected by Lu Baoren, March 20, 1976, at Chenhang and Xisha Islands.

Other Materials Examined: AST 76-0886, from Guangjin Island, Xisha Islands, and AST 76-1242, from Chenhang Island, Xisha Islands.

Remarks: *Sargassum ilicifolioides* Tseng et Lu is principally characterized by its secondary and ultimate branches with raised glandular dots on the surface; 2 kinds of leaves, obovate or ellipsoidal on the primary and secondary branches and lanceolate on the ultimate branches; and androgynous, compressed and spinous receptacles, racemosely arranged on fertile branchlets. It is closely related to *S. ilicifolium* (Turner) C. Agardh, but *S. ilicifolium* does not have raised glandular dots on the branches of the secondary and ultimate branches; 2 kinds of leaves, obovate or ellipsoidal on primary and secondary branches and lanceolate on the ultimate branches; or androgynous receptacles.

We (Tseng and Lu 1978, p. 5) published "*Sargassum ilicifolium*" collected from Xisha Islands on the basis of specimens with acanthocarpic androgynous, compressed receptacles, single, once or twice divided. Our identification was based entirely on the description of Grunow: "receptaculis ancipitibus, androgynis racemoses vel racemosocymosis, masculis hinc inde longioribus, omnibus acute spinosis." Yoshida (1988) reported *S. ilicifolium* from Taiwan, only with male receptacles. Japanese phycologists, including Dr. Yoshida, told us that *S. ilicifolium* is dioecious. Dr. Yoshida checked our specimen and agreed with our determination. In recent years, in studying the subsection *Biserrulae* of *Sargassum*, we have come to think that the algae, although very primitive plants, have a clear distinction between different sexual stages and should not have both androgyny and dioecism in the same species. Therefore, after careful study, we found the real female plants of *S. ilicifolium* and compared them with those of *S. ilicifolioides*. We find that these 2 species are conspicuously different individual species.

Conclusion

In this chapter, we report 5 new records for the algal flora of China. Of these, 3 are new species: the holozygocarpic species *S. weizhouense* Tseng et Lu, the pseudozygocarpic species *S. capitatum* Tseng et Lu, and *S. ilicifolioides* Tseng et Lu. *Sargassum euryphyllum* (Grunow) Tseng et Lu is a new combination. *Sargassum bulbiferum* of Tseng et Lu is simply a new record. We (Tseng and Lu 1988) have reported 17 species of zygocarpic *Sargassum* in China, and together with the 4 species just reported, the total is 21 zygocarpic *Sargassum* species for China. *Sargassum ilicifolioides* Tseng et Lu was formerly erroneously identified by Tseng et Lu (1999) as *S. ilicifolium* belonging to the series Odontocarpae (Coriifoliae) of biserrulic *Sargassum*.

Acknowledgments

This chapter is contribution No. 4182 from the Institute of Oceanology, Chinese Academy of Sciences, Qingdao. We thank Mr. Ding Lanpin for inking our drawings, and Dr. I. A. Abbott for advice and corrections.

Literature Cited

Ajisaka, T., Noro, T., and Yoshida, T. 1995. Zygocarpic *Sargassum* species (subgenus *Sargassum*) from Japan. In: Tax. Econ. Seaweeds 5, pp. 11–43, figs. 1–24.

Grunow, A. 1915. Additamenta ad cognitionem Sargassorum. Verh. K.-K. Zool.-Bot. Gesell. Wien 65:329–448.

Setchell, W. A. 1931a. Hong Kong Seaweeds, I. Hong Kong Nat. 11:39–60.

Setchell, W. A. 1931b. Hong Kong Seaweeds, II. Hong Kong Nat. 11:237–253.

Setchell, W. A. 1933. Hong Kong Seaweeds, III. Hong Kong Nat. Suppl. 2:33–49, pls. 1–20.

Setchell, W. A. 1935. Hong Kong Seaweeds, IV. Hong Kong Nat. Suppl. 4:1–24, pls. 1–17.

Setchell, W. A. 1936. Hong Kong Seaweeds, V. Hong Kong Nat. Suppl. 5:1–20, pls. 1–8.

Tseng, C. K., and Lu Baoren. 1978. Studies on the Sargassaceae of the Xisha Islands, Guangdong Province. Stud. Mar. Sinica 12:1–11, pls. 1–5.

Tseng, C. K., and Lu Baoren. 1988. Studies on Chinese species of zygocarpic *Sargassum*. In: Tax. Econ. Seaweeds 2, pp. 23–54, figs. 1–34.

Tseng, C. K., and Lu Baoren. 1999. Studies on the Biserrulic *Sargassum* of China: II. The series Coriifoliae (J. Agardh) Tseng et Lu. In: Tax. Econ. Seaweeds 7, pp. 3–22, figs. 1–17.

Yoshida, T. 1988. Japanese and Taiwanese species of *Sargassum* subgenus *Sargassum*. In: Tax. Econ. Seaweeds 2, pp. 5–21, figs. 1–18.

Yoshida, T. 1994. Three new species of *Sargassum* (Sargassaceae, Phaeophyta) from Japan. Jpn. J. Phycol. 42:43–51.

Section II. Gelidiales

INTRODUCTION

Isabella A. Abbott

Some genera, including *Sargassum, Ulva, Enteromorpha, Liagora, Gracilaria,* and *Gelidium,* require that you really like them and adopt them as you would a pet. Some of them (in my case, *Liagora* and its relatives) are like pets that you have had for a long time. Similarly, Dr. Santelices has thought about and worked on the Gelidiales since the late 1970s, and in this section (not surprising to anyone who knows him), he reports the results of an examination of the type materials of *Gelidiella adnata* Dawson, which had been placed in synonymy with *G. antipai* Célan. The type locality of *G. adnata* is near the Institute of Oceanography in Vietnam. Satoshi Shimada, in studying some of the Japanese species of *Pterocladiella,* found better material than was earlier available, and restored species to that genus that had earlier been placed in synonymy.

The Chinese species of *Gelidium* are presented in synoptic form, in both photographs and line drawings of all species, a testament to Xia Bangmei's skillful abilities (I wish I had some of her genes). A new species from Hainan Island was also added.

The Gelidiales Group. (Left to right): Bernabé Santelices, Ryuta Terada, Xia Bangmei, Khan Lewmanomont.

THE TAXONOMIC STATUS OF *GELIDIELLA ADNATA* (GELIDIALES, RHODOPHYTA)

Bernabé Santelices

Abstract

In recent years, *Gelidiella adnata* Dawson was considered a synonym of *G. antipai* Célan. Reexamination of the type materials of *G. adnata*, collected in Nha Trang, Vietnam, indicated that the arrangement of the external cortical cells and the number of tetrasporangia produced in each transverse tier of the stichidium segregate *G. adnata* from *G. antipai*. In addition, the patterns of apical division, the internal structure of the thallus, and the structure of the stichidium of this species are conspicuously different from the respective patterns in *G. acerosa*, the type species of the genus. It is concluded that the species presently recognized in *Gelidiella* may belong to more than a single genus.

Introduction

The taxonomic position of *G. adnata* Dawson (1954a) became increasingly confused during the past 10 years. This species was described by Dawson on the basis of specimens collected on intertidal surfaces along the rocky shores of Nha Trang, Vietnam. Later he reported the species from Isla San Benedicto, Revillagigedo Archipelago (Dawson 1954b), and at Arno Atoll in the Marshall Islands (Dawson 1956). While studying Hawaiian species of *Gelidiella*, I (Santelices 1977) noticed that 2 other species, *G. antipai* Célan and *G. stichidiospora* Dawson were similar to *G. adnata*. Previously, Boudouresque (1972) suggested that *G. stichidiospora* was a synonym of *G. antipai*, despite the different geographic origins of the 2 species (Caliacra, Roumania, reported by Célan in 1938, and Baja California, Mexico, reported by Dawson in 1952). Even though neither Boudouresque (1972) nor I (Santelices 1977) included *G. adnata* as a synonym of *G. antipai*, Norris (1992b) did so on the basis that both species produce 4 sporangia in each stichidial segment and have rhizoidal cells produced by most ventral cells of prostrate branches. Norris's suggestion (1992b), however, was not followed by Womersley and Guiry (1994). They identified *G. antipai* among materials collected in southern Australia but did not include *G. adnata* as a synonym. They commented that Dawson's figure of *G. adnata* (Dawson 1954a, p. 422, fig. 33p) lacked enough details to allow a determination of the status of the species. The first objective of the study reported here was to provide a more detailed account of the type materials of *G. adnata* as a basis for future comparisons with related species.

At the generic level, the taxonomic position of *G. adnata* also is a matter of confusion. *Gelidiella adnata* is the smallest of all the species of *Gelidiella*; it is approximately one-tenth the size of *G. acerosa*, the type species of the genus. Thus, whereas erect axes in *G. adnata* normally are up to 2.0 mm long and 70 µm in diameter, in *G. acerosa* they are up to 15 cm long and 600 μm in diameter (see Maggs and Guiry 1987, Ganzon-Fortes 1994, and Kraft and Abbott 1998 for comparative data). In addition to size differences, descriptions also suggest that *G. adnata* may differ morphologically from *G. acerosa*. For example, Norris (1992b) illustrated morphological differences between these 2 species.

Equivalent differences are apparent between *G. antipai* and *G. ramellosa* as described by Womersley and Guiry (1994) on the basis of Australian materials. Whereas the morphology of *G. ramellosa* reproduces in small size the general pattern of the morphology of *G. acerosa*, *G. adnata* and *G. antipai* seem to differ in the structure of the thallus. Thus, a second objective for a critical study of the type materials of *G. adnata* was to contrast its pattern of morphology with that of *G. acerosa*, the type species of the genus.

Materials and Methods

The specimen studied is the holotype of *G. adnata*, No. 56446 in the herbarium of the Smithsonian Institution (U.S. National Herbarium). The plants were collected by Dawson on February 13, 1953. They were growing mixed with *Herposiphonia* on intertidal rock surfaces along rocky shores below "the director's villa (Bao Dai Palace)," Nha Trang, Vietnam. The plants were hydrated, fixed with formalin (4% in sea water), stained with 1% aqueous aniline blue, and mounted in dilute corn syrup. A Leitz freezing microtome was used to cut rehydrated materials. Photomicrographs were taken with a Nikon Optiphot-2 microscope. Slides are deposited in the National Herbarium in the United States and in the Algal Collection of the Sala de Sistemática, P. Universidad Católica de Chile (SS/UC).

Observations

Specimens of *G. adnata* in the type materials are turfy, pale red, and up to 2.5 mm tall. They have a prostrate system from which originate simple, erect branches (Fig. 1A). In fertile specimens, the branches may have lanceolate or cylindrical stichidia (Fig. 1B).

The growth of the prostrate axis is indeterminate (Fig. 2), with a single apical cell that divides transversely. The subapical cells have longitudinal divisions in 2 directions, cutting off 2–4 periaxial cells, which cut off further cells. Lateral divisions are compressed, 65–95 μm wide by 50–75 μm thick, and are attached along their cortical cells. Rhizoids are 25–50 μm long and 2–3 μm wide, have thick cell walls, and narrow lumen (Fig. 3). Longer (up to 100 μm long) and thicker (7–8 μm thick) aggregations of coccoid cyanobacteria and amorphous, seemingly gelatinous substances are present among the attaching filaments.

A surface view of the creeping axes shows (Fig. 4) transversely arranged, elongated, rectangular or irregularly shaped cortical cells, 5–15 μm wide by 2–5 μm long. In longitudinal sections (Fig. 5), these external cortical cells are rounded, 3–5 μm in diameter, and internally flanked by a layer of larger and longitudinally elongated cortical cells, 4–7 μm in diameter and 10–15 μm long. The medulla is

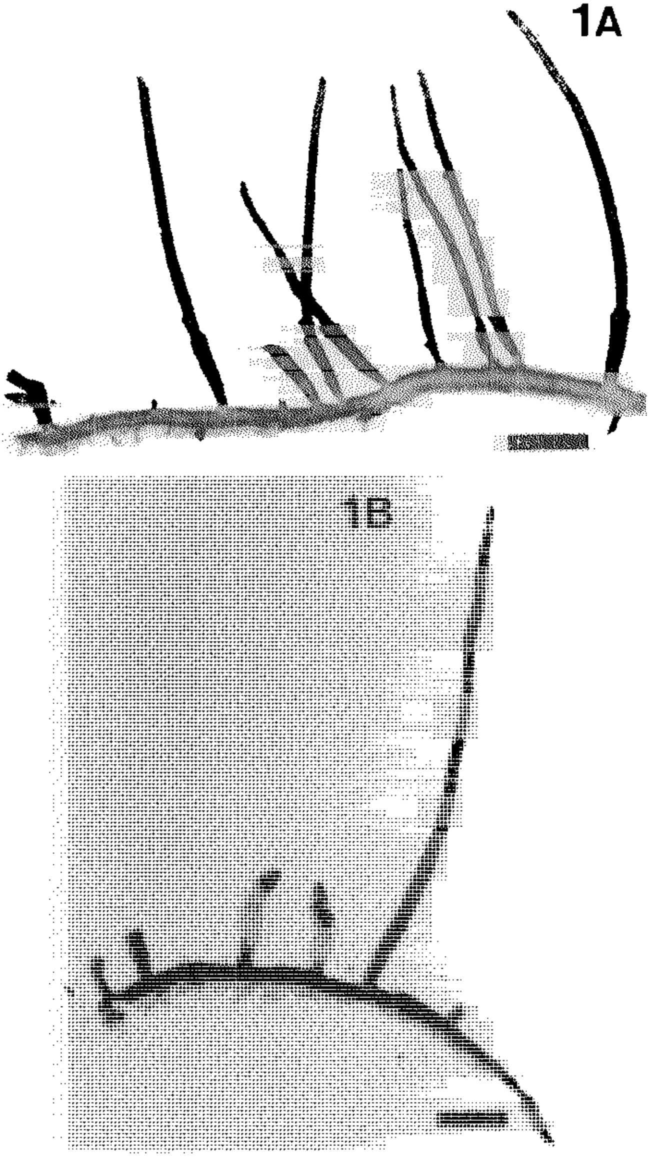
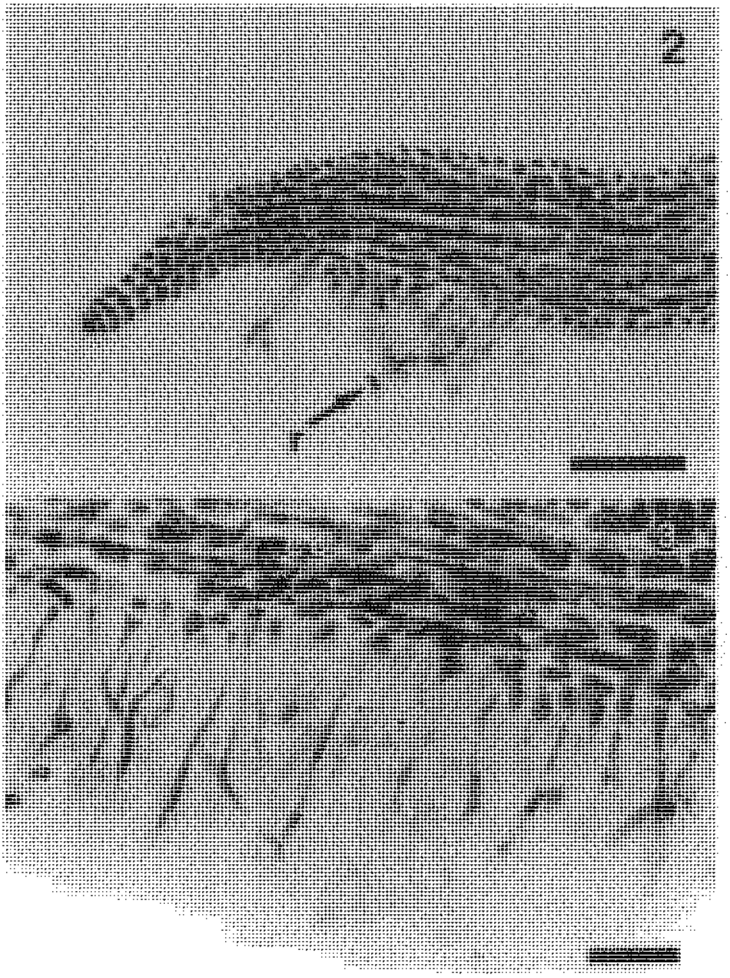


Fig. 1. External habit of *Gelidiella adnata*. A, Vegetative plant. B, Fertile, tetrasporic specimen with mature stichidia on short pedicels. Scale bar in both figures = 300 µm.



Figs. 2,3. Fig. 2. Apical tip of prostrate system of *Gelidiella adnata* with apical cell and patterns of cell division. Note unicellular rhizoids originating in the undersurface (arrow); r = rhizoidal cell; scale bar = 50 µm. Fig. 3. Close-up of attaching rhizoids in the creeping axes of *Gelidiella adnata*. Note the origin of each rhizoid from an external cortical cell (arrow). cc = cortical cell; scale bar = 20 µm.

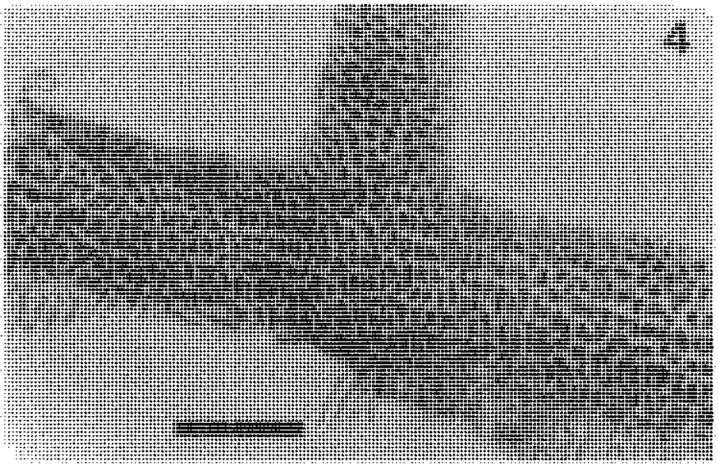
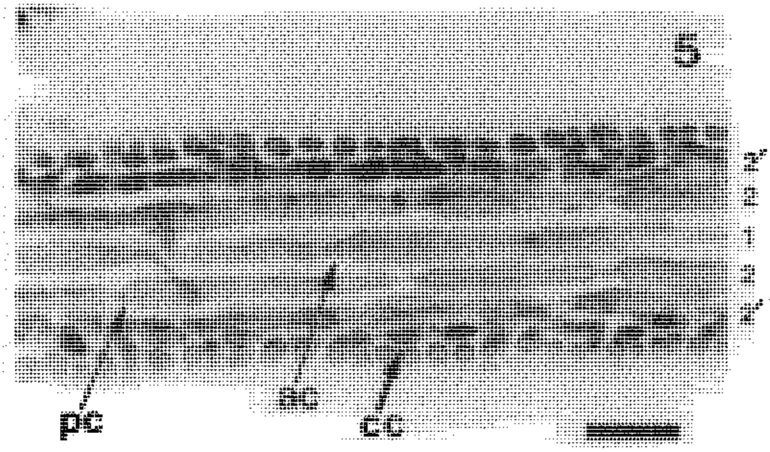


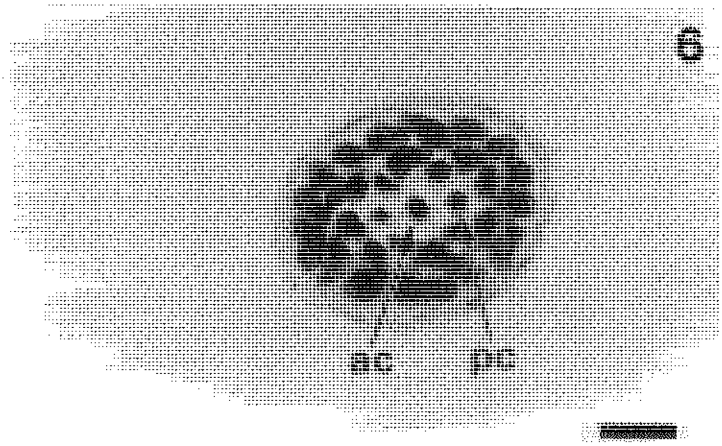
Fig. 4. Surface view of external cortical cells in horizontal creeping and vertical erect axes of *Gelidiella adnata*. Note the transverse orientation of these cells in creeping axes and their smaller size and longitudinal orientation in erect axes. Scale bar = 50 µm.

formed by 1, less often 3–5, rows of longitudinally elongated cylindrical cells with rounded tips and pit connections among successive cells in a longitudinal direction. Medullary cells are 7–10 µm wide and usually 40–60 µm long, occasionally up to 100 µm long.

A cross section of the prostrate axis (Fig. 6) shows a central axial filament, 4–7 µm in diameter, flanked by horizontally aligned medullary cells. The thinner parts of the thallus have a single periaxial cell; thicker parts of the thallus have 2 periaxial cells, 1 cell on each side of the axial cell. Medullary cells are surrounded by 1 or 2 layers of rounded cortical cells 4–6 µm in diameter.

Stoloniferous axes give rise to basally unconstricted or slightly constricted linear axes that are 70–80 µm in diameter and up to 2.5 mm long. The erect axes are unbranched (only 1 branch was found among the 20–25 axes examined), may have hairs in their apical parts, and often have truncations and evidence of renewed blade growth (Figs. 7 and 8). Upright branches normally originate from the face of the axis opposing the fringe of rhizoids. However, a few plants have upright branches originating from both surfaces of the creeping axes (Fig. 8).





Figs. 5,6. Fig. 5. Longitudinal section of a creeping axis of *Gelidiella adnata*. Note elongated medullary cells with attenuated ends and pit connections (long arrows) and elongated internal cortical cells (short arrows). This transection shows a medulla formed by the axial cell and 2 periaxial filaments (numbered 1, 2, and 2′, respectively). ac = axial cell, cc = cortical cell, pc = pit connection, scale bar = 20 μm. Fig. 6. Cross section through the prostrate axis of *Gelidiella adnata*. Note axial cell (ac) and the 2 pericentral cells (pc) flanking the axial filament. Scale bar = 20 μm.

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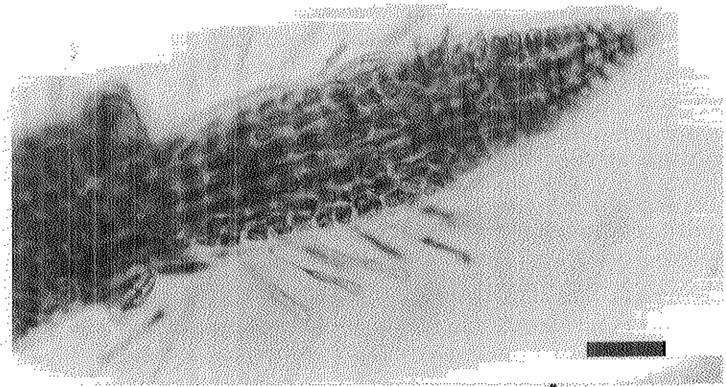

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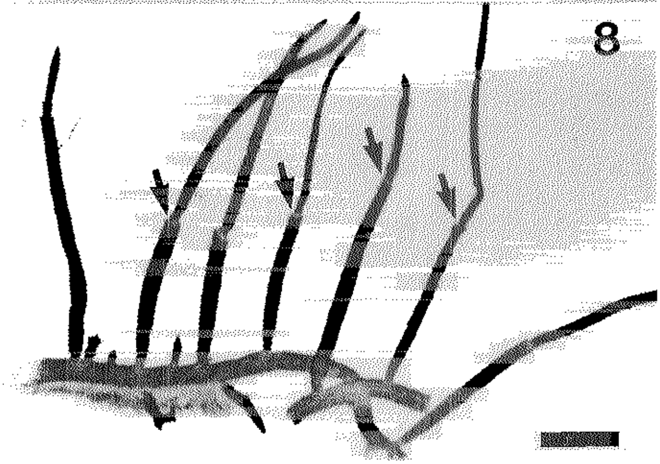

Figs. 7,8. Fig. 7. Apical part of erect axes of *Gelidiella adnata*. Note hairs and growth of a renewed blade from thallus truncation. Scale bar = 20 µm. Fig. 8. General habit of *Gelidiella adnata* with production of erect axes from both sides of the creeping axes. Note frequent regrowth from truncate axes (arrows). Scale bar = 300 µm.

Some of these upright branches later may become stoloniferous, developing rhizoidal attachments from the undersurface and giving rise to new erect axes.

The pattern of apical division of the erect axes is similar to that described for creeping axes (Fig. 9). However, lateral divisions of the periaxial cells and derivatives are comparatively more important in erect axes than in creeping axes, and the resulting uprights are compressed axes, 60–80 μm wide by 35–40 μm thick. Transections (Figs. 10A–10C) through the erect axes of *G. adnata* show a cortex formed by 1–2 layers of rounded cells 3–5 μm in diameter and 1 layer of up to 5 medullary cells in a transverse row. These cells are the axial and periaxial cells, characterized by their thicker cell walls. As illustrated in Figures 10A–10C, they remain evident throughout the plant. The axial cells are 4–8 μm in diameter, whereas the periaxial cells appear slightly smaller in cross section. In longitudinal sections, the medullary cells appear as elongated cylinders, with shapes and lengths similar to those in the creeping axes, but slightly narrower (up to 5 μm in diameter). Internal cortical cells also are similar to those in creeping axes but are shorter (up to 10 μm long). In surface view, cortical cells are cuboidal, with rounded borders, 4–6 μm by 3–5 μm, aligned in the direction of the axis (Fig. 4) Thus, compared with the cortical cells of creeping axes, external cortical cells of erect axes are smaller and are aligned in a different direction with respect to the axis.

Tetrasporangial stichidia (Fig. 11) occur often on short (20–50 μm long) pedicels and less often on medium-length (up to 600 μm long) and narrow (40–60 μm in diameter) pedicels. Stichidia are lanceolate when immature (Fig. 12) and cylindrical and terete when mature, 80–110 μm in diameter and 350–400 μm long. Tetrasporangia are formed in regular sequence from the apex, 6 per segment

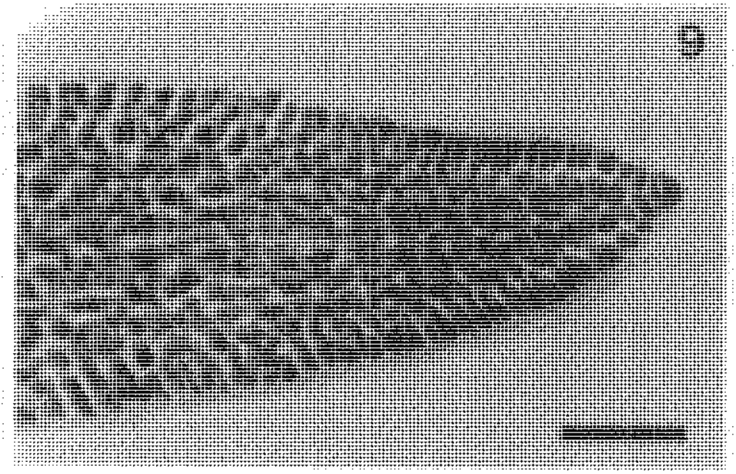

Fig. 9. Apical tip of erect axis of *Gelidiella adnata*. Note apical cell and patterns of cell division. Scale bar = 20 μm.

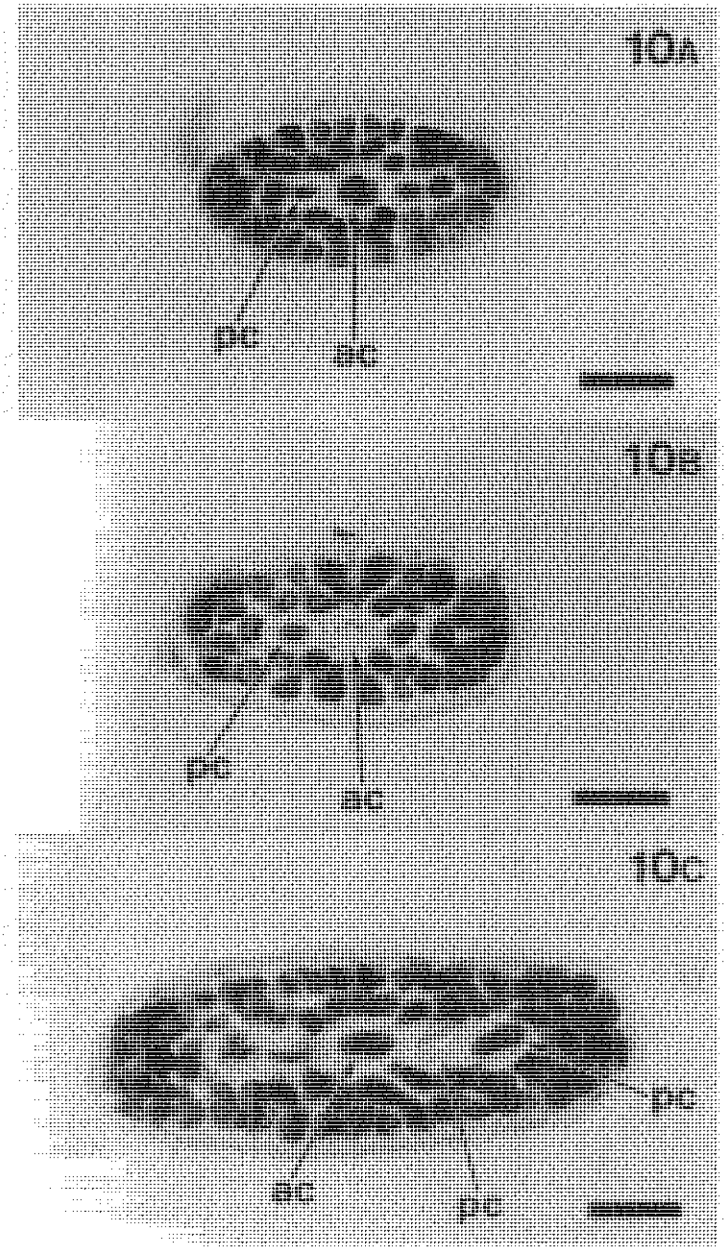

Fig. 10. Cross sections through erect axes of different sizes *Gelidiella adnata*. Note axial cell (ac) in all sections, 2 flanking periaxial cells (pc) in Figs. 10A and 10B, and 4 periaxial cells in Fig. 10C. Scale bar in all figure parts = 15 µm.

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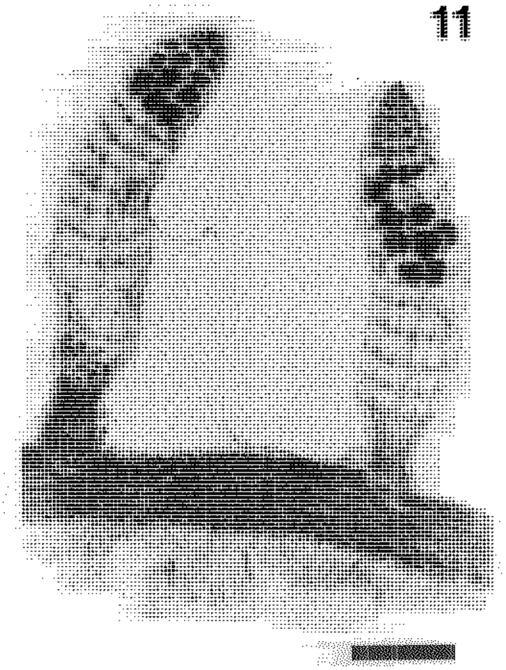


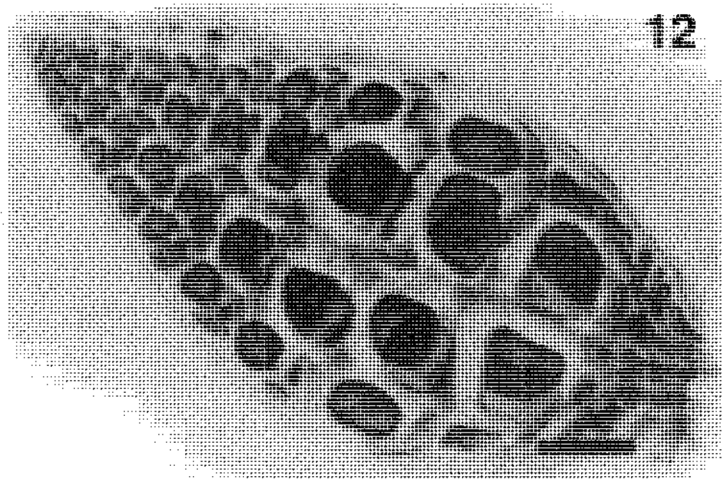
Fig. 11. Tetrasporangial stichidia on short pedicels of *Gelidiella adnata*. Scale bar = 100 µm.

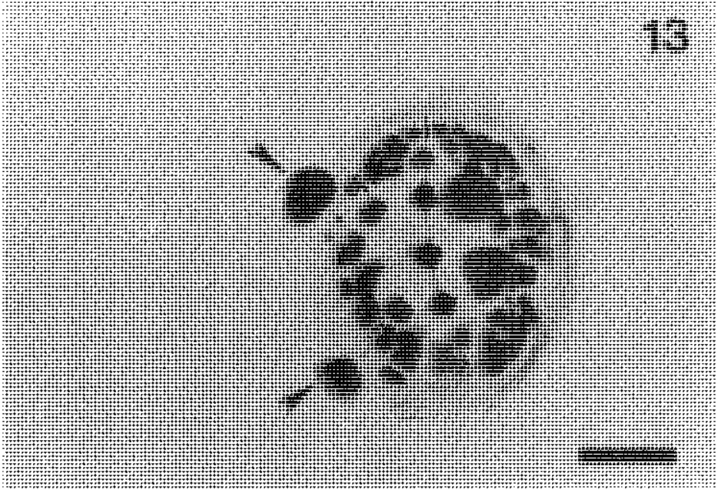
(Figs. 12–14); the 3 on each lateral side of the frond are cut off from each of 2 periaxial cells flanking the axial filament. The 6 tetrasporangia in a row may mature at different rates, and in surface view sometimes only 4 or 5 spores can be distinguished (Fig. 14A). In other stichidia, the 3 spores are clearly visible on surface view of each frond side (Fig. 14B). Tetrasporangia are surrounded by 1 or 2 layers of cortical cells (Figs. 13 and 15); the continuity of these cells is disrupted as the sporangia grow and mature. Tetrasporangia are subspherical, cruciately divided, and 20–30 µm in diameter (Fig. 14A).

Discussion

Comparison With the Original Description

The type materials examined fit most details of the original description provided by Dawson (1954a). However, the stichidia in the type materials have sporangia arranged in groups of 6 in regular transverse tiers and not in groups of 4 as indicated by Dawson in the original description. The number of stichidia in each stichidium segment has been used by many authors (e.g., Boudouresque 1972, Womersley and Guiry 1994, Kraft and Abbott 1998) as an important character to distinguish small-sized species of *Gelidiella*, and it was 1 of the 2 characters





Figs. 12,13. Fig. 12. Immature stichidia of *Gelidiella adnata* with 6 sporangia per stichidial segment. Two sporangia are above the focus, 2 are below the focus, and 2 are on the sides (1 per side) of the stichidium. Scale bar = 20 µm. Fig. 13. Transection through a mature stichidium of *Gelidiella adnata*. Arrows indicate the 6 sporangia produced by each stichidial segment. Two spores (arrowheads) corresponding to the segment immediately above lie in the border of the section. Note the axial cell and the two periaxial cells in the middle line of the thallus. Also note the pit connections between each periaxial cell and the 3 sporangia around it. Scale bar = 20 µm.

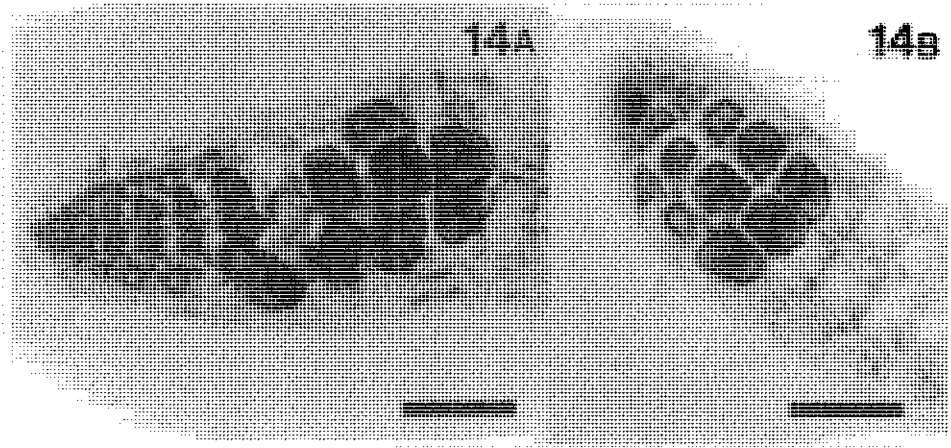


Fig. 14. Close-up of mature stichidia in surface view of *Gelidiella adnata.* Note 2 (Fig. 14A) and 3 (Fig. 14B) mature spores on each side of the stichidium. Scale bar in both figure parts = 40 μm.

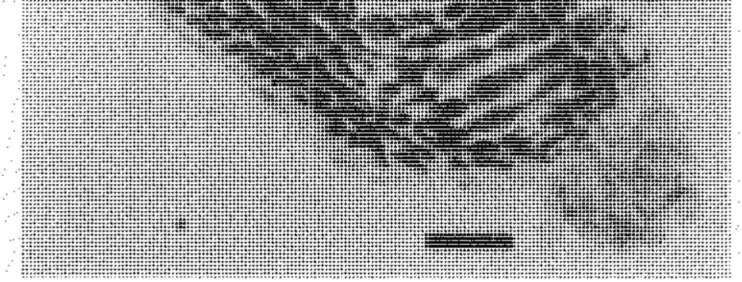


Fig. 15. Longitudinal section of a young stichidium of *Gelidiella adnata.* Note the short pedicel, a part of the creeping axes, and the rhizoids attaching the plant to the substratum. Note the disposition of sporangia in relation to the medullary filament. Scale bar = 30 μm.

used by Norris (1992a) to consider *G. adnata* as a synonym of *G. antipai*. Unfortunately, the decision was based on Dawson's (1954a) incomplete study of the type material, and it is not supported by the new evidence from reexamination of this material.

Comparisons With *Gelidiella antipai*

A comparison of the characters now found in *G. adnata* with descriptions of *G. antipai* is difficult because some of the specimens of the latter might have included materials of *G. adnata* (e.g., Norris 1992b). However, the careful descriptions and illustrations of *G. antipai* provided by Boudouresque (1972) for Mediterranean materials and by Womersley and Guiry (1994) for southern Australian plants indicate 2 and perhaps 3 important differences. One is the different size and dimensions of the external cortical cells of *G. adnata*. The external cortical cells in the creeping axes are about twice the size of those in the erect axes and are aligned transversely rather than longitudinally as in the erect axes. This difference between erect and creeping axes in the size and shape of the respective cortical cells was not described in either of the detailed accounts provided for *G. antipai* (Boudouresque 1972, Womersley and Guiry 1994).

A second important difference, already commented on, is the occurrence of 6 tetrasporangia per stichidial segment in *G. adnata* compared with 4 per segment in *G. antipai*. Furthermore, the relationship between tetrasporangia and axial and periaxial cells differs between these 2 species. A transection through a stichidium of *G. antipai* (Boudouresque 1972, figs. 3 and 8; Womersley and Guiry 1994, fig. 34N) shows the 4 tetrasporangia flanking the axial cell on all sides and no evidence of periaxial cells. Equivalent transections through the frond of *G. adnata* show periaxial cells flanking the axial cell, and each periaxial cell has pit connections to 3 sporangia.

As stated by Dawson (1954a), in the type materials of *G. adnata*, most of the stichidia are on short, slender pedicels. Only occasionally are they on medium-sized, erect axes. In contrast, Boudouresque (1972) and Womersley and Guiry (1994) described the stichidia of *G. antipai* as terminating the erect axes. Therefore, this finding may constitute a third interspecific difference, but additional population studies are required because the character varies some in the populations of *G. adnata* studied.

In summary, the comparisons of the characters found in the type materials of *G. adnata* with descriptions of *G. antipai* do not support the hypothesis that these materials are examples of the same species. Differences in size and arrangement of external cortical cells between erect and creeping axes, number and patterns of production of tetrasporangia in each stichidial segment, and disposition of stichidia in the axes are useful characters to use in segregating the 2 species. Future population studies with larger collections may help elucidate whether or not these characters indicate interspecific variation.

Comparison With Other Small-Sized Species of *Gelidiella*

The dimensions and general descriptions of several other species of *Gelidiella* (e.g., *G. stichidiospora*, *G. pannosa*, *G. tenuissima*) are close to those of *G. adnata*. However, several authors have reported on these species, and the descriptions are not always comprehensive enough to allow sharp distinctions between the species. Comparative work with the type materials complemented by population variation seems most needed to distinguish among this complex of small-sized species of *Gelidiella*.

Comparison With *Gelidiella acerosa*

Even though *G. acerosa* and *G. antipai* differ greatly in size, morphological comparisons are possible, and the 2 species have conspicuous differences in the structure of the thallus. Such differences include patterns of apical division, internal structures of the thallus and stichidium, and tetrasporangia formation.

In both species of *Gelidiella,* a single apical cell terminates axes and branches. In *G. acerosa*, cell divisions of the subapical and subsequent cells in the axial filament occur at right angles to each other in a short alternating series, forming a clearly decussate pattern. As a result, the central axial filament is discernible only a very short distance below the apex, and axes and branches are cylindrical in outline (see figs. 4 and 5 in Norris 1992a).

In contrast, in *G. antipai*, the axial filament is quite prominent. The axial cell cuts off 2–4 periaxial cells, which cut off further cells laterally. The patterns of division are much closer to a distichous pattern than to a decussate pattern, and the resulting axis is compressed.

A transection through the erect axes of *G. acerosa* shows 3–5 layers of small, anticlinally elongated, external cortical cells, followed by 5–6 layers of rounded internal cortical cells that grade into a medulla of globose cells. Axial cells and periaxial derivatives are not apparent in cross section.

As explained previously, transections through the erect parts of *G. adnata* show 1–2 layers of cortical cells and 1–2 layers of medullary cells. Axial and periaxial cells and their second-order derivatives are produced in a distinctive transverse row of thick-walled cells and remain evident throughout the plant.

An internal structure of the thallus similar to that of *G. adnata* was described and illustrated by Womersley and Guiry (1994) for *G. antipai*. In addition, the distinctive transverse rows of thick-walled cells formed by the axial and periaxial cells also exist in small-sized species of *Pterocladiella* (Frederiksen and Rueness 1990, Guiry and Womersley 1992), *Capreolia* (Guiry and Womersley 1993), and *Gelidium* (Rico and Guiry 1997), and the character may have phylogenetic importance.

Gelidiella acerosa and *G. antipai* also differ in the shape of cortical and medullary cells. The difference in medullary cells is perhaps the most obvious among the 2 species and involves differences other than size. In *G. acerosa*, medullary cells are globose, irregularly shaped, sometimes with narrow cell processes at the end of the cell, and with numerous pit connections on the side of the cell (Sreenivasa Rao 1971). In *G. adnata*, medullary cells are elongated cylinders with pit connections occurring only at the attenuated ends of the cells.

Stichidia and Tetrasporangia Formation

Already in 1934, Feldmann and Hamel distinguished between the unordered, acerosa-type stichidium and the orderly arranged pannosa-type stichidium. Later authors have questioned the separation of 2 types of arrangement because in some species the pattern tends to vary in how precisely the sporangia are ordered (Hatta and Prud'homme van Reine 1991). However, a comparison between *G. acerosa* and *G. adnata* indicates that the 2 species represent 2 different ways to build tetrasporangial stichidia, a finding that seems closely related to the 2 patterns of apical division found in these 2 species. In*G. acerosa*, the sporangia originate either from internal cortical cells or from medullary cells. This sporangial cell enlarges and becomes pigmented. Because of the abundance of these types of cells in the branches of *G. acerosa*, their decussate pattern of division, and possible modification of the relative position of these cells by thallus growth and elongation, sporangia are abundant, compact, and irregularly disposed and do not form transverse rows although they have a clear acropetal development. In the case of *G. adnata*, spores are cut off from the 2 periaxial cells flanking the axial cell on each side. Because of the orderly pattern of cell division and because production of sporangia is restricted to these periaxial cells, the resulting stichidium has a few and regularly arranged rows of sporangia.

Available descriptions in the literature are not sufficient to determine if the differences detected between these 2 species correspond to generic differences. Original and more recent descriptions of *G. hancockii* (Dawson 1952), *G. ligulata* (Dawson 1952, Shimada and Masuda 1999), and *G. ramellosa* (Feldmann and Hamel 1934, Womersley and Guiry 1994) suggest that these species share the morphological characters typical of *G. acerosa*, whereas *G. antipai*, the recently described *G. womersleyana*, and *G. pannosa* seem to have a morphological pattern more like that of *G. adnata*. However, examination of the type materials and additional numbers of species and specimens is needed before the generic limits are changed in this group of *Gelidiales*.

Acknowledgments

My gratitude 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 FONDECYT (grant 1990160) and the California Sea Grant College Program that enabled me to participate in the workshop in Vietnam and to complete the work in Santiago. The histological and photographic work of Ms. Verónica Flores is acknowledged with gratitude. The specimens for this study were kindly supplied by Dr. Jim Norris from the Smithsonian Institution.

Literature Cited

Boudouresque, C.-F. 1972. Végétation marine de l'ile de Port-Cros (Parc National): IX. Sur *Gelidiella antipai* Marie Célan (Gelidiales). Bull. Soc. Phycol. France 17:1–8.

Celan, M. 1938. Note sur la flore algologique du littoral roumain de la mer Noire IV...Bull. Sect. Scientifique de l'Académie Roumaine 19, pp. 76–79, Figs. A–F.

Dawson, E. Y. 1952. Marine red algae of Pacific Mexico: I. Bangiales to Corallinaceae subf. Corallinoideae. Allan Hancock Pac. Exped. 17:1–239.

Dawson, E. Y. 1954a. Marine plants in the vicinity of the Institut Océanographique de Nha Trang, Viet Nam. Pac. Sci. 8:372–469.

Dawson, E. Y. 1954b. The marine flora of Isla San Benedicto following the volcanic eruption of 1952–1953. Occ. Pap. Allan Hancock Found. 16:1–25.

Dawson, E. Y. 1956. Some marine algae of the southern Marshall Islands. Pac. Sci. 10:25–66.

Feldmann, J., and Hamel, G. 1934. Observations sur quelques Gélidiaceés. Rev. Gen. Bot. 46:528–549.

Frederiksen, S., and Rueness, J. 1990. Culture studies on *Pterocladia melanoidea* (Schousboe ex Bornet) comb. nov. (Gelidiales, Rhodophyta). Phycologia 29:182–190.

Ganzon-Fortes, E. T. 1994. Gelidiella. In: Akatsuka, I., Ed. Biology of economic algae. Academic Publishing, The Hague, the Netherlands, pp. 149–184.

Guiry, M. D., and Womersley, H. B. S. 1992. *Gelidiella minima* sp. nov. (Rhodophyta) from Victoria, Australia: implications for the generic classification of the Gelidiaceae. Br. Phycol. J. 27:165–176.

Guiry, M. D., and Womersley, H. B. S. 1993. *Capreolia implexa* gen. et sp. nov. (Gelidiales, Rhodophyta) in Australia and New Zealand: an intertidal mat-forming alga with an unusual life history. Phycologia 32:266–277.

Hatta, A. M., and Prud'homme van Reine, W. F. 1991. A taxonomic revision of Indonesian Gelidiales (Rhodophyta). Blumea 35:347–380.

Kraft, G. J., and Abbott, I. A. 1998. *Gelidiella womersleyana* (Gelidiales, Rhodophyta), a diminutive new species from the Hawaiian Islands. Bot. Mar. 41:51–61.

Maggs, C. A., and Guiry, M. D. 1987. *Gelidiella calcicola* sp. nov. (Rhodophyta) from the British Isles and Northern France. Br. Phycol. J. 22:417–434.

Norris, R. E. 1992a. The marine red algae of Natal, South Africa: order Gelidiales (Rhodophyta). Mem. Bot. Surv. S. Afr. 61:1–43.

Norris, R. E. 1992b. A proposed phylogenetic scheme for the Gelidiales. In: Tax. Econ. Seaweeds 3, pp. 151–171.

Rico, J. M., and Guiry, M. D. 1997. Life history and reproduction of *Gelidium maggsiae* sp. nov. (Rhodophyta, Gelidiales) from Ireland. Eur. J. Phycol. 32:267–277.

Santelices, B. 1977. A taxonomic review of Hawaiian Gelidiales (Rohodophyta). Pac. Sci. 31:61–84.

Shimada, S., and Masuda, M. 1999. First report of *Gelidiella ligulata* (Gelidiales, Rhodophyta) in Japan. Phycol. Res. 47:97–100.

Sreenivasa Rao, P. 1971. Studies on *Gelidiella acerosa* (Forsskål) Feldmann and Hamel: VI. Anatomy and developmental morphology. Phykos 10:70–78.

Womersley, H. B. S., and Guiry, M. D. 1994. Order Gelidiales Kylin 1923:132. In: Womersley, H. B. S., Ed. The marine benthic flora of southern Australia: Rhodophyta, part IIIA. Australian Biological Resources Study, Canberra, pp. 118–142.

JAPANESE SPECIES OF *PTEROCLADIELLA* SANTELICES ET HOMMERSAND (RHODOPHYTA, GELIDIALES)

Satoshi Shimada and Michio Masuda

Abstract

Five species of *Pterocladiella* are recognized in Japan and are described. Of these, *P. caerulescens* (Kützing) Santelices et Hommersand, *P. caloglossoides* (Howe) Santelices, and *P. capillacea* (S. Gmelin) Santelices et Hommersand are widely distributed, whereas *P. nana* (Okamura) Shimada, Horiguchi et Masuda and *P. tenuis* (Okamura) Shimada, Horiguchi et Masuda are endemic to Japan. Morphological features of *P. caerulescens* and *P. capillacea* are compared between Japanese and Hawaiian populations of each species. Japanese populations of *P. caerulescens* are similar in gross morphology, including color, to Hawaiian populations, although the former are slightly smaller (up to 3.5 cm tall) than the latter (up to 5 cm tall). Plants from Hachijo Island, the southernmost location of populations of *P. capillacea*, are densely branched in the distal parts and are most similar to Hawaiian populations of this species.

Introduction

In recent taxonomic reviews of the gelidialean genera *Pterocladia* J. Agardh and *Pterocladiella* Santelices et Hommersand (Santelices 1998, 1999), 3 Japanese species of *Pterocladia* described by Okamura (1932, 1934) were reduced to the synonymy of *Pterocladiella capillacea* (Gmelin) Santelices et Hommersand. Yoshida (1998) also recognized only a single species, *P. capillacea*, from Japan. However, our molecular and morphological studies revealed that 5 species of *Pterocladiella* are present in Japan (Shimada et al. 2000, Shimada and Masuda 2000). In this chapter, we describe the morphological features of these 5 Japanese species. In addition, we compare the gross morphological features of Japanese and Hawaiian populations of 2 widely distributed species, *P. caerulescens* (Kützing) Santelices et Hommersand and *P. capillacea*, to assess the effect of geographical isolation.

Materials and Methods

Both historical and contemporary specimens, including formalin/seawater-preserved material collected in Japan and deposited in the Herbarium of the Graduate School of Science, Hokkaido University, Sapporo (SAP), were used in this study. These specimens are cited in the following sequence: locality, town or city (or island), and prefecture (see Yamagishi and Masuda 1997, fig. 45, for the location of each prefecture). In addition, herbarium specimens collected from the Hawaiian Islands and presented by Dr. I. A. Abbott were used. Formalin/seawater-preserved specimens were 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.

Key to the Japanese Species of *Pterocladiella*

1. Plants less than 1 cm high; tetrasporangia regularly arranged in obliquely transverse rows .... *P. caloglossoides*
1. Plants more than 1 cm high; tetrasporangia irregularly arranged 2
   2. Plants blackish green and monoecious .... *P. caerulescens*
   2. Plants purplish red and dioecious 3
3. Second-order branches 1.5–2.5 mm wide at intervals of up to 11 mm .... *P. tenuis*
3. Second-order branches less than 1 mm wide at intervals of less than 2 mm 4
   4. Axes less than 2.5 cm high, with short (up to 1.5 cm) first-order branches formed at short (up to 1.5 mm) intervals .... *P. nana*
   4. Axes more than 3.5 cm high, with long (up to 4.5 cm) first-order branches formed at long (up to 5 mm) intervals .... *P. capillacea*

Description of the Species

Pterocladiella caerulescens (Kützing) Santelices et Hommersand, Phycologia 36, p. 118, 1997.

(Figs. 1–6)

Basionym: *Gelidium caerulescens* Kützing, Tabulae phycologicae, p.19, pl. 56c–d,1868.

Type Locality: New Caledonia.

Distribution: Tropical regions in the Pacific (Santelices 1998).

Japanese Name: Ao-obakusa.

Specimens Examined: From Japan: Oohama, Ishigaki Island, Okinawa Prefecture (4.iii.1999, SAP 071776); Sonai, Yonaguni Island, Okinawa Prefecture (1.iii.1999, SAP 071777); Irizaki, Yonaguni Island, Okinawa Prefecture (2.iii.1999, SAP 071774); and Agarizaki, Yonaguni Island, Okinawa Prefecture (3.iii.1999, SAP 071775). From the Hawaiian Islands: Ewa Beach, Oahu Island (3.iii.1985, SAP 086595); Kihei, Maui Island (vi.1986, SAP 086600); Napili, Maui Island (1.vii.1993, SAP 086598); Maalaea, Maui Island (5.x.1996, SAP 086596); Kapalua Bay, Maui Island (26.ii.1997, SAP 086597); and Kailua-Kona, Hawaii Island (28.iii.1984, SAP 086599).

Remarks: Plants grow gregariously on bedrock in the upper to middle intertidal zones, are up to 3.5 cm tall (Figs. 1–4), and are grayish to blackish green. Individual plants consist of a creeping axis and numerous erect axes. Erect axes arise from a creeping axis, which is fastened to the substratum by peglike secondary rhizoidal attachments. Erect axes are compressed to flattened, up to 1.3 mm wide and 150–180 μm thick in the middle part of each axis. Axes are oppositely or alternate-distichously branched 2 or 3 times. First- to third-order branches are terete to subterete, up to 2.3 cm long and 110–200 μm wide in the proximal region, becoming compressed to flattened upward, up to 940 μm wide and 130–160 μm thick in the distal part.

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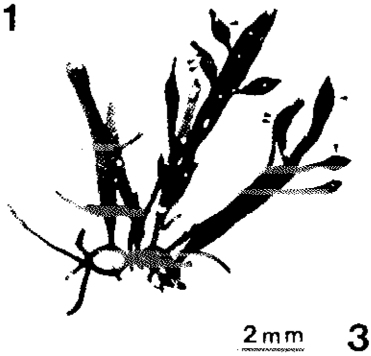

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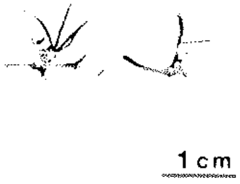

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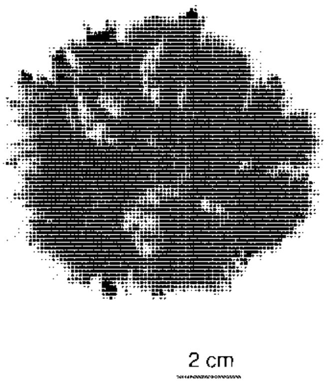

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Figs. 1–6. *Pterocladiella caerulescens*. Fig. 1, Formalin/seawater-preserved monoecious specimen (Sonai, Yonaguni Island, Okinawa Prefecture; 1.iii.1999, SAP 071777) with cystocarpic (arrowheads) and spermatangial branchlets (double arrowheads). Fig. 2, Dried herbarium specimens from Agarizaki, Yonaguni Island, Okinawa Prefecture (3.iii.1999, SAP 071775). Fig. 3, Dried herbarium specimen from Oohama, Ishigaki Island, Okinawa Prefecture (4.iii.1999, SAP 071776). Fig. 4, Spermatangial sori (arrowheads) on a spermatangial erect axis (Sonai, Yonaguni Island, Okinawa Prefecture; 1.iii.1999; formalin/seawater-preserved specimen, SAP 071777). Fig. 5, Dried herbarium specimen from Kailua-Kona, Hawaii Island (28.iii.1984, SAP 086599). Fig. 6, Dried herbarium specimen from Kihei, Maui Island (vii.1986, SAP 086600).

The majority of cystocarpic plants bear spermatangial sori on the cystocarpic branchlets. Some plants produce spermatangial sori on spermatangial branchlets that are independently formed from cystocarpic branchlets on the erect axes (Fig. 1). A few cystocarpic plants bear a special erect axis that produces only spermatangial branchlets (Fig. 4). In some instances, the 3 types of spermatangial sori are formed on different individual plants; in other instances, a single plant may bear all 3 types. Two spermatangia are cut off from an elongated spermatangial mother cell and are 2–3 μm in diameter.

Hawaiian materials (Figs. 5 and 6) of *P. caerulescens* (6 localities, 30 individual plants) are similar in color and in gross morphology to Japanese materials but are slightly larger (up to 5 cm long) than are Japanese specimens.

Pterocladiella caerulescens is characterized by the grayish to blackish green color, which is also maintained under experimental culture conditions. Some species of Gelidiales have monoecious gametophytes (Santelices and Flores 1995). *Pterocladiella caerulescens* is the only monoecious species in the genus *Pterocladiella.*

Pterocladiella caloglossoides (Howe) Santelices, J. Appl. Phycol. 10:244, 1998.
(Figs. 7–10)

Basionym: *Gelidium caloglossoides* Howe, Mem. Torrey Bot. Club 15, p. 96, pl. 34, fig. 7; pl. 35, 1914.

Type Locality: San Lorenzo Island, Peru.

Distribution: Tropical regions in the Pacific and Indian oceans (Santelices 1998).

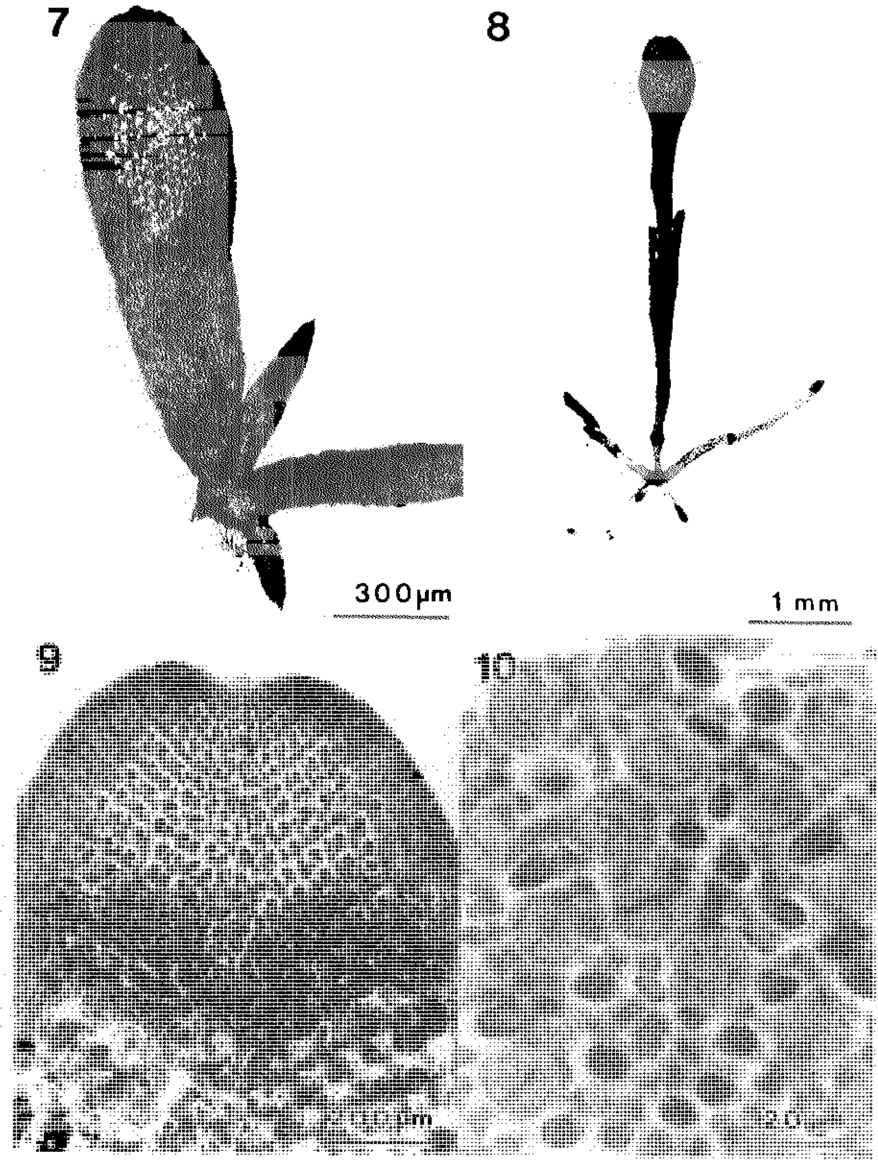
Japanese Name: Hime-obakusa.

Specimens Examined: Oohama, Ishigaki Island, Okinawa Prefecture (4.iii.1999, SAP 071778 and 086602).

Remarks: Plants grow gregariously on bedrock in the upper to middle intertidal zones and are purplish red. Individual plants consist of a creeping axis and erect axes (Figs. 7 and 8). Creeping axes are subterete to compressed and are fastened to the substratum by peglike attachments. Erect axes are up to 5 mm tall, terete to subterete, 60–240 μm in diameter in the basal part of each erect axis, becoming flattened upward, up to 700 μm wide and 60–120 μm thick in the middle part of the axis. Erect axes are usually simple but are sometimes irregularly branched.

Tetrasporangia are regularly arranged in obliquely transverse rows (Fig. 9), 8–16 per row, and are ovate in surface view, 16–32 μm in diameter. They are cruciately or decussately divided (Fig. 10).

In the original description by Howe (1914), *P. caloglossoides* was characterized as having repent flattened thalli throughout, regularly arranged tetrasporangia, and a single row of medullary cells. However, this species has a wide range of morphological variations: creeping axes are subterete to flattened, and the length of erect axes ranges from 0.8 mm to 25 mm (Howe 1914; Santelices



Figs. 7–10. ***Pterocladiella caloglossoides.*** Figs. 7 and 8, Formalin/seawater-preserved specimens (Oohama, Ishigaki Island, 4.iii.1999, SAP 071778 and 086602). Fig. 9, Surface view of a tetrasporangial stichidium with a "chevronlike" arrangement of tetrasporangia. Fig. 10, Surface view of a tetrasporangial stichidium with cruciately or decussately divided tetrasporangia.

1977; Cribb 1983; Norris 1987; Hatta and Prud'homme van Reine 1991). The Japanese materials are most similar to South African (Norris 1987) and Australian (Cribb 1983) specimens, which have longer erect axes than those of the original description and shorter axes than those of specimens from Hawaii (Santelices 1977) and Singapore (Hatta and Prud'homme van Reine 1991). However, all the specimens identified as *P. caloglossoides*, including Japanese material, have a regular arrangement of tetrasporangia that is a unique feature of this species (Howe 1914, Santelices 1977, Norris 1987, Cribb 1983, Shimada and Masuda 2000). This feature has been referred to as "chevronlike" (Fig. 9).

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

(Figs. 11–18)

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

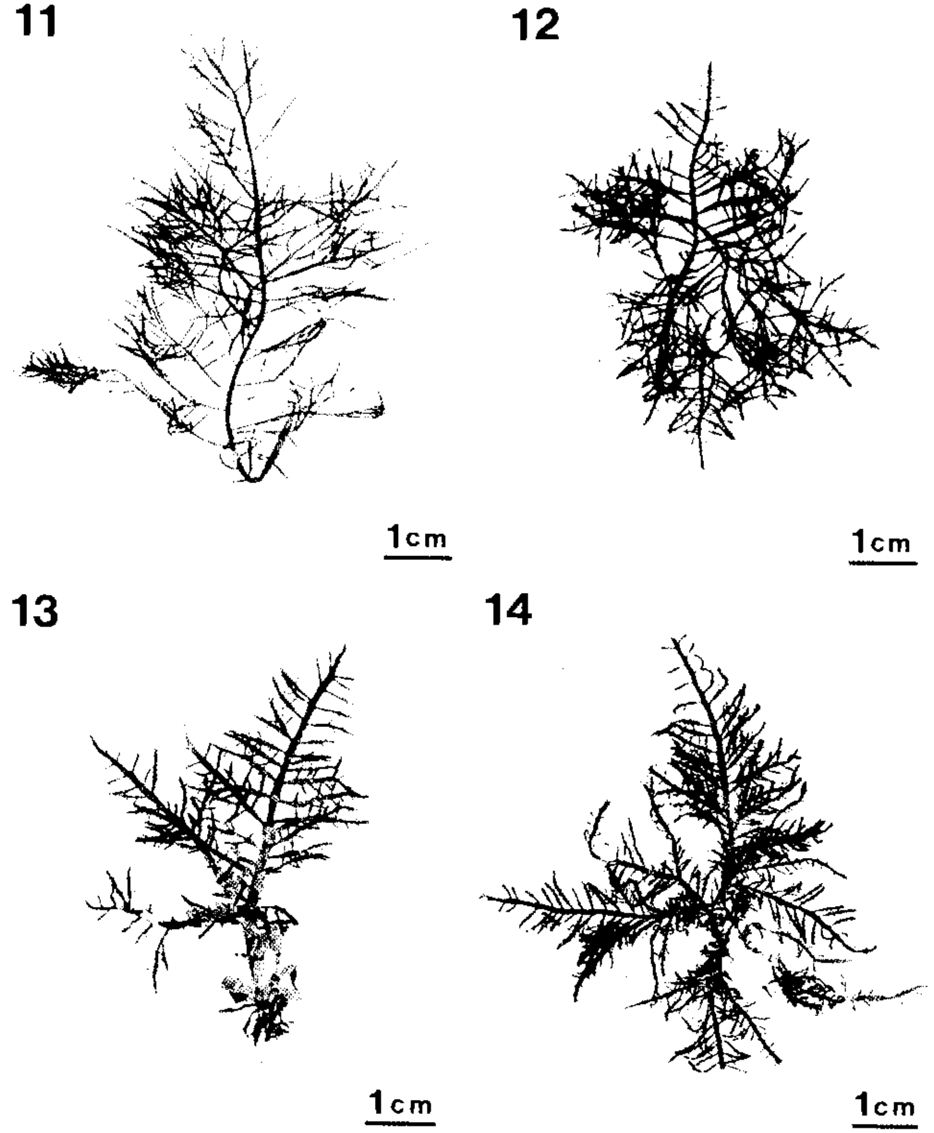
Type Locality: Mediterranean.

Distribution: Widespread in warm-temperate and tropical waters in the world (Santelices 1998).

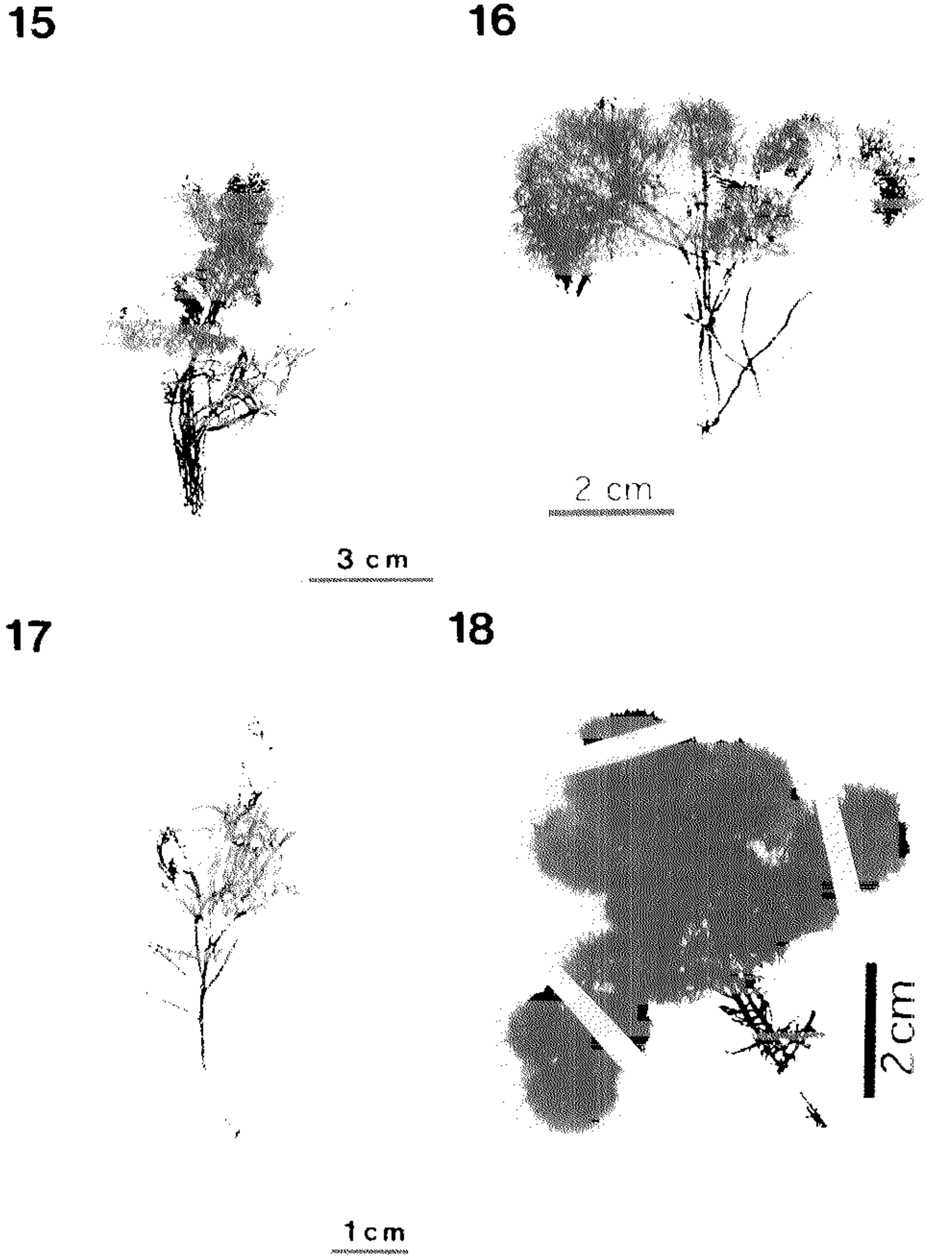
Japanese Name: Kata-obakusa.

Specimens Examined: From Japan: Taisei, Hokkaido (22.viii.1997, SAP 065455); Oshoro, Hokkaido (15.ix.1996, SAP 065447); Shiriya, Aomori Prefecture (7.iv.1998, SAP 065456); Oga, Akita Prefecture (19.vi.1997, SAP 065451); Kasashima, Niigata Prefecture (17.vi.1997, SAP 065450); Unoura, Ishikawa Prefecture (7.ix.1998, SAP 065458); Echizen, Fukui Prefecture (22.xi.1998, SAP 065498); Uradome, Tottori Prefecture (21.xi.1998, SAP 065465); Mihonoseki, Shimane Prefecture (20.xi.1998, SAP 086608); Hinomisaki, Shimane Prefecture (20.xi.1998, SAP 065464); Kiwado, Yamaguchi Prefecture (19.xi.1998, SAP 065463); Tsuyazaki, Fukuoka Prefecture (26.vii.1997, SAP 086606); Tomioka, Kumamoto Prefecture (30.vii.1997, SAP 065453), Takedatsu, Ooita Prefecture (4.viii.1997, SAP 065454); Onahama, Fukushima Prefecture (13.vi.1997, SAP 065449); Debana, Hachijo Island, Tokyo (9.vii.1998, SAP 065457); Hamashima, Mie Prefecture (17.xi.1998, SAP 065462); Kushimoto, Wakayama Prefecture (18.xi.1998, SAP 065461); Shirahama, Wakayama Prefecture (15.v.1984, SAP 047670); and Atsuhama, Awaji Island, Hyogo Prefecture (30.iv.1995, SAP 086607). From the Hawaiian Islands: Waikiki Beach, Oahu Island (20.ix.1994, SAP 086594); Ewa Beach, Oahu Island (3.iii.1985, SAP 086601); Ahihi Bay, Maui Island (18.vii.1990, SAP 086593); Kanaha Park, Maui Island (23/24.xi.1995, SAP 086589); Mahinahina Point, Maui Island (26.vii.1984, SAP 086590); Paia, Maui Island (6.vii.1993, SAP 086591); Napili, Maui Island (1.vii.1993, SAP 086592).

Remarks: Plants grow gregariously on bedrock in the middle to lower intertidal zones and are purplish red and up to 10 cm high (Figs. 11–15). Individual plants



Figs. 11–14. Dried herbarium specimens of *Pterocladiella capillacea*. Fig. 11, Specimen from Tsuyazaki, Fukuoka Prefecture (26.vii.1997, SAP 086606). Fig. 12, Specimen from Atsuhama, Awaji Island, Hyogo Prefecture (30.iv.1995, SAP 086607). Fig. 13, Specimen from Shirahama, Wakayama Prefecture (15.v.1984, SAP 047670). Fig. 14, Specimen from Mihonoseki, Shimane Prefecture (20.xi.1998, SAP 086608).



Figs. 15–18. Dried herbarium specimens of *Pterocladiella capillacea*. Fig. 15, Specimen from Debana, Hachijo Island, Tokyo (9.vii.1998, SAP 065457). Figs. 16 and 17, Specimens from Ewa Beach, Oahu Island (3.iii.1985, SAP 086601). Fig. 18, Lectotype specimen of *Pterocladia densa* Okamura (Uradome, Tottori Prefecture, viii.1923, Okamura Herb. in SAP).

consist of a creeping axis and several erect axes. Erect axes arise from a creeping axis, which is attached to the substratum by peglike secondary rhizoidal attachments. Up to 5 orders of branches are produced. First-order branches are borne regularly pinnately at intervals of up to 5 mm and are up to 4.5 cm long. These branches bear regularly, pinnately arranged second-order branches (0.2–1 mm wide) at intervals of 0.1–1.5 mm.

Tetrasporangia are irregularly disposed at the apices of branches. Cruciately divided sporangia are 40–48 µm long by 16–28 µm wide. Cystocarps are formed near the apices of branches of female gametophytes. A cystocarp is attached to 1 side of the cystocarp floor and produces chains of carposporangia from the remaining 3 sides. Nutritive filaments grow centripetally and form a virtually solid cylinder around the central axis. Carposporangia are 28–40 µm long by 20–24 µm wide.

Spermatangial sori are formed at the apices of branches of male gametophytes. Spermatangial mother cells are elongated and 8–10 µm long by 1.5–2 µm wide.

Japanese specimens of *P. capillacea* are similar in gross morphology to Hawaiian specimens (Figs. 16 and 17; 6 localities, more than 100 individual plants). Particularly, specimens from Hachijo Island (Pacific Ocean; Fig. 15) that branch densely in the upper part of plants, such as *Pterocladia densa* Okamura (Fig. 18), which is now a synonym of *P. capillacea*, are most similar to Hawaiian plants.

Pterocladiella capillacea is a widely distributed species (Santelices 1999) and has great variations in gross morphology (Stewart 1968). However, Shimada et al. (2000) showed that the components of a *P. capillacea* complex found in Japan that could be divided into 3 monophyletic clades via analysis of rbcL genes were clearly distinguishable from each other on the basis of gross morphology even when maintained under the same culture conditions. Thus, we recognize 3 species in the *P. capillacea* complex in Japan: *P. capillacea*, *P. nana*, and *P. tenuis*. *Pterocladiella capillacea* is characterized by the following combination of morphological features: (1) long erect axes (more than 3.5 cm tall) that produce long first-order branches (up to 4.5 cm long) formed at long intervals (up to 5 mm) and (2) narrow second-order branches (less than 1 mm wide) that are produced at close intervals (less than 2 mm).

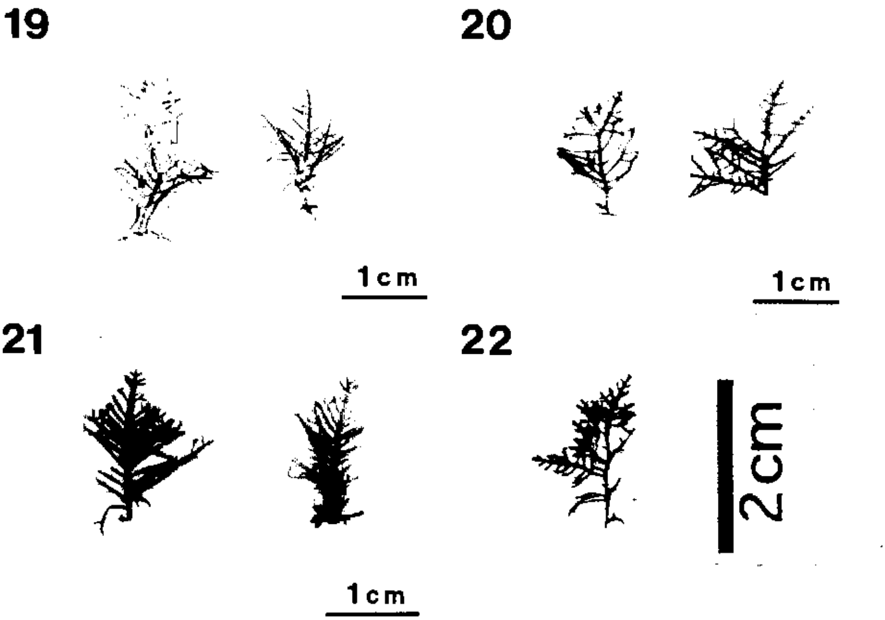
Pterocladiella nana (Okamura) Shimada, Horiguchi et Masuda, Phycologia 39:16, 2000.

(Figs. 19–22)

Basionym: *Pterocladia nana* Okamura, Icones of Japanese algae 6, pp. 53,54, pl. 278, figs. 1–14, 1931.

Type Locality: Yura-jima, Shimokoshiki Island, Koshiki Islands, Kagoshima Prefecture, Japan.

Distribution: Western to central Japan (Okamura 1934).



Figs. 19–22. *Pterocladiella nana*. Figs. 19 and 20, Dried herbarium specimens from Teuchi, Shimokoshiki Island, Kagoshima Prefecture (31.vii.1997, SAP 065468 and 065467). Fig. 21, Glycerin/seawater-preserved specimens from Teuchi, Shimokoshiki Island (31.vii.1997, SAP 065499). Fig. 22, Lectotype specimen of *Pterocladia nana* Okamura (Yura-jima, Shimokoshiki Island, 19.vii.1919, Okamura Herbarium in SAP).

Japanese Name: Chabo-obakusa.

Specimens Examined: Teuchi, Shimokoshiki Island, Kagoshima Prefecture (31.vii.1997, SAP 065452, 065467, 065468, and 065499).

Remarks: Plants grow gregariously on bedrock in the upper to middle intertidal zones and are purplish red and 1–2.5 cm tall (Figs. 19–22). Individual plants consist of a creeping axis and erect axes. Erect axes arise from a creeping axis, which is attached to the substratum by peglike secondary rhizoidal attachments. Up to 3 orders of branches are produced. First-order branches are borne regularly, pinnately at intervals of up to 1.5 mm and are up to 1.5 cm long. These branches bear irregularly pinnately arranged second-order branches (0.2–0.5 mm wide) at intervals of 0.1–1.5 mm.

Tetrasporangia are irregularly disposed at the apices of axes and branches. Cruciately divided sporangia are 44–48 μm long by 20–40 μm wide. Cystocarps are formed near the apices of branches of female gametophytes. A cystocarp is attached to 1 side of the cystocarp floor and produces chains of carposporangia from the remaining 3 sides. Nutritive filaments grow centripetally and form a virtually solid cylinder around the central axis. Mature carposporangia are 30–40 μm long by 16–20 μm wide.

When Okamura (1932) described this species, he commented that *P. nana* is distinguished from the other 2 species (*P. tenuis* and *P. densa*) by dwarf thalli. Although Santelices (1991) recognized *P. nana* as conspecific with *P. capillacea*, Shimada et al. (2000) showed that *P. capillacea* is 1 of 3 monophyletic clades and can be distinguished from *P. tenuis* and *P. densa* on the basis of gross morphology: (1) short axes (less than 2.5 cm tall) that produce short first-order branches (up to 1.5 cm long) formed at close intervals (up to 1.5 mm) and (2) narrow second-order branches (less than 1 mm wide) that are produced at close intervals (less than 2 mm). These morphological distinctions were also maintained under laboratory culture conditions.

Pterocladiella tenuis (Okamura) Shimada, Horiguchi et Masuda, Phycologia 39:17, 2000.

(Figs. 23–30)

Basionym: *Pterocladia tenuis* Okamura, J. Imp. Fish. Inst. vol. 29, p. 62, pl. 29,30, fig. 3, pl. 33, figs. 1–3, 1934.

Type Locality: Enoshima, Kanagawa Prefecture, Japan.

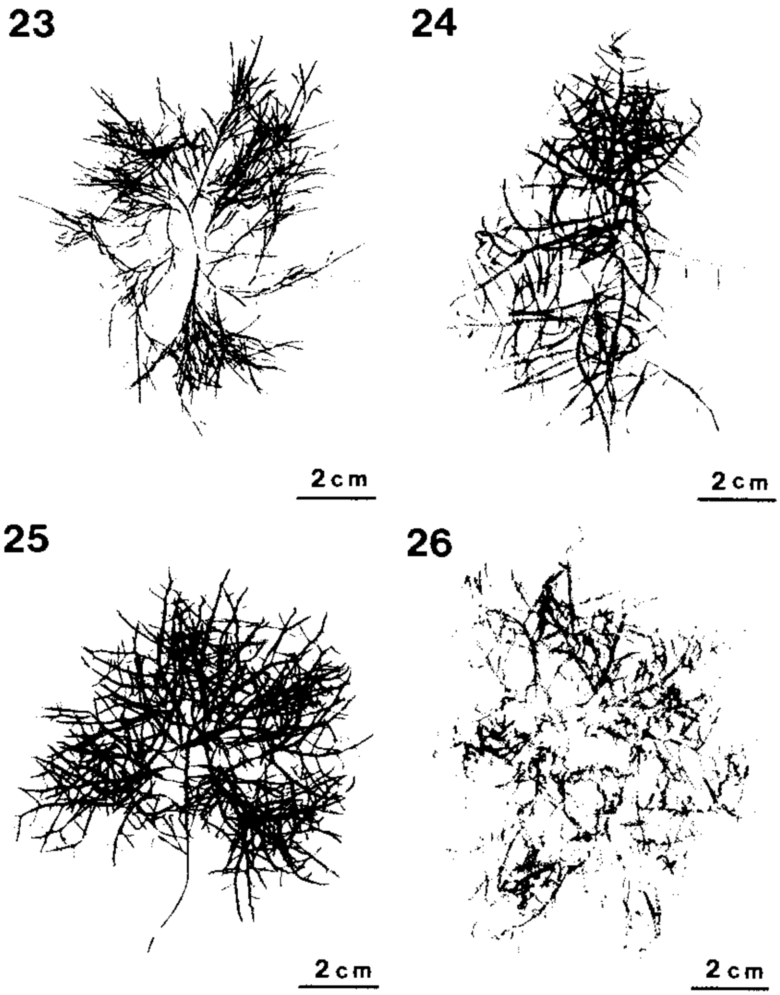
Distribution: Western to central Japan (Okamura 1934).

Japanese Name: Obakusa.

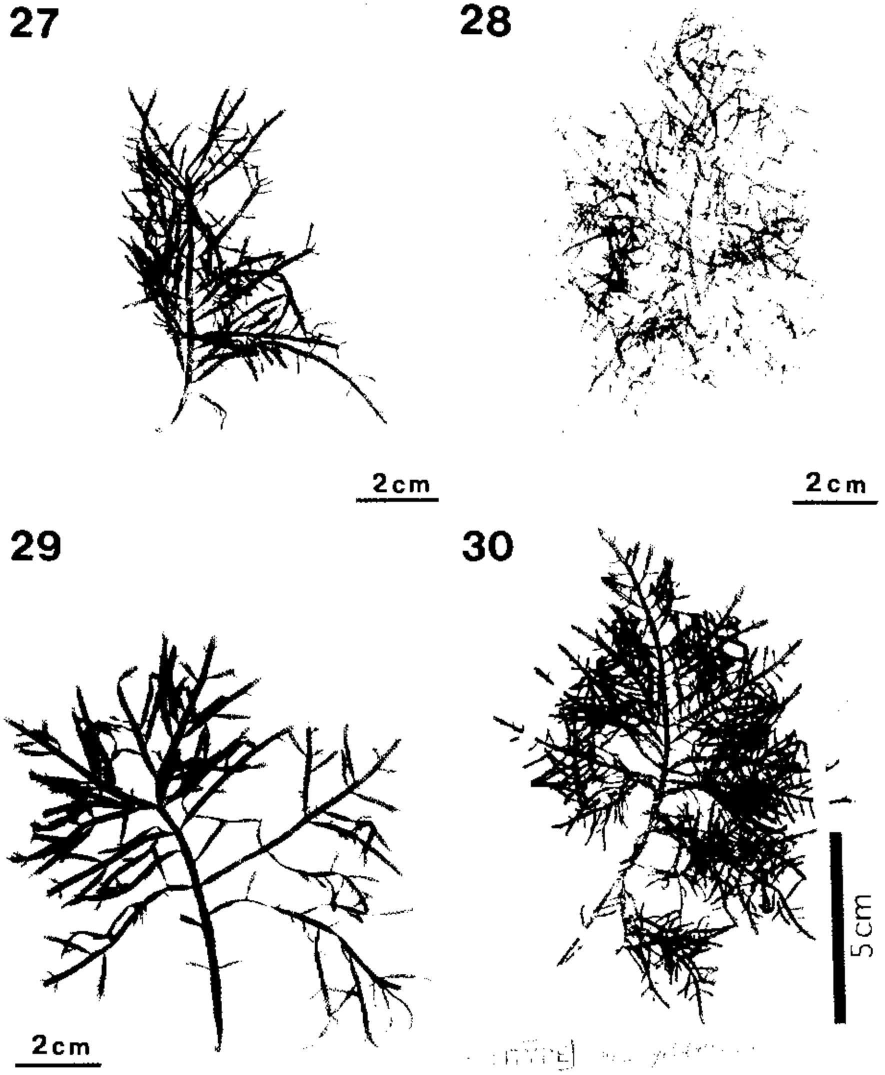
Specimens Examined: Hinomisaki, Shimane Prefecture (20.xi.1998, SAP 065483); Tsuyazaki, Fukuoka Prefecture (4.xi.1998, SAP 065459); Enoshima, Kanagawa Prefecture (5.i.1999, SAP 065466, 065482); Shimoda, Shizuoka Prefecture (25.ix.1996, SAP 064842 and 065448; 28 iii.1998, SAP 065469); Nishiizu, Shizuoka Prefecture (26.ix.1996, SAP 086605); Omaezaki, Shizuoka Prefecture (23.v.1993, SAP 060152); Hamashima, Mie Prefecture (28.ix.1996, SAP 086604); Shirahama, Wakayama Prefecture (15.v.1984, SAP 047689); and Yura, Awaji Island, Hyogo Prefecture (8.v.1996, SAP 086603).

Remarks: Plants grow gregariously on bedrock in the middle to lower intertidal zones and are purplish red and up to 18 cm tall (Figs. 23–30). Individual plants consist of a creeping axis and erect axes. Erect axes arise from a creeping axis, which is attached to the substratum by peglike secondary rhizoidal attachments. Up to 4 orders of branches are formed. First-order branches are borne regularly, pinnately at intervals of up to 16 mm and are up to 14 cm long. These branches bear regularly (sometimes irregularly), pinnately arranged second-order branches (1.5–2.5 mm wide) at intervals of 1–11 mm.

Tetrasporangia are irregularly disposed at the apices of branches. Cruciately divided sporangia are 48–52 μm long by 20–36 μm wide. Cystocarps are formed near the apices of branches of female gametophytes. A cystocarp is attached to 1 side of the cystocarp floor and produces chains of carposporangia from the remaining 3 sides. Nutritive filaments grow centripetally and form a virtually solid



Figs. 23–26. Dried herbarium specimens of *Pterocladiella tenuis*. Fig. 23, Specimen from Tsuyazaki, Fukuoka Prefecture (4.xi.1998, SAP 065459). Fig. 24, Specimen from Shirahama, Wakayama Prefecture (15.v.1984, SAP 047689). Fig. 25, Specimen from Yura, Awaji Island, Hyogo Prefecture (8.v.1996, SAP 086603). Fig. 26, Specimen from Hamashima, Mie Prefecture (28.ix.1996, SAP 086604).



Figs. 27–30. *Pterocladiella tenuis*. Fig. 27, Dried herbarium specimen from Omaezaki, Shizuoka Prefecture (23.v.1993, SAP 060152). Fig. 28, Dried herbarium specimen from Nishiizu, Shizuoka Prefecture (26.ix.1996, SAP 086605). Fig. 29, Glycerin/seawater-preserved specimen from Shimoda, Shizuoka Prefecture (25.ix.1996, SAP 064842). Fig. 30, Lectotype specimen of *Pterocladia tenuis* Okamura (Enoshima, Kanagawa Prefecture, iii.1897, Okamura Herbarium in SAP).

cylinder around the central axis. Mature carposporangia are 28–36 µm long by 16–22 µm wide.

Stewart (1968) reduced *P. tenuis* to the synonymy of *P. capillacea* because of the great morphological variation of *P. capillacea*. However, unlike *P. capillacea*, *P. tenuis* has broad second-order branches (1.5–2.5 mm wide) that are produced at long intervals (up to 11 mm) along elongated first-order branches (up to 14 cm long). These morphological distinctions were also maintained under laboratory culture conditions (Shimada et al. 2000).

Acknowledgments

We give sincere thanks to Professor Isabella A. Abbott for inviting us to participate in this workshop, for providing Hawaiian specimens, and for critically reading the manuscript. We also thank Dr. James Sullivan and the California Sea Grant College Program for financial sponsorship and Dr. Bernabé Santelices for his identification of some Hawaiian specimens. We are grateful to Dr. Nguyen Tac An and the staff of the Institute of Oceanography, Nha Trang, Vietnam, for all the arrangements of this workshop and for their hospitality.

Literature Cited

Cribb, A. B. 1983. Marine algae of the southern Great Barrier Reef, I. Rhodophyta. Handbook 2. Australian Coral Reef Society, Brisbane, Australia.
Gmelin, S. G. 1768. Historia fucorum. 4 pls., 239 pp., 35 pls. St. Petersburg.
Hatta, A. M., and Prud'homme van Reine, W. F. 1991. A taxonomic revision of Indonesian Gelidiales (Rhodophyta). Blumea 35:347–380.
Howe, M. A. 1914. The marine algae of Peru. Mem. Torrey Bot. Club 15:1–185.
Kützing, F. T. 1868. Tabulae phycologicae. Vol. 18. Nordhausen, 35 pp., 100 pls.
Norris, R. E. 1987. *Pterocladia* (Gelidiales, Rhodophyta), a genus previously unknown in South Africa, as it occurs in Natal. S. Afr. J. Bot. 53:39–43.
Okamura, K. 1932. Icones of Japanese algae. Vol. 6. Privately published, Tokyo, pp. 49–62, pls. 276–280.
Okamura, K. 1934. On *Gelidium* and *Pterocladia* of Japan. J. Fish. Inst. 29:47–67, pls. 16–33.
Santelices, B. 1977. A taxonomic review of Hawaiian Gelidiales (Rhodophyta). Pac. Sci. 31:61–84.
Santelices, B. 1991. Variations in cystocarp structure in *Pterocladia* (Gelidiales, Rhodophyta). Pac. Sci. 45:1–11.
Santelices, B. 1998. Taxonomic review of the species of *Pterocladia* (Gelidiales, Rhodophyta). J. Appl. Phycol. 10:237–252.
Santelices, B. 1999. Taxonomic status of the species originally ascribed to the genus *Pterocladia* (Gelidiales, Rhodophyta). In: Tax. Econ. Seaweeds 7, pp. 71–80.
Santelices, B., and Flores, V. 1995. Spermatangial sori in cystocarpic branchlets of species of *Gelidium* and *Pterocladia* (Gelidiales, Rhodophyta). Phycologia 34:337–341.
Shimada, S., Horiguchi, T., and Masuda, M. 2000. The confirmation of the status of three *Pterocladia* species (Gelidiales, Rhodophyta) described by K. Okamura. Phycologia 39:10–18.

Shimada, S., and Masuda, M. 2000. New records of *Gelidiella pannosa*, *Pterocladiella caerulescens* and *P. caloglossoides* (Rhodophyta, Gelidiales) from Japan. Phycol. Res. 48:107–114.

Stewart, J. G. 1968. Morphological variation in *Pterocladia pyramidale*. J. Phycol. 4:76–84.

Yamagishi, Y., and Masuda. M. 1997. Species of *Hypnea* from Japan. In: Tax. Econ. Seaweeds 6, pp. 135–162.

Yoshida, T. 1998. Marine algae of Japan. Uchida Rokakuho Publishing, Tokyo, 1222 pp. (in Japanese).

SYNOPSIS OF THE CHINESE SPECIES OF *GELIDIUM* (GELIDIALES, RHODOPHYTA)

Xia Bangmei, C.K. Tseng, and Wang Yongqiang

Abstract

The herbarium of the Institute of Oceanology (AST) in Qingdao, China, contains 13 species of *Gelidium*, including 3 varieties: *G. amansii* (Lamouroux) Lamouroux, *G. arenarium* Kylin, *G. crinale* (Turner) Lamouroux, *G. divaricatum* Martens, *G. japonicum* (Harvey) Okamura, *G. kintaroi* (Okamura) Yamada, *G. latiusculum* Okamura, *G. masudai* Xia et Tseng, sp. nov., *G. planiusculum* Okamura, *G. pusillum* (Stackhouse) Le Jolis var. *conchicola* Piccone et Grunow, *G. pusillum* var. *cylindricum* Taylor, *G. pusillum* var. *pacificum* Taylor, *G. tsengii* Fan, *G. vagum* Okamura, and *G. yamadae* Fan. Of these, *G. arenarium* and *G. pusillum* var. *conchicola* are new records for China. *Gelidium masudai* is a new species from China.

Introduction

Gelidium was reported from China for the first time by Grubb (1932) under the name of *G. amansii*. Thinking that this identification was erroneous, Fan (1961) gave this specimen the name of *G. grubbae*. However, Zhang and Xia (1984) recognized that this species was the same as *G. vagum* Okamura, published in 1934, and thus the name that had to be used, according to the Botanical Code. *Gelidium amansii* was subsequently collected from Qingdao by Tseng and Li (1935). That same year, Okamura (1935) documented 5 species of *Gelidium* from Taiwan: *G. clavatum*, *G. planiusculum*, *G. latiusculum*, *G. densum*, and *G. amansii*. Okamura (1936) further added 3 taxa from Taiwan: *G. crinale*, *G. divaricatum*, and *G. japonicum*. *Gelidium divaricatum* has been reported from Qingdao by Tseng (1938). Fan (1951) reported 7 species for Taiwan; Tseng and Chang (1954) added *G. crinale* and *G. pusillum* from Qingdao; Fan (1961) described 2 new species: *G. tsengii* from Hong Kong, and *G. grubbae*. Tseng et al. (1962) described 5 species from China and added *G. pacificum*. Xia et al. (1983) listed 6 species from China. Thirteen species of *Gelidium* were included in the Chinese flora by Zhang and Xia (1988) with a key and information on distribution. Santelices (1988) discussed 7 species of *Gelidium* from China, including 2 varieties, on the basis of his study of Chinese materials.

After reexamining and analyzing Chinese specimens, we concluded that the occurrence of *G. pacificum* and *G. johnstonii* cannot be substantiated. Among the various reports just listed, 2 species, *G. kintaroi* (Okamura) Yamada and *G. latiusculum* Okamura, are identified in the Chinese flora. Although these 2 species were originally published on the basis of Japanese materials, the taxa are not listed in the new marine flora of Japan (Yoshida 1998).

Key to Chinese Species of *Gelidium*

1. Plants with creeping prostrate axes 2
1. Plants with creeping, thickened rhizomatous holdfast 6
   2. Creeping axes cylindrical or slightly compressed 3
   2. Creeping axes flat, thallus small, 2–3 mm tall, erect axes flat for their entire length .... *G. pusillum* var. *conchicola*
3. Erect branches cylindrical or slightly compressed, branch axil nearly right-angled, branches with numerous short, opposite-alternate ultimate branchlets .... *G. divaricatum*
3. Erect branches cylindrical at the base, upwards becoming flat or compressed, unbranched or sparingly branched 4
   4. Plants less than 1 cm tall, erect axes cylindrical or subcylindrical .... *G. arenarium*
   4. Plants more than 1 cm tall 5
5. Plants up to 1.2 cm tall, erect axes cylindrical, normally finishing in truncate apices, occasionally with terminal proliferations .... *G. pusillum* var. *cylindricum*
5. Plants up to 2 cm tall, erect axes cylindrical below, and distally becoming flat, spatulate or lanceolate .... *G. pusillum var. pacificum*
5. Plants filiform, cylindrical or slightly compressed, 2–4 (-6) cm tall, 200–400 μm wide, branches with somewhat tetrastichous ultimate branchlets .... *G. crinale*
   6. Plants with apparent midrib, erect axes very compressed, up to 4 mm wide .... *G. japonicum*
   6. Plants without a midrib, erect axes cylindrical basally, and distally becoming compressed or flat above 7
7. Branches contiguous, densely repeatedly pinnate .... *G. yamadae*
7. Branches not repeatedly pinnate 8
   8. Basal branches longer than other branches .... *G. tsengii*
   8. Basal branches not longer than other branches 9
9. Ultimate branchlets dense 10
9. Ultimate branchlets few and clavate .... *G. kintaroi**
   10. Ramifications in final orders corymbose .... *G. planiusculum*
   10. Ramifications very irregular in all orders 11
11. Axes strap-shaped, widened and compressed at the branching points, some branches constricted at their bases .... *G. vagum*
11. Erect axes and primary branches lanceolate 12
    12. Branches more often regularly arranged, terminal branchlets pinnate with acute apices .... *G. amansii*
    12. Branches sparse, ultimate branchlets distichous pinnate 13
13. Plants small, 2–4 cm tall, axes conspicuous and percurrent .... *G. masudai*
13. Plants larger, 6–7 cm tall, axes inconspicuous .... *G. latiusculum**

*Not accepted by Yoshida (1998).

Description of the Species

Gelidium amansii (Lamouroux) Lamouroux, Ann. Mus. Hist. Nat. 20:129, 1813.
(Figs. 1–3, 71)

Basionym: *Fucus amansii* Lamouroux, Diss. Fucus, p. 48, 1805.

Misapplied Name: *Gelidium pacificum* of Zhang and Xia in Tseng et al., Econ. Seaweeds of China, p. 119, fig. 30, pl. VII, fig. 53, 1962.

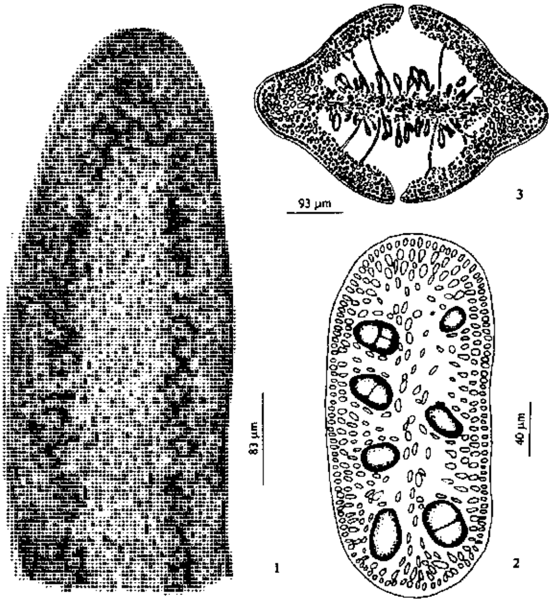
Plants purplish red, cartilaginous, erect, solitary or caespitose, 10–20 (–30) cm tall, attached by a rhizomatous holdfast that produces many upright axes up to 2 mm wide. Pinnately branched 4–5 times, alternate or opposite, branches compressed at the base, subcylindrical or compressed above, all branches with sharp and acute apices. In section, middle part of main branch 398–415 µm thick, medullary cells rounded or elliptical, 20–30 µm by 13–26 µm, outermost cortical cells rounded, 3.3–5 µm by 4–5 µm, with rhizoidal filaments just below the cortex.

Tetrasporangial sori on elongate-ovate or oblong branchlets, tetrasporangia arranged without order in sori, rounded or ovate in surface view, 26–40 µm by 20–33 µm, cruciately divided. Cystocarps on the ultimate branchlets, swollen, up to 1 mm in diameter. Spermatangial sori on apices of ultimate branchlets, elongate spermatangial initials cut off terminally, spermatangia subspherical or ovoid.

Habitat: Growing on upper intertidal to subtidal rocks.

Distribution: Abundant on the Huanghai Sea coast; also found on the east coasts of the South China Sea.

Remarks: *Gelidium amansii* is an important economic seaweed used as the main raw material in the Chinese production of agar.



Figs. 1–3. *Gelidium amansii* (Lamouroux) Lamouroux. Fig. 1, Transection of part of frond (Tseng et al. 1962, fig. 27-1). Fig. 2, Transection of tetrasporangia (AST 53-1338). Fig. 3, Longitudinal section of cystocarp (Tseng et al. 1962, fig. 28-1).

Gelidium arenarium Kylin, Lunds Univ. Arrskr., N. F. Avd. 2, Bd 34, Nr 8, fig. 2-D, 1938.

(Figs. 4–6)

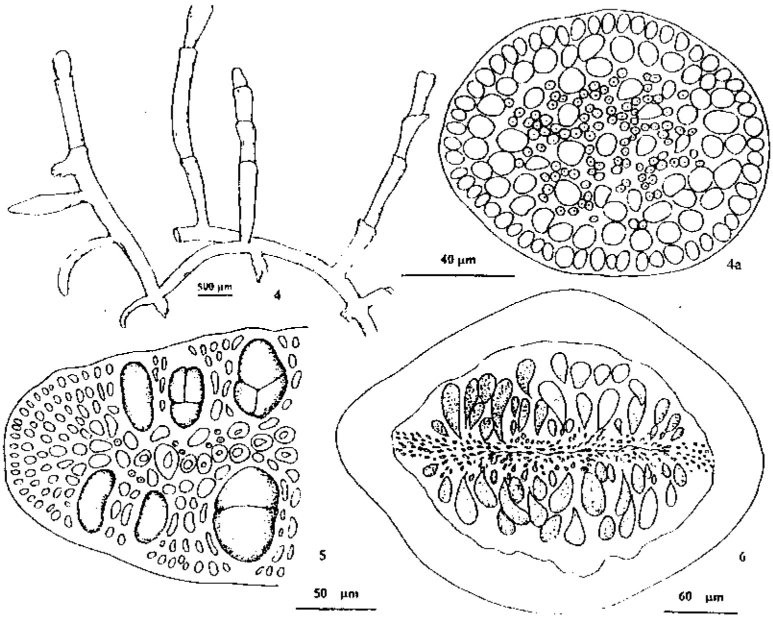
Plants purplish red, membranous, small, 4–6 mm tall, attached to the substratum by holdfast from a cylindrical creeping stem. Erect branches cylindrical or subcylindrical, arising from creeping axes, rarely branched 1–2 times. In cross section, creeping axes rounded, 116–172 µm in diameter, with a few rhizoidal filaments restricted to the medullary layer; erect branches subcylindrical, 125–152 µm by 100–118 µm, consisting of sparse irregularly rounded cells, 7–10 µm by 7–8 µm, outermost cortical cells ovate, 5–7 µm by 5 µm, with many rhizoidal filaments aggregated in the medullary layer.

Tetrasporangial sori on the apices of branchlets, tetrasporangia rounded or elliptical in surface view, 36–43 µm by 26–40 µm, cruciately or irregularly tetrahedrally divided. Cystocarps swollen, spherical, on the apices of branchlets, in cross section elliptical, 290–330 µm by 376–403 µm. Spermatangia not seen.

Habitat: Growing on intertidal shells.

Distribution: Hainan Province.

Remarks: *Gelidium arenarium* is a new record for China.



Figs. 4–6. *Gelidium arenarium* Kylin (AST PH 90-33). Fig. 4, Habitat sketch of part of frond. Fig. 4a, Transection of part of erect branch. Fig. 5, Transection of tetrasporangia. Fig. 6, Longitudinal section of cystocarp.

Gelidium crinale (Turner) Gaillon, Thalassiophytes. Dictionnaire des Sciences Naturelles [Levrault], 53, p. 362, 1828.

(Figs. 7, 8, 78)

Basionym: *Fucus crinalis* Turner, Fuci . . . vol. 4, p. 4, pl. 198, 1819.

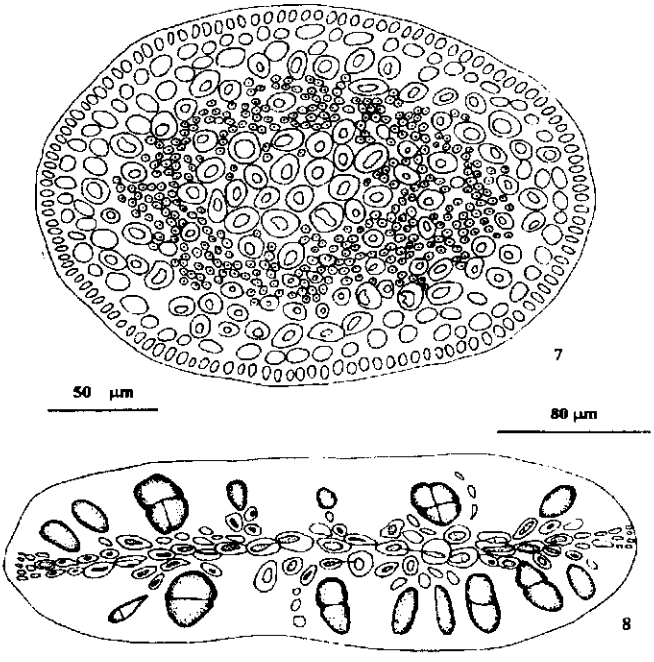
Synonym: *Gelidium crinale* (Turner) Lamouroux in Bory de Saint Vincent, J. B., Dictionnalre Classique d'Histoire Naturelle, vol. 7, p. 171, 1825.

Plants dark purple-red, subcartilaginous, forming a tuft of prostrate axes and upright branches, 2–4 cm tall, up to 5–6 cm tall, attached to substratum by stoloniferous rhizoids. Prostrate axes cylindrical, 150 μm in diameter, erect axes cylindrical at their base, subcylindrical above the bases, compressed at the upper part of the axes, 250–375 μm in diameter, irregularly pinnate, alternately or oppositely branched 2–3 or 2–4 times. In cross section, erect axes consisting of medulla and cortex, medullary cells roundish or ovate, cortical cells ovoid or elliptical, rhizoidal filaments aggregated in the medulla.

Tetrasporangial sori on the spatulate, lanceolate, or irregularly shaped apical parts of branches, tetrasporangia spherical or ovoid in surface view, 23–36 μm by 20–30 μm, cruciately divided. Spermatangia and cystocarps not seen.

Habitat: Growing on intertidal sandy rocks.

Distribution: Common on the entire coast of China.



Figs. 7–8. *Gelidium crinale* (Turner) Gaillon. Fig. 7, Transection of part of frond (AST 63-953). Fig. 8, Transection of tetrasporangia (AST 82-216).

Gelidium divaricatum Martens, Preuss. Exped. Ost-Asien, p. 30, pl. 8, fig. 4, 1868.
(Figs. 9–20, 80)

Plants brownish to reddish purple, cartilaginous, small and dwarf, densely caespitose, creeping and decumbent, up to 2 cm tall. Creeping axes cylindrical or slightly compressed, attached to the substratum by irregularly disposed holdfasts. Erect branches arising from creeping axes, cylindrical, bipinnately branched, with opposite or alternately disposed pinnulae, apex acute or blunt. In cross section, branches consisting of medulla and cortex, medullary cells rounded or ovate, 36–40 μm by 20–26 μm, outermost cortical cells ovate, 3.3–5 μm by 3.3 μm, rhizoidal filaments aggregated in the outer part of the medulla.

Tetrasporangial sori on the apex of ramuli, tetrasporangia roundish or ovate in surface view, 40–50 μm by 28–40 μm, cruciately divided. Cystocarps on the apex of ramuli, swollen to globose, 398–415 μm by 498–515 μm, with a single ostiole on each surface. Spermatangia not seen.

Habitat: Growing in dense clumps on upper intertidal rocks or shells.

Distribution: Widely distributed on the entire coast of China.

Gelidium japonicum (Harvey) Okamura, Illustr. Mar. Alg. Jpn. 1:57, pl. 21, 1901.
(Figs. 21–28, 77)

Basionym: *Suhria japonica* Harvey, Proc. Am. Acad. Arts Sci. 4:331, 1859.

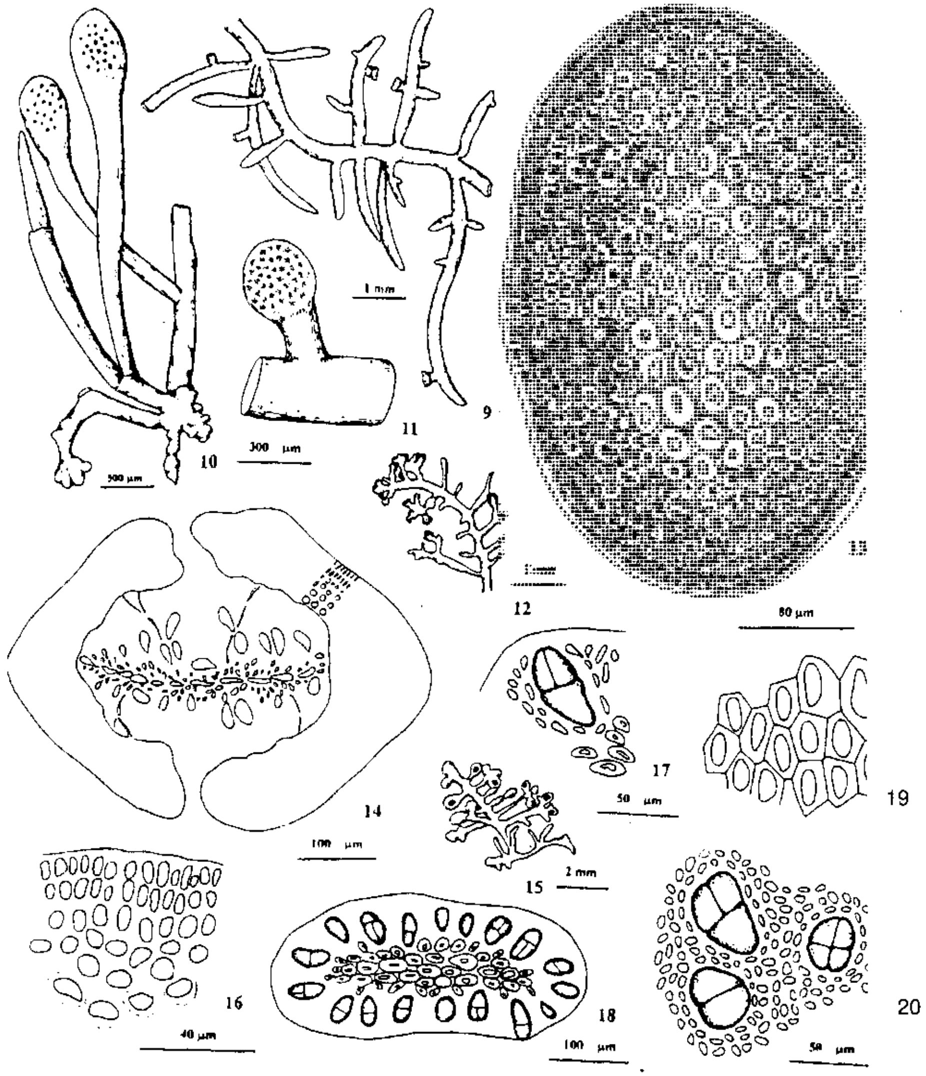
Plants purplish red, cartilaginous, erect, compressed, 6–12 cm high, 3–6 mm wide, attached by a rhizomatous holdfast, often with a slight thickening similar to a midrib along the median part of the fronds. Branching absent or irregular, with branches appearing as expanded proliferations from margins and surface of the thallus. In cross section, erect axes consisting of cortex and medulla, medullary cells irregularly rounded or oblong, 7–13 μm in diameter, cortical cells in 2–3 layers, outermost cortical cells oblong or cylindrical, 3.3–7 μm by 3.3–5 μm, innermost cortical cells irregularly ovate, 10–13 μm by 3.3–7 μm. Middle parts of erect axes 415–481 μm thick, margins of erect axes 116–166 μm thick. Rhizoidal filaments dispersed among inner cortical and medullary cells.

Cystocarps swollen, ovate, apically elongate, produced at apical parts of lateral proliferations attached to the margins of axes, cystocarpic ramuli 481–1660 μm long, up to 232–249 μm wide, in longitudinal section, cystocarps nearly globose, 432–465 μm by 481–498 μm. Tetrasporangia and spermatangia not observed in China.

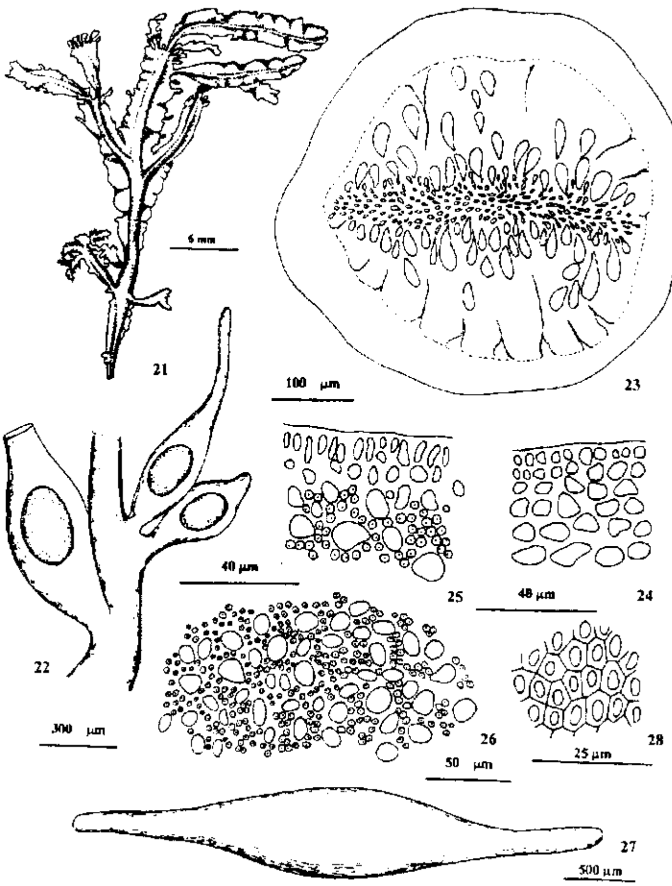
Habitat: Growing on intertidal to subtidal rocks.

Distribution: Fujian and Taiwan provinces.

Remarks: *Gelidium japonicum* is used as raw material in the production of agar.



Figs. 9–20. ***Gelidium divaricatum*** **Martens. Fig. 9, Habitat sketch of part of frond (AST PH 90-64). Fig. 10, Tetrasporangial branchlets (AST PH 90-64). Fig. 11, Tetrasporangial branchlet (AST 53-1021). Fig. 12, Tetrasporangial branchlets (Tseng et al. 1962, fig. 29-1). Fig. 13, Transection of frond (AST 53-1021). Fig. 14, Longitudinal section of cystocarp (AST 71-21). Fig. 15, Cystocarp branchlets (Tseng et al. 1962, fig. 29-2). Fig. 16, Longitudinal section of part of pericarp (AST 71-21). Figs. 17 and 18, Transections of tetrasporangia (AST 53-1021). Fig. 19, Surface view of tetrasporangia (AST 53-1021). Fig. 20, Surface view of outermost cortical cells (AST 58-2023).**



Figs. 21–28. *Gelidium japonicum* (Harvey) Okamura. Fig. 21, Habitat sketch of frond (Tseng et al. 1962, fig. 31). Fig. 22, Cystocarp branchlets (AST 63-4466). Fig. 23, Longitudinal section of cystocarp (AST 63-4466). Fig. 24, Longitudinal section of part of pericarp (AST 63-4466). Fig. 25, Transection of part of cortical cells and rhizoidal filament cells (AST 53-1604). Fig. 26, Transection of part of medullary cells and rhizoidal filament cells (AST 53-1604). Fig. 27, Transection of main axes showing midrib (AST 53-604). Fig. 28, Surface view of outermost cortical cells (AST 53-1604).

Gelidium kintaroi (Okamura) Yamada, Sci. Pap. Inst. Alg. Res. 2:201, 1941.
(Figs. 29, 30, 75)

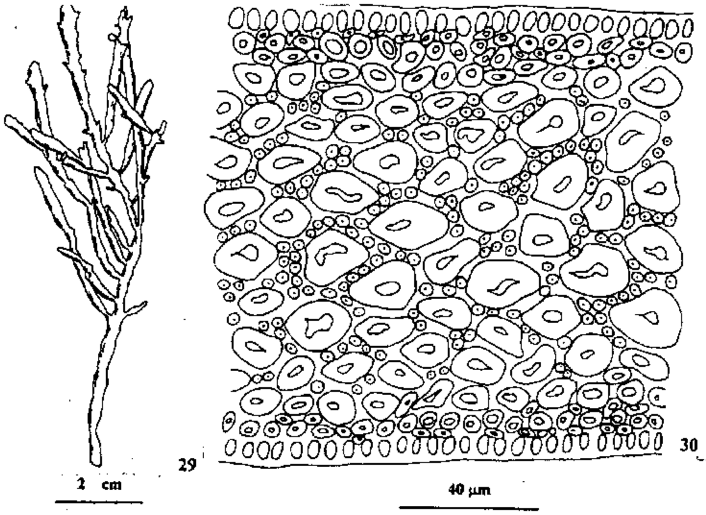
Synonym: *Gelidium clavatum* Okamura, J. Imp. Fish. Inst. 29:61, pl. 28, pl. 32, figs. 4–6, 1934.

Plants purplish red, cartilaginous, erect, complanate, 6–8 cm tall, attached by stemlike holdfasts. Main axes not percurrent, pinnately branched, alternate or opposite, very spread out, apices of branches and ramuli broadly rounded, ramuli few in number. In cross section, medulla consisting of irregular angular cells, 17–23 µm by 7–20 µm, inner cortical cells rounded to ovate, 7 µm by 3.3–5 µm, outermost layer of cells ovate or elliptical, 5 µm by 3.3 µm, middle parts of main branches 1792 µm wide, 142–205 µm thick, margins 99–132 µm thick, base of main branches subcylindrical, 448–465 µm wide, 316–332 µm thick. Rhizoidal filaments dispersed among the medullary cells. Reproductive organs not seen.

Habitat: Growing on low tidal rocks.

Distribution: Fujian Province.

Remarks: We have a few specimens of *G. japonicum* collected from the type locality (Amoy) that have some resemblance to the type specimen (Okamura, 1934, pl. 28, fig. 2).



Figs. 29–30. *Gelidium kintaroi* (Okamura) Yamada. Fig. 29, Branches (after Segi, 1954, fig. 4A–I). Fig. 30, Transection of part of frond (AST 82-465).

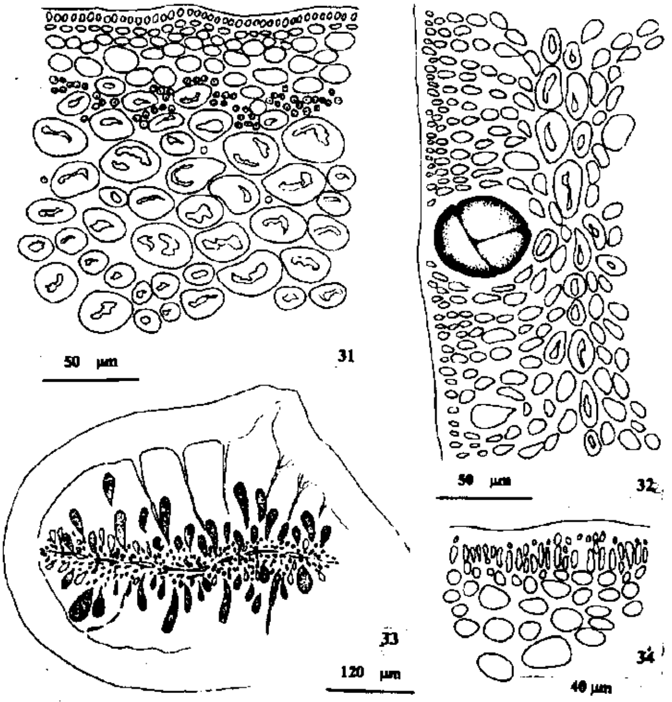
Gelidium latiusculum Okamura, Jpn. Assoc. Adv. Sci. 10:443, 1935.
(Figs. 31–34, 73)

Plants purplish red, cartilaginous, erect, caespitose, 6–7 cm tall, attached to the substratum by a stemlike holdfast. Erect axes percurrent, compressed at their bases, margins thin, with inconspicuous midrib at lower parts, 747–880 µm wide, 282–299 µm thick at middle parts, margins 66–83 µm thick, flat at upper parts, up to 2 µm wide and 133–282 µm thick, irregularly pinnately branched. Branches patent, blunt at apices; branchlets simple or branched, variable in length. In cross section, main axes consisting of medulla and cortex, medullary cells ovate and rounded, 23–30 µm by 17–26 µm, innermost cortical cells elliptical, 7–13 µm by 5–6.6 µm, outermost cortical cells pigmented, ovate, 3.3–5 µm by 3.3 µm, rhizoidal filaments aggregated between inner cortical layers and outer medullary layer.

Tetrasporangial branchlets obovate, 1079–1328 µm long, 365–448 µm wide, developed at the ultimate branchlets, tetrasporangia ovate to elliptical in surface view, 26–33 µm by 20–26 µm, rounded in cross section, 33–46 µm by 30–43 µm, cruciately divided. Cystocarps swollen, spherical, on the apex or middle parts of ultimate branchlets, in longitudinal section, 465–498 µm by 581–598 µm. Spermatangial sori developed on the ultimate branchlets, elongate spermatangial initials forming subspherical to ovoid spermatangia terminally.

Habitat: Growing on lower tidal to subtidal rocks.

Distribution: Zhejiang and Taiwan provinces.



Figs. 31–34. *Gelidium latiusculum* Okamura. Fig. 31, Transection of part of frond (AST 63-4260). Fig. 32, Transection of tetrasporangia (AST 63-4260). Fig. 33, Longitudinal section of cystocarp (AST 56-1637). Fig. 34, Transection of spermatangia (AST 59-3440).

Gelidium masudai Xia et Tseng, sp. nov.
(Figs. 35–46, 81)

Plantae 2–4 (–5) cm altae, axes percurrentes, rami distichi plerumque 2–3 ordinibus rami, secundarii et tertiarii dense vestiti alternis vel oppositis pinnatis ramunculis, hyphae inter corticem et medullam multae; ramuli cystocapio lanceolati, omnibus cystocarpum unicum ferentibus; ramuli tetrasporangiferi obovati vel lageniformes.

Plants purple-red, cartilaginous, erect, 2–4 (–5) tall, attached by a slender creeping rhizome, with some small holdfasts at intervals. Erect axes percurrent, flat, 1–1.5 mm wide. Branches distichous, usually 2–3 times branched, secondary and tertiary branches densely clothed with alternate or opposite pinnate ultimate branchlets, branches slender at their bases, obtuse at the apex, with some proliferations on the surface in the old parts of the frond. In cross section, erect axes consisting of cortex and medulla, medullary cells sparse, elliptical, 30–36 μm by 17–20 μm, rhizoidal filaments aggregated between inner part of cortex and outer part of medulla.

Tetrasporangia forming sori on the swollen parts of tetrasporangial branchlets, in surface view, rounded to elliptical, 26–30 μm by 20–23 μm, in cross section, sporangia ovate to obovate, 33–46 μm by 20–40 μm, cruciately divided, sometimes irregularly divided. Cystocarps spherical, developed on middle parts of ultimate branchlets, in longitudinal section, 249–398 μm by 581–597 μm; carposporangia obovate to clavate, 33–50 μm by 13–20 μm; pericarp 40–46 mm thick, consisting of 6–8 layers of cells, some sterile filaments from gonimoblast to pericarp, ostiolate, on both surfaces of cystocarp. Spermatangia not observed.

Holotype: AST 54-2590, cystocarpic.

Isotype: AST 54-2590a, tetrasporangial. Collected by Zheng Shudong, June 5, 1954, from midtide rock pool, in Jingan, Lishiliedao, Fujian Province, China.

Etymology: Named in appreciation of Professor Michio Masuda, Hokkaido University, Sapporo, for his confirmation that this species is probably a new one.

Remarks: This new species is characterized by short thalli, 2–4 cm tall, bases with creeping rhizomes, and some small secondary holdfasts on the rhizomes for attachment. The axes are percurrent, and branches are sparse, but the plant has many ultimate branchlets. These dense distichous, alternate or opposite branching branchlets are so distinctive as to separate this species from all others now reported in this genus.

Gelidium planiusculum Okamura, Jpn. Assoc. Adv. Sci. 10:442, 1935.
(Figs. 47–49, 76)

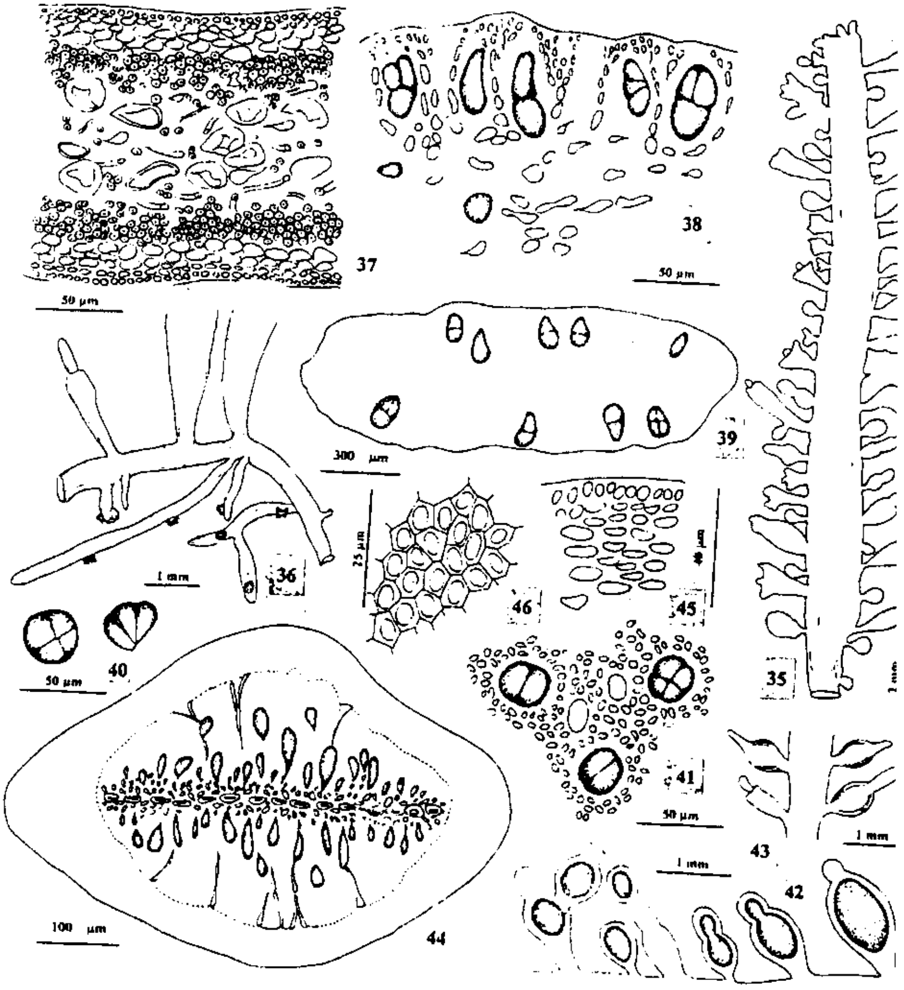
Plants purple red, cartilaginous, erect, compressed, 9–12 cm tall, 1–2 mm wide, consisting of several distichously, pinnately branched, percurrent axes arising from a massive rhizomatous holdfast. Four or more orders of branches, branches longest on lower parts of plant, shorter toward top of plant, corymbose, usually clothed with filiform branches and branchlets.

Tetrasporangial ramuli slenderly elongate-oblong or spatulate, tetrasporangia arranged without order in irregularly shaped sori, up to 35 μm in diameter, cruciately divided. Cystocarps and spermatangia not seen.

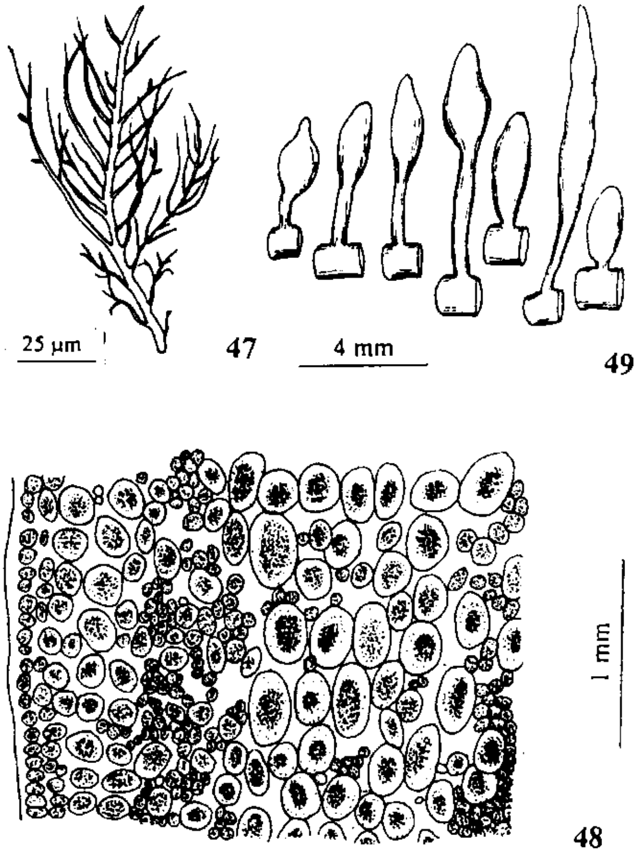
Distribution: Taiwan Province.

Remarks: We have not collected specimens of *G. planiusculum*. The description is according to Fan (1951) and Santelices (1988).

Gelidium pusillum (Stackhouse) Le Jolis, Mem. Soc. Imp. Sci. Nat. Cherbourg, vol. 10, p. 139, 1863.
Basionym: *Fucus pusillus* Stackhouse, Nereis Britannica, vol. 3, p. 17, 1801.
Gelidium pusillum var. *conchicola* Piccone et Grunow, in Piccone, Nuovo Giornaie Botanico Italiano 16:316, 1884.
(Figs. 50–53)



Figs. 35–46. *Gelidium masudai* Xia et Tseng, sp. nov. (AST 54-2590). Fig. 35, Main axis. Fig. 36, Creeping stem. Fig. 37, Transection of part of main axis. Figs. 38 and 39, Transections of tetrasporangia. Figs. 40 and 41, Surface views of tetrasporangia. Fig. 42, Tetrasporangial branchlets. Fig. 43, Cystocarp branchlets. Fig. 44, Longitudinal section of cystocarp. Fig. 45, Longitudinal section of part of pericarp. Fig. 46, Surface view of outermost cortical cells.



Figs. 47–49. ***Gelidium planiusculum*** **Okamura (after Fan 1951, fig. 4). Fig. 47, Part of branch showing mode of branching of filiform ramuli. Fig. 48, Part of a cross section of a branch. Fig. 49, Tetrasporic ramuli.**

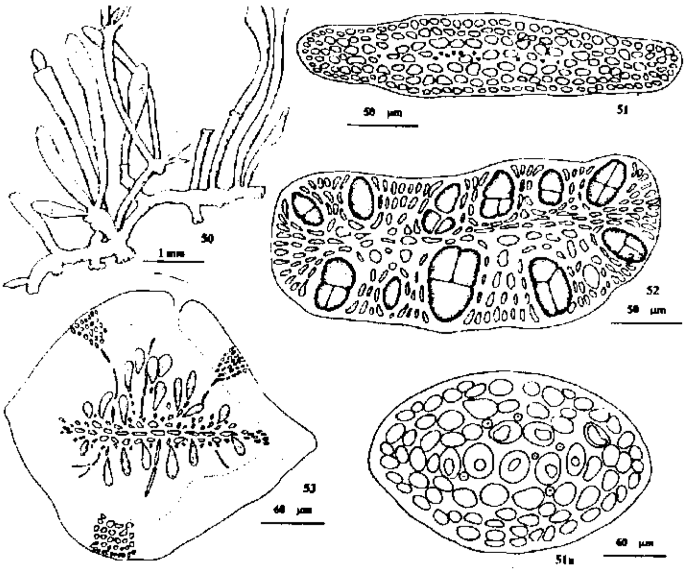
Plants purplish red, subcartilaginous, small, 2–3 mm tall, attached to the substratum by creeping axis with holdfast. Erect branches arising from creeping axis, simple or rarely branched. In cross section, creeping axis ovate, about 119 µm wide, 79 µm thick, with a few rhizoidal filaments dispersed in the medulla, erect branches 264–290 µm wide, 40–66 µm thick, with a few rhizoidal filaments dispersed in the medulla.

Tetrasporangial sori on the apex of branches, tetrasporangia rounded to ovate in surface view, 20–26 µm by 17–23 µm, cruciately divided. Cystocarp swollen, on the apex of branches, in longitudinal section, 238–197 µm by 264–330 µm. Spermatangia not seen.

Habitat: Growing on intertidal shells or rocks.

Distribution: Hainan Province.

Remarks: This record is a new one for China.



Figs. 50–53. *Gelidium pusillum* var. *conchicola* Piccone et Grunow (AST 92-62). Fig. 50, Habitat sketch of part of a frond. Fig. 51, Transection of part of an erect branch. Fig. 51a, Transection of part of a creeping stem. Fig. 52, Transection of tetrasporangia. Fig. 53, Longitudinal section of cystocarp.

Gelidium pusillum var. *cylindricum* Taylor, Allan Hancock Pac. Exped. vol. 12, p. 154, pl. 5, fig. 1, 1945.

(Figs. 54–56)

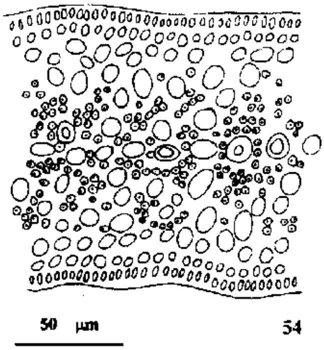
Plants dark red, cartilaginous, small, forming a mat of small bushes, up to 1.2 cm tall, attached to the substratum by cylindrical creeping axes, 83–99 µm in diameter, with small holdfasts at irregular intervals. Erect axes cylindrical, sometimes slightly compressed, rarely branched, normally finishing in truncate apices with several proliferations, imbricated segments common. In cross section, creeping axes consisting of irregularly rhomboidal cells, 10–13 µm by 5–7 µm, erect branches consisting of cortex and medulla, medullary cells round or ovate, 7–10 µm in diameter, outermost cortical cells ovate or elliptical, 5–7 µm by 3.3 µm, middle parts of erect branches 216–365 µm wide, 139 µm thick, rhizoidal filaments dispersed around medullary cells.

Tetrasporangia on apex of swollen parts of branches, forming small, oval sori, 332 µm by 299 µm, tetrasporangia ovoid to elliptical in surface view, 17–23 µm by 13–17 µm, scattered irregularly among cortical layers, cruciately divided. Cystocarps and spermatangia not observed.

Habitat: Growing on intertidal rocks.

Distribution: Hainan Province.

Remarks: Truncate apices and imbricated segments also occur in other species of Chinese *Gelidium*.



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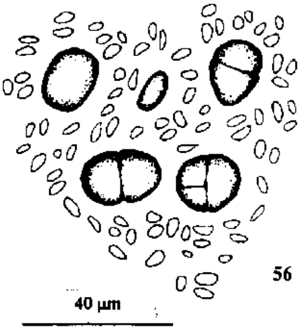

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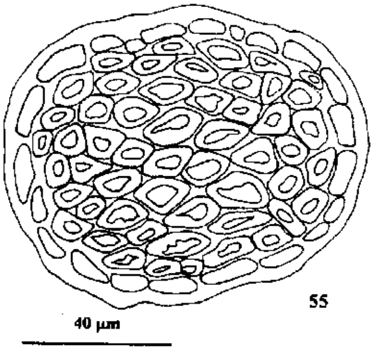

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Figs. 54–56. *Gelidium pusillum* var. *cylindricum* Taylor (AST PH 90-168). Fig. 54, Transection of part of a main axis. Fig. 55, Transection of part of basal creeping stem. Fig. 56, Surface view of tetrasporangia.

Gelidium pusillum var. *pacificum* Taylor, Allan Hancock Pac. Exped. vol. 12, p. 153, pl. 5, fig. 7, 1945.

(Figs. 57–59)

Plants purplish red, cartilaginous, erect, caespitose, up to 2 cm tall, attached by slender cylindrical creeping axes, up to 100 mm in diameter, with holdfasts at intervals. Erect axes cylindrical for a short distance (0.4 mm) from holdfast, up to 165 mm in diameter, subcylindrical beyond distance of 1 mm from holdfast, 297 µm by 231 µm; upper parts of erect axes with thin, flat, linear-lanceolate blades with a short stalk and lanceolate or spatulate marginal branchlets or proliferations arising from the truncate upper ends of blades; frequently, some erect axes or branches curved downwardly and becoming new creeping axes. In cross section, erect axes consisting of cortex and medulla, medullary cells irregularly rounded, 810 µm in diameter, outermost cortical cells ovate or obovoid, 3.3–5 µm by 3.3 µm, rhizoidal filaments restricted to medulla. Blades up to 764 µm wide, 73–86 µm thick.

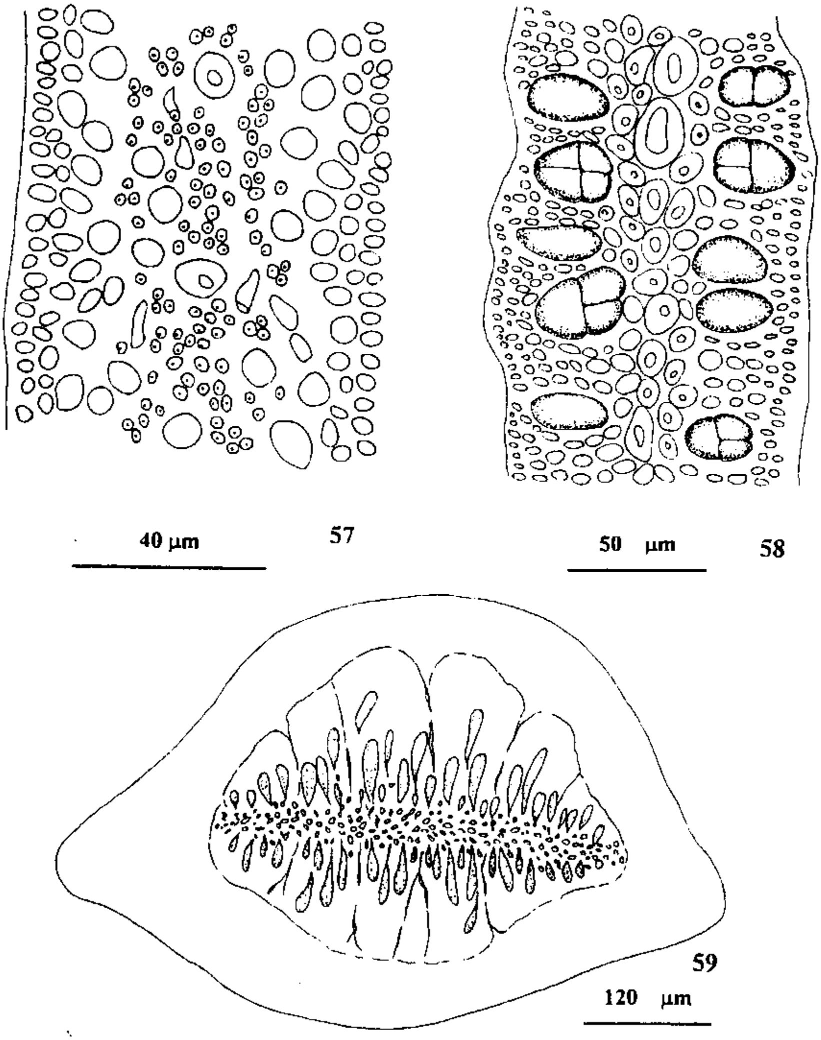
Tetrasporangia forming sori on ends of blades, tetrasporangia oblong in surface view, 23–26 µm by 15–17 µm, ovate or rounded in cross section, 30–36 µm by 23–30 µm, cruciately divided. Cystocarps ovate to spherical, developed on ultimate branchlets, in longitudinal section, 465–475 µm by 664–681 µm.

Spermatangia not observed.

Habitat: Growing on intertidal rocks.

Distribution: Guangdong and Hainan provinces.

Remarks: *Gelidium pusillum* was first reported without mention of infraspecific taxa in China (Tseng and Cheng 1954; Xia et al. 1983; Zhang and Xia 1988).



Figs. 57–59. *Gelidium pusillum* var. *pacificum* Taylor. Fig. 57, Transection of part of a main axis (AST 76-94). Fig. 58, Transection of tetrasporangia (AST 86-1227). Fig. 59, Longitudinal section of cystocarp (AST 76-94).

Gelidium tsengii Fan. Bot. Mar. 2:246, fig. 1, 1961.
(Figs. 60–62, 74)

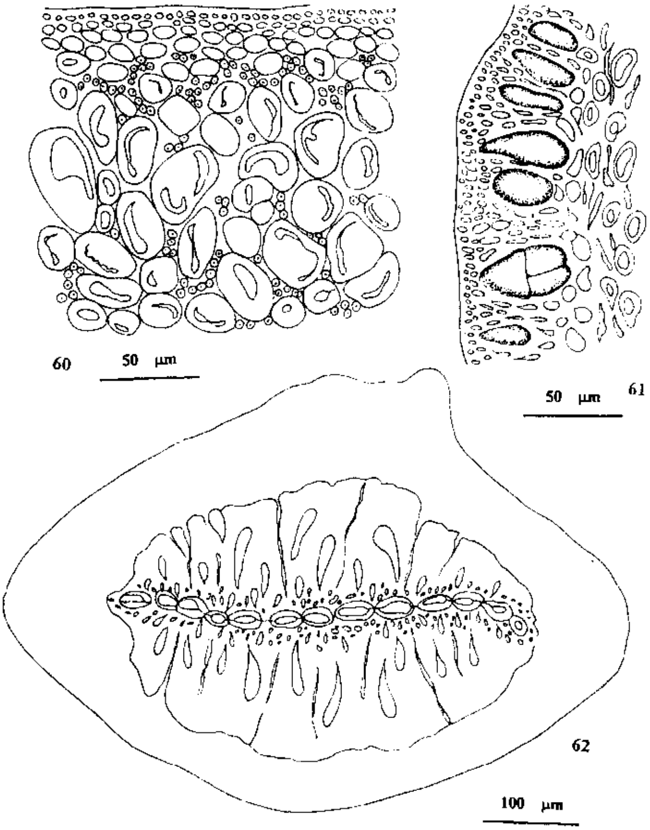
Misapplied Name: *Gelidium johnstonii* of Tseng et al. in Morton and Tseng, eds., Proc. 1st Int. Mar. Biol. Workshop, p. 57, 1980.

Plants purplish red, cartilaginous, 5–7 cm tall, attached to substratum by rhizomatous holdfast. Percurrent axes flat, middle parts slightly thick, about 2 mm wide, 3–4 times pinnately branched, base of branch slightly constricted, apex of branch acute or slightly obtuse. Branches longest on lower parts of plant, becoming gradually shorter toward tip of frond, giving a semicircular outline to the frond. In cross section, main axes consisting of cortex and medulla, rhizoidal filaments aggregated between inner part of cortex and outer part of medulla, with a few dispersed in medullary layer.

Tetrasporangial sori on the apex of branchlets, tetrasporangia rounded or ovate, cruciately divided. Cystocarps swollen, spherical, on ultimate branchlets. Spermatangia not seen.

Habitat: Growing on intertidal rocks or rock pools.

Distribution: Guangdong Province and Hong Kong.



Figs. 60–62. *Gelidium tsengii* Fan. Fig. 60, Transection of part of a main axis (AST 82-627). Fig. 61, Transection of tetrasporangia (AST 82-627). Fig. 62, Longitudinal section of cystocarp (AST 56-3221).

Gelidium vagum Okamura, J. Imp. Fish. Inst. 29:58, pl. 25, pl. 32, figs. 8–10, 1934.
(Figs. 63–66, 72)

Synonym: *Gelidium grubbae* Fan, Bot. Mar. 2:247, figs. 1–3, 1961, a substitute name for the misapplied *Gelidium amansii* of Grubb, J. Bot. 70:213, 1932.

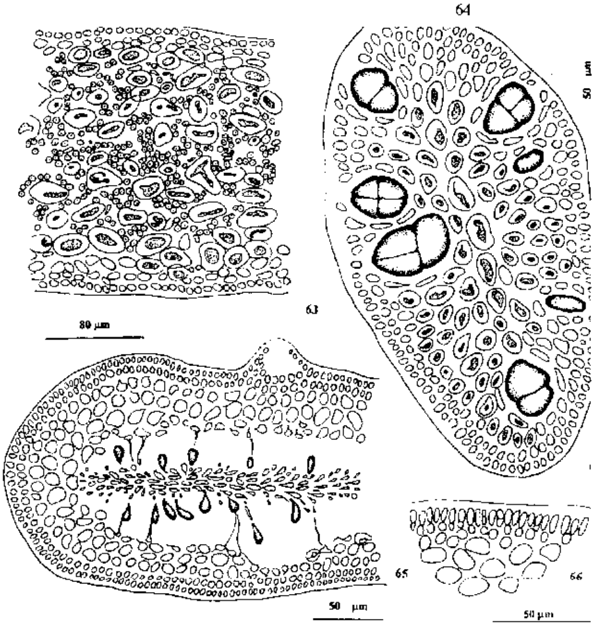
Plants purple-red or dark purple-red, subcartilaginous, erect, solitary or caespitose, 2.5–10 cm tall, thin and flat, composed of one to several distichously, pinnately branched percurrent axes rising from a stoloniferous holdfast. Percurrent axes flat, becoming abruptly narrowed into one to several very acute and sometimes incurved apices, 1–2 times, up to 3–4 times, branched. In cross section, main axes consisting of medulla and cortex, rhizoidal filaments aggregated in medulla of younger branches and aggregated in cortex and medulla of older branches.

Tetrasporangial sori on swollen apices of ramuli, tetrasporangia rounded, elliptical, or ovate, 40–73 µm by 23–33 µm. Cystocarps swollen, spherical, on the middle parts of ramuli; spermatangial sori on ultimate branchlets, elongate spermatangial initials cut off terminally and spermatangia subspherical or ovoid.

Habitat: Growing in low tidal rock pool or on subtidal rocks.

Distribution: Liaoning, Hebei, and Shandong provinces.

Remarks: Fan (1961) described a new species under the name *G. grubbae* from Beidaihe and Weihai, China. Zhang and Xia (1986) compared these specimens with many specimens of *G. vagum* Okamura from Beidaihe and other western Huanghai Sea coasts. Their results showed that *G. grubbae* and *G. vagum* are not separable from each other. Therefore, *G. grubbae* Fan was reduced to the synonymy of *G. vagum* Okamura.



Figs. 63–66. *Gelidium vagum* Okamura. Fig. 63, Transection of part of a main axis (AST 65-5424). Fig. 64, Transection of tetrasporangia (AST 82-338). Fig. 65, Longitudinal section of cystocarp (AST 64-666). Fig. 66, Transection of spermatangia (AST 65-4774).

Gelidium yamadae Fan, Taiwan Fish. Res. Inst. Lab. Fish. Biol. Rep. 2:10, pl. 5, fig. 1, text fig. 6, 1951.

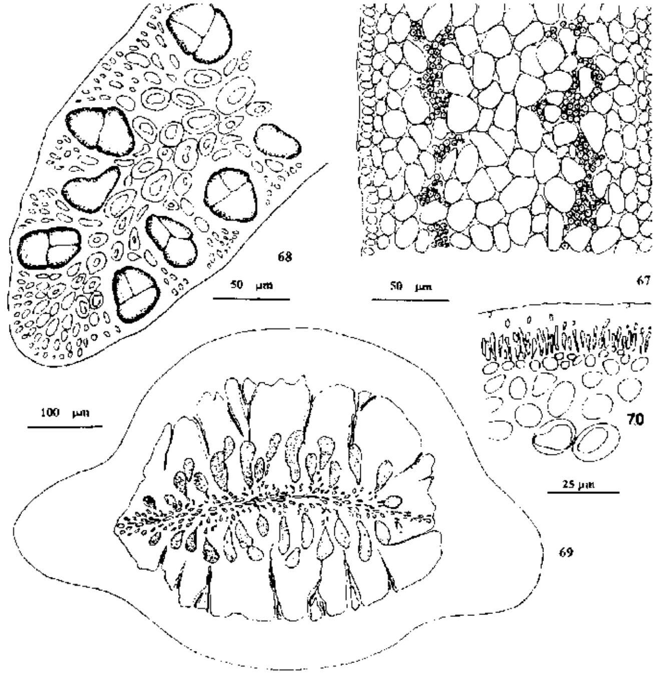
(Figs. 67–70, 79)

Plants purplish red, cartilaginous, erect, caespitose, 4–6 cm, up to 11 cm, tall, attached to substratum by rhizomatous holdfast. Axes percurrent, compressed at their bases, flat above the bases, 1–2.5 mm wide, with middle part thicker, 191–198 mm thick, margins slightly thin, 112 µm thick, 3–4 times densely pinnately branched. Branches contiguous, spread out, compound racemose or compound racemose corymbose in ramification, base of branches not constricted, apex acute, branchlets slender, short, densely pinnate. In cross section, erect axes consisting of medulla and cortex, medulla consisting of irregular parenchyma fous cells, 20–33 µm by 10–23 µm, outermost cortical cells elliptical, 3.3–6.6 µm by 3.3–5 µm, with rhizoidal filaments aggregated in outer medullary layers.

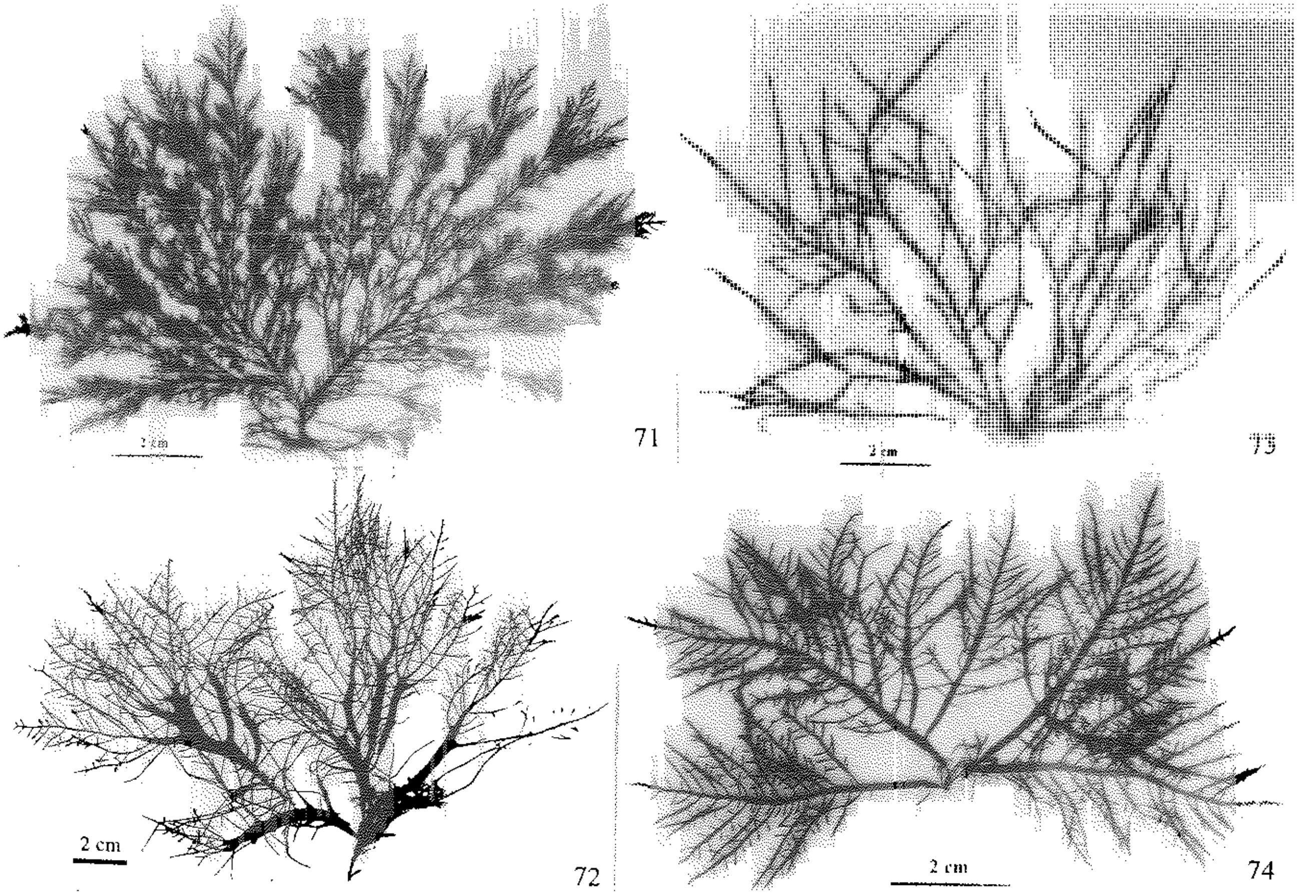
Tetrasporangia on apices of ramuli, roundish or elliptical in surface view, 33–53 µm by 26–33 µm. Cystocarps swollen, on middle parts of ramuli, spherical, 398–465 µm tall, 664–680 µm wide; spermatangia in sori near the apex of ramuli.

Habitat: Growing on subtidal rocks.

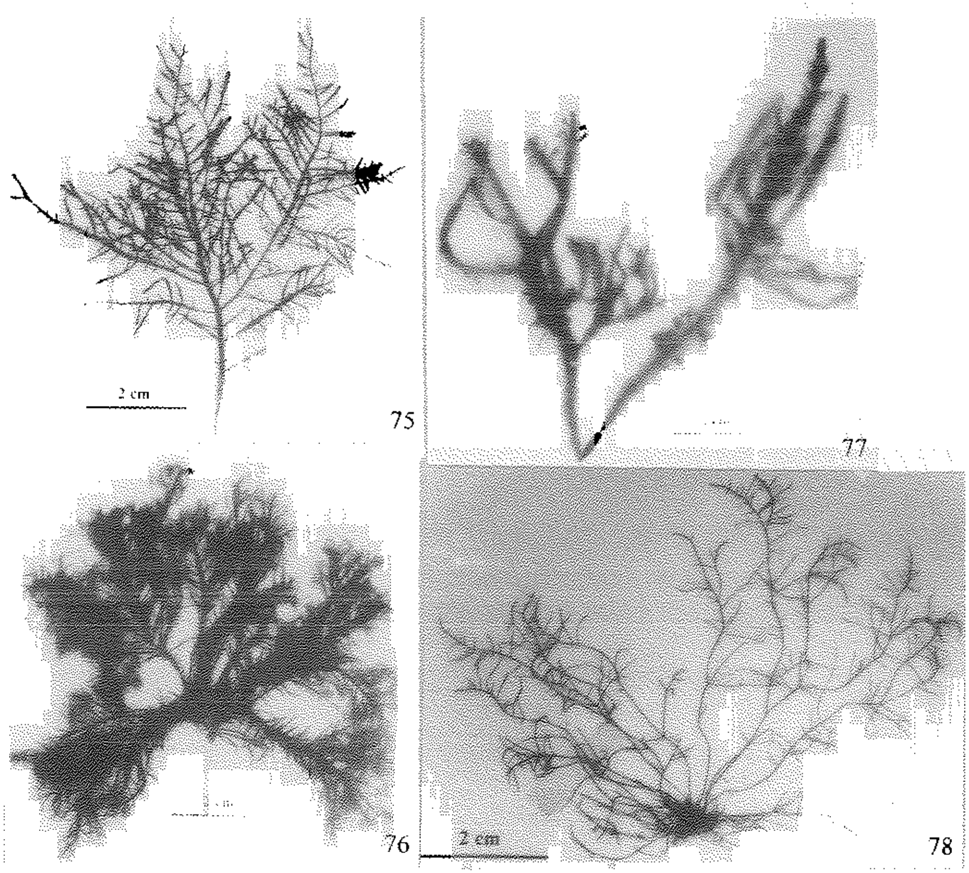
Distribution: Zhejiang and Taiwan provinces.



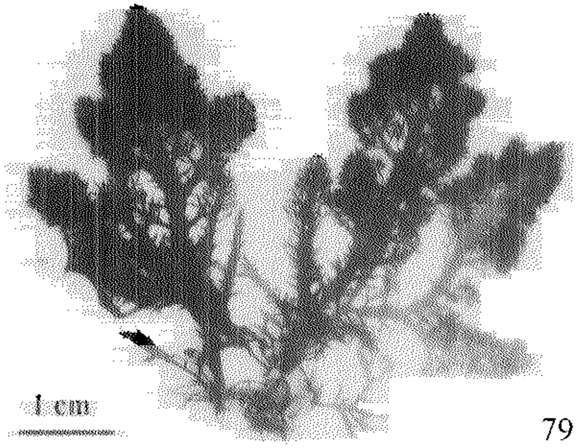
Figs. 67–70. *Gelidium yamadae* Fan. Fig. 67, Portion of branch in cross section (AST 87-320) showing rhizoidal filaments in outer medulla. Fig. 68, Cross section of branch showing cruciately divided tetrasporangia. Fig. 69, Longitudinal section of cystocarp (AST 87-1947). Fig. 70, Transection of spermatangia (AST 87-1891).



Figs. 71–74. Fig. 71, *Gelidium amansii* (Lamouroux) Lamouroux (AST 58-1085). Scale bar = 2 cm. Fig. 72, *Gelidium vagum* Okamura (AST 65-5416). Scale bar = 2 cm. Fig. 73, *Gelidium latiusculum* Okamura (AST 58-2001). Scale bar = 2 cm. Fig. 74, *Gelidium tsengii* Fan (AST 55-1236). Scale bar = 2 cm.



Figs. 75–78. Fig. 75, ***Gelidium kintaroi*** (Okamura) Yamada (AST 82-465). Scale bar = 2 cm. Fig. 76, ***Gelidium planiusculum*** Okamura (AST 87-1804). Scale bar = 2 cm. Fig. 77, ***Gelidium japonicum*** (Harvey) Okamura (AST 53-1604). Scale bar = 2 cm. Fig. 78, ***Gelidium crinale*** (Turner) Gaillon (AST 64-930). Scale bar = 1 cm.



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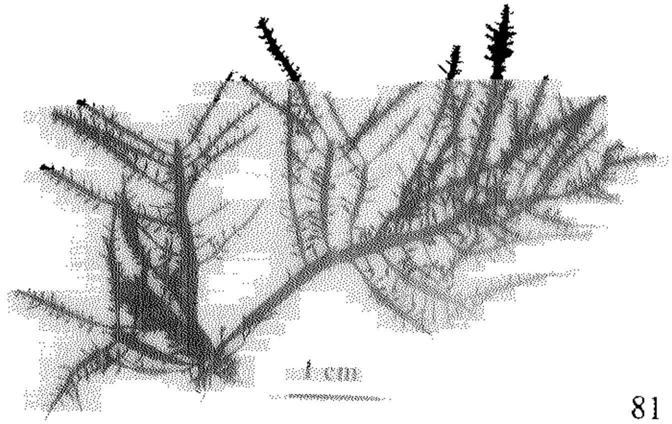

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Figs. 79–81. Fig. 79, *Gelidium yamadae* Fan (AST 87-1947). Scale bar = 2 cm. Fig. 80, *Gelidium divaricatum* Martens (AST 71-21). Scale bar = 1 cm. Fig. 81, *Gelidium masudai* Xia et Tseng (AST 54-2590). Scale bar = 1 cm.

Acknowledgments

This project was supported by a grant for systematic and evolutionary biology, Chinese Academy of Sciences. This chapter is contribution No. 3795 from the Institute of Oceanology, Chinese Academy of Sciences. We thank Dr. I. A. Abbott and Dr. Karla McDermid for reading and editing our manuscript. We also extend our appreciation to Dr. J. Sullivan, former director of the California Sea Grant College Program, for his continued interest and support.

Literature Cited

Fan, K. C. 1951. The genera *Gelidium* and *Pterocladia* of Taiwan. Taiwan Fish. Res. Inst. Lab. Fish. Biol. Rep. 2:1–22, figs. 1–11.

Fan, K. C. 1961. Two new species of *Gelidium* from China. Botanica Marina 2, p. 246, fig. 1.

Grubb, V. M., 1932. Marine algae of Korea and China, with notes on the distribution of Chinese marine algae. [London] J. Bot. 70:213–219.

Okamura, K. 1934. On *Gelidium* and *Pterocladia* of Japan. J. Imp. Fish. Inst. 29:7–67.

Okamura, K. 1935. Taiwan-San tengusa ni Tsuite Japan. Assoc. Adv. Sci. 10:441–443.

Okamura, K. 1936. Nippon kaiso-shi (Japanese algae). Uchida-Rokakuho Publishing, Tokyo (in Japanese).

Santelices, B. 1988. Taxonomic studies on Chinese Gelidiales (Rhodophyta). In: Tax. Econ. Seaweeds 2, pp. 91–107, figs. 1–11.

Santelices, B., and Stewart, J. 1985. Pacific species of *Gelidium* and other Gelidiales (Rhodophyta). In: Tax. Econ. Seaweeds 1, pp. 17–31.

Segi, T. 1954. On the species of Gelidium from Japan and its vicinity. Bull. Jpn. Soc. Phycol. 2:13–19, figs. 1–4.

Tseng, C. K. 1938. Notes on some Chinese marine algae. Lingn. Sci. J. 17:591–604.

Tseng, C. K., ed. 1983. Common seaweeds of China. Science Press, Beijing (in Chinese).

Tseng, C. K., Chang, C. F, Xia, E. Z., arid Xia, B. M. 1980. Studies on some marine red algae from Hong Kong. In: Morton, J., and Tseng, C. K., eds. Proceedings of the 1st International Marine Biology Workshop: The marine flora and fauna of Hong Kong and southern China. Hong Kong University Press, Hong Kong, pp. 57–84.

Tseng, C. K., Chang, T. J. K., Chang, C. F., Xia, E. Z., Xia, B. M., Dong, M. L., and Yanz, Z. D. 1962. Economic seaweeds of north China. Science Press, Beijing (in Chinese).

Tseng, C. K., and Cheng, P. L. 1954. Studies on the marine algae of Tsingtao, I. Acta Bot. Sin. 3:105–120, pls, 1–3.

Tseng, C. K., and Li, C. L. 1935. Some marine algae from Tsingtao and Chefoo, Shantung. Bull. Fan Mem. Inst. Biol. (Bot.) 6:183–235, 2 maps.

Yoshida, T. 1998. Marine algae of Japan. 1222 pp. (in Japanese).

Zhang Junfu (C. F. Chang) and Xia Enzhan. 1986. On *Gelidium vagum* Okamura and *G. grubbae* Fan. Oceanol. Limnol. Sin. 17:521–526, pl. 1.

Zhang Junfu (C. F. Chang) and Xia Enzhan. 1988. Chinese species of *Gelidium* Lamouroux and other Gelidiales (Rhodophyta), with key, list, and distribution to the common species. In: Tax. Econ. Seaweeds 2, pp. 109–113, figs. 1–9.

Section III. Gracilariales

INTRODUCTION

Isabella A. Abbott

Traditionally (that is to say, for 15 years), the number of persons interested in *Gracilaria* has been as great as the number interested in *Sargassum*. So this section has many species of *Gracilaria* to contemplate. Without a doubt, the next generation of *Gracilaria* workers that Professor Yamamoto has trained will straighten out this genus in an experimental way similar to the way he has contributed: microscopy and hybridization, learning both physiological and ecological ways to answer questions. I am very sorry that Dr. Yamamoto is retiring—we need him in phycology!

Another "gem" from his laboratory is examination of the type materials of Weber van Bosse's *Siboga* specimens of *Gracilariophila* and *Gracilariocolax* that were described as parasites on *Gracilaria* species. Examination showed that her concept of *Gracilariophila* was not the same as that of the authors of that genus and that the Asian species bearing that generic assignment could all be accommodated within the boundaries of *Gracilariocolax*. No one appreciates studies that help to straighten out correct names for taxa as much as I do.

The *Gracilaria* Group. (Left to right): Anong Chirapart, Xia Bangmei, Ryuta Terada, Khanjanapaj Lewmanomont.

THE TAXONOMY OF PARASITIC GENERA GROWING ON *GRACILARIA* (RHODOPHYTA, GRACILARIACEAE)

Grevo S. Gerung and Hirotoshi Yamamoto

Abstract

Because of the inaccessibility of materials, both fresh field collections and herbarium specimens, information on 4 species of *Gracilariophila* Setchell et Wilson that are known from Indonesia is limited to the original collections of Weber van Bosse. The type species of the genus, *G. oryzoides* Setchell et Wilson, is from California, where it is relatively widespread. Fresh material of the Asian parasites was collected recently in Indonesia, the type locality of 4 species and 1 variety of *Gracilariophila*, and was compared with dried material from the herbarium of Weber van Bosse at Leiden, the Netherlands. The results indicated that the 4 Indonesian species are not in any way similar to the type species of *Gracilariophila*, and therefore they are transferred to *Gracilariocolax* Weber van Bosse, a genus also previously reported from Indonesia. *Gracilariophila* species reported from China have also been removed to *Gracilariocolax*.

Introduction

In recent years, principally because of the opportunities provided by the Sea Grant workshops and other field trips, we collected algae in Thailand, Malaysia, and the Philippines. Consequently, we have a large number of specimens of adelphoparasites in our laboratory. Previously (Gerung et al. 1999), we published on a variety of materials in these new collections but could not determine the correct name(s) to apply to our specimens.

The one very important piece of information lacking was the results of examination of the materials from the Weber van Bosse herbarium at Leiden, which contain type materials of plants collected on the Siboga Expedition and named by Dr. Anna Weber van Bosse. An opportunity to examine those materials allowed us to solve the many questions about generic and specific boundaries.

Background

Three genera of adelphoparasites, namely *Gracilariophila* (Wilson 1910), *Gracilariocolax* (Weber van Bosse 1928), and *Congracilaria* (Yamamoto 1986), have been reported growing on Gracilariaceae; most are parasites of what is now known as *Gracilaria salicornia* (C. Agardh) Dawson. However, because these genera have similar morphological characteristics, the differences among the genera are not clear. Furthermore, descriptions of *Gracilariophila* as reported by Setchell et Wilson (Wilson 1910), Weber van Bosse (1928), and Chang and Xia (1978) vary in details.

Discussions of unidentified adelphoparasitic algae from Malaysia by Yamamoto and Phang (1997), from Thailand by Terada et al. (1999), and from

Indonesia by Gerung et al. (1999) suggested that the relationship between the genera *Gracilariophila* and *Gracilariocolax* should be reexamined.

In October 1999, we studied the Indonesian *Gracilariophila* and *Gracilariocolax* specimens named by Weber van Bosse and kept in Rijkherbarium/ Hortus Botanicus, Leiden University, the Netherlands, where the microscope slides of type specimens were kept. In this chapter, we report on the similarity between the Indonesian *Gracilariophila* and *Gracilariocolax.*

Weber van Bosse (1928) was the first to study Asian *Gracilariophila*, and she established 4 new species (*G. deformans*, *G. infidelis*, *G. setchellii*, *G. sibogae*) and 1 new variety (*G. setchellii* var. *aggregata*). At the same time, she (Weber van Bosse 1928) described *Gracilariocolax* (type species: *G. henriettae* Weber van Bosse). This genus was thought to be similar to *Gracilariophila*, but on the basis of the spermatangial pattern, the color of the plants, and the lack of a rhizoidal system, Indonesian *Gracilariophila* as described by Weber van Bosse differs from Californian *Gracilariophila* (type species: *G. oryzoides*). Chinese specimens of *Gracilariophila* (*G. deformans*, *G. infidelis*, *G. setchellii*) as described by Chang and Xia (1978) also differ on the basis of the spermatangial type and color of the plants.

Both *Gracilariophila* and *Gracilariocolax* species form small cushions of tissue on *Gracilaria*. The tubercles are of various sizes, normally spherical and mushroom- or dome-shaped. The color of the parasitic plants is similar to that of the host and differs from the colorless *G. oryzoides*, which looks like white rice grains ("oryzoides").

Gracilariophila oryzoides penetrates the host by means of numerous rhizoidal filaments (Wilson 1910, Abbott and Hollenberg 1976, Goff and Zuccarello 1994). However, no rhizoidal system could be found in *Gracilariophila* and *Gracilariocolax* on the microscope slides of Weber van Bosse. No special filaments, which may be involved in attaching the parasites to the host, were apparent. Weber van Bosse (1928) also did not mention any rhizoidal system, and therefore the *Gracilariophila* species were placed in the new section "Arhiza," with reference to the lack of rhizoids. This observation was confirmed by Yamamoto (1986), because the presence or absence of rhizoids appears to be an important point when distinguishing the genera of parasitic red algae that grow on *Gracilariaceae.*

Weber van Bosse (1928) did not report on the type of spermatangia in *Gracilariophila.* However, we found that the spermatangia of *G. deformans* and those of *G. henriettae* were borne in deep spermatangial conceptacles, or the "verrucosa" type of *Gracilaria* as described by Yamamoto (1978). Chang and Xia (1978) associated the Chinese *Gracilariophila* species with Weber van Bosse's concept of *Gracilariophila* and had already described deep spermatangial conceptacles in the Chinese specimens. However, Wilson (1910), Abbott and Hollenberg (1976), and Fredericq et al. (1989) reported superficial spermatangia of the "chorda" type (Yamamoto 1978) in the type species of *Gracilariophila.*

Results and Conclusion

We examined hundreds of adelphoparasites from Indonesia (Gerung et al. 1999), Japan (Yamamoto 1986), Malaysia (Yamamoto and Phang 1997), the Philippines (Yamamoto 1991), and Thailand (Terada et al. 1999) and confirm that all male gametophytes have deep spermatangial conceptacles of the verrucosa type. Following the taxonomic treatment of *Gracilaria* (Yamamoto 1978), we also use spermatangial types for distinguishing the genera among adelphoparasites growing on Gracilariaceae.

From the observations made in this study, we conclude that the Indonesian *Gracilariophila* described by Weber van Bosse differs from the Californian *Gracilariophila* Setchell et Wilson. Absence of rhizoids, the same color as the host, and deep spermatangial conceptacles of the verrucosa type all support our conclusion that the Asian species of *Gracilariophila* should be transferred to *Gracilariocolax* Weber van Bosse. We also propose to transfer to *Gracilariocolax* the Chinese materials of *Gracilariophila* as reported by Chang and Xia.

We recognize (1) *Gracilariophila* Setchell et Wilson (1910) on basis of the presence of rhizoids, colorless parasite body, and superficial spermatangia of the chorda type, with *G. oryzoides* Setchell et Wilson as the type species; (2) *Gracilariocolax* Weber van Bosse on the basis of the absence of rhizoids, the same color as the host, and deep spermatangial conceptacles of the verrucosa type, with *G. henriettae* Weber van Bosse as type species*; and (3) *Congracilaria* Yamamoto on the basis of the absence of rhizoids, the same color as the host, bisporangia, and deep spermatangial conceptacles of the verrucosa type.

The type material of *C. babae* Yamamoto (1986) had bisporangia, but material collected later had tetrasporangia. We are doing culture studies on these materials because more than a single species may be found in the materials. We therefore do not equate *Congracilaria* with *Gracilariocolax* at this time.

Material Now Classified as *Gracilariocolax*

On the basis of differences in spermatangial arrangements, we place 4 species and 1 variety of *Gracilariophila* in *Gracilariocolax.*

Gracilariocolax deformans (Weber van Bosse) Gerung et Yamamoto, comb. nov.

Basionym: *Gracilariophila deformans* Weber van Bosse, Siboga Exped. Monogr. 57d:442, fig. 179, 1928. Also used by Chang and Xia, Stud. Mar. Sin. 14:123, figs. 1–6, 1978.

Type Locality: Sula Besi (Sula Islands), Indonesia.

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*The type species of *Gracilariocolax*, *G. henriettae* Weber van Bosse (1928, p. 394, figs. 144–147), is named for Mme. Henrietta Becker-La Rivière, the collector of the type specimen from Java. Figures 145–146 show cystocarps of the parasites, and fig. 147 shows verrucosa-type spermatangial arrangements, as does the type material on microscope slides in Leiden.

Gracilariocolax infidelis (Weber van Bosse) Gerung et Yamamoto, comb. nov.

Basionym: *Gracilariophila gardneri* Setchell var. *infidelis* Weber van Bosse, Vidensk. Medd. Danske Naturh. Foren. 81:143–145, figs. 35–36, 1926.

Synonym: *Gracilariophila infidelis* (Weber van Bosse) Weber van Bosse, Siboga Exped. Monogr. 57d:443, 1928. Also used by Chang and Xia, Stud. Mar. Sin. 14:125, pl. 5, figs. 1–3, 1978.

Other specimens: Specimen (in the Leiden herbarium) collected at Nusa Kembangan (Jawa Island), Indonesia and a specimen from another locality, Tual (Kei Islands), Indonesia, were also listed by Weber-van Bosse.

Gracilariocolax setchellii (Weber van Bosse) Gerung et Yamamoto, comb. nov.

Basionym: *Gracilariophila setchellii* Weber van Bosse, Siboga Exped. Monogr. 57d:443–444, figs. 182–183, 1928. Also used by Chang and Xia, Stud. Mar. Sin. 14:123, pl. 4, figs. 1–2, 1978.

Remarks: Of the 2 localities listed where these specimens (in the Leiden herbarium) were collected, no parasites were observed on specimens from Nusa Endeh (Flores Island), Indonesia. This situation required that a lectotype be selected from specimens collected from the second locality, Nordwatcher (Jawa Island), Indonesia. Specimens from Nordwatcher did contain parasites and are designated as lectotypes.

Gracilariocolax setchellii var. *aggregata* (Weber van Bosse) Gerung et Yamamoto, comb. nov.

Basionym: *Gracilariophila setchellii* var. *aggregata* Weber van Bosse, Siboga Exped. Monogr. 57d:444–445, fig. 184, 1928.

Lectotype: Specimen (in Leiden herbarium) selected from materials collected from Nordwatcher (Jawa Island), Indonesia. Another specimen (in Leiden herbarium) is from materials collected from Nusa Endeh (Flores Island), Indonesia.

Gracilariocolax sibogae (Weber van Bosse) Gerung et Yamamoto, comb. nov.

Basionym: *Gracilariophila sibogae* Weber van Bosse, Siboga Exped. Monogr. 57d:443, figs. 180–181, 1928.

Type Locality: Donggala, (Sulawesi Island), Indonesia (specimen in Leiden herbarium).

Without attribution to specific species, we identify with *Gracilariocolax* the materials examined and reported on by Yamamoto and Phang (1997), Terada et al. (1999), and Gerung et al. (1999). We will need more time to determine what the limits of each of Weber van Bosse's species are before we assign the recent collections to some of these old species, or to new species.

Acknowledgments

We are grateful to Dr. Willem F. Prud'homme van Reine of Rijkherbarium/Hortus Botanicus, Leiden University, the Netherlands, for his assistance and encouragement. We also thank Dr. Isabella A. Abbott for critical reading and extensive suggestions and corrections of the manuscript and Dr. Ryuta Terada of Deep Sea Water Institute, Kochi, Japan, for his helpful discussion.

Literature Cited

Abbott, I. A., and Hollenberg, G. J. 1976. Marine algae of California. Stanford University Press, Stanford. California.

Chang, C. F., and Xia, B. M. 1978. Studies on parasitic red algae of China. Stud. Mar. Sin. 14:119–127.

Fredericq, S., Hommersand, M. H., and Norris, J. N. 1989. Morphological observations on the adelphoparasite *Gracilariophila oryzoides* (Gracilariales, Rhodophyta). Jpn. J. Phycol. 37:167–179.

Gerung, G. S., Terada, R., Yamamoto, H., and Ohno, M. 1999. An adelphoparasite growing on *Gracilaria edulis* (Gracilariaceae Rhodophyta) from Manado, Indonesia. In: Tax. Econ. Seaweeds 7, pp. 131–136.

Goff, L. J., and Zuccarello, G. 1994. The evolution of parasitism in red algae: cellular interaction of adelphoparasites and their host. J. Phycol. 30:695–720.

Terada, R., Yamamoto, H., and Muraoka, D. 1999. Observations on an adelphoparasite growing on *Gracilaria salicornia* from Thailand. In: Tax. Econ. Seaweeds 7, pp. 121–129.

Weber van Bosse, A. 1928. Liste des algues du Siboga, IV. Rhodophyceae: Gigartinales et Rhodymeniales. Siboga Exped. Monogr. 57d:393–533.

Wilson, H. L. 1910. *Gracilariophila*, a new parasite of *Gracilaria confervoides*. Univ. Calif. Publ. Bot. 4:75–84.

Yamamoto, H. 1978. Systematic and anatomical study of the genus *Gracilaria* in Japan. Mem. Fac. Fish. Hokkaido Univ. 25:97–152, pls. 1–49.

Yamamoto, H. 1986. *Congracilaria babae* gen. et sp. nov. (Gracilariaceae), an adelphoparasite growing on *Gracilaria salicornia* of Japan. Bull. Fac. Fish. Hokkaido Univ. 37:281–290.

Yamamoto, H. 1991. Observations on the adelphoparasite *Congracilaria babae* Yamamoto (Gracilariaceae, Rhodophyta) of the Philippines. Jpn. J. Phycol. 39:381–384.

Yamamoto, H., and Phang, S. M. 1997. An adelphoparasitic alga growing on *Gracilaria salicornia* from Malaysia. In: Tax. Econ. Seaweeds 6, pp. 91–94.

REVIEW OF *GRACILARIA VERMICULOPHYLLA* AND OTHER SPECIES IN JAPAN AND ASIA

Ryuta Terada and Hirotoshi Yamamoto

Abstract

Japanese species of *Gracilaria asiatica* Zhang et Xia were recently merged with *Gracilaria vermiculophylla* (Ohmi) Papenfuss by Yoshida and Yamamoto on the basis of successful crosses between the 2 taxa at Hokkaido, Japan. The relationship between *G. asiatica* and *G. vermiculophylla* is reviewed, and the conspecific nature of these 2 taxa is described. In addition, the typical appearance and reproductive structures of *G. vermiculophylla* are reviewed, and variations in morphology are noted. Finally, the Asian distribution is given for *G. vermiculophylla*, which was known in Japan since 1911 by the names *G. confervoides* and *G. verrucosa*. More recently, the names *Gracilariopsis rhodotricha* and *G. asiatica* were misapplied to this species.

Introduction

Since Yendo (1911) first reported *Gracilaria confervoides* (Stackhouse) Greville from Japan, this name was used by many researchers. Later, the name *G. verrucosa* (Hudson) Papenfuss was used for a Japanese taxon in place of *G. confervoides* (Papenfuss 1950, Ohmi 1958, Yamamoto 1978).

Zhang and Xia (1985) proposed a new name, *G. asiatica* Zhang et Xia, for Chinese and Japanese specimens, which had been identified with *G. verrucosa*. Zhang and Xia used the following features to highlight this species: deep spermatangial conceptacles, larger tetrasporangia, smaller carposporangia, and distinctive structure of pericarp as compared with *G. verrucosa* from England (type locality). *Gracilaria verrucosa* has been reported from nearly every coast in the world; the taxon bearing this name is now known as *G. gracilis* (Stackhouse) Steentoft, Irvine et Farnham, which is an older specific name.

On the other hand, *Gracilaria vermiculophylla* (Ohmi) Papenfuss was established by Ohmi (1956) as *Gracilariopsis vermiculophylla* Ohmi on the basis of specimens collected at Akkeshi Bay, Hokkaido. Ohmi (1958) characterized this species by the absence of traversing filaments in cystocarps, large gonimoblasts of small and densely protoplasmic cells, occurrence of tetrasporangial nemathecia, and vermiform upper branches. Later, this taxon was transferred to *Gracilaria* by Papenfuss (1967). However, these features of *G. vermiculophylla* are not always distinct from the features of *G. asiatica*. In particular, although Ohmi reported that traversing filaments were absent, they are present (Yamamoto 1978). Spermatangial conceptacles are also similar to those of Japanese *G. asiatica* (verrucosa type). It is suggested that vermiform morphology could be recognized as an ecad or morphological variation of *G. asiatica*.

To verify the taxonomic relationship of the 2 taxa, Yamamoto and Sasaki (1988) successfully made reciprocal crosses between *G. asiatica* from Hakodate

City (as *G. verrucosa*) and *G. vermiculophylla* from Akkeshi and indicated that the 2 taxa were probably conspecific.

If the Japanese *Gracilaria asiatica* Zhang et Xia (1985) from Hakodate and *Gracilariopsis vermiculophylla* Ohmi (1956) from Akkeshi Bay are conspecific, the earlier name, *G. vermiculophylla* should be used for the Chinese and Japanese plants. Yoshida and Yamamoto (1998) merged Japanese *G. asiatica* with *G. vermiculophylla* and used the earlier name in their publication.

Description of the Species

Gracilaria vermiculophylla (Ohmi) Papenfuss, Phykos 5:101, 1967; Yamamoto, Mem. Fac. Fish. Hokkaido Univ. 25:130, pls. 28–29, 47, figs. 2–3, 1978; Yoshida and Yamamoto in Yoshida, Marine algae of Japan, p. 825, 1998.

Basionym: *Gracilariopsis vermiculophylla* Ohmi, Bull. Fac. Fish. Hokkaido Univ. 6:271, figs. 1–4, pls. 1–2, 1956.

Synonyms: *Gracilaria confervoides* of Japanese authors. Yendo, Marine botany, p. 637, fig. 182, 1911, Okamura, Icones of Japanese algae 4, p. 1, pl. 151, figs. 1–9, 1916; *Gracilaria verrucosa* of Japanese authors. Ohmi, Mem. Fac. Fish. Hokkaido Univ. 6:6, figs. 1–2, pl. 1, figs. A–D, 1958, Yamamoto, Mem. Fac. Fish. Hokkaido Univ. 25:128, pl. 24, fig. 4–7, pls. 25–27, 46, 47, fig. 1, 1978; *Gracilariopsis rhodotricha* sensu Ohmi (non Dawson), Mem. Fac. Fish. Hokkaido Univ. 6:47, fig. 23, pl. 10, 1958; *Gracilaria asiatica* Zhang et Xia, Oceanol. Limnol. Sin. 16:175, figs. 1–2, 1985.

Holotype: Ohmi 200, spermatangial (Fig. 1 in this chapter; pl. II, fig. 1 in Ohmi 1956; p. 46 in Ohmi 1958).

Isotype: Ohmi 201, cystocarpic (Fig. 2 in this chapter; pl. I, fig. 2 in Ohmi 1956), currently housed in herbarium at Faculty of Fisheries, Hokkaido University.

Type Locality: Gomejima, Akkeshi Bay (Lake Akkeshi), Hokkaido, Japan.

Distribution: Japan, from Hokkaido to Okinawa (Okamura 1936, Ohmi 1958, Yamamoto 1978, Yoshida and Yamamoto 1998); Korea: (Lee et al. 1995); and China, mainland except Hainan Island and Xisha Islands (Chang and Xia 1962, 1976).

Habitat: Plants grow on pebbles and rocks slightly covered with sand and mud in the intertidal to upper sublittoral zone and are sometimes luxuriant at the mouth of rivers.

Plants dark brown to pale brown with cylindrical axes and branches throughout, up to 50 cm long, up to 2 mm wide, arising from small discoid holdfasts, branching alternately or irregularly, sometimes secundly or subdichotomously. Branches and branchlets slightly constricted at bases of old plants but not in young plants. Branchlets arising alternately or on all sides at irregular intervals, variable in length, tapering toward apices and bases. Not adhering to paper upon drying (Figs. 3–6).

Multiaxial, cortex consisting of 1–2 layers of anticlinally elongated cortical cells with dense cytoplasm, up to 10 μm long, up to 5 μm wide (Fig. 7). Cortical cells connecting with only their parental cell by primary pit connections. Medulla

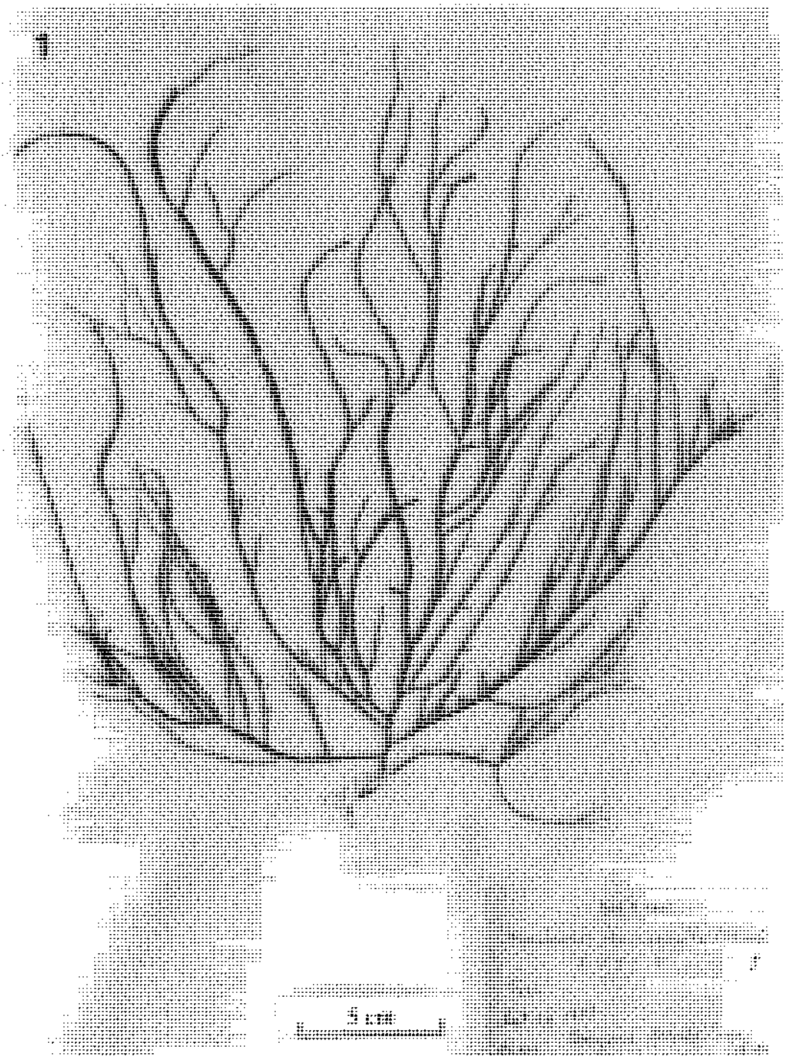


Fig. 1. Holotype specimen of *Gracilaria vermiculophylla* (Ohmi) Papenfuss (male plant, Ohmi 200 in herbarium at Faculty of Fisheries, Hokkaido University) collected September 24, 1955, from Gomejima, Akkeshi Bay (so-called Lake Akkeshi), Hokkaido.

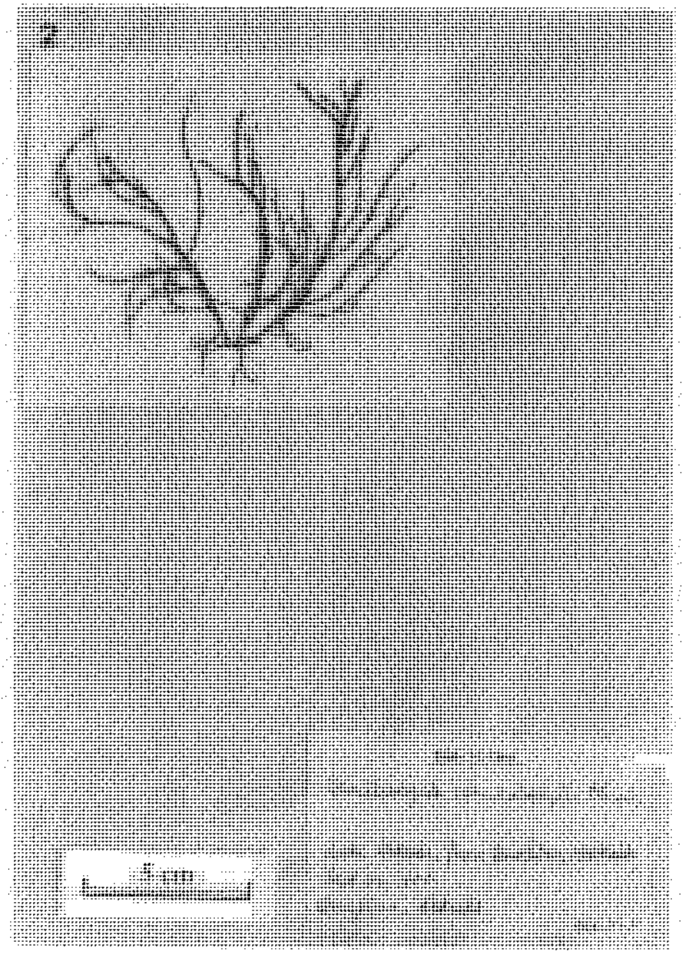
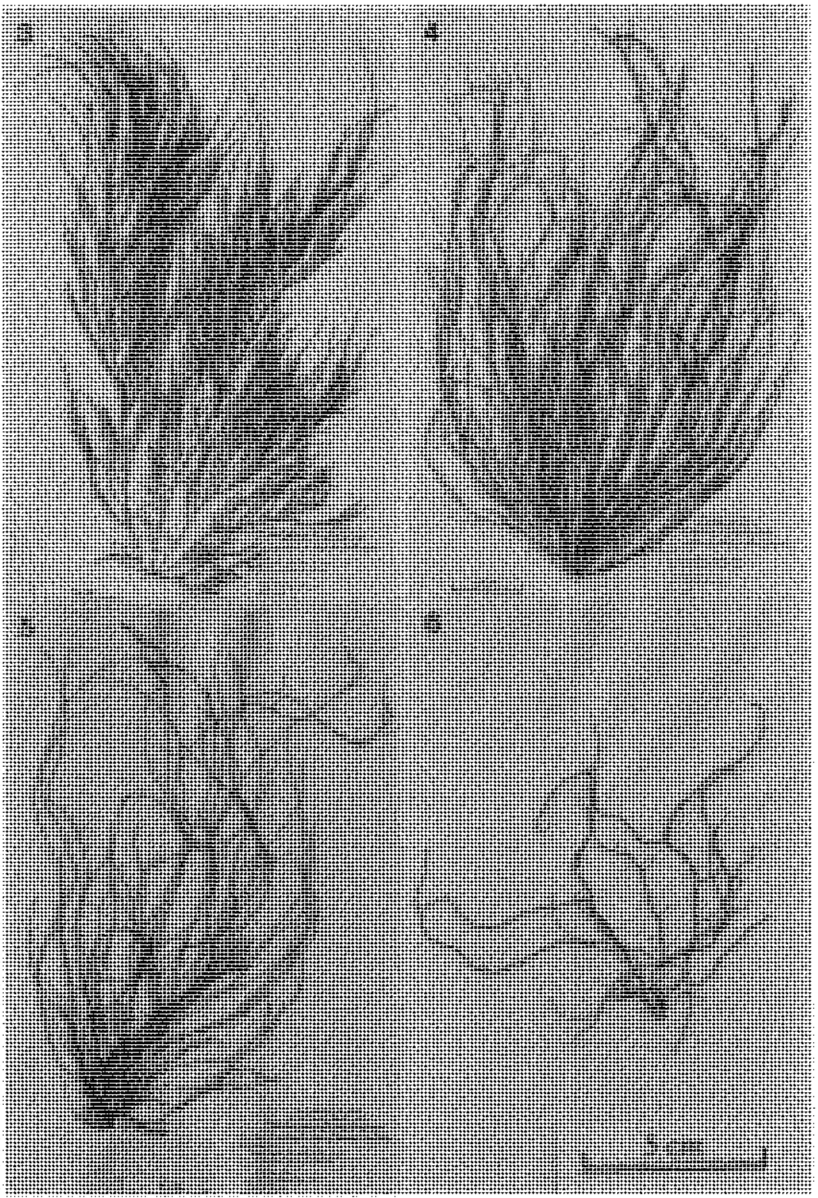


Fig. 2. Isotype specimen of *Gracilaria vermiculophylla* (Ohmi) Papenfuss (cystocarpic, Ohmi 201 in herbarium at Faculty of Fisheries, Hokkaido University).



Figs. 3–6. Herbarium specimens of *Gracilaria vermiculophylla* (Ohmi) Papenfuss from several districts of Japan. Fig. 3, Tetrasporophyte collected July 24, 1998, from Hakodate, Hokkaido (Terada 741). Fig. 4, Cystocarpic plant collected March 29, 1998, from Shimoda, Shizuoka Prefecture (Terada 758). Fig. 5, Tetrasporophyte collected April 9, 1996, from Shioya, Tanoura Town, Kumamoto Prefecture (Terada 305). Fig. 6, Cystocarpic plant collected January 7, 1994, from Yamada, Onna Village, Okinawa Prefecture (Terada 25).

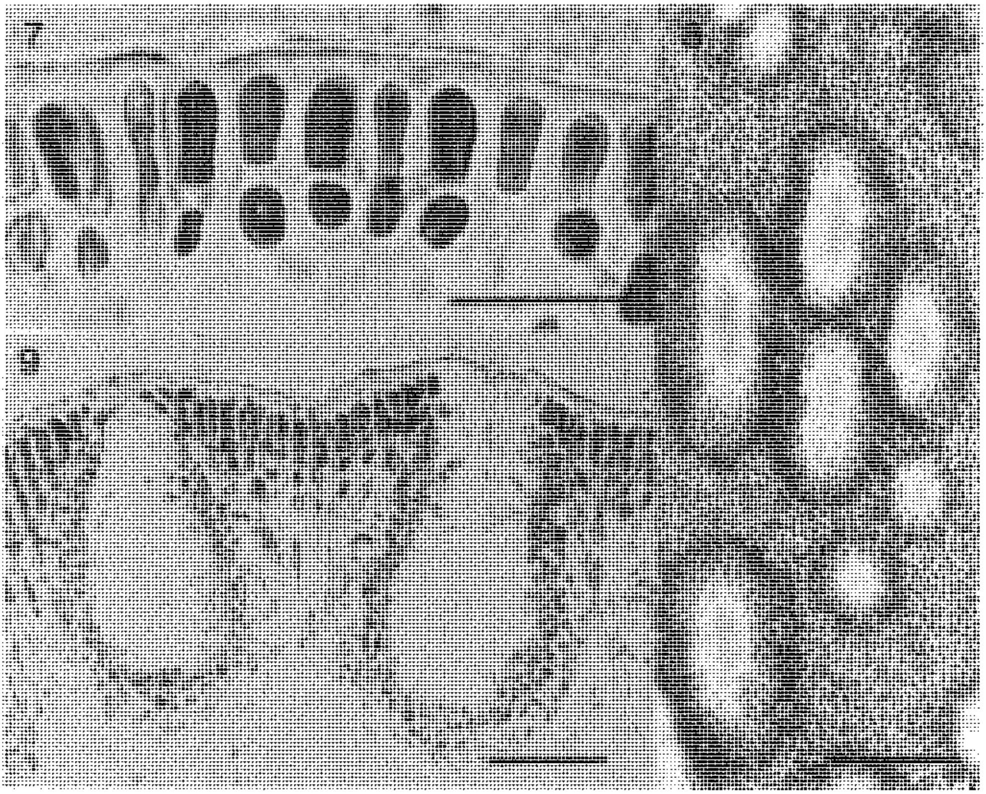
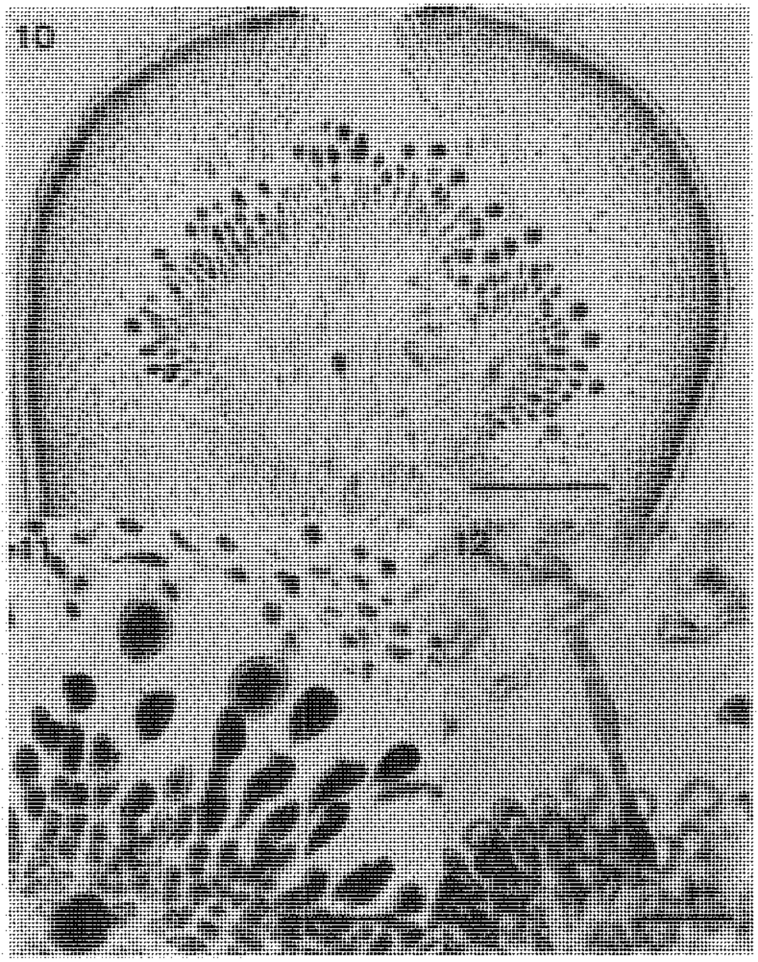


Fig. 7. Transverse section of *Gracilaria vermiculophylla* showing the cortex of main axes. Scale bar = 30 μm. Figs. 8–9. Spermatangial conceptacles of *Gracilaria vermiculophylla*. Fig. 8, Surface view of the plant shows conceptacles are formed separately from one another. Scale bar = 100 μm. Fig. 9, Transverse section of spermatangial conceptacles shows they are the deep pot-shaped verrucosa type. Scale bar = 50 μm.

consisting of 6–8 layers of unpigmented spherical cells with abundant vacuoles. Medullary cells increasing abruptly in size toward the center, up to 500 μm in diameter, often connecting by secondary pit connections with surrounding cells.

Spermatangia formed on entire surface except apical and basal parts (Fig. 8), in deep pot-shaped verrucosa-type conceptacles (Yamamoto 1978), 80–120 μm deep, 60–80 μm wide (Fig. 9). Cystocarps formed on entire surface except basal and apical parts, prominently protruding from the surface, globose, up to 1 mm high, up to 1.5 mm wide, each with a slightly rostrate ostiole, slightly constricted at bases (Fig. 10). Gonimoblast consisting of large pseudoparenchymatous cells, 80 µm in diameter (Figs. 10 and 11). Traversing filaments present between gonimoblast and pericarp (Fig. 12). Pericarp consisting of approximately 9 layers of cells. Carpospores up to 30 µm in diameter. Tetrasporangia scattered on entire surface except basal and apical parts, approximately 30 µm by 45 µm, cruciately divided (Fig. 13).



Figs. 10–12. Cystocarp of *Gracilaria vermiculophylla*. Fig. 10, Gonimoblast of large-sized cells in vertical section of the cystocarp. Scale bar = 100 µm. Fig. 11, Marginal part of the gonimoblast with chains of carposporangia. Scale bar = 50 µm. Fig. 12, Traversing filament connecting to pericarpic cells. Scale bar = 30 µm.

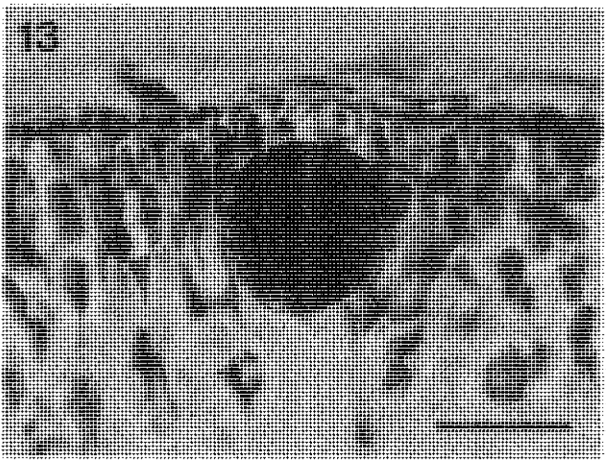


Fig. 13. Transverse section of *Gracilaria vermiculophylla* showing cruciately divided tetrasporangium. Scale bar = 30 µm.

Discussion

As mentioned earlier, Ohmi (1956) placed this species in the genus *Gracilariopsis*, mainly on the basis of the absence of traversing filaments in the cystocarps. However, using topotype materials, Yamamoto (1978) found that traversing filaments are rare but clearly present in the cystocarps. Our comparisons of *G. asiatica* and *G. vermiculophylla* from several places in Japan (Figs. 3–6) confirmed the presence of traversing filaments in the plants from the topotype. We also examined material of *G. asiatica* from several sites in Japan. The gonimoblast of *G. vermiculophylla* was originally described as consisting of small and densely protoplasmic cells, which are diagnostic for the genus.

Successful crosses between *G. vermiculophylla* and *G. verrucosa* by Yamamoto and Sasaki (1988) made the taxonomic relationship clear and indicated that the 2 taxa were probably conspecific. Successful crosses were later obtained between specimens from several localities of Japan from north to south: Hakodate City, Hokkaido; Tsuruoka City, Yamagata Prefecture; Kominato City, Chiba Prefecture; Tosa City, Kochi Prefecture; Akune City, Kagoshima Prefecture; and Onna Village, Okinawa Prefecture (Yamamoto, Kudo, and Terada, unpublished data). These results indicate that the 2 Japanese taxa should be placed in the same species despite morphological variations.

Although Ohmi provided illustrations of 4 specimens (1956, pl. I, figs. 1–2; pl. II, figs. 1–2), they did not include the type specimen. Later, he (Ohmi 1958) cited a male plant "Ohmi 200," which was collected in September 1955, as the type specimen but did not provide a photograph or an illustration. Fortunately, we found

2 specimens that were examined by Ohmi (1958): one labeled "Ohmi 200" and "type specimen" in his handwriting and one labeled "Ohmi 201" (Fig. 2). We confirmed that Ohmi 200 and Ohmi 201 are identical to the photographs in pl. II, fig. 1 and pl. I, fig. 2, respectively, in the 1956 article. The dates of collection of the 2 specimens are written on each label as September 24, 1955. Ohmi 200 is the lectotype, and Ohmi 201 is selected as the isotype of *G. vermiculophylla*.

Formerly, *G. verrucosa* was reported from various regions of the northwestern Pacific. However, several of the reported specimens were transferred to other species or were described as new species in the past 20 years. For example, although *G. verrucosa* was reported from the Philippines by Trono et al. (1983) and Yamamoto (1989), these plants separately are now accepted as *G. manilaensis* Yamamoto et Trono (1994). Thus, we suggest that the distribution of *G. vermiculophylla* in the Philippines is doubtful.

Lee et al. (1995) detailed the morphology and anatomy of Korean *G. verrucosa* and concluded that this taxon could be distinguished from authentic *G. verrucosa* of Britain. Furthermore, they suggested that the Korean plant differs from plants of China and Japan in the constriction at the bases of branches, the size of carpospores, the abundance of traversing filaments, and the structure of the pericarp. They also pointed out that on the basis of the depth-width ratio of the conceptacles, spermatangial arrangements of the Korean taxon have a morphological continuum from textorii type to verrucosa type. Lee et al. suggested that the Chinese, Korean, and Japanese taxa should be studied with crossing experiments. Although they also cited Lee et al. (1995), Tseng and Xia (1999) placed the Korean taxon in *G. vermiculophylla*. We think the continuous spermatangial conceptacles of the Korean plants should be referred to as typical verrucosa type because figure 4F in the article by Lee et al. shows fully mature deep pot-shaped conceptacles that are separated from each other. Some authors (Zhang and Xia 1984, Reading and Schneider 1986, Lee et al. 1995) have emphasized the difference between textorii and verrucosa types in the depth-width ratio of the conceptacles. We suggest that the textorii type basically differs from the verrucosa type in having "surrounding elongated cells and confluent conceptacles" (see Yamamoto 1978, p. 123). We support the name *G. vermiculophylla* for the Korean taxon as described by Lee et al. (1995) and suggested by Tseng et Xia (1999).

Acknowledgments

We are grateful to Professor I. A. Abbott, University of Hawaii, for the invitation to the eighth international workshop and for a critical reading of the manuscript. We also acknowledge the California Sea Grant College Program and Dr. J. Sullivan for our participation in the workshop. We thank Professor T. Yoshida, Graduate School of Science, Hokkaido University, for reading the manuscript and for his comments. Cordial thanks are due to Professor Xia Bangmei, Institute of Oceanology, Chinese Academy of Sciences; Professor K. Lewmanomont and Dr. A. Chirapart, Faculty of Fisheries, Kasetsart University; and other participants of the eighth workshop for their suggestions for this study.

Literature Cited

Chang, C., and Xia, B. 1962. A preliminary phytogeographical studies on Chinese species of *Gracilaria*. Oceanol. Limnol. Sin. 4:189–198.

Chang, C., and Xia, B. 1976. Studies on Chinese species of *Gracilaria*. Oceanol. Limnol. Sin. 11:91–166, pls. 1–2 (in Chinese).

Lee, I. K., Kim, M. S., and Boo, S. M. 1995. A taxonomic appraisal of Korean *Gracilaria verrucosa* (Rhodophyta, Gracilariales). In: Tax. Econ. Seaweeds 5, pp. 213–222.

Ohmi, H. 1956. Contributions of the knowledge of Gracilariaceae from Japan, II. On a new species of the genus *Gracilariopsis* with some considerations on its ecology. Bull. Fac. Fish. Hokkaido Univ. 6:271–279, pls. 1–2.

Ohmi, H. 1958. The species of *Gracilaria* and *Gracilariopsis* from Japan and adjacent waters. Mem. Fac. Fish. Hokkaido Univ. 6:1–66, pls. 1–10.

Okamura, K. 1936. Nippon kaiso-shi (Japanese algae). Uchida-rhokakuho, Tokyo (in Japanese).

Papenfuss, G. F. 1950. Review of the genera of algae described by Stackhouse. Hydrobiologia 2:181–208.

Papenfuss, G. F. 1967. Notes on algal nomenclature, V. Various Chlorophyceae and Rhodophyceae. Phykos 5:95–105.

Reading, R. P., and Schneider, C. W. 1986. On the male conceptacles of two terete species of *Gracilaria* (Rhodophyta, Gigartinales) from North Carolina. J. Phycol. 22:395–398.

Trono, G. C., Jr., Azanza-Corrales, R., and Manuel, D. 1983. The genus *Gracilaria* (Gigartinales, Rhodophyta) in the Philippines. Kalikasan Philipp. J. Biol. 12:15–41.

Tseng, C., and Xia, B. 1999. On the *Gracilaria* in the western Pacific and the southeastern Asia region. Bot. Mar. 42:209–217.

Yamamoto, H. 1978. Systematic and anatomical study of the genus *Gracilaria* in Japan. Mem. Fac. Fish. Hokkaido Univ. 25:97–152, pls. 1–49.

Yamamoto, H. 1989. *Gracilaria* and *Polycavernosa* species of the Philippines. In: Umezaki, I., ed. Scientific survey of marine algae and their resources in the Philippines Islands. Kyoto University Press, Kyoto, Japan, pp. 35–40.

Yamamoto, H., and Sasaki, J. 1988. Interfertility between so-called *Gracilaria verrucosa* (Huds.) Papenfuss and *G. vermiculophylla* (Ohmi) Papenfuss in Japan. Bull. Fac. Fish. Hokkaido Univ. 39:1–3.

Yamamoto, H., and Trono, G. C., Jr. 1994. Two new species of *Gracilaria* from the Philippines. In: Tax. Econ. Seaweeds 4, pp. 95–101.

Yendo, K. 1911. Marine botany. Hakubunkan, Tokyo (in Japanese).

Yoshida, T., and Yamamoto, H. 1998. Gracilariales. In: Yoshida, T. Marine algae of Japan. Uchida-rokakuho, Tokyo (in Japanese).

Zhang, J., and Xia, B. 1984. Some problems in the taxonomy of Chinese species of *Gracilaria* (Rhodophyta). Hydrobiologia 116/117:59–62.

Zhang, J., and Xia, B. 1985. On *Gracilaria asiatica* sp. nov. and *G. verrucosa* (Huds.) Papenfuss. Oceanol. Limnol. Sin. 16:175–180.

ADDITIONAL NOTES ON *GRACILARIA EUCHEUMATOIDES* HARVEY FROM VIETNAM

Ryuta Terada and Hirotoshi Yamamoto

Abstract

Mature female plants of *Gracilaria eucheumatoides* Harvey were first reported by Chang and Xia from China (as *G. eucheumoides*) and in Asia were collected for the second time from Nha Trang, Vietnam. A detailed structure of the cystocarp and the external morphology of *G. eucheumatoides* are presented. This record of cystocarpic *G. eucheumatoides* is the second record for Asia.

Introduction

The species of *Gracilaria* (Gracilariaceae, Rhodophyta) are well represented on the shores of Vietnam and have been reported by several authors. Dawson (1954) reported 4 species of *Gracilaria* and 2 species of *Gracilariopsis* from Nha Trang. Pham (1969) reported 7 species of *Gracilaria* and 2 species of *Gracilariopsis* from the coasts of southern Vietnam. Nguyen (1969) reported 9 species of *Gracilaria* and later added 2 species of *Gracilaria* and 2 species of *Polycavernosa* (now merged with *Gracilaria* by Abbott et al. 1991). Later, Nguyen (1992) reviewed the reports mentioned here and listed 13 species of *Gracilaria* from Vietnam.

Recent taxonomic concepts of *Gracilaria* are mainly based on features of the carposporophytes and on spermatangial development (Yamamoto 1978). Using and emphasizing of reproductive characteristics, Yamamoto et al. (1994) reported *G. firma* Chang et Xia and *G. heteroclada* Zhang et Xia (now *G. bailiniae* [as *bailinae*] Zhang et Xia). Ohno et al. (1999) carried out a geographic survey in Vietnam in 1993 and 1994 and reported 9 species of *Gracilaria*. However, in their report, no reproductive plants were noted for a few species of *Gracilaria*, including *G. eucheumatoides.*

Gracilaria eucheumatoides was originally described by Harvey (as *G. eucheumoides,* 1859) from Ryukyu Islands (Okinawa, Japan), and this species has been reported from various districts of southeastern Asia. The thick, coarse, rough-surfaced plants are among the easiest ones to identify on the basis of external morphology and habitat. *Gracilaria eucheumatoides* cannot be confused with other taxa, and for this reason, its reproductive structures have rarely been examined. Mature gametophytes are rare in natural populations, but sporophytes are common. No male plants from natural populations have been reported (Yamamoto and Noro 1993). Female plants also have not been reported except by Chang and Xia (1976).

We collected some species of *Gracilaria* at Nha Trang and vicinity in April and May 1999, and we found cystocarpic plants. In this chapter, we report the detailed structure of the cystocarp and the external morphology of *G. eucheumatoides.*

Materials and Methods

Specimens were collected April 28, 1999, at the beach in front of the Institute of Oceanography, Cau Da Village, near Nha Trang City, Vietnam. Specimens fixed and preserved in a 5% solution of formalin in seawater were used for microscopic observations. Sections were made by using a freezing microtome (Yamato & Co.) and were stained with 1% cotton blue in glycerol/seawater. Specimens examined were deposited in the herbarium of the Faculty of Fisheries, Hokkaido University.

Observations

Gracilaria eucheumatoides Harvey, Proc. Am. Arts Sci. 4:321–335, 1859; Okamura, Nippon Kaiso-Shi, p. 634, 1936; Dawson, Pac. Sci. 8:438, fig. 48, 1954; Chang and Xia, Stud. Mar. Sin. 11:134, figs. 32–33, 1976; Yamamoto, Mem. Fac. Fish. Hokkaido Univ. 25:136, pls. 37, 49, fig. 5, 1978; Yamamoto and Noro, Jpn. J. Phycol. 41:131, figs. 1–8, 1993; Lewmanomont, Tax. Econ. Seaweeds 4, p. 139, fig. 5, 1994.

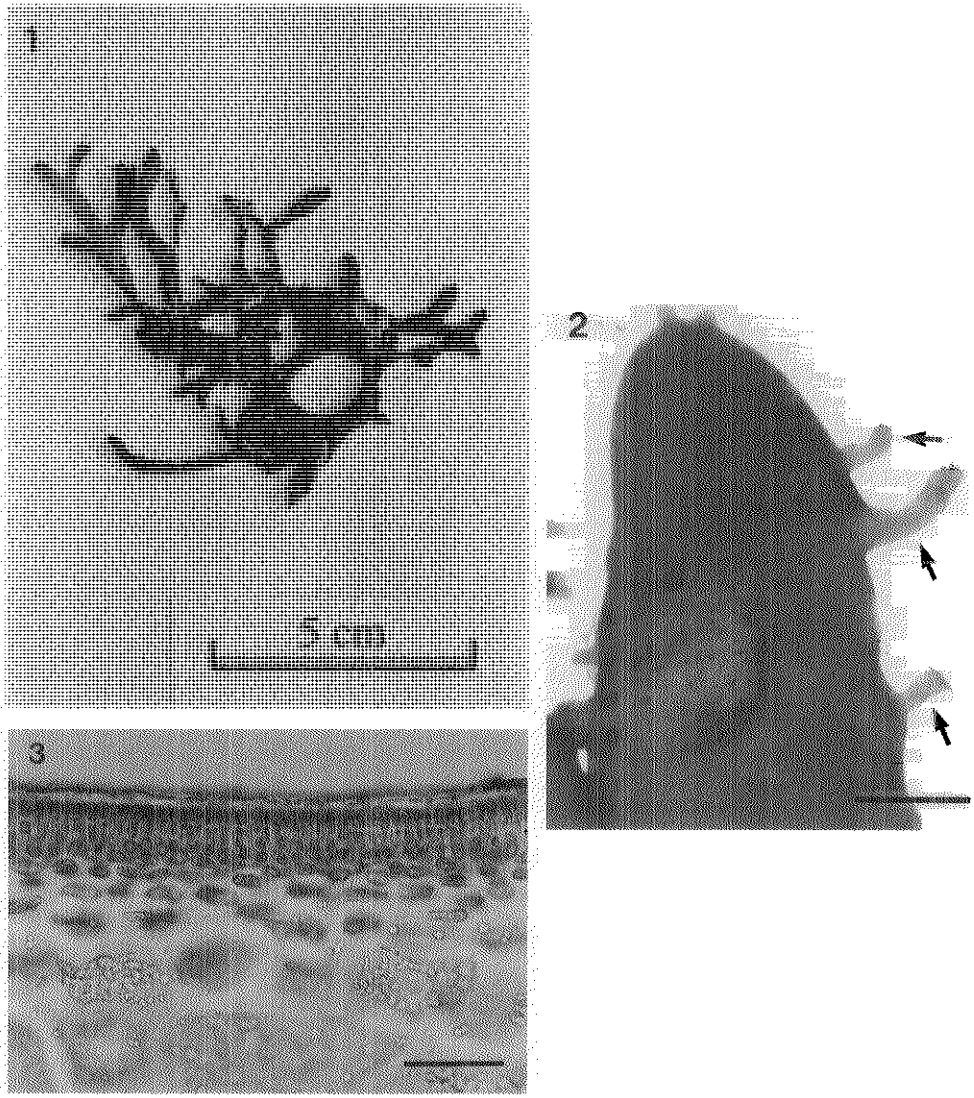
Distribution: Tropical and subtropical regions in the western Pacific: Japan (Okamura 1936, Yamamoto 1978); China (Chang and Xia 1976); Taiwan (Yang and Chiang 1982), Philippines (Trono et al. 1983, Yamamoto and Noro 1993); Vietnam (Dawson 1954, Pham 1969, Ohno et al. 1999); Thailand (Lewmanomont 1994, Lewmanomont and Ogawa 1995); and Micronesia (Kanda 1944, Trono 1969).

Habitat: Plants grow on rocks and pebbles or fragments of dead coral in upper subtidal zone.

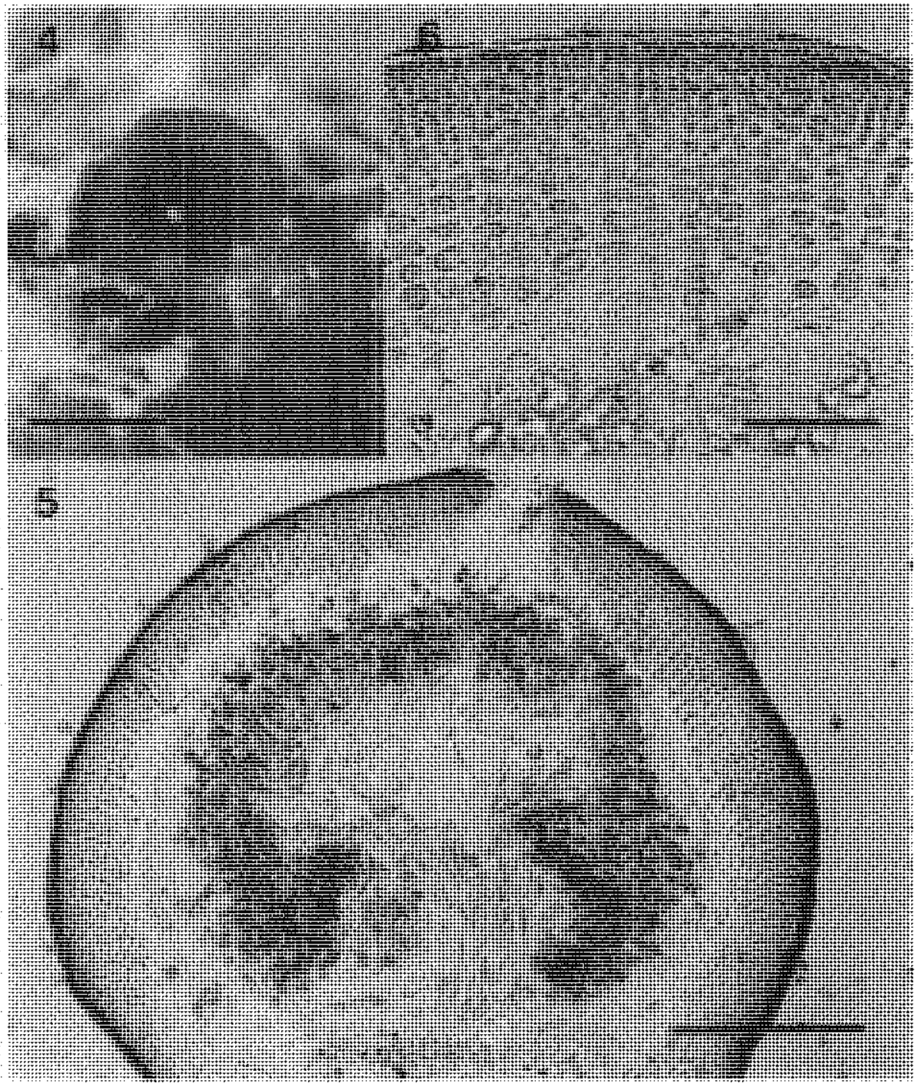
Plants dark purplish to dark brown, prostrate, attached by a small discoid holdfast, sometimes secondarily attached as well. Generally compressed to flattened, thick and coarse, branching irregularly, pinnately, dichotomously (Fig. 1). Branches 1–3 cm long, 0.5–1 cm wide, 0.2–0.9 cm thick, with raised or thickened dentate margins, attaching to other branches by extensions (Fig. 2).

Thallus multiaxial, consisting of cortex and medulla. Cortex consisting of 2–4 layers of globular cells, 5–10 µm long, 6–9 µm wide. Cells filled with cytoplasm and connected with only their mother cells by primary pit connections (Fig. 3). Medulla consisting of 8–10 layers of spherical, oval, or isodiametric cells, up to 300 µm in diameter. Cells increasing in size gradually toward center of medulla. Medullary cells distinguishable from cortical cells by abundant vacuoles and secondary pit connections to surrounding cells.

Cystocarps formed on the entire surfaces of female plants except for basal and apical parts. Mature cystocarps protruding prominently from the bearing axes and branches (Fig. 4), globose, up to 1.5 mm high by 2 mm wide, each with a slightly rostrate ostiole and a slightly constricted base (Fig. 5). Gonimoblasts consisting of a few large cells 80–150 µm wide in the center, with a corridor of elongated cells arising in connection with the basal part of the gonimoblast adjacent to the cortex of the axial tissue. Traversing filaments present in the cystocarp. Pericarp consisting of 10–13 layers of oval to spherical cells arranged



Figs. 1–3. Fig. 1, *Gracilaria eucheumatoides* Harvey from Cau Da Village near Nha Trang, Vietnam. Herbarium specimen of a cystocarpic plant (Terada 1063) collected April 28, 1999. Fig. 2, *Gracilaria eucheumatoides* Harvey from Cau Da Village (Nha Trang City), Vietnam. Compressed branch, with thick marginal extensions (arrows). Scale bar = 2 mm. Fig. 3, *Gracilaria eucheumatoides* Harvey from Cau Da Village. Transverse section of main axes showing the cortex and medulla. Scale bar = 50 μm.



Figs. 4–6. *Gracilaria eucheumatoides* Harvey from Cau Da Village. Fig. 4, Surface view of a cystocarp. Scale bar = 1000 µm. Fig. 5, Vertical section of the cystocarp showing the gonimoblast of large-sized cells. Scale bar = 500 µm. Fig. 6, Vertical section of the pericarp. Scale bar = 100 µm.

in singly branched filaments (Fig. 6).

Sporangial groups scattered on the entire surfaces of sporophytes except for basal, apical, and marginal parts. Tetrasporangia with cruciately arranged spores up to 25 µm by 20 µm (Fig. 7). No mature divided tetrasporangia found.

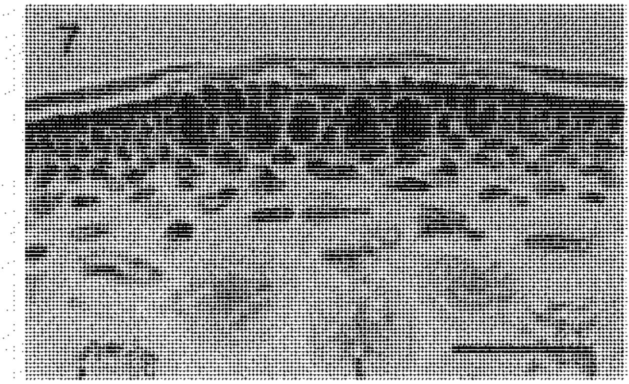


Fig. 7. *Gracilaria eucheumatoides* Harvey from Cau Da Village. Transverse section of main axes showing undivided tetrasporangia. Scale bar = 50 µm.

Discussion

Since Harvey (1859) described *G. eucheumatoides* on the basis of materials collected at Ryukyu Islands (Okinawa, Japan), this species has been reported from many areas in southeastern Asia. However, the reproductively mature plants appear to be rare in natural populations except in China (female and tetrasporophyte, Chang and Xia 1976) and the Philippines (tetrasporophyte, Trono et al. 1983). Thus, the life history was not known because male plants were never collected. Using the Philippine materials, Yamamoto and Noro (1993) carried out in vitro cultures and confirmed that the spermatangial conceptacles were the polycavernosa type (see Yamamoto and Noro 1993, p. 133, fig. 7).

Gracilaria eucheumatoides was first reported from Vietnam by Dawson (1954). Although it is a common species in Vietnam, mature plants were not reported previously. We also confirmed some cystocarpic plants, which were sold at the market of Nha Trang City. Inner structures of the cystocarp of our plants agree well with those of Chinese materials (Chang and Xia 1976).

Acknowledgments

We are grateful to Professor I. A. Abbott, University of Hawaii, for critically reading and correcting the manuscript. We also acknowledge Dr. S. Kawaguchi, Faculty of Agriculture, Kyushu University, for supplying some materials for this study. Cordial thanks are due to Professors T. Yoshida and M. Masuda, Graduate School of Science, Hokkaido University, for their valuable suggestions.

Literature Cited

Abbott, I. A., Zhang, J., and Xia, B. 1991. *Gracilaria mixta*, sp. nov. and other western Pacific species of the genus (Rhodophyta: Gracilariaceae). Pac. Sci. 45:12–27.

Chang, C., and Xia, B. 1976. Studies on Chinese species of *Gracilaria*. Stud. Mar. Sin. 11:91–163, pls. 1–2.

Dawson, E. Y. 1954. Marine plants in the vicinity of the Institute of Oceanographique de Nha Trang, Viet Nam. Pac. Sci. 8:373–481.

Harvey, W. H. 1859. Characters of new algae, chiefly from Japan and adjacent regions, collected by Charles Wright in the north Pacific exploring expedition under Captain John Rodgers. Proc. Am. Arts Sci. 4:327–335.

Kanda, C. 1944. Ecological studies on the marine algae from Koror and adjacent islands in South Sea Islands. Palau Trop. Biol. Sta. Stud. 2:737–800.

Lewmanomont, K. 1994. The species of *Gracilaria* from Thailand. In: Tax. Econ. Seaweeds 4, pp. 135–148.

Lewmanomont, K., and Ogawa, H. 1995. Common seaweeds and sea grasses of Thailand. Faculty of Fisheries, Kasetsart University, Bangkok.

Nguyen, H. D. 1969. Raucan: *Gracilaria* of North Vietnam. NXSB KK, Hanoi (in Vietnamese)

Nguyen, H. D. 1992. Vietnamese species of *Gracilaria* and *Gracilariopsis*. In: Tax. Econ. Seaweeds 3, pp. 207–210.

Ohno, M., Terada, R., and Yamamoto, H. 1999. The species of *Gracilaria* from Vietnam. In: Tax. Econ. Seaweeds 7, pp. 99–111.

Okamura, K. 1936. Nippon kaiso-shi (Japanese algae). Uchida-rhokakuho, Tokyo (in Japanese).

Pham, H. H. 1969. Marine algae of South Vietnam. Ministry of Education and Youth, Trung-Tam Hoc-Lieu Xuat-Btan, Saigon (in Vietnamese).

Trono, G. C., Jr. 1969. The benthic algae of the Caroline Islands, II. Phaeophyta and Rhodophyta. Micronesia 5:25–121.

Trono, G. C., Jr., Azanza-Corrales, R., and Manual, D. 1983. The genus *Gracilaria* (Gigartinales, Rhodophyta) in the Philippines. Kalikasan Philipp. J. Biol. 12:15–41.

Yamamoto, H. 1978. Systematic and anatomical study on the genus *Gracilaria* in Japan. Mem. Fac. Fish. Hokkaido Univ. 25:97–152, pls. 1–49.

Yamamoto, H., and Noro, T. 1993. In vitro life history and spermatangial types of *Gracilaria eucheumoides* (Gracilariaceae, Rhodophyta). Jpn. J. Phycol. 41:131–135.

Yamamoto, H., Ohno, M., and Nguyen, H. D. 1994. In vitro life histories and spermatangial types of two *Gracilaria* species from Vietnam, *G. heteroclada* and *G. firma*. Jpn. J. Phycol. 42:331–333.

Yang, H., and Chiang, Y. 1982. Taxonomical study on the *Gracilaria* from Taiwan. J. Fish. Soc. Taiwan 9:55–71 (in Chinese).

A NEW SPECIES OF *GRACILARIA* FROM CHINA

Xia Bangmei and Wang Yongqiang

Abstract

A new foliose species, *Gracilaria yinggehaiensis* sp. nov., is described. The new species is characterized by a small, short thallus, decumbent on the substratum, about 1–2 cm in diameter, with *Sargassum*-like flat leaves that are incised, irregularly dentate, and sometimes scalloped. The thallus is about 1–2 cm in diameter; the fronds arise in a cluster. Comparisons of the new species with other species of *Gracilaria* with flattened blades and dentate protuberances on blade margins indicated that it differs in these leafy characteristics, thus justifying its erection as a new species.

Introduction

Eight foliose species of *Gracilaria* have been reported from China (Zhang and Xia 1994, Tseng and Xia, 1999), a relatively large number for a coastline. Recently, we examined some samples of unidentified specimens and discovered a foliose new species of *Gracilaria*. This material was collected in 1993 from Yinggehai, Hainan Island, Hainan Province, China.

Description of the Species

Gracilaria yinggehaiensis Xia et Wang, sp. nov.
(Figs. 1–11)

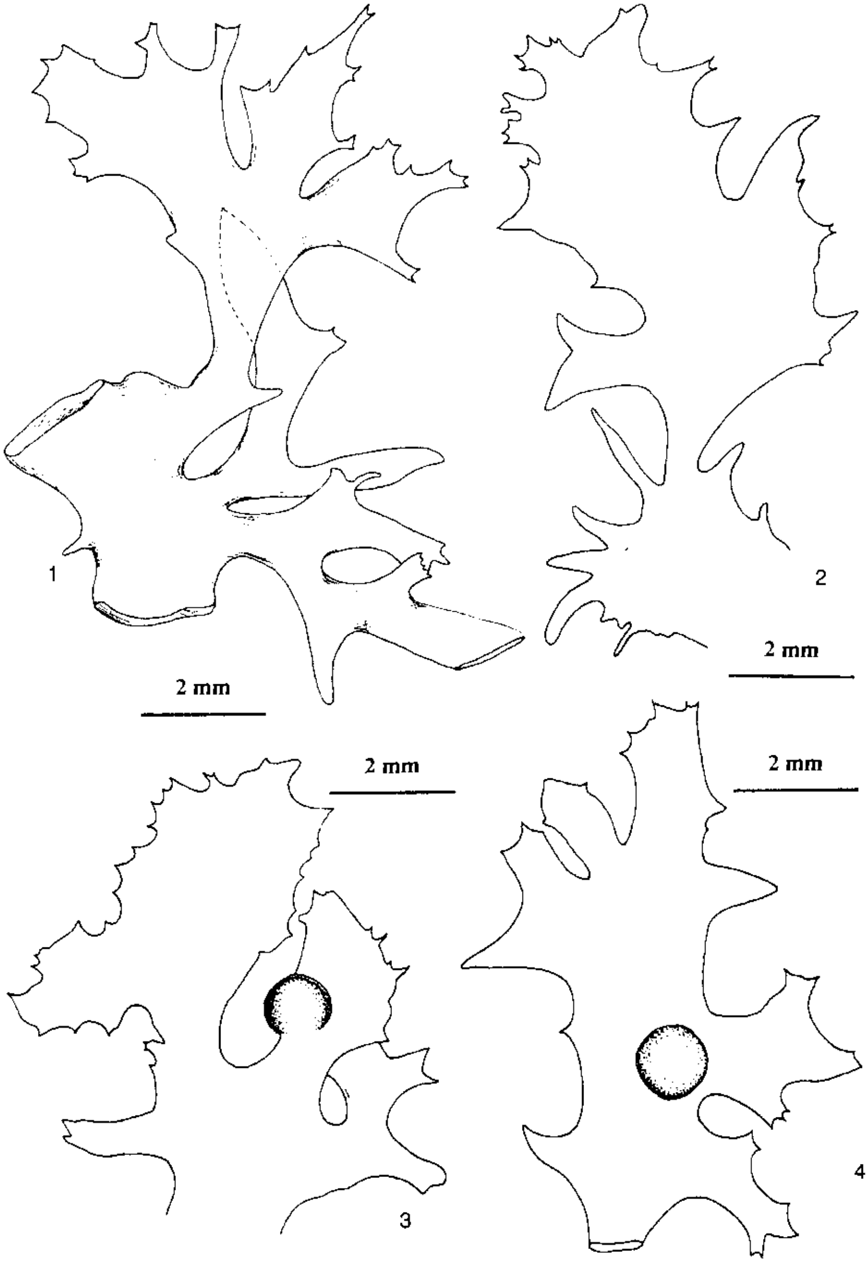
Plantae parvae, foliosae, decumbentes, 1–2 cm altae, irregulariter lateraliter ramosae. Folia rotunda, elliptica vel lanceolata, 0.5–4 (–7) mm, diametro, margine irregulariter dentatis. Thallus 145–481 µm crassus, in sectione transversali, cellulae medullosae 46–112 µm x 30–73 µm, pigmentosae. Cystocarpia globosa, parum rostrata vel non rostrata, 1.5–1.8 mm diametro; cellulae gonimoblasti parvae; carposporangia terminalia, rotunda vel ovalia, 20–23 µm long x 15–20 µm.

Tetrasporangia et spermatangia non observata.

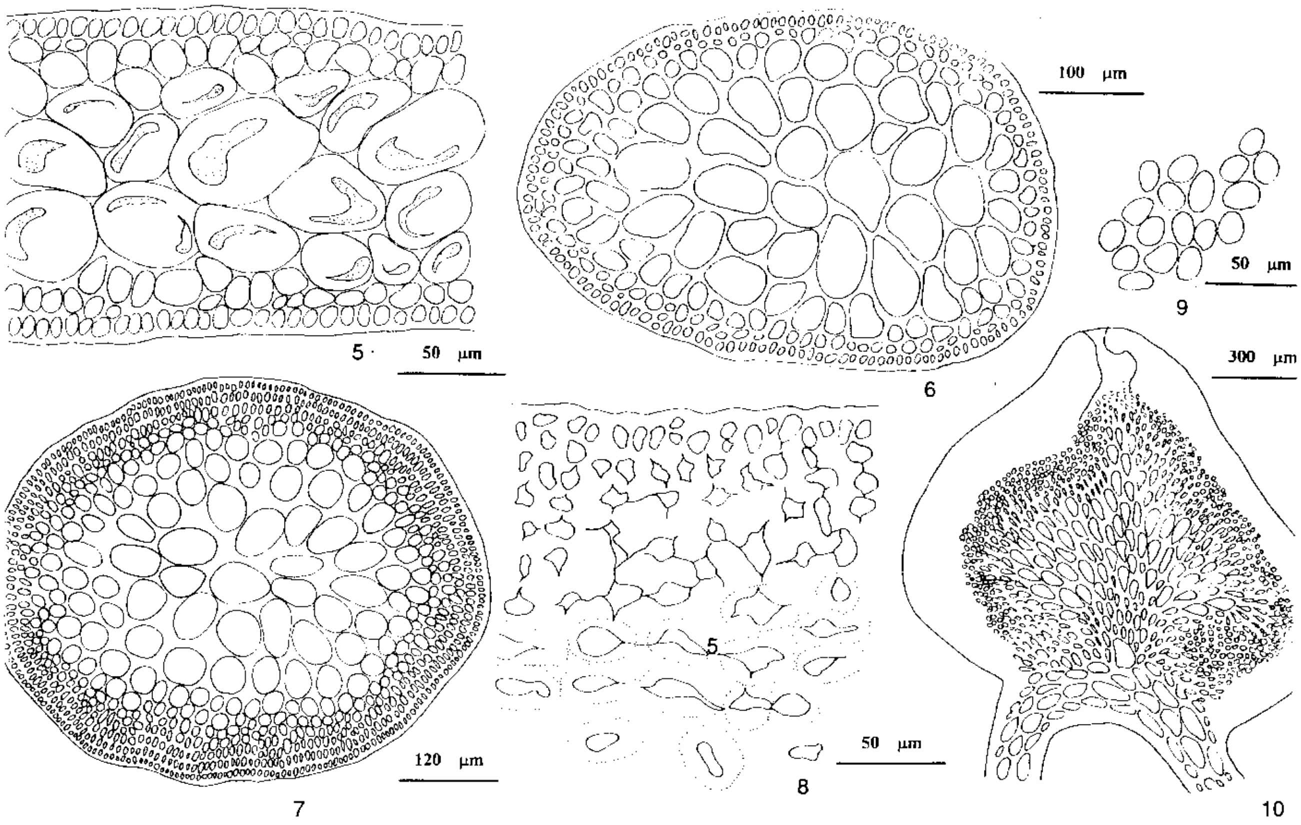
Holotype: AST 93-0773, cystocarpic, growing in a rock pool in the intertidal zone, collected by Xia Bangmei, Kuang Mei, and Wang Yongqiang, September 21, 1993, at Yinggehai, Hainan Island, Hainan Province, China. The type specimen of the new species is deposited in the herbarium of the Institute of Oceanology, Chinese Academy of Sciences, Qingdao (AST).

Etymology: Named for its type locality, Yinggehai, on the western shore of Hainan Island, China.

Plants small, foliose, decumbent, 1–2 cm tall, irregularly laterally branched, with leaves rounded, elliptical, or lanceolate, 0.5–4 mm, up to 7 mm, in diameter with irregularly dentate margins. Thallus 145–481 mm thick in transverse section; medullary cells 46–112 µm by 30–73 µm, pigmented.



Figs. 1–4. ***Gracilaria yinggehaiensis*** **Xia et Wang, sp. nov. Figs. 1–2, Sketch of part of a frond. Figs. 3–4, Sketch of part of a frond with cystocarp.**



Figs. 5–10. *Gracilaria yinggehaiensis* Xia et Wang, sp. nov. Fig. 5, Transection of part of a blade. Figs. 6–7, Transection of the stipe of a blade. Fig. 8, Transection of part of the pericarp. Fig. 9, Carposporangia. Fig. 10, Longitudinal section of cystocarp.

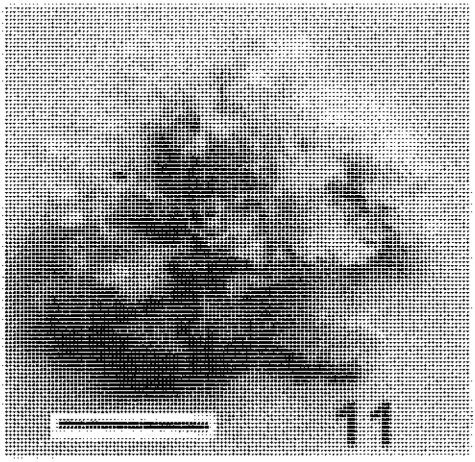


Fig. 11. ***Gracilaria yinggehaiensis*** **Xia et Wang, sp. nov. (AST 93-773). Scale bar = 1.75 cm.**

Cystocarps globose, slightly rostrate to nonrostrate, 1.5–1.8 mm in diameter, gonimoblast cells small, carposporangia terminal, spherical or oval, 20–23 µm by 15–20 µm. Tetrasporangia and spermatangia not observed.

Plants dark purplish red. Leaves of primary and secondary branches stipitate and irregularly laterally branched, with 3–5 orders of branching, some branches somewhat twisted. Central parts of blades in cross section consisting of a medulla of large, thin-walled cells, 50–89 µm by 30–59 µm in diameter, with walls about 5.5 µm thick, surrounded by 1–2 layers of smaller subcortical cells, 10–20 µm by 7–13 µm, outermost layer of small, pigmented cortical cells, 7–13 µm by 7–10 µm; lower parts of blades in transection 398–481 µm thick, medullary cells with thick walls, 12–17 µm thick; stipes of leaves of branchlets in section 415–564 µm thick, medullary cells of stipes 73–92 µm by 59–66 µm in diameter, with cell walls 7–13 µm thick.

Cystocarps occurring on both surfaces of frond, prominently protruding, 1.5–1.8 mm in diameter, slightly constricted at the base when mature; gonimoblast consisting of many small cells, 33–53 µm by 13–33 µm, carposporangia small, rounded to ovoid, 20–23 µm by 15–20 µm, traversing filaments absent, pericarp 231–264 µm thick, consisting of 2 kinds of tissue, the outermost consisting of 6–7 rows of smaller, dense, oblong-shaped contents, inner 2–3 rows consisting of larger, loosely attached, horizontally oblong cells.

Remarks: *Gracilaria yinggehaiensis* is characterized by its small thallus, decumbent and adherent habit, and *Sargassum*-like leaves, which are so distinctive that they can be used to separate this species readily from all other foliose species now reported in this genus.

Acknowledgments

This chapter is contribution No. 3745 from the Institute of Oceanology, Chinese Academy of Sciences. We are grateful to Dr. I. A. Abbott for critically reading and correcting the manuscript and to Dr. Karla McDermid for writing the Latin diagnosis. We are grateful to Dr. James Sullivan, formerly of the California Sea Grant College Program, for his interest and support.

Literature Cited

Tseng, C. K., and Xia, B. 1999. On the *Gracilaria* in the western Pacific and the southeastern Asia region. Bot. Mar. 42:209–217.

Zhang, J., and Xia, B. 1994. Three foliose species of *Gracilaria* from China. In: Tax. Econ. Seaweeds 4, pp. 103–110.

A DIFFERENT FLATTENED SPECIES OF *GRACILARIA* FROM THAILAND

Anong Chirapart and Khanjanapaj Lewmanomont

Abstract

A flattened species of *Gracilaria* collected from Koh Nui, Ranong Province, on the Andaman Sea coast of Thailand was examined. The morphological characteristics of this taxon distinguish it from the other flattened species of *Gracilaria* reported from Thailand. The external appearance of the specimen is similar to that of *G. multifurcata* Børgesen reported from Mauritius. However, only vegetative plants and a few female gametophytes with young cystocarps were found. Therefore, this taxon is tentatively reported as a new record for Thai waters.

Introduction

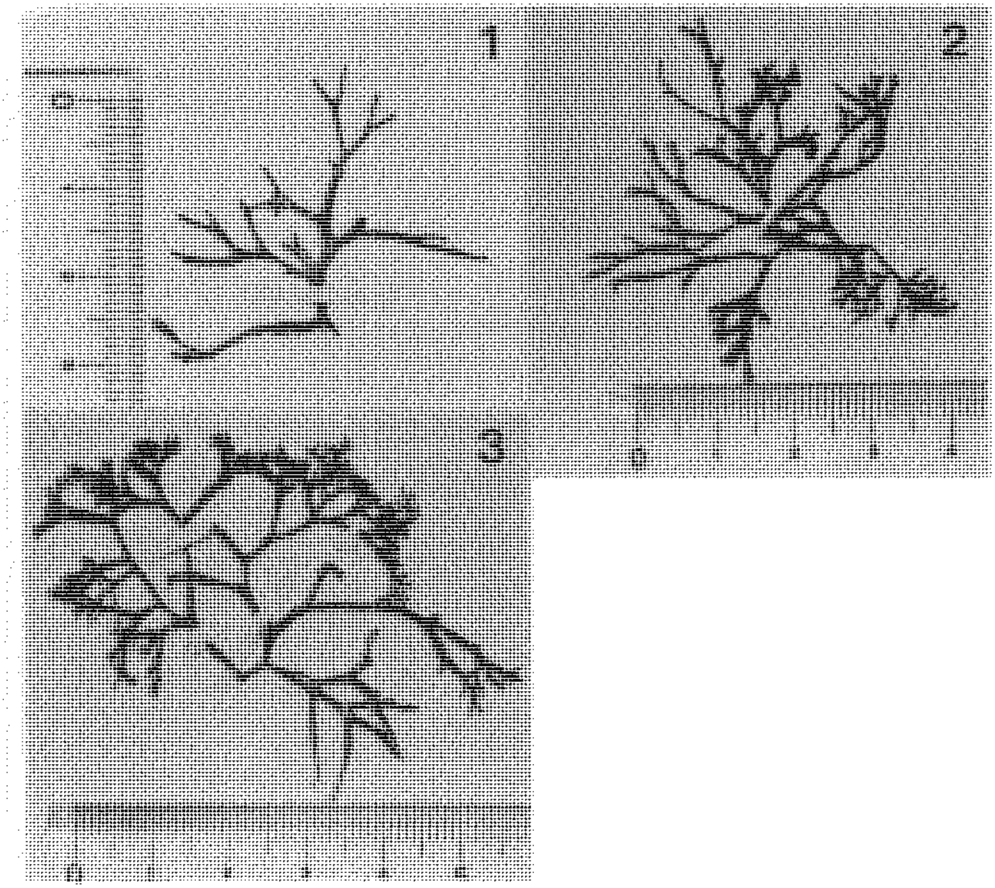
Species of *Gracilaria* are widely distributed along the coast of the Andaman Sea and along the coast of the Gulf of Thailand. Fourteen species of *Gracilaria* have been reported (Lewmanomont 1994, Chirapart and Ruangchauy 1999). Most of them belong to terete species. Only 2 flattened species of this genus have been reported previously from Thailand: *G. textorii* (Suringar) DeToni and *G. eucheumatoides* Harvey (Lewmanomont 1994). To date, however, some taxa of *Gracilaria* species are still unidentified because of a lack of reproductive material. The flattened species of *Gracilaria* that grows along the coast of Koh Nui, Ranong Province, is one of these taxa. We report it here as a different flattened species of *Gracilaria* from Koh Nui, Andaman Sea, southern Thailand.

Materials and Methods

Specimens were collected from Koh Nui, Ranong Province, in the Andaman Sea on the coast of Thailand (lat 9°57′N, long 98°35′E). The collected specimens were preserved in a solution of 10% formalin, and the remainder was dried on a herbarium sheet. Sections of specimens were prepared by hand, stained with 1% aqueous aniline blue intensified with 1% HCl, and mounted in 50% Karo brand corn syrup on glass slides. The specimens examined are deposited in the herbarium of Faculty of Fisheries, Kasetsart University.

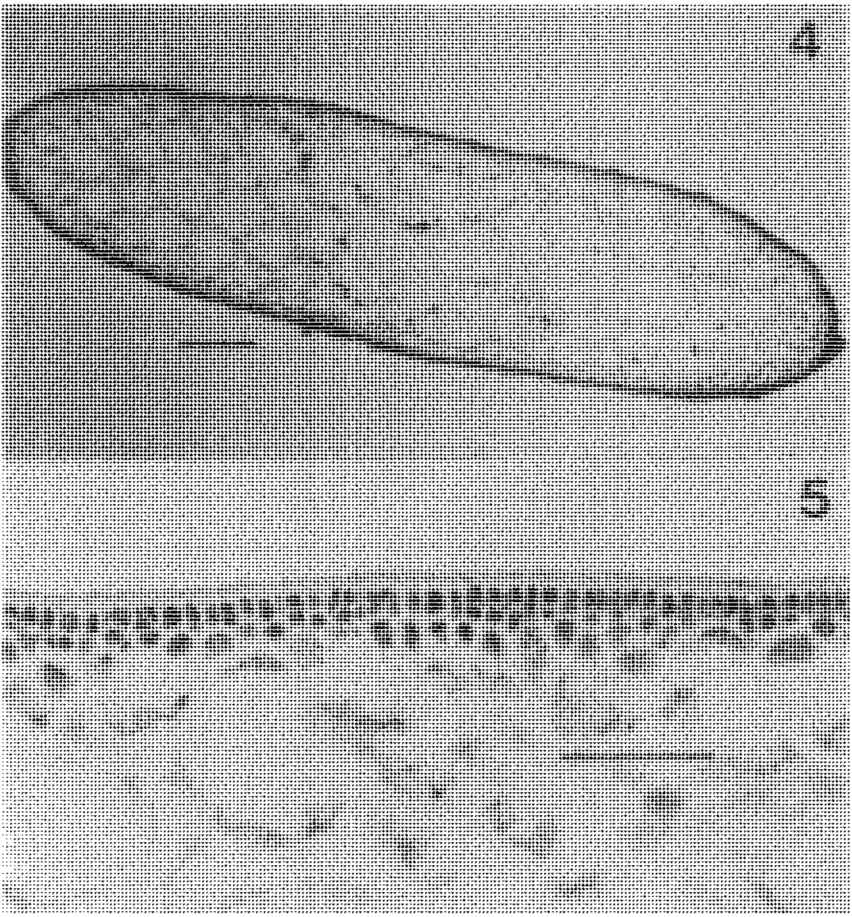
Description of the Species

Plants (Fig. 1) dark brown, erect to semierect, 1.4–5.5 cm tall, arising from a small discoid holdfast by a short slender subterete stipe, 1–2 mm long, adhering imperfectly to paper on drying. Branches flattened to compressed, 1–2.4 mm thick and 3.7–6.7 mm wide when dried, regularly dichotomously branched (Fig. 1), divaricately to alternately branched (Fig. 2), and with mixed branching (Fig. 3). Main axes not markedly wider or thicker than primary branches, branches close and clustered near apices of some axes, apices acute, tapered, never rounded,



Figs. 1–3. Different specimens of flattened species of *Gracilaria* from Thailand. Fig. 1, Habit of regularly branched plant with dichotomous branching. Fig. 2, Habit of plant with divaricate branching. Fig. 3, Habit of plant with irregularly dichotomous branching, with densely clustered apices.

otherwise irregularly branched to 6–7 orders (Fig. 3), but also branching only 1–3 times (Figs. 1–2). Cartilaginous. Cortex consisting of 1–2 layers of cells, 8.2–16.4 µm thick; medulla consisting of large cells, 30 µm by 50 µm to 60 µm by 410 µm in diameter; transition in cell size from cortex to medulla abrupt (Figs. 4–5). Male reproductive structures and tetrasporangia unknown.



Figs. 4–5. Transverse sections of branches of flattened species of *Gracilaria* from Thailand. Fig. 4, Section showing large medullary cells. Scale bar = 1000 µm. Fig. 5, Detail of the cortical layers showing ovoid cortical cells. Scale bar = 50 µm.

Discussion

This species of *Gracilaria* grows at a depth of 1–3 m, attaching by a small holdfast on rocks in clear water of the littoral zone. Thalli generally grow near the holdfasts of *Sargassum* and are shaded by this seaweed. Plants are usually exposed to strong waves during the long monsoon period, from April to December. Almost all of the collected specimens were vegetative; no male gametophytes or tetrasporophytes with tetrasporangia were found. A few young female gametophytes (Figs. 6–7) were found in April.

Only two flattened species, *G. textorii* and *G. eucheumatoides*, have been reported from Thailand (Lewmanomont 1994). The specimens of the species we examined have short subterete stipes. In cross section, the holdfast (Fig. 8) and the stipe/axes (Fig. 9) have a pseudoparenchymatous central medulla. The plants are dichotomously branched, with acute apices and never rounded, unlike *G. textorii*, which generally has rounded branch apices. When dried, our specimens are similar in external habit to *G. bangmeiana* Zhang et Abbott from Thailand. However, our plants with entirely flattened thalli are clearly distinguishable from *G. bangmeiana*, which has terete thalli (Lewmanomont 1994). Our plants with entire margins and thinner thalli are also clearly distinguishable from *G. eucheumatoides*, which has dentate margins and thick thalli. The external appearance and sections of the Thai plants are similar to those of *G. multifurcata* originally reported from Mauritius (Børgesen 1953). *Gracilaria multifurcata* was recently reported from Australia (Millar 1997) and Malaysia (Terada et al. 2000). However, the cortical layer of the plants from Mauritius and Australia is thicker than that of the plants from Thailand. The Thai specimens also closely resemble the Malaysian plants (Terada, personal communication).

Currently, only a few young cystocarps have been examined; hence, the generic and specific identification remains tentative. We suggest that this flattened *Gracilaria* is new for Thai waters. When spermatangial, mature cystocarpic, and tetrasporangial plants are found, we may be able to more adequately describe this species.

Acknowledgments

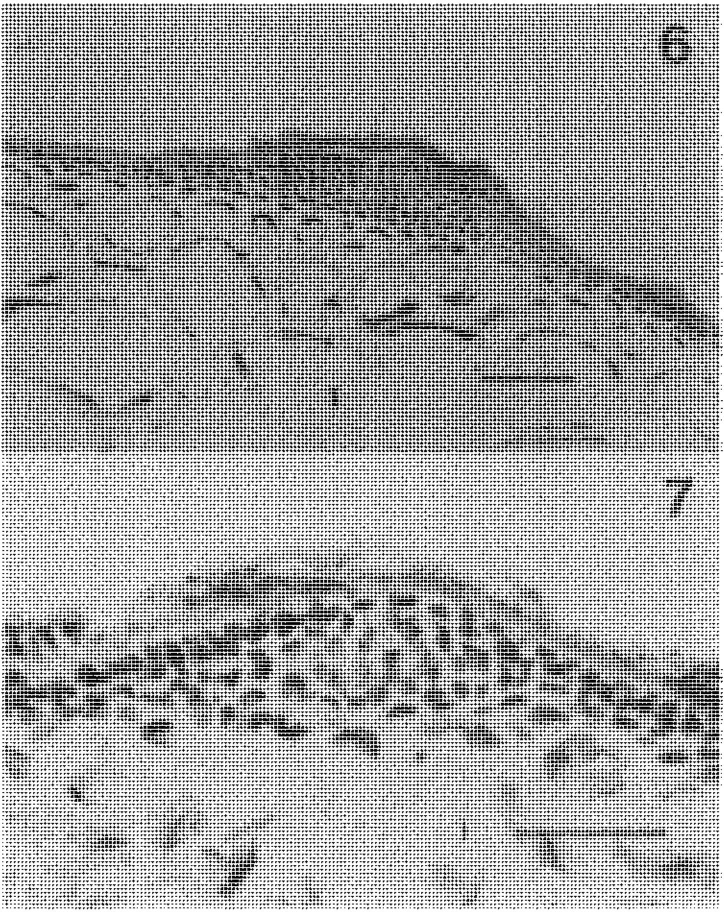
We sincerely thank Professor Isabella A. Abbott and the California Sea Grant College Program for the invitation and transportation support to participate in the eighth workshop on taxonomy of economic seaweeds. We also thank the Kasetsart University Research and Development Institute for financial support of the research.

Literature Cited

Børgesen, F. 1953. Some marine algae from Mauritius: additions to the parts previously published, V. Kongl. Danske Vidensk. Selsk. Biol. Medd. 21:1–62, pls. 1–2.

Table 1. Characteristics of the *Gracilaria* sp. From Koh Nui and of Similar Flattened Species From Thailand and the Western Pacific Ocean

Species	Locality	Habit/Habitat	Male Conceptacle	Cystocarp	Branching
Gracilaria sp.	Koh Nui, Ranong Province, Andaman Sea, coast of Thailand	Thalli compressed to flattened with entire margin, erect/semierect from holdfast by short stipe, cartilaginous, growing on rocks near the holdfasts of *Sargassum*	Not found	Young cystocarp	Dichotomously branched to 6–7 orders
Gracilaria eucheumatoides Harvey	Rawai Beach, Phuket Province, Thailand	Thalli compressed with dentate margin, prostrate, thalli thick and succulent, growing on dead coral fragments	Polycavernosa type (cultured)	See Terada & Yamamoto this volume	Pinnate to dichotomous
Gracilaria textorii (Suringar) DeToni	Trang Province, Thailand	Thalli foliose with entire margin, membranous when dried, growing on rocks and fish cages	Textorii type	Semiglobose to globose	Dichotomously or subdichotomously branched in a single plane
Gracilaria bangmeiana Zhang et Abbott	Ban Phe, Rayong Province, and Palian Trang Province, Thailand	Thalli terete, rigid, dense tuft growing on rocks in clear water of sublittoral zone and on fish cages	Polycavernosa type	Globose, rostrate, constricted at bases	Dichotomously branched
Gracilaria multifurcata Børgesen	Western Indian (Mauritius and Seychelles) and southwestern Pacific Ocean	Thalli flattened, erect, forming cushions on exposed rocks	Polycavernosa type	Papillate to hemispherical	Dichotomously, divaricately to alternatively branched



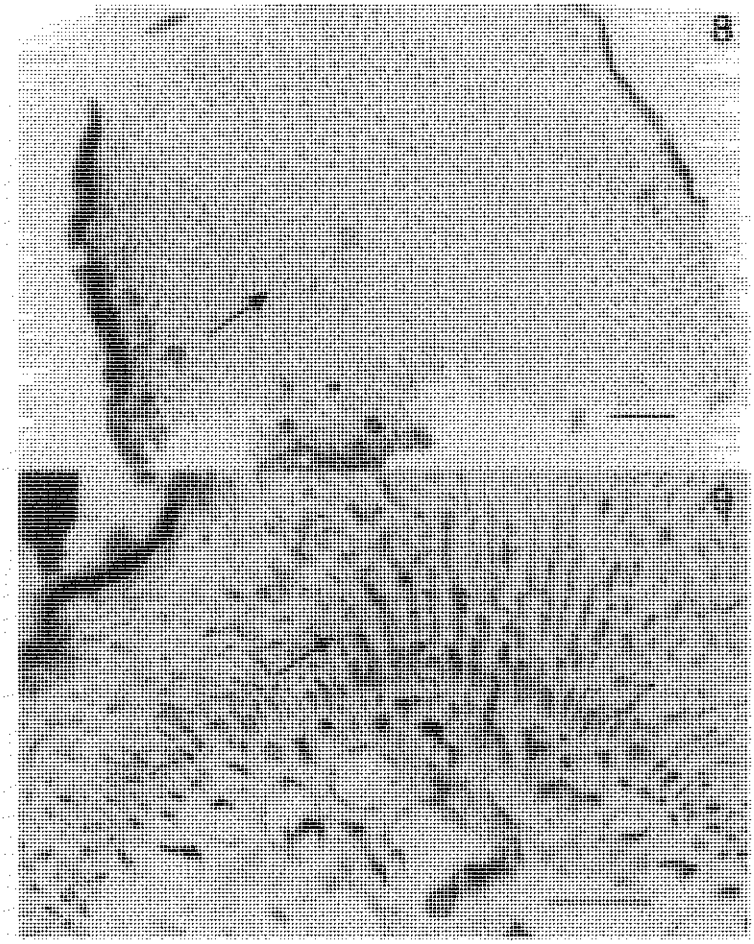
Figs. 6–7. Female gametophyte of flattened species of *Gracilaria* from Thailand. Fig. 6, Vertical section of young female plant. Scale bar = 80 μm. Fig. 7, Detail of cystocarp showing unorganized development of young cystocarp. Scale bar = 50 μm.

Chirapart, A., and Ruangchauy, R. 1999. A new record of *Gracilaria*, *G. rubra* C. F. Chang et B. M. Xia from Thailand. In: Tax. Econ. Seaweeds 7, pp. 137–143.

Lewmanomont, K. 1994. The species of *Gracilaria* from Thailand. In: Tax. Econ. Seaweeds 4, pp. 135–148.

Millar, A. J. K. 1997. Some flattened species of from Australia. In: Tax. Econ. Seaweeds 6, pp. 111–123.

Terada, R., Kawaguchi, S., Masuda, M., and Phang, S. M. 2000. Taxonomic notes on marine algae from Malaysia, III. Seven species of Rhodophyceae. Bot. Mar. 43:347–357.



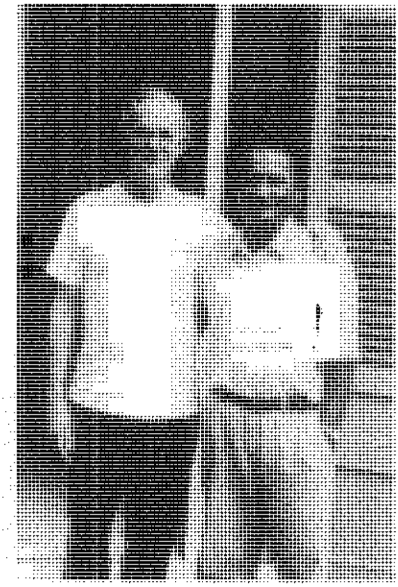
Figs. 8–9. Cross sections through stipe of flattened species of *Gracilaria* from Thailand. Fig. 8, Pseudoparenchyma cells in stipe/holdfast. Arrow points to pseudoparenchyma cells. Scale bar = 80 µm. Fig. 9, Cellular detail of stipe cortex, arrow showing cortical filaments radiating outward, similar to menstematic activity. Scale bar = 50 µm.

Section IV. *Kappaphycus/Eucheuma*

INTRODUCTION

Isabella A. Abbott

About 65 years ago, William Randolph Taylor of the University of Michigan told me that one reason to name varieties and forms of *Caulerpa* was to warn people who came after you that these are all a part of a continuum of morphological or ecological expression in the particular species (such as *C. racemosa*). Although Pham Huu Tri never heard that lecture, he understands it very well, and his chapter on the variations in *Eucheuma cottonii* will be useful for those who come after him.



The *Kappaphycus/Eucheuma* Group. (Left to right): Jack Fisher, Pham Huu Tri.

MORPHOLOGICAL VARIABILITY OF *KAPPAPHYCUS COTTONII* IN VIETNAM

Pham Huu Tri

Abstract

The distribution of *Kappaphycus cottonii* (Solieriaceae) is scarce at Ly Son Island south of Da Nang,* north central Vietnam, but the alga occurs on nearly all of the islands of the Spratly Archipelago (between lat. 10ºN and 12ºN, near long. 15ºE). This species varies morphologically according to its environment. Five forms of *K. cottonii* collected for the first time in the Spratly Archipelago are described. It is not known whether this species is indigenous to these islands or whether it was introduced at some previous time.

Introduction

Kappaphycus and *Eucheuma* (Solieriaceae) have been studied in Vietnam since 1985. The results of field studies indicated that *K. cottonii* is scarce along the coast of Ninh Thuan and at Ly Son Island, where the local people exploit it for food. In the Spratly Archipelago, natural wild crops are abundant, especially at Son Ca Island, where 6 tons wet weight was obtained from 2 hectares. Harvesting began recently (unpublished data 1988).

Earlier reports on *Eucheuma* in Vietnam were published by Nguyen (1993), who described 3 species collected from central Vietnam. Nguyen and Huynh (1995) reported 4 species of *Eucheuma* and *Kappaphycus* collected from Ninh Thuan, Ly Son Island, and from Truong Sa Islands. Pham and Nguyen (1997) reported on some species of *Eucheuma* and *Kappaphycus* found in Vietnam for the first time. Reports on *Kappaphycus* and *Eucheuma* from the Spratly Archipelago have also been published (Pham 1998). This chapter gives information on some forms of *K. cottonii* distributed in the Spratly Archipelago, along the coast of Ninh Thuran (south of Nha Trang) and at Ly Son Island (Fig. 1).

Materials and Methods

Specimens were collected at Ly Son Island and along the coast of Ninh Thuan in April and May 1990, 1991, and 1992 and in the Spratly Archipelago in April 1993, 1994, and 1995. Some materials were preserved in approximately 5%

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*When Doty (1988) made several new combinations in taxa in the genus *Eucheuma*, he did not give the exact page on which the basionym was named. Under Article 33.2 of the International Code of Botanical Nomenclature, this combination is invalid. Nguyen Huu Dinh and Huynh Quang Nang were the first to furnish the pagination; hence their names are appended to the author of this binomial and that of *Kappaphycus inerme* (Schmitz) Doty ex Nguyen Huu Dinh et Huynh Quang Nang. I thank W.F. Prudhomme van Reine for pointing this situation out to me. I. A. Abbott, Editor.

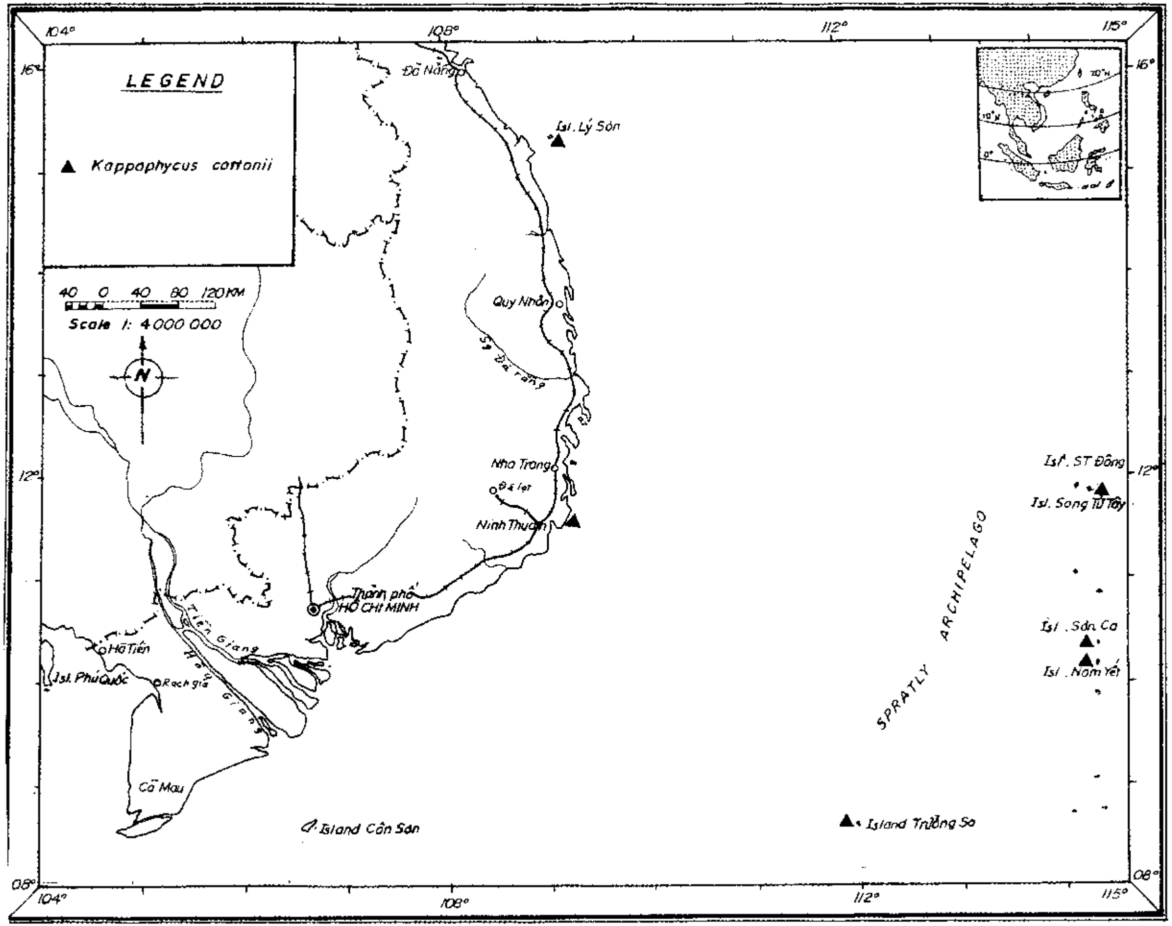


Fig. 1. Distribution of *Kappaphycus cottonii* in Vietnam.

formalin in seawater for anatomical studies. All sections were cut by hand by using single-edged razor blades. Photomicrographs were obtained with a SC-35 camera attached to an Olympus CH-30 compound microscope.

Results

The following are descriptions of various ecological forms of *Kappaphycus cottonii* (Weber-van Bosse) Doty ex Nguyen Huu Dinh et Huynh Quang Nang, Tax. Econ. Seaweeds 5, p. 234, figs. 5A–5B, 1995.

Form 1

The plants (Figs. 2A–2D) grow in densely interlacing clumps with a diameter of 20–30 cm but sometimes form a large cluster with a diameter of 80–100 cm. Fronds are cylindrical or slightly compressed upward, about 1–1.5 cm wide; prostrate parts are sometimes attached to each other, divided irregularly dichotomously or trichotomously. Branches taper upward, forming slightly pointed apices. The dorsal surfaces of branches are covered with conical spines that have with nearly spherical apices, about 1–2 mm tall; spines that form on the margins elongate into new branches. The ventral surfaces of the branches are mostly smooth, with no spines except near the apex.

In cross section, the medulla consists of round or polygonal cells with lenticular thickenings in the walls, about 300 µm in diameter, surrounded by small cells; the inner cortex consists of polygonal-ovoid cells 200 µm in diameter that become smaller toward the margin. The outer cortex consists of 2 or 3 rows of ovoid cells about 12–15 µm in diameter. Tetrasporangia are about 62.5 µm in diameter, zonately divided, and immersed in the outer cortex.

Specimens Examined: SC 94051f, SC 34052, SC 94053, SC 94054, and SC 94055.

Habitat: At Truong Sa, Nam Yet, and Song Tu Tay islands, plants are commonly found growing on dead corals at a depth of 1.5–3 m. At Son Ca Island, plants grow on dead corals at a depth of 1–1.5 m and at low-tide depth (0.1–0.2 m), are exposed to strong waves. The salinity is generally 33–35 ppt, and the temperature 25ºC–30ºC.

Distribution: Plants are scarce at Truong Sa, Nam Yet, and Song Tu Tay islands but plentiful at Son Ca Island (6 tons wet weight in 2 hectares). This form is also found in Tanzania, Hainan (China), the Philippines, Guam, southern Japan, and Malaysia.

Form 2

Plants (Figs. 3A–3C) grow in thick, heavy clumps about 15 cm wide, 5 cm tall. Fronds are short, irregular, cylindrical, sometimes tortuous or turbinate, and covered with irregular conical spines. Apical branches are swollen and attached to each other, forming plants that resemble inverted baskets. In the same plant,

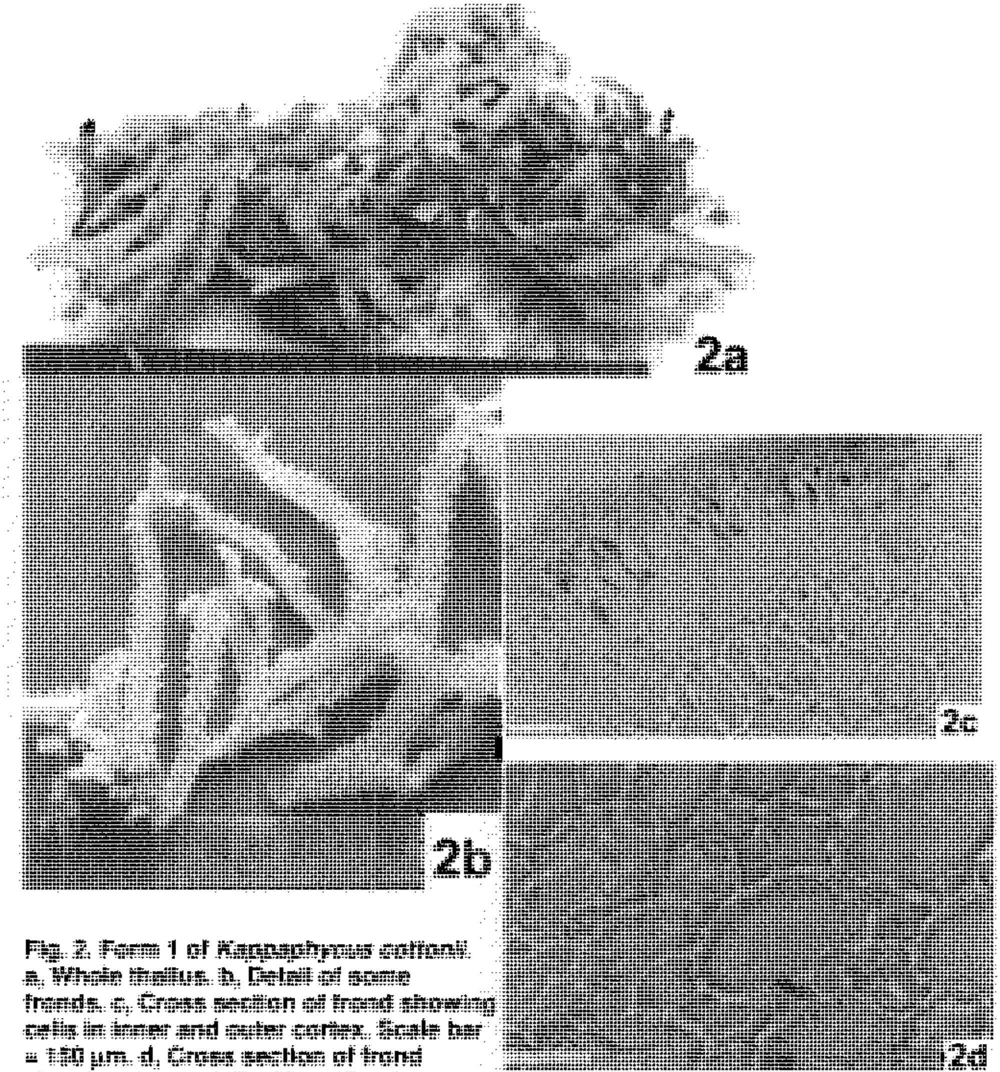


Fig. 2. Form 1 of *Kappaphycus cottonii*. a, Whole thallus. b, Detail of some fronds. c, Cross section of frond showing cells in inner and outer cortex. Scale bar = 150 µm. d, Cross section of frond showing the medulla. Magnification = 10X; scale bar = 150 µm.

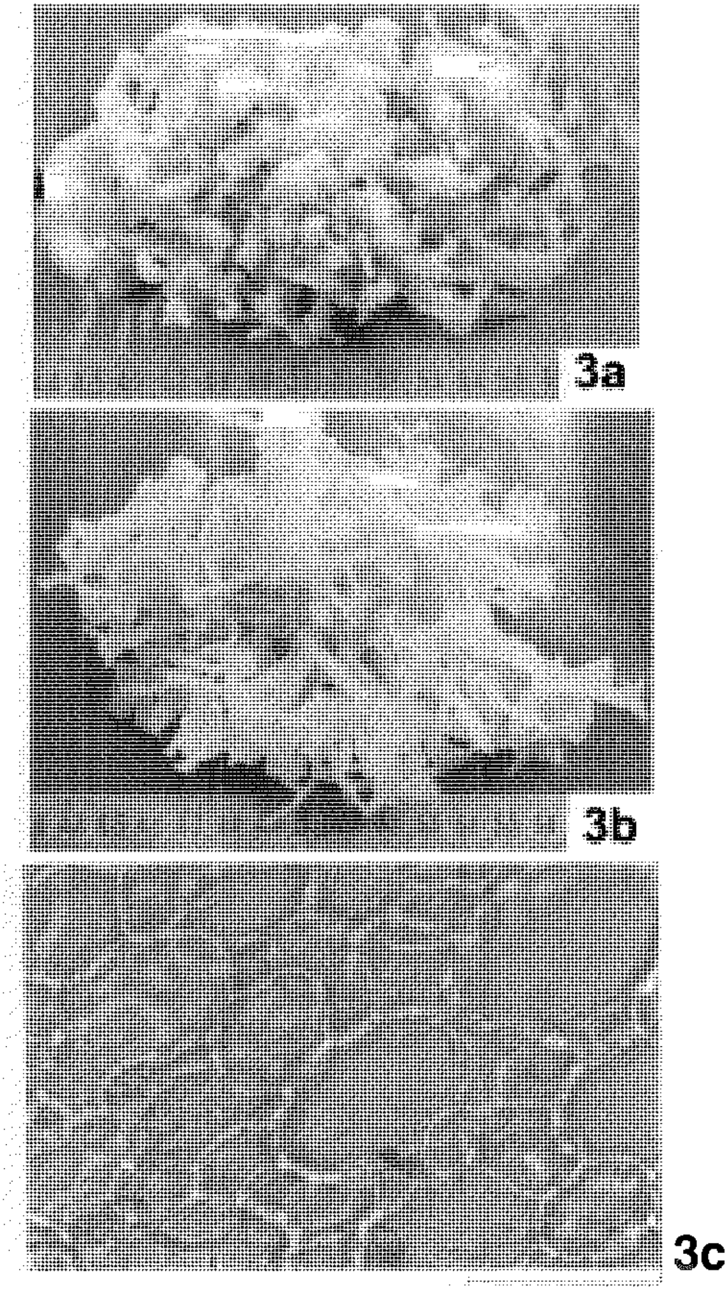


Fig. 3. Form 2 of *Kappaphycus cottonii.* a and b, Dorsal (a) and ventral (b) surfaces of whole thallus. c, Cross section of frond showing the medulla. Scale bar = 150 µm.

cylindrical fronds about 1.5–2 mm in diameter that taper toward the apices are formed from inner axes (Fig. 3B).

Specimens Examined: SC 94055, SC 94056, and SC 94057.

Habitat: Plants grow on dead corals at a depth of 2.5 m, especially in tide pools, and are often exposed when waves are calm. The salinity is generally 33–35 ppt and the temperature 25ºC–30ºC.

Form 3

Plants are 15 cm wide with sprawling irregular axes (Fig. 4), with a prostrate part bearing rhizoids for attachment. Fronds are cylindrical, 0.5 cm wide and irregularly branched or filiform and about 0.2 cm wide. The surfaces of the branches are covered densely with short, blunt spines; the spines are sometimes elongated and form a rhizoid. Erect fronds are swollen at the apices, with 3–4 convex papillae, 1 cm wide.

Specimens Examined: SC 94060 and SC 94061.

Habitat: Plants grow on dead corals at a depth of 2.5 m, especially in tide pools, and are often exposed when waves are calm. The salinity is generally 33–35 ppt and the temperature 25ºC–30ºC.

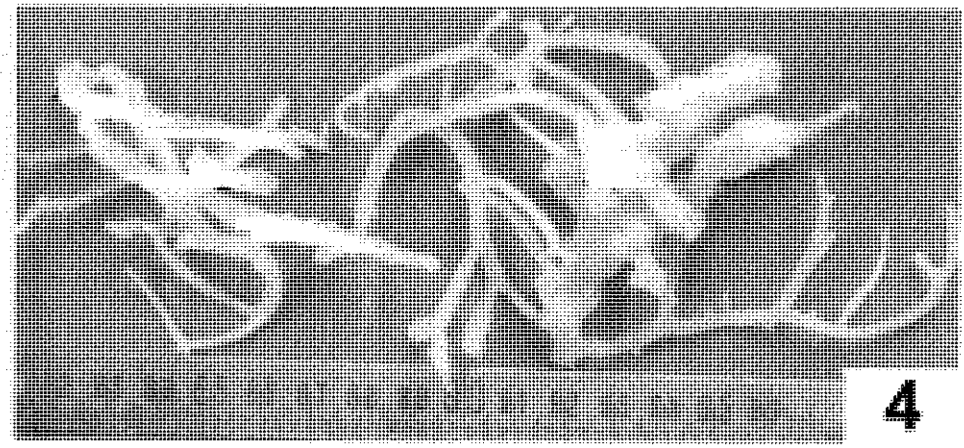


Fig. 4. Whole thallus of form 3 of *Kappaphycus cottonii.*

Form 4

Plants usually grow in a thick bush 10 cm wide, 5 cm tall, with numerous erect axes and branches attached to the substratum by rhizoids (Fig. 5). Fronds are nearly cylindrical at the base, 1.5 mm wide, but soon become compressed, 1 cm wide, and from this part are divided irregularly and dichotomously. Fronds form irregular cylindrical branches, sometimes with turbinate branches, about 2–3 mm wide, with apices becoming swollen and bearing 2–3 protuberances. The surfaces of the branches are usually densely covered with blunt spines; the apices of branches are sometimes attached to each other.

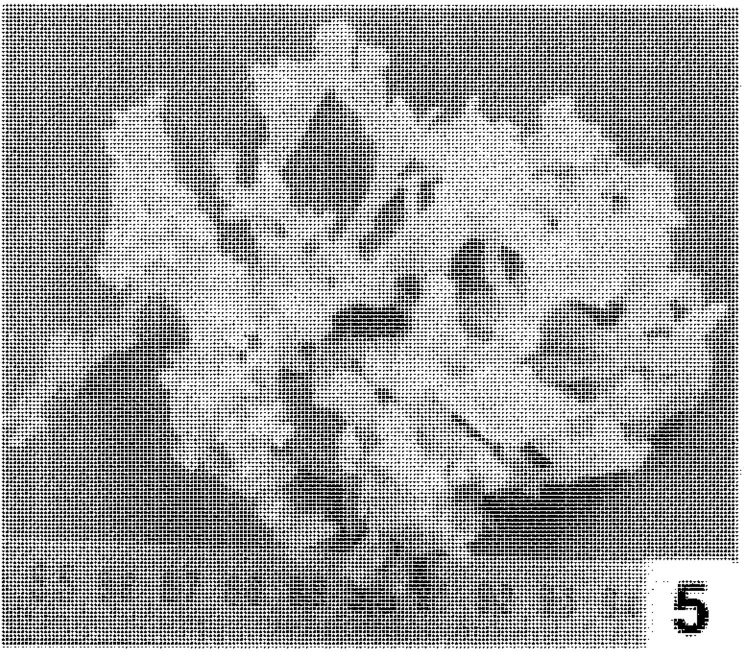


Fig. 5. Whole thallus of form 4 of *Kappaphycus cottonii.*

Specimen Examined: SC 94070.

Habitat: Plants grow on dead corals at a depth of 2.5 m, especially in tide pools, and are often exposed when waves are calm. The salinity is generally 33–35 ppt and the temperature 25ºC–30ºC.

Distribution: Plants are found only at Son Ca Island, growing in the same area as form 1 (see earlier).

Form 5

Plants (Figs. 6A–6C) grow in clumps with a diameter of 10–15 cm. Fronds are cylindrical or slightly compressed, 9–10 mm wide, with short irregular branches, and adhere to one another, forming a decumbent mass. Spines are blunt, conical, 1–2 cm tall, densely cover the dorsal surfaces of branches, and form a margin that sometimes elongates to form new branches. The ventral surfaces of branches have no spines but sometimes have some tubercles, which form rhizoids.

Specimens Examined: LS 84510 and LS 84511.

Habitat: Plants grow on dead corals at the depth of 1.5–2 m and are exposed to strong waves. The salinity is 30–34 ppt and the temperature 20ºC–30ºC.

Distribution: Plants are found along the coast of Ninh Hai, Ninh Thuan Province; at Ly Son Island; and in Tanzania, southern Japan, China, the Philippines, and Malaysia.

Remarks: Specimens: LS 84510 and LS 84511 were collected at Ly Son Island, where the wild crops are small and the local people exploit them for food.

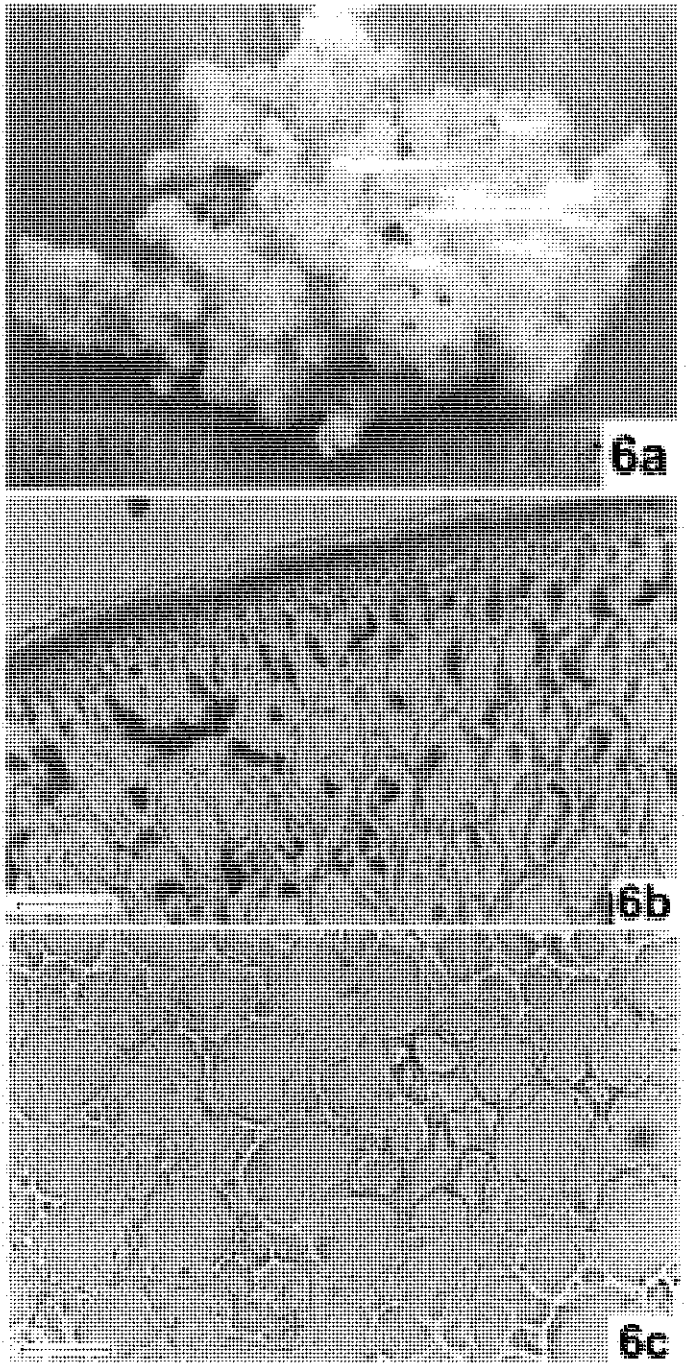


Fig. 6. Form 5 of *Kappaphycus cottonii*. a, Whole thallus. b, Cross section of frond showing inner and outer cortex. Scale bar = 150 µm. c, Cross section of frond showing the medulla. Scale bar = 150 µm.

Discussion

Form 2 of *K. cottonii* (Figs. 3A–3C), which was collected at Son Ca Island, resembles the species of *E. striatum* described by Weber-van Bosse (1928, pp. 423–424, fig. 171, pl. XVI, fig. 4). The original specimens of *E. striatum* are usually described as attaching to the substratum by only a single small disk. From this disk, a thin axis forms, and soon branches divide, forming a plant. Apart from that method, the pointed spines that cover the surfaces of branches can elongate, forming new branches. In the materials from Son Ca Island that are attached by many rhizoids, the spines on the branches are blunt and never form new branches. The Son Ca materials also resemble the species of *E. muricatum* that Yamada (1936, pp. 122–125, figs. 3–5; pl. 23, figs. 1–2) described as one of the species of *Eucheuma* from Ryudyu and Formosa. However, this species belongs to the section Axifera (including the species of *Eucheuma*) that have rhizoidal cells in the medulla and branches covered by many spines that are pointed like branchlets.

Currently, I think the 5 forms described in this chapter, which could have been recognized as different species, are ecological variants of *K. cottonii.*

Acknowledgments

I thank Dr. I. A. Abbott, University of Hawaii, for the invitation to participate in the eighth workshop and for reading and correcting the manuscript, Mr. Jack Fisher for his help in comparing specimens at the Bishop Museum, and Dr. Karla McDermid for her help during the workshop. I acknowledge the financial support of the California Sea Grant College Program and Dr. James Sullivan for participation in the workshop.

Literature Cited

Doty, M. S. 1988. Prodromus ad systematica Eucheumatoideorum: a tribe of commercial seaweeds related to *Eucheuma* (Solieriaceae, Gigartinales) In: Tax. Econ. Seaweeds 2, pp. 159–207, figs. 1–37.

Nguyen Huu Dai. 1993. The genus of *Eucheuma* along the coast of central Vietnam. Biol. J. 15:9–15.

Nguyen Huu Dinh and Huynh Quang Nang. 1995. Species of *Eucheuma* and *Kappaphycus* in Vietnam. In: Tax. Econ. Seaweeds 5, pp. 229–235, figs. 1–5.

Pham Huu Tri. 1998. The resource of the genus *Eucheuma* and *Kappaphycus* at the Spratly Archipelago. Paper presented at the National Symposium on the Technology and Science of Marine Biology, Hanoi.

Pham Huu Tri. 1999. The resource of marine algae at Son Ca and Song Tu Tay islands, Spratly Archipelago. In: Nguyen Tac An (ed.), Collection of marine research works, Science and Technique Publ., Hanoi, 9, pp. 205–215.

Nguyen Huu Dai and Pham Huu Tri. 1997. Some species of *Eucheuma* and *Kappaphycus* (Solieriaceae, Gigartinales) found in Vietnam for the first time. In: Dang Ngoc Thanh (ed.), Proceedings of the First National Symposium on Marine Biology, Science and Technique Publ., Hanoi, pp. 97–102.

Weber van Bosse, A. 1928. Liste des algues du Siboga, IV. Rhodophyceae: Gigartinales et Rhodymeniales. Siboga Exped. Monogr. 59d:393–533, pls. 1–19.

Yamada, Y. 1936. The species of *Eucheuma* from Ryukyu and Formosa. Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Imp. Univ. 1:119–134, pls. 26–27.

Section V. *Halymenia* Species

INTRODUCTION

Isabella A. Abbott

Along the path of trying to understand the intricacies of reproductive structures, upon which the taxonomy of *Halymenia* species rests, learning how to grow these seaweeds may be a key step in being able to propagate the species and to merchandise them. Anywhere that people like vegetable salads, or naturally thickened soups, *Halymenia* can be sold either fresh or dried. In Hawaii, Hawaiians love to eat *Halymenia* raw, especially with raw fish; Japanese and Koreans treat these plants "namasu style"; and others rehydrate dried pieces, adding the pieces to fresh salads or to "cream style" soup (without the calorie-rich cream). *Halymenia* species have a ready market in the United States and Japan. Karla McDermid found that it was "easy" to propagate plants (much easier than trying to figure out the characteristics of the species).

But it is that master halymeniaceous specialist, Shigeo Kawaguchi, who joined Khan Lewmanomont in one chapter and in another added Khan and Karla.

The *Halymenia* Group. (Left to right): Shigeo Kawaguchi, Khanjanapaj Lewmanomont, Isabella Abbott, Karla McDermid, Nguyen Xuan Vy.

MORPHOLOGY OF *HALYMENIA MACULATA* J. AGARDH FROM VIETNAM

Shigeo Kawaguchi, Khanjanapaj Lewmanomont, and Karla McDermid

Abstract

The morphology of a foliose red alga from Vietnam was examined to clarify the relationships of the alga with *Halymenia maculata* J. Agardh and *H. stipitata* Abbott. The alga is similar in gross morphology to *H. maculata* but also occasionally has a stout stipe, a finding considered characteristic of *H. stipitata.* A study of the material from Vietnam and of the literature revealed that the alga in question belongs in *H. maculata* and is distinct from *H. stipitata.*

Introduction

During a survey of marine algal flora of Vietnam in 1993–1994, a *Halymenia* that usually has a stout stipe was found at Nha Trang in central Vietnam. This alga is otherwise referable to *H. maculata* J. Agardh (1885) in gross morphology and agrees well with Dawson's description (1954) of *H. maculata* from the same area. In the meantime, Abbott (1998) added a new species of *Halymenia* to the Hawaiian flora, *H. stipitata* Abbott, which was considered unique because it has a conspicuous, tough stipe. We examined the morphology of the Vietnamese alga to clarify the taxonomic relationships between this alga and *H. maculata* and *H. stipitata.*

Materials and Methods

Dried specimens used for this study were all derived from samples collected at Cau Da, Nha Trang, central Vietnam, on March 5 and 14, May 15, and September 3 in 1992 and on June 22 in 1993 from depths of 1–5 m (specimen numbers, Kawaguchi 1149–1157). In addition, liquid-preserved materials were also used, particularly for microscopic observations. Four authentic specimens of *H. stipitata* kindly supplied by Dr. I. A. Abbott were used for a comparative study.

Sections of dried and liquid-preserved specimens were made by hand with a razor blade, stained with 0.5% (w/v) cotton blue in a lactic acid–phenol–glycerol–water (1:1:1:1) mixture, and mounted on microscope slides in glycerin.

Observations

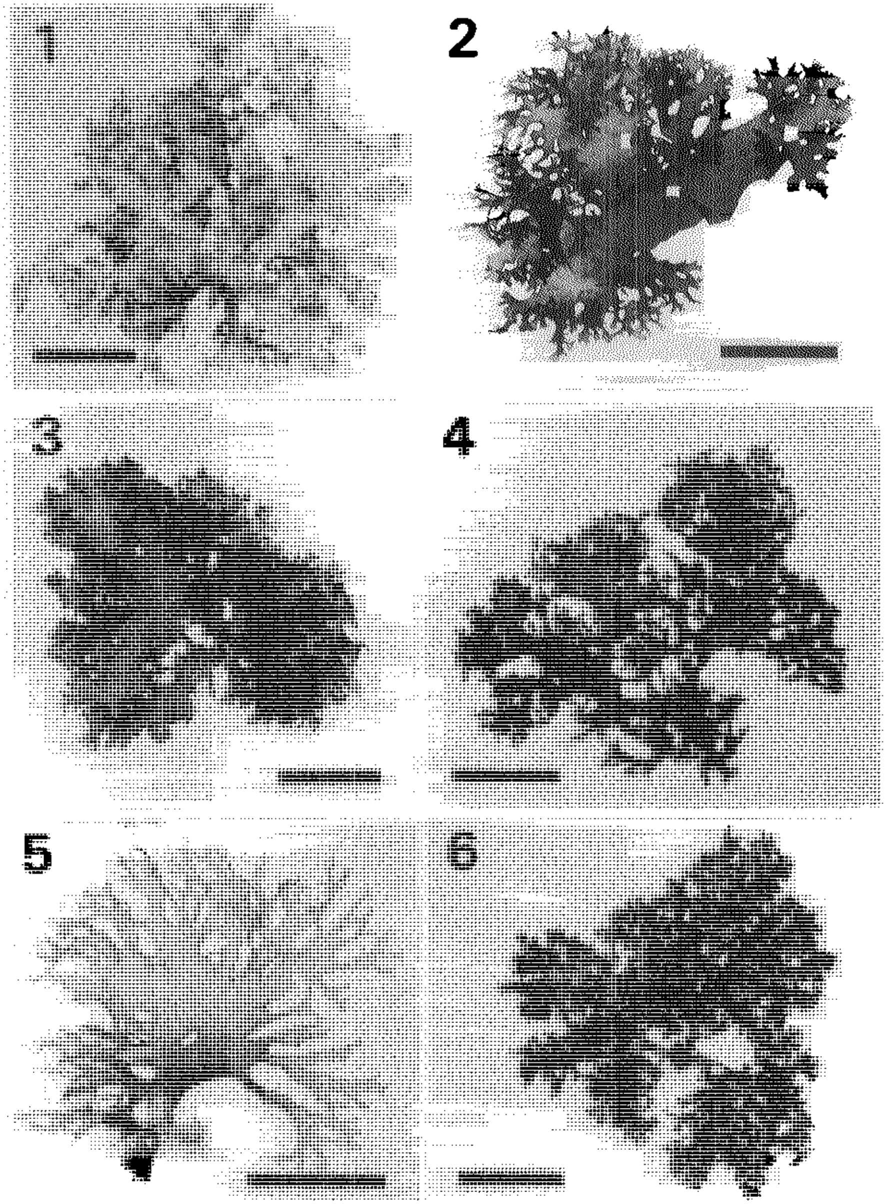
The Vietnamese plants are 7.5–11.5 cm tall, consisting of discoid or scutate holdfasts and foliose blades with solid, cylindrical stipes 0.2–1.3 cm long and 2–3 mm in diameter. The stipe is usually simple or, rarely, branched once near the base. The blades are brownish to dark red or purplish red with a somewhat carnose texture, and the clearly maculated surfaces, although slippery to the touch, are not soft, but rather rugose. The shapes of the blades vary greatly. Most plants have irregularly palmately lobed blades with cordate bases or are sinuate in cuneate lobes with the margin usually fimbriated with densely placed proliferations (Figs. 1–5). Other plants have repeatedly subdichotomously branched blades with cuneate bases with the segments wider upwards (Fig. 6); the margins of these plants are fringed with short proliferous bladelets beset with short proliferations. Other plants have intermediate forms between the 2 blade forms just described.

Cross sections of the stipe show no clear growth rings, suggesting the annual nature of this alga (Fig. 7). The blades are 250–350 µm thick in the upper part of the stipe, 450–600 µm thick in the lower part. The cortical layer is rather well developed, 75–130 µm thick, and consists of an outer layer of 3–4 ellipsoidal cells arranged in anticlinal rows and an inner layer of 3–5 larger, rectangular or stellate-shaped cells that are connected by secondary pit connections (Figs. 8–10). Irrespective of sexual or asexual plants, most of the outermost cortical cells are conspicuously elongated, 13–20 µm long by 2–5 µm in diameter, and some have the typical "rabbit ear" appearance (Fig. 11). In general, the outer cortical cells of tetrasporangial plants are more elongated than are those of the sexual plants (Fig. 12). The medullary layer consists of moderately intermingled, oblique or periclinal filaments with occasional anticlinal filaments from cortex to cortex. Large stellate cells with slightly refractive contents are at times inserted among the medullary filaments (Figs. 8 and 9).

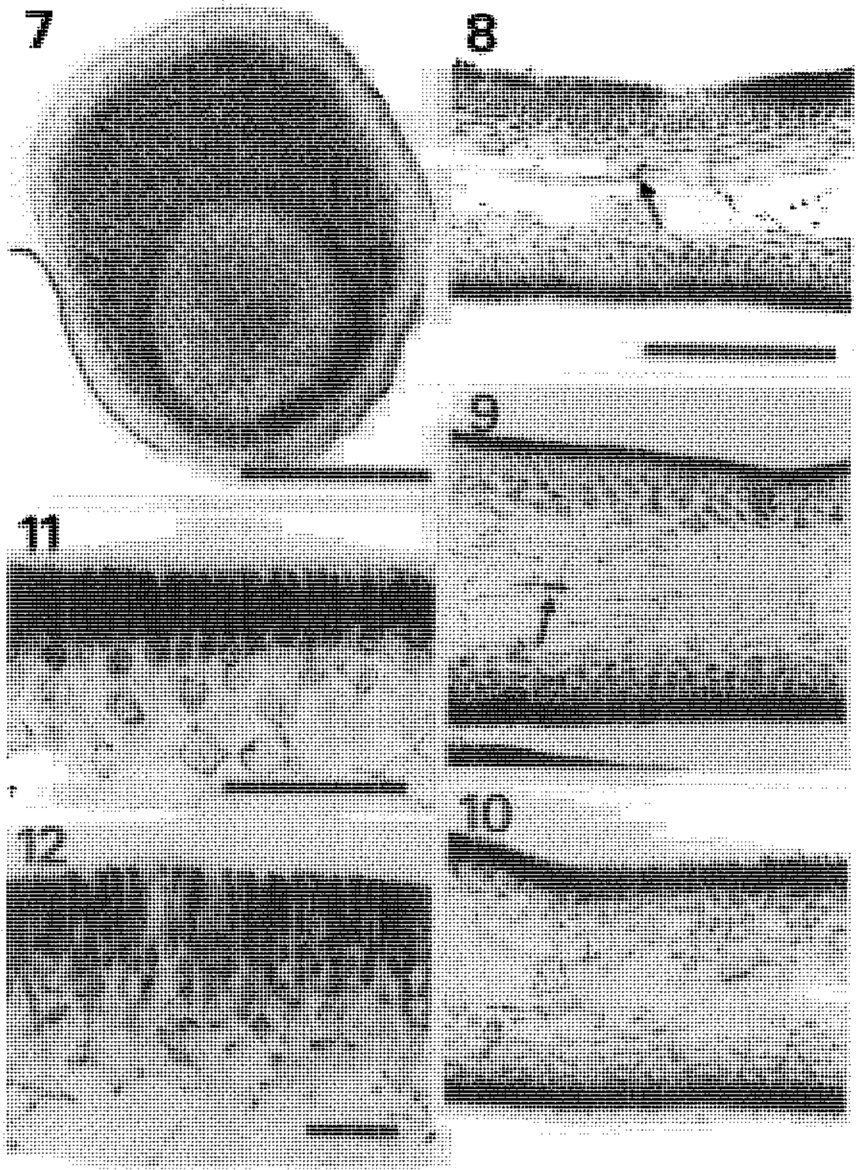
This alga is dioecious. Spermatangia are scattered on both surfaces and are formed from the outermost cortical cells. Spermatangia are rounded or broadly ellipsoidal, 3–4 µm long by 2–3 µm wide (Figs. 13 and 14). We could not find carpogonial branches in the specimens at hand. Auxiliary cells are formed in bushy ampullae, which are branched to the third or fourth order, and the ampullar basket usually has a narrow neck (Figs. 15–17). Gonimoblasts develop from the auxiliary cells in contact with an incoming connecting filament (Figs. 18 and 19). Then, a cell is cut off from the auxiliary cell at the opposite side of the incoming connecting filament, and from that new cell, several outgoing connecting filaments are produced (Figs. 20–22). As the gonimoblasts develop further, the ampullary cells become elongated and surround the gonimoblast filaments as a loose basket of filaments (Figs. 22 and 23). The mature cystocarp is spherical to pyriform, deeply embedded in the thallus interior, 170–200 µm in diameter, and has a clear, large pore above (Fig. 23). Tetrasporangia are scattered on both surfaces and are produced laterally from the outer cortical cells in the second or third layer from the surface. Tetrasporangia are broadly ellipsoidal, 28–37 µm long by 20–25 µm wide, cruciately divided, and embedded in the outer cortex (Figs. 24 and 25).

Discussion

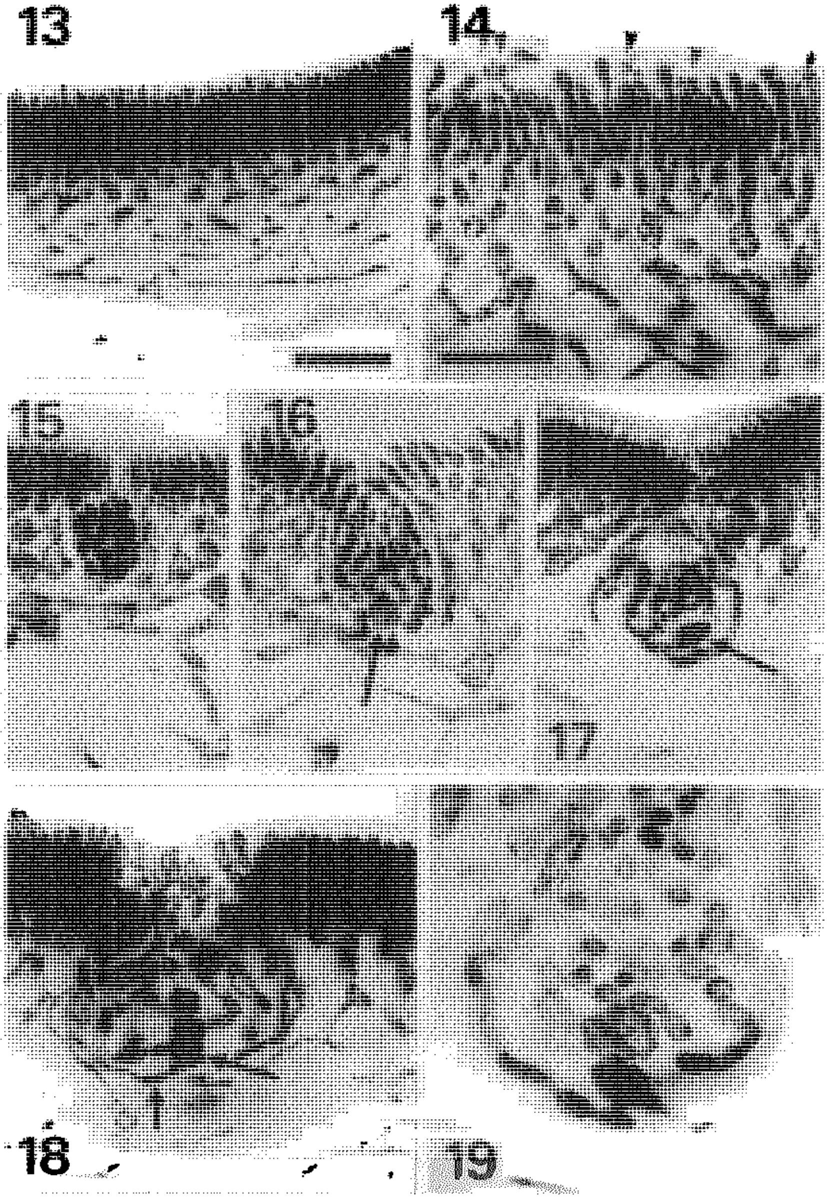
Among some 20 species of *Halymenia* reported in the Indo-West Pacific (Silva et al. 1996), the alga in question from Vietnam is most similar in several features to *H. maculata*, which was originally described by J. G. Agardh (1885) on the basis of material from Mauritius. Such features include deeply cleft or irregularly fringed blades, dark red color, somewhat carnose texture, clear maculae on the



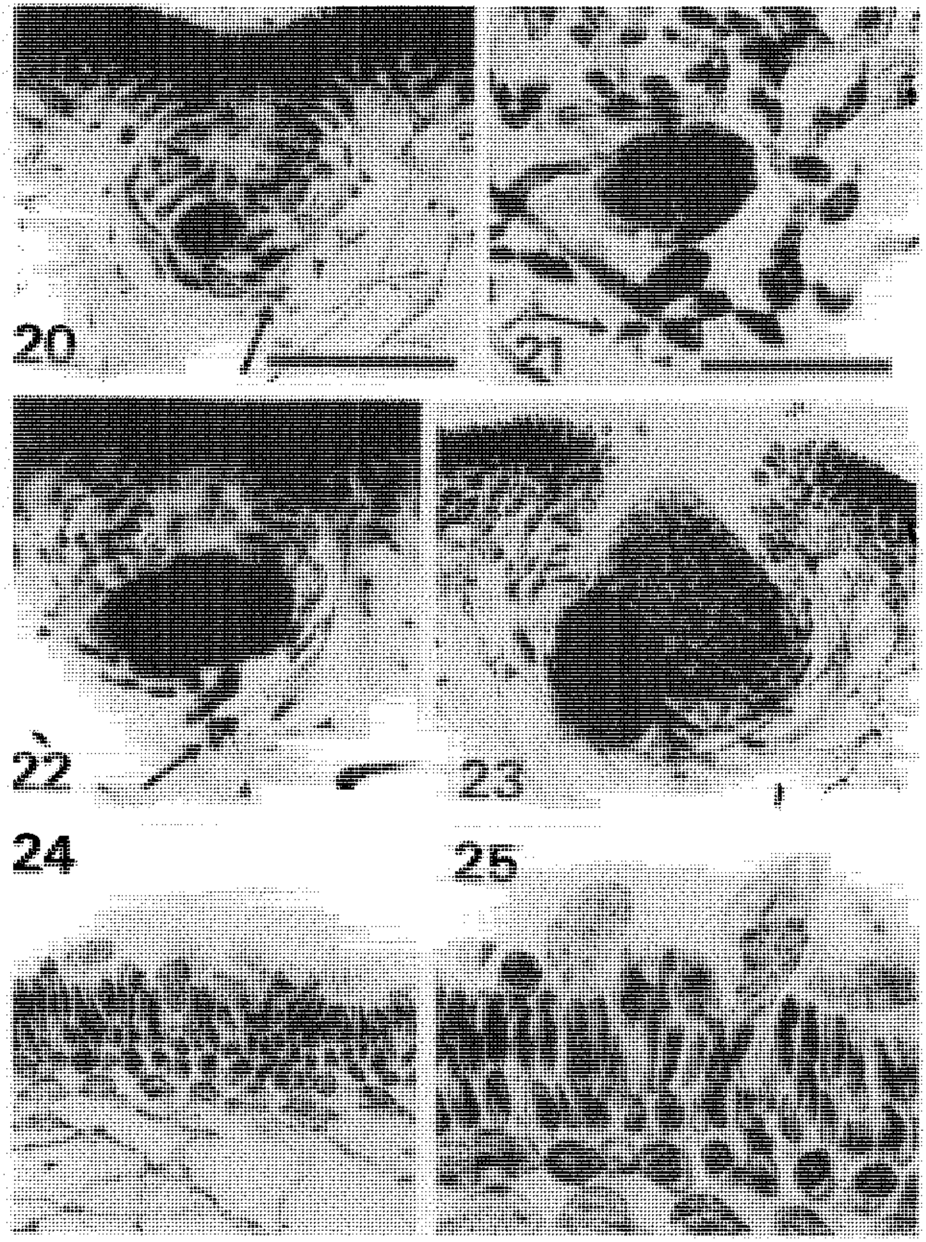
Figs. 1–6. Dried specimens of *Halymenia maculata* J. Agardh from Vietnam. Fig. 1, Sterile plant (Kawaguchi 1156). Fig. 2, Cystocarpic plant (Kawaguchi 1149). Fig. 3, Tetrasporangial plant (Kawaguchi 1151). Fig. 4, Spermatangial plant (Kawaguchi 1150). Fig. 5, Tetrasporangial plant (Kawaguchi 1154). Fig. 6, Spermatangial plant (Kawaguchi 1153). For all figures, scale bar = 5 cm.



Figs. 7–12. *Halymenia maculata* J. Agardh from Vietnam. Fig. 7, Cross section of a stipe (Kawaguchi 1153). Fig. 8, Transverse section of male plant (Kawaguchi 1150) with a refractive large stellate cell (arrow). Fig. 9, Transverse section of female plant (Kawaguchi 1149), arrow showing stellate cell. Fig. 10, Transverse section of tetrasporangial plant (Kawaguchi 1155). Fig. 11, Cortical construction of female plant (Kawaguchi 1149). Note elongated outermost cortical cells. Fig. 12, Cortical construction of tetrasporangial plant (Kawaguchi 1155). Scale bar = 600 μm for Fig. 7, 200 μm for Figs. 8–10 (shown in Fig. 8), and 50 μm for Figs. 11 and 12.



Figs. 13–19. *Halymenia maculata* J. Agardh from Vietnam. Figs. 13 and 14, Cross sections of a male plant (Kawaguchi 1150). Arrowheads in Fig. 14 indicate spermatia. Figs. 15–17, Cross sections of female plant (Kawaguchi 1149) with auxiliary-cell ampulla. Arrows in Figs. 16 and 17 indicate auxiliary cell. Fig. 18, Early stage of gonimoblast development. Note that gonimoblast initial cell is cut off from the auxiliary cell (long arrow) in contact with connecting filament (short arrow). Fig. 19, Slightly advanced stage of gonimoblast development. Scale bar = 50 µm for Figs. 13, 15–18 (shown in Fig. 13) and 30 µm for Figs. 14 and 19 (shown in Fig. 14).



Figs. 20–25. *Halymenia maculata* J. Agardh from Vietnam. Figs. 20 and 21, More advanced stage of gonimoblast development. Arrows indicate an initial cell producing outgoing connecting filament (arrowhead). Fig. 22, Immature cystocarp. Arrow indicates initial cell of outgoing connecting filament (arrowheads). Fig. 23, Mature cystocarp with 2 gonimolobes. Figs. 24 and 25, Cross sections of tetrasporangial plant (Kawaguchi 1151). Scale bar = 100 μm for Figs. 20, 22–24 (shown in Fig. 20) and 50 μm for Figs. 21 and 25 (shown in Fig. 21).

surfaces, and conspicuously elongate outermost cortical cells previously illustrated by Børgesen (1950) for the species. The only significant difference is that the Vietnamese plants usually have stout stipes, a feature not clearly noticed for this genus. In fact, when Abbott (1998) described a new species of *Halymenia*, *H. stipitata*, from the Hawaiian Islands, a species similar in several respects to *H. maculata*, she counted the absence of stout stipe in *H. maculata* as a main distinctive feature. Previously, we overlooked the presence of stipes in *H. maculata*, although on material from the type locality, Børgesen (1950) did observe this character and wrote that "the specimen has a quite short stipe scarcely 1.5 cm long." The longest stipe that we measured on the specimens at hand was 1.3 cm long. This value coincides well with that reported by Børgesen. Therefore, we see no strong reason to separate the Vietnamese plants from *H. maculata*. In our observation, *H. maculata* and *H. stipitata* can be distinguished on a combination of the following features: plant length, stipe-to-plant length ratio, and gross morphology. *Halymenia maculata* is 7–15 cm tall, with a stipe-to-plant length ratio of 0.02–0.2, and deeply cleft. In contrast, *H. stipitata* is 5–7 cm tall, with a stipe-to-plant length ratio of 0.2–0.3, and shallowly cleft.

In 3 types of plants (male, female, and tetrasporangial) of *Halymenia maculata* from Vietnam, whether young or old, the outermost cortical cells are conspicuously elongated. This feature is characteristic of this alga and might be associated with the dark red or purplish red color of the blades, although older plants of *H. dilatata* Zanardini also occasionally have this feature (Kawaguchi and Lewmanomont 1999). The rather thick cortex with moderate medullary filaments might cause its carnose texture, which contrasts with the texture of other members of this genus such as *H. floresia* (Clemente) C. Agardh, which has a very soft and gelatinous texture (Balakrishnan 1961, Codomier 1974).

Overall, morphological features of *H. maculata* are in good agreement with those of other members of the genus (Balakrishnan 1961, Codomier 1974 Womersley and Lewis 1994). The presence of an outgoing connecting filament with an initial cell connected to the auxiliary cell was reported also in *H. dilatata* (Kawaguchi and Lewmanomont 1999). This finding may suggest that *H. maculata* is closely related to *H. dilatata*, although the latter species is monoecious and generally has rounded to elliptical, bright red, soft, gelatinous blades.

We conclude that the Vietnamese alga clearly falls within the range of *H. maculata* irrespective of the presence of a stout stipe and is distinct from *H. stipitata* in plant length, stipe-to-plant length ratio, and gross morphology.

Acknowledgments

We thank Professor Isabella A. Abbott for inviting us to participate in this workshop. We also gratefully acknowledge the support of the California Sea Grant College Program and Dr. James Sullivan. The first author (S. K.) is deeply indebted to Professor Abbott for furnishing specimens of *H. stipitata* and library materials and especially for her continuous encouragement. This study was also in part supported by a Grant-in-Aid for Scientific Research (International Scientific Program, Field Research, No. 04041015) from the Ministry of Education, Science and Culture, Japan.

Literature Cited

Abbott, I. A. 1998. Some new species and new combinations of marine red algae from the central Pacific. Phycol. Res. 46:97–109.

Agardh, J. G. 1885. Til algernes systematik, VII. Lunds Univ. Arskrift 23, 117 pp., 1 pl.

Balakrishnan, M. S. 1961. Studies of Indian Cryptonemiales, III. *Halymenia* C. Ag. J. Madras Univ. B 31:183–217.

Børgesen, F. 1950. Some marine algae from Mauritius: additions to the parts previously published, II. Kongl. Danske Vidensk. Selsk. Biol. Medd. 18:1–44.

Codomier, L. 1974. Recherches sur la structure et le developpement des *Halymenia* C. Ag. (Rhodophycées, Cryptonémiales) des côtes de France et de la Méditerranée. Vie Milieu A 24:1–42.

Dawson E. Y. 1954. Marine plants in the vicinity of the Institut Oceanographique de Nha Trang, Viet Nam. Pac. Sci. 8:372–481.

Kawaguchi, S., and Lewmanomont, K. 1999. Morphology and culture study of a red alga, *Halymenia dilatata* Zanardini, from Vietnam and Japan. In: Tax. Econ. Seaweeds 7, pp. 147–161.

Silva, P. C., Basson, P., and Moe, R. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Press, Berkeley.

Womersley, H. B. S., and Lewis, J. A. 1994. Family Halymeniaceae In: Womersley, H. B. S. The marine benthic flora of southern Australia: Rhodophyta, part IIIA. Australian Biological Resources Study, Canberra, pp. 167–218.

FOLIOSE *HALYMENIA* (HALYMENIACEAE, CRYPTONEMIALES, RHODOPHYTA) FROM THAILAND

Khanjanapaj Lewmanomont and Shigeo Kawaguchi

Abstract

Two species of foliose *Halymenia* from Thailand, *H. dilatata* Zanardini and *H. maculata* J. Agardh, were studied. Morphological and anatomical structures of the 2 species were described and compared.

Introduction

Halymenia, a genus of red algae (Cryptonemiales), has been used as food in many countries. Silva et al. (1996) included 21 species in the Catalogue of the Benthic Marine Algae of the Indian Ocean. In Thailand, 4 species had been reported. The first report was that of Nateewathana et al. (1981), who reported *H. maculata* from Phuket, which was deposited in the reference collection at Phuket Marine Biological Center. Saraya et al. (1983) reported *H. durvillei* Bory and *H. harveyana* J. Agardh, now known as *H. floresia* subspecies *harveyana* Womersley et Lewis, collected from Phuket. Lewmanomont (1988) reported 2 species of *Halymenia* found on coral reefs in Thai waters: *H. durvillei* and *H. maculata*. One additional species, *H. dilatata* from Phuket, was added by Lewmanomont and Ogawa (1995). In all these reports, only gross morphological features were described. No details of anatomical characteristics and reproductive structures were reported.

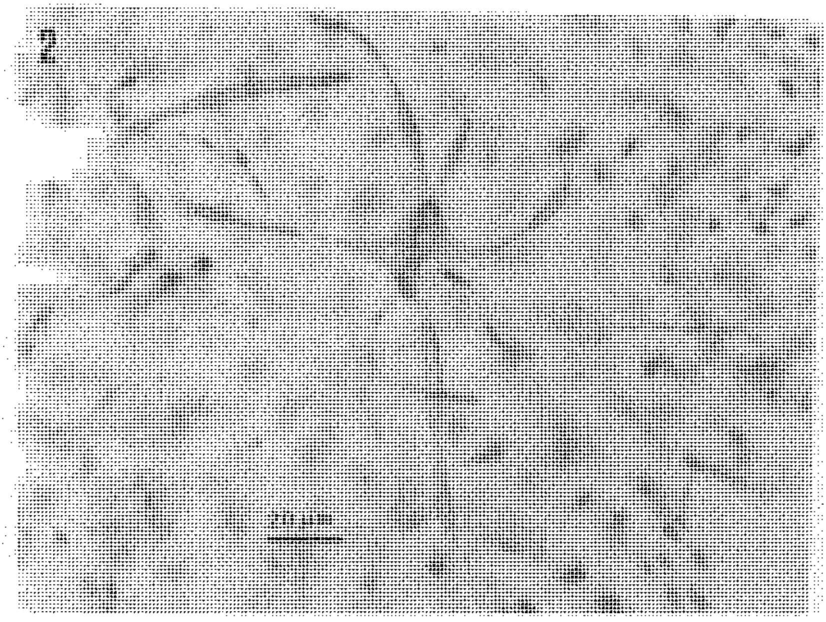
Materials and Methods

Herbarium specimens and liquid-preserved specimens of *Halymenia* kept in the Kasetsart University Museum of Fisheries (KUMF) in Bangkok were used for this study. The specimens of *H. dilatata* were collected by Khanjanapaj Lewmanomont in September 1975 from a sublittoral habitat at Haad Ra Wai, Phuket, and those of *H. maculata* by Suwan Sae Aueng in March 1985 from a subliltoral habitat at Ao Bang Klee, Phang Nga. Thin sections were made by hand by using a razor blade and a stereomicroscope. The sections were stained with aniline blue and examined with a light microscope.

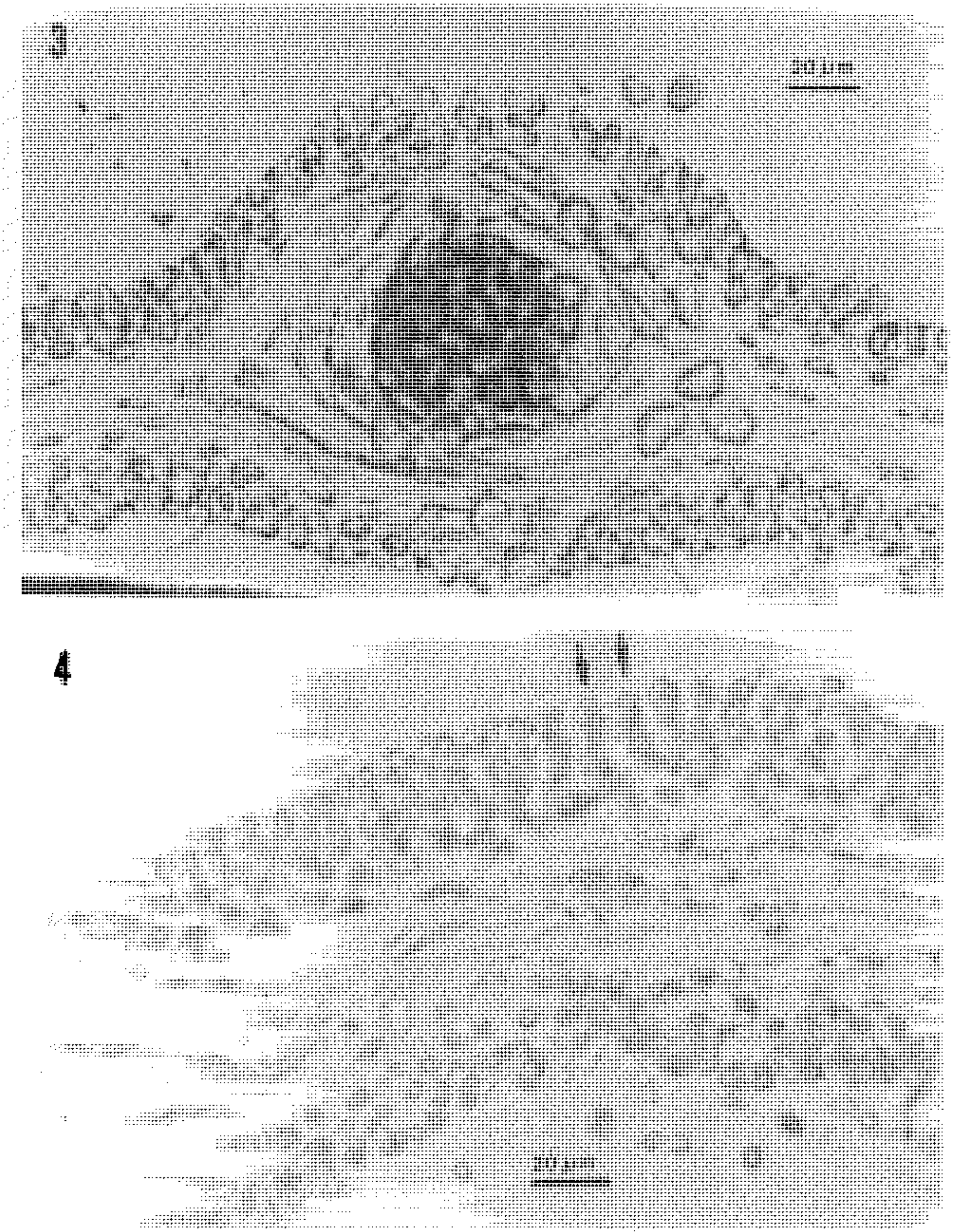
Results

Halymenia dilatata Zanardini, Flora 34:35, 1951.
(Figs. 1–4)

Plants are foliose, dark dull pink to pinkish brown, membranous with a soft texture, 10–16 cm tall, and 16–28 cm wide and attach to dead coral by means of a small discoid holdfast. Blades are suborbicular with reniform base and undulate



Figs. 1,2. ***Halymenia dilatata***. Fig. 1, Habit of plant. Fig. 2, Refractive ganglionic cell in surface view (squash).



Figs. 3,4. ***Halymenia dilatata.*** **Fig. 3, Mature cystocarp surrounded by thin filaments. Fig. 4, Transverse section of thallus with spermatangia (arrows).**

edge (Fig. 1). The blade margins are entire, crenulate to dentate, consisting of small toothlike protuberances.

In transverse sections of dried specimens, blades are 145–185 µm thick. The cortex is thin, consisting of 3–4 layers of cells. The outermost cortical cells are rounded to oblong, about 4–6 µm long and 3–4 µm wide. The medullary layer is composed of filamentous structures running periclinally to the surface and anticlinally through the medulla from one cortex to the other. Refractive ganglionic cells are stellate with many short and long arms (Fig. 2).

Plants are monoecious. Cystocarps are scattered over the surface as small blisters 150–180 µm in diameter. Mature carposporangia are spherical, 12–15 µm in diameter (Fig. 3). Spherical spermatangia 3–4 µm in diameter are superficially scattered on both surfaces (Fig. 4).

Remarks: Balakrishnan (1961) reported *H. dilatata* from Pamban, India, as a monoecious plant with blades 150–200 µm (rarely more) thick and a thin cortex consisting of 3–5 layers of cells. The outermost layer of the cortex was composed of short, cylindrical, rounded cells 3–6 µm wide and 3–6 µm long or occasionally slightly longer. Xia and Wang (1999) reported the same species from Xisha and Nansha islands, China, in which the thalli were 133–166 µm thick with a thin cortex with up to 4 layers of cells.

Descriptions of specimens from Phuket, Thailand, agree with those of specimens from India and China but differ from those of specimens from Kagoshima and Okinawa, Japan, and Nha Trang, Vietnam, which were reported by Kawaguchi and Lewmanomont (1999). The specimens from Japan and Vietnam had thicker thalli, 350–400 µm, and 5–7 layers in the cortex (Table 1). The difference in the thickness of the blades between the Thai and Japanese or Vietnamese *H. dilatata* might be related to the age or the environmental conditions, such as seawater temperatures.

Halymenia maculata J. G. Agardh, Lund Univ. Arskrift. Afd. Fysiograf. Sallsk. 21:12, 1885.

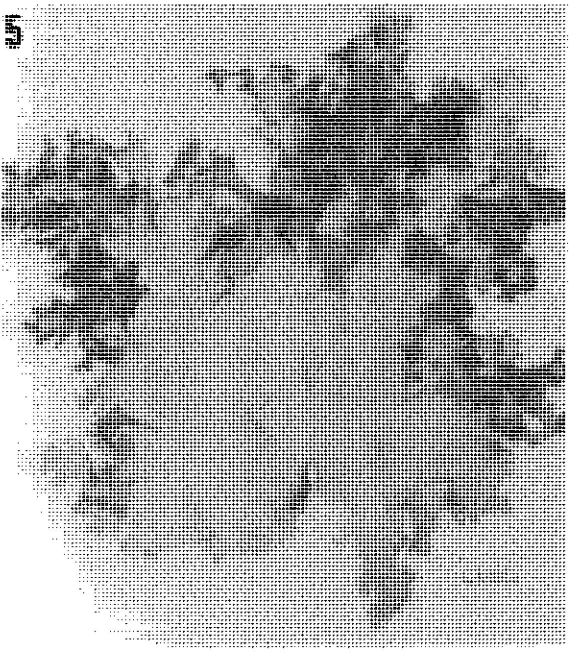
(Figs. 5–12)

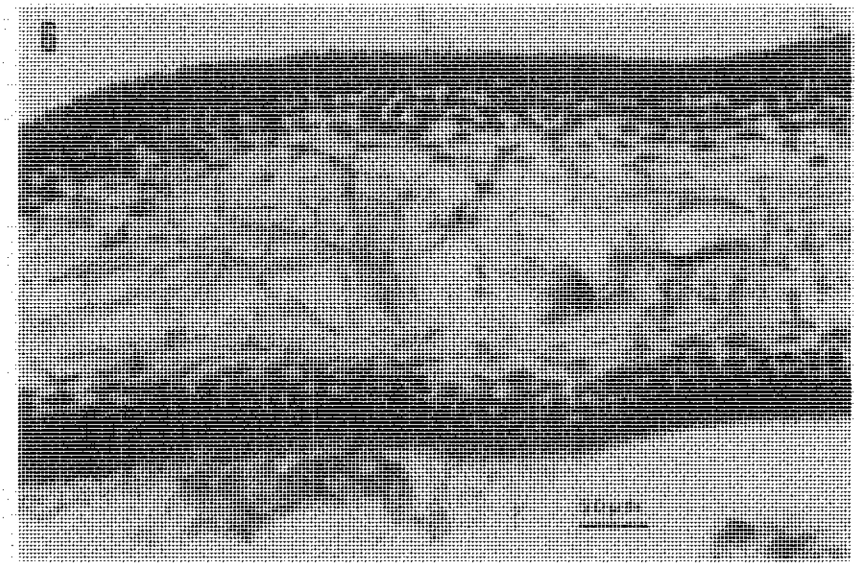
Plants are foliose, dark red with shades of yellow, rather rugose, 15–19 cm tall, and 10–23 cm wide and attach by a discoid holdfast with a stipe about 1 cm long. Blades are cleft with irregularly fimbriate margins (Fig. 5). The surface is somewhat erose, densely maculated with blotchy to spotted color variation from dark red to yellowish red. The texture is firm and slippery. The plants were found growing on dead coral in clear water about 2 m deep.

Plants are monoecious. Cystocarps are scattered over both surfaces of the thalli as small hemispherical blisters, 300–450 µm in diameter. In transverse sections, fronds are 210–320 µm thick and have a rather thick cortex of 4–6 layers of cells. The outermost cortical cells are oblong to elongate, 2–4 times as long as wide, arranged in pairs like rabbit ears (Fig. 7). Medullary filaments are mostly periclinally arranged with occasional anticlinal arrangement (Fig. 6). Refractive

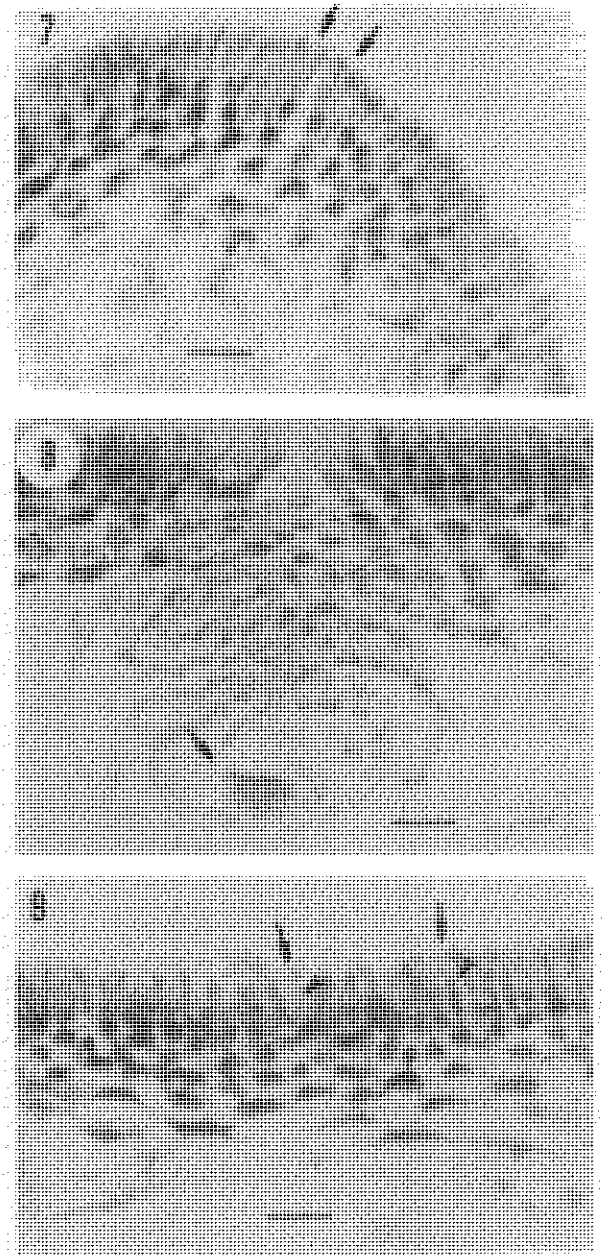
Table 1. Comparison of *Halymenia dilatata* From Various Countries

Characteristic	Country (Reference)			
	India **(Balakrishnan 1961)**	**Japan and Vietnam** **(Kawaguchi and Lewmanomont 1999)**	**China** **(Xia and Wang 1999)**	**Thailand** **(This study)**
Thickness of thalli, μm	150–200	350–400	133–166	145–185
Cortex, number of layers	3–5	5–7	4	3–4
Margins	Wavy and lacinate-dentate	Entire or mostly lacinate to sinuate	Entire, crenate or crisp	Entire, crenulate to dentate
Texture when fresh	No data	Lubricous, becoming rugose when aged	Gelatinous, membranous	Slippery and membranous
Reproductive plants	Monoecious	Only female	Only male	Monoecious
Outermost cortical cells	Short, cylindrical, rounded 3–6 μm or slightly longer	Elongate, up to 20 μm	Elliptical to oblong	Rounded to oblong

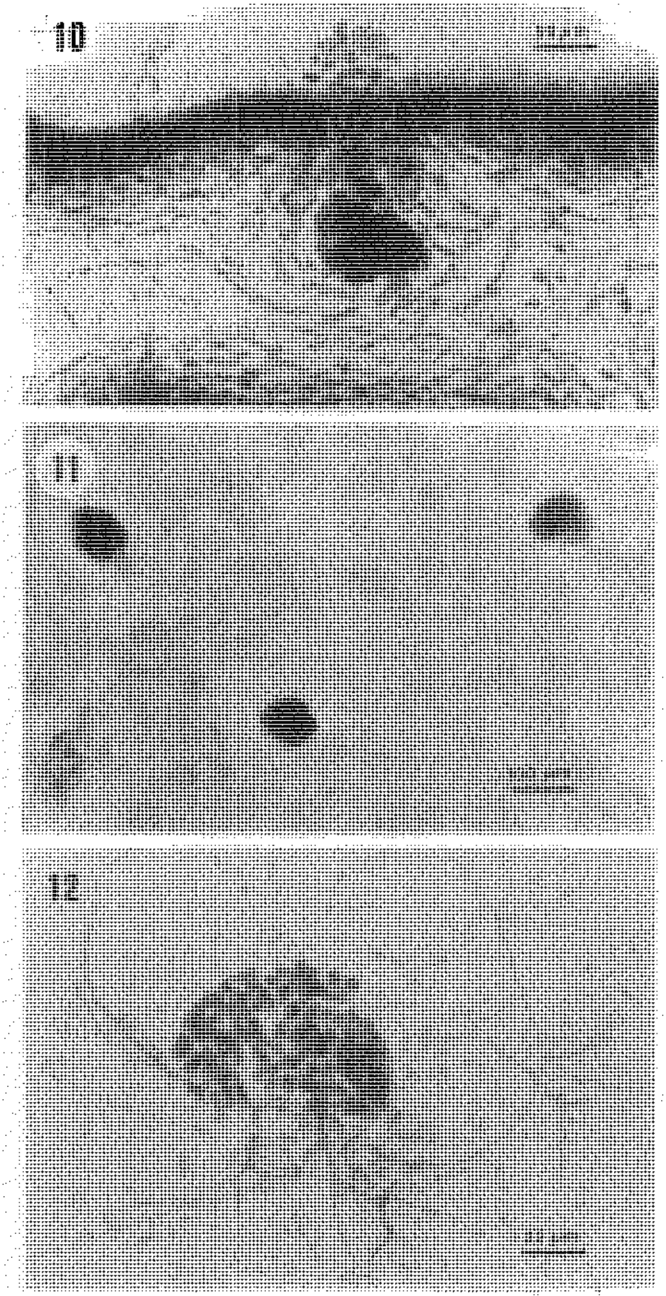




Figs. 5,6. *Halymenia maculata.* Fig. 5, Habit of plant. Fig. 6, Transverse section of thallus shows medullary filaments.



Figs. 7–9. *Halymenia maculata*. Fig. 7, Transverse section of thallus shows the arrangement of cortical cells and rabbit-ear cells (arrows). Fig. 8, Transverse section of thallus through an auxiliary-cell (arrow) ampulla. Fig. 9, Transverse section of thallus shows spherical spermatangia (arrows) and spermatangial mother cells (arrowheads). Scale bar = 25 μm for Figs. 7–9.



Figs. 10–12. *Halymenia maculata.* Fig. 10, Mature cystocarp. Fig. 11, Cystocarp with gonimolobes in surface view. Fig. 12, Gonimolobe with connecting filaments (squash).

ganglionic cells have many short and long arms. Female reproductive structures include auxiliary-cell ampullae (Fig. 8), and cystocarps are present. Mature carposporangia are 18–23 µm in diameter. Spherical spermatangia 3–4 µm in diameter are superficially scattered on both surfaces. Spermatangial mother cells develop from outermost cortical cells and are more elongated than are ordinary cortical cells (Fig. 9). Tetrasporangial plants were not found.

Remarks: Descriptions of specimens from Phang Nga, Thailand, agree with those of specimens from Nha Trang, Vietnam, reported by Abbott (1999), and with those of specimens from Hainan Island, China, reported by Xia and Wang (1999), with regard to the thickness of thalli and the fimbriate margins. The cortex of Thai specimens, reported as consisting of 4–6 layers, seems to be thicker than the cortex of specimens from Vietnam (4–5 layers) and China (3–4 layers). Abbott found male and female structures but did not mention whether they were on the same thallus or different thalli. Xia and Wang found only tetrasporangia; no cystocarps or spermatangia were seen. The specimens from Phang Nga, Thailand are monoecious (Table 2).

Table 2. Comparison of *Halymenia maculata* From Various Countries

Characteristic	Country (Reference)		
	Vietnam **(Abbott 1999)**	**China** **(Xia and Wang 1999)**	**Thailand** **(This study)**
Thickness of thalli, µm	250–300	282–365	210–320
Cortex, number of layers	4–5	3–4	4–6
Margins	Fimbriate	Fimbriate proliferation	Irregularly fimbriate
Texture when fresh	No data	Gelatinous, membranous	Firm and slippery
Reproductive plants	Male, female, and tetraspores	Tetraspores	Male and female Monoecious
Outermost cortical cells	No data	Elongated papillalike 13–20 µm	Oblong to elongate 2–4 times as long as wide

Discussion

Halymenia dilatata and *H. maculata* are foliose species. The 2 species can be distinguished from each other on the basis of the texture of fresh plants, the margins, the thickness of the thallus and cortex, the number of cell layers in the cortex, and the shape of the cells in the outermost layer of the cortex (Table 3). The spermatangial mother cells of both species are more elongated than are ordinary outermost cortical cells, sometimes more than 5 times as long as wide in *H. maculata.*

Table 3. Comparison of *Halymenia dilatata and H. maculata* From Thailand

	Country (Reference)	
Characteristic	***H. dilatata*** **(from Phuket)**	***H. maculata*** **(from Phang Nga)**
Texture when fresh	Membranous and soft	Slippery and firm
Margins	Entire, crenulate to dentate	Regularly fimbriate
Thickness of thalli, µm	145–185	210–320
Cortex, number of layers	3–4	4–6
Outermost cortical cells	Rounded to oblong	Oblong to elongate

Acknowledgments

We are grateful to Professor Isabella A. Abbott for correcting and editing the manuscript and for inviting us to participate in the workshop. Our sincere thanks to Dr. James Sullivan and the California Sea Grant College Program for financial support and also to Dr. Nguyen Tac An, Director of the Institute of Oceanography, Nha Trang, and his staff for their efforts in organizing the workshop.

Literature Cited

Abbott, I.A. 1999. Notes on some species of *Halymenia* in the southwestern Pacific. In: Tax. Econ. Seaweeds 7, pp. 163–172.

Balakrishnan, M. S. 1961. Studies of Indian Cryptonemiales, III. *Halymenia* C. A. Ag. J. Madras Univ. B 31:183–217, figs. 1–41, pl. VI.

Kawaguchi, S., and Lewmanomont, K. 1999. Morphology and culture study of a red alga, *Halymenia dilatata* Zanardini, from Vietnam and Japan. In: Tax. Econ. Seaweeds 7, pp. 147–161.

Lewmanomont, K. 1988. Marine algae of coral reefs of Thailand. Thai Fish. Gaz. 41:561–568.

Lewmanomont, K., and Ogawa, H. 1995. Common seaweeds and seagrasses of Thailand. Faculty of Fisheries, Kasetsart University, Bangkok.

Nateewathana, A., Tantichodok, P., Busarawich, S., and Sirivejabandhu, R. 1981. Marine organisms in the reference collection. Phuket Mar. Biol. Cent. Res. Bull. 28:43–82.

Saraya, A., Seelamak, B., Kannasutr, Y., and Loychusak, M. 1983. Marine algae of Phuket Island. Department of Fisheries, Bangkok. Publication No. 3.

Silva, P. C., Basson, P. W., and Moe, R. L. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Press, Berkeley.

Xia, B., and Wang, Y. 1999. Taxonomic studies on *Halymenia* (Halymeniaceae, Halymeniales, Rhodophyta) from China. In: Tax. Econ. Seaweeds 7, pp. 173–176.

PHENOLOGY AND SPORE GERMINATION IN A *HALYMENIA* POPULATION AT MAHAIULA BAY, HAWAII

Karla J. McDermid

Abstract

The population of an edible red alga, *Halymenia* sp., at Mahaiula Bay on the west coast of the island of Hawaii was monitored for 1 year. Data collected include number of plants, population structure based on reproductive state, morphological differences between tetrasporophytes and gametophytes, and spore germination patterns. Population size was greatest in summer months. Tetrasporophytes were present year-round, whereas the larger, bushier gametophytes were found only in summer months. Both tetraspores and carpospores were viable and in culture developed into branched acrochaetioid filaments, characteristic of the genus.

Introduction

In the summer of 1999, a Sea Grant extension agent sent I. A. Abbott and me specimens of an unidentified red alga that was "blooming" and washing up on the shores of Mahaiula Bay north of Kailua Kona on the west side of the island of Hawaii. The thalli collected in the drift were easily recognizable as belonging to the genus *Halymenia* C. Agardh and fit the description in Abbott (1999) of the most commonly occurring *Halymenia* in Hawaii: *H. formosa* Harvey ex Kützing. In fact, until recently (Abbott 1996, 1998, 1999; Kraft and Abbott 1997), *H. formosa* was considered the only *Halymenia* in the Hawaiian flora (Chamberlain 1880, 1881; Reed 1907; Rock 1913; MacCaughey 1918; Fortner 1978; Magruder and Hunt 1979; Abbott 1984). *Halymenia formosa* was first described by Kützing (1866) on the basis of a collection from the Friendly Islands (Tonga) and New Holland (Australia) by Harvey in Sonder's Herbarium. Kützing's Latin description (1866, p. 33) is as follows: "*H. grandis*, phycomate primario incrassate ramosissimo, ramis fastigiatim multifidis, ramulis crebris acutis spinaeformibus. Alga mollis, gelatinosa, intense coccinea." (Large *Halymenia* with main thallus thickly very much branched, with branches fastigiately cleft into many parts, with numerous, pointed, spinelike branchlets. Alga soft, gelatinous, intensely deep red-crimson.)

Kützing's (1866) illustrations on plate 91, figs. g and h (Fig. 1) show a piece of a narrow branch with up to 4 orders of narrow branchlets and a cross section with a two-layered cortex without obvious "rabbit-ear" elongated outermost cortical cells and a medulla of many periclinal, but few anticlinal, filaments. The characteristics of the *Halymenia* specimens from Mahaiula Bay and other Hawaiian specimens previously identified as *H. formosa* do not agree morphologically or anatomically with Kützing's description and illustrations of *H. formosa*. A thorough review of *H. formosa* from Hawaii is under way to determine if *H. formosa* is indeed present in the Hawaiian flora. Meanwhile, this study of the population of *Halymenia* sp. at Mahaiula Bay was completed to record the seasonal abundance, reproductive phenology, morphological variation, and spore germination pattern of the species, all pieces to the puzzle of its taxonomy.

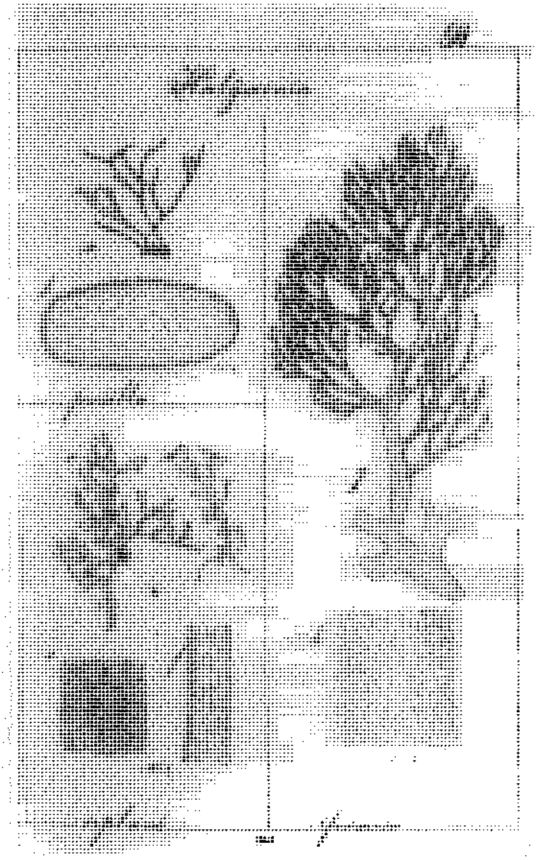


Fig. 1. Branch and cross section of *Halymenia formosa* Kützing on plate 91, figs. g and h on right. Reproduced from Kützing 1866.

Materials and Methods

The size and composition of the *Halymenia* population at Mahaiula Bay (lat 19º47′N, long 156º2′W; Fig. 2) on the island of Hawaii was assessed from July 1999 to June 2000. Surveys were made on July 3, September 19, and November 21 in 1999 and on January 17, March 4, and June 9 in 2000. On each date, individual *Halymenia* plants were counted by direct observation by snorkeling along the shoreline of the bay in water 1.7–3.3 m deep. The area of the zone surveyed was approximately 3000 m^2. Whole thalli including holdfasts or parts of fronds were sampled during each survey. Samples were dried and prepared as herbarium specimens. From this dried preserved material, sections were made by hand with a razor blade, rehydrated in a 4% formalin-seawater solution, stained with 1% aniline blue solution intensified with 1% hydrochloric acid, and mounted on microscope slides in a 25% Karo brand corn syrup solution.

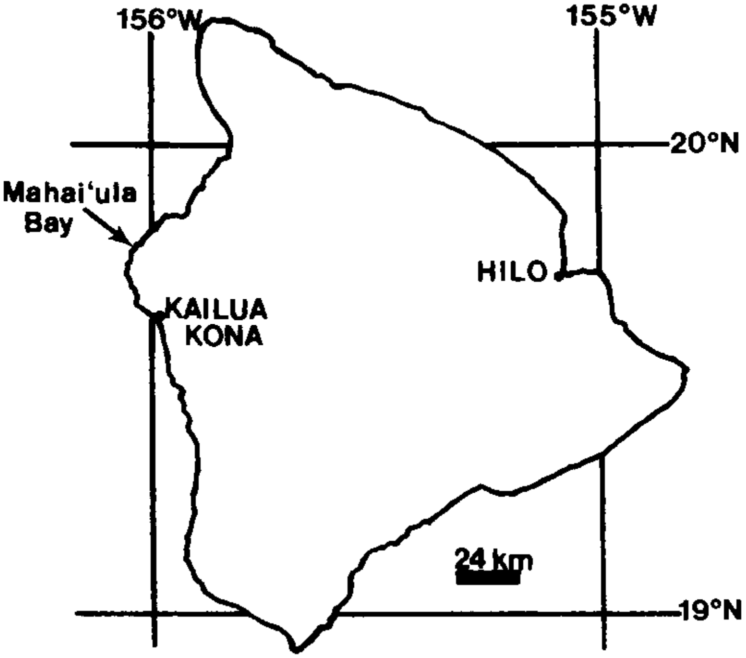
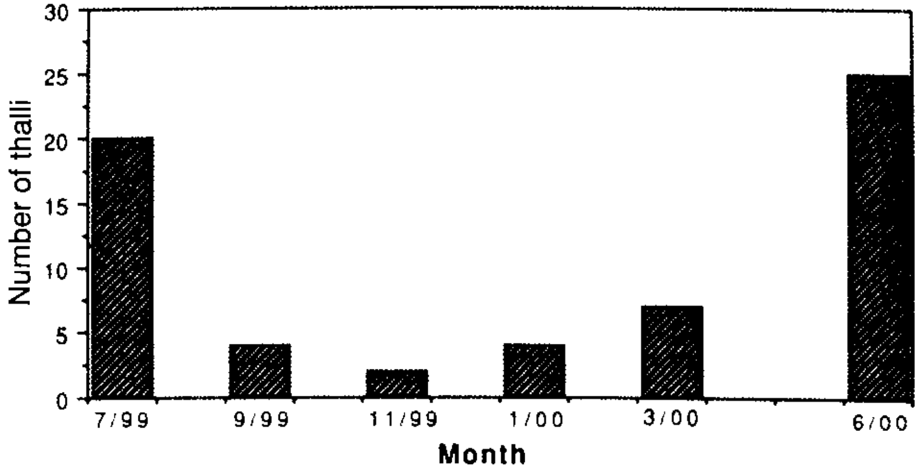


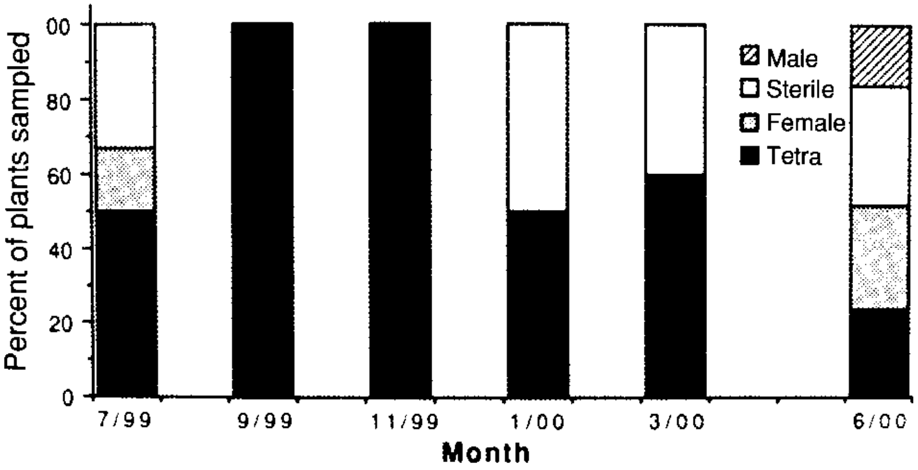
Fig. 2. Site where *Halymenia* population was found.

On June 9, 2000, thalli were brought to the laboratory in an insulated container. Parts of live, fertile female and tetrasporangial blades were placed in individual polystyrene petri dishes containing autoclaved seawater and were allowed to sit for 24 hours. Liberated carpospores and tetraspores were collected and transferred to sterile petri dishes containing Provasoli's Enriched Seawater Medium with modifications as described in McDermid (1989). Plants were grown at 23ºC–25ºC under natural light conditions. GeO2 (Germanium dioxide) was added to control diatom growth. The medium was changed every 2 weeks.

Results

The population size of *Halymenia* sp. at Mahaiula Bay had a seasonal pattern (Fig. 3). The greatest number of plants was observed in the summer months during the July 1999 and June 2000 surveys. Only 2 plants were seen in November 1999. In samples collected from September to March (the fall and winter months), only tetrasporophytes (identified on the basis of the presence of tetrasporangia) or sterile plants (without any distinguishable reproductive structures visible in cross sections) were present (Fig. 4). In summer months, female





Figs. 3,4. Fig. 3, Seasonal variation of *Halymenia* population size at Mahaiula Bay, Hawaii, July 1999–June 2000. Fig. 4, Composition of *Halymenia* population at Mahaiula Bay, Hawaii, July 1999–June 2000. Tetra indicates tetrasporophytes.

gametophytes at various stages of development composed 16.7%–28% of the population. Tetrasporophytes and sterile plants were also important components of the June and July populations. Male gametophytes, recognized on the basis of spermatangial sori, were observed only in June 2000 and accounted for 16% of the population.

When whole thalli with intact holdfasts were measured, on average, gametophytes were larger than tetrasporophytes (Table 1). Female gametophytes (Figs. 5 and 6) and tetrasporophytes (Figs. 7–9) generally formed 2 or more lobes immediately above the holdfast; however, females usually had broader lobes and more branches and branchlets than did tetrasporophytes. In male gametophytes (Figs. 10 and 11), a single main broad lobe with side branches arose from the holdfast.

Table 1. Comparison of Sizes of *Halymenia* Plants at Mahaiula Bay Hawaii*

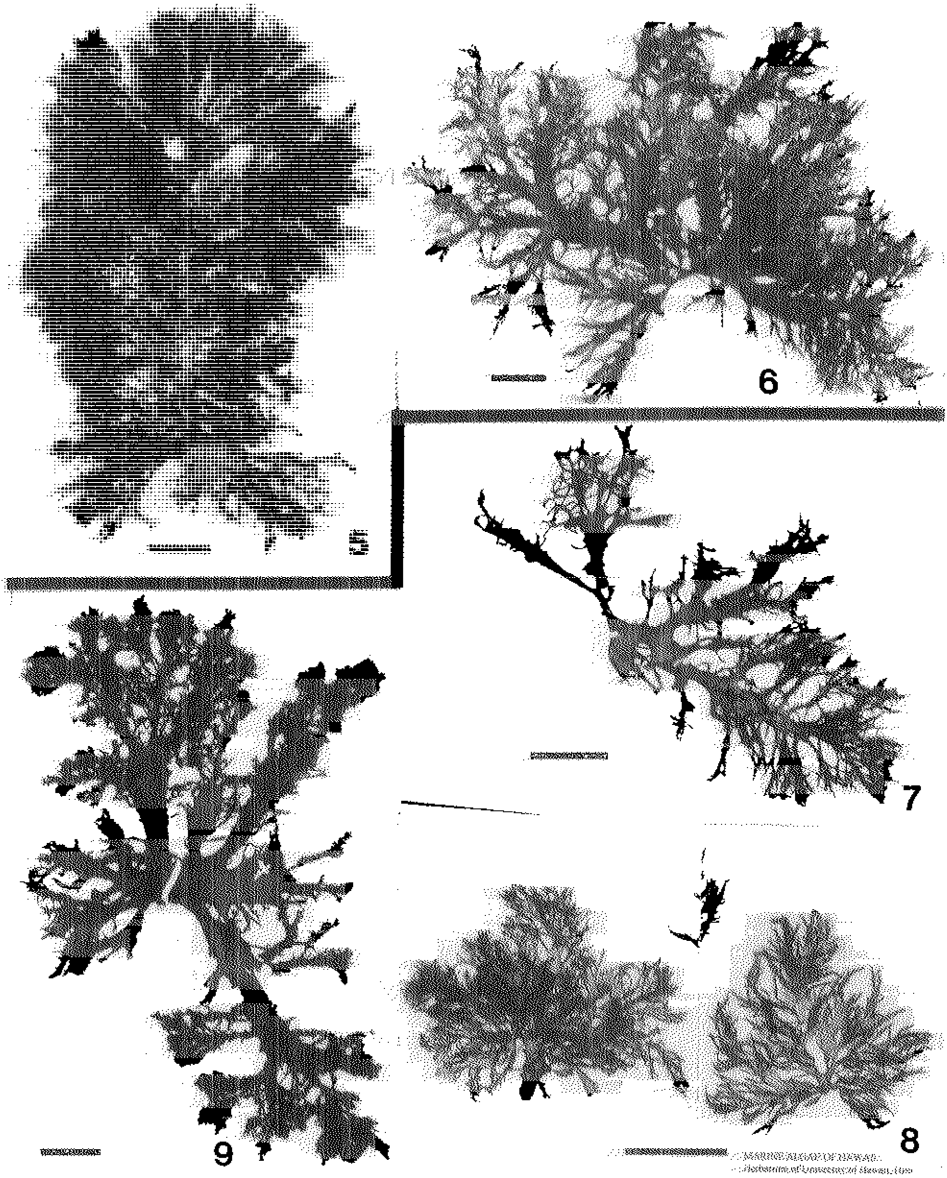
Plant	Height, mean (SD), cm	Width, mean (SD), cm	No. of plants measured
Tetrasporophytes	14.8 (6.53)	14.4 (8.90)	9
Female gametophytes	23.7 (4.51)	34.7 (11.85)	3
Male gametophytes	20.5 (3.54)	21.0 (9.90)	2

*Height was measured from holdfast to uppermost tip. Width was measured at broadest point approximately perpendicular to line of height.

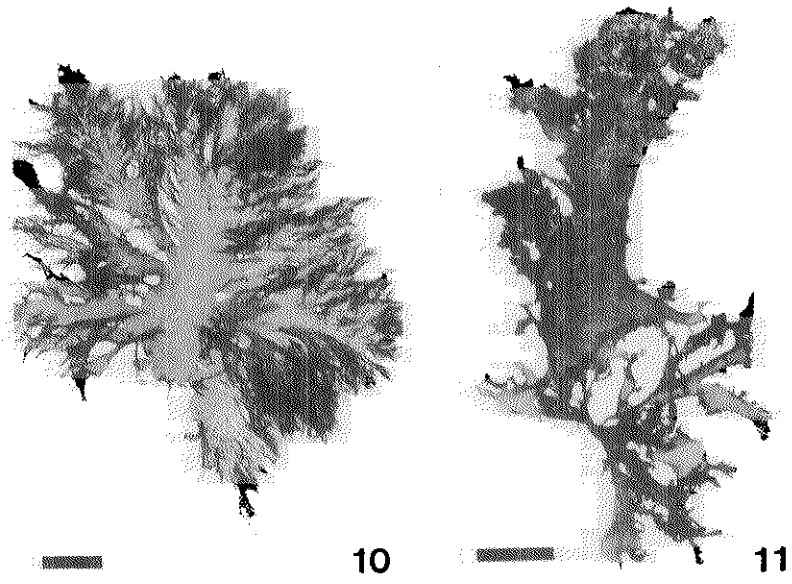
Viable tetraspores and carpospores were released continuously for 3–4 days from thalli brought to the laboratory. Germination occurred within 1–2 days of spore settlement, although some tetraspores remained ungerminated even after 1 month. During germination of both types of spores, after germ tube formation, the spore protoplasm evacuated the spore wall, moved into the germ tube, and divided into a multicellular, uniseriate filament (Figs. 12 and 13). Within 1 week of germination, the germlings were branched filaments. After 1 month of growth in culture, germlings differed in filament length and degree of branching (Figs. 14 and 15). Germlings from tetraspores seemed to grow more slowly than did germlings produced from carpospores.

Discussion

On collecting trips in the Hawaiian Islands, finding *Halymenia* plants is usually a hit-or-miss situation, and locating even one or two thalli is cause for celebration. However, at Mahaiula Bay, *Halymenia* predictably can be found year-round, with



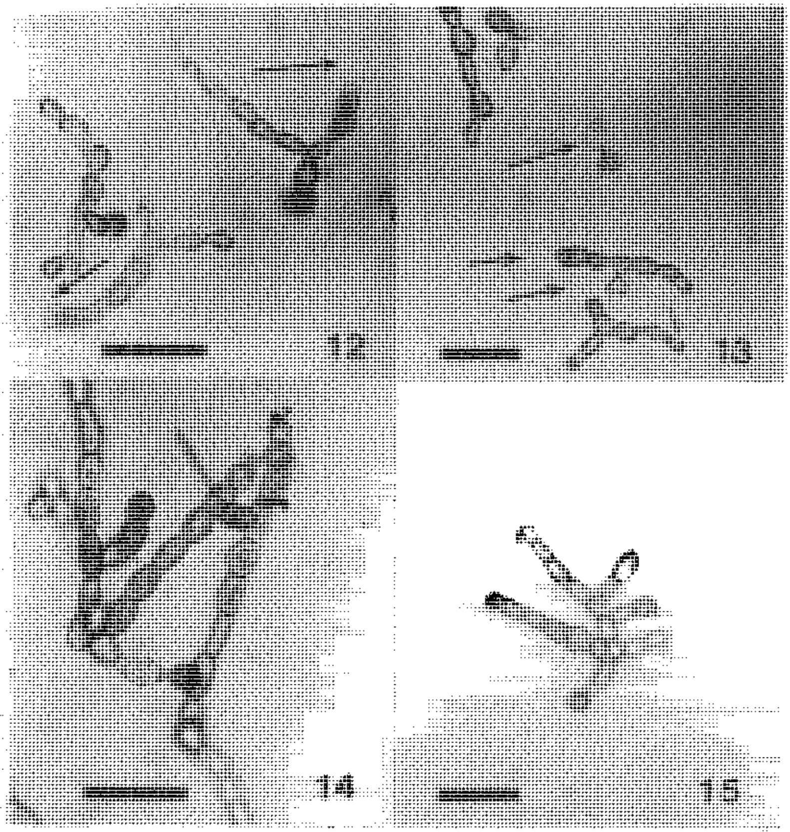
Figs. 5–9. Dried female *Halymenia* specimens from Mahaiula Bay, Hawaii. Scale bars = 4 cm. Fig. 5, Cystocarpic specimen (KM5068) collected July 3, 1999. Fig. 6, Cystocarpic specimen (KM5142) collected June 9, 2000. Figs. 7–9. Dried tetrasporangial *Halymenia* specimens from Mahaiula Bay, Hawaii. Scale bars = 4 cm. Fig. 7, Tetrasporangial specimen (KM5070) collected July 3, 1999. Fig. 8, Tetrasporangial specimens (AMK7) collected January 17, 2000. Fig. 9, Tetrasporangial specimens (KM5140) collected June 9, 2000.



Figs. 10–11. Dried male *Halymenia* specimens from Mahaiula Bay, Hawaii. Scale bars = 4 cm. Fig. 10, Spermatangial specimen (KM5141) collected June 9, 2000. Fig. 11, Spermatangial specimen (KM5143) collected June 9, 2000.

peak population and plant size in summer months. In studies of *Halymenia* in Europe, erect, foliose thalli of *Halymenia* were present only in certain seasons. In the Mediterranean, *H. floresia* fronds were reported only in the summer, and the populations overwinter as dark red "pom-poms" of acrochaetioid filaments (van den Hoek and Cortel-Breeman 1970). In Irish populations of *H. latifolia*, small, upright blades first appear in April, reach maximum size by December, and then degenerate, leaving acrochaetioid filaments derived from carpospores as the overwintering stage (Maggs and Guiry 1982).

The *Halymenia* population at Mahaiula Bay appears to be completing its life history within 1 year, based on the assumption that this species of *Halymenia* has an isomorphic polysiphonia-type triphasic life history. In summer, fertile female gametophytes release carpospores, which probably germinate into the tetrasporophytes seen in the fall and winter months. Their tetraspores would then develop into the gametophytes of the following summer. Sterile plants seen in January and March may be juvenile gametophytes. Data are needed on growth rates and longevity of individual thalli in situ and on the life history of plants in culture to determine the actual population dynamics of *Halymenia* at Mahaiula Bay.



Figs. 12–15. Cultured *Halymenia* germlings. Scale bars = 5 µm. Fig. 12, Two-week-old germlings of carpospores. Arrows indicate empty spore walls. Fig. 13, Two-week-old germlings of tetraspores. Arrows indicate empty spore walls. Fig. 14, Four-week-old germling of carpospore with branched uniseriate filaments. Fig. 15, Four-week-old germling of tetraspore. Note shortness of branches.

Most of the thousands of spores released by gametophytes and tetrasporophytes in the laboratory were viable and readily germinated within 1–2 days. The germination pattern of both carpospores and tetraspores included germ tube formation and subsequent uniseriate, branched acrochaetioid filamentous growth comparable to the pattern of other members of the genus: *H. floresia* (van den Hoek and Cortel-Breeman 1970); *H. floresia*, *H. latifolia*, and *H. trigona* (Codomier 1974); *H. latifolia* (Maggs and Guiry 1982); and *H. dilatata* (Kawaguchi and Lewmanomont 1999).

Growth of cultured Hawaiian *Halymenia* germlings seemed slower in this study than in other culture studies. No upright fronds were observed even after 1.5 months; whereas, Kawaguchi and Lewmanomont (1999) reported fronds forming in culture 1 month after germination of *H. dilatata* carpospores. Similarly, cultured *H. latifolia* carpospores produced erect plants in 58–101 days, and cultured tetraspores formed upright fronds in about 40 days (Maggs and Guiry 1982). Chen and Chen (1996) stated that in *H. microcarpa* cultures, the "filamentous stage can be turned into frond by changing the temperature," but they did not specify the temperature. Maggs and Guiry (1982) found that large mature fronds developed only in cultures with sterilized shells, and that in cultures on glass slides without shells, the fronds died soon after initiation. The apparently slow growth rate and longer development time in Hawaiian *Halymenia* cultures may be due to lower light levels, temperature conditions, or the lack of calcium carbonate material in culture. These variables remain to be tested in the laboratory.

Because of the great number of carpospores and tetraspores released in the laboratory within only a few days, and the even larger number of spores that are presumably being released in the wild population, I have questions about spore survival and recruitment at Mahaiula Bay. Are most of the *Halymenia* spores eaten by planktivores, or lost in the competition for space in the *Martensia fragilis* and *Laurencia* spp. understory, or consumed by grazers, or dispersed out of the bay?

This *Halymenia* species is favored as an edible seaweed by several ethnic groups in Hawaii (Fortner 1978, Abbott 1984). It may have potential for domestication, especially if spores could be seeded onto coral rubble and outplanted into appropriate local habitats. Future studies will provide valuable information on the life history, growth requirements, and accurate taxonomy of *Halymenia* in Hawaii.

Acknowledgments

Special thanks to Isabella A. Abbott for her encouragement of my work on Hawaiian *Halymenia*, to Ann M. Kreischer for the loan of her *Halymenia* specimens collected during her senior thesis work on edible Hawaiian seaweeds, and to Sara Peck for bringing the Mahaiula Bay population to our attention. My participation in this workshop was supported by California Sea Grant, Hawaii Sea Grant, and a University of Hawaii Research Council Travel Grant.

Literature Cited

Abbott, I.A. 1984. Limu: an ethnobotanical study of some Hawaiian seaweeds. 3rd. ed. Pacific Tropical Botanical Garden, Kauai, Hawaii.

Abbott, I. A. 1996. New species and notes on marine algae from Hawaii. Pac. Sci. 50:142–156, figs 1–27.

Abbott, I. A. 1998. Some new species and new combinations of marine red algae from the central Pacific. Phycol. Res. 46:97–108, figs. 1–26.

Abbott, I. A. 1999. Marine red algae of the Hawaiian Islands. Bishop Museum Press, Honolulu.

Chamberlain, J. E. 1880. Algae of the Hawaiian Islands. Thrum's Hawaiian Annual for 1881, pp. 32–33.

Chamberlain, J. E. 1881. Algae of the Hawaiian Islands. In: Whalle Nicholson, J. From sword to share; or a fortune in five years in Hawaii. W. H. Allen, London.

Chen, C.-S., and Chen, C. Y. 1996. Inorganic nitrogen (NH_4^+-N and NO_3^--N) uptake by red alga *Halymenia microcarpa* (Montagne) P. C. Silva. Acta Oceanogr. Taiwanica 35:283–295.

Codomier, L. 1974. Recherches sur la structure et le développement des *Halymenia* C. Ag. (Rhodophycées, Cryptonémiales) des côtes de France et de la Méditerranée. Vie Milieu A 24:1–42.

Fortner, H. J. 1978. The limu eater: a cookbook of Hawaiian seaweed [miscellaneous report]. University of Hawaii Sea Grant, Honolulu.

Hoek, C. van den , and Cortel-Breeman, A. M. 1970. Life-history studies on Rhodophyceae, II. *Halymenia floresia* (Clem.) Ag. Acta Bot. Neerl. 19:341–362.

Kawaguchi, S., and Lewmanomont, K. 1999. Morphology and culture study of a red alga, *Halymenia dilatata* Zanardini, from Vietnam and Japan. In: Tax. Econ. Seaweeds 7, pp. 147–162.

Kraft, G. T., and Abbott, I. A. 1997. *Platoma ardreanum* (Schizymeniaceae, Gigartinales) and *Halymenia chiangiana* (Halymeniaceae, Halymeniales), two new species of proliferous, foliose red algae from the Hawaiian Islands. Cryptogam. Algol. 18:97–116, figs. 1–27.

Kützing, F. T. 1866. Tabulae phycologicae. Vol.16. Privately published, Nordhausen.

Maggs, C. A., and Guiry, M. D. 1982. Morphology, phenology and photoperiodism in *Halymenia latifolia* Kütz. (Rhodophyta) from Ireland. Bot. Mar. 25:589–599.

MacCaughey, V. 1918. Algae of the Hawaiian Archipelago, II. Bot. Gaz. 65:121–149.

Magruder, W. H., and Hunt, J. W. 1979. Seaweeds of Hawaii, a photographic identification guide. Oriental Publishers, Honolulu.

McDermid, K. J. 1989. *Laurencia crustiformans* sp. nov. (Ceramiales, Rhodophyta) from the Hawaiian Islands. Phycologia 28:352–359.

Reed, M. 1907. The economic seaweeds of Hawaii and their food value. Hawaii Agric. Exp. Sta. Ann. Rep. pp. 61–88.

Rock, J. F. 1913. List of Hawaiian names of plants. Bot. Bull. Hawaii Board Agric. For. 2:1–20.

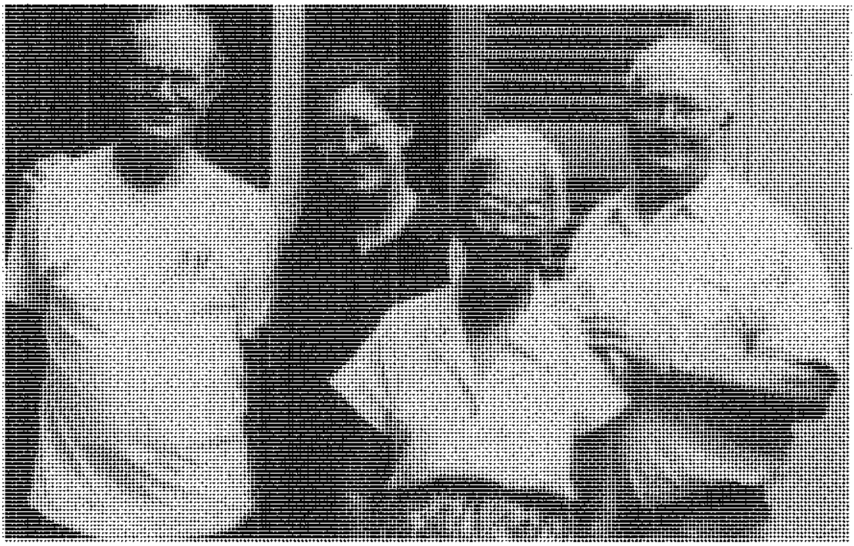
Section VI. The Marine Algae of Vietnam

INTRODUCTION

Isabella A. Abbott

One of the special goals for the eighth workshop in Nha Trang, Vietnam was to collect marine algae as widely as possible within the five days that we were there. The idea was to compare our species list with those of Dawson's 1954 study, and Pham Hoang Ho's 1969 study. Our purpose was not to show that we could collect a larger list but to see, in this relatively objective way, whether the marine flora had changed for the better or the worse. In many places in the West in and around various countries of Europe, parts of the United States, and in many islands in the Pacific (even without comparing species lists, which express diversity or species richness), the nearshore places near cities and industries that dump their wastes into the surrounding ocean are now species-poor. Everyone knows that some of the best *Porphyra* (*nori*) beds previously traditional in Tokyo Bay have within our lifetimes been moved elsewhere—out of the bay because of industrialization and pollution.

We are very happy to be able to say that the marine flora in the vicinity of Nha Trang has maintained its integrity, and indeed the flora appears to have gained in species number since 1954. New species continue to be added, and many new records were found for the area.



The General Flora Group. (Left to right): Jack Fisher, Karla McDermid, Isabella Abbott, James Sullivan.

NEWLY REPORTED AND REVISED MARINE ALGAE FROM THE VICINITY OF NHA TRANG, VIETNAM

Isabella A. Abbott, Jack Fisher, and Karla J. McDermid

Abstract

Several species of marine algae were collected from locations near the Institut Océanographique de l'Indochine, Nha Trang, Vietnam, by participants in the eighth Sea Grant workshop in late April 1999. The marine flora of Vietnam is known from earlier studies of Dawson and Pham Hoang Ho, the latter being brought up to date by Nguyen Huu Dinh et al. recently. The Dawson paper, because written in English, has been widely used as a guidepost for flora in the western Pacific. A few smaller studies added a few more species to the totals from these major studies. The total numbers of Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae) from these studies are 47, 34, and 167 species, respectively; the blue-green algae (Cyanobacteria) and the crustose coralline algae in the Rhodophyta are not included. Duplicate names occur in the reports of Dawson and Pham. After the duplicate names are eliminated, the total number of species is 243. We report here 125 species that we collected and identified, providing a total of about 278 species. Of these, 46 are new distribution records, a surprisingly large number because the geographic focus was the same as that of the 3 previous studies, and those earlier studies were conducted over longer periods than our 5-day stay in Nha Trang. Also given is a list of species names that have been changed since the earlier publications. Most of these changes are nomenclatural. Two of the new records of *Polysiphonia*-like species are transferred to *Neosiphonia* M. S. Kim et I. K. Lee, a new usage outside the Korean flora. Two new species are listed here, but are being published elsewhere.

Introduction

E. Yale Dawson (1954) published an annotated list of marine algae from the vicinity of Nha Trang that was the first major report in English of the marine algae of an Asian locality. When the blue-green and crustose coralline algae are excluded, he described a total of 92 genera and 184 species. Dawson's collections were made in the winter of 1953. Pham Hoang Ho (1967) published an extensive study of *Sargassum* species from Vietnam and later a study of general flora (Pham 1969). Pham's flora included a total of 99 genera and 203 species, plus blue-green and crustose coralline algae, and covered a larger geographic area than did Dawson's studies—from Nha Trang south to the border with Cambodia.[1]

Pham's 1969 study of marine flora is written in Vietnamese, and even when translated, the material does not lend itself well to critical descriptions that a principally English-language person would understand unequivocally. It is not

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[1] We do not include the taxa of bluegreen algae and crustose coralline algae because their identification varies widely among investigators. It is difficult to equate names used in publications 40 years old with any current classification of these groups without examining the specimens cited. These are unavailable. I.A.

clear, for example, if taxa previously identified and listed by Dawson (1954) and included in Pham's list were also collected by Pham. On the other hand, Pham was clearly the collector of some of the taxa on his own list. For example, 12 taxa of red algae not described by Dawson are included in Pham's list, including several noncontroversial records new to Vietnam, such as *Gloiopeltis minuta* and *Desmia* (*Portieria*) *hornemannii*. However, for many taxa, as indicated by Nguyen (1992) for *Gracilaria* and *Gracilariopsis*, Pham repeated the species named by Dawson. Both names (*Gracilaria verrucosa* and *Gracilariopsis rhodotricha*) were misapplied to Vietnamese specimens (Nguyen 1992; Abbott, personal observation) by Dawson (1954), and the mistaken identifications were repeated by Pham (1969). Lack of access to Pham's herbarium hampers a critical resolution of similar discrepancies or questions.

Several chapters have been published recently on Vietnamese flora. These include information on *Sargassum* (Ajisaka et al. 1995); species of *Eucheuma* and *Kappaphycus* (Nguyen and Huynh 1995); *Sargassum duplicatum* (Ajisaka, Huynh, Nguyen, Lu, Ang, Phang, Noro, and Yoshida 1997); *S. hemiphyllum* var. *chinense* (Ajisaka, Huynh, Lu, Chiang, and Yoshida 1997); two Vietnamese entities of *Sargassum* (Ajisaka, Huynh, Nguyen, and Yoshida 1997); and, finally, new taxa of *Sargassum* (Nguyen and Huynh 1999). All of these chapters were published in previous volumes based on the results of Sea Grant workshops. A translation of material by Nguyen Huu Dai published earlier in Vietnamese on a few species of *Sargassum* appears in this volume.

A further important article, describing species with very wide Pacific distribution, was written earlier by Tanaka and Pham (1962) and includes information on 2 species of red algae subsequently found to be common in the Hawaiian Islands (*Porphyra vietnamensis* Tanaka et Pham Hoang Ho and *Grateloupia phuquocensis* Tanaka et Pham Hoang Ho).

Materials and Methods

Specimens were collected by snorkeling, principally around Cau Da Village, a short distance south of Nha Trang City on a peninsula on which the Bao Dai summer palace is located; the area is referred to as Bao Dai in this chapter. The collecting area covered is roughly from the seashore outside the Institut Océanographique eastward and north to the tip of the peninsula, a distance of about 1 km. The bottom is rocky with rocks or shelves barely exposed at low tide. Nguyen Xuan Vy, Shigeo Kawaguchi, and one of us (J. F.) contributed specimens from that area. Other shore areas were reached closer to Nha Trang City at Hon Chong by Lu Baoren, Khan Lewmanomont, Anong Chirapart, Ryuta Terada, and Bernabé Santelices. A ship belonging to the Institut Océanographique took Nguyen Xuan Vy, Pham Huu Tri, Michio Masuda, Satoshi Shimada, Tadahide Noro, Tetsuro Ajisaka, Tadao Yoshida, and 2 of us (J. F. and K. M.) to 2 sites (near lat 12°13′887″N, long 109°14′461″E) off Tre "Black Rocks" and 2 sites (near lat 12°8′685″N, long 109°13′463″E) off Hon Mieu (Tam Island) south of Cau Da Village, Song Lo Cua Be (on rock), and Nuu Cau Hin. Dredge hauls were estimated to be at depths of about 5–6 m and snorkeling at about the same depths. After the return to the laboratory, some specimens were pressed as herbarium sheets, and a few were prepared in 4%–5% formalin solution for future microscopic studies and sectioning. About 240 microscope slides were prepared and 56 herbarium sheets.

Collection Sites

A general description of the 6 main collecting places follows (see map).

1. Bao Dai. The shoreline is composed of granite rock. Low intertidal level to a depth of about 2 m is dominated by relatively dense young *Sargassum* and isolated clumps of *Colpomenia*. *Halimeda* was mainly confined to large, heavily silted beds at this level. Two *Halymenia* species started at this depth and continued to depths of 3–3.5 m. Below 3.5 m were a few hard and soft coral genera, but almost no algae. A segment of nylon cord was found that had many epiphytes, which were not observed on the macroalgae in the area. Most of the collections from this site were made by one of us (J. F.). A small collection was made by Shigeo Kawaguchi and was given to us for reporting purposes. This site is east and north of the Institut Océanographique, and is surrounded on 2 sides by Cau Da Village.

2. Black Rocks. This site is an isolated group of rocks in deep water off the northwest side of Tre Island. It has a heavy wave area with very few algae; algae seem to be restricted to the surge zone and slightly deeper. Tre Island is relatively large and fronts the area opposite and south of Cau Da Village.

3. Tre Island. Collections from Tre Island were from Bai Tre, a small bay on the northwest side of the island. The bay has a fairly shallow zone (possibly, higher levels are exposed at low spring tides) of rugged, dead coral with conspicuous stands of blue-green algae. A wide range of algae was found in this locality.

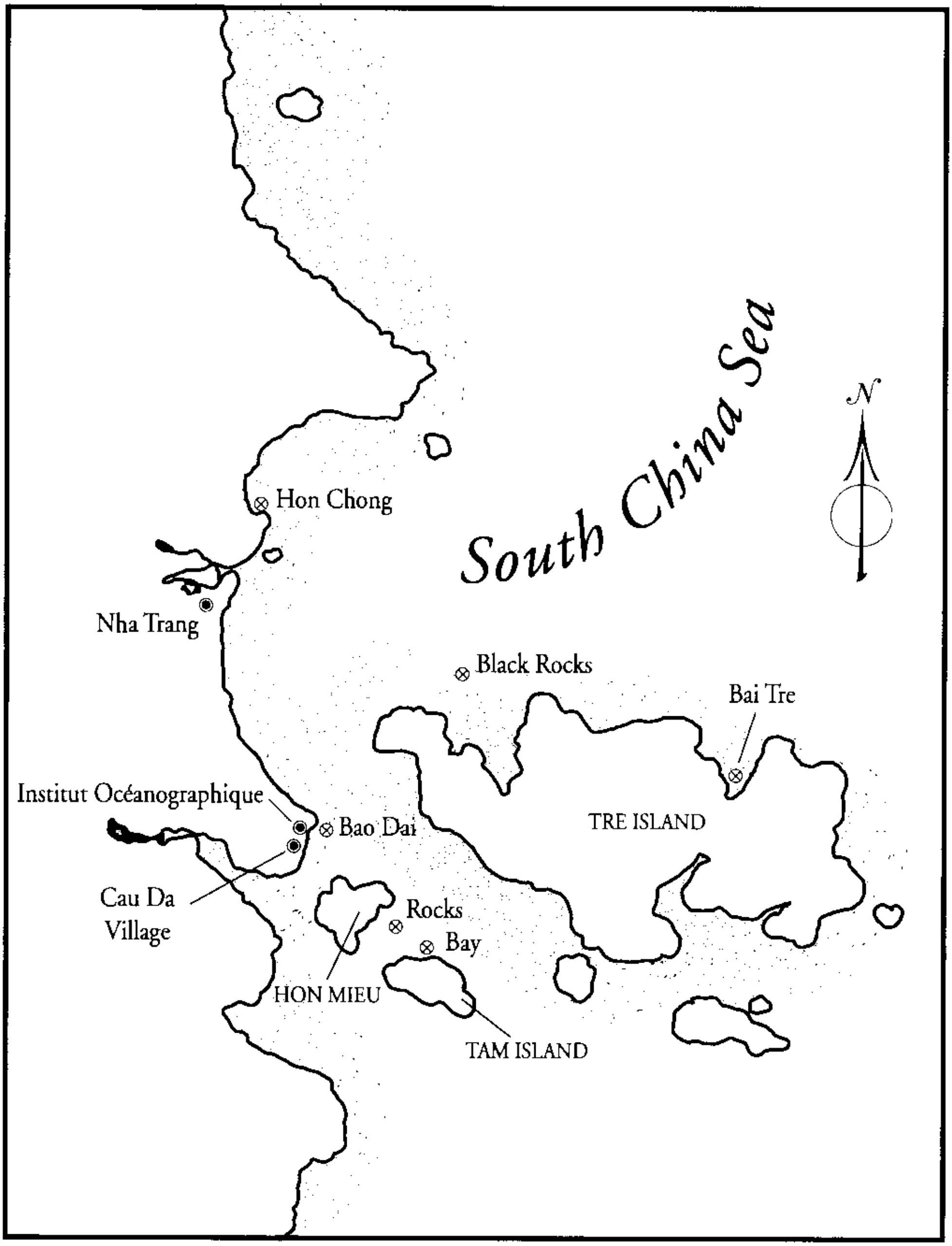
4. Hon Mieu Rocks. Algae were collected from rocks located between Hon Mieu and Tam islands. Large beds of blood-red *Ganonema farinosum* were found subtidally.

5. Tam Island. Algae were collected from the bay on the northwest side of the island. This location was a very productive area for epiphytes, which were found on old monofilament netting and a piece of cloth. The area is similar to the Black Rocks site but has deeper areas between higher dead coral formations. Many plants of *Gelidium*, *Gracilaria*, and *Hypnea* were found. Most of the collections gathered from these sites and reported here were made by Nguyen Xuan Vy and 2 of us (J. F. and K. M.).

6. Hon Chong. Algae were collected from the shore along the coast north of Cau Da Peninsula, on rock. Collections were made by Lu, Lewmanomont, Anong, and Terada.

Disposition of the Collections

The first set of herbarium sheets and slides prepared at the Bishop Museum (BISH) will remain there; the second set will be sent to the Institut Océanographique in Nha Trang. The *Sargassum* specimens were taken by the



Map of the city of Nha Trang and its southern vicinity showing Bao Dai peninsula and the Institut Océanographique, as well as collecting places. Graphics by Karla McDermid.

"Sargassum Group," and we hope that when the plants are identified, duplicates will be sent to the Bishop Museum and a set deposited at the Institut Océanographique. Nguyen Huu Dai gave us the names of the most common species in Nha Trang Bay. When material permits, as many species as possible will be sent to the U.S. National Herbarium, Smithsonian Institution (U.S.), to join Dawson's first set of algae from Vietnam. The Bishop Museum has Dawson's second set.

Results

Although we were unable to examine the specimens listed by Pham (1969), we did have access (in the Bishop Museum) to the second set of Dawson's (1954) specimens, which contain most of the species described by Dawson. Consequently, we can tally the marine flora of southern Vietnam, particularly in the vicinity of Nha Trang, with some confidence.

The lists of species in the studies by Dawson (1954), Pham (1969), and Nguyen et al. (1993) were examined, and duplicate names of species were removed. This step gave a total of 243 species (the names of species of Cyanobacteria and crustose coralline algae described by these authors but not collected by us were not included). We collected about 125 species (Table 1), about 50% of the known flora. Of the 125, a total of 46 are new records for Vietnam. In the following sections, we do not list all the known flora because the publications of Dawson, Pham, and Nguyen et al. are still available for reference. Instead, we list what we collected, and we tried to match these specimens to previously collected specimens. In the last section, we list the names of taxa that were changed.

The species listed in Table 1 are arranged alphabetically within the Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae). The species we collected and identified are given in column 1. Columns 2–5 refer to the publications of Dawson (1954), Pham (1969), and Nguyen et al. (1993) and to this chapter (Abbott et al. 2002). Column 6 gives one or more collecting locations for the 1999 specimens, although in many cases more collections were made at other sites. The point of this table is the record of occurrence or biogeographic distribution, not the abundance or seasonality. The taxa in this table that represent records new to Vietnam are described in detail in the next section. These species have never been reported for Vietnam previously. A few species previously recognized under other names are also noted.

The final section gives names that are in current use (Silva et al. 1987, Silva et al. 1996) and that on nomenclatural grounds supersede names that were used by Dawson (1954) and Pham (1969). The species are the same but bear different (earlier or correct) names than the names used by Dawson and Pham. A few algae that had been incorrectly identified previously are included; examination of the specimens upon which those names were given is the basis for a different opinion or correction.

Table 1. Vietnam Algae Collected April 1999
x = present; o = absent; D = different name; ? = uncertain

Species name and author	Dawson 1954	Pham 1969	Nguyen et al. 1993	Abbott 2002	Locations in 1999	IA #
GREENS						
Anadyomene wrightii Harvey ex J.E. Gray	x	x	o	x	Tre Island	24180
Boodlea composita (Harvey & Hooker) Brand	x	x	x	x	Tam Island	24135
Caulerpa racemosa (Forsskål) J. Agardh var. *marcrophysa* (Sonder ex Kützing) W.R. Taylor	x	o	x	x	Tre Island	24083
Caulerpa serrulata (Forsskål) J. Agardh	o	x	o	x	Bao Dai	Kawaguchi
Caulerpa verticillata J. Agardh	x	x	o	x	Hon Mieu Rock	24104
Chaetomorpha crassa Kützing	x	x	x	x	Hon Chong	24179
Cladophora socialis Kützing	o	x	o	x	Tre Island	24181d
Cladophora vagabunda (Linnaeus) van den Hoek	x	x	“x,D”	x	Bao Dai	24018
Cladophoropsis membranacea (C. Agardh) Børgesen	x	x	x	x	Tam Island	24146
Derbesia attenuata Dawson	x	x	o	x	Tam Island	24122a
Dictyosphaeria cavernosa (Forsskål) Børgesen	x	x	o	x	Bao Dai	Kawaguchi
Dictyosphaeria versluysii Weber-van Bosse	x	x	o	x	Black Rock	24042
Halimeda discoidea Decaisne	x	x	o	x	Tre Island	24069
Halimeda opuntia (Linnaeus) Lamouroux	x	x	o	x	Tre Island	24113
**Microdictyon japonicum* Setchell	o	o	o	x	Tam Island	24143
Neomeris annulata Dickie	o	x	o	x	Bao Dai	Kawaguchi
Neomeris van-bosseae Howe	o	x	o	x	Tam Island	24118
Ulva “lactuca” Linnaeus	x	x	x	x	Tam Island	24214
Ulva reticulata Forsskål	o	x	o	x	Hon Chong	24178
BROWNS						
Colpomenia sinuosa (Roth) Derbes et Solier	x	x	x	x	Bao Dai	24034
**Dictyota crispata* Lamouroux	o	o	o	x	Hon Mieu Rocks	24102
Dictyota friabilis Setchell	x	x	x	x	Black Rock	24047
Hincksia indica (Sonder) J. Tanaka	“x,D”	“x,D”	“x,D”	x	Tam Island	24152
Hincksia breviarticulata (J. Agardh) P.C. Silva	x	"x,D"	o	x	Black Rock	24046
Hincksia mitchelliae (Harvey) Silva, Menez et Moe	“x,D”	“x,D”	“x,D”	x	Black Rock	24045
Hydroclathrus clathratus (C. Agardh) Howe	x	x	x	x	Bao Dai	Kawaguchi
Kuetzingiella elachistaeformis (Heydrich) Balakrishnan et Kinkar	“x,D”	“x,D”	o	x	Tam Island	24161
Lobophora variegata (Lamouroux) Womersley	x	x	x	x	Black Rock	24054

Table 1 (continued)

Species name and author	**Dawson 1954**	**Pham 1969**	**Nguyen et al. 1993**	**Abbott 2002**	**Locations in 1999**	**IA #**
Padina australis Hauck	o	x	x	x	Bao Dai	24037
Sargassum crassifolium J. Agardh	x	x	o	x	Nhatrang Bay	Nguyen Huu Dai
Sargassum mcclurei Setchell	x	x	x	x	Black Rock	24040
**Sargassum oligocystum* Montagne	o	o	o	x	Nhatrang Bay	Nguyen Huu Dai
Sargassum polycystum C. Agardh	x	x	x	x	Nhatrang Bay	Nguyen Huu Dai
**Sargassum* sp. nov.	o	o	o	x	Nhatrang Bay	Nguyen Huu Dai
Sphacelaria novae-hollandiae Sonder	x	x	o	x	Black Rock	24061
Sphacelaria rigidula Kützing	x	x	x	x	Bao Dai	24011
Sphacelaria tribuloides Meneghini	x	o	o	x	Tam Island	24215
Turbinaria ornata (Turner) J. Agardh	x	x	x	x	Bao Dai	24012
Zonaria stipitata K. Nozawa	o	x	o	x	Tam Island	24140
REDS						
Acanthophora spicifera (Vahl) Børgesen	x	x	o	x	Bao Dai	24028
**Acrochaetium barbadense* (Vickers) Børgesen	o	o	o	x	Tre Island	24000b
**Acrochaetium catenatulum* Howe	o	o	o	x	Tam Island	24151
**Acrochaetium liagorae* Børgesen	o	o	o	x	Tre Island	24195
Acrochaetium seriatum Børgesen	o	x	o	x	Tam Island	24218
Acrochaetium thuretii (Bornet) Collins et Hervey	o	o	x	x	Bao Dai	24026
Actinotrichia fragilis (Forsskål) Børgesen	x	x	o	x	Bao Dai	24015
**Aglaothamnion* sp.	o	o	o	x	Tam Island	24124
**Amphiroa beauvoisii* Lamouroux	o	o	o	x	Bao Dai	24013
**Amphiroa valonioides* Yendo	o	o	o	x	Tam Island	24137
Anotrichium tenue (C. Agardh) Nägeli	"x,D"	"x,D"	o	x	Tre Island	24092
**Antithamnion erucacladellum* R.E. Norris	o	o	o	x	Bao Dai	24228
**Antithamnionella graeffei* (Grunow) Athanasiadis	o	o	o	x	Tam Island	24123
Asparagopsis taxiformis (Delile) Collins et Hervey	x	x	o	x	Tre Island	24079
**Bangia atropurpurea* (Roth) C. Agardh	o	o	o	x	Hon Chong	Lewmanomont
**Branchioglossum prostratum* Schneider	o	o	o	x	Tre Island	24100
Centroceras clavulatum (C. Agardh) Montagne	x	x	x	x	Black Rock	24182
**Ceramium aduncum* Nakamura	"o,D"	"o,D"	o	x	Tam Island	24149
Ceramium flaccidum (Kützing) Ardissone	x	x	o	x	Black Rock	24048
Ceramium macilentum J. Agardh	"x,D"	"x,D"	"x,D"	x	Black Rock	24126
**Ceramium vagans* Silva	o	o	o	x	Tam Island	24147

Table 1 (continued)

Species name and author	**Dawson 1954**	**Pham 1969**	**Nguyen et al. 1993**	**Abbott 2002**	**Locations in 1999**	**IA #**
Ceratodictyon spongiosum Zanardini	x	x	o	x	Tam Island	24117
Champia parvula (C. Agardh) Harvey	x	x	o	x	Bai Try	24212
Champia viellardii Kützing	x	x	o	x	Tam Island	24141
Cheilosporum spectabile Harvey	o	x	o	x	Hon Chong	24222
Chondria dangeardii Dawson	x	x	o	x	Black Rock	24058
*_Chondria simpliciuscula_ Weber-van Bosse	o	o	o	x	NW Tam I.	24095
Chroodactylon ornata (C. Agardh) Basson	“x,D”	o	o	x	Hon Chong	24126a
*_Corallophila apiculata_ (Yamada) R.E. Norris	o	o	o	x	Bao Dai	24021
*_Corallophila bella_ (Setchell et Gardner) R.E. Norris	o	o	o	x	Tam Island	24190
Corallophila huysmansii (Weber van-Bosse) R.E. Norris	x	x	o	x	Tre Island	24189
*_Crouania attenuata_ (C. Agardh) J. Agardh	o	o	o	x	Black Rock	24065
*_Crouania minutissima_ Yamada	o	o	o	x	Hon Chong	24186
Dermonema pulvinata (Grunow) Fan	o	o	x	x	Bao Dai	24027
*_Diplothamnion jolyi_ Hoek	o	o	o	x	Hon Mieu Rock	24109
*_Erythrotrichia carnea_ (Dillwyn) J. Agardh	o	o	o	x	Bao Dai	24227
*“Falkenbergia” _hillebrandii_ (Bornet) Falkenberg	x	x	o	x	Black Rock	24044
Ganonema farinosum (Lamouroux) Fan et Wang	“x,D”	“x,D”	o	x	Bao Dai	24006
Gelidiella acerosa (Forsskål) Feldmann et Hamel	x	x	x	x	Tam Island	24121
Gelidium sp.	?	?	?	x	Tam Island	24119
Gracilaria edulis (Gmelin) Silva	o	o	“x,D”	x	Tam Island	24120
Gracilaria eucheumatoides Harvey	x	o	o	x	Hon Chong	Terada
Gracilaria salicornia (C. Agardh) Dawson	“x,D”	o	x	x	Hon Chong	Terada
*_Gracilaria tenuistipitata_ Chang et Xia var. _liui_ Chang et Xia	o	o	o	x	Hon Chong	Terada/Anong
*_Griffithsia heteromorpha_ Kützing	“x,D”	“x,D”	o	x	Tam Island	24125
Halymenia dilatata Zanardini	x	x	o	x	Cau Da	Kawaguchi
Halymenia maculata J. Agardh	x	x	o	x	Bao Dai	24032
*_Herposiphonia crassa_ Hollenberg	o	o	o	x	Tam Island	24204
*_Herposiphonia delicatula_ Hollenberg	o	o	o	x	Bao Dai	24210
*_Herposiphonia parca_ Setchell	o	o	o	x	Black Rock	24043
Herposiphonia secunda (C. Agardh) Ambronn var. _tenella_	x	x	o	x	Bao Dai	24009
Hypnea “esperi” Bory	x	x	x	x	Tam Island	24116
Hypnea pannosa J. Agardh	o	x	x	x	Bao Dai	24024
Hypnea sp.	x	o	o	x	Tam Island	24217
Hypnea spinella (C. Agardh) Kützing	x	x	“x,D”	x	Bao Dai	24030

Table 1 (continued)

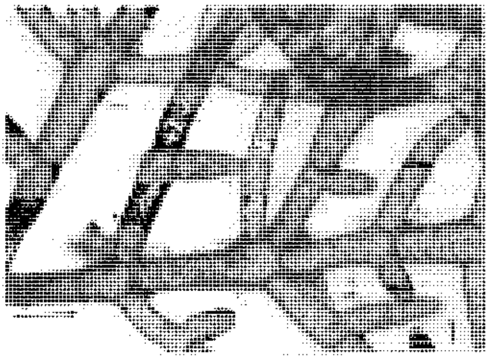
Species name and author	**Dawson 1954**	**Pham 1969**	**Nguyen et al. 1993**	**Abbott 2002**	**Locations in 1999**	**IA #**
**Jania adhaerens* Lamouroux	o	o	o	x	NW Tam I.	24145
**Jania micarthrodia* Lamouroux	o	o	o	x	Tam Island	24191
Jania pumila Lamouroux	o	x	o	x	Black Rock	24060
**Laurencia* sp.	o	o	o	x	Hon Mieu Rock	24103
**Laurencia majuscula* (Harvey) Lucas	o	o	o	x	Bao Dai	24208
Laurencia parvipapillata Tseng	x	x	x	x	Tre Island	24074
**Laurencia yamadana* Howe	o	o	o	x	Tre Island	24081
Leveillea jungermannioides (Hering et Martens) Harvey	x	x	x	x	Tre Island	24085
Liagora ceranoides Lamouroux	x	x	o	x	Tre Island	24002
**Liagora* sp. nov.	o	o	o	x	Tre Island	24001
**Liagora samaensis* Tseng	o	o	o	x	Bao Dai	24000a
**Liagora valida* Harvey	o	o	o	x	Tam Island	24197
**Liagorophila endophytica* Yamada	o	o	o	x	Tre Island	24000c
**Lomentaria hakodatensis* Yendo	o	o	o	x	Black Rock	24050
**Lophosiphonia prostrata* (Harvey) Falkenberg	o	o	o	x	Tam Island	24132
Mastophora rosea (C. Agardh) Setchell	o	x	o	x	Tam Island	24115
**Neosiphonia poko* (Hollenberg) Abbott, new comb.	o	o	o	x	Tre Island	24071b
**Neosiphonia sparsa* (Setchell) Abbott, new comb.	o	o	o	x	Tre Island	24181b
Neosiphonia sphaerocarpa (Børgesen) M.S. Kim et I.K. Lee	x	x	x	x	Black Rock	24211
Neosiphonia subtilissima (Montagne) M.S. Kim et I.K. Lee	x	x	x	x	Bao Dai	24233
**Nitophyllum adhaerens* Wynne	o	o	o	x	Bao Dai	24022
**Peyssonnelia inamoena* Pilger	o	o	o	x	Tam Island	24223a
Polysiphonia spp.	?	?	?	x	Bao Dai	24209
Polysiphonia scopulorum Harvey	x	x	o	x	Tre Island	24203
**Pterocladiella caerulescens* (Kützing)	o	o	o	x	Tre Island	24067
Stylonema alsidii (Zamardini) Drew	x	x	o	x	Tam Island	24159
Taenioma perpusillum (J. Agardh) J. Agardh	x	x	o	x	Bao Dai	24008
Tolypiocladia glomerulata (C. Agardh) Schmitz	"x,D"	"x,D"	"x,D"	x	Tre Island	24229
**Tricleocarpa fragilis* (Linnaeus) Huisman et Townsend	"x,D"	"x,D"	o	x	Bao Dai	24005
**Wrangelia dumontii* (Dawson) Abbott	o	o	o	x	Tre Island	24213
**Yamadaella caenomyce* (Decaisne) Abbott	"x,D"	o	o	x	Bao Dai	Dawson

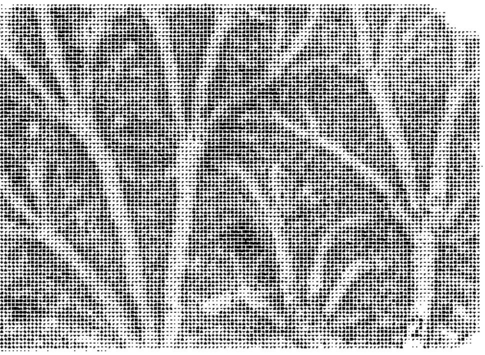
Algae Collected in Vietnam in April 1999

A total of 19 species of green algae is listed in Table 1. Of these 19, *Microdictyon japonicum* Setchell (Fig. 1) is a species new to Vietnam. This species has primary filaments or "veins" containing cells about one fourth the diameter of the cells of *M. okamurai* Setchell, cited by Pham (1969). *Microdictyon japonicum* is a close relative of the spectacular *Anadyomene wrightii* Harvey (Fig. 2), which was reported by both Dawson (1954) and Pham (1969).

Of the 20 species of brown algae listed, 1 is a new species of *Sargassum* (Nguyen Huu Dai, in preparation), and 2 are new records (*Dictyota crispata* Lamouroux and *Sargassum oligocystum* Montagne). We include an illustration of *Padina australis* Hauck (Fig. 3) to show a plant that differs in appearance from the one shown by Pham (1969, p. 330, fig. 3.29). Finally, 86 species of red algae are listed. Of these, 43 are new records for Vietnam, and 1, a species of *Liagora*, is a new species, to be published elsewhere.

The total of 125 species in the new collection represents about 50% of the known marine flora in southern Vietnam. The total number of specimens processed was about 275; more than half of them are on microscope slides.





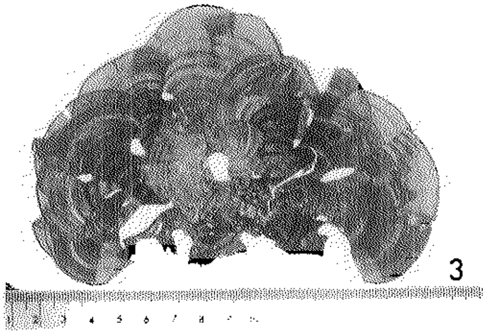

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Fig. 1. Primary axis and laterals of *Microdictyon japonicum*. Scale bar = 100 µm. Fig. 2. Elaborate "veins" and interstitial network of *Anadyomene wrightii*. Scale bar = 100 µm. Fig. 3. *Padina australis*. The appearance of the plant differs from that of those previously illustrated from Vietnam.

Records of Species New to Vietnam

The new records are marked with an asterisk (*) and are listed with the authors and the references where the names were first published. This information is followed by the major collecting site or sites in boldface, the host or substratum, and a generalized world distribution. The references for these new records are not listed in the "Literature Cited"; publications listed there appear in other parts of the text. We list and discuss here 46 new records of marine algae from the waters around Nha Trang.

DIVISION CHLOROPHYTA

**Microdictyon japonicum* Setchell, Univ. Calif. Publ. Bot. 13:107, 1925.

Tam Island. As described by Setchell, the plants (Fig. 1) are between 4 and 7 cm in size, twice the size of Vietnamese and Hawaiian specimens. We can confirm the distinguishing delicate measurements; the ultimate (i.e., apical) cells of the nets are 60 μm in diameter at the base of the cell, narrowing to about 40 μm at the apex; other proximal cells are 120–140 μm in diameter, with thin walls. The type locality is Ateyama in central Japan. Recently, Coppejans et al. (2000) reported this species from Tanzania.

Figure 2 shows a frond of *Anadyomene wrightii* Harvey ex J. E. Gray, a close relative of *Microdictyon*, previously reported from Vietnam. The type locality is the Ryukyu Islands, Japan, and the species is common in the Indian Ocean.

DIVISION PHAEOPHYTA

1. **Dictyota crispata* Lamouroux. Exposition des caractèes du genre Dictyota, et tableau des espèces qu'il renferme. J. Bot. Desveaux 2:44, 1809.

Hon Mieu Rocks. This species was previously recorded for Indonesia by Weber-van Bosse as *D. apiculata* J. Agardh, which, however, lacks involucrayte sporangia, which are present in *D. crispata* and in our specimen. According to DeClerck and Coppejans (1997), the name *D. crispata* should be applied to the identifications made by Vickers et Shaw (1908, pl. 12, as *D. bartayresii*), Allender and Kraft (1983, as *D. bartayresii*), and Coppejans et al. (1995, as *D. bartayresiana*), with which we agree. This species was first described for the Caribbean Sea and has been only recently recognized for the Pacific by DeClerck and Coppejans (1997).

2. **Padina australis* Hauck, Hedwigia 26:44, 1887.

This species was previously listed by Pham (1969) and Nguyen et al. (1993). Figure 3 shows a newly collected specimen (one of many from Bao Dai) that has a different aspect from those illustrated previously and that indicates the variability of the species.

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

Nha Trang Bay. This species is common in the warm western Pacific. It was to be expected in Vietnam.

DIVISION RHODOPHYTA

1. **Acrochaetium barbadense* (Vickers) Børgesen, Dansk Bot. Ark. 3:43, 1915.

Tre Island. The plant was epi-endophytic on *Liagora samaensis*. The type locality is Barbados. *Acrochaetium barbadense* is widely distributed through the tropical Atlantic, Caribbean, Pacific, and Indian oceans.

2. **Acrochaetium catenatulum* Howe, Mem. Torrey Bot. Club 15:84, pl. 31, figs. 12–18, 1914.

Tam Island. This species is epiphytic on many species of algae, but in our Vietnamese collections, we found it solely on *Ceramium* species. The type locality is Callao, Peru. *Acrochaetium catenatulum* is widely distributed in the tropics, into temperate seas.

3. **Acrochaetium liagorae* Børgesen, Dansk Bot. Ark. 3:58, 1915.

Bao Dai. This taxon is a common endophyte in species of *Liagora* and *Ganonema*. It is found mostly in the tropics. The type locality is the Virgin Islands. It also occurs in the Caribbean Sea, the Hawaiian Islands, the Philippines, and the Indian Ocean.

4. **Amphiroa beauvoisii* Lamouroux, Hist. polyp. corall. flex., p. 299, 1816.

Tam Island, on dead coral. Portugal is the type locality, into subtropical regions.

The species of *Amphiroa* and *Jania* reported in this chapter may have been given other names previously, but because we were not able to examine the specimens upon which the other names were based, the names we use may express a different assessment of characters shown by these species. As treated here, the species of *Amphiroa* and *Jania* follow the classification adopted by Johansen (in Abbott, 1999) for the Hawaiian articulated coralline algae.

5. **Amphiroa valonioides* Yendo, J. Coll. Sci. Imp. Univ. Tokyo 16:5, 1902.

Tam Island, on dead coral. The type locality is Japan. This species is also found in the Hawaiian Islands and the Gulf of California. When examined closely, many specimens listed in herbaria as *A. fragilissima* have conspicuous swellings of the intergenicular area adjacent to a geniculum, a feature lacking in *A. valonioides*. The sizes of these 2 species overlap.

6. *Anotrichium tenue* (C. Agardh) Nägeli, Sitzungsber. Bayer. Akad. Wiss. München 1861(2), p. 399, 1862.

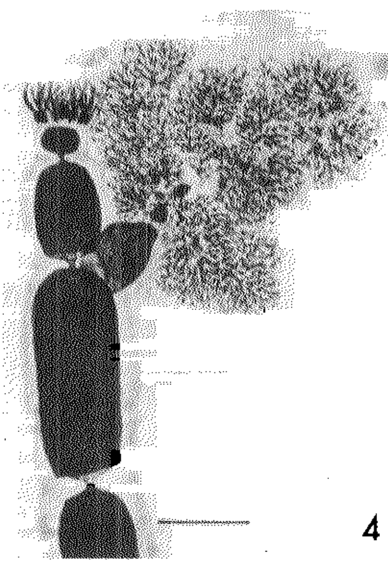
Tre Island. This species was formerly reported as *Griffithsia tenuis*. The illustration of *A. tenue* (Fig. 4) is provided to show the rarely seen open (noninvolucrate) spermatangial branchlets of this species.

7. **Antithamnion erucacladellum* R. E. Norris, Phycologia 32:455, 1993.

Bao Dai. This species was previously known only in the Hawaiian Islands.

8. **Antithamnionella graeffei* (Grunow) Athanasiadis, Opera Bot. 128:107, fig. 47a, 1996.

Tam Island. The specimen (Fig. 5) was found entangled with the endemic green alga *Derbesia attenuata* Dawson, the latter previously reported from Hon Mieu. Under the previous classification, *A. graeffei* was known as *Antithamnionella flagellata* (Børgesen) Abbott and was reported from Mauritius, the type locality,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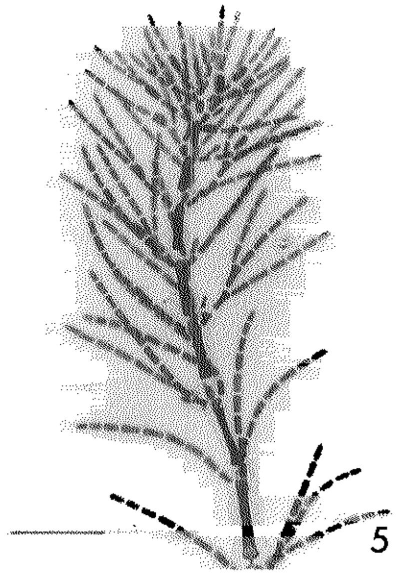
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Fig. 4. *Anotrichium tenue*. Note elaborately branched spermatangial clusters. Scale bar = 100 μm. Fig. 5. *Antithamnionella graeffei*. Note variously branched-whorl branchlets at nodes. Scale bar = 100 μm.

and from the Hawaiian Islands and St. Croix, Virgin Islands. As *A. graeffei*, this species has a wide distribution.

9. **Bangia atropurpurea* (Roth) C. A. Agardh, Syst. algarum, p. 76, 1824.

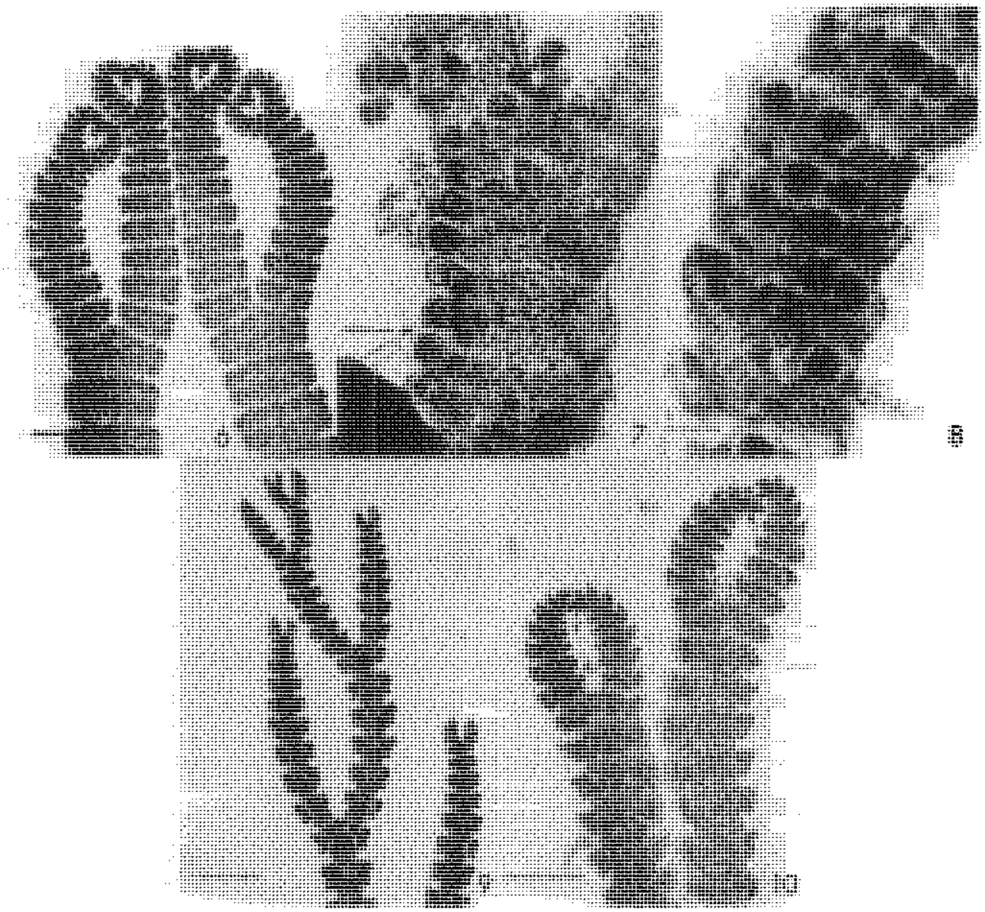
Hon Chong, on rock. Our specimen was collected by Khan Lewmanomont. The type locality is the Weser River in Germany. The species is widely distributed in temperate areas; few collections from the tropics are known.

10. **Branchioglossum prostratum* Schneider, Bull. Mar. Sci. Gulf Caribbean 24:1094–1097, figs. 1–2, 1974.

Tre Island. This sterile specimen was a small piece of a plant. We compared it with material from the Hawaiian Islands, which had been compared with the type material. We tentatively identify this species for Vietnam. More material would be helpful to ensure accuracy. The type locality is offshore of North Carolina.

11. **Ceramium aduncum* Nakamura, Sci. Pap. Inst. Algol. Res. Fac. Sci. Hokkaido Imp. Univ. 3:158, figs. 2b, 3, 1956.

Tam Island. This species (Figs. 6 and 7) was not reported by Dawson (1954), who had erroneously applied the name *Ceramium clarionensis* Setchell et Gardner to his Vietnamese material (Dawson specimen 11129). When Meneses (1995) examined Dawson's specimen and the material of *C. clarionensis* of Setchell and Gardner, she identified Dawson's Vietnamese *C. clarionensis* as *Ceramium aduncum* Nakamura. Nakamura (1965) was uncertain about the status of *C. aduncum* Nakamura and was confused over the identity of the 2 species,



Figs. 6–10. *Ceramium* species. Fig. 6, Crossing of terminal segments in *Ceramium aduncum* form heart-shaped overlapping, characteristic of approximately one third of rapidly growing plants. Scale bar = 150 µm. Fig. 7, Older plant of *Ceramium aduncum* with abaxial tetrasporangia forming before others are positioned. Scale bar = 100 µm. Fig. 8, Nodal whorls of tetrasporangia of *Ceramium vagans*. Each whorl is involucrate and then coalesces in the node. Scale bar = 100 µm. Fig. 9, Terminal branching pattern of *Ceramium flaccidum*. This pattern occurred in about three-fourths of the plants examined. Scale bar = 100 µm. Fig. 10, Spermatangial filaments of *Ceramium macilentum*. The protruding spermatangia at the nodes accentuate the fact that nodes are usually wider than the internodes. Many plants have arching terminal apices as shown here. Scale bar = 150 µm.

because he had only a single specimen of *C. clarionensis* for comparison. Meneses had a large number of specimens of both taxa in her Hawaiian study of *Ceramium* species. The important characters of *C. aduncum* are the lack of involucres around the tetrasporangia and the lack of pseudoperiaxial cells, both features present in *C. clarionensis*.

The type locality of *C. aduncum* is Japan. The species has also been reported from California, Pacific Mexico, the Hawaiian Islands, the Marshall Islands, and Taiwan. This record is the first for *C. aduncum* for Vietnam under the name *C. aduncum*.

12. **Ceramium vagans* Silva, Smithsonian Contrib. Mar. Sci. 27:56, 1987.

Tam Island, on dead coral. The type locality is the Marshall Islands. This species is also found in the Philippines, the Solomon Islands, the Great Barrier Reef, and the Hawaiian Islands. *Ceramium vagans* (Fig. 8) is a substitute name for *C. vagabunda* Dawson, which is a later homonym of *C. vagabundum* (Linnaeus) Roth. In gross aspect, *C. vagans* looks somewhat like *C. macilentum* (Fig. 10), but the nodes are more crowded in *C. macilentum* because of the presence of pseudoperiaxials, which are lacking in *C. vagans.* The tetrasporangia in *C. vagans* are involucrate and whorled in the nodes, differing from *C. aduncum* shown in Figure 7. The branching patterns of *C. macilentum* and *C. vagans* are different from the pattern shown in *C. flaccidum* (Fig. 9) and in nodal details.

13. *Chondria dangeardii* Dawson, Pac. Sci. 8:460, figs. 62f–62g, 1954.

Black Rocks. In Dawson's paper on Vietnamese algae, he gave the name *dangeardii* to the material that he had collected at the locations we call Bao Dai and Cau Da in this chapter. *Chondria dangeardii* was a new name for a species "platyclada" from Senegal that had been given earlier to a different species of *Chondria*, creating a duplication that required a new name. *Chondria dangeardii* is a widely distributed tropical species of *Chondria* and is easily identified on the basis of its large, compressed frond (Fig. 11).

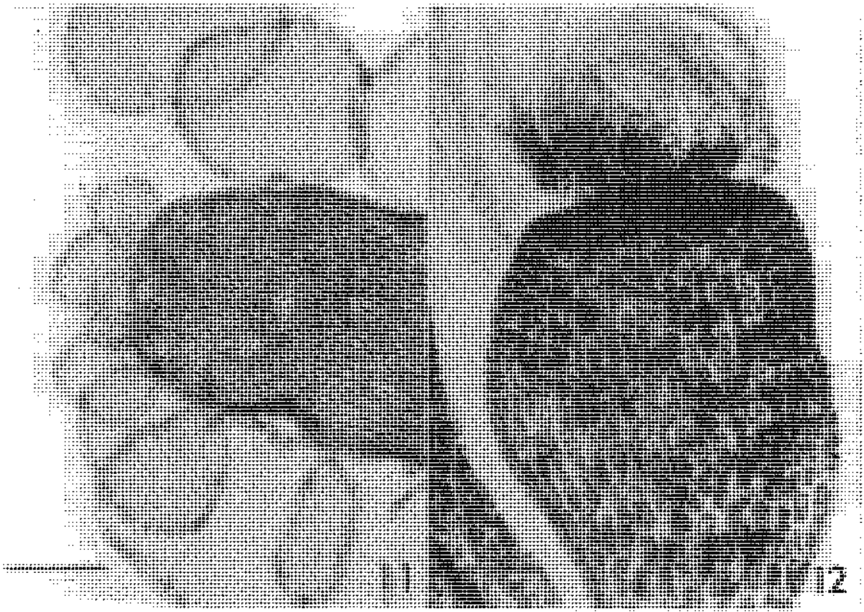
14. **Chondria simpliciuscula* Weber van Bosse, Trans. Linn. Soc. Bot. 8:125, pl. 12, figs. 9–10, 1913.

Black Rocks and **Tre Island**. The type locality is Aldabra Island in the Indian Ocean. This species is also found in the Maldive Islands; Queensland, Australia; and Ant Atoll in Micronesia. It is common in the Hawaiian Islands and is found there in the shallow subtidal to deep subtidal waters at a depth of 35 m. *Chondria simpliciuscula* (Fig. 12) is roughly the same size as *C. dangeardii*, but the external cellular features of the 2 species differ.

15. **Corallophila apiculata* (Yamada) R. E. Norris, Bot. Mar. 36:395, 1993.

Bao Dai, on rope and dead coral. The type locality is Ant Atoll in Micronesia. This species is also found in the Great Barrier Reef, the Philippines, the Maldive Islands, the Solomon Islands, the Marshall Islands, and the Hawaiian Islands.

The prostrate and erect axes are 150–200 μm in diameter, with 6–10 periaxial cells. Tetrasporangia are formed within the corticated segments near the apices of erect axes. The apices terminate abruptly into a sharp point. Among the common



Figs. 11–12. *Chondria* species. Fig. 11, *Chondria dangeardii* with flat clusters of spermatangia, characteristic of the genus. Note also "dimples" in the surface of the frond indicating former location of trichoblasts. Scale bar = 75 µm. Fig. 12, *Chondria simpliciuscula* with turbinate lateral branch and very conspicuous sets of trichoblasts and colorless filaments at the apex. Scale bar = 100 µm.

species of *Corallophila* found in the Pacific tropics, *C. apiculata* is the one that shows the prostrate and erect axes the best.

16. **Corallophila bella* (Setchell et Gardner) R. E. Norris, Bot. Mar. 36:395, 1993.

Tam Island. In the absence of tetrasporangia, which are described by the authors of the basionym, *Centroceras bellum*, as being in specialized branches (stichidia), we cannot identify this entity with certainty. However, because the Vietnamese plants have 8–10 pericentral cells and basipetal filaments with up to 12 cells, we think the plants more clearly represent *C. bella* than they do *C. apiculata* (Yamada) R. E. Norris, despite the widely separated distribution of the 2 species. The description of the type specimen of *C. bella* gives 110–130 µm for the diameter of the main axis; the main axis of the Vietnamese plant is between 150 and 200 µm in diameter. Thus, the Vietnamese specimen is much larger than the Mexican material and may represent another species. *Corallophila bella* is reported from the Gulf of California at Guaymas; the type locality of *C. apiculata* is Ant Atoll in Micronesia. Although it might appear that *C. apiculata* would be a better name for this alga, the anatomic details mentioned and the tapering axial and branch apices are further differences from *C. apiculata*.

17. **Crouania attenuata* (Bonnemaison) J. Agardh, Alg. medit., p. 83, 1842.

Black Rocks, **Bao Dai**, and **Tam Island.** The specimens were found growing in strong water movement at Black Rocks and in calm areas at Bao Dai. The type locality is Brittany in France. This species is also found in the Caribbean Sea, Australia, the Hawaiian Islands, and throughout the Indian Ocean. *Crouania attenuata* (Fig. 13) is somewhat larger than and has axes nearly twice as broad as those of *C. minutissima*.

18. **Crouania minutissima* Yamada, Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Imp. Univ. 3:40, 1944.

Black Rocks. The specimen was collected in an area of strong water motion at a depth of about 6.5 m. Ant Atoll in Micronesia is the type locality. The species is also found in the Hawaiian Islands, the Philippines, southern Japan, and the Seychelles. The erect axes of *C. minutissima* (Fig. 14) are about 200 µm wide at midheight, whereas those of *C. attenuata* at a similar location are about 400 µm wide. These 2 species are common epiphytes in the Pacific tropics.

19. *Dermonema pulvinata* (Grunow ex Holmes) Fan, Acta Bot. Sin. 10:336–338, pls. 1–2, 1962.

Bao Dai. The type locality is Japan. This species is also found on the southern Fujian and Guandong coasts of China and in the Hawaiian Islands. It was also reported by Nguyen et al. (1993), but we did not examine their material.

20. *Erythrotrichia carnea* (Dillwyn) J. Agardh, Acta Univ. Lund 19:15, 1883.

Erythrotrichia carnea is a common species in both temperate and tropical waters, but because of its small size, it is frequently missed. It rarely grows in large numbers.

21. "Falkenbergia," the alternate (heteromorphic) phase of *Asparagopsis taxiformis* (Delile) Trevisan, Nomenclator algarum, p. 1, 1845.

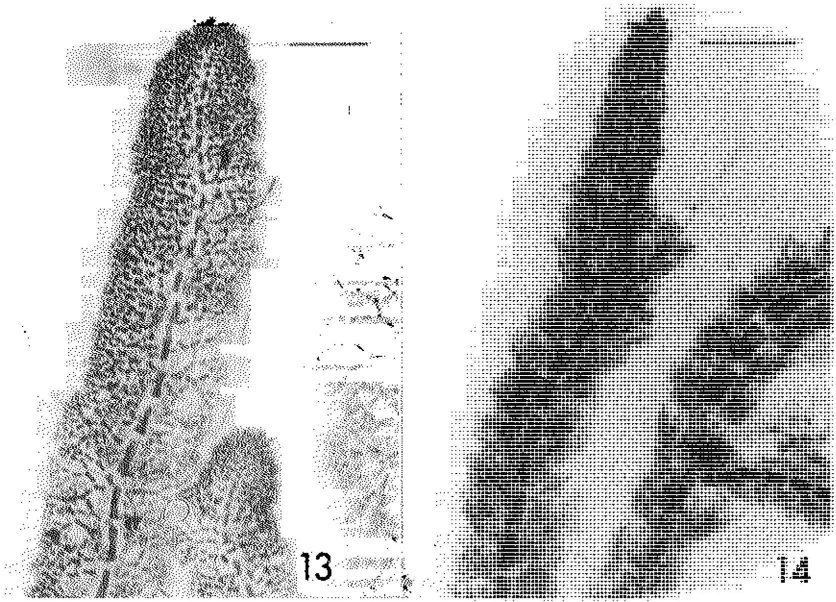
Tre Island. In Vietnam and throughout the warm Pacific, both phases of *A. taxiformis* are common. Persons unfamiliar with the heteromorphic phase (Fig. 15), however, may think that they have a species of *Polysiphonia*. However, *Polysiphonia* species almost always have uniseriate filaments that are connected to colorless branched filaments (trichoblasts), and *Falkenbergia* does not have such filaments.

22. **Gracilaria tenuistipitata* var. *liui* Zhang et Xia, Stud. Mar. Sin. 11:102, 1976.

Hon Chong, rocks. Although this species is known in Vietnam from 7 different aquaculture centers (Ohno et al., 1999), it had not been reported previously from any site outside of the aquaculture facilities. Our material was collected and identified by Anong Chirapart and Ryuta Terada.

23. **Griffithsia heteromorpha* Kützing, Tab. Phycol. vol. 13, pl. 3, 1861.

Both Dawson (1954) and Pham (1967) reported and illustrated what they thought was *Griffithsia metcalfii* Tseng, but their illustrations clearly indicate that they had *G. heteromorpha* in hand. *Griffithsia heteromorpha* consists of filaments of cells that are spherical distally and near the apices but elongate toward the base, as well illustrated in Dawson's paper (1954, figs. 56k–56l) and fig. 2.174 of Pham's book (1969). In *G. metcalfii* as originally stated by Tseng and currently circumscribed by Abbott (1999, pp. 300–301, figs. 84d–84f), cells are never elongate; rather, they are nearly perfectly spherical throughout. Moreover, the



Figs. 13–14. *Crouania* species. Fig. 13, *Crouania attenuata* with rounded apices and larger than *C. minutissima*. Fig. 14, *Crouania minutissima* characteristically is more slender than *C. attenuata* and has gradually pointed apices. Described by Yamada from Ant Atoll, *C. minutissima* has gradually become recognized throughout the warm Pacific into the Indian Ocean.

cystocarps of *G. metcalfii* are borne between segments (intercalary) and are without involucres; those of *G. heteromorpha* are borne on fertile laterals and are involucrate, a condition illustrated by Pham (1969, fig. 2.174).

24. **Herposiphonia crassa* Hollenberg, Pac. Sci. 22:539, figs. 12–13, 1968.

Tam Island. The type locality is Maui in the Hawaiian Islands. The axes of *H. crassa* are up to 300 µm in diameter, the largest of any species of *Herposiphonia* in the tropics.

25. **Herposiphonia delicatula* Hollenberg, Pac. Sci. 22:540, figs. 1A, 1B, 3, 21, 1968.

Bao Dai. This species is similar to *Herposiphonia secunda* f. *tenella* but is more slender and has reproductive structures borne closer to the prostrate axes.

26. **Herposiphonia parca* Setchell, Univ. Calif. Publ. Bot. 12:103, pl. 20, fig. 2, 1926.

Black Rocks. This species is epiphytic on larger algae (Fig. 16). The type locality is Tahiti. It is also found throughout eastern, central, and northern Polynesia and from Micronesia to continental Asia. *Herposiphonia parca* is one of the most common species of *Herposiphonia* in the warm Pacific.

27. *Jania adhaerens* Lamouroux, Hist. polyp. corall. flex., p. 270, 1816.

Bao Dai. *Jania adhaerens* is a common epiphytic species on large algae such as *Sargassum*.

28. *Jania micarthrodia* Lamouroux, Hist. polyp. corall. flex., p. 271, 1816.

Tre Island, in shallow water on dead coral. The type locality is southern Australia. This species is also found in New Zealand and the Hawaiian Islands. (See note under *Amphiroa*).

29. *Laurencia majuscula* (Harvey) Lucas, Proc. Linn. Soc. New South Wales 60:223, 1935.

Bao Dai. *Laurencia majuscula* is a large species and is common in the Hawaiian Islands. It is conspicuous because of its habit and anatomic features. The species is widely distributed in the Pacific.

30. *Laurencia yamadana* Howe, J. Wash. Acad. Sci. 24:37–38, fig. 4, 1934.

Tre Island, in shallow water on dead coral. The type locality is Oahu in the Hawaiian Islands. This species is also reported from Hachijo Island, Japan. *Laurencia yamadana* is a small decumbent species, distinguished by arching axes with frequent secund branching (Fig. 17).

31. *Liagora ceranoides* Lamouroux, Hist. polyp. corall. flex., p. 238, 1816.

Tre Island, on dead coral, also epiphytic and epizoic. Plants have slender

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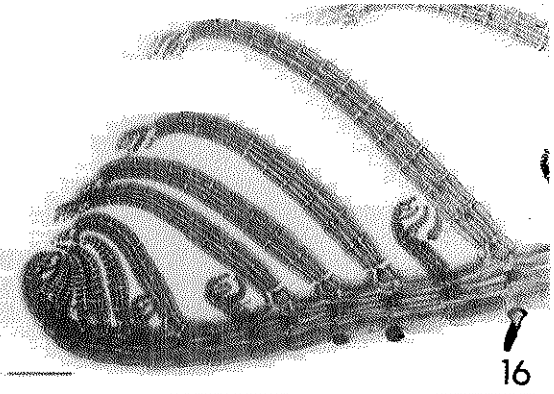

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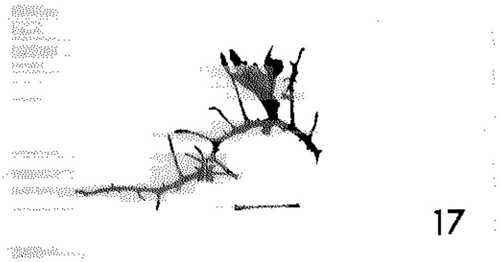

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Fig. 15. "Falkenbergia," the tetrasporophytic and heteromorphic phase in the life history of *Asparagopsis taxiformis*. This phase is common in the tropics but is seldom recognized for what it is. Scale bar = 60 μm. Fig. 16. *Herposiphonia parca*, a creeping and common epiphyte among branches or fronds of other algae. This species is abundant in the Hawaiian Islands and is found throughout the warm Pacific; Tahiti is the type locality. Scale bar = 180 μm. Fig. 17. *Laurencia yamadana*, a short plant with arching axes. Scale bar = 1 cm.

axes and branches and are pale pink, not more than 4 cm tall when living (Figs. 19 and 20). *Liagora ceranoides* is possibly the most common species of *Liagora* in the tropics, but its distribution extends into warm temperate regions; it is often an outlier representing the genus. Figure 20 illustrates the contrast between the spermatangia of *L. ceranoides* and the spermatangial heads of *Ganonema farinosum* (Fig. 21).

32. *Ganonema farinosum* (Lamouroux) Fan et Wang, Acta Phytotax. Sin. 12:492, pl. 1, 1974.

Bao Dai. This species was reported previously by Dawson (1954) and Pham (1969) as *Liagora farinosa*. One of the primary features of *G. farinosum* is the caplike spermatangia (Fig. 21) that cover the apices of the cortical filaments far more densely than in any species that is known in *Liagora* (or even other species of *Ganonema*). Features of the female reproductive system must also be considered.

33. **Liagora samaensis* Tseng, Bull. Fan Mem. Inst. Biol. 5:275, figs. 8–10, 1941.

Bao Dai, on granite rock in the low intertidal zone. Dawson's material (specimen 11111) identified erroneously as *L. orientalis* J. Agardh matches the specimens we collected. However, *L. orientalis* is more calcified than is *L. samaensis* and generally has a more delicate thallus. *Liagora samaensis* is often polycarpogonial (Fig. 18), a condition never observed in *L. orientalis*. The type locality is Hainan Island in China. The species is also found in Bangladesh and the Hawaiian Islands. It is highly seasonal.

34. **Liagora valida* Harvey, Smithsonian Contrib. Knowl. 5 (art. 5), p. 138, figs. 1–5, 1853.

Bao Dai. This record is a new one for Vietnam. *Liagora valida* is moderately to heavily calcified and in many locations is very common. However, many species resemble it externally and differ internally. Among features that should be examined are the carposporangia, which usually occur in short chains, a rare condition in *Liagora*.

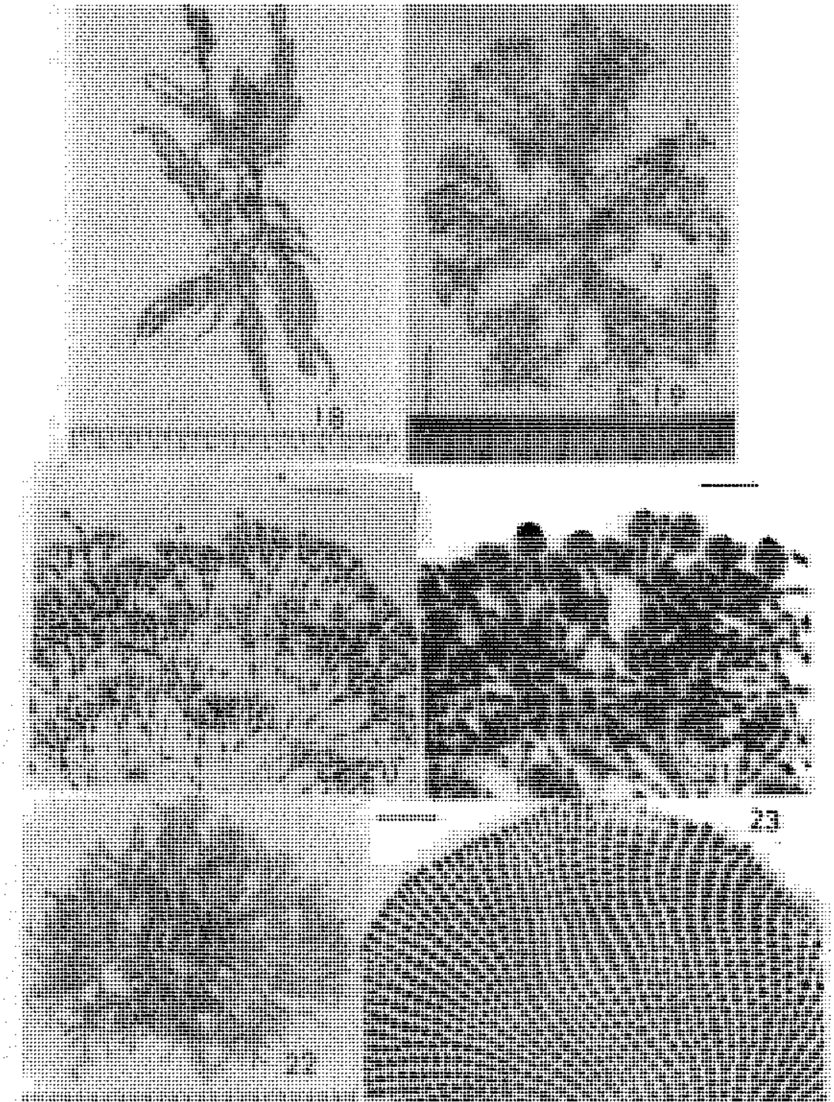
35. **Liagorophila endophytica* Yamada, Sci. Pap. Inst. Algol. Res. Fac. Sci. Hokkaido Imp. Univ. 3:11, 1944.

Bai Tre and **Bao Dai**. *Liagorophila endophytica* bears spermatangia, carpogonial branches, cystocarps, and monosporangia. It is common in the cortical tissues of *L. samaensis*. The type locality is Taiwan. It is also found in the Ryukyu Islands, the Hawaiian Islands, Ecuador, and Colombia.

36. **Lomentaria hakodatensis* Yendo, Bot. Mag. (Tokyo) 34:6, 1920.

Black Rocks. The type locality is Hakodate, Japan. This species is a widely distributed but inconspicuous epiphyte in the eastern, south, central and western Pacific. It is a common epiphyte on deep-water algae in the Hawaiian Islands and probably is not more widely recorded because of its small size.

37. **Lophosiphonia prostrata* (Harvey) Falkenberg, Rhodomelaceen golfes neapel monogr. vol. 26, p. 501, 1901.



Figs. 18–20 *Liagora* species. Fig. 18, *Liagora samaensis* was erroneously identified previously as *L. orientalis*. *Liagora samaensis* is the host of *Acrochaetium liagorae* and *Liagorophila endophytica*, which are new, records for Vietnam. Fig. 19, A typical habit of *Liagora ceranoides*. Note slender axes and branches. Fig. 20, Photomicrograph of small terminal clusters of spermatangia of *Liagora ceranoides*. Scale bar = 50 µm. Fig. 21. *Ganonema farinosum* with dense, large spermatangial heads, one of the important characteristics of the *genus*. Scale bar = 50 µm. Fig. 22. Habit of chalky, heavily calcified *Yamadaella caenomyce*. This species is distinguished from *Liagora species* on the basis of reproductive features. Fig. 23. Decalcified crustlike frond of *Peyssonnelia inamoena* with lines of filaments containing rounded to hexagonal cells. Scale bar = 100 µm.

Tam Island. The type locality is western Australia. This species is also found in other parts of Australia, South Africa, Tuamotu Archipelago, and the Hawaiian Islands. *Lophosiphonia* is separated from *Polysiphonia* because most of the *Lophosiphonia* species have a dorsiventral organization, whereas *Polysiphonia* species typically have a radial organization.

38. **Neosiphonia poko* (Hollenberg) Abbott, comb. nov.

Basionym: *Polysiphonia poko* Hollenberg, Pac. Sci. 22:70, figs. 3A, 15, 1968.

Bao Dai, epiphytic on *Boodlea composita*. The type locality is Johnston Atoll in the central Pacific Ocean. *Neosiphonia poko* is also found in the Hawaiian Islands, Phoenix Islands, Marshall Islands, Line Islands, Caroline Islands, Tuamotu Archipelago, and the Maldive Islands. Spermatangial heads are borne on the epibasal cell of the trichoblasts (Figs. 24 and 25). Tetrasporangia borne in spiral series, carpogonial filament with 3 cells, and rhizoids pit-connected to pericentral cells are the main features of the new genus *Neosiphonia* M. S. Kim et I. K. Lee (Kim and Lee 1999), which is segregated from *Polysiphonia* Greville on the basis of these and a few other characters. Compared with the other species of *Neosiphonia* described in this chapter, *N. poko* is clearly both prostrate and erect, with very few or no lateral branches, and when elongating, it forms many trichoblasts, which are early deciduous. In contrast, *N. sphaerocarpa* has a very limited prostrate system and is mostly an erect species with many lateral branches. Both species have 4 pericentral cells that are mostly isodiametric. *Neosiphonia sparsa* is distinguished by pericentral cells that are wider than they are tall.

39. **Neosiphonia sparsa* (Setchell) Abbott, comb. nov.

Basionym: *Lophosiphonia sparsa* Setchell, Univ. Calif. Publ. Bot. 12:103, pl. 21, figs. 3–4, 1926.

Black Rocks, **Tam Island,** and in the intertidal zone at **Hon Chong**. Specimens from Hon Chong were collected by Lu Baoren. This species is very different from the more plentiful taxa that have nearly isodiametric or rectangular pericentral cells. The pericentral cells of *N. sparsa* (Figs. 26 and 27) tend to be wider than they are tall, thus forming large segments, often 200–300 µm wide, whereas the segments of the common *N. sphaerocarpa* are usually 100–170 µm wide and those of *N. subtilissima* (Montagne) M. S. Kim et I. K. Lee are usually 70–130 µm wide. Additionally, the apices of *N. sparsa* are abruptly tapered, usually in pairs, one of the apices shorter than the other, and slightly turned adaxially. Trichoblasts are conspicuous on fertile plants. The spermatangia, carpogonial filaments, and tetrasporangia, all present in Vietnamese material, are as described for *Neosiphonia*.

40. *Neosiphonia sphaerocarpa* (Børgesen) M. S. Kim et I. K. Lee, Phycol. Res. 47:280, 1999.

Basionym: *Polysiphonia sphaerocarpa* Børgesen, Dansk Bot. Ark. 3:321, figs. 267–271, 1918.

Black Rocks, **Tam Island**, and **Hon Chong**. The specimens from Hon Chong were collected by Lu Baoren from intertidal areas. The type locality is St. Thomas in the Virgin Islands. This species is also found in Bermuda, the Hawaiian Islands,

Figs. 24–27. *Neosiphonia* species. Figs. 24, *Neosiphonia poko* with apical part of erect axis bearing many trichoblasts. Scale bar = 100 µm. Fig. 25, Male plant of *Neosiphonia poko* with spermatangial head borne from the first division of the trichoblast (arrowhead). Scale bar = 125 µm. Fig. 26, *Neosiphonia sparsa* with apical part and arrangement of spermatangial heads with trichoblast (arrowhead). Pericentral cells are wider than they are tall in this species (compare with Fig. 25). Scale bar = 125 µm. Fig. 27, Part of *Neosiphonia sparsa* with spiraling of tetrasporangia in the fertile pericentral cells, characteristic also of this genus. Scale bar = 200 µm.

Tuamotu Archipelago, Kiribati, the Caroline Islands, Guam, the Maldive Islands, and Seychelles. *Neosiphonia sphaerocarpa* is difficult to identify because it is a very variable species vegetatively. The length and width of pericentral cells must be established in relationship to the occurrence of branches, distal versus proximal position, prostrate versus erect axes, trichoblasts present or lacking, and so forth. In most specimens, a gradual elongation of pericentral cells from the apices to the bases occurs. However, other specimens may have long, rectangular pericentral cells but otherwise have a branching pattern and other features similar to those of specimens with isodiametric pericentral cells. If features and measurements are too narrow, many species may be included; if too broad, other similar looking taxa that may be truly independent may be excluded.

41. **Nitophyllum adhaerens* Wynne, Cryptogamie Algol. 18:211–221, 1997.

Bao Dai, on rope. The type locality is Puerto Morelos, Mexico. This species is also found in the Antilles, Virgin Islands, Bahamas, Bermuda, and the Hawaiian Islands. *Nitophyllum adhaerens* has a small, rounded blade with marginal rhizoids, 1-cell thick in section, and lacking microscopic veins.

42. **Peyssonnelia inamoena* Pilger, Bot. Jahrb. Syst. 45:293–464, 1911.

Tam Island. The type locality is Cameroon, West Africa. This species is also found in the Mediterranean, the Adriatic, and the Hawaiian Islands. As described by Denizot (1968), *P. inamoena* is one of the few species of *Peyssonnelia* that is easily separated from its substrate. The cells of the filaments are usually somewhat hexagonal (Fig. 23).

43. *Polysiphonia scopulorum* Harvey, Trans. R. Irish Acad. (Sci.) 22:540, 1853.

Tam Island and **Hon Chong**. In contrast to the species of *Neosiphonia* described in this chapter, *P. scopulorum* bears spermatangia that are not connected to branching of trichoblasts (confirmed in the material collected at Hon Chong) and has tetrasporangia in a straight series as in Hawaiian material that is identified as this species. We did not examine cystocarpic material, however, and the rhizoid shown in Abbott (1999, fig. 125f) although clearly continuous with the pericentral cell, is erroneously captioned as pit-connected to the pericentral cell. Rhizoids are continuous with the pericentral cells in *P. scopulorum*.

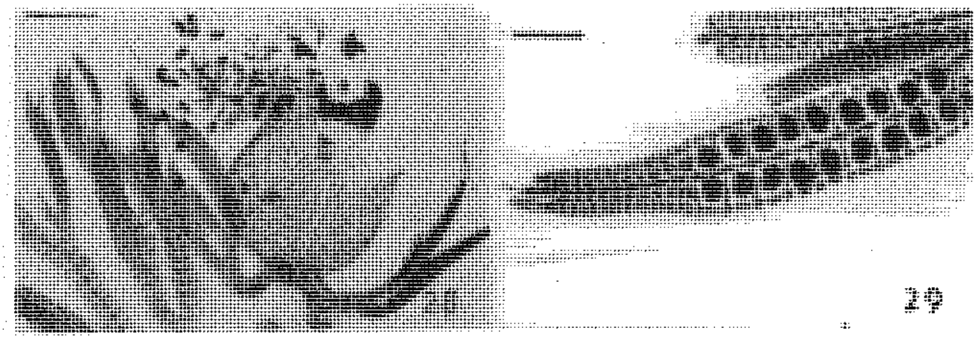
44. *Polysiphonia* spp. We have 3 slides (IA 24071c, IA 24233, and IA 24234) that are incomplete scraps of specimens and cannot be identified either as *Polysiphonia* or *Neosiphonia* because the specimens are sterile. All 3 came from a small bay on the northwestern side of **Tre Island.**

45. *Pterocladiella caerulescens* (Kützing) Santelices et Hommersand, Phycologia 36:118. 1997.

Tre Island, on rock. The type locality is New Caledonia. This species is widely distributed in the Pacific, from the Hawaiian Islands to the southern Chinese coastline.

46. *Taenioma perpusillum* (J. Agardh) J. Agardh, Ofvers. Kongl. (Svenska) Vetensk.-Akad. Förhandl. 5:16, 1847.

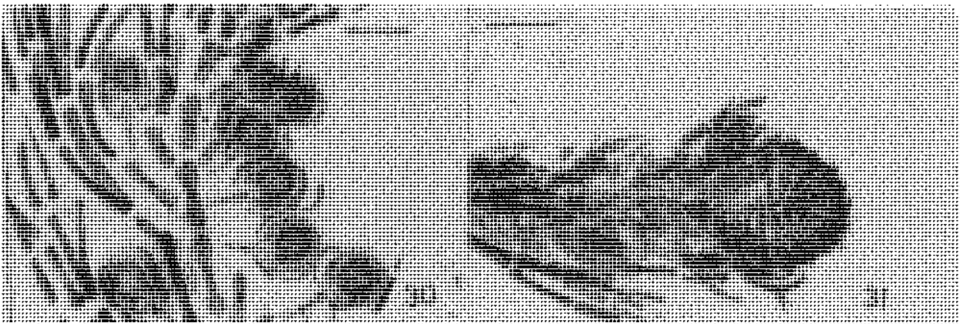
Tam Island. This species was previously reported by Dawson (1954) and Pham (1969). Our figures of this attractive and unique species show a very large cystocarp losing carposporangia (Fig. 28) and pairs of tetrasporangia in a stichidium (Fig. 29).



Figs. 28–29. *Taenioma perpusillum*. Fig. 28, Very large cystocarp with some loose carposporangia. Scale bar = 75 µm. Fig. 29, Tetrasporangial stichidium with developing tetraspores. Scale bar = 150 µm.

47. **Wrangelia dumontii* (Dawson) Abbott, Phycologia 18:222–224, figs. 21–26, 1979.

Tam Island and **Bao Dai**. Our specimens include spermatangial (Fig. 30), cystocarpic (Fig. 31), and tetrasporangial plants. These specimens resemble *Wrangelia argus* Montagne (see Børgesen, 1915, p. 117, figs. 125–126); both species lack cortication and have involucral cells among tetrasporangia and spermatangia (Fig. 30). Unlike *W. dumontii* of the Virgin Islands and islets off Pacific Panama (the type locality of *W. dumontii*), *W. argus* lacks strong rhizoids that are modifications of the whorl branchlets. The Vietnamese plants have mostly 3-whorl branchlets, rarely 4-whorl, whereas *W. argus* of the Canary Islands (the type locality of *W. argus*) and the Caribbean has 4-whorl branchlets (rarely 5-whorl). Cystocarps are borne at the apex of indeterminate branches, thus terminating the growth of that axis. According to the description by Børgesen (1915), *W. argus* plants are mostly erect, whereas *W. dumontii* plants are mostly repent; as are the Vietnamese plants, which are slightly erect at the apical ends of the axes. *Wrangelia dumontii* is also found in St. Croix in the Virgin Islands and in the Hawaiian Islands. In order to resolve these discrepancies, all little-corticated



Figs. 30–31. *Wrangelia dumontii.* Fig. 30, Spermatangial plant with no cortication or rhizoids along main axis and spermatangial heads with involucral filaments. Scale bar = 50 µm. Fig. 31, Cystocarp terminating indeterminate branch. Note whorl branchlets without cortication. Scale bar = 50 µm.

species of *Wrangelia* should be reexamined.

48. *Yamadaella caenomyce* (Decaisne) Abbott, Phycologia 9:117, figs 1, 3–9, 1970.

Bao Dai. Dawson's material (specimen 11109) was also from Bao Dai, and with other specimens from Cu Lao (specimen 11148) was identified as *Liagora divaricata* Tseng, a poorly known species from China. The materials with this name in Dawson's collections represent *Y. caenomyce* (Decaisne) Abbott (Fig. 22), which was segregated from *Liagora* by Abbott (1970). *Yamadaella* has reproductive structures, both spermatangial and cystocarpic, that do not match any species of *Liagora.* Abbott (1999) treats the genus as a member of the Dermonemataceae, although others may treat the genus as a member of the Liagoraceae.

New Names for Species Previously Identified and Published Under Other Names by Dawson and Pham

Basionyms are not included in the following material; only changes of names in the literature are given. The former names are in Dawson (1954) and Pham (1969).

RHODOPHYTA

Current Name: *Anotrichium tenue* (C. Agardh) Nägeli Sitzungsber, Bayer. Akad. Wiss. München 1861(2), p. 399, 1862.

Former Name: *Griffithsia tenuis* of Dawson and of Pham.

Current Name: *Ceramium macilentum* J. Agardh, K. Fysiogr. Sällsk. Handl. 33:15, 1894.

Former Name: *Ceramium mazatlanense* of Dawson and of Pham.

Current Name: *Ceramium flaccidum* (Kützing) Ardissone, Nuovo Giorn. Bot. Ital. 3:40, 1871.

Former Names: *Ceramium gracillimum* var. *byssoideum* of Dawson; *C. gracillimum* of Pham.

Current Name: *Chroodactylon ornata* (C. Agardh) Basson, Bot. Mar. 22:67, 1979.

Former Names: *Asterocytis* [*Asterocystis*] *ornata* of Dawson. Pham (1969, pp. 68–69, fig. 2.2) misapplied his illustrated material to this species; we think that his material represents a species of *Stylonema*.

Current Name: *Ganonema farinosum* (Lamouroux) Fan et Wang. Acta Phytotax. Sin. 12:492, pl. 1, 1974.

(Previously reported as *Liagora farinosa* by Dawson and by Pham. See *G. farinosum* in the preceding section on new records for Vietnam.)

Current Name: *Tricleocarpa fragilis* (Linnaeus) Huisman et Townsend, Linn. Soc. Bot. 113:100. 1993.

Former Names: *Galaxaura fastigiata, G. vietnamensis, G. oblongata* of Dawson; *G. fastigiata, G. oblongata* of Pham.

PHAEOPHYTA

Current Name: *Hincksia indica* (Sonder) J. Tanaka, Mem. Nat. Sci. Mus. Tokyo 23:24–25, figs. 6–7, 1990.

Former Name: *Giffordia indica* of Nguyen et al. (1993).

Current Name: *Hincksia breviarticulata* (J. Agardh) Silva, Smithsonian Contrib. Mar. Sci. 27:73, 1987.

Former Names: *Ectocarpus breviarticulata* of Dawson; *Feldmannia breviarticulata* of Pham.

Current Name: *Hincksia mitchelliae* (Harvey) Silva, Smithsonian Contrib. Mar. Sci. 27:73, 1987.

Former Names: *Ectocarpus mitchelliae* of Dawson; *Giffordia mitchellae* of Pham.

CHLOROPHYTA

Current Name: *Cladophora vagabunda* (Linnaeus) van den Hoek, Revision of the European species of *Cladophora*. p. 144, 1963.

Former Names: *Cladophora inserta* var. *ungulata* of Dawson; *Cladophora inserta* and *C. fascicularis* of Pham.

Conclusions

In this study, the collecting efforts of more than 14 persons were combined and processed together, thus increasing the number and diversity of taxa reported. For some of those collectors more familiar with northern field situations (most of the participants from Japan and some of the participants from China), the eroded coral substrata and the algal inhabitants were new and different. Habitats that lack kelps but have beds of *Sargassum* were also novel. The participants from Hawaii also noted that the *Sargassum* specimens were "clean" of epiphytes. In Hawaii, *Sargassum* is a favorite place to look for articulate and small crustose corralline algae, filamentous species in the Ectocarpales, and small red filamentous species.

Although we collected *Laurencia* species, they were mostly so young they could not be identified. We could not guess how they would structure the nearshore communities as they do in Hawaii, where as many as 9 species may grow sympatrically in the intertidal zone (McDermid 1988). Although this community was unusual, having many species of *Laurencia* in most collecting places is expected in Hawaiian waters. The *Laurencia* of Vietnam may be comparable in variety and importance at a different time and season.

The works of Dawson (1954), Pham (1969), Nguyen et al. (1993), plus the results of this study, bring the total of macroalgal species (not including Cyanobacteria and crustose coralline algae) in the vicinity of Nha Trang to 278. For islands in the tropics about 12° north (or south) of the equator, this number would denote a representative flora from the intertidal zone to the shallow subtidal zone. However, for a region dominated by rivers and run-off from a continental land mass, it seems that the marine flora has only been superficially collected and little studied; many more taxa should be present. The numbers for all groups, but particularly the red algae, can be increased markedly, and intensive scuba-assisted collections would reveal much of the rich algal diversity, which is becoming known from the borders of the western Pacific.

One of the announced goals of the eighth workshop was to make good general collections of marine algae in order to determine if the total flora had changed measurably since Dawson first studied it in 1953. No estimates of quantity of biomass were made by Dawson or by us, but from the species lists that were compared, it appears that no great changes have affected the nature of the marine flora. Indeed, it is rather surprising to find some taxa that are in apparently the same microhabitat now as they were 46 years ago. A case in point is the large foliose (bladelike) species of red algae *Halymenia maculata* Børgesen that Dawson found in large numbers around Cau Da and its peninsula (Bao Dai): it is still growing well in the same locality. On the other hand, the large number of taxa that we found as new records were mostly of microscopic size and in general collections would have been ignored or lost among the larger specimens.

If a generalization can be made without quantifying it, we think that the marine flora is much the same as it was when surveyed 46 years ago. We are pleased to make this contribution to the people of Nha Trang, because it is not possible in most coastal areas of the world to make this kind of conclusion.

Acknowledgments

First, and foremost, our deep thanks for the vision and foresight of Dr. James Sullivan, who could see international cooperation on an important aspect of the ocean's resources for the people who live on the warm coastlines of the Pacific. Bringing the marine flora in the vicinity of Nha Trang, Vietnam up-to-date is something that all participants could contribute to, and many did. The participants from the United States were committed to doing so before they left Hawaii, and we are very grateful to Drs. Shigeo Kawaguchi, Anong Chirapart, and Ryuta Terada; Professor Lewmanomont; and among our hosts, Pham Huu Tri and Nguyen Xuan Vy (who besides collecting with Jack Fisher, helped to type the species lists for us). We also thank Dr. An, the director of the Institut Océanographique de l'Indochine, and Mrs. Thu, the librarian/secretary, for their kindnesses and helpfulness.

All algal photographs were taken by Jack Fisher, except for Figures 2, 7, 8, 10, and 24, which were taken by Lynn Hodgson, to whom we extend many thanks.

Literature Cited

Abbott, I. A. 1970. *Yamadaella,* a new genus in the Nemaliales (Rhodophyta). Phycologia 9:115–123, figs. 1–9.

Abbott, I. A. 1999. Marine red algae of the Hawaiian Islands. Bishop Museum Press, Honolulu.

Ajisaka, T., Huynh Quang Nang, and Nguyen Huu Dinh. 1995. Studies of two zygocarpic species of *Sargassum* (subgenus *Sargassum*) from Vietnam. In: Tax. Econ. Seaweeds 5, pp. 45–54, figs. 1–15.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Ang Put, Jr., Phang Siew Moi, Noro, T., and Yoshida, T. 1997. Taxonomic and nomenclatural study of *Sargassum duplicatum* Bory and related species. In Tax. Econ. Seaweeds 6, pp. 27–36, figs. 1–12.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, Lu Baoren, Young-Meng Chiang, and Tadao Yoshida. 1997. *Sargassum hemiphyllum* (Turner) C. Agardh var. *chinense* J. Agardh from Vietnam, the Chinese mainland, and Taiwan. In: Tax. Econ. Seaweeds 6, pp. 37–49, figs. 1–24.

Ajisaka, T., Huynh Quang Nang, Nguyen Huu Dinh, and Tadao Yoshida. 1997. *Sargassum carpophyllum* J. Agardh var. *nhatrangense* (Pham) Ajisaka, comb. nov. and *S. piluliferum* (Turner) C. Agardh var. *serratifolium* Yamada from Vietnam. Tax. Econ. Seaweeds 6, pp. 51–60, figs. 1–23.

Allender, B., and Kraft, G. T. 1983. The marine algae of Lord Howe Island (New South Wales): the Dictyotales and Cutleriales (Phaeophyta). Brunonia 6:73–130.

Børgesen, F. 1915–1920. Marine algae of the Danish West Indies, 2: Rhodophyceae with Addenda to the Chlrophyceae, Phaeophyceae and Rhodophyceae. [*Wrangelia argus*, pp. 116–117, figs. 125–126.]

Coppejans, E., DeClerck, O., and Van den heede, C. 1995. Annotated and illustrated survey of the marine macroalgae from Motupore Island and vicinity (Port Moresby area, Papua New Guinea), II: Phaeophyta. Belg. J. Bot. 128:371–380.

Coppejans, E., Leliaert, F. and De Clerk, O. 2000. Annotated List of New Records of Marine Macroalgae for Kenya and Tanzania, Since Isaac's and Jaasund's Publications. Biol. Jaarb. Dodonaea, 67(1):31–93.

Dawson, E. Y. 1954. Marine plants in the vicinity of Nha Trang, Viet Nam. Pac. Sci. 8:373–481, figs. 1–62.

Dawson, E. Y. 1956. Some marine algae of the southern Marshall Islands. Pac. Sci. 11:92–132.

DeClerck, O., and Coppejans, E. 1997.The genus Dictyota (Dictyotaceae, Phaeophyta) from Indonesia in the Herbarium Weber-van Bosse, including the description of *Dictyota canaliculata* spec. nov. Blumea 42:407–420.

Denizot, M. 1968. Les algues Floridées encroutantes (a l'exclusion des Corallinacées). Laboratoire de Cryptogamie, Museum National d'Histoire Naturelle, Paris.

Hoek, C. van den. 1963. Revision of the European species of *Cladophora*. Leiden. 248 pp., 55 pls. Brill, Leiden.

Kim, M. S., and Lee, I. K. 1999. *Neosiphonia flavimarina* gen. et sp. nov. with a taxonomic reassessment of the genus *Polysiphonia* (Rhodomelaceae, Rhodophyta.). Phycol. Res. 47:271–281.

McDermid, K. J. 1988. Community ecology of some intertidal subtropical algae, and the biology and taxonomy of Hawaiian *Laurencia* (Rhodophyta) [Ph.D. dissertation]. University of Hawaii at Manoa.

Meneses, I. 1995. Notes on *Ceramium* (Rhodophyta: Ceramiales) from the Hawaiian Islands. Pac. Sci. 49:165–174, figs. 1–14.

Nakamura, Y. 1965. Studies of the genera *Ceramium* and *Campylaephora*, especially those of northern Japan. Sci. Pap. Inst. Algol. Res. Fac. Sci. Hokkaido Imp. Univ. 5:119–180, 14 pls.

Nguyen Huu Dinh. 1992. Vietnamese species of *Gracilaria* and *Gracilariopsis*. In: Tax. Econ. Seaweeds 3, pp. 207–210.

Nguyen Huu Dinh and Huynh Quang Nang. 1995. Species of *Eucheuma* and *Kappaphycus* in Vietnam. in: Tax. Econ. Seaweeds 5, pp. 229–235, figs. 1–5.

Nguyen Huu Dinh and Huynh Quang Nang. 1999. Some new taxa of *Sargassum* (Phaeophyta) from Vietnam. In: Tax. Econ. Seaweeds 7, pp. 43–51, figs. 1–14.

Nguyen Huu Dinh, Huynh Quang Nang, Tran Hgoc But, and Nguyen van Tien. 1993. Marine Algae of North Vietnam. Agriculture Publishing House, Ho Chi Minh City, Vietnam (in Vietnamese).

Ohno, M., Terada, R., and Yamamoto, H. 1999. The species of *Gracilaria* from Vietnam. In: Tax. Econ. Seaweeds 7, pp. 99–111, figs. 1–9.

Pham Hoang Ho. 1967. Contribution a l'étude des algues littorales du Vietnam: le genre *Sargassum*. Ann. Fac. Sci. Saigon, pp. 259–332 (in French).

Pham Hoang Ho. 1969. Marine algae of South Vietnam. Ministry of Education and Youth, Saigon (in Vietnamese).

Setchell, W. A., and Gardner, N. L. 1930. Marine algae of the Revillagigedo Islands Expedition in 1925. Proc. Calif. Acad. Sci, ser. 4, 19:109–215, pls, 1–12.

Silva, P. C. , Basson, P. W., and Moe. R. L. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Press, Berkeley.

Silva, P. C., Meñez, E. G. ,and Moe, R. L. 1987. Catalog of the benthic marine algae of the Philippines. Smithsonian Contrib. Mar. Sci. 27:1–179.

Tanaka, T., and Pham Hoang Ho. 1962. Notes on some marine algae from Viet Nam, I. Mem. Fac. Fish. Kagoshima Univ. 2:24–40, figs. 1–20.

Vickers, A., and Shaw, M.H. 1908. *Phycollogia barbadensis*... Paris. 44 pp., LIII + XXXIV pls., Publ. Librairie Sciences Naturelles.

Section VII. Taxonomic Index