THE SPECIES OF GRACILARIA AND GRACILARIOPSIS FROM
JAPAN AND ADJACENT WATERS

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I. INTRODUCTION

The species of Gracilaria are, as a whole, widely distributed in the northern hemisphere from the Arctic Ocean to the tropical seas and even in the southern hemisphere. The genus Gracilaria was established by Greville in 1830, when it was defined as comprising the following four species: G. confervoides, G. compressa, G. purpurascens (now placed in Cystoclonium) and G. erecta (now placed in Cordylecladia). In 1852 J. Agrardh revised and redefined the genus designating G. confervoides as its type species. Lately G. confervoides and G. compressa were revised as G. verrucosa (Huds.) Papenfuss (1950) and G. bursa-pastoris (Gmel.) Silva (1952) respectively. Since the publication of the just mentioned work of J. Agrardh, a good number of new species amounting to more than one hundred and fifty in number have been added to the genus by various authors and at the same time many other species were replaced from this genus to other genera. Of these authors the following are to be mentioned here: Börgesen (1920, 1929, 1934, 1943, 1950, 1952, 1953), Setchell et Gardner (1924), Sjöstedt (1926), Taylor (1928, 1945, 1947, 1954), Kylin (1930, 1932, 1941), Yamada (1933, 1938, 1941), Smith (1944) and Dawson (1944, 1945, 1945a, 1949, 1952, 1953, 1953a, 1954, 1954a).

A detailed anatomical study of Gracilaria was first made by Sjöstedt (1926) with G. confervoides, G. compressa and G. robusta. In the last mentioned species, which was later recognized by Kylin (1930) as a new species and was named G. sjösteddii, the cystocarp was described by Sjöstedt to show several striking characters differing
from those in the other two species. The peculiarity of *G. sjöstedtii* thus elucidated was later considered by Dawson to be of generic importance, and he established *Gracilariopsis* for that species and other related ones in his monographic work on the Northeast Pacific Gracilariaceae (1949). This work presents his descriptions of the critical anatomy of reproductive organs and throws much light on the taxonomy of *Gracilaria* and its related genera. It goes without saying, that the Japanese species of *Gracilaria* hitherto reported fragmentally by various authors such as K. Yendo, K. Okamura, and Y. Yamada were in need of revision. So the present writer started a systematic study of them several years ago under the guidance of Professor J. Tokida, as he believed that taxonomic knowledge of this group of plants is indispensable for any further studies on their ecology or industrial possibilities. Some new data have already been reported in previous papers (1955 & 1956). In the present paper it is proposed to give descriptive accounts of all the species of *Gracilaria* and *Gracilariopsis* occurring in Japan and its neighboring waters. These several years the writer has been doing his best to collect fresh materials from various localities as far as possible, and he has tried to study specimens preserved in liquid except when dried specimens only were available. Anatomical details of various plants were examined with the material thus collected by the writer himself. On the other hand, herbarium specimens made available from various sources were, of course, quite helpful, or in some cases indispensable, for the present systematic studies. The following is a list of the main sources of such specimens.

1. Herbarium of the Faculty of Fisheries, Hokkaido University, containing specimens mostly collected by Professor J. Tokida or under his care from the coasts of Saghalien, Hokkaido, Honsyû, Ryûkyû and Formosa.

2. Collection of Professor Y. Yamada in the Herbarium of the Botanical Institute, Faculty of Science, Hokkaido University; they are noted in the following pages as *Herb. B. H.* (Herbarium of the Botanical Institute, Hokkaido University) together with their number.

3. A comprehensive collection from the Northeast Pacific Coast made by Dr. E. Yale Dawson.

4. Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science, Tokyo University.

5. Collection from the coast of Honsyû made by Dr. S. Ueda of the Tokyô College of Fisheries.


7. Collection from the coasts of Honsyû and Shikoku by Mr. I. Umezaki.

8. Collection from the coast of Shikoku by Mr. S. Yagi.

9. A small but useful collection made by Mr. K. C. Fan from the coast of Formosa.

In addition to these collections, many other specimens were submitted for examination by many gentlemen including Dr. S. Segawa of the Faculty of Agriculture,
Kyūshū University, Dr. T. Segi of the Faculty of Fisheries, Prefectural University of Mie, Dr. G. W. Lawson of the University College of Ghana, Achimota, Ghana, and Mr. K. Čushima in Toyama Prefecture. After studying carefully all of these specimens the writer gives in the following pages thorough descriptions based on his own observations for each of fifteen species and one forma of Gracilaria and three species of Gracilariopsis, including one species new to Japan, Gracilariopsis rhodotricha Dawson, one species new to Ryûkyû, Gracilaria salicornia (Ag.) Dawson and one species with newly combined name, viz., Gracilariopsis chorda (Holm.) Ohmi. Gracilaria sublittoralis is described herein for the first time. The identity of Corallopsis opuntia and Gracilaria crassa, which was already reported by Börgesen (1952) and Dawson (1954, 1954a), is again ascertained positively herein. Antheridia of the following species are reported herein for the first time: Gracilaria blodgettii, G. bursa-pastoris, and G. arcuata. Antheridia of Gracilaria testorii were first reported by the writer in 1955. Tetrasporangia of Gracilaria edulis and G. incurvata and gland-like cells of G. crassa and G. salicornia are reported herein for the first time.

For the determination of genera and species, the writer has followed Dawson in laying stress on the internal structure of cystocarp, the characters of the male reproductive organ, and on the structure of tetrasporic cortex. In addition, the structure of sterile frond as seen through longitudinal section and of the carpogonial branch was also useful in some cases for the specific distinction.

All the specimens used for the present study, except Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science, Tokyo University, and Professor Yamada's collection, are now deposited in the Herbarium of the Faculty of Fisheries, Hokkaido University.

In Gracilaria and Gracilariopsis, there are several species which deserve special consideration from the economic standpoint. One chapter (Chapter IV) will be devoted to such considerations, especially on the resources of Gracilaria verrucosa and the agar-agar production from Gracilaria in Japan.

Acknowledgements. The writer wishes to take this opportunity to tender thanks to all of those who have aided him in one way or another, during the course of the present study. First of all, the writer will always heartily feel the warmest gratitude to his teacher, Professor J. Tokiga, under whose guidance the present work has been carried out. He kindly made available all the specimens he gathered in many years from Saghalien, Hokkaido, Honsyû as well as from Ryûkyû and Formosa, gave permission to make free use of his library and moreover kindly read this manuscript. Cordial thanks are due to Professor Y. Yamada, Faculty of Science, Hokkaido University, for the loan of a number of valuable specimens in the Herbarium of the Botanical Institute and for his constructive criticism of the manuscript; also to Professor Emer. T. Fukushi, Hokkaido University, for the interest he has shown.
and the advice he has offered throughout the course of this study. The writer likewise desires to make acknowledgement of indebtedness to Professor Emer. M. Honda, Tokyo University, through whose kindness it was made possible to examine abundant specimens in Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science. It is difficult sufficiently to express thankfulness to Dr. E. Yale Dawson who was kind enough to present a comprehensive suite of specimens treated in his "Northeast Pacific Gracilariaceae" and many copies of his publications; they were not only invaluable, but also indispensable for the present study. Furthermore the writer feels very grateful to the late Dr. F. Borgezen of Copenhagen and to Professor W. R. Taylor of Ann Arbor for examining certain specimens sent to them and for returning helpful notes. To Professor T. Tamura, Faculty of Fisheries, Hokkaido University, to Dr. P. C. Silva, University of Illinois, also to Mr. K. Ogaki, Director of Hokkaido Regional Fisheries Research Laboratory at Yoichi, Hokkaido, the writer is much indebted for their great kindness in granting many facilities for the prosecution of this work. Finally the writer acknowledges his great obligation to all gentlemen who kindly placed rich materials in their possessions at his disposal, among whom the names of the following contributors should be particularly mentioned here: Dr. S. Ueda, Tokyo College of Fisheries; Dr. S. Segawa, Faculty of Agriculture, Kyushu University; Dr. Y. Okada, Faculty of Fisheries, Nagasaki University; Dr. T. Segi, Faculty of Fisheries, Prefectural University of Mie; Dr. G. W. Lawson, Department of Botany, University College of Ghana, Achimota, Ghana; Mr. I. Umezaki, Department of Botany, University College of Ghana, Achimota, Ghana; Mr. T. Masaki, Faculty of Fisheries, Hokkaido University; Mr. M. Chihara, Shimoda Marine Biological Station, Tokyo University of Education; Mr. S. Yagi, Ehime Prefecture; Mr. K. Oshima, Toyama Prefecture; Mr. M. Durairatnam, Fisheries Research Station of Ceylon; Mr. K. C. Fan, Taiwan Fisheries Research Institute, Formosa, China; Messrs. H. Okesaku and S. Sasaki, Kushiro Station, Hokkaido Regional Fisheries Research Laboratory.

II. KEY TO THE SPECIES OF GRACILARIA AND GRACILARIOPSIS

1. Cystocarps with a large-celled, usually small-based gonimoblast and nutritive filaments extending into the pericarp
   A. Thalli cylindrical throughout, or sometimes more or less compressed
      1. Branches constricted at the base
         a. Branch base more or less constricted; branching highly variable, sparing to abundant; thalli slender ..............................
            ................................. 1. Gracilaria verrucosa (Huds.) Papenfuss (p. 6)
b. Branch base gradually constricted; branching rather sparing, irregular and multifarious; thalli conspicuously robust, at least in lower or middle parts; apices acute .......... 2. Gracilaria gigas Harv. (p. 10)
c. Branch base abruptly constricted; branching frequent to abundant, alternate or partly secund; thalli robust and turgid ......................... 3. Gracilaria blodgettii Harv. (p. 13)

2. Branches hardly constricted at the base
a. Substance rather stiff and consistent; branching divaricately pinnate; aspect somewhat corymbose; thalli up to 30 cm in length .............. 4. Gracilaria edulis (Gmel.) Silva (p. 16)
b. Substance soft cartilaginous or membranaceous; branching subdichtomous, provided with short branchlets; aspect somewhat flexuous ........ 5. Gracilaria bursa-pastoris (Gmel.) Silva (p. 18)
c. Substance succulent; aspect conspicuously corymbose; thalli less than ca 11 cm in length .... 6. Gracilaria coronopifolia J. Agardh (p. 20)
d. Substance membranaceous and fleshy; branching extremely divergent, irregularly pinnate, sometimes arcuated above; aspect flexuous or corymbose; thalli 5-10 cm in length ........................................ 7. Gracilaria arcuata Zanard. (p. 23)

3. Branches or branchlets articulato-constricted
b. Both branches and branchlets markedly articulato-constricted .... 9. Gracilaria salicornia (Ag.) Dawson (p. 27)

B. Thalli distinctly flattened or complanate
1. Thalli provided with abundant marginal spinulose proliferations or denticulate processes
a. Frond broad; margins provided with denticulate processes ........... 10. Gracilaria denticulata (Kütz.) Weber van Bosse (p. 29)
b. Frond rather narrow, with blunt or ligulate apices; margins heavily crisped ........... 11. Gracilaria purpurascens (Harv.) J. Ag. (p. 30)
c. Frond broader than the former, with obtuse or truncate apices; margins provided with more abundant spinous processes .... 11 a. Gracilaria purpurascens (Harv.) J. Agardh f. spinulosa (Okam.) Yamada (p. 32)

2. Thalli provided with entire or proliferous margins which are at least not spinulose
a. Thalli complanate, 1-2.5 cm broad, with entire margins, variegated with spots on the surface .. 12. Gracilaria punctata (Okam.) Yamada (p. 35)
b. Thalli complanate, ordinarily with entire margins but without spots on the surface, sometimes channeled or more or less incurved and often
twisted .................... 13. *Gracilaria incurvata* Okam. (p. 38)
c. Thalli broader, frequently to abundantly lobed, not incurved, with blunt or ligulate apices, and with or without proliferations ............

.................... 14. *Gracilaria textorii* (Suring.) J. Ag. (p. 40)
d. Thalli broadest, sparingly lobed; margins smooth and normally non-proliferous .... 15. *Gracilaria sublittoralis* Yamada et Segawa (p. 44)

II. Cystocarps with a small-celled, broad-based gonimoblast and destitute of nutritive filaments extending into the pericarp
  A. Branches swollen in part, vermiform in shape ............... 16. *Gracilariopsis vermiculophylla* Ohmi (p. 46)
  B. Branches without enlargement or swelling in any part
1. Plant small and slender, up to 20 cm in length, seldom exceeding 1000 μ in diam., frequently branched ..................... 17. *Gracilariopsis rhodotricha* Dawson (p. 47)
2. Plant large, coarse and robust, 60–110 cm in length, 2–3 mm in diam., sparingly branched ....... 18. *Gracilariopsis chorda* (Holm.) Ohmi (p. 50)

III. DESCRIPTIONS OF THE SPECIES

1. *Gracilaria verrucosa* (Huds.) Papenfuss

*Pl. I, A–D, and Text-figs. 1–2.*


Japanese name: *Ogo-nori.*

Material examined: *Ohmi* 109–111, ♀; 112–128, +, all from Lake Komuke, Prov. Kitami, Hokkaido, July 1956; *Ohmi* 129–133, ♀; 134–145, +, all from Lake Notoro, Prov. Kitami, July 1956; *Masaki,* Oshoro Bay, Otaru, Hokkaido, July 1956 (*Herb. Ohmi* 146 a-b, ♀, c-g, ♀; 147, ♀; 148 a, ♂, b, sterile, c, +, d, ♀, e, ♀; 149 a-b, ♀, c, ♂, d, +; 150–151, sterile, +).

Fronds arising usually in a fairly great number from a common small fleshy flat disc, composed of vertical cell-rows; the upright cylindrical frond reaches 2 mm
or more, seldom exceeding 1.5 mm in diam., attaining a length of 90 cm in the specimens collected at Lake Notoro, Prov. Kitami, Hokkaido, while most of the specimens collected at Oshoro Bay, Hokkaido, hardly exceeding 20 cm in length; branching alternately and repeatedly on all sides with mostly patent or erect axils, sometimes one-sidedly or quite naked and flagelliform; branches elongated, with longer or shorter internodes, tapering upwards and also perceptibly contracted to their bases, and provided with similarly shaped but shorter branchlets which are loaded with mostly simple, longer or shorter ramuli, ending in blunt apices. The plant varies within a wide range in length, thickness, color and even in ramification; purplish red or sometimes greenish or brownish in color, cartilagenous in substance, and adhering well to paper on drying; frond tissue differentiated into a thin cortex composed of two to three layers of small cortical cells and a thick medullary tissue built up of large (150–250 μ, rarely to 360 μ in diam.), round, isodiametric cells having a wall ca 6 μ thick. The frond sometimes becomes hollow when old. The outermost cortical cells are strongly pigmented, more or less anticlinally elongated, 6–8 μ×10–14 μ in dimensions as viewed in transverse section. The infracortical cells are mostly three-layered, being connected with each other by numerous pits. Transition from inner medulla to outer cortex is abrupt. The young parts of the plant bear numerous hairs. Hairs are ca 5 μ thick, with obtuse apex, supported by a large elongated hair "base-cell", deciduous, particularly abundant near the frond apex, where they are somewhat thinner, ca 3 μ thick, and their length is variable. Surface jelly substance ca 6 μ thick. Tetrasporangia densely scattered over the greater part of frond, bright red in color, and cruciately divided. In transverse view they are ovoid in shape, up to 40 μ×50 μ, surrounded by unmodified cortical cells, and in surface view roundish in shape. Cystocarps hemispherical, non-rostrate, not constricted at the base, scattered on the whole surface of the frond, often aggregated, 0.9 mm in diam., 0.7 mm in height at maturity as observed in Oshoro specimens, whereas they attain 1.4 mm in diam., 1.0 mm in height in Notoro plant. According to Sjöstedt (1926) and Kylin (1930), the carpogonial branch is two-celled and developed from a primary cortical cell. The writer observed in a specimen from Asano-cho, Hakodate, a structure probably identifiable as the initial of a carpogonial branch (Fig. 2, A–C), which was deeply stained with cotton blue. The pericarp is connected with the gonimoblast by numerous nutritive filaments, which are 15 μ in thickness and ca 150–180 μ in length. Gonimoblast consists of large vacuolated cells. Carpospores are round or ovate in shape, up to 40 μ in diam. Pericarp is ca 100–240 μ thick, consists of one layer of outermost pigmented cells and ca 10 layers of inner hyaline cells arranged anticlinally and radially and connected by pits with each other. Antheridia occur densely on the frond surface in deep depressions, which are round in shape or sometimes oblong along the frond axis as seen in surface view, deep pocket-like in transverse view, bordered by unmodified cortical cells, and packed with small globular antherozoids, ca 3–5 μ in diam. The dimensions of the
Fig. 1. *Gracilaria verrucosa* (Huds.) Papenfuss. A. Transverse section of a sterile frond from Nanaehama near Hakodate, Aug. 1955. ×284. B-C. Transverse section of a sterile frond to show a hair in the cortex, B from Tobetsu near Hakodate, May 1955, and C from Oshoro, July 1947. ×514. D. Transverse section of a tetrasporic frond from Oshoro, July 1956. ×284. E. Transverse section of a mature cystocarp; Oshoro, July 1956. ×50. F. Detail of carpospores showing stellate central body; Oshoro, July 1956. ×284. G. Part
of an antheridal frond as seen in surface view, showing openings of elliptical antheridial cavities; Matsushima Bay, Miyagi Pref., June 1953. ×284. H. Transverse section of a part of an antheridal frond, showing the deep, conceptacular antheridial cavities; Oshoro, July 1956. ×284. I. Surface view of an antheridial cavity; Oshoro, July 1956. ×514.

Fig. 2. Gracilaria verrucosa (Huds.) Papenfuss. A. Transverse section of a female frond showing the initial of a carpogonial branch; Asano-cho, Hakodate, July 1955. ×284. B. The same as A, more highly magnified. ×514. C. Microphotograph of the same carpogonial branch. ×324. D. Surface view of antherozoids in an antheridial cavity; Tōbetsu near Hakodate, June 1953. ×514. E. Transverse section of a male frond, showing the deep, elliptical antheridial cavities; Tōbetsu near Hakodate, June 1953. ×284. F. Transverse section of a male frond showing a spherical antheridial cavity; Matsushima Bay. Miyagi Pref., June 1953. ×284.

antheridial cavities are shown in Table 1.

This species is cosmopolitan in distribution and is widely spread within the boundaries of this study. It grows mostly near the shore at a depth of less than about one meter or at most two meters. In Lake Notoro it thrives well on shallow
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Table 1: Dimensions of antheridial cavities on one and the same frond, measured in transverse section. Specimen collected at Oshoro, Sept. 1947.

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<th>No.</th>
<th>Breadth (μm)</th>
<th>Depth (μm)</th>
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<td>1</td>
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The plant is perennial. In calm places this alga often attains to a great length as in Lake Akkeshi, Prov. Kushiro, Hokkaido, where it grows luxuriantly, being detached from the substrata and lying loosely on the bottom in quiet water among gregarious growths of *Zostera marina*. When matured bears only tetrasporangia. Besides this detached form, there is also a dwarf form of this alga on the shore of the same lake which grows attached to gravels or shells and bears on maturity not only tetrasporangia but also antheridia and cystocarps. The large detached form is that which fishermen harvest in late autumn and sell to agar-manufacturers. In these past six years the annual yield of this alga in Lake Akkeshi was estimated in the maximum 423,344 kan (1 kan is equivalent to 3.75 kg) in dry weight in 1952, and in the minimum 64,060 kan in 1955.

The marked characters of the present species may be tabulated as follows:

1. Branches attenuated, ending in blunt apices and slightly contracted to the base.
2. Cortex two to three layered, consisting of anticlinally arranged cells.
3. Tetrasporangia scattered over surfaces of frond, surrounded by unmodified cortical cells.
4. Cystocarps hemispherical, unconstricted at the base, nonrostrate, with abundant nutritive filaments connecting the gonimoblast with the pericarp.
5. Antheridial cavities deep pocket-like, bordered by unmodified cortical cells.

2. *Gracilaria gigas* Harvey


Japanese name: علىgonori.

Ohmi: Species of *Gracilaria* and *Gracilariaopsis*

Yendo 319, ♀); Ueda B-1, ♀, Enoshima, Kanagawa Pref., June 1951; Tokida 3-a, ♀, 3-b, ♀, both from Seto-kanayama, Wakayama Pref., Apr. 1938; Akiyama, Misaki, Kanagawa Pref., May 1927 (Herb. B. H. 9463, ♀); Teramachi, Wakayama Pref., without date of collection (Herb. B. H. 11075, ♀, ♀); Teramachi, Wakayama Pref., without date of collection (Herb. B. H. 11076, ♀, ♀); Yamada, Misaki, Kanagawa Pref., May 1937 (Herb. B. H. 20074, ♀); Inoh, Seto-kanayama, Wakayama Pref., June 1940 (Herb. B. H. 27270, ♀); Inoh, Seto-kanayama, Wakayama Pref., June 1940 (Herb. B. H. 27271, ♀).

Frond solitary or caespitose, cylindrical, arising from a scutate disc, reaching the length of 60 cm or more, 2–4 mm in diam., irregularly and sparingly branched at short intervals (mostly 0.5–3 mm in distance) on all sides, or sometimes subsecundly branched with patent and roundish axils, highly fleshy in substance, somewhat translucent light purplish red in color when fresh, but on drying dull red or pale greenish in color and much collapsed and wrinkled, adhering well to paper; branches up to 50 cm in length, narrowing towards the base ordinarily in a gradual but occasionally in an acute manner, constricted at the base, long attenuated to a fine apex, scarcely furnished with branchlets; main axis obscurely traceable; frond tissue consisting of large, colorless thin-walled medullary cells (6–9 μ to 15 μ in thickness), which are roundish in shape as viewed in transverse section, 0.5–0.7 mm in maximum diameter, almost empty in content, often becoming hollow (measuring 1.0 mm in diam.) at the innermost part of old frond; cortex composed of 3–4 layers of small pigmented cortical cells, of which outermost cells are cuboid in shape, somewhat anticlinally disposed, measuring 6–8 μ x 10 μ in dimensions as viewed in transverse section and 6μ x 9μ in surface view; hairs long or stubby in shape, infrequently present; infracortical layer built up of 3–4 layers of periclinaly oblong cells, measuring 15–40 μ x 45–170 μ in dimensions as observed in longitudinal section, thus an abrupt transition from inner medulla to outer cortex results; in some specimens the infracortical layer is traversed here and there by thin, axially elongated cells, 5–8 μ thick, which run between the above mentioned oblong cells, and bear a resemblance to the filamentous cells in the medulla of Laminariaceous plants, and may probably belong to an endophyte. Tetrasporangia densely scattered over surface of frond except at the extreme base of branches, ovoid to oblong in shape, cruciate, 36–51 μ x 60 μ in dimensions in transverse section, closely packed in the slightly-modified cortex of anticlinally elongated cells. Cystocarps hemispherical, up to 1.6 mm in diam., rostrate, scattered on surface of entire frond; gonimoblast composed of large parenchymatous cells, connected with the pericarp by several nutritive filaments; pericarp ca 180 μ in thickness, consisting of 10–15 layers of minute cells, of which the outermost are 5–6 μ x 6–12 μ in dimensions and more or less anticlinally elongated, while the inner cells are somewhat compressed in the anticlinial direction; carpospores round or ovoid, 33–51 μ in diam. at maturity, with a conspicuously pigmented stellate central body; antheridia unknown.
Fig. 3. *Gracilaria gigas* Harv. A. Surface view of a part of a sterile frond, showing arrangement of vegetative cortical cells. ×514. B. Part of a sterile frond in transverse view. ×284. C. Longitudinal section of a sterile frond, showing thin, elongated cells between infracortical cells. ×284. D. Transverse section of a tetrasporic frond. ×284. E. Part of the pericarp of a cystocarp in section. ×284. F. Section of a mature cystocarp. ×50. G. Detail of carpospores showing stellate central body. ×514. (A-G. Plant from Nabeta near Shimoda, Shizuoka Pref., May 1955).
At first sight the present plant has some resemblance in external appearance to *Gracilaria blodgettii* Harvey. However, it differs from the latter in its scarcer ramifications and in having peculiarly constructed infracortical layer. That layer consists in the present species of oblong or axially elongated cells, whereas in *G. blodgettii* it is composed of approximately isodiametric parenchymatous cells. In addition, the pericarpial cells of the present species are compressed in the anticlinal direction with the exception of the outermost anticlinally elongated cells, whilst those of the latter species are all elongated anticlinally. In referring specimens at hand to this species it was possible to compare them with a photograph of Harvey's original specimen taken by Yendo. The paper on which the specimen was mounted is shown to bear a label with hand writing which reads “Herbarium of the U. S. North Pacific Exploring Expedition under Commanders Ringgold and Rodgers, 1853–56, collected by C. Wright at Shimoda, growing on rock.” According to Okamura (1923), “In the frond growing in a calm place after having dropped off the most of branches, the remaining ones, either almost naked or provided with short filiform secondary ramuli, become very much elongated so long as 5 m or even 10 m, having the diameter of 4–5 mm.” As to the habitat, Chihara supplies the information by letter that it grows at Nabeta Bay on rocks and boulders on sandy bottom below low tide mark, preferring calm and protected places near the open sea, and particularly luxuriantly at estuarine waters.

3. *Gracilaria blodgettii* Harvey


Japanese name: *Kubire-ogonori* (n. n).

Material examined: Chihara, Susaki near Shimoda, Shizuoka Pref., July 1955 (*Herb. Ohmi* 68–69, ♂; 70–71, ♀; 72 a, ♀, 72 b, ♂; 73, ♀); Chihara, Susaki, March–June 1955 (*Herb. Ohmi* 75–78, 82, ♂; 79–80, ♀; 81, ♀; 82–84, ♂; 85, ♀); Fan 1856 a, ♀, b, ♀, ♀, c, ♀, d–e, ♀, f, ♀, g–h, ♀, i, ♀, j, ♀, k, ♀, l, ♀, m–o, ♀, Tung-shih, Chia-I Pref., Formosa, June 1953.

Frond caespitose, robust and turgid, mostly 10–30 cm in length, cylindrical, reaching a thickness of 3.5 mm, arising from a small disc; percurrent axis obscure or sometimes traceable; branches abundantly spread out on all sides, alternately or secundly, 3–16 cm in length, abruptly constricted at the base; frond consisting of three kinds of tissues; medulla composed of large parenchymatous isodiametric or polygonal cells which are 0.5–0.6 mm, rarely up to 0.7 mm in diam. and with a thin wall, 2–5 μ in thickness, merging rather abruptly into the sub cortex of one to two layers of ovoidal
cells, 18–30 μ in diam., and essentially two-layered cortex of small, pigmented, more or less anticlinally arranged cells, which are roundish square in shape, 4–9 μ × 9–12 μ in dimensions and with surface jelly ca 9 μ thick. Tetrasporangia densely scattered

Fig. 4. *Gracilaria blodgettii* Harv. A. Detail of branching in the terminal portion of a frond. × 2/3. B. Longitudinal section of a sterile frond. × 284. C. Transverse section of a sterile frond. × 284. (A–C. Plant from Susaki near Shimoda, Shizuoka Pref., July 1955).
Fig. 5. *Gracilaria blodgettii* Harv. A. Section of a mature cystocarp. ×50. B. Detail of carpospores showing stellate central body. ×284. C. Part of the pericarp of a cystocarp to show the radial arrangement of cells. ×284. D. Part of an antheridial frond in transverse section, showing deep conceptacular cavities. ×284. E. Transverse section of a tetrasporic frond. ×50. F. The same section, more highly magnified. ×284. (A-F. Plant from Susaki near Shimoda, Shizuoka Pref., July 1955).
over the greater part of frond, ovate to oblong in shape as seen in transverse section of the frond, \(15 \mu \times 36 \mu\) to \(54 \mu \times 66 \mu\) in dimensions at maturity, bordered by conspicuously anticlinally modified cortical cells, cruciately divided, rose-red in color.

Cystocarps prominently protruding, up to 1.7 mm in diam., globose, subrostrate, slightly constricted at base, with a large, somewhat lobed gonimoblast of large parenchymatous cells, arising from a large fusion cell, ca \(75 \mu \times 120 \mu\) in dimensions, with a wall \(4-5 \mu\) in thickness, and connected to the pericarp by a number of nutritive filaments, \(170-260 \mu\) in thickness; carpospores round or ovoid in shape, \(20-30 \mu\) rarely up to \(54 \mu\) in diam. at maturity, containing a conspicuous stellate central body.

Antheridia borne abundantly all over the surface of frond, in deep, ovoid, regularly and closely spaced cavities, up to \(36-70 \mu \times 45-120 \mu\) in dimensions, surrounded by modified cortical cells. They have a rather small opening. The specimens from Susaki were found to bear tetrasporangia and cystocarps in March, and tetrasporangia, antheridia and cystocarps in the months from April to June. Among the specimens from Formosa an interesting frond was observed which was bearing both antheridial cavities and tetrasporangia, each in separate groups. *Ulva pertusa* Kjellm. and *Bryopsis* sp. are often found growing upon the branches. When fresh, the plant is succulent cartilaginous in substance and translucent deep rosy red, often chestnut or rusty-brown or aeruginose as observed in Formosan plants. Upon drying it changes into dull red or greenish red in color, and becomes much collapsed, adhering rather well to paper.

The present species exhibits a good resemblance to *Gracilaria cylindrica* Börgeisen, but it differs from the latter in having customarily filiform branch-apex, and more gradually narrowed branch bases when old, and in its rather indistinct primary axis and more abundant ramification. Judging from the description given by De-Toni (1900) and from description and photograph by Taylor (1928), the specimens at hand are somewhat larger and thicker in external size than their materials. However, in the internal structure no line of demarcation between them can be found by the writer. So it seems that the specimens may be referable to the present species, which is known to be extremely variable in external morphology. As regards the habitat of the Formosan plant, its collector states: "On the shells of oyster or washed ashore, of which substratum is muddy."

4. *Gracilaria edulis* (Gmelin) Silva

Pl. III, B, and Text-fig. 6

Japanese name: *Kata-ogonori*.

Material examined: *Okada* (without number and date of collection), ⊕, Ryūkyū; *Urabe*, Ariake Bay, Aug. 1909 (*Herb. Yendo 426, ⊕*).

Frond filiform, cylindrical, 2.5 mm in diam., up. to 30 cm in length, with a flexuous aspect in habit, gradually attenuating upwards to a sharp apex, repeatedly branched in a divaricate manner; main axis elongated, hardly traceable, provided with subdichotomous branches slightly or not constricted at the base and standing with a patent axil; general outline of branches somewhat corymbose; frond in transverse section consisting of a large-celled medulla bordered by two layers of much smaller cortical cells; medulla composed of 4–5 layers of large roundish cells ca 500 μ in the greatest diam., possessing a wall 6–15 μ thick; cortical cells cuboid, 6 μ × 10 μ in dimensions; transition from medulla to cortex strikingly abrupt; brownish red in color, soft cartilaginous in substance, adhering rather well to paper on drying.

![Transverse section of a sterile frond](image1)

![Transverse section of a tetrasporic frond](image2)

**Fig. 6.** *Gracilaria edulis* (Gmel.) Silva. A. Transverse section of a sterile frond. × 284. B. Transverse section of a tetrasporic frond. × 284. (A-B. plant from Ariake Bay, Kyūshū, Aug. 1909).
Tetrasporangia ovoid or oblong, 18-36 μ×45–50 μ in dimensions, cruciate, densely scattered on the surface of frond, surrounded by more or less modified cortical cells. Antheridia and cystocarps absent in the material examined. Though the writer was not able to observe them in the material collected within the area under discussion it, fortunately, was possible to examine the cystocarps as well as tetrasporangia in the so-called Ceylon moss, *Gracilaria edulis*, through the kindness of Mr. M. Durairatnam of the Fisheries Research Station of Ceylon. His plant, collected by himself at Kalpitiya, Ceylon, in March 1956, coincides with the present specimens in external and internal characters. The cystocarp of his plant is provided with abundant nutritive filaments connecting the gonimoblast to the pericarp, and thus it is confirmed that this species is a *Gracilaria*. Judging from the description by Okamura and from the two photos of *Gracilaria lichenoides* from Java in J. Agardh's Herbarium (nos. 29051–29052) taken by Yendo, the placement of the specimens at hand under the present species is believed reasonable.

5. *Gracilaria bursa-pastoris* (Gmel.) Silva

*Pl. III, C–IV, B, and Text-fig. 7.*


Japanese name: *Shira-mo.*


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Frond erect, caespitose, terete, 15-30 cm high, 2–3.5 mm thick, repeatedly pinnately branched; branches elongated, subdichotomously and usually divaricately branched, somewhat flexuous, arising alternately or subsecundly with patent and rounded axes from unconstricted insertions, often with long intervals below and with short ones above, tapering to a fine apex, provided with short ramuli; frond in transverse section consisting of large thin-walled (3–5 \(\mu\) thick), roundish, nearly empty medullary cells covered by a cortex composed of two layers of smaller pigmented cells; medullary cells 6–7 layered, 200–600 \(\mu\) in diam., largest in the central portion and diminishing in diameter outwardly; cortical cells cuboid or elongated, 6 \(\mu\) \(\times\) 6 \(\mu\) to 6 \(\mu\) \(\times\) 20 \(\mu\) in dimensions, anticlinally arranged; surface jelly ca 6 \(\mu\) thick; dark or purplish red to brownish in color, soft cartilaginous or membranous in substance, adhering firmly to paper on drying. Tetrasporangia densely scattered over entire surface of frond, ovoid, up to 33 \(\mu\) \(\times\) 50 \(\mu\) in dimensions at maturity, cruciate, surrounded by somewhat modified cortical cells. Cystocarps prominent, conical in shape, constricted at the base, up to 2 mm in diam., 1.7 mm high, non-rostrate; gonimoblast more or less lobulated, composed of extremely vacuolate, elongated cells up to 105 \(\mu\) \(\times\) 170 \(\mu\) in dimensions, connected to the pericarp by numerous nutritive filaments 5 \(\mu\) thick and 150–240 \(\mu\) long; pericarp thick, ca 225 \(\mu\) in thickness, consisting of 10–17 layers of cells, of which the outermost layer cells are pigmented and anticlinally erect, whereas inner layer cells are colorless, connected radially and periclinally with each other by means of distinct connecting filaments. Antheridia borne in the bottom of rather shallow cup or saucer-like cavities, 18–30 \(\mu\) deep, 30–50 \(\mu\) broad, at first separated by modified cortical cells, but later becoming confluent.

The present species is characterized by its divaricate aspect, broad insertions of the branches with finely tapering apices and in having conical cystocarps constricted at the base, and shallow cup-like antheridal cavities often more or less confluent. A specimen from Chiba Prefecture (\textit{Yendo} 332) was found to bear both tetrasporangia and antheridal cavities scattered side by side on the frond surface.

As to the habitat of this plant, it is stated by several authors to grow on rocks and stones in calm places near the open sea.

6. \textit{Gracilaria coronopifolia} J. Agradh


Fig. 9. *Gracilaria coronopifolia* J. Ag. A. Longitudinal section of a plant bearing very young tetrasporangia. ×284. B. Habit of a tetrasporic plant. ×4/5. (A-B. Plant from Rukyusho, Formosa, March 1952).

1949, p. 22, pl. 24, figs. 2-5.

Japanese name: *Mosa-ogonori*.

Material examined: *Yamada*, Garanbi, Formosa, Apr. 1934 (*Herb. B. H. 21742 a, sterile, b, young +; 21743 a, b, young +; 21744 a, b, sterile, c, young +; 21745 a, b, c, young +*); *Tokida* 10 a, b, sterile, Garanbi, Formosa, May 1938; *Fan*, Rukyusho, Formosa, March 1952 (*Herb. Ohmi 160*).

Frond cylindrical, 7-11 cm long, seldom exceeding 1.5 mm in diam., sometimes arising in large number from a common small disc, dark red to purplish red in color, succulent in substance, becoming cartilaginous and adhering rather well to paper upon drying; branching frequent, particularly more often and densely at upper parts, subdichotomous, sometimes secund, with wide, rounded angle with a rather long internode up to 15 cm long below, but with a shorter one above; branches corymbose, occasionally arcuated at upper parts, ending in bifurcate apices; branchlets occurring mostly near the top of branches, very short and spinous; frond in transverse section consisting of a large medullary tissue of colorless rounded cells, up to 150-250 μ in diam. with walls 6-8 μ thick, surrounded by a narrow, infracortical layer of two-layered cells and two to three layers of smaller cortical cells, pigmented, cuboid, antilcinally arranged, minute, 3-5 μ × 5-12 μ in dimensions; transition from
medulla to cortex extremely abrupt; hairs sparsely present; tetrasporangia oblong in surface view, $10\mu \times 15\mu$ to $12\mu \times 18\mu$ in dimensions, ovoid in sectional view, anticlinally arranged, $10\mu \times 18\mu$ to $12\mu \times 20\mu$ in dimensions, scattered over surface of almost entire frond, embedded in the cortex, surrounded by anticlinal rows of 2–3 unmodified cortical cells.

External appearance of the present species is so peculiar that one can easily tell the species from others by its corymbose habit. The cortical cells surrounding the tetrasporangia are unmodified, as described above, but it should be noted here that the sporangia observed were all very young.


Pl. V, A–C, and Text-fig. 10.


Japanese name: *Yumigata-ogonori*.


Frond cylindrical, thick and solid, 5–10 cm in length, up to 3 mm or rarely more in diam. when reimmersed in water, arising from a small disc, brownish red or deep purplish in color, often turning into blackish on drying, membranaceous, fleshy in substance, and with a smooth surface while fresh, but collapsed and longitudinally rugose, not adhering firmly to paper, when dried; branching irregularly pinnate, rather distant below with a patent rounded axil and with short intervals above with a narrow axil; branches unconstricted at the base, extremely divergent, flexuous or corymbose in general outline, sometimes arcuated upwards, ending in sharp acute apices, provided with secund branches or branchlets mostly on the outer side of the curved portions; Frond in transverse section consisting of a medulla of large thin-walled (5–8 μ in thickness) cells arranged in 5–6 layers, roundish in shape, 150–350 μ in diam., and an infracortex of 1–2 layered cells, roundish in shape, 30–45 μ in diam., filled richly with floridean starch grains, bounded by a cortex of small globular pigmented cells mostly two-layered, of which the outermost cells are roundish or slightly oblong in shape, 4 μ×10 μ in dimensions, with surface jelly ca 10–15 μ thick. Tetrasporangia densely scattered over almost entire surface of frond, round in shape.
in surface view, ovoid or oblong in transverse section, up to 24 μ×45 μ in dimensions, surrounded by somewhat anticlinally elongated cortical cells, cruciately divided. Cystocarps globoid prominently protruding, non-rostrate, up to 1.2 mm in diam., 1 mm
in height, constricted at the base; gonimoblast simple, not lobulated, small-based, composed of extremely vacuolate elongated cells; pericarp ca 250 µ in thickness, connected to the gonimoblast by a number of nutritive filaments 3–6 µ in thickness, 150–270 µ in length; carpospores round or ovoid, 24–30 µ in diam. at maturity, with a conspicuous pigmented body in the center. Antheridia in roundish sori in surface view, borne in deep pocket-like cavities up to 45 µ in breadth, 60 µ in depth as seen in transverse section, separated by slightly modified cortical cells.

8. **Gracilaria crassa** Harvey

Pi. V, D–E, and Text-fig. 11.


Japanese name: **Taiwan-ogonori** or **Fushikurenori**.


Frond cylindrical, caespitose, often attaching to corallinous algae or mollusc shells, up to 8 cm in length, ca 2.5 mm in diam., constricted below when old, repeatedly branched irregularly and divaricately to trichotomously; purplish or dark greenish in color, carnose or soft cartilaginous in substance, adhering firmly to paper on drying; branches, when the plant matured, markedly articulato-constricted, with ovate, subcuneate, oblong or subpyriform articulations, 1.5-5 mm broad, 2–4 times as long as broad.

The above description is a modification of what Okamura gave in 1933 to *Corallopsis opuntia* J. Agardh.

The following description is based on the writer's own observations of the material at hand.

Frond in transverse section with a cortex ordinarily consisting of two layers of pigmented small cells, of which the outermost ones more or less anticlinally disposed, 4 µ × 6–12 µ in dimensions, with surface jelly ca 15 µ thick. The cortex in surface view is always provided with abundant large gland-like cells; they scatter over the surface of frond, mostly roundish or sometimes longitudinally elliptical in surface view, 45–50 µ.
in diam., oblong in transverse section, filled with a bright orange-yellow content; when those cells occur intermixedly with tetrasporangia on the same frond, they are larger than the latter and are in a marked contrast to those purplish structures. At first sight those gland-like cells bear some likeness in their appearance to hair "base-cells" which are frequently observed in various species of *Gracilaria* and *Gracilarioopsis*. However, they differ from the hair "base-cells" in being markedly larger in size and bright orange yellow in color, and furthermore in lacking even a scar of hair. Judging from these characters, the writer is inclined to consider them to be "gland-cells". However, the true nature of these cells is not clear at present.

As regards the "gland-cells" in *Gracilaria* and allied genera, so far as the writer is aware, no one has ever reported their existence with the exception of Inagaki (1933), who described and illustrated "gland-cells" in his specimens of *Gracilaria confervoides* and *G. textorii* from Oshoro Bay, Hokkaido. He states that they are ovoid or elliptical in shape in transverse section, light yellow in color and refractive of light. He further states that similar "gland-cells" are present in *G. gigas*. As far as the present writer could determine from the specimens of these three species at hand, the "gland-like cells" were present only in *G. textorii* from Oshoro.

Tetrasporangia scattered amidst the superficial layer of frond, ovate to oblong as seen in transverse section, roundish in surface view, 30–50 μ in diam., cruciate, dark red or purplish in color but not in the sori, surrounded by somewhat modified cortical cells. Cystocarps and antheridia unknown.

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Fig. 11. *Gracilaria crassa* Harvey. A. Surface view of a part of a tetrasporic frond, showing two globoid tetrasporangia and an oblong gland-like cell. ×514. B. Transverse section of a frond showing a pyriform gland-like cell. ×514. (A-B. Plant from Naha, Ryūkyū, June 1938).
Börgesen (1952) and Dawson (1954, 1954a) made it clear that _Corallopsis opuntia_ and _Gracilaria crassa_ are one and the same species. Dawson (1954) states, "Although the constrictions of the pendant branches are extreme for the genus _Gracilaria_, they seem to constitute insufficient reason for generic segregation, particularly in view of the progressive approach to this condition exhibited by the development of _Gracilaria crassa_ Harvey, ex. J. Agardh (=_Corallopsis opuntia_ J. Ag.). Accordingly, the name _Corallopsis_ Greville (1830, p. 53) is reduced under _Gracilaria_ Greville (1830, p. 54)."

After studying the specimens at hand, the present writer has come to agree with their views.

9. _Gracilaria salicornia_ (C. Ag.) Dawson

Pl. V, F-VI, A, and Text-fig. 12.


Japanese name: _Tokida-fushikurenori_ (n. n.).

Material examined: _Tokida_ 24, ⊕, ⊙, Itoman, Ryūkyū, June 1938.

Frond caespitose, cylindrical, 6–10 cm high, 2–2.5 mm in diam., irregularly and repeatedly dichotomo-divaricately branched, greenish or yellowish red in color, soft cartilaginous in substance, adhering rather well to paper on drying; branches and branchlets conspicuously articulato-constricted to a sharp spine, and because of this they are apt to be separated from the main axis at the sharpened base while treating; articulations obcuneate, oblong or elongated inverted pyriform, 2–15 times as long as broad. Frond in transverse section consisting of a medulla of large isodiametric parenchymatous cells, 260–350 μ in diam., with walls ca 8 μ thick, and two layers of small, anticlinally arranged pigmented cortical cells; transition from medulla to cortex is abrupt. Tetrasporangia scattered over almost entire surface of frond, round in shape in surface view, ovoid or oblong in transverse section, 15–20 μ × 45 μ in dimensions, cruciate, bounded by somewhat anticlinally elongated cortical cells; gland-like cells abundantly scattered over the surface of frond, roundish or elliptical in surface view, 20–30 μ × 30–45 μ in dimensions, oblong or pyriform in transverse section, 30 μ × 45–60 μ in dimensions, filled with a bright orange yellow content. When the gland-like cells occur intermixedly with tetrasporangia on the same frond, the latter are clearly distinguished from them by their smaller size and purplish color. As stated above, the gland-like cells are closely similar in their features to those of _Gracilaria crassa_. Cystocarps globoid, prominently protruding, non-rostrate, up to 1.8 mm in diam., constricted at the base; gonimoblast more or less lobulated, small-based, composed of conspicuously vacuolate cells; pericarp ca 240 μ in thickness, connected.
Fig. 12. *Gracilaria salicornia* (C. Ag.) Dawson. A. Surface view of a part of a tetrasporic frond to show three tetrasporangia and four gland-like cells scattered among cortical cells. $\times 284$. B. Transverse section of a frond showing an oblong gland-like cell. $\times 284$. C. Transverse section of a part of a tetrasporic frond. $\times 284$. D. Section through a mature cystocarp. $\times 50$. (A-D. Plant from Itoman, Ryūkyū, June 1938).

To gonimoblast by numerous nutritive filaments; carpospores round or ovoid, 15–20 $\mu$ in diam. at maturity. Antheridia unknown.

The present species closely resembles *Gracilaria crassa* in the internal structure as well as in the external character. However, it is easily distinguished from the latter.
in its extremely narrowed or sharply defined base of branches and branchlets. On the basis of comparison with the description and the illustration of the present species given by Dawson (1954), the specimens at hand can be referred to it without hesitation.

10. *Gracilaria denticulata* (Kütz.) Weber van Bosse

Pl. VI, B, and Text-fig. 13.


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![Diagram](image-url)

**Fig. 13.** *Gracilaria denticulata* (Kütz.) Weber van Bosse. A. Apical portion of a frond showing numerous denticulate processes on the margin. × ca 5. B. Transverse section of a sterile frond. × 284. C. Section of a mature cystocarp. × 50. (A-C. Plant from Okinawa-jima, Ryūkyū, 1923).
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**Japanese name:** Toge-kabanori.

**Material examined:** Sakaguchi, Ryūkyū, 1923 (Herb. B. H. 21126 a-b, ♀; 21127, ♀; 21128 a-b, ♀).

Frond foliose, flabelliform, 8-10 cm high, 0.5-1.5 cm broad, provided with abundant denticulate processes on the margins, rosy to pinkish red, partially turning into yellowish color, coriaceous and slightly adherent to paper on drying, cylindrical and long stipe-like ca 4-5 cm in length below, arising from a small disc, repeatedly dichotomously lobed ending in blunt apices; frond in transverse section up to 180 μ thick when soaked in water, consisting of a medulla of 3-4 layers of large cells 160 μ in diam., and containing globular floridean starch grains, with a wall ca 3 μ thick, and a cortex of 1-2 layers of flattened cells 10-12 μ broad and 5 μ high with surface jelly ca 15 μ thick; infracortical cell is one-layered. Cystocarps on both surfaces of frond, prominent, globular, low dome-like in appearance, up to 1.75 mm in diam., ca 1 mm in height, non-rostrate, constricted at the base; gonimoblast lobulated, composed of large vacuolate cells, connected to the pericarp by several nutritive filaments; carpospores roundish or ovoid, 20-25 μ in diam. containing a rosy red chromatophore; pericarp up to 140 μ thick, constructed of a superficial layer of anticlinally erected small pigmented cells and about 10 layers of anticlinally arranged flat colorless cells. Tetrasporic and antheridial individuals unknown.

11. *Gracilaria purpurascens* (Harv.) J. Agardh

Pl. VI, C-D and Text-fig. 14.


**Japanese name:** Murasaki-kabanori.

**Material examined:** Yamada, Naha, Ryūkyū, May 1932 (Herb. B. H. 21121 a, ♀, b, ♀, c, ♀; 21122, a, b, ♀, c, ♀; 21123, ♀; Yamada, Daibanratu, Formosa, 1923 (Herb. B. H. 21124, ♀; 21125, ♀); Fan 1107-4, ♀, Daibanratu, Formosa, Apr. 1951.

Frond foliose, flabellate, heavily crisped and furnished with numerous short spinulate processes on the margins, 6-8.5 cm high, 0.2-1.5 cm broad, less than 330 μ in thickness, dark red to purplish red or sometimes yellowish in color, coriaceous and adhering imperfectly to paper on drying, repeatedly dichotomously divided, ending in
Fig. 14. *Gracilaria purpurascens* (Harv.) J. Ag. A. Detail of the crenulate margin of a frond. × 85. B. Surface view of a part of a tetrasporic frond. × 514. C. The same frond as seen in transverse section. × 284. D. Section of a mature cystocarp. × 50. (A-D. Plant from Naha, Ryūkyū, May 1932).

Blunt or somewhat ligulate apices, arising from a small disc by a short cylindrical stipe, which expands into a cuneate base of the foliose frond; frond in transverse section consisting of a medulla of 2–3, rarely of 4 layers, of large roundish cells up to 160 μ in
diam., containing masses of globular floridean starch grains, with a wall 3–6 μ thick and
an infracortex of one-layered somewhat flattened cells, 20 μ × 30–45 μ in dimensions,
bounded by two-layered small pigmented flattened cortical cells, cuboid or sometimes more or
less anticlinally elongated, 6 μ × 10 μ in dimensions, with surface jelly up to ca 15–
18 μ thick. Tetrasporangia densely scattered on both surfaces of entire frond, roundish and ca 15 μ in diam. in surface view, ovoid and 12 μ × 18 μ in dimensions in section-
al view, surrounded by unmodified cortical cells. Cystocarps prominent on both surfaces of frond, globular, low dome-like in appearance, non-rostrate, constricted at the base, 0.5–1.0 mm in diam., 0.4–0.9 mm in height; gonimoblast consisting of vacuolate cells, connected to the pericarp by abundant nutritive filaments 6 μ × 180 μ in dimensions; carpospores small, roundish or oblong, 15–20 μ in diam.; pericarp 120–210 μ thick, composed of 10–15 layers of radially elongated outer cells and compressed inner cells.

11 a. *Gracilaria purpurascens* (Harv.) J. Agardh

f. *spinulosa* (Okam.) Yamada

Pl. VI, E–VII, B, and Text-figs. 15–16.


Japanese name: *Toge-itsutsuginu.*

Material examined: Tanaka, Tairi, Formosa, Apr. 1934 (*Herb. B. H. 21746 a, b, +; 21747 a, +, b, ⊕; 21748 a, +, b, +*); Tokida 17, sterile, Fukikaku, Formosa, May–June 1938; Tokida 21, ⊕, Fukikaku, Formosa, May–June 1938; Fan 1003–1, ⊕, Garanbi, Formosa, Apr. 1951; *Fan* 1102–1, 2, ⊕, Garanbi, Apr. 1951; *Fan* 1103–1, ⊕, Garanbi, Apr. 1951.

Frond foliose, flabellate, complanate, ca 6–9 cm high, 0.7–1.5 cm broad, seldom exceeding 350 μ, rarely up to 520 μ in thickness, often lacerated and furnished with abundant spinous processes on the margins, arising from a small disc by a short subterete stipe, expanding above into the cuneate base of the foliose frond, dull red to purplish russet or yellowish green in color, carnose in substance while fresh, but becoming subcartilaginous and adhering not well to paper on drying; branching dichotomous; branches ending in obtuse or occasionally somewhat truncate tips; frond in transverse section consisting of a medulla of 3–4 layers of cells containing numerous globular floridean starch grains 5–6 μ in diam., with cell walls ca 6 μ thick, diminishing in diameter towards the exterior, grading into an infracortex of 2–3 layers of cells, bounded by a cortex of two layers of minute pigmented cells mostly cuboid, ca 6 μ × 9 μ in dimensions, which are roundish and ca 10 μ in diam. in surface view,
Fig. 15. *Gracilaria purpurascens* f. *spinulosa* (Okam.) Yamada. A. Detail of the margin of a frond bearing spinous processes. ×50. B. A compound marginal process of the same frond as in fig. A, highly magnified. ×284. C. Transverse section of a sterile frond. ×284. D. Longitudinal section through the center of a cystocarp, showing the ostiole and the fusion cell measuring 45 μ broad and 120 μ long. ×50. E. Transverse section of an antheridial frond showing antheridial pits and modified cortical cells. ×284. F. The same antheridial frond in surface view. ×514. G. Transverse section of a tetrasporic frond. ×284. H. Detail of three nutritive filaments. ×284. (A-F. Plant from Tairi, Formosa, Apr. 1934. G-H. Plant from Garanbi, Formosa, Apr. 1951).
with surface jelly 6–10 μ thick. Tetrasporangia roundish or ovoid and densely scattered over both surfaces of entire frond, borne in a slightly modified cortex, 10–22 μ × 18–27 μ in dimensions in transverse section, roundish and up to 18 μ in diam. in surface view, cruciate. Cystocarps scattered on both surfaces of frond, exceedingly prominent, low dome-like or almost globular in appearance, reaching 0.8–1.3 mm in diam., ca 0.7–1.0 mm in height at maturity, non-rostrate, strongly constricted at the base; gonimoblast sometimes lobed, formed of vacuolate cells, seated on the floor which is ca 120 μ thick and composed of 5–6 layers of radially arranged cells; nutritive filaments connecting the gonimoblast to the pericarp solid and thick, ca 6 μ thick and ca 105 μ long; carpospores rather small, ovoid or roundish, 15–22 μ in diam., compactly filling the cystocarpic cavity; pericarp 120–350 μ in thickness, consisting of many layers of small cells, of which the outermost pigmented cells are anticlinally erect, 5–6 μ × 9–12 μ in dimensions, while inner colorless ones more or less flattened, anticlinally arranged in 20–26 layers. Antheridia borne in solitary or confluent shallow, broad pits, 15–20 μ in depth, 15–30 μ or more in breadth, surrounded by modified cortical cells.

The present species seems to come very near *Gracilaria millarètii* (Mont.) J. Ag. However it can easily be distinguished from the latter in having shallow pit-like antheridal cavities.
12. *Gracilaria punctata* (Okam.) Yamada

*Pl. VII, C-VIII, B, and Text-figs. 17-18.*


*Japanese name:* *Itsutsu-ginu.*


Frond complanate, foliose, 5–10 cm long, 1–2.5 cm broad, dichotomously divided, often markedly contracted in the middle portion of the lobes, obtuse or irregularly cleft in apices, sometimes arcuated at the upper portion of frond, possessing a general outline oblong or ovate or sometimes like an inverted triangle, arising from a small discoid holdfast attached to coralline crust by a short terete stipe expanding into the cuneate base of the foliose frond, which is undulate or crisped and entire or infrequently provided with small protuberances on the margin, variegated here and there on the surface with elliptical spots measuring ca 0.5 mm x 0.7 mm in dimensions; dark red or purplish russet, often becoming slightly greenish in color, thickly membranaceous or cartilaginous in substance while fresh, becoming coriaceous and poorly adhering to paper on drying; frond in transverse section up to 450μ in thickness, consisting of a medulla of 2–3, rarely up to 4, layers of large cells 105μ in diam., and an infracortex of two-layered smaller cells, bounded by a cortex of 2–3 layers of cells, cuboid or somewhat anticlinally elongated, mostly 6–10μ x 10–12μ in dimensions; cells of medulla and infracortex are both filled in the content with innumerable floridean starch grains, which are globular in shape, reaching 6μ in diam., and with walls less than 8μ in thickness. Tetrasporangia densely scattered on both surfaces of frond, ovoid, 20–30μ high and 10–24μ broad in transverse section, roundish in surface view, dark red in color, in unmodified cortical cells; in an old tetrasporic frond can be frequently seen small whitish specks on the surface. Cystocarps scattered on both surfaces of frond, prominently protruding, up to 3 mm in diam., 1.2 mm in height at maturity, dome-like in appearance, non-rostrate, strongly constricted at the base; gonimoblast consisting of large vacuolate cells, connected to the pericarp by nutritive filaments; carpospores roundish or oblong, 20μ in diam. to 15μ x 30μ in dimensions, almost filling the cystocarpic cavity; pericarp ca 200μ thick, consisting of 1–2 superficial layers of...
anticlinally erect pigmented cells, $6\mu \times 15\mu$ in dimensions, and 8–12 inner layers of colorless, irregularly shaped, more or less anticlinally arranged cells; surface jelly 13$\mu$ thick.

The above description is a modification of that given by Yamada (1941).

Antheridia borne in solitary or confluent, small, shallow, saucer-like antheridial pits 10–20$\mu$ deep and 20–45$\mu$ diam., surrounded by more or less modified cortical cells; in surface view antheridial sori densely scattered over the greater part of the frond surface as small white flecks separated by islands of linear or lenticular groups of vegetative cells.

The present species seems to bear some resemblance in its texture to *Gracilaria crisipata* Setchell et Gardner as was already pointed by Yamada. However, after
compa riting with the specimens of the latter now at hand (Dawson 1713, ♂, Bahia Bocochibampo, near Guaymas, Sonora, May 1946; Dawson 3470, ♀, Bahia de La Paz, Baja Calif., overcast, Nov. 1946; Dawson 3552, ♀, Ensenada de San Francisco, near Guaymas, Sonora, Nov. 1946), the present writer can distinguish it from the latter by its
broader frond and thinner cortical layer. Among the Formosan specimens the
writer was able to find five antheridial individuals so he could confirm Okamura's
observation on the structure of the antheridial cavity.


Pl. VIII, C–IX, B, and Text-fig. 19.

Okam., Icon. Jap. Alg. VI, 1931, p. 41. 273, figs. 1–6; Id., Nippon Kaisō-shi, 1936,
p. 633.

Japanese name: *Mizo-ogonori.*

Material examined: Tokida 2, sterile, Jyōga-shima, Kanagawa Pref., Apr. 1938;
Umezaki, Shirahama, Wakayama Pref., May 1951 *(Herb. Ohmi 3–4, ?); Yagi,
Mitsuhama, Ehime Pref., July 1953 *(Herb. Ohmi 30, ?); Yagi, Mitsuhama, Ehime
?); Yagi, Mimatoyama, Ehime Pref., Aug. 1953 *(Herb. Ohmi 36, ?); Yagi, Mimato-
41, ?); Yagi, Mimatoyama, Ehime Pref., Aug. 1953 *(Herb. Ohmi 42, ?); Yagi, Yanagihara,
46, ?); Yagi, Mitsuhama, Ehime Pref., Nov. 1953 *(Herb. Ohmi 47, ?); Yagi, Gogo-
50, sterile); Yagi, Minatoyama, Ehime Pref., Aug. 1955 *(Herb. Ohmi 51, sterile)*.

Plant foliose, caespitose and massive, erect, 6–14 cm high, more or less flabelliform,

arising from a callous disc; frond flat or compressed except the very base, reaching a
thickness of 0.6–0.8 mm, rarely up to 1.2 mm, provided with numerous dichotomous
lobes above the first fork at fairly short intervals, with patent round axes, channeled
or more or less incurved and often twisted at some part; branches tapering upwards in
some cases, but almost equal in breadth in others, ending in blunt or long attenuated
bifurcate apices, and occasionally arcuated at upper lobes, sometimes furnished with
short adventitious proliferations on both surfaces and margins, broadly linear or band-
shaped, 5–10 mm up to 15 mm in breadth, abruptly narrowed at the base to a very
short, subcylindrical stipe; segments slightly tapered in some specimens, 0.3–2 mm in
breadth below the apex; margins smooth and entire. Coriaceous and brittle in substance
when fresh, imperfectly adhering to paper on drying; frond in transverse section consist-
ing of a medulla of large, normally 5–6 layered, thin-walled cells with walls less than 6μ
in thickness, up to 350μ×610μ in dimensions, and an infracortex of 2–3 layered cells,
mostly somewhat compressed interconnected by distinct filaments between each
other, containing numerous floridean starch grains, bounded by a cortex of a single or
sometimes two-layered pigmented cells 3-5μ thick, 6-9μ high anticlinally erected, which
in surface view are from 4μ in diam. to 10μ×14μ in dimensions, with surface jelly ca
5μ thick. Tetrasporangia densely scattered over both surfaces of frond, bright red in
color, ovate to oblong, cruciate, 12-35μ×40-65μ in dimensions in transverse section,
12μ×30μ to 30μ×45μ in surface view, surrounded by modified cortical cells. Cystocarps
globose, prominently rostrate, scattered over both surfaces of frond, 0.7-1.5 mm in
diam.; gonimoblast built up of large parenchymatous cells, connected to the pericarp by
nutritive filaments; pericarp 105-150μ in thickness, constructed of many-layered
cells, of which the outermost ones are strongly pigmented and somewhat anticlinally
elongated, while the inner colorless cells are rather flat in shape; mature carpospores
spherical 20-36μ in diam. with a reddish chromatophore in the center. Antheridial
plant unknown. The specimens from Takamatsu, Ehime Prefecture are found to
bear a number of spherical bodies of an endophyte, scattered over the frond surface
and embedded in the cortex of the greater parts of a frond as well as in the pericarp
of a cystocarp. They are 18-25μ in diam. and have a colorless wall 2.5μ thick.
They often contain many swarmer-like globules, which are 5-6μ in diam. and
green in color, but most of them are empty being provided with an apical aperture.
This endophyte may probably be a species of Chlorochytrium.

The present plant bears a close resemblance to Gracilaria textorii, with which
it had been confused until Okamura (1931) made their differences clear and erected a new
species for the plant. He says that the frond of the present species is smaller, less
broad, incurved or somewhat distorted, and closely dichotomous in branching as
compared with that of G. textorii. However, he further continues, “All those differences
are not always strongly manifest, but there are often intermediate forms between it
and G. textorii.” In present writer's opinion, this species is decidedly distinguishable
from G. textorii in having not only the above mentioned characteristics but also long
attenuated terminal branches and strongly rostrate cystocarps.

14. Gracilaria textorii (Suringar) J. Agardh

Text-figs. 20–21.
1958] Ohmi: Species of *Gracilaria* and *Gracilariopsis*


Japanese name: *Kaba-nori.*


Plants foliose, caespitose, arising from a common scutate disc, with a short subcylindrical stipe, soon expanding into the cuneate base of frond, irregularly dichotomously to flabellately lobed with broad linear patent segments whose axils are rounded; dull- or brownish-red to somewhat yellowish or greenish in color, membranous to thick coriaceous in substance, imperfectly adhering to paper on drying; frond variable in size and shape, usually 4.7–18.5 cm high and 7–45 mm broad under the dichotomies when mature, with rounded or somewhat attenuated apices, also variable in thickness, young plants being quite thin (240 μ), while old ones may be as much as 750–875μ thick; margins smooth and entire, occasionally slightly undulate, normally non-proliferous but sometimes with more or less simple or branched proliferations; apical segments, 0.5–7 mm broad below the apex, sometimes end in blunt or ligulate, or sometimes in acute or bifid apices; in other cases, terminal segments are much slenderer and more pale in color than the remaining portion, being divided repeatedly in dichotomous manner; frond in transverse section consisting of a prominent cellular medulla of large (230–400μ in diam.) thin-walled (5–9μ thick) cells, which are colorless in content; cortex normally made of a pigmented single layer of more or less anticlinally elongated cells, which in older parts become two-layered, measuring 5–12μ long, 4–9μ broad; subcortical layers of somewhat larger cells, containing globular floridean starch grains which are 3–7μ in diam.; transition from the large medullary cells to the small cells of the cortex is abrupt; colorless hairs occasionally present on frond surface, measuring up to 320μ long and 6μ thick; surface jelly thin. Tetrasporangia are densely scattered over both surfaces of the frond except the apical and the lowermost portions, ovate to elongate in shape, attaining 22μ×13μ–35μ×28μ in transverse section and 8.5μ×8.5μ–40μ×22μ in surface view, cruciately divided. They are bright red in color.

Sexual plants are heterothallic.

Cystocarps hemispherical or almost globular, up to 1.7 mm in diam., ostiolate,
Fig. 20. *Gracilaria textorii* (Sur.) J. Ag. A-B. Habit of two antheridial plants. $\times$ ca 2/3.
C. Surface view of a tetrasporic frond. $\times$ 284. D. The same tetrasporic frond in transverse section. $\times$ 284.
densely scattered over both surfaces of frond; pericarp thick, being constructed of many layers of cells, which are anticlinally elongated; gonimoblast nearly filling the cystocarpic cavity and keeping connection with the pericarp by means of numerous nutritive filaments; nutritive filaments irregularly shaped, 105–180μ long, 10–20μ broad; outermost cells of the pericarp red in color, 9–15μ long, 6–9μ broad, while inner ones are yellowish in color or almost colorless; carpospores spherical or slightly elongated in shape, measuring 13μ×9μ–28μ×22μ, having a red chromatophore in the central portion.

Male frond is sometimes distinguishable by its pale red color from others. Antheridia are borne abundantly all over the surfaces of frond, in superficial shallow saucer- or cup-like cavities or pits, 20μ wide, 17μ deep, surrounded by modified, pigmented cortical cells. Antheridial pits are formed at first solitarily, but later become adjoining side by side or even confluent. Spermatia are colorless, globular, mostly 2–3μ in diam. as seen from surface.

A thorough description and remarks on this species are given in the writer's previous paper cited above.

Among the specimens in the Herbarium of the Department of Botany, Faculty
of Science, Hokkaido University, a large tetrasporic frond (Herb. B. H. 25481) collected by S. Sakaguchi in Wakayama Pref., in June 1943 was found to measure 30 cm in length, and 6 cm in breadth. It is the largest specimen of this species the writer has ever examined. A specimen from Oyano-shima, Kumamoto Pref. was found to bear antheridia in broad, shallow cup-like cavities bounded by conspicuously modified cortical cells as shown in Fig. 20, F. In a tetrasporic specimen from Oshoro, Hokkaido, the tetrasporangia were observed to be bounded by slightly modified cortical cells as figured in Pl. I, Fig. 3 of the writer's previous paper (1955). However, in other specimens from the same locality which bear abundant tetrasporangia the cortical cells are considerably modified (Fig. 20, D).

On reexamining the specimens collected at Oshoro in November 1954, the present writer could observe gland-like cells scattered over the surface of frond, light yellow or pale red in color, roundish, more or less larger in dimensions than the adjoining cortical cells when observed in surface view, and ovoid in shape as viewed in transverse section, measuring $6 \mu \times 10-15 \mu$. They correspond closely to the "gland-cells" which were described and illustrated by Inagaki (1933). However their true nature is not clear to the present writer at the moment.

15. *Gracilaria sublittoralis* Yamada et Segawa (nom. nud.)

Pl. IX, C–D, and Text-fig. 22.


Japanese name: *Shinkai-kabanori*.


This species was recently added to the list of the species of *Gracilaria* by the above mentioned authors without giving any diagnosis or illustrations. Through the kindness of Dr. Segawa and Mr. Yagi, present writer was fortunately able to examine some specimens including three tetrasporic and one cystocarpic plants.

Plant complanate, foliose, irregularly and sparingly lobed into broad linear patent segments with round axils, brownish red in color, membranous to thick coriaceous in substance, adhering imperfectly to paper on drying, rather variable in size and shape, when matured reaching 20 cm in length, 3–6 cm in breadth, blunt or ligulate at the apex, smooth and entire on the margins, provided with a few proliferations or sometimes non-proliferous; frond in transverse section seen to consist of a medulla of large cells 260–600$\mu$ in diam., roundish or polygonal and thin-walled (ca 6$\mu$ thick), bounded by a single layered infracortex or in older parts it may become distromatic to rarely three layered; cortex of pigmented cells, minute, irregularly shaped, mostly
Fig. 22. *Gracilaria sublittoralis* Yamada et Segawa. A. Transverse section of a sterile frond. ×284. B. Surface view of a tetrasporic frond. ×284. C. The same tetrasporic frond in transverse section. ×284. D. Detail of the pericarp of a cystocarp. ×284. E. Outlines in section of two cystocarps showing the low dome-like shape. ×13. F. Section of a mature cystocarp. ×50. G. Detail of carpospores. ×284. (A-G. Plant from Kozushima, Izu Islands, Aug. 1936).
3-4 μ×6 μ, reaching 6 μ×9 μ in dimensions. Tetrasporangia densely scattered on both sides of frond, cruciate, roundish in shape in surface view, 15-45 μ in dimensions, ovoidal or somewhat elongated oblong and 36 μ×42 μ in the maximum dimensions in transverse section, surrounded by somewhat modified cortical cells. Cystocarps abundantly scattered over both surfaces of frond, exceedingly low dome-like in shape, 0.9 mm in height, less than 2.3 mm in diam., non-rostrate, occasionally slightly concaved at the top; pericarp fairly thick, built up of many-layered cells, of which the outermost pigmented ones are anticlinally erect, whereas inner colorless ones are compressed; gonimoblast consisting of large parenchymatous cells relatively poor in protoplasmic content, connected to the pericarp by several nutritive filaments; mature carpospores roundish or more or less elongated in shape, 28-36 μ or rarely up to 48 μ in diam., containing a reddish stellate chromatophore; antheridia unknown.

According to a personal communication from Dr. Takamine, this alga was first collected by means of a drag-net from a depth of about 10 m at Sugashima, Ise Bay in early summer. Dr. Segawa informs that it grows in the sublittoral zone at Kōzushima, Izu Islands.

16. *Gracilariopsis vermiculophylla* Ohmi

Ohmi, Contributions to the knowledge of Gracilariaceae from Japan. II, 1956, P. 271, figs. 1-4, pl. 1-2.

Japanese name: *Ogo-modoki*.


Frond solitary or tufted, arising from a very small callous disc, usually 4-30 cm but sometimes up to 80 cm in length, cylindrical throughout, slightly flexuous; dark red or rather blackish in color, cartilaginous in substance, often adhering imperfectly to paper upon drying; main axis percurrent; branches long-attenuated, issuing alternately on all sides from the main axis or sometimes one-sidedly, mostly with patent, sometimes even rectangular axils, branching up to four times, usually alternately but sometimes also subdichotomously, branches of every type tapering towards apex, hardly constricted at the base except those at the lower portion of the plant, 4.2-17 cm in length in the first order branches, 0.5-4 cm in the second, and shorter than 0.5 cm in the third order, the last one being simple, very short ramulus.

The main axis in the middle portion of the frond, in transverse section, consists in the medulla of 12-13 layers of large, round subisodiametric cells, up to 350 μ diam, with walls 5-7 μ to 15 μ thick; outer cells of the medulla merging gradually into a 2-3
layered subcortex composed of ovoidal cells, 30\(\mu\) high, 12–15\(\mu\) thick. Medullary cells contain several transparent, highly refractive globules, round or pod-like in shape, up to 75\(\mu\)×60\(\mu\) in dimensions; cystocarps subglobose, protruding up to 1.2 mm diam., somewhat rostrate, ostiolate and a little basally constricted, scattered on all sides of branches, often aggregated, with a large gonimoblast parenchyma of small, densely massed, richly protoplasmic cells producing dense, radiating chains of ovoid carpospores almost fully filling the cystocarpic cavity; carpospores roundish or more or less elongated, 30–50\(\mu\) in length, containing a conspicuous stellate, central body, nourished only by the gonimoblast, without nutritive filaments; placenta elongated and not lobed. Pericarp 130–150\(\mu\) thick, its cortex being composed of two layers of cells, outermost one is 9–15\(\mu\) high, 3–5\(\mu\) thick, while inner one is usually flat in shape, 8–12\(\mu\) high, 4–6\(\mu\) thick. Antheridia formed in cavities all over the surface of frond, but occasionally on slightly swollen, somewhat vermiform upper branches; cavities deep, open, conceptacular pockets mostly with a broad opening, 70–150\(\mu\) deep and 45–120\(\mu\) wide, well-separated by mediately anticlinally modified cortex; tetrasporangia scattered over the surface of frond, circular in shape as seen from surface, up to 42\(\mu\) diam., cruciately divided, rose-red in color, borne in a somewhat nemathecially modified cortex with elongated outer cortical cells which are up to 60\(\mu\) high and 42\(\mu\) thick in transverse view; these three kinds of reproductive organs are, of course, ordinarily formed on different plants.

In some specimens, tetrasporangia and antheridia occurred mixed together. These were scattered over the surface of the frond separately or gathered in small irregular groups which show no elevation above surface. When occurring solitarily the antheridial cavities are broadly urn-shaped or deep pocket-like, well separated from others by somewhat modified cortical cells, but when packed together, oblong. They have a somewhat narrowed opening and are about 45\(\mu\) to 70–150\(\mu\) deep, 24\(\mu\) to 45–120\(\mu\) wide in transverse section and 90–150\(\mu\) deep, 50–60\(\mu\) wide in longitudinal section.

The discovery of the present species is reported with a detailed description and remarks in the writer's previous paper cited above.

17. **Graciliopsis rhodotricha** Dawson

Pl. X, A–B, and Text-fig. 23.


Japanese name: **Hoso ogo-mcdoki** (n. n.).


Frond cylindrical throughout, forming entangled clusters or masses, arising from
a small disc, 11 cm in length, rarely up to 1.4 mm in diam. though seldom exceeding 1 mm, scarcely stipitate; branching generally irregular, alternate or secund in places; primary axis scarcely traceable; branches issued on all sides with patent axils at rather short intervals, mostly 1–10 mm in distance; branchlets tapering towards apex, mostly slightly contracted at the base though in some cases considerably contracted; very slender in texture, purple or somewhat greenish in color, collapsing completely and adhering fairly evenly to paper on drying; frond in transverse section consisting of a medulla of large colorless cells with thin walls usually less than 8 μ, rarely up to 17 μ in thickness, roundish, up to ca 180 μ in diam. in the central cells, gradually becoming smaller in diameter towards the exterior region, and of an infracortex of 2–3 layers of cells, somewhat longitudinally elongated, bounded by a cortex of 1–2 layers of pigmented cortical cells, 4–6 μ × 12–15 μ in dimensions, anticlinally erect, with numerous hairs on the surface.

Tetrasporangia scattered among the surface layer of frond, ovate to oblong in transverse section, measuring up to 40 μ × 48 μ in dimensions, cruciate, not in sori but slightly upheaved above the vegetative surface by modified cortical cells because of their anticlinal elongation. Cystocarps globular, scattered over the greater part of frond, at maturity becoming very large as compared with the thickness of frond, up to 1.5 mm in diam., rostrate; gonimoblast simple, not lobulated, consisting of fairly small parenchymatous cells with rich contents, without nutritive filaments in connection with the pericarp; pericarp 90–120 μ in thickness, consisting of several layers of colorless compressed cells bounded by a cortex of cuboid pigmented cells; carpospores roundish or ovoid, 30–42 μ in diam. at maturity, with a pigmented body in the center. Antheridia borne over almost whole surface of frond in deep pocket-like, anticlinally oblong cavities varying within a wide range in their dimensions (cf. Table 2), surrounded by modified, elongated cortical cells; their measurements are shown in Table 2; antherozoids colorless, roundish or polygonal, 3–6 μ in diam.

Table 2. Measurement of antheridial cavities formed on the same frond which is 962 μ in diam., collected by Chihara at Nabeta near Shimoda, Shizuoka Pref., in July 1955.

<table>
<thead>
<tr>
<th>No.</th>
<th>Breadth</th>
<th>Depth</th>
<th>No.</th>
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— 48 —
The plant in question appears at first sight to have some likeness in external features to *Gracilariopsis sjöstedtii* (Kylin) Dawson as compared with a number of herbarium specimens and sun-dried specimens of that species. In *Gracilariopsis sjöstedtii*, however, the antheridia are described by Dawson (1949, p. 40, pl. 17, fig. 6) to be "borne in a continuous superficial layer arising from the cortex of the entire surface of the thallus," whereas in the present species they are borne in deep cavities as shown in Fig. 23 F, and as understood from Table 2. Moreover, the cortex of the present
species consists of 1–2 layers of pigmented cells, while that of *Gracilariopsis sjöstedtii* consists of 4–6 layers (cf. Kylin, 1930, p. 55). From *Gracilaria verrucosa* (Huds.) Papenfuss, to which the present species has also a similarity in the external appearance, it differs in lacking nutritive filaments in the cystocarps, in having larger antheridial pits and also in having tetrasporangia embedded in semi-nemathecially modified cortex.

18. *Gracilariopsis chorda* (Holm.) Ohmi, comb. nov.


Japanese name: Tsuru-shiramo.


Frond solitary or caespitose, arising from a small disc, flagelliform, cylindrical throughout, 60–110 cm long; main axis more or less traceable, thickened at the middle portion up to 2–3 mm in diam., attenuated below into a slender short stipe ca 6 mm in length and tapering above into the filiform apical portion, provided on all sides with similarly shaped alternate branches; branches generally simple and naked, but sometimes loaded with slender filiform branchlets; several long slender young branchlets are frequently observed to arise from a single branch apex; rose purple in color and succulent in substance while fresh, becoming much collapsed and adhering firmly to paper on drying; frond in transverse section consisting of a medulla of large (612–700 µ in diam.), almost empty cells with a wall up to 15 µ thick, covered with sharply defined thin cortex consisting of 2–3 layers of somewhat anticlinally arranged cells, 4–8 µ× 9–12 µ in dimensions, without hairs. Tetrasporangia scattered over the whole surfaces of frond, among slightly modified cortical cells, ordinarily oblong in shape in transverse section, 15–30 µ×33–60 µ in dimensions, cruciate. Cystocarps hemispherical, dome-like in appearance, slightly or non-rostrate; gonimoblast simple, not lobulated, consisting of small-celled parenchymatous tissue, without nutritive filaments; pericarp up to 175 µ in thickness; carpospores globular or ovoid in shape, 30–50 µ in diam., containing one or two conspicuously stellate chromatophores. Antheridia unknown.

The above description is a modification of that given by Okamura in 1918.

As to the habitat, Mr. Chihara advises by letter that the plant grows on rocks and boulders on sandy bottom about one meter below the low tide mark, protected from
1958] Ohmi: Species of *Gracilaria* and *Gracilariopsis*

![Diagram of *Gracilaria chorda* (Holm.) Ohmi.](image)

**Fig. 24.** *Gracilariopsis chorda* (Holm.) Ohmi. A. Longitudinal section of a tetrasporic frond. $\times$284. B. The same tetrasporic frond in transverse section. $\times$284. C. Section of a mature cystocarp. $\times$50. D. Part of the pericarp in a section of a cystocarp. $\times$284. E. Detail of carpospores. $\times$284. (A-E. Plant from Susaki near Shimoda, Shizuoka Pref., Apr. 1955).

the open sea, intermixed with *Gracilaria gigas* Harvey, or growing in isolation at places in estuarine waters which are generally deeper than the latter's habitat.

The fact that the present species is destitute of the nutritive filaments connecting the gonimoblast and the pericarp was already noticed by Okamura in 1918. Present writer could confirm their absence in a specimen from Susaki made available by the kindness of Mr. Chihara. It bears some resemblance in external appearance to *Gracilaria blodgettii* from the same locality, but differs in having several filiform branchlets issued from a common branch apex and in having low dome-like, slightly or non-rostrate cystocarps which are showing all the characteristics of *Gracilariopsis*.
IV. ECONOMIC IMPORTANCE OF GRACILARIA AND GRACILARIOPSIS

(a) General

Gracilaria species have long been used in Japan for food in two ways: First, after washed free from salt water they are eaten either raw or after boiling as a salad or a garnish, or cooked as a vegetable. Second, after sun-bleached and dried they are marketed as a cheap substitute for gelatine or as a supplementary material for the manufacture of agar-agar. However, the gelose extracted by water from Gracilaria plants has been considered useless as any important material of the agar industry owing to its weak gelatinizing power. Recent investigations have shown that its gelatinizing power can be much increased by the addition of alkali solution to the extract. So, Gracilaria species have now become a very important source of agar-agar being employed as a principal material of the agar industry in Japan as well as in Australia, America, South Africa, etc.

Before entering into further practical accounts on Gracilaria plants, agar production in Japan and foreign countries will be briefly outlined in the following three tables.

Table 3. Annual output and exported amount of Japanese agar-agar in the past twenty years.

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<th>Year</th>
<th>Output (in 1,000 lbs.)</th>
<th>Exported amount</th>
<th>Exp./Outp.</th>
<th>Year</th>
<th>Output (in 1,000 lbs.)</th>
<th>Exported amount</th>
<th>Exp./Outp.</th>
</tr>
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<tbody>
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<td>1934</td>
<td>5,150</td>
<td>2,790</td>
<td>54.2%</td>
<td>1945</td>
<td>1,600</td>
<td>99</td>
<td>6.2%</td>
</tr>
<tr>
<td>1935</td>
<td>5,540</td>
<td>3,355</td>
<td>60.6%</td>
<td>1946</td>
<td>610</td>
<td>188</td>
<td>30.8%</td>
</tr>
<tr>
<td>1936</td>
<td>7</td>
<td>3,931</td>
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<td>1947</td>
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<td>583</td>
<td>59.3%</td>
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<tr>
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<td>5,900</td>
<td>3,537</td>
<td>59.9%</td>
<td>1948</td>
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<td>892</td>
<td>59.5%</td>
</tr>
<tr>
<td>1938</td>
<td>5,750</td>
<td>3,530</td>
<td>58.8%</td>
<td>1949</td>
<td>1,500</td>
<td>688</td>
<td>42.6%</td>
</tr>
<tr>
<td>1939</td>
<td>6,000</td>
<td>2,980</td>
<td>49.8%</td>
<td>1950</td>
<td>2,200</td>
<td>?</td>
<td>?</td>
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<tr>
<td>1940</td>
<td>5,500</td>
<td>2,611</td>
<td>47.5%</td>
<td>1951</td>
<td>3,300</td>
<td>1,981</td>
<td>60.0%</td>
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<tr>
<td>1941</td>
<td>3,700</td>
<td>1,430</td>
<td>38.6%</td>
<td>1952</td>
<td>4,350</td>
<td>1,605</td>
<td>36.9%</td>
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<tr>
<td>1942</td>
<td>3,600</td>
<td>829</td>
<td>23.0%</td>
<td>1953</td>
<td>5,200</td>
<td>2,520</td>
<td>42.7%</td>
</tr>
<tr>
<td>1943</td>
<td>4,400</td>
<td>513</td>
<td>11.7%</td>
<td>1954</td>
<td>4,060</td>
<td>1,521</td>
<td>37.5%</td>
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<td>1944</td>
<td>2,600</td>
<td>142</td>
<td>5.5%</td>
<td>1955</td>
<td>3,650</td>
<td>3,000</td>
<td>82.2%</td>
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</table>

As understood from Table 3, the Japanese agar-agar to as much as 5.5~82.2% of its annual output has been exported yearly to foreign countries including the United Kingdom and the United States, which, in the amount of Japanese agar import have ranked higher than nearly fifty other countries.
Ohmi: Species of *Gracilaria* and *Gracilariopsis*

Table 4. Amount of agarophytes supply and agar-agar production per factory in Japan before and after World War II.

<table>
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<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>C/A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of factories</td>
<td>Amount of agarophytes supply (air-dry weight in 1,000 kan. 1 kan = 3.75 kg)</td>
<td>B/A (1,000 kan)</td>
<td>Amount of agar production (weight in 1,000 lbs.)</td>
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<tr>
<td>1935</td>
<td>449</td>
<td>3,164</td>
<td>70.5</td>
<td>5,540</td>
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<tr>
<td>1936</td>
<td>512</td>
<td>3,319</td>
<td>64.8</td>
<td>5,621</td>
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<td>1937</td>
<td>520</td>
<td>3,241</td>
<td>62.3</td>
<td>5,900</td>
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<tr>
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<td>528</td>
<td>2,968</td>
<td>65.8</td>
<td>5,750</td>
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<tr>
<td>1939</td>
<td>623</td>
<td>3,685</td>
<td>57.2</td>
<td>6,000</td>
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</table>

D: Average of five years

<table>
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<th>C</th>
<th>C/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>526</td>
<td>3,331</td>
<td>63.7</td>
<td>5,782</td>
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E: 1956

<table>
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<td>1950</td>
<td>629</td>
<td>1,218</td>
<td>19.4</td>
<td>2,200</td>
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<td>1951</td>
<td>676</td>
<td>1,805</td>
<td>26.7</td>
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<td>1952</td>
<td>488</td>
<td>1,990</td>
<td>40.9</td>
<td>4,350</td>
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<td>1953</td>
<td>560</td>
<td>2,288</td>
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<td>5,200</td>
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<td>1954</td>
<td>584</td>
<td>2,186</td>
<td>45.2</td>
<td>4,080</td>
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<td>1955</td>
<td>507</td>
<td>2,633</td>
<td>51.7</td>
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E/D

<table>
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<tr>
<td>1956</td>
<td>97%</td>
<td>78%</td>
<td>78%</td>
<td>66%</td>
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</table>

Table 5. Estimated average annual production of agarophytes and agar-agar in various countries, and probable amount of agar-agar exported annually from them.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Agarophytes production (in 1,000 kan)</th>
<th>Agar production (in 1,000 lbs.)</th>
<th>Probable amount of exported agar (in 1,000 lbs.)</th>
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<tbody>
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<td>Australia</td>
<td>20</td>
<td>50-100</td>
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<tr>
<td>Canada</td>
<td>?</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Chile</td>
<td>?</td>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>China</td>
<td>?</td>
<td>150</td>
<td>—</td>
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<tr>
<td>Denmark</td>
<td>1,170</td>
<td>1,000-1,200</td>
<td>500-550</td>
</tr>
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<td>Germany</td>
<td>20</td>
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<td>—</td>
</tr>
<tr>
<td>Indonesia</td>
<td>?</td>
<td>300</td>
<td>—</td>
</tr>
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<td>Japan</td>
<td>2,400</td>
<td>4,000-5,000</td>
<td>2,500</td>
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<td>Java</td>
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<td>Korea</td>
<td>300</td>
<td>300-800</td>
<td>300-500</td>
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<td>Mexico</td>
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<td>50</td>
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<tr>
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<td>110</td>
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<tr>
<td>Spain</td>
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<td>400-500</td>
<td>250</td>
</tr>
<tr>
<td>Sumatra</td>
<td>?</td>
<td>200</td>
<td>—</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>?</td>
<td>440</td>
<td>—</td>
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<tr>
<td>U.S.A</td>
<td>200</td>
<td>200</td>
<td>—</td>
</tr>
<tr>
<td>U.S.S.R.</td>
<td>100</td>
<td>440</td>
<td>—</td>
</tr>
</tbody>
</table>

(b) Industrial utilization of *Gracilaria* plants in foreign countries

Australia is one of the main countries producing *Gracilaria*-agar. According to
Chapman (1950) agar is manufactured in New South Wales from *Gracilaria confervoides* which grows very abundantly in Botany Bay. It has been estimated that an annual production of 100 tons of agar is possible in New South Wales. This amount is said to be sufficient for Australian home needs. The following table gives the industrial uses of agar in Australia in 1938.

Table 6. Uses of agar in Australia (Ferguson Wood, 1946).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Lbs. per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat preserving</td>
<td>99,350</td>
</tr>
<tr>
<td>Confectionery</td>
<td>33,235</td>
</tr>
<tr>
<td>Spices and condiments</td>
<td>24,416</td>
</tr>
<tr>
<td>Chemical, medical, etc.</td>
<td>1,459</td>
</tr>
<tr>
<td>Jams and vegetable pastes</td>
<td>1,459</td>
</tr>
<tr>
<td>Aerated waters and cordials</td>
<td>396</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>160,255</strong></td>
</tr>
</tbody>
</table>

*G. confervoides* is reported to form the basis of a small agar industry in South Africa (Issac et Molteno, 1953). It is also used in the agar industry on the Atlantic coast of North America and along the Gulf of Mexico coasts (Zaneveld, 1955). In Ceylon, both *G. confervoides* and *G. lichenoides* are sold after having been washed and dried as 'Ceylon Moss' at Rs. 2/50 per lb. in dry weight. They are employed as the chief source of agar and several thousand pounds are produced in Ceylon (Zaneveld, 1955).

(c) Manufacture of agar-agar from *Gracilaria* in Japan

*Gracilaria* species have been used in Japan as one of the principal materials of agar manufacture since more than twenty years ago. Details of the process of agar manufacture from *G. verrucosa* are shown on page 55 in the scheme given by Kojima et al. (1952).

Table 7 gives details of the so-called "industrial agar" manufacture in the past 18 years in Japan. This kind of agar is manufactured in a factory equipped with latest chemical apparatuses. As is known from the table, *Gracilaria verrucosa* was used as the only source of agar by the nine manufacturers among the seventeen which were in operation in 1957. This is probably due to the fact that *Gracilaria* is not only lower in price but also easier to obtain in the market than *Gelidium*.

(d) Chemical properties of *Gracilaria* plants from Hokkaido

Ohmi et Kuroda (1955) reported the results of their chemical analyses of *Gracilaria verrucosa* from various localities in Japan and *Gracilariopsis sjöstedtii* from Carpenteria, California, as shown in Table 8.
Ohmi: Species of *Gracilaria* and *Gracilariopsis*

Flow diagram of crude agar manufacture from *G. verrucosa* (Kojima *et al.*, 1952)
Table 7. Industrial agar manufacture in Japan.

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*Gracilaria verrucosa* is only used as the source of agar by these manufacturers.
Table 8. Chemical composition of *Gracilaria* plants from various localities in per cent of anhydrous material.

<table>
<thead>
<tr>
<th>Species</th>
<th>Gracilaria verrucosa</th>
<th>Gracilariopsis sjostedtii</th>
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<tr>
<td>Ash</td>
<td>8.58</td>
<td>11.27</td>
</tr>
<tr>
<td>Crude protein</td>
<td>24.03</td>
<td>19.21</td>
</tr>
<tr>
<td>SO₃</td>
<td>4.51</td>
<td>7.09</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>8.56</td>
<td>4.97</td>
</tr>
<tr>
<td>Ether extract</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>Agar substance</td>
<td>38.81</td>
<td>42.36</td>
</tr>
</tbody>
</table>

As observed in the above table, *Gracilariopsis sjostedtii* from Carpenteria, California proved to excel the others in the content of agar substance which amounted to 49.91% of anhydrous matter. Agar content of six samples of *Gracilaria verrucosa* from Japan ran from 38.81 to 42.36%.

The seasonal variation of the chemical constituents of *G. verrucosa* from Tōkai, Lake Akkeshi was reported by Kuroda et Matsumura (1954) as shown in Table 9.

Table 9. Seasonal variation of the chemical constituents of *Gracilaria verrucosa* from Lake Akkeshi in 1953 (in per cent of anhydrous matter).

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Date of sampling</th>
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<tbody>
<tr>
<td></td>
<td>June 15</td>
</tr>
<tr>
<td>Ash</td>
<td>10.63</td>
</tr>
<tr>
<td>Crude protein</td>
<td>17.68</td>
</tr>
<tr>
<td>SO₃</td>
<td>5.75</td>
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<tr>
<td>Crude fibre</td>
<td>5.50</td>
</tr>
<tr>
<td>Ether extract</td>
<td>0.09</td>
</tr>
<tr>
<td>Agar substance</td>
<td>42.75</td>
</tr>
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</table>

As understood from the table, the chemical constituents of this plant did not show any remarkable variation by seasons at least from July to October.

(e) Ecology of *Gracilaria* plants and their production in Japan

In Japan, *Gracilaria verrucosa* grows most abundantly in Lake Akkeshi, Hokkaido, and in Tokyo Bay along the northeastern side. In Lake Akkeshi it occurs in great profusion, being detached from the substrata and lying loosely on the sandy and muddy bottom among the vegetation of *Zostera marina*; after a strong wind it is often found cast ashore in a considerable amount. Such cast up plants show various color graduations from dark red to greenish-brown or almost white. Limnological observations and bottom soil analyses of Lake Akkeshi in Prov. Kushiro and Lake Furen (includ-
ing Lake Onne) in Prov. Nemuro were carried out by Kuroda et Okesaku (1956) with the object of studying the ecology of *Gracilaria verrucosa*. They state in the conclusion of their report that: (1) The water of these lakes is under constant agitation on account of their shallowness, constant inflowing of rivers, and the tidal in- and outflow of the sea-water; (2) The salinity of these lakes is consequently rather low; (3) The bottom is mostly muddy and the water is always turbid; (4) Nutrient substances are poor in the bottom as compared with other brackish lakes while they exist abundantly in the water being in a state to be absorbed easily by algae; (5) These lakes are to be classified as eutrophic brackish-water lakes.

In Lake Akkeshi, fishermen harvest *G. verrucosa* from the end of September to the beginning of October. Table 10 shows the annual yield of *G. verrucosa* from Lake Akkeshi for the past ten years while Table 11 shows the same from 16 districts of Japan for the past four years.

Table 10. Annual yield of *Gracilaria verrucosa* from Lake Akkeshi
(air-dry weight in *kan*=3.75 kg).

<table>
<thead>
<tr>
<th>Year</th>
<th>1947</th>
<th>1948</th>
<th>1949</th>
<th>1950</th>
<th>1951</th>
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<tr>
<td></td>
<td>7,050</td>
<td>18,962</td>
<td>36,000</td>
<td>32,480</td>
<td>122,320</td>
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<tr>
<td>1952</td>
<td>423,344</td>
<td>60,126</td>
<td>107,872</td>
<td>62,470</td>
<td>117,660</td>
</tr>
<tr>
<td>Average</td>
<td>98,330</td>
<td></td>
<td></td>
<td></td>
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58---
Table 11. Annual yield of *Gracilaria verrucosa* from 16 districts of Japan (air-dry weight in *kan*).

<table>
<thead>
<tr>
<th>District</th>
<th>1953</th>
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<th>1955</th>
<th>1956</th>
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<tbody>
<tr>
<td>Hokkaido</td>
<td>63,652</td>
<td>115,738</td>
<td>89,482</td>
<td>119,862</td>
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<tr>
<td>Miyagi</td>
<td>50,084</td>
<td>58,506</td>
<td>62,875</td>
<td>23,571</td>
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<tr>
<td>Fukushima</td>
<td>8,550</td>
<td>7,700</td>
<td>8,400</td>
<td>8,000</td>
</tr>
<tr>
<td>Chiba</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>3,000</td>
</tr>
<tr>
<td>Tokyo</td>
<td>14,000</td>
<td>11,000</td>
<td>12,000</td>
<td>?</td>
</tr>
<tr>
<td>Shizuoka</td>
<td>24,739</td>
<td>16,339</td>
<td>300</td>
<td>3,250</td>
</tr>
<tr>
<td>Mie</td>
<td>2,615</td>
<td>1,710</td>
<td>3,220</td>
<td>?</td>
</tr>
<tr>
<td>Shimane</td>
<td>26,000</td>
<td>20,800</td>
<td>8,500</td>
<td>11,000</td>
</tr>
<tr>
<td>Okayama</td>
<td>8,380</td>
<td>19,130</td>
<td>20,900</td>
<td>23,830</td>
</tr>
<tr>
<td>Saga</td>
<td>1,645</td>
<td>14,863</td>
<td>5,934</td>
<td>8,000</td>
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<td>Nagasaki</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>2,140</td>
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<td>Kumamoto</td>
<td>11,070</td>
<td>10,380</td>
<td>14,210</td>
<td>?</td>
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<td>Oita</td>
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<td>30,000</td>
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<tr>
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<td>?</td>
<td>?</td>
<td>?</td>
<td>2,500</td>
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<td>Kagoshima</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Total | 240,715 + α | 294,326 + α | 235,801 + α | 601,729 + α |

The annual yield of *G. verrucosa* from Lake Akkeshi in the past four years, as shown in the tables, corresponds to 89−98% of the annual total production of the alga from Hokkaido. Hokkaido is second only to Chiba in the annual yield of this alga in 1956 when Lake Akkeshi produced 98% of the total yield from Hokkaido. Thus, Tokyo Bay and Lake Akkeshi are most important from the standpoint of the production of *Gracilaria verrucosa*. Further studies on the ecology and artificial propagation of this agarophyte and other related species in these waters are pressingly needed for the development of agar industry in Japan. The present contribution is believed to be a useful stepping-stone for making progress in such studies.

V. SUMMARY

For these several years the writer under the guidance of Professor J. Tokida has been working on a taxonomic study of *Gracilaria* and related genera hitherto known to occur in Japan and neighboring waters. In Part I of the series of contributions published in 1955, the writer reported his discovery of antheridia in *Gracilaria textori*, and stated that it was identical with *Gracilaria vivessii*; in Part II, description was given of a new species, *Gracilariopsis vermiculophylla*, which was collected in Lake Akkeshi, Hokkaido.

In the present paper are given full descriptions of all the species of *Gracilaria* and *Gracilariopsis* known to occur in Japan and vicintiy. An analytical key to all of these species is also given. The following data reported herein are worthy of special mention.
(1) Fifteen species and one forma of Gracilaria and three species of Gracilariopsis are treated herein, of which one species of Gracilariopsis, G. rhodotricha Dawson, is new to Japan, one species of Gracilaria, G. salicornia (Ag.) Dawson, is new to Ryūkyū, one Gracilariopsis, G. chorda (Holm.) Ohmi, is newly combined species, and Gracilaria sublittoralis is given a description herein for the first time.

(2) Antheridia of the following three species are first observed and described herein: Gracilaria blodgettii, G. bursa-pastoris and G. arcuata.

(3) Tetrasporangia of the following two species are first observed and described herein: Gracilaria edulis and G. incurvata.

(4) Coexistence of antheridia and tetrasporangia on one and the same frond, which was reported in Gracilariopsis vermiculophylla in the previous paper (1956), is again observed and described herein with the material of Gracilaria blodgettii and G. bursa-pastoris.

(5) Gland-like cells of the following two species are first observed and described herein: Gracilaria crassa and G. salicornia.

(6) In view of the economic importance of Gracilaria plants, some brief considerations on their use are offered on the basis of the latest statistics.

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**Yendo, K.**


**Zaneveld, J. S.**


### VII. INDEX OF LATIN NAMES

Page numbers where descriptions appear are indicated in thick type and those where synonyms appear are given in italics.

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sinicola  41
sjöstedtii  1, 2
sublittoralis  3, 6, 44, 45, 60
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vivesii  40, 59
vivipara  41
Gracilaropsis chorda  3, 6, 50, 51, 60
rhodotricha  3, 6, 47, 49, 60

sjöstedtii  49, 50, 54, 57
vermiculophylla  6, 46, 59, 60
Rhodymenia punctata  35
purpurascens  30
spinulosa  32
Sphaerococcus denticulatus  30
Sphaerococcus (Rhodymenia) textorii  40
Zostera marina  10, 57
Ulva pertusa  16

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EXPLANATION OF PLATES
Plate I

Gracilaria verrucosa (Huds.) Papenfuss

A. Tuft of tetrasporic fronds from Oshoro, Hokkaido.
B. Cystocarpic plant from Susaki near Shimoda, Shizuoka Prefecture.
C. Cystocarpic plant from Oshoro, Hokkaido.
D. Tuft of male fronds from Oshoro.

Gracilaria gigas Harv.

E. Cystocarpic plant from Nabeta near Shimoda, Shizuoka Prefecture.
Plate II

*Gracilaria gigas* Harv.

A. Tuft of tetrasporic fronds from Chiba Prefecture.

*Gracilaria blodgettii* Harv.

B. Tetrasporic plant from Susaki near Shimoda, Shizuoka Prefecture.

C. Cystocarpic plant from the same locality as above.

D. Male plant from Tung-shih, Chia-I Pref., Formosa.
Plate III

*Gracilaria blodgettii* Harv.

A. Plant from Tung-shih, Chia-I Pref., Formosa bearing both tetrasporangia and antheridia on the same branch.

*Gracilaria edulis* (Gmel.) Silva

B. Tetrasporic plant from Ryûkyû. × 1/2.

*Gracilaria bursa-pastoris* (Gmel.) Silva

C. Tuft of tetrasporic fronds from Shirahama, Wakayama Prefecture.

D. Cystocarpic plant from the same locality.
Plate IV

*Gracilaria bursa-pastoris* (Gmel.) Silva

A. Male plant from Himi, Toyama Prefecture.
B. Plant from Chiba Prefecture bearing both tetrasporangia and antheridia on the same branch.

*Gracilaria coronopifolia* J. Agardh

C. Young tetrasporic plant from Garanbi, Formosa.
D. Sterile plant from the same locality.
Plate V

*Gracilaria arcuata* Zanard.
A. Tetrasporic plant from Susaki, Kōchi Prefecture.
B. Cystocarpic plant from Kashiwajima, Kōchi Prefecture.
C. Male plant from the same locality.

*Gracilaria crassa* Harv.
D. Sterile plant from Shinko, Taitung Pref., Formosa.
E. Tuft of tetrasporic plants from Naha, Ryūkyū.

*Gracilaria salicornia* (Ag.) Dawson
F. Tuft of cystocarpic plants from Itoman, Ryūkyū.
Plate VI

*Gracilaria salicornia* (Ag.) Dawson

A. Tuft of tetrasporic plants from Itoman, Ryûkyû.

*Gracilaria denticulata* (Kütz.) Weber van Bosse

B. Cystocarpic plant from Ryûkyû.

*Gracilaria purpurascens* (Harv.) J. Agardh

C. Tetrasporic plant from Naha, Ryûkyû.
D. Tuft of cystocarpic plants from the same locality.

*Gracilaria purpurascens* (Harv.) J. Ag. f. *spinulosa* (Okam.) Yamada

E. Male plant from Tairi, Formosa.
Plate VII

*Gracilaria purpurascens* (Harv.) J. Ag. f. *spinulosa* (Okam.) Yamada

A. Tuft of tetrasporic plants from Tairi, Formosa.
B. Tuft of cystocarpic plants from Fukikaku, Formosa.

*Gracilaria punctata* (Okam.) Yamada

C. Tetrasporic plant from Garanbi, Formosa.
Plate VIII

*Gracilaria punctata* (Okam.) Yamada

A. Cystocarpic plant from Tairi, Formosa.
B. Male plant from Garanbi, Formosa.

*Gracilaria incurvata* Okam.

C. Sterile plant from Mitsuhama, Ehime Prefecture.
D. Tuft of sterile plants from Minatoyama, Ehime Prefecture.
Plate IX

*Gracilaria incurvata* Okam.

A. Tuft of tetrasporic plants from Mitsuhama, Ehime Prefecture.
B. Tuft of cystocarpic plants from Gogo-shima, Ehime Prefecture.

*Gracilaria sublittoralis* Yamada et Segawa

C. Tetrasporic plant from Kōzu-shima, Izu Isl. × ca 1/2.
D. Cystocarpic plant from the same locality. × 5/9.
Plate X

*Gracilariopsis rhodotricha* Dawson

A. Tetrasporic plant from Nabetan near Shimoda, Shizuoka Prefecture.
B. Cystocarpic plant from the same locality.

*Gracilariopsis chorda* (Holm.) Ohmi

C. Sterile plant from Enoshima, Kanagawa Prefecture.
D. Tetrasporic plants from Seto-kanayama, Wakayama Prefecture.