TAXONOMY, DISTRIBUTION AND SEASONAL OCCURRENCE OF THE GENUS *GALAXAURA* IN THE VICINITY OF THE SETO MARINE BIOLOGICAL LABORATORY[1)]

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With Text-figs. 1–14, Map 1 and Pls. I–V

Contents

I. Introduction

In 1969 the Seto Marine Biological Laboratory of Kyoto University (herein abbreviated to SMBL) started a long-term survey to learn the growths and successions of littoral organisms in the vicinity of the laboratory, around the cape of Banshozaki from Takashima Islet in Kanayama Bay to Hatakejima Island in Tanabe Bay (Tokioka, 1969). So far, however, the observations have been made mainly on the shore fauna, while the flora has been left nearly unreported. This unbalanced state of research prompted the present writer to do something with the algal composition in the vicinity, actually the taxonomy, distribution and seasonal occurrences of the genus *Galaxaura* (Nemaliales, Rhodophyta). The present paper is to record the results of these studies made in two years 1973–1975.

HISTORICAL REVIEW

The first report of the genus *Galaxaura* in the vicinity of the SMBL was apparently

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made by Kintaro Okamura (1934) who recorded *Gal. Schimperi* and *Gal. obtusata* in his paper entitled "Notes on the algae collected near Namariyama (mistake for Kanayama), Prefecture of Wakayama". The third species, *Gal. kjellmanii*, appeared in the paper by Takesi Tanaka (1936). "The genus *Galaxaura* of Japan". Later, a total of fifteen species of *Galaxaura* were found in an extensive list of the marine algae from the coast of Wakayama Prefecture, compiled by Torao Yamamoto (1963). They were:

Galaxaura arborea	*Gal. hystrix*
Gal. clavigera	*Gal. kjellmanii*
Gal. cuculligera	*Gal. obtusata*
Gal. elongata	*Gal. pacifica*
Gal. falcata	*Gal. papillata*
Gal. fastigiata	*Gal. subverticillata*
Gal. filamentosa	*Gal. veprecula*
Gal. robusta.	

Of these, *Gal. cuculligera*, *Gal. fastigiata*, *Gal. robusta* and *Gal. veprecula* are now known as *Gal. elongata*, *Gal. oblongata*, *Gal. obtusata* and *Gal. tenera*, respectively.

In two papers, the present writer (Cordero 1975 a, b) has recorded already three epiphyte-bearing species of *Galaxaura* from the vicinity, *Gal. fastigiata* (!) and *Gal. subverticillata* as well as *Gal. oblongata* that was newly recorded from Japan.

THE AREA STUDIED

The area studied covers the northern portion of Kanayama Bay and the southern portion of Tanabe Bay, around the cape from Takashima Islet (Section I) to Hatakejima Island (Section XIII). This area is affected by the warm Kuroshio Current and the waters considerably clearer in the exposed portions (Sections II to VII, IX-X and XIII) than in the protected ones (Sections I, VIII and XI-XII). Thus, respective portions in the area (Map 1) show somewhat varied characteristics.

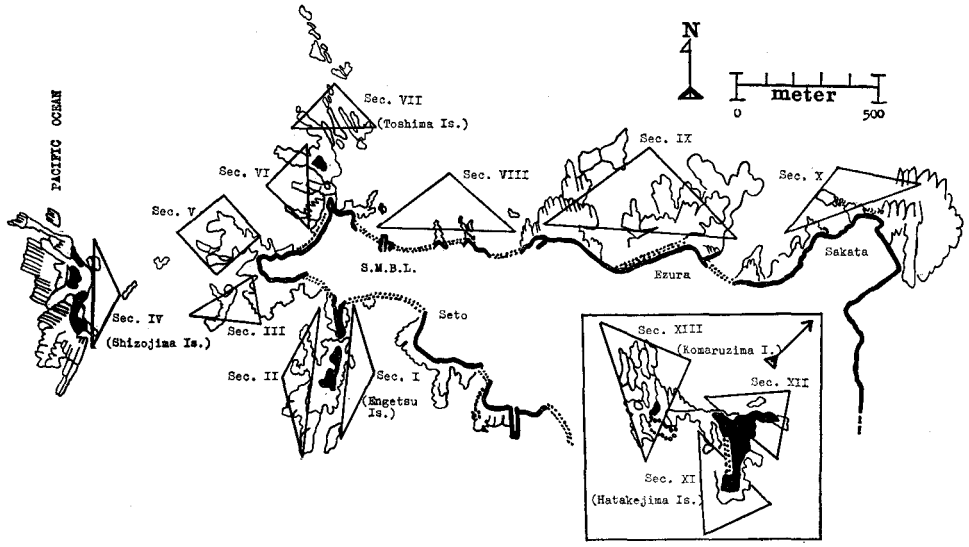
Section I (East side of Takashima Islet). This is the protected side of the islet, including a sandy beach, a breakwater made of rock and cement and the east foot of the islet. In this section were collected three species of *Galaxaura*, *Gal. oblongata*, *Gal. papillata* and *Gal. subverticillata*; the last forming a colony along the east side of the breakwater. In association with *Galaxaura* were growing *Pterocladia*, *Amphiroa*, *Chondrococcus*, *Microcladia*, *Martensia*, *Porphyra*, *Sargassum*, *Colpomenia*, *Hydroclathrus*, *Alaria*, *Codium*, *Microdictyon*, *Ulva* and others.

Section II (West side of Takashima Islet). The section faces the open Kii Channel and is subjected to the incessant wave action. Excepting *Gal. oblongata*, no species of *Galaxaura* was found there. The most dominant algae were the corallinaceous group and kelps.

Section III (Nakase). This is a portion around the south corner of the tip of the cape and consisting of a small sandy beach, where some seeped freshwater empties, and a flat rocky shore extending below it to a width of a few meters and furnished with numerous tide pools. Across a narrow water there is a rocky formation very much

rugged and therefore going down with no definite shoreline. Only stunted growths of *Gal. oblongata* were found in association with *Actinotrichia fragilis, Amphiroa aberrans, Chondrococcus hornemanni, Sargassum* spp., *Leathesia, Colpomenia sinuosa, Ishige, Hizikia,* and in the shallow portion with such green algae as *Ulva conglobata, Microdictyon* and *Enteromorpha prolifera.*

Section IV (Shisojima). This is a low rocky island lying nearly 600 m off the cape tip. Only a single species of *Galaxaura, Gal. oblongata,* was observed growing in tide pools with other algae. It was from this section that Okamura (1934) collected a new form of *Gelidium pusillum* forma *foliaceum.* As this section is exposed to the strong wave, the growth of fragile algal species is seemingly disadvantaged and only coralinaceous algae are found there in a considerable abundance.



Map 1. Detailed topography of the collecting stations.

Section V (Banshozaki). This is a rocky shore around the middle of the cape top and is submerged during the high tide. *Gal. fasciculata, Gal. oblongata* and *Gal. subverticillata* were found growing on the vertical wall of submerged rocks. Shorter species of *Amphiroa, Pterocladia, Chondrococcus* and *Microcladia* were observed there, while stranded fronds of *Centroceras clavulatum* were found lodged on *Sargassum.*

Section VI (Northern corner of the tip of Banshozaki). This section is partly covered by a rocky islet which is then protecting the northern end of an indented sandy-rocky part of the cape. Three species of *Galaxaura, Gal. elongata, Gal. fasciculata* and *Gal. oblongata,* were prominent in this section, the first and last species forming scattered patches. The commoner algae found in this section were mostly *Sargassum, Hydroclathrus, Colpomenia* and a few coralline forms.

Section VII (Tip of Toshima reef). This rocky reef is a narrow northward extension from the cape, with two small islets on it and bordered with the cliff abruptly merging into the sea. The place observed is a surfbeaten habitat and covered with

oysters, mussels and barnacles up to the splash zone. *Porphyra* and *Hizikia* were the commonest algae in this particular zone and *Gal. elongata, Gal. oblongata* and *Gal. fasciculata* were found there, but sparsely.

Section VIII (Northern beach of Laboratory). This section stretching eastwards from the east side of Toshima reef is protected against the strong waves and winds from the northwest and is fringed with grouped rocks and strips of sandy beach. The bottom of the deeper portion, 8 to 15 m, is rocky and covered with *Gal. acuminata, Gal. arborea, Gal. elongata, Gal. fasciculata, Gal. oblongata, Gal. obtusata, Gal. papillata* and *Gal. tenera.* This was confirmed, as these species were brought up by a dragnet (jibiki-ami in Japanese). This section is thus seemingly the richest in terms of the number of species of *Galaxaura.* Kelps and a few coralline forms are growing on the vertical wall of some rocky reefs protruding seawardly.

Section IX (Ezura). The section includes two wide flat rocky reefs respectively extending several ten meters seawards, exposed at low tide, and bordered on the landside with a narrow sandy beach across some boulder zone. The following species of *Galaxaura* occurred there, *Gal. arborea, Gal. elongata, Gal. falcata, Gal. fasciculata, Gal. oblongata* and *Gal. obtusata,* usually in the offshore parts of the section beyond the kelp growths. Other algae found in the section were *Amphiroa, Microcladia, Titanophora, Caulerpa, Codium* and *Ulva.*

Section X (Sakata). This section is characterized by steep rocky shore with rich crevices and boulders. Kelps such as *Undaria, Alaria, Eisenia* and *Sargassum* were covering most parts of the rocky substratum, forming dense thickets down to shallow sublittoral zone. On the offshore side of these growths were growing a few species of *Gelidium, Laurencia* and coralline forms, sparsely mingled with *Colpomenia sinuosa.* Only *Gal. oblongata* was found among the members of family Chaetangiaceae.

Section XI (Southern part of Hatakejima Island). A few patches of *Gal. oblongata* were found on the rocky substrata fringing the foot of a wide sandy beach in this section, together with *Pterocladia, Gelidium, Dictyota, Padina* and *Sargassum* growing near the patches. *Amphiroa* was found in the deeper portion forming a narrow bed. In addition, a marine angiosperm, *Halophila ovalis,* was forming a narrow patch in the sandy muddy part of this section.

Section XII (Northern part of Hatakejima Island). The section is formed of very ruggy rocky shore irregularly furnished with boulders and rocks. On vertical rock walls were found *Caulerpa racemosa* var. *laete-virens* and a few delicate forms of coralline algae. Only *Gal. oblongata* was found in this section associated with *Pterocladia, Gelidium, Padina, Dictyota, Colpomenia, Hydroclathrus* and *Sargassum.*

Section XIII (West reef inclusive of Komarujima Islet). The exposed part of this section yielded no trace of *Galaxaura,* but other sturdier algae. In the protected portion, however, there were found patches of *Gal. oblongata* including a few *Gal. elongata.* The rest algal species were the same as in Section XII, but for the occurrence of *Meristotheca, Hypnea, Monostroma* and *Microdictyon* in the present section.

II. Material and Method

The present study, started in winter of 1974 and closed in autumn of 1975, was carried out by several periodic observations and collections by SCUBA- and skin-diving in the intertidal and shallow sublittoral zones of the area. Some materials of *Galaxaura* were brought about by fishing dragnets, while others were collected stranded on the beach after storms.

The collected algae had been fixed with a 5–10 percent solution of formaldehyde in seawater before they were prepared for herbarium specimens. The specimens were then sectioned and mounted in balsam for illustration and description, of course decalcification before section was indispensable.

In this paper, ten species of *Galaxaura* are described, namely: *Gal. acuminata, Gal. arborea, Gal. elongata, Gal. falcata, Gal. fasciculata, Gal. oblongata, Gal obtusata, Gal. papillata, Gal. subverticillata* and *Gal. tenera*. Of these, *Gal. oblongata, Gal. elongata* and *Gal. fasciculata* are the commonest species in this vicinity, while *Gal. acuminata, Gal. falcata* and *Gal. tenera* are rare ones. *Galaxaura obtusata* and *Gal. falcata* are regarded to be deep-water forms, while *Gal. oblongata* is a shallow-water one and seemingly most tolerant to environmental fluctuations.

In addition to the description of species, some notes are given on their distributions and seasonal occurrences. Among the species mentioned above only *Gal. subverticillata* might be safely considered as colonial in growth, and *Gal. oblongata* was found occurring in scattered patches.

III. Taxonomy

The following artificial key to the species refers only to the *Galaxaura* specimens collected in the vicinity of SMBL. The materials described in this paper are kept by the present author and the duplicates are deposited in the SMBL herbarium.

Key to the Species

1. Thallus always cylindrical ..... 2.
   Thallus canaliculate or sub-canaliculate ..... 7.
2. Thallus with assimilating filaments ..... 3.
   Thallus without assimilating filaments ..... 5.
3. Assimilating filaments only found basally..... *Gal. elongata*
   Assimilating filaments found all over the frond..... 4.
4. Long and short assimilating filaments distributed alternately..... *Gal. subverticillata*
   Long and short assimilating filaments evenly distributed ..... *Gal. fasciculata*
5. Thallus terete, distinctly articulate in a moniliform structure; terminal cells funnel-shaped ..... *Gal. obtusata*
   Thallus glabrous to sub-glabrous, indistinctly articulate; terminal cells never funnel-shaped..... 6.
6. Segments prominently tapered apically; terminal cells obconical or pyramidal, bearing 1–2 roundish papillae ..... *Gal. papillata*
   Segments very slightly tapered; terminal cells obconical or sub-globose, without papillose growths ..... *Gal. oblongata*

7. Stipe usually long; branches at narrow angles.....*Gal. falcata*
   Stipe short; branches at broader angles .....*Gal. arborea*
8. Terminal cells usually ovoid to elliptic with acute or rarely roundish apex.....*Gal. acuminata*
   Terminal cells clavate with apiculate apex.....*Gal. tenera*

1. *Galaxaura acuminata* Kjellman

(Figs. 1–2; Pl. I, A)

Butters 1911:180; Svedelius 1953:63, figs. 53 & 57–60.

Gal. apiculata Kjellman, 1900:74, tab. 12, figs. 13–26, tab. 20, fig. 36; Chou 1945:51, pl. 5, figs. 13–19, pl. 9, fig. 1; Tanaka 1936:162, pl. XLI, fig. 2, text-figs. 25–26.

Plants are brownish red to greenish, to 8 cm in height, regularly dichotomous, subcanaliculate, and stipitate. Stipe is cylindrical, slightly villous and with rhizoidal filaments. Internodes are subcanaliculate, faintly striated, less than 20 mm long and up to 2 mm broad, broader distally.

Structure: Frond shows to globose terminal cells, up to 20 μ broad and 30 μ tall, and with apiculate or roundish apices.

Locality: Section VIII, (no number) mounted in 2 herbarium sheets, March 26, 1975; Ibid., (no number), March 28, 1975; Ibid., (no number), March 30, 1975; Ibid., (no number) in 2 herbarium sheets, June 22, 1975.

Distribution: Indian Ocean and Pacific Ocean.

2. *Galaxaura arborea* Kjellman

(Fig. 3; Pl. I, B)

1900:72, tab. 11, figs. 1–11, tab. 20, fig. 39; Butters 1911:80; Tanaka 1936:162, pl. XL, text-figs. 24–25.

Plant greenish red when fresh, up to 8 cm in height, regularly dichotomous, subcanaliculate and stipitate. Stipe is short, cylindrical, villous and with rhizoidal filaments. Internodes up to 8 mm long and 2 (—3) mm broad, and transversely striated.

Structure: Frond shows usually 3 layers of parenchymatic cells. Terminal cells are ovoid to elliptic, to 26 μ broad and to 35 μ tall. Assimilating filaments are provided with unicellular stalk. The innermost cells are larger and taller than others.

Locality: Section VIII, (no number) in 2 herbarium sheets, March 11, 1975; Ibid., (no number), March 26, 1975; Ibid., (no number) in 3 herbarium sheets, March 28, 1975; Ibid., (no number) in 2 herbarium sheets, March 29, 1974; Ibid., (no number) in 4 herbarium sheets, June 10, 1975.

Section IX, (no number) in 3 herbarium sheets, by dragnet, February 15, 1974; Ibid., (no number), by dragnet, February 22, 1974.

Distribution: Japan; Hawaii; Australia; Philippines.

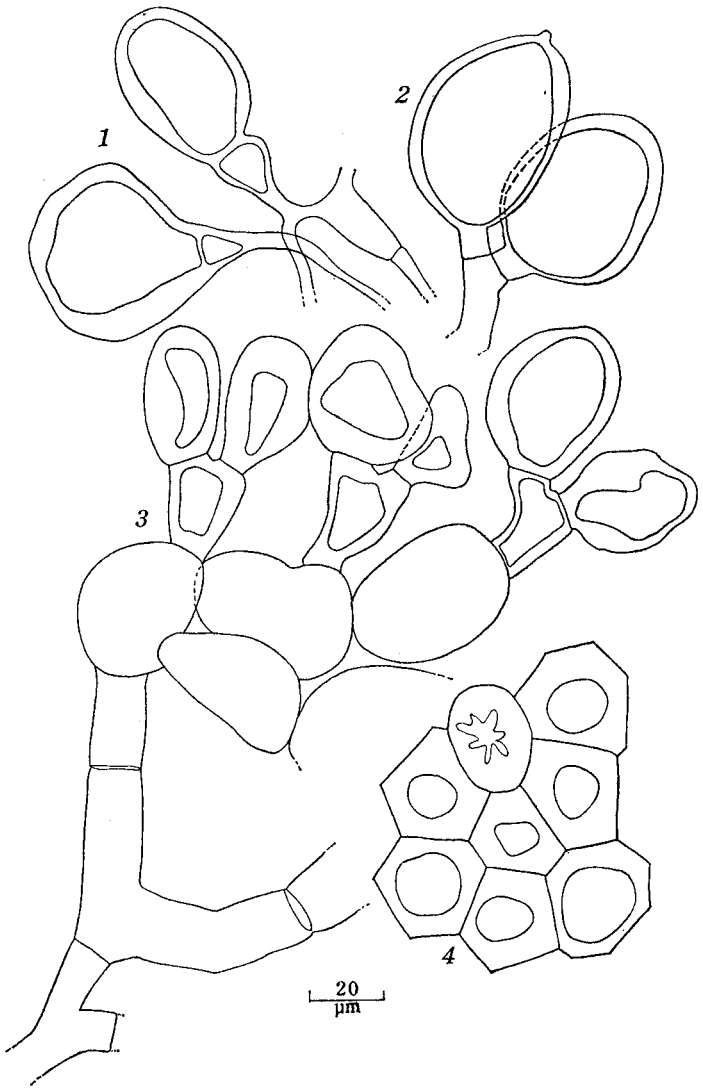
3. *Galaxaura elongata* J. Agardh

(Figs. 4–6; Pl. III, C)

1876:529; Yendo 1916:254; Weber van Bosse 1921:212; Okamura 1936:443; Tanaka 1936:153, pl. XXXVIII, text-figs. 16–17; Svedelius 1945:38, pl. 11; Levring 1953:513; Papenfuss and Chiang 1969:312, fig. 56.

Gal. cuculligera Kjellman, 1900:58, tab. 6, figs. 23–30, tab. 20, fig. 30.

Gal. glabriuscula Kjellman, 1900:56, tab. 7, figs. 1–7, tab. 20, fig. 26.



Figs. 1–2. *Gal. acuminata* Kjellman. Transverse sections of frond showing two papillae with and without apiculate apex.

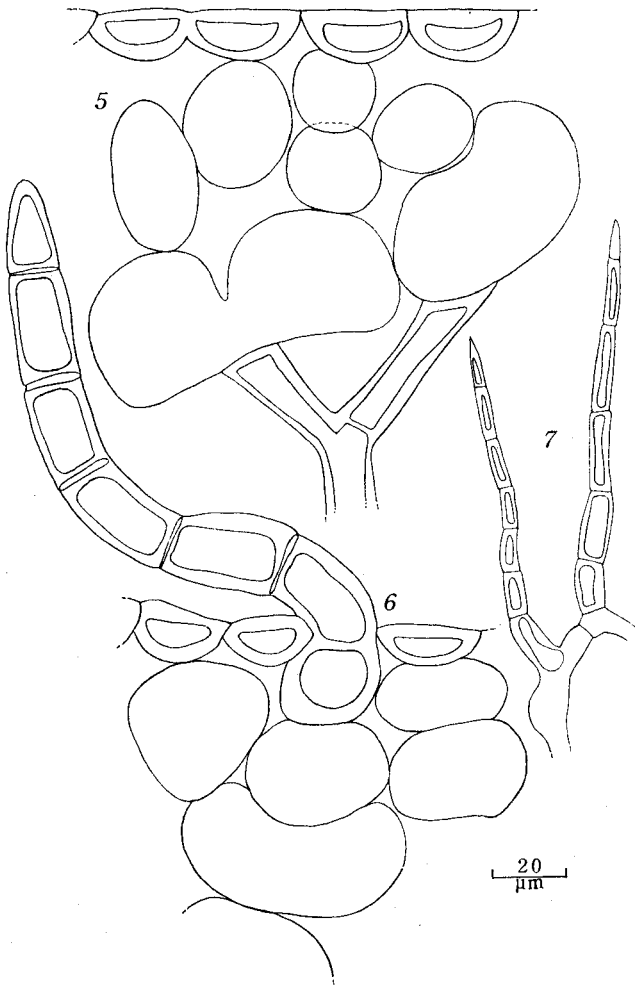
Fig. 3. *Gal. arborea* Kjellman. Transverse section of frond including branched medullary filament.

Fig. 4. *Gal. elongata* J. Agardh. Epidermal cells seen from above with an abortive roundish cell.

Plant reddish brown, to 10 cm tall, cylindrical, regularly dichotomous and stipitate. Internodes are cylindrical, to 10 mm long and 2 mm broad; lower ones are villous and inconspicuously jointed, while upper ones are glabrous, non-villous and prominently striated.

Structure: Frond has 3 layers of parenchymatic cells. Uppermost cells are penta- to hexagonal in surface view (Fig. 4) and lens-like in transverse section (Fig. 5), followed by roundish to ovate ones, to 10 μ broad or more; an inner layer is composed of larger similarly shaped cells, to 25 μ tall. Medullary filaments are cylindrical and ramified.

Locality: Section VI, (PAC–JW–1973–64), December 14, 1973. VII, (PAC–JW–1973–76), December 19, 1973. VIII, (no number), March 28, 1975. IX, (no number), by dragnet, February 22, 1974. XIII, (no number), May 26, 1974.



Figs. 5–6. *Gal. elongata* J. Agardh. (5) Transverse section of frond's upper portion without hair-like part. (6) Transverse section of frond's lower portion with an assimilator.
Fig. 7. *Gal. falcata* Kjellman. Peripheric filaments of the stipe.

Distribution: Hawaii; New Holland; Friendly Islands; Japan; Vietnam; Philippines.

4. *Galaxaura falcata* Kjellman

(Fig. 7; Pl. II, C)

1900:73, tab. 11, figs. 12–31, tab. 12, figs. 1–4, tab. 20, fig. 23; Tanaka 1936:158, pl. XXXIX, text-figs. 22–23; Noda and Kitami 1971:40.

Plant reddish brown, to 12 cm in height, regularly dichotomous, subcanaliculate and stipitate. Stipe is about 1 cm long, cylindrical, villous and bearing rhizoidal filaments. Internodes are subcanaliculate and faintly striated, to 3 mm broad and about 10 mm long, longer distally.

Structure: Frond has 2 layers of parenchymatic tissue. Terminal cells are ovoid to globose, up to 25 μ broad and 45 μ tall, and with roundish apex.

Locality: Station IX, (no number) in 3 herbarium sheets, T. Yamamoto, March 6, 1974.

Distribution: Japan; Philippines.

5. *Galaxaura fasciculata* Kjellman

(Fig. 13; Pl. III, B)

1900:53, tab. 11, figs. 5–19, tab. 20, fig. 14; Weber van Bosse 1921:12; Tanaka 1936:147, pl. XXXIV, fig. 3, text-figs. 5–6; Trono 1969:46, pl. 6, fig. 2.

Plant reddish brown, to 8 cm in height, cylindrical and villous all over. Branches are irregularly dichotomous and nodes are undefined toward the base. Internodes are up to 10 mm long and 2 mm broad.

Structure: Frond shows a poorly developed cortical layer with prominent assimilators issuing from it. These assimilators are cylindrical, about 20 μ long and with an oval apical cell, to 40 μ in diameter. Medullary region is composed of filaments of about 15 μ broad.

Locality: Section V, (PAC-JW-1973-60), December 14, 1973. VI, (PAC-JW-1973-62), December 14, 1973. VII, (PAC-JW-1973-75), December 19, 1973. VIII, (PAC-JW-1973-80), December 19, 1973. IX, (no number), April 25, 1974.

Distribution: Japan; East Indies; Caroline Islands; Celebes; Philippines; Indian Ocean.

6. *Galaxaura oblongata* (El. & Sol.) Lamouroux

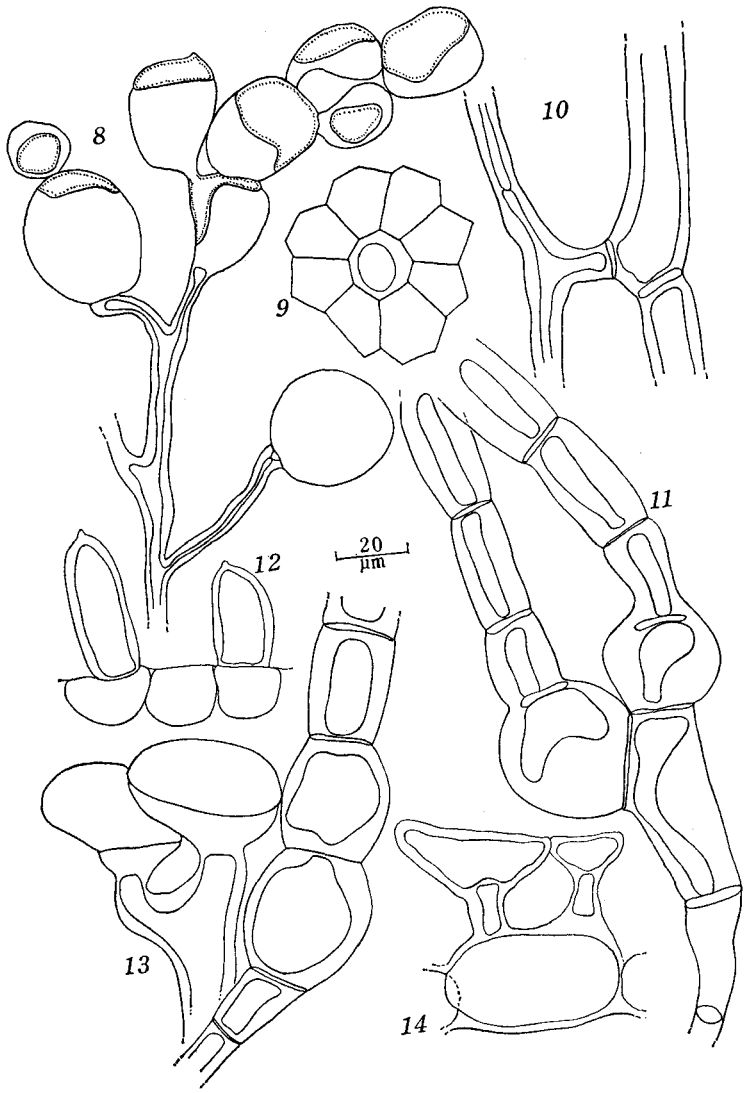
(Figs. 8–10; Pl. II, A; Pl. IV, C)

1816:262; Taylor 1928:139, pl. 21, fig. 15, pl. 31, fig. 5; Tseng 1941:43; Chou 1947:7, pl. 2, figs. 1–6, pl. 3, figs. 1–14; Cordero 1975b:37, text-figs. 1–2; Papenfuss and Chiang 1968:308.

Gal. fastigiata Decaisne, J. Agardh 1876:527; Tanaka 1936:157, pl. XXXVII, fig. 2, text-figs. 20–21; Dawson 1944:258; Kang 1966:62.

Gal. fragilis Lamarck, Boergesen 1916:105, text-figs. 112–114.
Gal. Schimperi Decaisne, Butters 1911:179.

Plants are bushy, greenish to reddish, fragile, cylindrical, regularly dichotomous and with short stipe. Internodes are cylindrical, to 10 mm long and 2 mm broad,



Figs. 8–10. *Gal. oblongata* (El. & Sol.) Lamouroux. (8) Transverse section of frond. (9) Epidermal cells seen from above with an abortive cell. (10) Detailed medullary filament.
Fig. 11. *Gal. subverticillata* Kjellman. Long assimilating filaments issued from the same supporting cell.
Fig. 12. *Gal. tenera* Kjellman. Portion of frond in transverse section showing clavate papillae.
Fig. 13. *Gal. fasciculata* Kjellman. Transverse section of frond showing apical cells of short assimilating filaments larger than basal ones.
Fig. 14. *Gal. obtusata* (Sol.) Lamouroux. Portion of frond in transverse section showing portion of funnel-shaped papillae.

and with faint striations. Uppermost branches are trichotomous and have swollen tip.

Structure: Frond shows epidermal cells that are penta- to hexagonal in surface view and hemispherical in transverse section. Peripheral tissue consists of 2 or more layers of similarly shaped but loosely arranged cells inwardly becoming bigger, up to 25 μ broad.

Locality: Section I, (PAC–JW–1973–18 to 20), December 10, 1973; Ibid., (no number), October 6, 1974; (no number), February 1, 1975; Ibid., (no number) in 2 herbarium sheets, May 31, 1975; Ibid., (no number) in 4 herbarium sheets, Yamamoto & Cordero, June 26, 1975. Section II, (PAC–JW–1973–24 & 25), December 10, 1973; Ibid., (no number), February 1, 1975. Section III, (PAC–JW–1973–46), December 14, 1973; Ibid., (PAC–JW–1973–47), December 14, 1973. Section IV, (PAC–JW–1975–121 also as T. Yamamoto no. 7693), April 9, 1976, Yamamoto & Cordero. Section V, (PAC–JW–1973–49, 56 & 57), December 14, 1973; Ibid., (no number) in 2 herbarium sheets, February 24, 1975. Section VI, (PAC–JW–1973–63), December 14, 1973; Ibid., (no number), October 6, 1974. Section VII, (PAC–JW–1973–69), December 19, 1973. Section VIII, (no number), March 29, 1975; Ibid., (no number), June 10, 1975. Section IX, (no number), February 15, 1974; Ibid., (no number) in 6 herebarium sheets. Section XII, (no number) in 2 herbarium sheets, September 4, 1975. Section XIII, (no number) in 4 herbarium sheets, May 26, 1974.

Distribution: Pacific Ocean; Caroline Islands; New Caledonia; Japan; Hawaii; Korea; Philippines.

7. *Galaxaura obtusata* (Sol.) Lamouroux

(Fig. 14; Pl. III, A; Pl. V, A–B)

J. Agardh 1876:525; Batters 1893:144; Kjellman 1900:88; Weber van Bosse 1921:220; Tanaka 1936: 171, pl. XLV, text-figs. 40–41; Svedelius 1945:52, pls. VIII-IX; Taylor 1969:68.

Gal. robusta Kjellman, 1900:85, tab. 18, figs. 19–32, tab. 20, fig. 2; Papenfuss and Chiang 1968:308.

Plant pale red, but faded away to colorless by drying, slightly calcified, to 12 cm in height, copiously branched and with short and robust stipe. Internodes cylindrical, deeply articulate to almost moniliform basally, to 15 mm long and 2.5 mm broad.

Structure: Frond has 2–3 layers of parenchymatic tissue. Terminal cells bear funnel-shaped papillae borne by unicellular pedicel. Assimilating region is two-layered; uppermost cells are globose, to 10 μ in diameter, while the lowermost ones similar in shape, are larger. Medullary filaments are branched and entangled loosely.

Locality: Section VIII, (no number) in 3 herbarium sheets, March 11, 1975; Ibid., (no number), June 22, 1975; Ibid., (no number) in 2 herbarium sheets, August 26, 1975. Section IX, (no number), February 15, 1974; Ibid., (no number), February 20, 1974; Ibid., (no number), February 22, 1974.

Distribution: Canary Island; Japan; Australia; Madagascar; West Indies; Florida;

Indian Ocean; Pacific Ocean.

8. *Galaxaura papillata* Kjellman

(Pl. IV, A)

1900:59, tab. 7, figs. 13–19, tab. 20, fig. 37; Tanaka 1936:154, pl. XXXVI, fig. 2, text-figs. 18–19.

Plant reddish brown, to 8 cm in height, cylindrical, regularly dichotomous and stipitate. Stipe is short, cylindrical and villous. Internodes are cylindrical, up to 1.5 mm in diameter and 10 (—15) mm in length, with prominently tapered apical part.

Structure: Frond shows several but usually 2–3 layers of parenchymatic tissue. Outermost cells appear subconical and bear clavate to roundish papillae. An intermediate layer is composed of ovate often lobed cells and followed by an innermost layer of large and oblong to ovate cells. Medullary filaments are ramified and entangled.

Locality: Section I, (no number), May 31, 1975. Section VIII, (PAC–JW–1973–79), December 9, 1973.

Distribution: Japan.

9. *Galaxaura subverticillata* Kjellman

(Fig. 11; Pl. IV, B)

1900:48, tab. 3, figs. 12–14, tab. 20, fig. 17; Boergesen 1916:92, fig. 97; Tanaka 1936:146, pl. XXXIV, fig. 2, text-figs. 3–4; Chou 1945:45; Svedelius 1953:38, text-figs. 33–42.

Plant dark reddish brown, to 9 cm in height, cylindrical, villous, regularly dichotomous and stipitate. Stipe is short and thickly villous. Internodes are cylindrical, to 6 mm long, less than 2 mm broad, constricted at the base and transversely striated.

Structure: Frond shows shorter and longer assimilating filaments which are verticillately arranged and alternating with each other. Shorter filaments have large ellipsoidal lower cells, to 30 μ tall and twice taller than broad, and supporting 1–2 upper cells of about 15–18 μ broad, while longer ones are composed of several cells averaging 15 μ in diameter. Medullary filaments are cylindrical and ramified.

Locality: Section I, (PAC–JW–1973–21), December 10, 1973; Ibid., (no number), October 6, 1974. Section VI, (no number), October 16, 1974.

Distribution: Japan; Florida; West Indies; Philippines; Pacific Ocean.

10. *Galaxaura tenera* Kjellman

(Fig. 12; Pl. II, B)

1900:27, tab. 14, figs. 10–19, tab. 20, fig. 32; Papenfuss and Chiang 1968:307, figs. 2–4.

Gal. veprecula Kjellman, 1900:80, tab. 16, fig. 17, tab. 20, fig. 20; Tanaka 1936:169, pl. XLIII, fig. 1,

text-figs. 36–37; Chou 1947: 16, pl. VI, figs. 1–8, pl. XII, fig. 1.

Plant greenish red to brownish, to 6 cm in height, dichotomous, canaliculate and stipitate. Stipe is short, terete and villous. Internodes are canaliculate, to 2 mm broad and 5 mm long, with striations.

Structure: Frond shows 3 layers of parenchymatic tissue. Terminal cells are roundish, bearing single, clavate papillae which are about 25 μ tall and 10 μ broad. Innermost cells are globose and large, to 65 μ broad and 35 μ tall. Medullary filaments are branched and irregularly arranged.

Locality: Section VIII, (no number), February 24, 1975; Ibid., (no number), March 4, 1975; Ibid., (no number), March 11, 1975; Ibid., (no number), March 26, 1975.

Distribution: Madagascar; Japan; Ceylon; China; Philippines.

IV. Distributional Account

Members of the genus *Galaxaura* are always saxicolous, though rarely found growing on other hard objects. Generally, the species of *Galaxaura* described in this paper are non-colonial excepting *Gal. subverticillata* and *Gal. oblongata,* the latter was often found forming scattered patches. An interesting association between *Gal. oblongata* and *Actinotrichia fragilis–Amphiroa aberrans* was observed prevailing in some places, especially in that of Section I, though it remains unknown what factors are concerned with such an association. Only it was found out that whenever this association was observed in exposed situations, both *Galaxaura* and *Actinotrichia* were dwarf and bearing fewer branches, while *Amphiroa* seemed less disturbed because of its more or less prostrate habit. Also, by compiling the data gathered in 1973–1975, the distribution of the genus *Galaxaura* in the vicinity of SMBL could be plotted in detail (Table 1). Of the ten species found in the vicinity, *Gal. oblongata* was the most commonly distributed species. As occurrences and abundance of these species in respective sections were seemingly reflecting several environmental factors, considerations are made on some of them as follows.

a) Substratum. *Galaxaura* species are confined to the areas where the substratum is considerably rocky, as their small disc-shaped holdfast needs a firm object for attachment. Therefore, these species are definitely absent on the sandy or gravelly floor, for instance the sandy beach along the southern coast of the laboratory and the narrow channel between the breakwater and Takashima Islet in Kanayama Bay (Sec. I), some parts of Sections III, V, VI, VIII and IX around the cape and XI of Hatakejima Island.

b) Wind and Wave Actions. The area studied, excepting Sections I, II, IV, VIII, XI and XII, is generally exposed to the wave action affected by winds from the northwest the year round, especially remarkably from autumn to spring (Fuse et al., 1971), and all the sections, but Sec. XI and a part of Sec. XII, are washed by the oceanic water. As already mentioned above, some collecting sections are protected from the wave action to some extent, while others are directly exposed to it. The

Table 1. Seasonal succession in relative abundance and growth stage of *Galaxaura* species in the vicinity of SMBL, together with their occurrences in respective sections.

Species	Months						
	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Galaxaura acuminata	X+	X+	X	X	X	X	X
Gal. arborea	X+	X+	X	X	X	X	X
Gal. elongata	X+	X+	X	XX	(XX)	(XX)	(XX)
Gal. falcata	X+	X+	X	XX	XX	XX	XX
Gal. fasciculata	X+	X+	X	XX	(XX)	(XX)	(XX)
Gal. oblongata	(X+)	(X+)	(X)	(XXX)	(XXX)	(XXX)	(XXX)
Gal. obtusata	X+	X+	X	X	X	X	X
Gal. papillata	(X+)	X+	X	X	X	X	X
Gal. subverticillata	(X+)	X+	X	XX	XX	(XX)	XX
Gal. tenera	X+	X+	X	XX	XX	XX	XX
Section	I	II	III	IV	V	VI	VII

Species	Months						Type of Growth
	Jul.	Aug.	Sep.	Oct.	Nov.		
Galaxaura acuminata	(X)	X	X	X–	X–		solitary
Gal. arborea	(X)	(X)	X	X–	X–		–do–
Gal. elongata	(XX)	(XX)	XX	X	X–	( )	in patches
Gal. falcata	XX	(XX)	XX	X–	X–		solitary
Gal. fasciculata	(XX)	(XX)	XX	X	X–		in patches
Gal. oblongata	(XXX)	(XX)	(XX)	(X)	(X–)	( )	colonial
Gal. obtusata	(X)	(X)	X	X–	X–		solitary
Gal. papillata	(X)	X	X	X–	X–		–do–
Gal. subverticillata	XX	(XX)	XX	X	X–		colonial
Gal. tenera	(XX)	XX	X	X–	X–		solitary
Section	VIII	IX	X	XI	XII	XIII	

For seasonal succession: X–, rare to wanting; X+, young plantlet; X, few; XX, fair; XXX, abundant.

For local occurrence: In the column of respective sections, only the species marked with parentheses were found there growing.

species of *Galaxaura* growing in protected situations are comparatively bigger and furnished with more branches than those in exposed places. Because of its gross morphology, having only a small disc-shaped holdfast to hold a bushy frond, the plant cannot tolerate strong waves and currents. Thus, it is common to find species of *Galaxaura* stranded on the beach detached from the substratum after storms.

c) Nature of Water and Underwater Illumination. The transparency of the water depending upon the amount of suspended matters affects much the penetration of light, that is closely related with the algal growth. The transparency is much lower around Sections XI and XII facing the coves at the head of the bay, as the inflow of the clear oceanic water by wind is much lesser there, especially from spring to autumn,

on the one hand and the water is much more heavily polluted by domestic sewage emptied along the coves on the other hand. The cove water generally flows out along the northern coast of the cape from the east to the west, therefore the transparency of the water arises from Sec. X to Sec. VIII.

The grade of underwater illumination may affect the color of algae. Thus, *Galaxaura* and other red algae show a variety of colors from reddish, greenish, brownish to blackish; a fact explained by Dixon (1973) as "—more to the destruction of phycoerythrin by light rather than the induction of any new pigments—".

Finally, grazers such as snails, fishes and some sea urchins such as *Tripneustes gratilla* (Linnaeus), and other benthonic arimals which may feed on algae might be included in the factors affecting the algal composition of the area, although any actual investigation has not yet been made as to this problem.

V. Seasonal Occurrences

The present surveys proved that fragile *Galaxaura* plantlets, 5 to 10(—15) mm in height, 2–3 branched, and purplish red in color, became visible to the naked eye in autumn. The plantlets continued to grow till they reached in spring of the following year full maturity, assuming the characteristic dense branching and bushy habit (Table 1). In *Gal. fasciculata* and *Gal. subverticillata* bearing extended assimilators or hairs, assimilators became noticeable in early winter when their plantlets were still about 1 cm in height. The average heights of the four commonest *Galaxaura* species in the vicinity of SMBL were 7.1 cm for *Gal. oblongata* and *Gal. obtusata*, 5.8 cm for *Gal. fasciculata* and 4.5 cm for *Gal. subverticillata*.

The growth of *Galaxaura* began to decline in midsummer when the water temperature had risen from 13°C in the winter season to 28° (—32°)C. Death of the algae is shown by yellowing and then total decoloration of the frond, followed by shading and decay of upper parts. It was noteworthy, though unexplainable, that non-hairy forms of *Galaxaura* disappeared earlier than the hairy or villous ones.

VI. Common Algae Growing together with *Galaxaura* in the Area

The common algae found growing together with *Galaxaura* in the vicinity of SMBL are given on the following list; of these, 74 are red, 25 brown, and 25 are green algae.

CHLOROPHYTA

Ulvales
- Monostromacae
  - *Monostroma nitida* Wittrock
- Ulvaceae
  - *Ulva conglobata* Kjellman
  - *U. pertusa* Kjellman
  - *Enteromorpha prolifera* (Muell.) C. Agardh
  - *E. compressa* (L.) Greville
  - *E. intestinalis* (L.) Link
  - *E. linza* (L.) J. Agardh

Siphonocladales
- Valoniaceae
  - *Valonia ventricosa* J. Agardh
  - *V. macrophysa* Kuetzing
- Siphonocladaceae
  - *Struvea delicatula* Kuetzing
- Boodleaceae
  - *Boodlea coacta* (Dickie) Murrey et De Toni

Cladophoraceae
Cladophora ohkuboana Holmes
Chaetomorpha crassa (Ag.) Kuetzing

Siphonales
Bryopsidaceae
Bryopsis plumosa (Huds.) C. Agardh
Caulerpaceae
Caulerpa racemosa var. *clavifera* W.v. Bosse
C. cupressoides var. *lycopodium* f. *elegans* W.v. Bosse
C. racemosa var. *laete-virens* W.v. Bosse
Codiaceae
Codium adhaerens (Cabr.) C. Agardh
C. cylindricum Holmes
C. pugniformis Okamura
C. tenue Kuetzing

PHAEOPHYTA

Dictyotales
Dictyotaceae
Dictyota dichotoma (Huds.) Lamouroux
D. dilatata Yamada
Pachydictyon coriaceum (Holmes) Okamura
Spathoglossum pacificum Yendo
Dictyopteris undulata (Holmes) Okamura
D. prolifera (Okam.) Okamura
Chlanidophora repens Okamura
Padina arborescens Holmes
P. crassa Yamada
P. japonica Yamada

Chordariales
Leathesiaceae
Leathesia difformis (L.) Areschoug
Scytosiphonaceae
Colpomenia sinuosa (Roth) Derbes et Solier
Hydroclathrus clathratus (Bory) Howe

Laminariales
Laminariaceae
Ecklonia cava Kjellman
Undaria pinnatifida (Harv.) Suringar

Fucales
Sargassaceae
Hizikia fusiforme (Harv.) Okamura
Sargassum patens C. Agardh
S. pinnatifidum Harvey
S. filicinum Harvey
S. serratifolium C. Agardh
S. tortile C. Agardh
S. confusum C. Agardh
S. thunbergii (Mert.) O. Kuntze
S. hemiphyllum C. Agardh
S. duplicatum J. Agardh

RHODOPHYTA

Bangiales
Bangiaceae
Bangia fusco-purpurea (Dill.) Lyngbye
Porphyra suborbiculata Kjellman
P. sp.

Nemaliales
Nemalionaceae
Liagora boergesenii Yamada
L. ceranoides Lamouroux
L. farinosa Lamarck
L. japonica Yamada
Chaetangiaceae
Actinotrichia fragilis (Forssk.) Boergesen
Gloiophloea okamurai Setchell
Scinaia cottonii Setchell
S. japonica Setchell
Bonnemaisoniaceae
Asparagopsis taxiformis (Delile) Trevisan
Delisea fimbriata (Lamx.) Montagne

Gelidiales
Gelidiaceae
Gelidium amansii Lamouroux
G. divaricatum Martens
G. pacificum Okamura
G. pusillum (Stackh.) Le Jolis
G. pusillum f. *foliaceum* Okamura
Pterocladia nana Okamura
Gelidiella acerosa (Forssk.) Feldmann et Hamel
Rhizophyllidaceae
Chondrococcus hornemanni (Mert.) Schmidt
Squamariaceae
Peyssonelia rubra (Grev.) J. Agardh
P. caulifera Okamura
Corallinaceae
Amphiroa dilatata Lamouroux
A. aberrans Yendo
A. ephedracea Decaisne
Corallina pilulifera Postels et Ruprecht
Jania arborescens Yendo
J. capillacea Harvey
J. decussato-dichotoma (Yendo) Yendo
J. tenella var. *tenella* Dawson
Grateloupiaceae
Carpopeltis affinis (Harv.) Okamura
C. angusta (Harv.) Okamura
C. flabellata (Holmes) Okamura
Grateloupia turuturu Yamada

G. filicina (Wulf.) J. Agardh
Halymenia dilatata Zanardini
H. acuminata (Holmes) J. Agardh
Endocladiaceae
Gloiopeltis furcata Postels et Ruprecht
Kallymeniaceae
Kallymenia perforata J. Agardh
K. stipitata
Callophyllis palmata Yamada

Gigartinales
Solieriaceae
Eucheuma muricatum (Gmel.) W.v. Bosse
E. serra J. Agardh
Meristotheca papulosa (Mont.) J. Agardh
Plocamiaceae
Plocamium leptophyllum Kuetzing
P. telfairiae Harvey
Hypneaceae
Hypnea cervicornis J. Agardh
H. charoides Lamouroux
H. japonica Tanaka
Gracilariaceae
Gracilaria compressa (C. Ag.) Greville
G. arcuata Zanardini
G. purpurascens J. Agardh
G. textorii Suringar
G. verrucosa (Huds.) Papenfuss
Gelidiopsis intricata (C. Ag.) Vickers
G. repens Kuetzing
Ceratodictyon spongiosum Zanardini
Phyllophoraceae
Gymnogongrus divaricatus Holmes
Gigartinaceae
Gigartina tenella Harvey

Rhodymeniales
Rhodymeniaceae
Rhodymenia adnata Okamura
R. coacta Okamura et Segawa
Chrysymenia sp.
Fauchea spinulosa Okamura et Segawa
Champiaceae
Champia expansa Yendo
C. parvula (C. Ag.) J. Agardh
Lomentaria rosea (Harv.) Thuret

Ceramiales
Ceramiaceae
Centroceras clavulatum (C. Ag.) Montagne
Ceramium tenerrimum (Mart.) Okamura
Wrangelia argus Montagne
Rhodomelaceae
Acanthophora spicifera (Vahl) Boergesen
Laurencia cartilaginea Yamada
L. undulata Yamada
Herposiphonia tenella (C. Ag.) Naegeli
Polysiphonia spp.

VII. Summary

A study was made on the taxonomy, distribution and seasonal occurrence of the genus *Galaxaura* (Nemaliales, Rhodophyta) in the vicinity of the Seto Marine Biological Laboratory from around Takashima Islet in Kanayama Bay to Hatakejima Island in Tanabe Bay. This study, covering the period from winter of 1973 to autumn of 1975, yielded ten species of *Galaxaura* from thirteen collecting sections; they were *Gal. acuminata, Gal. arborea, Gal. elongata, Gal. falcata, Gal. fasciculata, Gal. oblongata, Gal. obtusata, Gal. papillata, Gal. subverticillata* and *Gal. tenera.* Of these, *Gal. oblongata* was distributed most commonly and seemingly tolerated different environmental conditions in the area, while *Gal. papillata* and *Gal. falcata* represented the rare forms. All these algae are generally saxicolous and grow mainly in the lower intertidal to the shallow sublittoral zone, begin to appear in autumn, luxuriate from spring to early summer of the following year, and disappear in late summer when the water temperature reaches 28°C or more.

Some factors affecting the growth and distribution of *Galaxaura* in the area are briefly discussed. The northern-most record of the genus *Galaxaura* is so far Sado Island, Niigata Prefecture, in the Japan Sea and the southern-most is in North Australia. It has ever been reported from the Indian Ocean and Red Sea, but more

commonly from the tropical West Pacific; the last waters might be the probable center of divergence for this genus.

Also, a list of prominent algae growing together with *Galaxaura* in the area is included in this report.

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EXPLANATION OF PLATES I–V

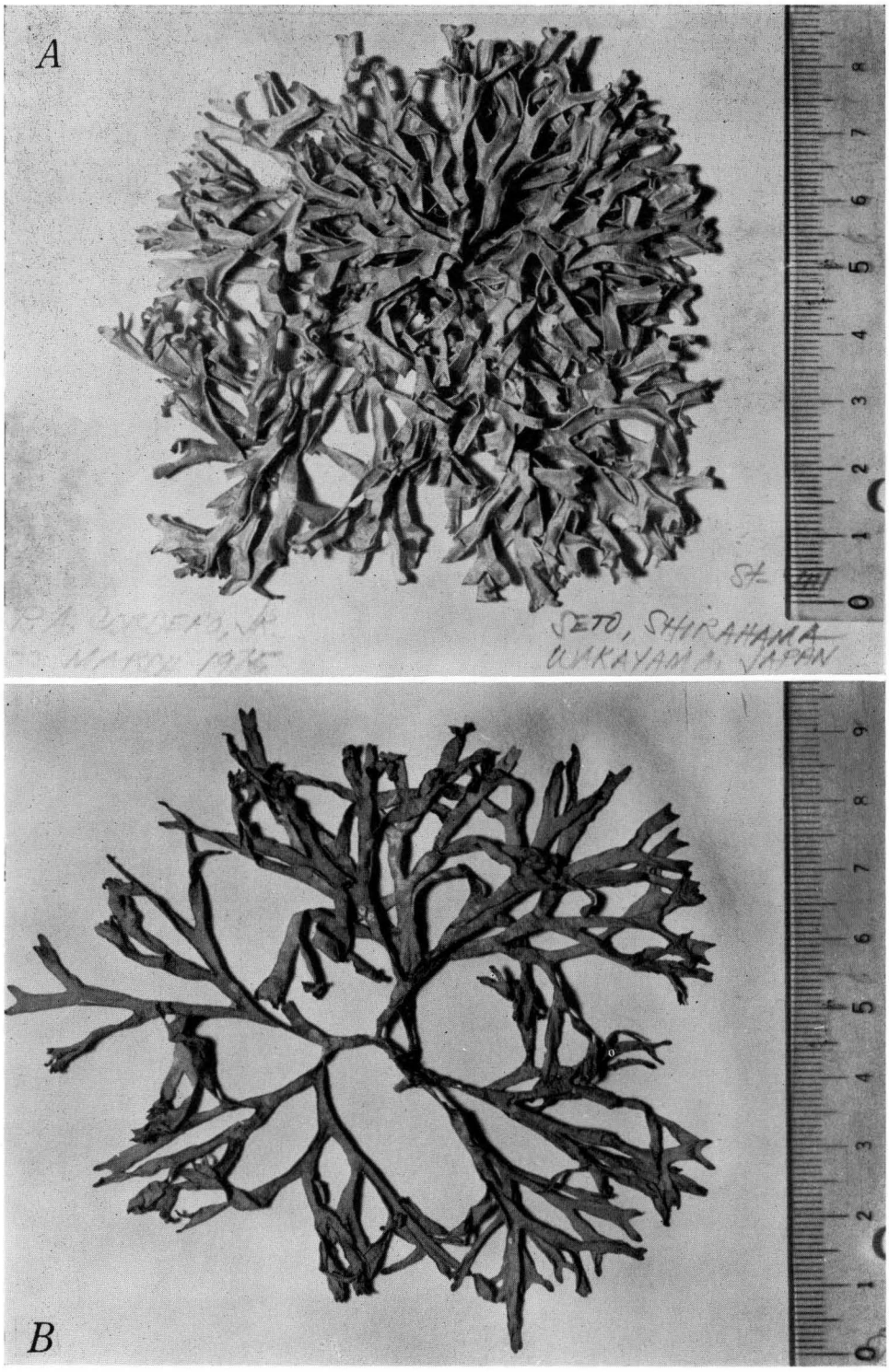
PLATE I. A. Habit of *Gal. acuminata* Kjellman. Collected on March 30, 1975–Sec. VIII. B. Habit of *Gal. arborea* Kjellman. Collected on March 11, 1975–Sec. VIII.

PLATE II. A. Habit of *Gal. oblongata* (El. & Sol.) Lamouroux. Collected on June 26, 1975–Sec. I. "Robust type" B. Habit of *Gal. tenera* Kjellman. Collected on February 24, 1975–Sec. VIII. C. Habit of *Gal. falcata* Kjellman. Collected on March 6, 1974–Sec. IX.

PLATE III. A. Habit of *Gal. obtusata* (Sol.) Lamouroux. Collected on March 11, 1975–Sec. VIII. B. Habit of *Gal. fasciculata* Kjellman. Collected on December 19, 1973–Sec. VIII. C. Habit of *Gal. elongata* J. Agardh. Collected on December 14, 1973–Sec. III.

PLATE IV. A. Habit of *Gal. papillata* Kjellman. Collected on May 31, 1975–Sec. I. B. Habit of *Gal. subverticillata* Kjellman. Collected on October 6, 1974–Sec. I. C. Habit of *Gal. oblongata* (El. & Sol.) Lamouroux. Collected on May 26, 1974–Sec. XIII. "Slender type"

PLATE V. A Habit of *Gal. obtusata* (Sol.) Lamouroux. Collected on June 22, 1975–Sec. VIII. "Robust type" B. Habit of *Gal. obtusata* (Sol.) Lamouroux. Collected on June 22, 1975–Sec. VIII. "Slender type"



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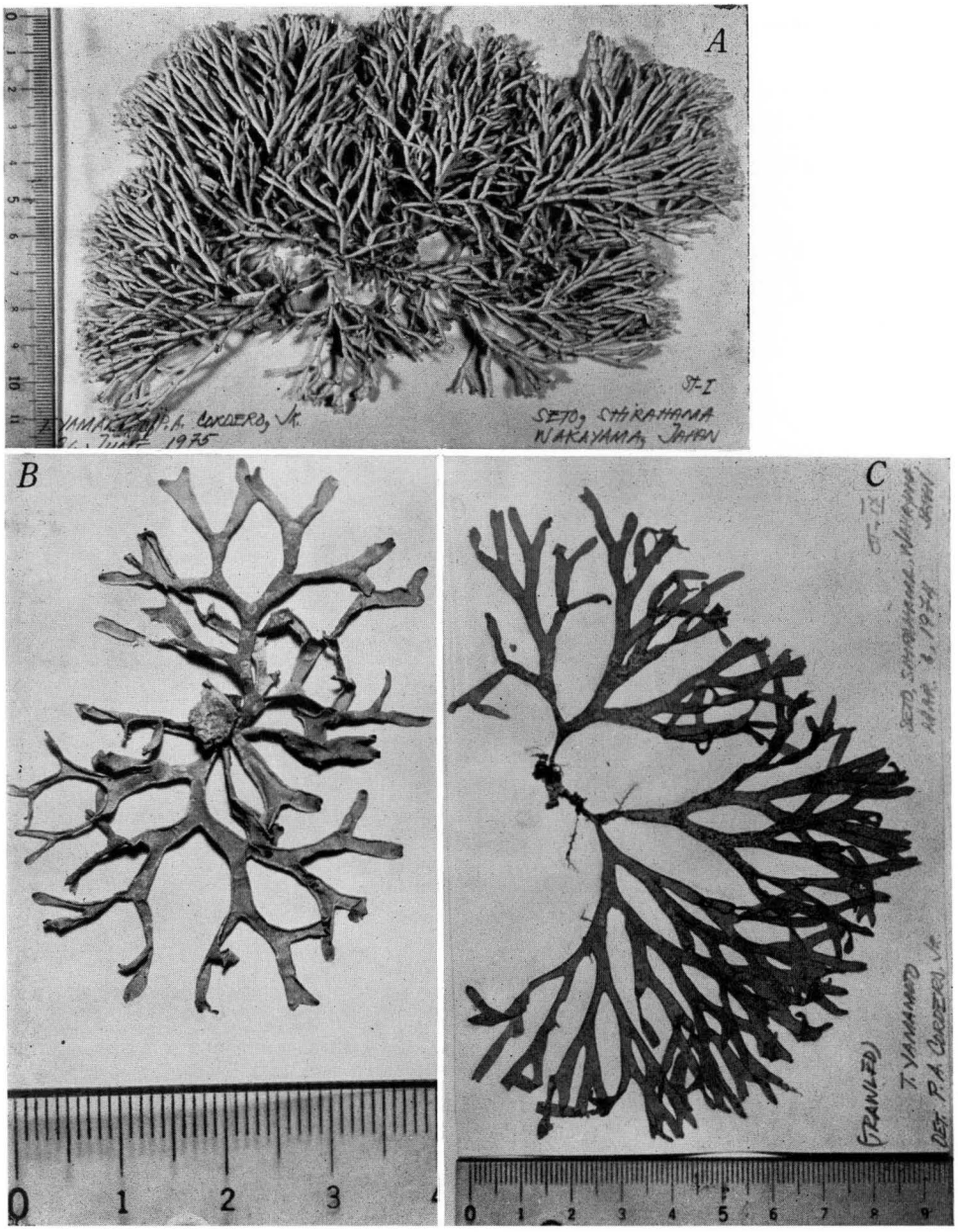

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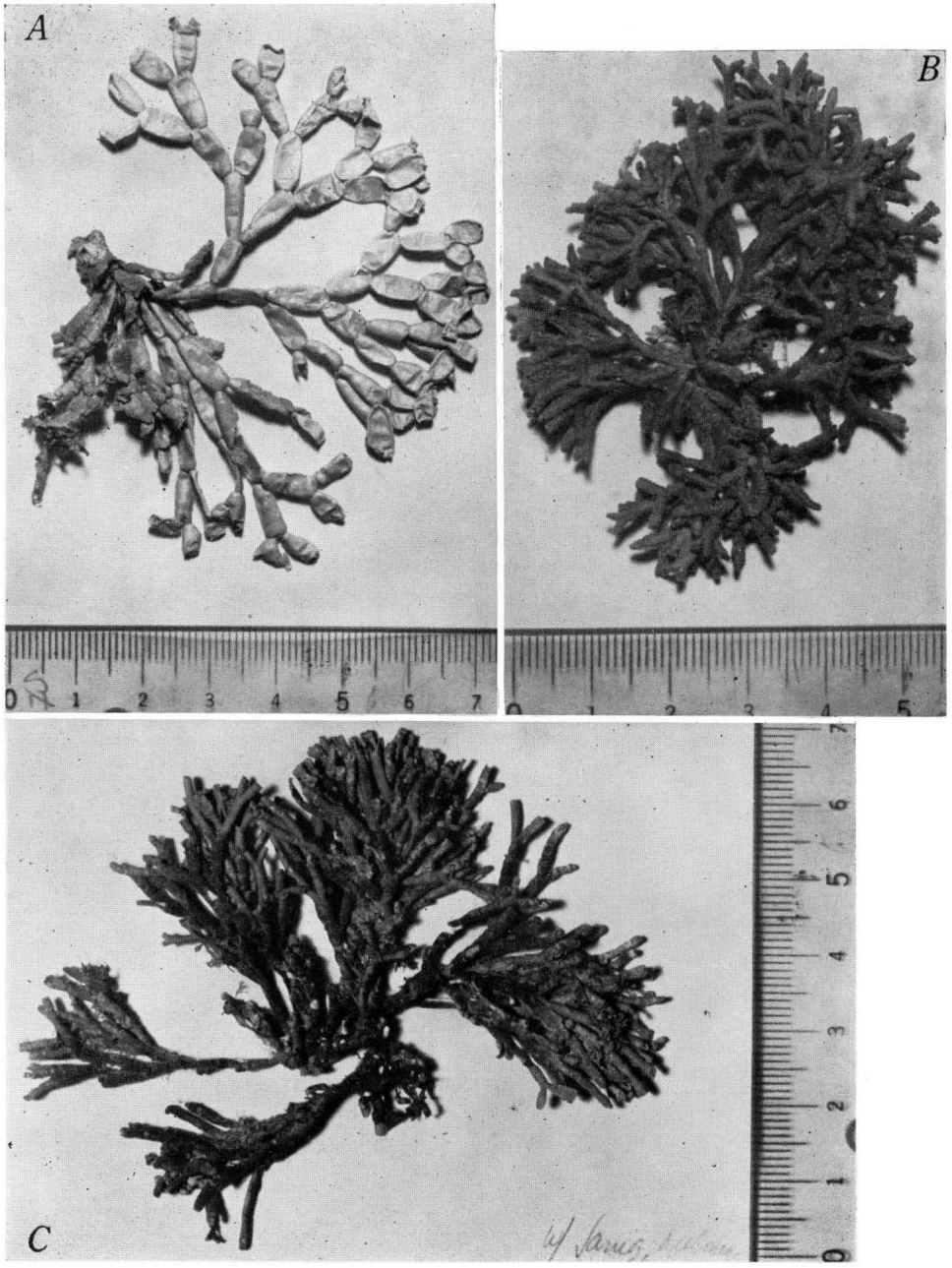
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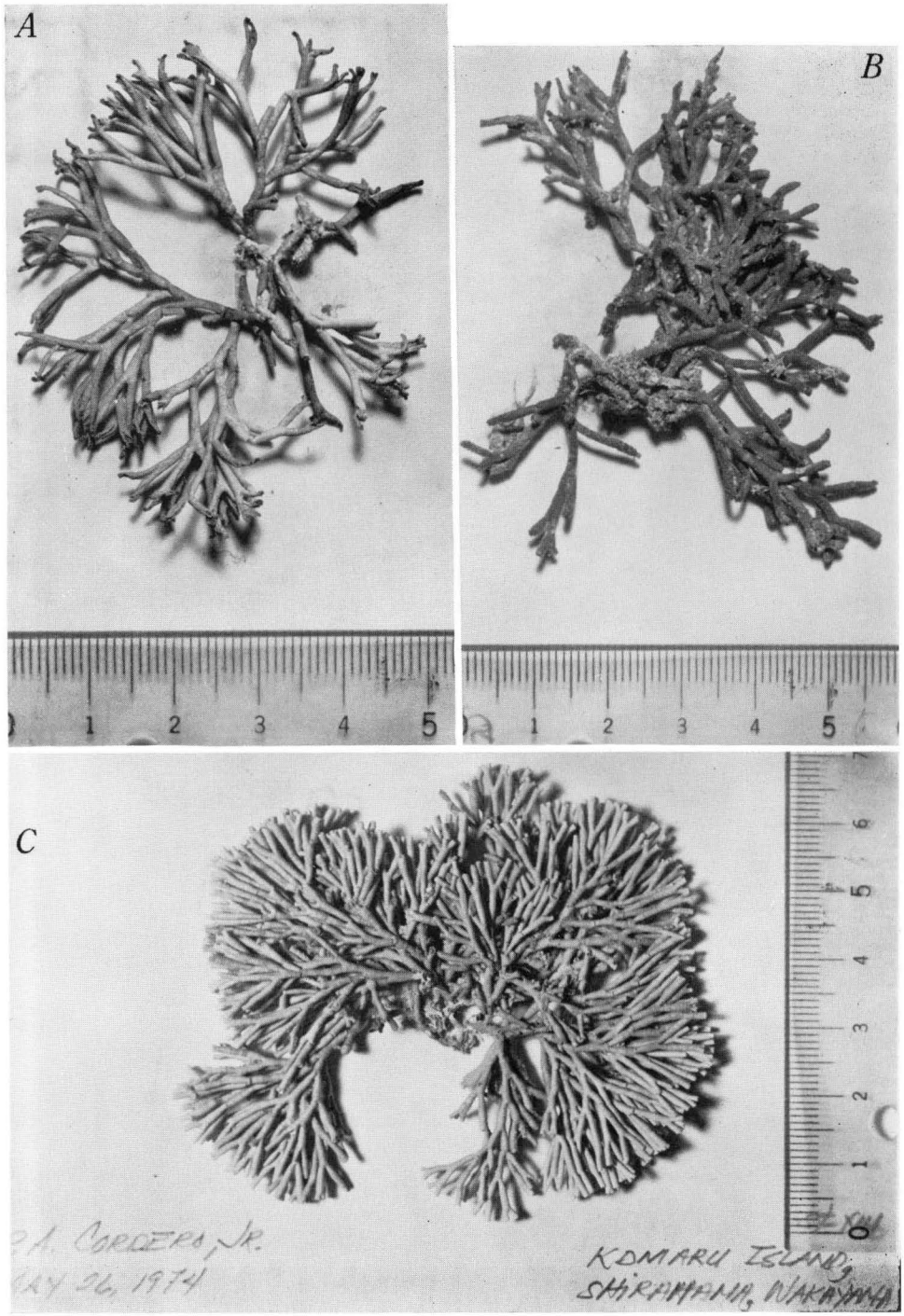
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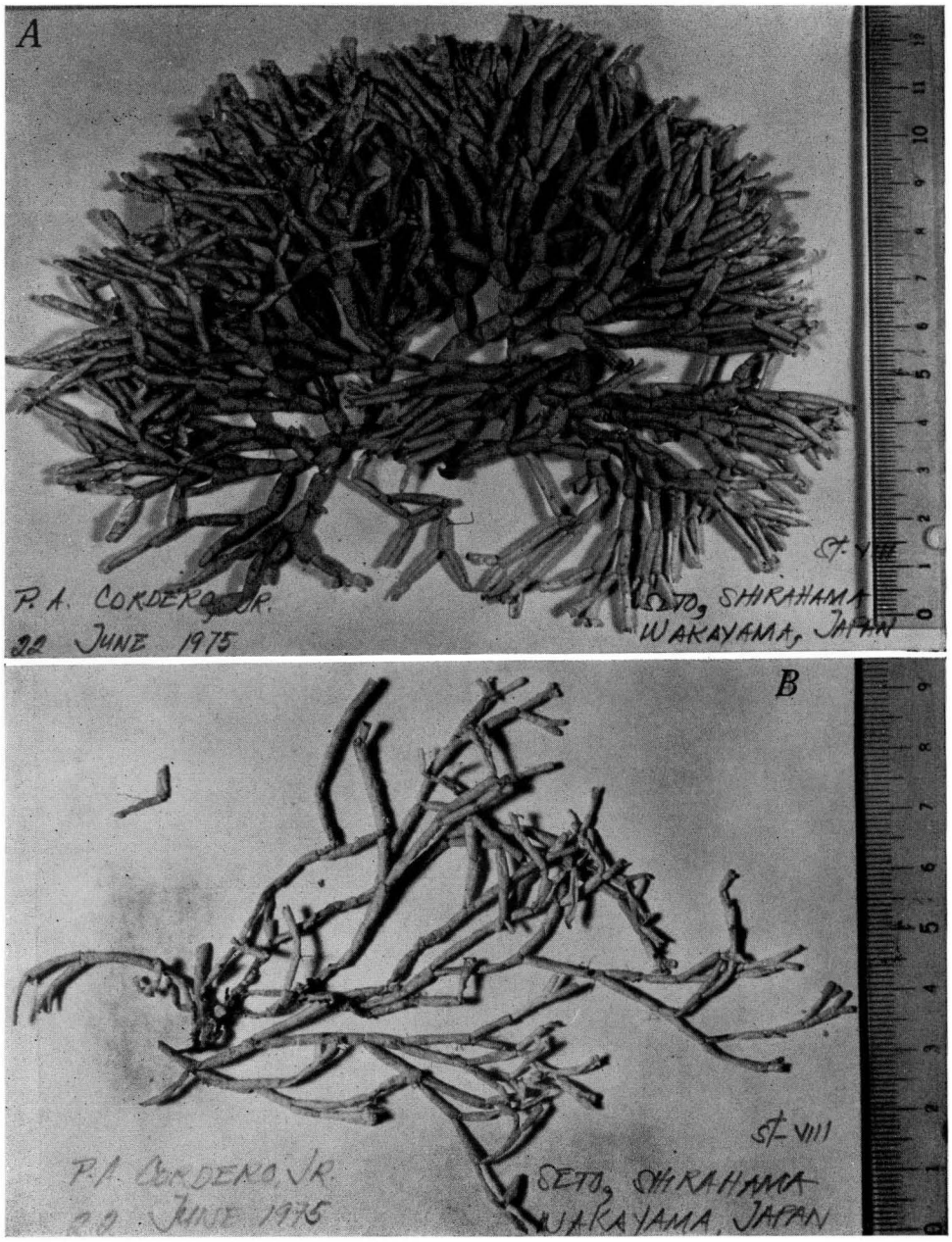
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