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Review

Floristics and geographic distribution of *Halimeda* (Chlorophyta) in the Ryukyu Islands

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Eleven species of *Halimeda* occur in the Ryukyu Islands, based on the reexamination of the majority of specimens previously reported in the literature, examination of unreported specimens, and the acceptance of one previous species record. The species are *H. incrassata, H. simulans, H. macroloba, H. opuntia, H. distorta, H. velasquezii, H. renschii, H. tuna, H. discoidea, H. micronesica* and *H. fragilis* (not substantiated). *Halimeda renschii* and *H. distorta*, previously reported as *H. opuntia* f. *renschii* and *H. opuntia* v. *hederacea*, respectively, are substantiated from the island chain. *Halimeda cuneata* is not among the specimens examined; specimens previously identified as *H. cuneata* from the Ryukyu Islands, mainland Japan and the Bonin Islands were identified as either *H. discoidea* or *H. tuna*. A general attenuation of species is evident as one moves from the southwest to the northeast along the island chain—Sakishima Is., includes Yaeyama Is. and Miyako Is. (10 species), Okinawa Is. (10 species), Amami Is. (5 species), Osumi Is. (3 species) and mainland Japan (2 species). Although *H. macroloba* is present at Kume I., its absence from Okinawa I. is a mystery. Fifteen new island records for species of *Halimeda* are cited.

Key Index Words: coral reefs—geographic distribution—Halimeda—*Japanese Southwestern Islands—marine benthic algae—Ryukyu Islands.*

The Ryukyu Islands (Fig. 1), i.e. those subtropical islands from Tanegashima I. (Osumi Islands) to Yonaguni I. (Yaeyama Islands) which lie in a northeast-southwest orientation between the southern coast of Kyushu and the northeastern coast of Taiwan, are phytogeographically interesting because the island chain serves as a filtering region for those marine benthic algae deemed tropical in habit. One such alga is the conspicuous *Halimeda* (Caulerpales, Halimedaceae) which is usually associated with coral reefs and which abounds in tropical waters, e.g. 20 species reported from the Philippines (see species listing and references in Silva *et al.* 1987) and 21 species reported from adjacent Micronesia (see species listing and references in Tsuda and Wray 1977, Hillis-Colinvaux 1980).

The original concept of the study was to examine the geographic distribution of the species of *Halimeda* along the Ryukyu Islands based on records in past literature and supplemented through the examination of *Halimeda* specimens deposited in the Herbarium of the University of the Ryukyus and other specimens in the personal possession of the second co-author. Eleven species, including four varieties and eight forms, have been previously reported in the literature (Table 1) from 17 islands within the island chain—Heydrich (1894), Okamura (1915, 1932, 1936), Yamada (1934), Yamada and Tanaka (1938), Tanaka (1950, 1956, 1957, 1960), Hillis (1959), Segawa and Kamura (1960), Kida (1964), Moul (1964), Kamura (1966, 1977), Tanaka and Itono (1968, 1972), Akatsuka (1973), Itono (1973), Yamazato *et al.* (1976), Kamura and Iida (1981), and Ohba and Aruga (1982). Three species of

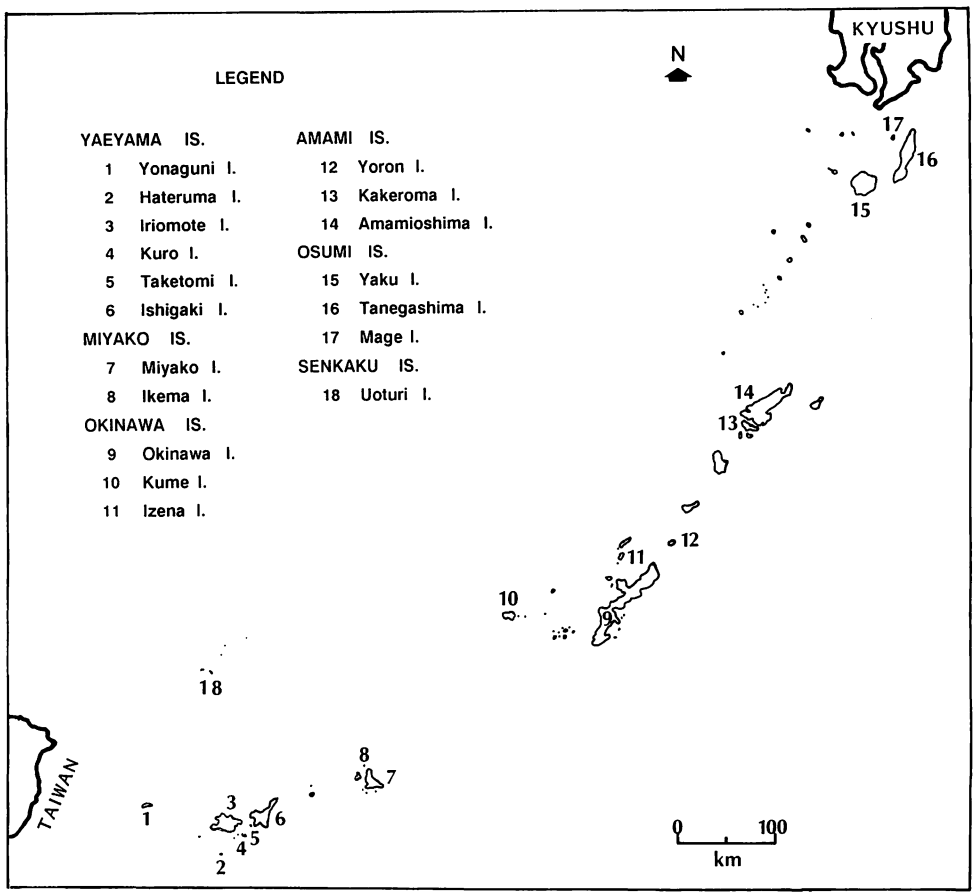

Fig. 1. Map of the Ryukyu Islands.

Halimeda, i.e. *H. cuneata* Hering (Okamura 1930, 1936, Segawa 1935, Chihara 1956, Ichiki 1956, Yagi 1962, Iida 1979), *H. tuna* (Ellis and Solander) Lamouroux (Okamura 1936) and *H. discoidea* Decaisne (Chihara and Yoshizaki 1970, Yamamoto 1988), have been reported from the Japanese mainland and its vicinity.

Initially, the approach seemed quite satisfactory since previous Japanese authors had been quite detailed in attributing names at the infraspecific ranks to such species as *H. opuntia* (L.) Lamouroux and *H. incrassata* (Ellis) Lamouroux. The task of applying the current applicable specific names to the varieties and forms would be relatively routine, e.g. *H. velasquezii* W.R. Taylor for *H. opuntia* f. *intermedia* Yamada. It soon became apparent that any discussion of the geographic distribution of the species of *Halimeda* within the Ryukyu Islands must be more solidly based on the reexamination of specimens on which the initial identifications were made by previous authors. This matter was especially important in terms of earlier authors since many changes relative to species concept have occurred since their studies were published. Prior to the monographic revision of the genus *Halimeda* by Hillis (1959), phycologists were following the taxonomy of the initial monograph of Barton (1901) who recognized seven species; *H. discoidea* was then considered a synonym of *H. tuna*. Hillis (1959) recognized 21 species and since her revision, nine additional species have been attributed to the genus *Halimeda* (see Hillis-Colinvaux, 1980). Twenty-five of the 30 species recognized worldwide can be found in the In-

Table 1. Past references of species of *Halimeda* reported from islands within the Ryukyu Islands.

Section RHIPSALIS

H. incrassata (Ellis) Lamouroux. YAEYAMA IS.: Yonaguni I.—Tanaka and Itono (1972), as f. *lamourouxii* J. Agardh; Iriomote I.—Ohba and Aruga (1982); Taketomi I.—Ohba and Aruga (1982). MIYAKO IS.: Miyako I.—Kamura (1977). OKINAWA IS.: Okinawa I.—Yamada (1934), as f. *typica* and f. *ovata* J. Agardh; Moul (1964); Kamura (1966); Yamazato *et al.* (1976), as f. *ovata*; Kume I.—Kamura and Iida (1981), as v. *lamourouxii*. AMAMI IS.: Yoron I.—Tanaka (1960), as f. *typica*; Tanaka and Itono (1968), as f. *lamourouxii*; Amamioshima I.—Tanaka (1956), as f. *typica*. RYUKYU IS.: Okamura (1915), as f. *lamourouxii*; Hillis (1959).

H. cylindracea Decaisne. RYUKYU IS.: Hillis (1959), specimen is labeled Okinawa I.

H. macroloba Decaisne. YAEYAMA IS.: Yonaguni I.—Yamada and Tanaka (1938); Iriomote I.—Akatsuka (1973); Ohba and Aruga (1982); Taketomi I.—Ohba and Aruga (1982); Ishigaki I.—Okamura (1915, 1936); Akatsuka (1973). MIYAKO IS.: Miyako I.—Kamura (1977). AMAMI IS.: Yoron I.—Tanaka (1957, 1960); Kakeroma I.—Kida (1964); Amamioshima I.—Kida (1964); RYUKYU IS.: Hillis (1959).

H. simulans Howe. OKINAWA IS.: Okinawa I.—Moul (1964).

Section OPUNTIA

H. opuntia (L.) Lamouroux. YAEYAMA IS.: Yonaguni I.—Yamada and Tanaka (1938), as f. *typica* and f. *intermedia* Yamada; Taketomi I.—Ohba and Aruga (1982), as v. *opuntia* and v. *hederacea* (Barton) Hillis; Ishigaki I.—Okamura (1915, 1936), as f. *cordata* (J. Agardh) Barton; Segawa and Kamura (1960), as f. *typica*; Akatsuka (1973), as f. *typica* and f. *cordata*; Ohba and Aruga (1982), as v. *opuntia*. MIYAKO IS.: Miyako I.—Heydrich (1894); Kamura (1966), as f. *typica*; Kamura (1977); Ikema I.—Kamura (1977). OKINAWA IS.: Okinawa I.—Yamada (1934), as f. *typica* and f. *intermedia* (f. nov.); Moul (1964), as v. *opuntia* and v. *hederacea*; Kamura (1966), as f. *intermedia*. AMAMI IS.: Yoron I.—Tanaka (1960), as f. *cordata*; Amamioshima I.—Tanaka (1956), as f. *cordata*; Kida (1964). OSUMI IS.: Mageshima I.—Tanaka (1950), as f. *cordata* and f. *renschii* (Hauck) Barton. RYUKYU IS.: Okamura (1915), as f. *renschii*; Okamura (1936), as f. *typica* and f. *renschii*; Hillis (1959).

H. velasquezii W.R. Taylor. YAEYAMA IS.: Kuro I.—Ohba and Aruga (1982); Ishigaki I.—Ohba and Aruga (1982).

Section HALIMEDA

H. tuna (Ellis and Solander) Lamouroux. YAEYAMA IS.: Ishigaki I.—Akatsuka (1973), as f. *typica*. RYUKYU IS.: Okamura (1932, 1936), as f. *typica*.

H. discoidea Decaisne. YAEYAMA IS.: Taketomi I.—Ohba and Aruga (1982). MIYAKO IS.: Miyako I.—Kamura (1977). OKINAWA IS.: Okinawa I.—Moul (1964); Kume I.—Kamura and Iida (1981).

H. cuneata Hering. OKINAWA IS.: Okinawa I.—Yamada (1934); Yamazato *et al.* (1976). AMAMI IS.: Yoron I.—Tanaka (1960); Amamioshima I.—Okamura (1915, 1936); Tanaka (1956); Kida (1964). OSUMI IS.: Tanegashima I.—Okamura (1915, 1936); Mageshima I.—Tanaka (1950).

Section MICRONESICAE

H. micronesica Yamada. YAEYAMA IS.: Hateruma I.—Itono (1973); Taketomi I.—Ohba and Aruga (1982).

H. fragilis W.R. Taylor. YAEYAMA IS.: Hateruma I.—Itono (1973).

do-Pacific region.

Materials and Methods

The floristic section of this study is based on the examination or reexamination of specimens from the Herbaria of the following institutions and the private collections of the following individuals.

(1) Herbarium of the University of the Ryukyus and collections in the personal possession of the second co-author, based on past reports (Segawa and Kamura 1960, Kamura 1966, 1977, Yamazato *et al.* 1976, Kamura and Iida 1981, Kamura *et al.* 1982) and other unreported specimens;

(2) Personal collections of Dr. Washiro Kida, Faculty of Fisheries, University of Mie, based on Kida (1964);

(3) Herbarium of the Tokyo University of Fisheries and personal collections of Dr. Hideo Ohba and Dr. Yusho Aruga, based on

Ohba and Aruga (1982);

(4) Herbarium (SAP) of the Department of Botany, Faculty of Science, Hokkaido University, Sapporo, based on past reports (Okamura 1932, Yamada 1934, Yamada and Tanaka 1938), Dr. Kintaro Okamura's collections, and other unreported specimens.

(5) Herbarium of the Faculty of Fisheries, Kyushu University, based on past reports (Ichiki 1956, Segawa 1956, 1958, Segawa and Kamura 1960), and other unreported specimens of Dr. Yoshikazu Okada, Dr. Sokichi Segawa, Dr. Takeo Okuda and the second co-author.

(6) Herbarium of Marine Botany, Faculty of Fisheries, Kagoshima University, and personal collections of Dr. Tadahide Noro.

(7) Herbarium (MICH) of the University of Michigan (Hillis, 1959).

Unfortunately, the specimens of Dr. Takesi Tanaka and the late Dr. Hiroshi Itono (i.e. Tanaka 1950, 1956, 1957, 1960, Tanaka and Itono 1968, 1972, Itono 1973) were not curated and, thus, could not be loaned in their present state. Other collections and the detailed description provided by Itono (1973), however, substantiate most of the island records. In addition, *Halimeda* specimens collected by the first co-author during his three-month research visit to Okinawa during January to March 1990 are incorporated in this study.

Since the Herbarium of Hokkaido University, Sapporo, is the only Japanese institution listed above that has an official Herbarium designation, i.e. SAP, the following designations were used for the other institutions as a guide to where the specimens are located—University of the Ryukyus (RYUK), University of Mie (MIE), Tokyo University of Fisheries (TUF), Kyushu University (KYU) and Kagoshima University (KAG).

Locality data for the specimens examined are cited with the applicable island groups and specific islands in order of their location from southwest to northeast within the Ryukyu Islands, i.e. Yaeyama Is., Miyako Is., Okinawa Is., Amami Is. and Osumi Is. Those specimens examined from the Japanese mainland and the Bonin Islands are also cited. Although the Senkaku Islands are not officially part of the Ryukyu Islands, specimens (Kamura *et al.* 1982) were reexamined and incorporated in the listing. Specimens which have not been designated an acquisition or field number are cited with the designation "s.n." (sine num.) after the name(s) of the collector(s) or the Herbarium.

Materials from herbarium specimens for microscopic examination were obtained by sectioning a thin rectangular strip, ca. 1-2 mm wide and 4-6 mm long, from mature nodal regions that included portions of the upper and lower segments located mid-way between the basal and apical segments. In those cases where the nodal regions were extremely narrow, adjacent mature segments with nodes were taken from the herbarium specimens. The strips or segments were decalcified in 10% HCl, placed in an aqueous solution of detergent for 5-10 minutes, sectioned and other parts teased under the dissecting microscope (35×), and examined under the compound microscope (100× and 400×). The above technique differs slightly from that recommended by Hillis-Colinvaux (1980) who decalcified her sections after the sections were made. Macroscopic observations and measurements, i.e. thallus height and segment size, were obtained from dried specimens, unless otherwise stated. All anatomical measurements were made under high power (400×).

Since the range of surface diameters of peripheral utricles of a particular specimen played an important role in differentiating species which appeared morphologically similar, range of means, based on a minimum of 10 measurements per segment or per thallus (Hillis-Colinvaux 1980), was used in this study instead of the extreme range to differentiate species, especially those in the Section Rhipsalis. Past experiences by the co-authors have shown that if one looks long enough, extreme range can be found in any specimen which negates the usefulness of the measurements of surface diameters. The

range of means provided the co-authors with a useful tool to separate species of *Halimeda*.

The information on the geographic distribution of *Halimeda* in the Ryukyu Islands is primarily based on specimens actually examined by the co-authors. Only in a few cases, when specimens were not available for our reexamination, did the co-authors rely on the past reports.

Results

The 11 species of *Halimeda* which we recognize in the Ryukyu Islands are discussed individually under their respective Sections, as defined by Hillis-Colinvaux (1980: 85). Therefore, the degree of fusion, if any, of the medullary filaments at the nodal regions is not discussed in detail, since the nodal characteristic of the species is defined by the Section.

Section RHIPSALIS

Halimeda incrassata (Ellis) Lamouroux; Okamura 1915: 213, pl. 150 (figs. 1-7); Yamada 1934: 81, fig. 52; Hillis 1959: 365, pl. 4 (figs. 1, 2), pl. 5 (fig. 21), pl. 6 (figs. 21-24), pl. 12; Hillis-Colinvaux 1980: 93, fig. 22.

Plate 1, Figs. 1-5

Japanese name: Mitsude-sabotengusa.

Specimens examined. MIYAKO IS.: Miyako I.—*Kamura 2967* (RYUK), Oonogoshi, X-11-73 (Kamura 1977). OKINAWA IS.: Okinawa I.—*MICH s.n.* (MICH), V-5-28, leg. M. Higashi (Hillis 1959, as *H. cylindracea*); *TUF s.n.* (TUF), V-5-28, collector not cited; *Segawa s.n.* (KYU), V-5-28, leg. T. Tamayose (Segawa 1956, No. 93); *SAP 14376* (SAP), V-32, leg. Y. Yamada (Yamada 1934, as f. *typica*); *Segawa s.n.* (KYU), Naminoue, V-56; *Kamura 78* (RYUK), fertile, Itoman, VII-7-56, leg. K. Hanashiro; *Kamura 80* (RYUK), fertile, Itoman, V-7-56; *Segawa s.n.* (KYU), fertile, Itoman, V-7-56; *Kamura 117* (RYUK), Henza I., 2 m deep (MLLW), sand-rubble substratum, X-11-77; *Kamura 255* (RYUK/KYU), Itoman, IV-26-57; *Kamura 941* (RYUK/KYU), Oomine, III-26-59; *Kamura 942* (RYUK/KYU), Yonashiro, III-13-59; *Kamura 943* (RYUK), Henoko, III-27-59; *Kamura 944* (RYUK), Hiyakuna, III-29-59; *Kamura 1240* (RYUK), Itoman, VI-27-61; *Kamura 1325* (RYUK), Itoman, VIII-12-59; *Kamura 1726* (RYUK), Itoman, V-5-57; *Kamura 1941* (RYUK), Itoman, VI-4-62; *Kamura 1974* (RYUK), Itoman, VI-18-68; *Kamura 1995* (RYUK), fertile, Itoman, VI-30-62; *Kamura 2554* (RYUK), Nakagusuku (Kitahama), III-16-72; *Tsuda 90-68* (RYUK), Henoko, sandy seagrass bed, 1 m deep (MLLW), III-9-90. RYUKYU IS.: *SAP 10078* (SAP), III-31, leg. S. Inoh (Yamada 1934, as f. *typica*).

The specimens, up to 18 cm tall, possess fan-shaped basal regions, up to 2 cm broad, which are formed by the fusion of subcylindrical or barrel-shaped segments. The subsequent segments usually grow in one plane and vary in shape from cylindrical, i.e. characteristic of *H. cylindracea*, to subcuneate and reniform, i.e. typical of *H. incrassata*. The cortex consists of up to five layers of utricles. The peripheral utricles are 42-67 μm in surface diameter (i.e. range of means of 10 measurements each from 18 different thalli) with an overall mean of 48 μm, which is lower than the mean of 73 μm cited for *H. incrassata* by Hillis-Colinvaux (1980). The peripheral utricles of fresh specimens are 48-57 μm in surface diameter (i.e. range of means of 10 measurements each from 5 thalli) with an overall mean of 53 μm. The peripheral utricles are 50-125 μm long and remain laterally attached after decalcification. Secondary utricles are globose, subglobose or elongated, 25-50 μm broad and 60-88 μm long.

Initially, we had attributed certain specimens, i.e. *Kamura 117, 255, 941, 944*, and *2554* to *Halimeda cylindracea* Decaisne; however, the large diameter of the peripheral utricles and the fact that the surface diameters of the peripheral utricles did not differ from the typical *H. incrassata* convinced us to include all specimens under *H. incrassata*. Interestingly, three specimens which we had

received on loan were collected on the identical date, i.e. 5 May 1928, as the specimen collected by Dr. Michitaro Higashi which Hillis (1959) attributes to *H. cylindracea*. The specimens, i.e. *TUF s.n.* and *Segawa s.n.* (two specimens), are labeled "*Halimeda incrassata* Lam. f. *typica* Barton". The specimens are morphological identical to the *MICH s.n.*

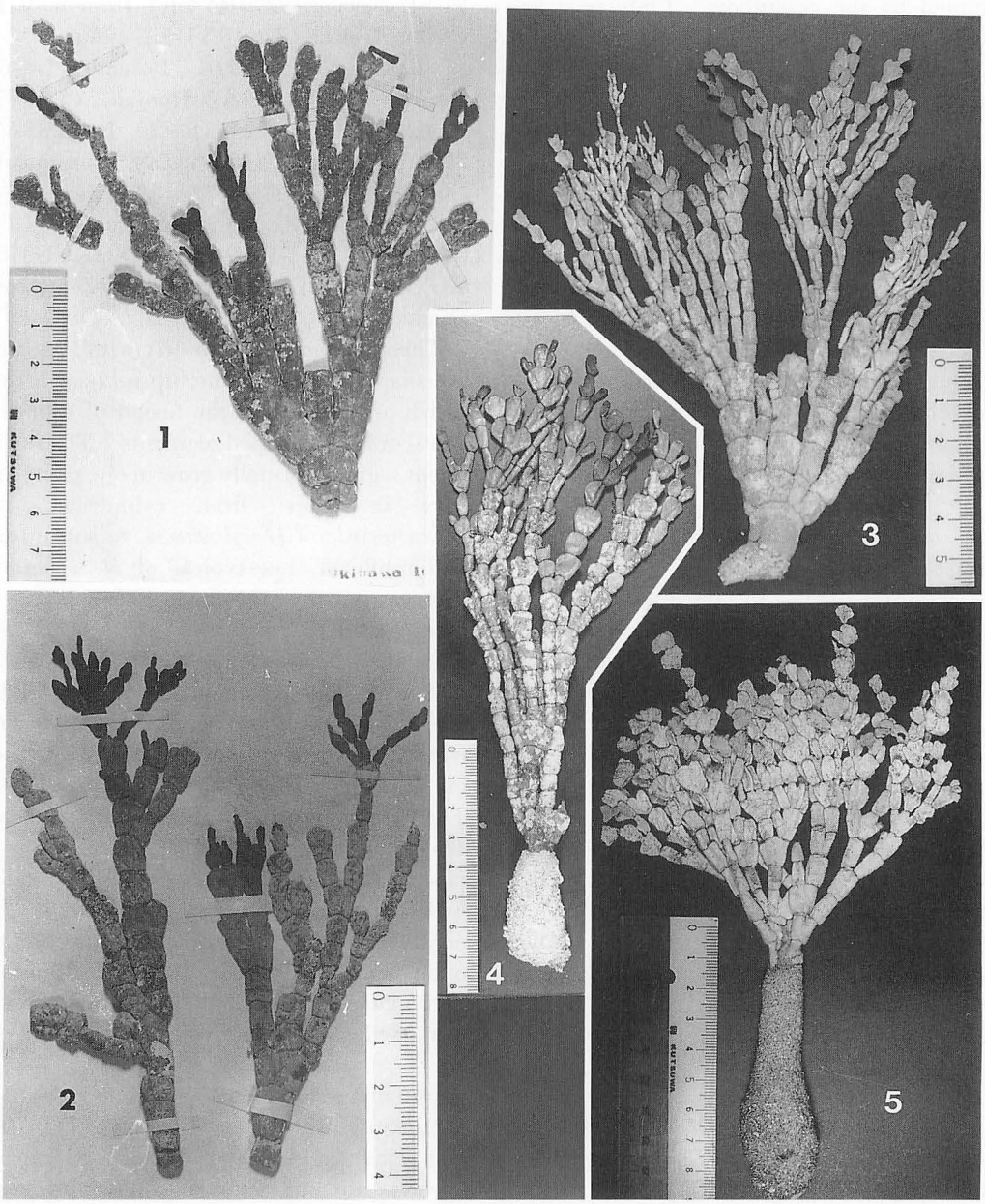

Plate 1.

Fig. 1. *Halimeda incrassata*; TUF s.n., V-5-28, Okinawa I.
Fig. 2. *Halimeda incrassata*; MICH s.n., V-5-28, Okinawa I. [Cited by Hillis (1959) as *H. cylindracea*.]
Fig. 3. *Halimeda incrassata*; Kamura 117, XI-11-77, Henza, Okinawa I.
Fig. 4. *Halimeda incrassata*; Tsuda 90-68, III-9-90, Henoko, Okinawa I.
Fig. 5. *Halimeda incrassata*; Kamura 2967, X-11-73, Oonogoshi, Miyako I.

specimen cited by Hillis (1959) as *H. cylindracea* and to some of our specimens recently collected in March 1990. The anatomical characteristics of the specimens collected on 5 May 1928 are typical of *H. incrassata*, i.e. peripheral utricles are 50-67 μm in surface diameter and 112-125 μm long, and the secondary utricles are globose, subglobose or oblong, 35-62 μm broad and 42-150 μm long.

Halimeda simulans Howe 1907: 503, pl. 29; Hillis 1959: 368, pl. 3 (fig. 4), pl. 5 (fig. 27), pl. 6 (fig. 15), pl. 11; Hillis-Colinvaux 1980: 103, fig. 26.

Halimeda incrassata (Ellis) Lamouroux f. *lamourouxii* J. Ag.; Barton 1901: 27, fig. 41.

Plate 2, Figs. 1, 2

Japanese name: Fusa-sabotengusa (nov.) [=Ramorou-sabotengusa].

Specimens examined. YAEYAMA IS.: Iriomote I.—*Ohba and Aruga B-65* (TUF), juvenile, 3 cm tall, Yuba I., VI-21-75 (Ohba and Aruga 1982, as *H. incrassata*); Taketomi I.—*Ohba and Aruga B-64* (TUF), west side, I-29-75 (Ohba and Aruga 1982, as *H. incrassata*). MIYAKO IS.: Miyako I.—*Kamura 1312* (RYUK), VIII-25-60; *Kamura 2888* (RYUK), Ooura, III-18-68; *Kamura s.n.* (RYUK), Yonaha Bay, X-9-73; *Kamura s.n.* (RYUK), Turiba, X-10-73; *Kamura s.n.* (RYUK), Oonogoshi, X-11-73. OKINAWA IS.: Okinawa I.—*Kamura 75* (RYUK), V-26-56; *Kamura 76* (RYUK), V-30-56; *Kamura 1327* (RYUK), fertile, Itoman, VIII-12-59; *Kamura 1371* (RYUK), Tina, I-20-58; *Kamura 1430* (RYUK), Itoman, VI-30-57; *Kamura 1471* (RYUK), Tina, I-20-58; *Kamura 1472* (RYUK), Itoman, I-24-58; *Kamura s.n.* (RYUK), Itoman, VI-28-61; *Kamura s.n.* (RYUK), Sesoko I. (Anchibama, north side), VIII-2-77; *Tsuda 90-19* (RYUK), Motobu (Ohama), sandy substratum, 0.2 m deep (MLLW), I-12-90; *Tsuda 90-40* (RYUK), Shinzato, adjacent to seagrass bed, sandy substratum, at MLLW, I-26-90; *Tsuda 90-61b* (RYUK), Motobu (Ohama), sandy substratum, 0.2-0.5 m deep (MLLW), II-7-90, leg. S. Kamura, S. Nakamura and R.T. Tsuda; *Tsuda 90-65* (RYUK), Henoko, sandy substratum (seagrass bed), near MLLW, III-9-90; Kume I.—*Kamura and Iida s.n.* (RYUK), Ohara, III-12-74, leg. Y. Iida (Kamura and Iida 1981, as *H. incrassata* f. *lamourouxii*); Izena I.—*Kamura 1123* (RYUK), Nakada, III-17-61. RYUKYU IS.: *SAP s.n.* (SAP), fertile, VII-20, leg. Yagi.

The thalli are erect, compact and bushy, up to 8.5 cm tall (excluding holdfasts which may be up 1 to 3 cm long), and are heavily calcified. A stalk region is usually evident and is formed by the fusion of cuneate segments or consists of a single reniform segment which supports several subcuneate segments which may appear in an imbricated (i.e. overlapping) arrangement. The segments at the upper half are usually subcuneate and reniform, up to 9 mm long and 13 mm broad; however, smaller segments, variously shaped, may be present. The cortex consists of two to four layers of utricles. The peripheral utricles are 31-50 μm in surface diameter (i.e. range of means of 10 measurements each from 17 different thalli) with an overall mean of 38 μm, and are 37-75 μm long. The secondary utricles are 20-45 μm broad and 52-135 μm long.

The compact habit, imbricated arrangement of basal segments of branches, and the multi-plane growth (i.e. fresh and air dried specimens appear round when viewed from the top) of *H. simulans* distinguishes it morphologically from *H. incrassata*. *H. simulans* is quite common in the Ryukyu Islands; the herbarium specimens are often labeled as *H. incrassata* or *H. incrassata* f. *lamourouxii*. Okamura's (1915: 213, pl. 149, figs. 9, 10) description and illustration of *H. incrassata* f. *lamourouxii* Barton appear very similar to our *H. simulans*.

Halimeda macroloba Decaisne; Okamura 1915: 211, pl. 149 (figs. 1-8); Yamada 1941: 108, figs. 1 and 2; Hillis 1959: 375, pl. 3 (fig. 3), pl. 5 (figs. 19, 20), pl. 6 (fig. 17), pl. 12; Hillis-Colinvaux 1980: 108, fig. 28.

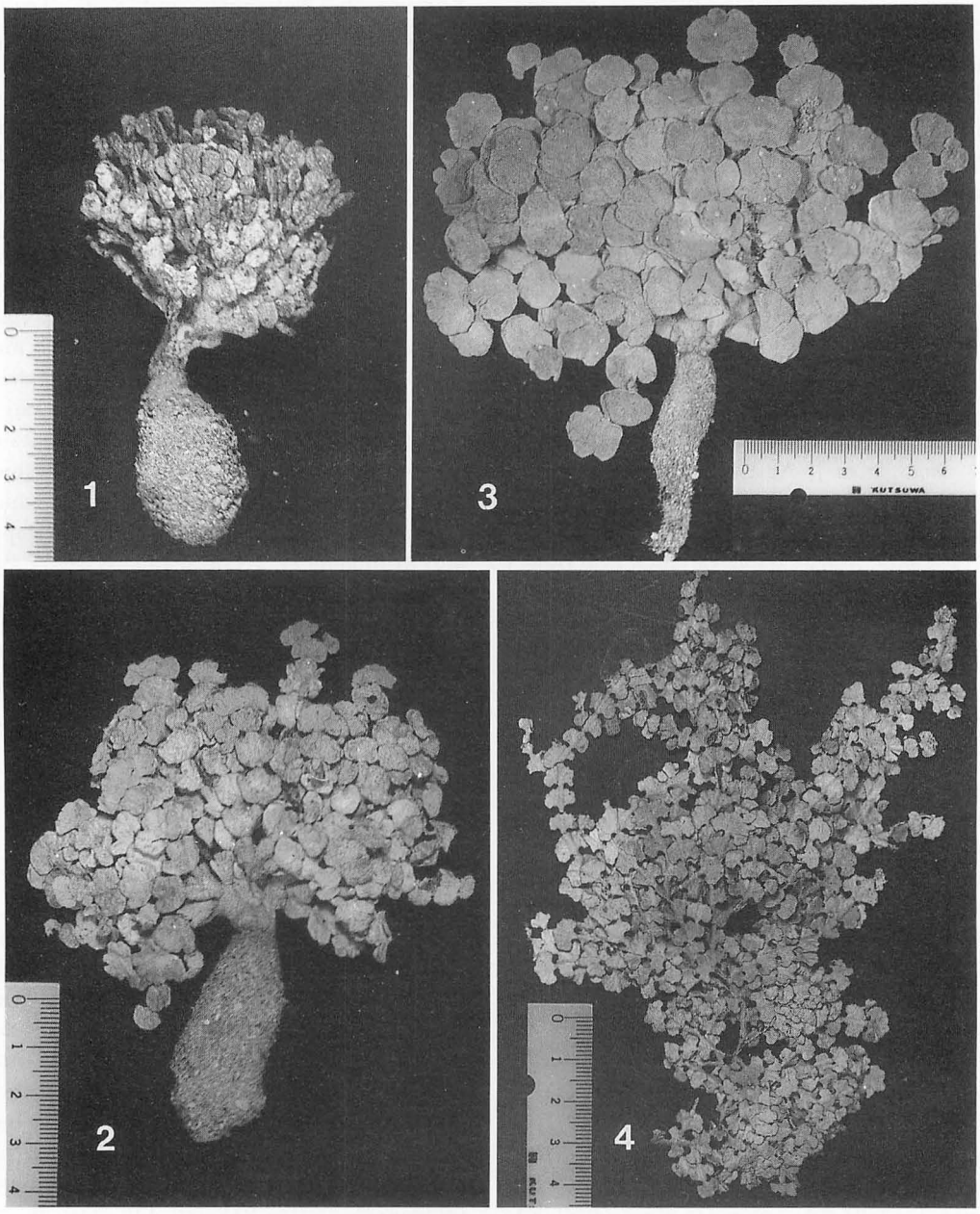

Plate 2.
Fig. 1. *Halimeda simulans*; Tsuda 90-65, III-9-90, Henoko, Okinawa I.
Fig. 2. *Halimeda simulans*; Kamura s.n., X-11-73, Oonogoshi, Miyako I.
Fig. 3. *Halimeda macroloba*; Kamura 2966, X-11-73, Oonogoshi, Miyako I.
Fig. 4. *Halimeda opuntia*; Kamura 82, VIII-9-56, Kabira, Ishigaki I.

Plate 2, Fig. 3

Japanese name: Hiroha-sabotengusa.

Specimens examined. YAEYAMA IS.: *Segawa s.n.* (KYU), VIII-57, leg. J. Isa (specific island not specified); Yonaguni I.—*SAP 21140* (SAP), IV-15-35, leg. T. Tanaka (Yamada and Tanaka 1938); *SAP 21141* (SAP), IV-15-35, leg. T. Tanaka (Yamada

and Tanaka 1938); *Kamura 940* (RYUK), X-28-59, leg. S. Shinohara; *Kamura 2398* (RYUK), Higawa, III-26-72; *Kamura 2589* (RYUK), Higawa, patch reef, III-26-72; Iriomote I.—*Kamura 804* (RYUK), Sonai, VI-27-60, leg. S. Nishijima; *Ohba and Aruga A-38* (TUF), Yuba I., V-5-73 (Ohba and Aruga 1982); Taketomi I.—*Ohba and Aruga A-39* (TUF), north side, V-3-73 (Ohba and Aruga 1982); *Ohba and Aruga B-66* (TUF), north side, VI-16-75 (Ohba and Aruga 1982); *Ohba and Aruga B-67/B-68* (TUF), west side, I-29-75 (Ohba and Aruga 1982); *Ohba and Aruga B-69* (TUF), west side, I-28-75 (Ohba and Aruga 1982). MIYAKO IS.: Miyako I.—*Kamura 1230* (RYUK), Turiba, VIII-23-60 (Kamura 1977); *Kamura 1337* (RYUK), Hisamatsu, VIII-25-60 (Kamura 1977); *Kamura 1508* (RYUK), Nogawazaki, VIII-25-60 (Kamura 1977); *Kamura 1614* (RYUK), Turiba, VIII-22-60, leg. K. Sunagawa (Kamura 1977); *Kamura 2091* (RYUK), Turiba, VIII-18-63 (Kamura 1977); *Kamura 2966* (RYUK), Oonogoshi, X-11-73 (Kamura 1977). OKINAWA IS.: Kume I.—*Kamura and Iida s.n.* (RYUK), Nakadomari, III-11-74, leg. Y. Iida. AMAMI IS.: Amamioshima I.—*Kamura 1268* (RYUK), Koniya, VI-28-61, leg. T. Yoshida; *Kida s.n.* (MIE), Sokari Bay, VII-11-63 (Kida 1964); *Kamura 2752* (RYUK), Koniya, VI-28-72; Kakeroma I.—*Kida s.n.* (MIE), Eniya-banare, VII-7-63 (Kida 1964).

Halimeda macroloba is morphologically the most distinctive of the species within the Section Rhipsalis. The heavily calcified thallus, up to 13 cm tall, possesses a massive holdfast and large flat thick segments, up to 22 mm long, 37 mm broad and about 1 mm thick. A few segments, which arise from the flat segments, may be much smaller, even cylindrical (i.e. 6 mm long and 2.5 mm in diameter); however, the majority of the segments are commonly subcuneate, subdiscoidal, or subreniform. The cortex consists of usually three to four layers of utricles. The peripheral utricles are 27-37 μm in surface diameter, appear round in surface view, and separate with ease after decalcification.

This species grows intertidally or subtidally in sand-mud areas near MLLW level. Hillis-Colinvaux (1980) described its vertical distribution from above low-tide level to 12 m deep. Neither of us have seen this species inhabiting waters deeper than 2 meters (MLLW) in either the Ryukyu Islands or Micronesia.

Section OPUNTIA

Halimeda opuntia (L.) Lamouroux; Yamada 1941: 113, figs. 1, 7, 8; Hillis 1959: 359, pl. 2 (figs. 7, 8), pl. 5 (figs. 3, 4), pl. 6 (fig. 6), pl. 7 (fig. 3), pl. 10; Hillis-Colinvaux 1980: 110, figs. 19, 51, 92.

Halimeda opuntia (L.) Lamouroux v. *opuntia*.

Halimeda opuntia (L.) Lamouroux f. *typica* Barton 1901: 20, pl. 2 (fig. 19).

Halimeda opuntia (L.) Lamouroux f. *cordata* (J. Agardh) Barton 1901: 20, pl. 2 (fig. 21).

Plate 2, Fig. 4

Japanese name: Sabotengusa.

Specimens examined. YAEYAMA IS.: Yonaguni I.—*Kamura 2382* (RYUK), III-26-72, leg. K. Yamazato; Iriomote I.—*Kamura 800* (RYUK), VII-2-60; *Kamura 803* (RYUK), V-27-60; *Kamura 832* (RYUK), Akabanare, VII-7-60, leg. N. Nishishimamoto; Taketomi I.—*Ohba and Aruga B-61* (TUF), west side, I-29-75 (Ohba and Aruga 1982); Ishigaki I.—*Kamura 82* (RYUK/KYU), Kabira, VIII-9-56, leg. S. Segawa (Segawa and Kamura 1960, as *H. opuntia* f. *typica*); *Ohba and Aruga A-33* (TUF), Ohhama, VI-30-73 (Ohba and Aruga 1982); *Kamura 3499* (RYUK), Kabira Bay, I-17-77; *Kamura 3501* (RYUK), Kabira Bay, I-18-77. MIYAKO IS.: Miyako I.—*Kamura 1229* (RYUK), Turiba, VIII-23-60 (Kamura 1977); *Kamura 1311* (RYUK), Hisamatsu, VIII-25-60 (Kamura 1977); *Kamura 2877* (RYUK), Tomori, III-17-68 (Kamura 1977); *Kamura 2878* (RYUK), small segments, Tomori, III-17-68 (Kamura 1977); *Kamura 3403* (RYUK), Yanaha Bay, X-9-73; *Kamura 3435* (RYUK), Turiba, X-10-73 (Kamura 1977); Ikema I.—*Kamura 1555* (RYUK), VIII-26-60 (Kamura 1977). OKINAWA

IS.: Okinawa I.—*Kamura s.n.* (RYUK), Sesoko I., VIII-2-73; Kume I.—*Kamura and Iida s.n.* (RYUK), Madomari, III-23-74, leg. Y. Iida; Izena I.—*Kamura 2797* (RYUK), VIII-5-67.

Halimeda opuntia forms compact prostrate clumps on hard substratum and/or sprawls horizontally over sandy substratum and produces rhizoids in several areas where it contacts the hard substratum. The shapes of the segments are variable; however, the most common segments are flat, reniform and usually with ribs, up to 6 mm long and 10 mm broad. The cortex consists of up to five layers of dichotomous branches, i.e. not utriculiform. The peripheral utricles (i.e. the outer tier) are 18-31 μm in surface diameter (i.e. range of means of 10 measurements each from 7 different thalli) and fall within the 15-59 μm length, as described by Hillis-Colinvaux (1980).

Halimeda opuntia is most commonly found on the shallow reef flats, especially in calmer waters such as inner bays, in water less than 0.5 m deep (MLLW); however, it can be found in water 90 m deep (Hillis-Colinvaux 1980).

Halimeda distorta (Yamada) Hillis-Colinvaux; Colinvaux 1968: 33, figs. 4, 6 (2); Hillis-Colinvaux 1980: 120, fig. 34.

Halimeda incrassata (Ellis) Lamouroux f. *distorta* Yamada 1941: 119, fig. 14; Yamada 1944: 28, pl. 4.

Halimeda opuntia (L.) Lamouroux v. *hederacea* (Barton) Hillis 1959: 360.

Plate 3, Fig. 1

Japanese name: Soriha-sabotengusa.

Specimens examined. YAEYAMA IS.: Taketomi I.—*Ohba and Aruga A-34/A-35* (TUF), north side, V-3-73 (Ohba and Aruga 1982, as *H. opuntia* v. *hederacea*). OKINAWA IS.: Okinawa I.—*Kamura 2616* (RYUK), Sesoko I., 2 m deep (MLLW), VII-8-72; *Kamura s.n.* (RYUK), Sesoko I., VIII-1-73; *Tsuda 90-64* (RYUK), Sesoko I., over reef margin, 2 m deep (MLLW), II-7-90, leg. S. Nakamura.

The straggly thalli, up to 23 cm long, appear very similar to *H. distorta*, as described and illustrated by Yamada (1941, 1944, as *H. incrassata* f. *distorta*) and Colinvaux (1968). The segments are heavily calcified, brittle, glossy white or pale green on drying, and up to 10 mm long and 14 mm broad. The peripheral utricles are 35-45 μm in surface diameter (i.e. range of means of 10 measurements each from 6 different thalli) and are 40-50 μm long.

Since *H. distorta* may have several rhizoidal areas, it appears very much like straggly *H. opuntia*, but with larger segments. The mean surface diameter of the peripheral utricles seem to be consistently larger, i.e. 35-45 μm, in *H. distorta* than in *H. opuntia* which has a mean range of 18-25 μm. The presence of short fusion of medullary filaments in twos and threes at the nodal region eliminates the possibility of these specimens being *H. gracilis* Harvey, which morphologically resembles *H. distorta*.

Halimeda velasquezii W.R. Taylor 1962: 176, figs. 8-14; Hillis-Colinvaux 1980: 117, fig. 32.

Halimeda opuntia (L.) Lamouroux f. *intermedia* Yamada, 1934: 81, figs. 50, 51.

Plate 3, Figs. 2, 3

Japanese name: Hira-sabotengusa.

Specimens examined. YAEYAMA IS.: Yonaguni I.—*SAP 21149* (SAP), IV-35, leg. T. Tanaka (Yamada and Tanaka 1938, as *H. opuntia* f. *intermedia*); *Kamura 2457* (RYUK), III-30-72; *Kamura 2658* (RYUK), III-29-72; Kuro I.—*Ohba and Aruga B-63* (TUF), VI-75 (Ohba and Aruga 1982); Ishigaki I.—*Ohba and Aruga A-36* (TUF), Ohhama, V-1-73 (Ohba and Aruga 1982). MIYAKO IS.:

Fig. 1. *Halimeda distorta*; Kamura 2616, VII-8-72, Sesoko, Okinawa I.
Fig. 2. *Halimeda velasquezii*; Kamura s.n., IV-23-67, Komesu, Okinawa I.
Fig. 3. *Halimeda velasquezii*; Kamura 1227, fertile, VII-24-61, Gushichan, Okinawa I.
Fig. 4. *Halimeda renschii*; Kamura 937; 1959, Okinawa I.
Fig. 5. *Halimeda tuna*; Tsuda 90-29, I-18-90, Sesoko, Okinawa I.

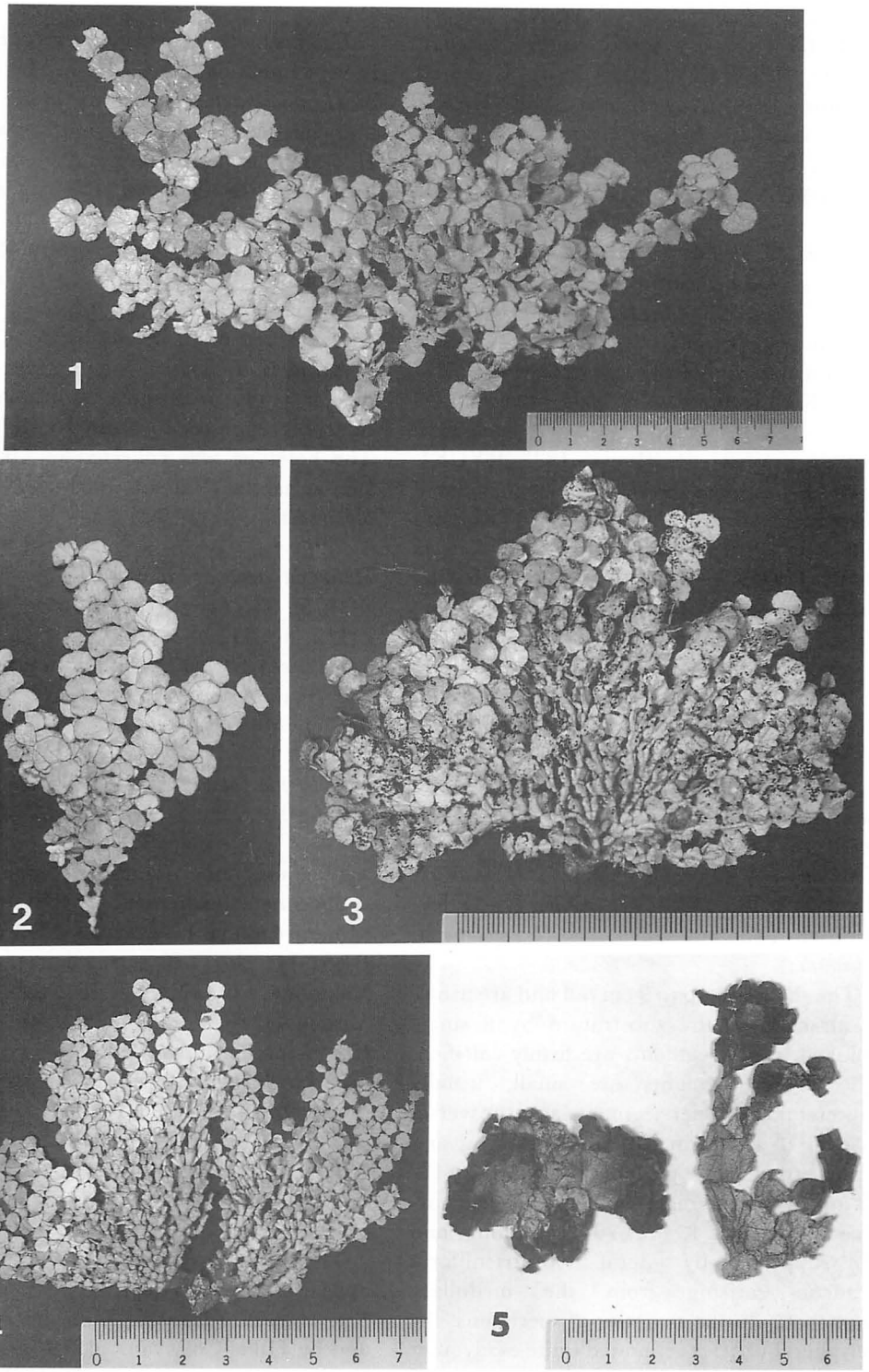

Plate 3.

Miyako I.—*Kamura 2875* (RYUK), Tomori, III-17-68 (Kamura 1977, as *H. opuntia*); *Kamura 2947* (RYUK), Bora, III-16-68 (Kamura 1977, as *H. opuntia*). SENKAKU IS.: Uotsuri I.—*Kamura 3583* (RYUK), VI-16-81 (Kamura *et al.* 1982, as *H. opuntia*). OKINAWA IS.: Okinawa I.—*SAP 11100* (SAP), V-31, leg. T. Teramati (Yamada 1934, as *H. opuntia* f. *intermedia*); *Segawa s.n.* (KYU), Naha, V-39; *Segawa s.n.* (KYU), Tina, V-2-56; *Segawa s.n.* (KYU), Naminoue, VI-56; *Segawa s.n.* (KYU), Ninatogawa, VI-24-56; *Kamura 253* (RYUK), Komesu, V-2-57; *Kamura 254* (RYUK), Kamiyama, V-1-57; *Kamura 1135* (RYUK), VI-27-61; *Kamura 1227* (RYUK), 10 of 11 specimens fertile, Gushichan, sides of deep pool near reef edge, VII-24-61 (Kamura 1966, as *H. opuntia* f. *intermedia*); *Kamura 1969* (RYUK), all 19 specimens fertile, Gushichan, sides of deep pool near reef edge, VI-17-62 (Kamura 1966, as *H. opuntia* f. *intermedia*); *Kamura s.n.* (RYUK), Komesu, IV-23-67; *Tsuda 90-88* (RYUK), Shinzato, channel wall, 0.5 m deep (MLLW), III-11-90, leg. S. Kamura; Kume I.—*Kamura and Iida s.n.* (RYUK), Ohara, III-26-74, leg. Y. Iida; Izena I.—*Kamura 1020* (RYUK), III-18-61; *Kamura 2016* (RYUK), V-19-61; *Kamura 2745* (RYUK), VIII-5-67. RYUKYU IS.: *SAP 10416* (SAP), III-31, leg. S. Inoh (Yamada 1934, as *H. opuntia* f. *intermedia*).

The thalli are up to 9 cm tall and are usually attached to the substratum by a single holdfast. The segments are firmly calcified. The lower segments are small, usually subterete; the upper segments are transversely oval to reniform, up to 5 mm long and 9 mm broad. The peripheral utricles are 10-20 μm in surface diameter, with a mean surface diameter of 13 μm, 20-37 μm long, and are supported by lateral non-utriculiform branches arising from the medullary filaments. In the majority of specimens, the peripheral utricles separated quite easily after decalcification; however, the peripheral utricles did not separate easily in three sets of specimens (i.e. Kamura, 1135, 1227 and 1969).

Halimeda velasquezii appears morphologically very much like *H. renschii*. The segments of *H. velasquezii* are slightly larger and the branches seem to arise in one plane whereas *H. renschii* is more erect and bushier. The mean surface diameter of the peripheral utricles are consistently smaller in *H. velasquezii* than in *H. renschii*. Six of the fertile specimens (*Kamura 1967*) of *H. velasquezii* have matted rhizoids at the base, which is characteristic of *H. renschii*.

Halimeda velasquezii inhabits the perpendicular walls of surge channels and open tidepools exposed to strong water motion. The holotype was collected in Okinawa in similar habitat (Yamada 1934, as *H. opuntia* f. *intermedia*).

Halimeda renschii Hauck; Hillis-Colinvaux 1975: 93, fig. 1; Hillis-Colinvaux 1980: 115, fig. 31.

Halimeda opuntia (L.) Lamouroux f. *renschii* (Hauck) Barton; Okamura 1915: 208, pl. 148 (figs. 8-12); Yamada 1941: 115, fig. 9.

Halimeda batanensis W.R. Taylor 1973: 34, figs. 1, 2.

Plate 3, Fig. 4

Japanese name: Hime-sabotengusa.

Specimens examined. SENKAKU IS.: Minami-kojima I.—*Kamura 2542* (RYUK), III-31-71, leg. K. Nagahama and Y. Nakasone. OKINAWA IS.: Okinawa I.—*Kamura 937* (RYUK/KYU), 1959. AMAMI IS.: Amamioshima I.—*Kida s.n.* (MIE), Ushuku, VII-5-63 (Kida 1964, as *H. opuntia*). OSUMI IS.: Yaku I.—*KAG s.n.* (KAG), Anbou, IX-13-83, leg. N. Higo. BONIN IS.: Chichijima I.—*Segawa s.n.* (KYU), V-38 (Segawa 1956, No. 90, as *H. opuntia*).

The specimens which we examined do not appear as robust as depicted by Taylor (1973: Fig. 1, as *H. batanensis*) from the Philippines and by Hillis-Colinvaux (1975: Fig. 1) from Kenya; however, the specimens are quite similar to the illustrations of Yamada (1941) of *H. opuntia* f. *renschii* from Micronesia. The

thalli, up to 7 cm tall, have matted rhizoidal bases and segments which are oval or spathulate. The largest segments are 4 mm long and 5 mm broad, and are consistently smaller than the segments of *H. velasquezii*. The peripheral utricles are 15-23 μm in surface diameter; the secondary utricles are not particularly utriculiform, 17-20 μm in diameter, but do expand toward the apex as described by Taylor (1973).

Section HALIMEDA

Halimeda tuna (Ellis and Solander) Lamouroux; Okamura 1932: 70, pl. 285; Taylor 1950: 84, pl. 43 (fig. 2); Hillis 1959: 342, pl. 1 (figs. 4, 5), pl. 5 (fig. 9), pl. 6 (fig. 7), pl. 9; Hillis-Colinvaux 1980: 122, fig. 35.

Plate 3, Fig. 5

Japanese name: Tsuna-sabotengusa.

Specimens examined. OKINAWA IS.: Okinawa I.—*Kamura 3521* (RYUK), Motobu (Sesoko Channel), 10 m deep (MLLW), III-28-76, leg. M. Nishihira; *Kamura 3530* (RYUK), Motobu (Sesoko Channel), 7 m deep (MLLW), III-26-76, leg. M. Nishihira; *Tsuda 90-18b* (RYUK), Motobu (Ohama), in crevise on side of dead coral mound, 0.2 m deep (MLLW), I-12-90; *Tsuda 90-29* (RYUK), Sesoko I. (southeast side), in crevise on side of dead coral mound, 0.4 m deep (MLLW), I-18-90. RYUKYU IS.: *SAP s.n.* (SAP), VII-20, leg. Yagi (Okamura, 1932: 70, pl. 285, fig. 1). HONSHU: *Segawa s.n.*(KYU), Susaki, VIII-28-34; *Segawa s.n.* (KYU), Tago, VI-19-35; *Okada s.n.* (KYU), Susaki, III-37; *Segawa s.n.* (KYU), fertile, Susaki, VII-30-50, leg. S. Segawa and T. Segi. BONIN IS.: *Segawa s.n.* (KYU), Hachijo I., VII-11-29; *Segawa s.n.* (KYU), Hahajima I., VI-38; *Segawa s.n.* (KYU), Hachijo I., V-29-52.

The specimens, up to 7 cm tall, are lightly calcified and consist of subcuneate and reniform segments, up to 10 mm long and 13 mm broad. The peripheral utricles, angular in surface view, are 98-133 μm in surface diameter (i.e. range of means of 10 measurements each from 11 thalli), 125-320 μm long, and are firmly attached after decalcification. Secondary utricles are 60-100 μm broad and 142-170 μm long. Although the dimensions of the fused peripheral utricles exceed the normal ranges described by Hillis-Colinvaux (1980), i.e. (25-) 34-100 (-125) μm in surface diameter and (46-) 60-130 (-230) μm long for unfused peripheral utricles, the specimens do fall within the overall taxonomic circumscription for *H. tuna*.

One specimen (*Kamura 3530*) was initially identified as *Halimeda gigas* W.R. Taylor. The thallus is lightly calcified and consists of two large thin segments, 17-22 mm long and 26 mm broad, and about 14 smaller segments, up to 10 mm long and 12 mm broad. The peripheral utricles are 129-150 μm in surface diameter (i.e. range of means of 10 measurements from one large segment and one small segment); the smaller segment had the higher mean value. It seems, however, that the overall appearance and the surface diameter of the peripheral utricles are similar to other specimens of *H. tuna*.

Halimeda discoidea Decaisne; Taylor 1950: 85, pl. 45 (fig. 1); Hillis 1959: 352, pl. 2 (fig. 5), pl. 5 (fig. 11), pl. 6 (fig. 11), pl. 7 (figs. 9, 10), pl. 8 (figs. 5-8), pl. 11; Hillis-Colinvaux, 1980: 136, fig. 41.

Plate 4, Fig. 1

Japanese name: Uchiwa-sabotengusa.

Specimens examined. YAEYAMA IS.: Taketomi I.—*Ohba and Aruga B-60* (TUF), west side, I-29-75 (Ohba and Aruga 1982). MIYAKO IS.: Miyako I.—*Kamura 2781* (RYUK), III-18-68 (Kamura 1977). OKINAWA IS.: Okinawa I.—*Okada s.n.* (KYU), III-30-29, leg. T. Tamayose; *SAP 14349* (SAP), Naha, V-33, leg. Y. Yamada (Yamada 1934, as *H. cuneata*); *Okada s.n.* (KYU), IV-1-37, leg. T. Tamayose; *Segawa s.n.* (KYU), Naha, III-39 (Segawa 1956, as *H. macroloba*, No. 92); *Segawa s.n.* (KYU), Tina, V-2-56; *Segawa s.n.* (KYU), Tina, V-8-56; *Segawa s.n.* (KYU), Naminoue, V-26-56; *Segawa s.n.* (KYU), Naminoue, V-56; *Kamura s.n.* (RYUK), Ooyama, III-17-57;

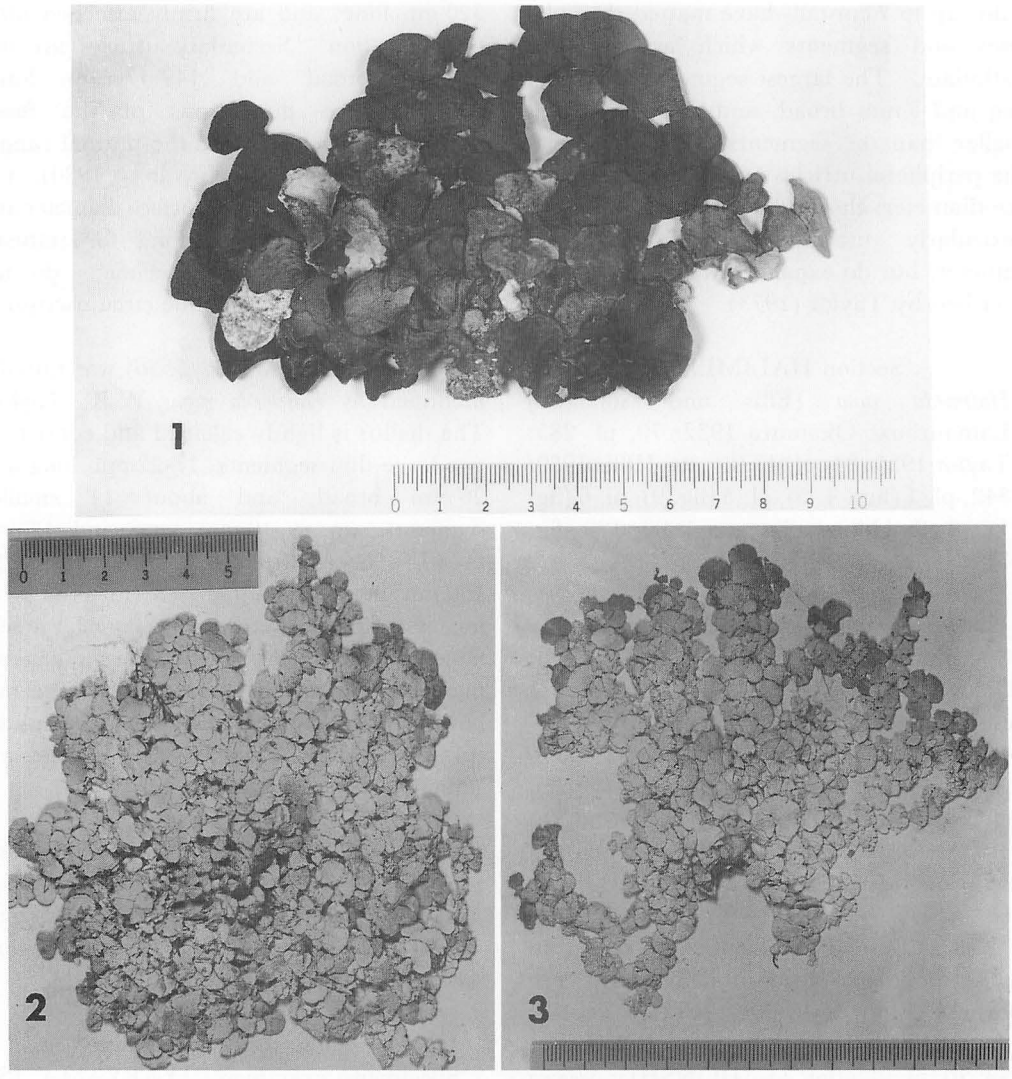

Plate 4.
Fig. 1. *Halimeda discoidea*; Tsuda 90-87, III-11-90, Shinzato, Okinawa I.
Fig. 2. *Halimeda micronesica*; SAP 14342, V-33, Itoman, Okinawa I.
Fig. 3. *Halimeda micronesica*; SAP 14343, V-33, Itoman, Okinawa I.

Kamura s.n. (RYUK), Naminoue, IV-6-57; *Kamura s.n.* (RYUK), Naminoue, IV-15-57; *Kamura s.n.* (RYUK), Kamiyama, V-1-57; *Kamura s.n.* (RYUK), Gushichan, I-7-58; *Kamura s.n.* (KYU), Gushichan, I-19-58; *Kamura s.n.* (KYU), Minatoga, II-4-58; *Kamura s.n.* (KYU), Aja, III-9-59; *Kamura s.n.* (RYUK), V-16-61; *Kamura s.n.* (RYUK), V-29-61; *Kamura s.n.* (RYUK), VI-14-61; *Kamura s.n.* (RYUK), IV-23-67; *Tsuda 90-61a* (RYUK), Motobu (Ohama), reef platform, 0.2-0.5 m deep (MLLW), II-7-90, leg. S. Kamura, S. Nakamura and R.T. Tsuda; *Tsuda 90-67* (RYUK), Henoko, east of Cape Henoko, dead coral reef, 0.5 m deep (MLLW), III-9-90, leg. T. Yoshida; *Tsuda 90-86* (RYUK), Minna I., southeast side, reef pavement, at MLLW, III-10-90; *Tsuda 90-87* (RYUK), Shinzato, pool on reef margin, 0.2 m deep (MLLW), III-11-90, leg. S. Kamura; Izena I.—*Kamura s.n.* (RYUK), III-18-61. AMAMI IS.: Amamioshima I.—

SAP 20735 (SAP), Shimama, VIII-14-23, leg. K. Hamana; *Kida s.n.* (MIE), Ushuku, VII-5-63; *Kida s.n.* (MIE), Surikozaki, VII-3-63 (Kida 1964, as *H. cuneata*); *KAG s.n.* (KAG), Kasari, VI-15-88; Kakeroma I.—*SAP 45305* (SAP), Ankyaba, VI-25-61, leg. T. Yoshida. OSUMI IS.: Yaku I.—*KAG s.n.* (KAG), Anbou, IX-13-83, leg. N. Higo; Tanegashima I.—*KAG s.n.* (KAG), off Shimama Harbor, VI-22-83, leg. N. Higo; *KAG s.n.* (KAG), beachdrift, Maenohama, Minamitane, VI-23-83, leg. T. Noro; RYUKYU IS.: *SAP 10079* (SAP), III-31, leg. S. Inoh (Yamada 1934, as *H. cuneata*); *SAP 10445* (SAP), III-31, leg. S. Inoh (Yamada 1934, as *H. cuneata*); *SAP 11101* (SAP), V-31, leg. T. Teramati (Yamada 1934, as *H. cuneata*). KYUSHU: *SAP s.n.* (SAP), Nagasaki (Takahama), ca. 26 m (14 fathoms) with gill net, VII-03, leg. K. Okamura; *Ichiki s.n.* (KYU), Nagasaki (Meshima), IV-15 to V-12-54 (Ichiki 1956, as *H. cuneata*); *Segawa s.n.* (KYU), Nomo, VIII-6-56, leg. T. Yoshida (Segawa 1958, No. 20, as *H. cuneata*); *SAP 23897* (SAP), Katura I., Goto Is., Nagasaki, VII-28-42, leg. Y. Yamada and T. Tanaka; *SAP 24251* (SAP), Nomozaki, Nagasaki, IV-15-33, leg. T. Tanaka; *SAP 35099* (SAP), Hirado, Nagasaki, VII-19-77, leg. T. Yotsui; *SAP 35422* (SAP), Nomozaki, Nagasaki, VIII-6-56, leg. T. Yoshida; *SAP 43625* (SAP), Hirado, Nagasaki, 16 m deep at Mozone Bank in Shijiki Bay, V-25-83, leg. T. Yoshida; *SAP 49263* (SAP), Nomozaki, Nagasaki, IV-25-32, leg. T. Tanaka. SHIKOKU: *SAP 42138* (SAP), Tojima I., Ehime, leg. S. Ouchi. HONSHU: *SAP s.n.* (SAP), Hamajima, X-18-10, leg. K. Okamura; *Segawa s.n.* (KYU), Susaki, VIII-28-34; *Okada s.n.* (KYU), Hamashima, VIII-3-36; *SAP 9643* (SAP), Hamajima, Shima, Mie, VIII-31, leg. K. Inagaki; *SAP 28290* (SAP), Tanabe, Wakayama, IX-9-53, leg. K. Mihashi; *SAP 34587* (SAP), Mishima I., Yamaguchi, 16 m deep, VIII-11-69, leg. N. Kadota; *SAP 35370* (SAP), Tanabe, Wakayama, IX-14-54, leg. K. Mihashi; *SAP 38787* (SAP), Iwaizaki, Shima, Mie, X-26-81, leg. T. Yoshida; *SAP 46780* (SAP), Tuzuno (Hidaka-gun), Wakayama, V-11-64, leg. T. Yamamoto.

The specimens, up to 9 cm tall, arise from distinct holdfasts which may be up to 1 cm in length. The discoidal and reniform segments are of various size; one specimen (*Tsuda 90-67*) from Okinawa I. has one segment which measures 21 mm long and 32 mm broad. The inflated secondary utricles are characteristic of this species; however, the size of the secondary utricles can vary, i.e. (70-) 95-155 (-260) μm broad and 100-350 (-435) μm long, as described by Hillis-Colinvaux (1980). The peripheral utricles in the specimens we examined are 31-44 μm in surface diameter (i.e. range of means of 10 measurements each from 19 thalli), which are narrower, more like *H. cuneata*, than the normal range of (30-) 40-90 μm cited by Hillis-Colinvaux (1980). Measurements of the surface diameter of peripheral utricles from fresh thalli also fall between the above range; the inflated secondary utricles are much more conspicuous in fresh materials.

Section MICRONESICAE

Halimeda micronesica Yamada 1941: 121, fig. 15; Yamada 1944: 29, pl. 5; Taylor 1950: 89, pl. 46 (fig. 2), pl. 47; Hillis, 1959: 364, pl. 3 (fig. 1), pl. 5 (figs. 13, 14), pl. 6 (fig. 2), pl. 9; Itono, 1973: 160, fig. 21; Hillis-Colinvaux, 1980: 149, fig. 46.

Plate 4, Figs. 2-3

Japanese name: Ko-sabotengusa (=Kobano-sabotengusa).

Specimens examined. YAEYAMA IS.: Taketomi I.—*Ohba and Aruga B-62* (TUF), west side, VI-17-75 (Ohba and Aruga 1982). OKINAWA IS.: Okinawa I.—*SAP 14342* (SAP), two specimens, Itoman, V-33, leg. Y. Yamada (Yamada 1934, as *H. incrassata* f. *ovata* Barton); *SAP 14343* (SAP), Itoman, V-33, leg. Y. Yamada (Yamada 1934, as *H. incrassata* f. *ovata*).

All four specimens lack the most distinctive character of this species, i.e. the enlarged basal segment, which Hillis-Colinvaux (1980) cites as being large or less distinctive;

however, all other macroscopic and microscopic characters are applicable to *H. micronesica*. The dried specimens, up to 15 cm tall, are white or steel grey in color. All branches seem to radiate from the small cuneate basal segment, up to 7 mm long and 10 mm broad; long fibrous rhizoids can be seen at the base of the basal segments. All of Yamada's specimens have strands of medullary filaments, up to 17 mm long, arising from a few nodal regions. The segments are trilobed at the basal area, and range from subcuneate, discoidal and reniform, occasionally lobed, up to 7 mm long and 10 mm broad, throughout most of the thalli.

The medullary filaments at the nodal region remain free and are few in number, i.e. 8-10, based on the examination of nine nodal regions. The peripheral utricles are 33-38 μm in surface diameter (i.e. range of means of 10 measurements of 9 segments from four thalli), 25-32 μm long, and separate with ease after decalcification. The secondary utricles, which are not particularly utriculiform, are about 20 μm broad. Interestingly, the Okinawa (Itoman) specimens are those which Yamada (1934: 83) examined and referred to when he stated, "The filaments of the central strand do not usually fuse in the node..."

Only two other species, *H. fragilis* W.R. Taylor and *H. melanesica* Valet, are included in the Section Micronesicae, which is characterized by the free (i.e. unfused) medullary filaments at the nodal region. Neither of these species resembles the specimens we examined. One other record of *H. micronesica* from Hateruma I. (Itono 1973) exists. Although we have not had the opportunity to examine Itono's specimen, his photograph depicts the characteristic enlarged basal segment with long fibrous rhizoids.

Halimeda fragilis W.R. Taylor 1950: 88, pl. 48 (fig. 2); Hillis 1959: 363, pl. 3 (fig. 2), pl. 5 (fig. 10), pl. 6 (fig. 1), pl. 7 (fig. 1), pl. 8 (fig. 1), pl. 9; Itono 1973: 161, fig. 22; Hillis-Colinvaux 1980: 151, fig. 47.

Japanese name: Moro-sabotengusa (nov.).

The only record of *H. fragilis* from the Ryukyu Islands is that of Itono (1973) from Hateruma I. He provided a detailed description, emphasizing the unfused medullary filaments, and a photograph of his specimen, which leaves absolutely no doubt in our minds that *H. fragilis* is a component of the marine flora of the Ryukyu Islands.

Discussion

Our examination of over 180 specimens of *Halimeda* and the acceptance of the past record of *H. fragilis* (Itono 1973) indicate that 11 species of *Halimeda*, within four of the five Sections, occur in the Ryukyu Islands. The species within their respective Sections are as follows—Section Rhipsalis: *H. incrassata, H. simulans* and *H. macroloba*; Section Opuntia: *H. opuntia, H. distorta, H. velasquezii* and *H. renschii*; Section Halimeda: *H. tuna* and *H. discoidea*; and Section Micronesicae: *H. micronesica* and *H. fragilis*.

The presence of *H. renschii*, previously reported by Okamura (1936) and Tanaka (1950) as *H. opuntia* f. *renschii*, is substantiated for the island chain. *Halimeda distorta*, previously reported by Ohba and Aruga (1982) as *H. opuntia* v. *hederacea*, is now attributed to the Ryukyu Islands, instead of *H. copiosa* Goreau and Graham (1967) which was also part of the *H. opuntia* v. *hederacea* and, later, *H. hederacea* complex. We feel that the specimen (*MICH s.n.*) attributed to *H. cylindracea* by Hillis (1959) is best considered under *H. incrassata*.

Although *H. cuneata* had been reported by various authors from the Ryukyu Islands, we could not attribute any of the specimens we examined to this species. Gilbert (1947), Papenfuss and Egerod (1957) and Hillis (1959) have previously commented on the situation in which past authors have reported specimens of *H. discoidea* as *H. cuneata*, based on the descriptions and illustrations of Barton (1901). Based on the species listing of Japanese marine benthic algae, Yoshida *et al.* (1985) seem to have accepted the suggestion by Hillis (1959) that *H. cuneata* probably does

Table 2. Species records of *Halimeda* from islands within the Ryukyu Islands, based on specimens examined by co-authors (X) and records from past references (R). New island records are underlined. Key to species of *Halimeda*: Hi=*H. incrassata*, Hs=*H. simulans*, Hma=*H. macroloba*, Ho=*H. opuntia*, Hdt=*H. distorta*, Hv=*H. velasquezii*, Hr=*H. renschii*, Ht=*H. tuna*, Hdi=*H. discoidea*, Hmi=*H. micronesica*, Hf=*H. fragilis*.

Islands (N Lat)	Species of *Halimeda*										
	Hi	Hs	Hma	Ho	Hdt	Hv	Hr	Ht	Hdi	Hmi	Hf
OSUMI IS.											
Mage (30°45′)				R			R				
Tanegashima (30°35′)									X		
Yaku (30°21′)							X		X		
AMAMI IS.											
Amamioshima (28°20′)	R		X	R			X		X		
Kakeroma (28°05′)			X								
Yoron (27°02′)	R		R	R							
OKINAWA IS.											
Izena (26°56′)				X		X			X		
Kume (26°20′)		X	X			X					
Okinawa (26°12′)	X	X		X	X	X	X	X	X	X	
SAKISHIMA IS.											
MIYAKO IS.											
Ikema (24°56′)				X							
Miyako (24°47′)	X	X	X	X		X			X		
YAEYAMA IS.											
Ishigaki (24°30′)			R	X		X		R			
Taketomi (24°20′)		X	X	X	X				X	X	
Iriomote (24°20′)		X	X	X							
Kuro (24°14′)						X					
Hateruma (24°03′)										R	R
Yonaguni (24°27′)	R		X	X		X					

not occur in Japanese waters. All specimens labeled *H. cuneata*, which we examined, were identified as either *H. discoidea* or *H. tuna*.

Table 2 presents the species of *Halimeda* which occur on individual islands within the Ryukyu Islands; fifteen new island records are cited. The difference in the number of species from any one island within an island group, e.g. Yaeyama Islands, is, no doubt, based on the collection effort undertaken in the various islands. The few number of species, i.e. six species, from Miyako Islands

Table 3. Geographic distribution of species of *Halimeda* in the major island groups within the Ryukyu Islands. Species reported from Taiwan and species substantiated from mainland Japan are included for comparative purposes. See Table 1 for key to abbreviations of species of *Halimeda*.

Island Groups	Species of *Halimeda*										
	Hf	Hmi	Hv	Hi	Hr	Hdi	Ho	Hma	Hs	Ht	Hdt
Jpn. Mainland						X				X	
Osumi Is.					X	X	X				
Amami Is.				X	X	X	X	X			
Okinawa Is.		X	X	X	X	X	X	X	X	X	X
Sakishima Is.*	X	X	X	X		X	X	X	X	X	X
Taiwan			X	X	X	X	X	X			

* Includes both Miyako Is. and Yaeyama Is.

Table 4. Monthly means and monthly ranges of surface seawater temperatures in degree centigrade during winter (January to March) and summer (July to September) for Ishigaki I., Miyako I., Okinawa I. (Naha) and Amamioshima I. (Naze), based on seven-year period, 1978–84 (Japan Meteorological Agency).

Islands	Monthly Means (Monthly Range)	
	Winter	Summer
Amamioshima I. (Naze)	18.7 (17.7–19.7)	27.7 (26.6–29.1)
Okinawa I. (Naha)	20.6 (19.4–21.7)	28.1 (27.3–29.5)
Miyako I.	20.5 (19.4–22.4)	29.2 (28.2–30.3)
Ishigaki I.	21.4 (20.1–23.0)	28.8 (27.7–30.2)

in comparison to the 10 species in the Yaeyama Islands and the 10 species in the Okinawa Islands is most likely again based on collection efforts. We feel that the species of *Halimeda* present in the Yaeyama Islands and Okinawa Islands will be eventually found in the Miyako Islands, which should make these island groups homogeneous in terms of species of *Halimeda*.

The absence of the conspicuous *H. macroloba* from Okinawa I., where collection effort has been the greatest, remains a mystery, especially since it is found on Kume I., located just 80 km east of Naha. *Halimeda macroloba* is present in the Yaeyama and Miyako Islands to the south, and the Amami Islands to the north of Okinawa I.

When the species present within island groups are consolidated (Table 3), a general attenuation of species is evident from the southwest to the northeast, i.e. from the Sakishima Islands (includes the adjacent Yaeyama Islands and the Miyako Islands) to the Japanese mainland—Sakishima Is. (10 species), Okinawa Is. (10 species), Amami Islands (5 species), Osumi Is. (3 species) and the Japanese mainland (2 species). The six species of *Halimeda* reported from Taiwan (see references in Lewis and Norris 1987) are included in Table 3 for comparative purpose. The absence of *H. renschii* from the Sakishima Islands is interesting since this species is found in the southern tropical waters of the Philippines (see references in Silva *et al.* 1987) and the cooler waters of the Japanese Bonin Islands. We feel that the presence of only five species and three species of *Halimeda* in the Amami Islands and the Osumi Islands, respectively, is not an artifact, but represents a good portrayal of the geographic distribution of *Halimeda* in the Ryukyu Islands. No record seems to exist of any collections of *Halimeda* from the Tokara Islands, located between the Amami Islands and the Osumi Islands.

We can only speculate that the causal factor for the attenuation of species of *Halimeda* from the Okinawa Islands to the Amami Islands in the north is most likely related to the surface seawater temperature, i.e. survival of the species based on winter temperature and the fruiting capability of the species based on summer temperature. Kamura (1966) found fruiting thalli of three species, i.e. *H. incrassata, H. opuntia* and *H. velasquezii*, in Okinawa I. only during the late spring and early summer, i.e. June to August. In addition, fruiting specimens of *H. simulans* collected in August were among the specimens which we examined. As shown in Table 4, the surface seawater temperatures during winter varies the greatest between Okinawa I. and Amamioshima I.

Further collection efforts from the Miyako Islands and collections from the Tokara Islands should provide further answers to the distribution of species of *Halimeda* in the Ryukyu Islands.

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R. T. Tsuda*・香村真徳**：琉球列島における緑藻サボテングサ属の種類相と地理的分布

琉球列島からこれまでに報告されたサボテングサ属 (*Halimeda*) 海藻の標本及び未発表標本（北大・九州大・東水大・三重大・琉球大等）を調べ，同列島産のサボテングサ属を次の11種に整理した。ミツデサボテングサ *H. incrassata*, フササボテングサ *H. simulans*, ヒロハサボテングサ *H. macroloba*, サボテングサ *H. opuntia*, ソリハサボテングサ *H. distorta*, ヒラサボテングサ *H. velasquezii*, ヒメサボテングサ *H. renschii*, ツナサボテングサ *H. tuna*, ウチワサボテングサ *H. discoidea*, コサボテングサ *H. micronesica*, モロサボテングサ *H. fragilis*（標本を実見できなかった）である。*H. renschii* と *H. distorta* は，それぞれ *H. opuntia* の品種及び変種として取り扱われていた種である。*H. cuneata* に同定されていた本邦産の標本の中には，本種に該当するものは認められず，*H. discoidea* か *H. tuna* のいずれかであった。サボテングサ属の種数は本邦南西域から九州・本州中南部域にかけ，先島諸島10，沖縄諸島10，奄美諸島5，大隅諸島3，日本本土2と減少する。(*Marine Laboratory, University of Guam, UOG, Station, Mangilao, Guam 96923, USA: **905-02 沖縄県本部町字瀬底3422　琉球大学熱帯海洋科学センター)