

First record of genuine *Codium mamillosum* Harvey (Codiaceae, Ulvophyceae) from Japan

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Abstract A marine benthic green alga, *Codium mamillosum* Harvey (Codiaceae, Bryopsidales, Ulvophyceae) was collected from the mesophotic zone off Chichi-jima Island, Ogasawara Islands, Japan. In Japan, at the end of the 19th century, this species name was used by Okamura (in Matsumura and Miyoshi, 1899) for his specimens of solid globular *Codium* collected from main islands of Japan, afterward it was synonymized by Silva (1962) into *Codium minus* (O.C. Schmidt) P.C.Silva as “*Codium mamillosum* sensu Okamura”. The present alga collected recently from Ogasawara Islands was identified as a genuine *C. mamillosum* because the thalli have relatively larger utricles (550–1100 µm in diameter) than those of *C. minus*.

Key words: Codiaceae, *Codium mamillosum*, Japan, marine benthic green alga, Ogasawara Islands, Ulvophyceae.

In the end of the 18th century, the marine green algal genus *Codium* (Codiaceae, Bryopsidales, Ulvophyceae) was established by Stackhouse (1795). This genus has 120–144 species (Huisman, 2015; Guiry and Guiry, 2017), which are extremely various in external morphology: flattened to erect, dorsiventral or isobilateral, branched or unbranched, complanate to terete, membranous to globular, etc. In particular, most of globular species of *Codium* are also remarkably different from other species in having larger utricles (inflated terminal portions of non-septate filament in the cortex of coenocytic algae). At present, more than ten species are known as globular *Codium* in the world: *Codium bursa* (Olivi) C.Agardh, *C. elisabethiae* O.C.Schmidt, *C. globosum* A.H.S.Lucas, *C. mamillosum* Harvey, *C. megalophysum* P.C.Silva, *C. minus* (O.C.Schmidt) P.C.Silva, *C. ovale* Zanardini, *C. papenfussii* P.C.Silva, *C. pomoides* J.Agardh, *C. saccatum* Okamura, *C. spongiosum* Harvey.

Codium mamillosum Harvey was described by

Harvey (1855) based on the specimens collected from Western Australia, whose appearance was described as “a very solid, green, mamillated (having nipples) ball”. In Japan, Okamura in Matsumura and Miyoshi (1899) and Okamura (1915) identified the specimens of solid globular *Codium* collected from main islands of Japan as *C. mamillosum*. Afterward, however, this species was divided by Schmidt (1923) into three varieties: *C. mamillosum* var. *typicum*, var. *capens* and var. *minus*, and then Okamura (1936) used “*Codium mamillosum* var. *minus*”. At present, the two varieties, var. *capens* and *minus* are treated by Silva (1959; 1962) as a heterotypic synonym of *C. megalophysum* P.C.Silva and the basionym *C. minus* (O.C.Schmidt) P.C.Silva respectively. In the latest version of “Checklist of Marine Algae of Japan (Revised in 2015)”, this species was listed as “*Codium minus* (Schmidt) Silva [*Codium mamillosum* var. *minus*] [*Codium mamillosum* sensu Okamura]” (Yoshida *et al.*, 2015).

Ogasawara Islands (= Bonin Islands) are oceanic islands located ca. 1,000 km south of Izu Peninsula. In the investigations of algal flora around the Islands, several rare algae were found from the mesophotic zone or middle light zone (30–150 m in depth) using a dredge: for example, mesophotic marine alga, *Aneurianna ogasawaraensis* Kitayama (Kitayama, 2014), *Disco-sporangia mesarthrocarpum* (Meneghini) Hauck (Kitayama, 2012), *Zosterocarpus ogasawaraensis* Kitayama (Kitayama, 2013). There is a possibility of that the Ogasawara Islands have a unique algal flora different from any area of the Japanese Archipelago. In this study, to confirm the identity of the present alga from the Islands and the reconsideration on the distribution of *Codium mamillosum* Harvey in Japan, the author made anatomical observations on the material using a microscope.

Material and Methods

The green algal material referable to *Codium*

mamillosum Harvey was collected from the mesophotic zone (30–150 m in depth) of Chichijima Island in the Ogasawara archipelago (= Bonin Islands), Japan by a dredge using the fishing vessel “*The 7th Ushiwo-maru*” (steering by Captain Y. Takase), on 16 and 17 July 2017. For preservation, the material was fixed in 10% Formalin-seawater. Specimens were mounted in glycerine jelly after staining by 1% aniline blue solution. Anatomical observations were made on the material using a microscope. Voucher specimens were deposited in the algal herbarium of the National Museum of Nature and Science (TNS).

Results

Class Ulvophyceae K.R. Mattox et
K.D. Stewart, 1984

Order Bryopsidales J.H. Schaffner, 1922
Family Codiaceae Kützinger, 1843

Codium mamillosum Harvey

Trans. Roy. Irish Acad. 22: 565 (1855).

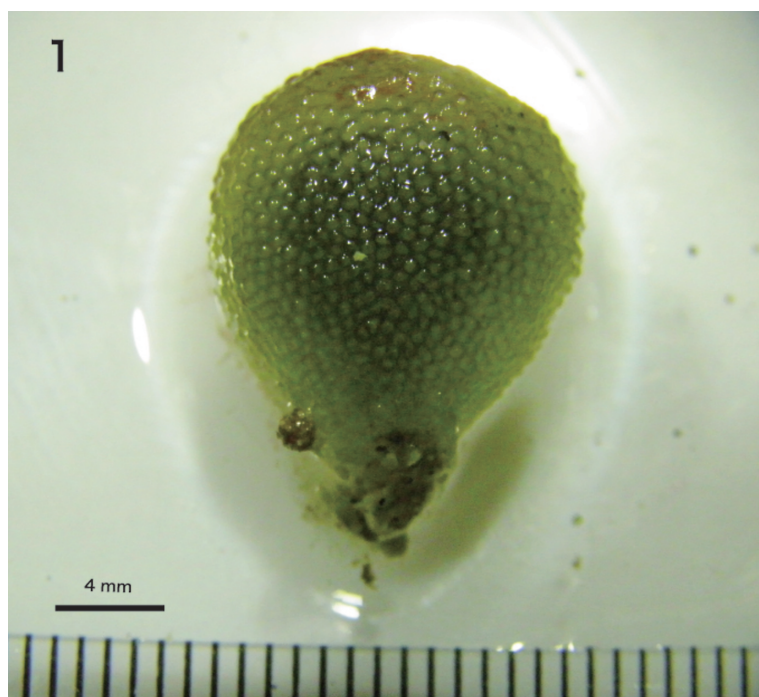
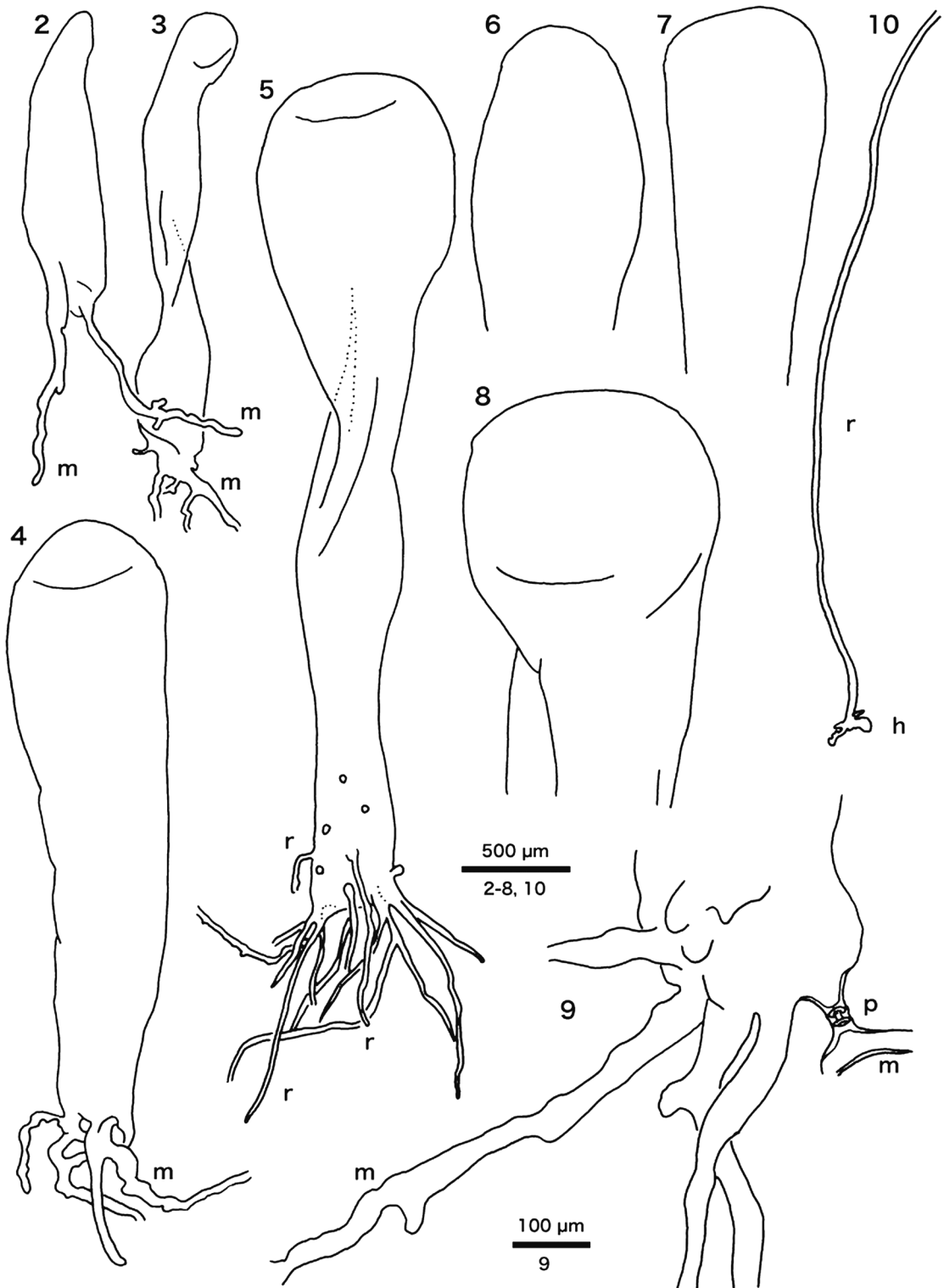


Fig. 1. *Codium mamillosum* Harvey from Chichijima Island, Ogasawara Islands, Japan. Habit (TNS-AL 209135).



Figs. 2–10. *Codium mamillosum* Harvey from Chichijima Island, Ogasawara Islands, Japan. 2–8. Various stages of utricles showing medullary filaments (m) and rhizoidal filaments (r). 9. Basal portion of a utricle showing a plug (p). 10. Rhizoidal filament with a hapteron (h).

[Figs. 1–10]

[Lectotype locality: Swan River, Western Australia (Silva, Basson and Moe, 1996). Lectotype: TCD, Algae Australicae Exsiccatae 578 (Silva and Womersley, 1956: 271).]

Synonym: *Lamarckia mamillosa* (Harvey) Kuntze, 1891.

Codium bursa var. *australe* Sonder, 1853.

Codium mamillosum var. *typicum* O.C. Schmidt, 1923.

Habitat: Grew on rock in the mesophotic zone (41–54 m in depth).

Morphology: Plants are epilithic, attached on rocks by central tuft of rhizoids. Thalli are globose, solid, spongy, erect, up to 1.7 cm in height, 1.4 cm in diameter, green in color, composed of a single, macroscopic, siphonous, coenocytic cell (Fig. 1). Utricles are cylindrical or clavate, slightly flattened or rounded at apex, often expanded below apex, 550–1100 μm in diameter in the upper portion, tapering toward the base, 280–500 μm in diameter in the upper portion, 1400–3800 μm in length (Figs. 2–8). Plug is located beneath the utricle (Fig. 9, p). Hairs are

absent. Medullary filaments are colorless, cylindrical, 10–30 μm in diameter issued from the basal portion of the utricle (Figs. 4 and 9, m). Rhizoidal filaments are slender, under 10 μm in diameter, arising by outgrowths from the base of each utricle (Fig. 5, r), elongated up to 3 mm, often with a digitate hapteron (Fig. 10, h).

Specimens examined: Ogasawara Islands, Japan: Off Cape Yagiyama (41.3–42.5 m in depth), Futami Bay (27°2'17"N, 142°6'27"E), 16 July 2017, leg. T. Kitayama (TNS-AL 209135); Kurazonone (53.5–53.9 m in depth), Chichijima Island (27°30'55"N, 142°6'20"E), 16 July 2017, leg. T. Kitayama (TNS-AL 209136).

Japanese name: Chikubi-miru.

Distribution: *Indian Ocean*: Western Australia (type locality), Tanzania (Silva, Basson and Moe, 1996); *Pacific Ocean*: American Samoa (Skellon and South, 2004), Fiji (N'Yeurt, South and Keats, 1996), Hawaiian Islands (Abbott and Huisman, 2004), Japan (Ogasawara Islands, the present study).

The size of utricles in the eight globular species of *Codium* are showed in Table 1. The plants

Table 1. Comparison of the size of utricles among the globular species of *Codium*

	Outward form	Utricles		Distribution
		Diameter	Length	
<i>C. bursa</i> (Burrows, 1991)	spherical	250–550 μm	up to 4.5 mm	Atlantic Ocean, New Zealand
<i>C. elisabethiae</i> (O. C. Schmidt, 1929)	globose to subglobose, hollow	350–485 μm	1.6–2.5 mm	Atlantic Ocean
<i>C. globosum</i> (Lucas, 1927)	globose, solid	275–350 μm	3 mm	Queensland
<i>C. megalophysum</i> (Silva, 1959)	hemispherical or globose, hollow	1–3.9 mm	5–12 mm	South Africa
<i>C. minus</i> (Okamura, 1915*; Verbruggen <i>et al.</i> , 2012)	globose, oval, obovoid	160**–564 μm	1.4–2.6 mm**	Japan, Korea
<i>C. ovale</i> (Itono, 1973)	globose, pedicellate, hollow	170–230 μm	660–715 μm	cosmopolitan
<i>C. papenfussii</i> (Silva, 1959)	hemispherical to subglobose, hollow	300–680 μm	2.4–5.4 mm	South Africa
<i>C. pomoides</i> (Silva and Womersley, 1956)	globose, subglobose, hollow	69–175 μm	1–3 mm	Pacific Ocean
<i>C. saccatum</i> (Kraft, 2007)	subspherical, hollow	120–230 μm	200–300 μm	Pacific Ocean
<i>C. spongiosum</i> (Kraft, 2007)	subspherical, partially fused globose	165–600 μm	1850–5000 μm	Indian Ocean, Pacific Ocean
<i>C. mamillosum</i> (Silva and Womersley, 1956)	globose	400–1000 μm	3–9 mm	Indian Ocean, Pacific Ocean
<i>C. mamillosum</i> (the present study)	globose, solid	550–1100 μm	1400–3800 μm	Ogasawara Isls.

*) Okamura (1915) treated this species as "*C. mamillosum*". **) Estimated from the fig. 7 in Verbruggen *et al.* (2012).

from the Ogasawara Islands agree well with *Codium mamillosum* in the diameter of utricles showed by Silva and Womersley (1956) and their utricles are distinguishably larger in diameter than most of the globular members of the genus (except *C. megalophysum*).

Discussion

The present alga collected from the mesophotic zone off the Ogasawara Islands possess the characteristics of *Codium mamillosum* Harvey in morphology. This is the first record of a genuine *C. mamillosum* from Japan. *C. mamillosum* is similar in appearance to the other globular species of the genus *Codium*, though this species

is different in the diameter of utricles from the other globular species of the genus *Codium* (Table 1). *C. mamillosum* has remarkably thicker utricles (550–1100 μm in diameter) than most species of globular *Codium*. The presence of this species suggests that mesophotic marine algal flora of Ogasawara Islands has close relationships to those of the South Pacific Ocean.

As a result, presently five species of the globular *Codium* including *Codium mamillosum* are distributed to Japan, though their distribution may not be accurate because they are so similar each other in appearance. To clarify the distribution of this species, anatomical observations and molecular analyses are required.

Key to the species of globular *Codium* in Japan

- 1a. Plant a hollow membranous sac.....2
- 1b. Plant a solid spongy ball.....3
- 2a. Utricles 200–300 μm in length.....*C. saccatum*
- 2b. Utricles 660–715 μm in length.....*C. ovale*
- 3a. Utricles 160–600 μm in diameter on the apex.....4
- 3b. Utricles 550–1100 μm in diameter on the apex.....*C. mamillosum*
- 4a. Thalli globose throughout the life.....*C. minus*
- 4b. Thalli globose when young, becoming irregularly protubelant as they grow.....*C. spongiosum*

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