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First Record of *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne (Cladophoraceae, Ulvophyceae) from Japan

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Abstract A benthic marine green alga, *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne (Cladophoraceae, Cladophorales, Ulvophyceae) was collected from the mesophotic zone (40–54 m in depth) of Chichi-jima Island and Ototo-jima, Ogasawara Islands, Japan. This alga is different from the other species of the genus *Lychaete* in having a long basal stipe (up to 1.6 cm) and a main axis (up to 220 µm in diameter), numerous, fine, tapering laterals (18–120 µm in diameter) with 1–3(4) branches and extremely slender apical cells (15–23 µm in diameter). The presence of this species, which has been known only from southern Australia and Tasmania so far, raises a possibility that the mesophotic algal flora of Ogaswara islands has some relationship with the one of the South Pacific Ocean.

Key words: benthic marine green alga, Cladophoraceae, *Lychaete bainesii*, Ogasawara Islands, Ulvophyceae.

A marine green alga, *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne had recently changed its genus name in succession. Since the original description of Harvey (1859), this species had been treated for a long time as "*Cladophora bainesii* F.Müller et Harvey ex Harvey", a member of the large genus *Cladophora* Kützing. In 2016, the species was transferred to the genus *Acrocladus* Nägeli by Boedeker *et al.* (2016), who segregated a marine algal clade from the genus *Cladophora* based on the results of their molecular analysis. This clade had been known as "section *Longi-articulatae* Hamel", having several morphological characteristics: acropetally organized branch systems, growth by division of conspicuous apical cells with subsequent considerable cell elongation, conspicuous stipes, etc. (Hoek, 1963; Hoek and Chihara, 2000). They proposed the resurrection of the old genus *Acrocladus* for this clade, assigning nineteen species including "*Acrocladus bainesii* (F.Müller et Harvey ex Harvey) Boedeker" (Boedeker *et al.*, 2016). However, Wynne (2017) pointed out that "*Acrocladus mirabilis* (C.Agardh) Boedeker" which was listed in the genus *Acrocladus* emended by Boedeker, had another name, *Lychaete mirabilis* (C.Agardh) J.Agardh. This genus name, *Lychaete*, was lectotypified with *L. mirabilis* and validated by J. Agardh in 1846 and thus predated the establishment of "*Acrocladus*" by Nägeli in 1847. Therefore, Wynne (2017) reinstated the genus *Lychaete* and proposed to transfer eighteen species from "*Acrocladus*" to the older genus, *Lychaete*.

As a result, in Japan, six species and a variety of "*Acrocladus*" were transfered taxonomically to *Lychaete* by Wynne (2017): *Lychaete dotyana* (W.J.Gilbert) M.J.Wynne, *L. herpestica* (Montagne) M.J.Wynne, *L. japonica* (Yamada) M.J.Wynne, *L. japonica* var. *kajimurae* (C.Hoek et Chihara) M.J.Wynne, *L. minisakai* (C.Hoek et

Chihara) M.J.Wynne, *L. ohkuboana* (Holmes) M.J.Wynne, *L. sakai* (I.A.Abbott) M.J.Wynne. In this investigation *L. bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne is added to the list of Japanese *Lychaete*.

Ogasawara Islands (also called the Bonin Islands) are oceanic islands located ca. 1,000 km south of Izu Peninsula, Japan. In recent 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 dredging apparatus: for example, mesophotic marine algae, *Aneurianna ogasawaraensis* Kitayama (Kitayama, 2014), *Codium mamillosum* Harvey (Kitayama, 2017), *Discosporangia mesarthrocarpum* (Meneghini) Hauck (Kitayama, 2012), *Zosterocarpus ogasawaraensis* Kitayama (Kitayama, 2013). In addition to these species unknown in the Japanese Archipelago, the appearance of *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne, which is known only to be from the southern Hemisphere so far, suggests a possibility that the Ogasawara Islands have a unique algal flora derived from areas outside the Japanese Archipelago. In this study, to confirm the identity of the present alga from the islands, the author made anatomical observations on the material using microscopes.

Material and Methods

The green algal material refered to as *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne was collected from the mesophotic zone of Chichi-jima Island (40–54 m in depth) and Ototo-jima Island (56–63 m in depth) in the Ogasawara Islands, Japan used a dredging apparatus and the fishing vessel "*The 7th Ushiwo-maru*" (steering by Captain Y. Takase), on 16 and 17 July 2017. For preservation, the material was fixed and stored in 10% Formalin-seawater, and specimens were mounted in glycerine jelly. Anatomical observations were made on the material by using a microscope. Voucher specimens were deposited in the algal herbarium of the Department of Botany, National Museum of Nature and Science (TNS).

Results

Class Ulvophyceae K.R.Mattox et K.D.Stewart, 1984
Order Cladophorales Haeckel, 1894
Family Cladophoraceae Wille in Warming, 1884

Lychaete bainesii (F.Müller et Harvey ex Harvey) M.J.Wynne
Notulae Algarum 31: 1 (2017).

[Figs. 1–7]

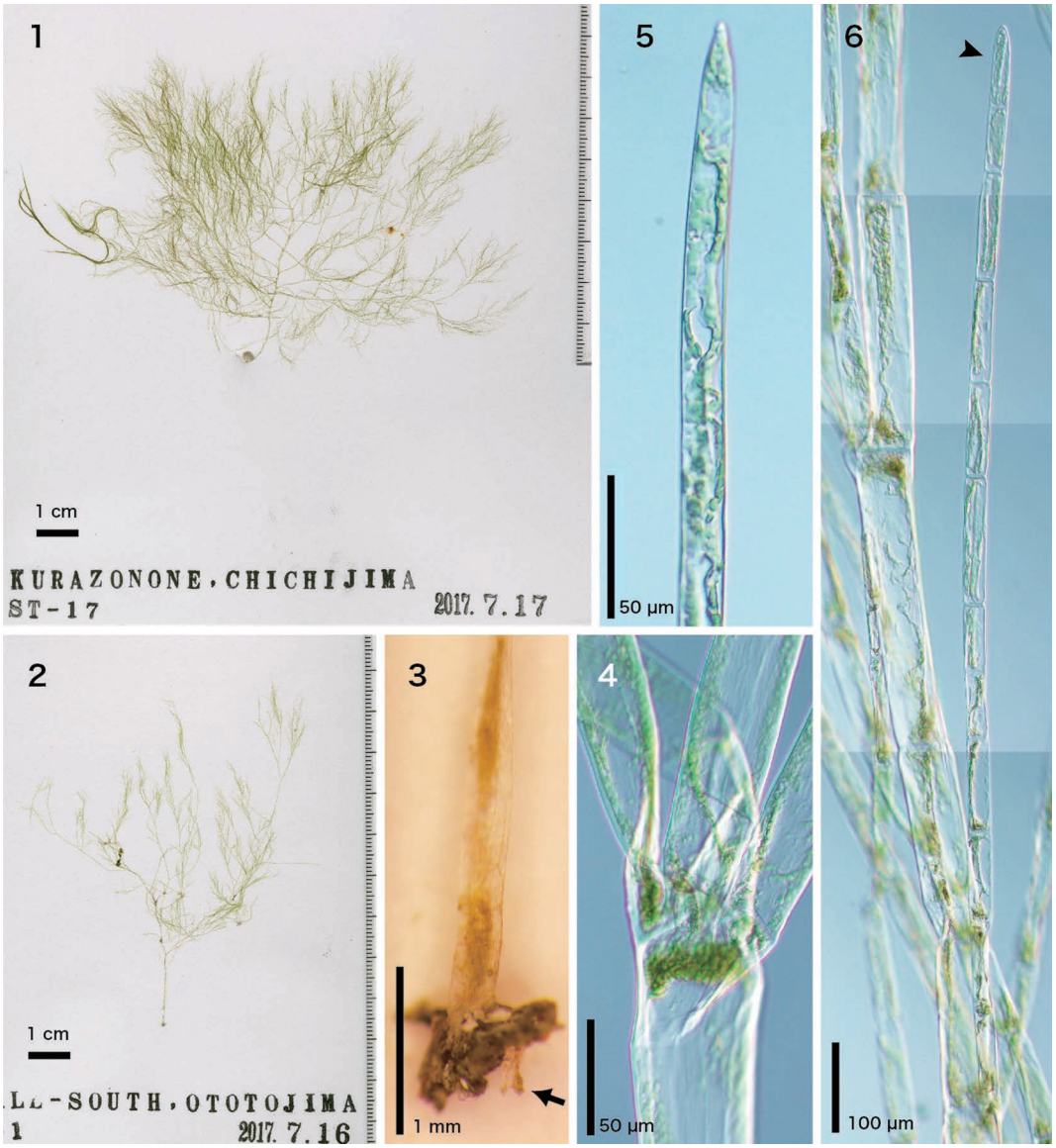
[Type locality: Port Phillip, Victoria, Australia. Lectotype: TCD (Womersley, 1956: 358), Herb. Harvey, Algae Australicae Exsiccatae 579F (Womersley, 1984: 194; Guiry in Guiry and Guiry, 2019).]

Basionym: *Cladophora bainesii* F.Müller et Harvey ex Harvey, Phycologia Australica, vol. 2. pl. 112, 1859.

Synonym: *Acrocladus bainesii* (F.Müller et Harvey ex Harvey) Boedeker, Journal of Phycology, 52: 919, 2016.

Habitat: Grew on rock in the mesophotic zone (40–54 m in depth).

Morphology: Plants are light to medium green, erect, up to 8 cm in height (Figs. 1 and 2), with one long stipe basally attached on rocks by a holdfast with branched haptera (Fig. 3, arrow). Stipes are elongated, up to 1.6 cm in height. Thalli are filamentous, monosiphonous, composed of main axes and numerous laterals, acropetal (intercalary cell divisions apparently absent in the lower portions) (Fig. 4), growing by apical cells (Fig. 5) and intercalary divisions in the upper portions (Fig. 6). Filaments are gently tapering and branched often above every 1–4 cells, forming delicate, fastigiate tufts (Fig. 7). Main axes are elongated, up to 220 µm in diameter. Lateral branches are fine, 18–120 µm in diameter, ultimate, arising di-, tri- or tetrachotomous at acute angles from each parent cell (Fig. 4). Cross walls are almost horizontal to parent cells. Apical cells are obtuse to acute, small, slender, needlelike, 15–23 µm in diameter (Figs.



Figs. 1–6. *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne from Ogasawara Islands., Japan. 1. Thallus from Chichi-jima Island, Ogasawara Islands, Japan (TNS-AL 210218). 2. Thallus from Ototo-jima Island, Ogasawara Islands, Japan (TNS-AL 210219). 3. Holdfast of the thallus from Ototo-jima (Fig. 2) showing a hapteron (arrow). 4. Tetrachotomous branching at acute angles from a parent cell in the lower portion of the thallus. 5. Apical cell with an acute apex. 6. Various laterals branching at acute angles showing an apical cell with obtuse apex (arrowhead).

5 and 6, arrow). Reproductive organs were not observed (According to Womersley (1984), zooidangia were transformed from upper cells of the filaments and then quadriflagellate zoospores were observed once).

Specimens examined: Ogasawara Islands, Japan: Off Kurazone (53.5–53.9 m in depth), Chichi-jima Island (27°5′N, 142°11′E), 17 July 2017, leg. T. Kitayama (TNS-AL 210218) (Fig. 1); Off Small-hama beach (ca. 40 m in depth), Ototo-jima

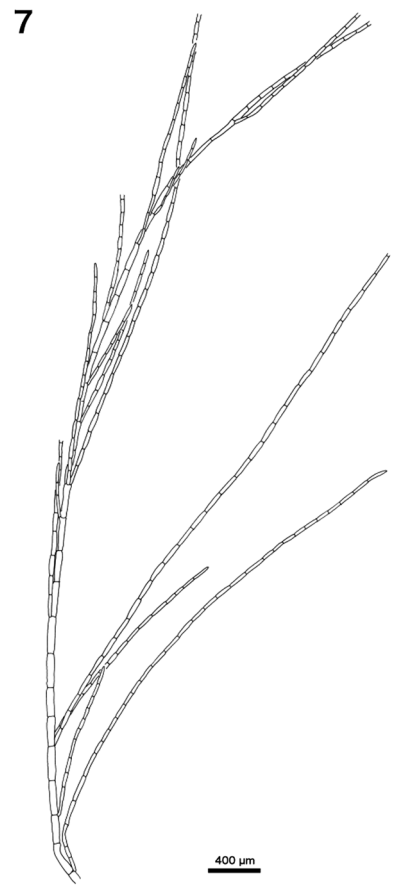


Fig. 7. *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne from Ogasawara Islands, Japan. Upper branch system.

Island (27°8′N, 142°11′E), 16 July 2017, leg. T. Kitayama (TNS-AL 210219) (Fig. 2).

Japanese name: Sakiboso-shiwogusa (nov.).

Distribution: *Indian Ocean*: South Australia (type locality), Tasmania, Victoria (Womersley, 1984); *Pacific Ocean*: Japan (Ogasawara Islands, the present study).

Comparisons of apical and intercalary cells among the seven species (including one variety) of *Lychaete* distributed in Japan are showed in Table 1.

Discussion

The present cladophoracean alga collected from the mesophotic zone of the Ogasawara Islands possesses the characteristics of *Lychaete bainesii* (F.Müller et Harvey ex Harvey) M.J.Wynne in morphology. It agrees well with the description of *L. bainesii* by Womersley (1984), while different from all species of Japanese *Lychaete* in the diameters of both apical cells and intercalary cells (Table 1). In Japan there have been no known species of *Lychaete* having extremely thin apical cells below 25 µm in diameter. This is the first record of *L. bainesii* from Japan.

Outside of Japan, *Lychaete pseudobainesii* (C.Hoek and Searles) M.J.Wynne, which is distributed to the Atlantic coast of North America, is very similar to *L. bainesii* in having extremely slender apical cells (12–20 µm in diameter). However, this Atlantic species differs from *L. bainesii* by the larger number of branches which can be formed at a node: *L. pseudobainesii* has 1–4(6) branches, while *L. bainesii* has 1–3(4) branches (Hoek and Searles, 1988). In addition, *L. pseudobainesii* has intercalary divisions which divide the internodes in the basal portions of thalli, forming a thin stipe. In *L. bainesii* has no intercalary division in the basal portions and so has actually one huge basal stipe cell (Hoek and Searles, 1988).

The presence of *Lychaete bainesii* suggests that mesophotic marine algal flora of Ogasawara Islands has close relationships to the one of the South Pacific Ocean. *L. bainesii* as well as *Aneurianna ogasawaraensis* Kitayama, *Codium mamillosum* Harvey, *Discosporangia mesarthrocarpum* (Meneghini) Hauck, *Zosterocarpus ogasawaraensis* Kitayama, which were recorded from Ogasawara Islands in recent years (Kitayama, 2012; 2013; 2014; 2017), has no distribution in not only the Japanese Archipelago but all over Asia. Thus the author considers that in the Ogasawara Islands expansion mechanism of geographic distribution of algae is different in depth. In the shallow zone there are many algal species common in the Japanese Archipelago (in particular the Ryukyu Islands), because of the strong influence of the surface currents, mainly branches of the Kuroshiwo Current (the Japan Current)

Table 1. Comparisons of apical and intercalary cells among the Japanese species of *Lychaete* based on Hoek and Chihara (2000) and Womersley (1984).

	Apical cells		Intercalary cells	Distribution**
	Shape of tip	Diameter	Diameter	
*L. bainesii**	Obtuse to mucronate	14–25(–35) µm	15–300 µm	South Australia, Tasmania, Victoria
L. bainesii (the present study)	Obtuse to acute	15–23 µm	18–120 µm	Japan (Ogasawara Isls.)
L. dotyana	Rounded	160–340 µm	180–700 µm	Fiji, Hawaii, Japan (Miyake-jima Isl., Misaki, Oki Isl., Philippines, Queensland, South Africa, Taiwan, Tanzania
*L. herpestica**	Rounded	240–370 µm	240–370 µm	Austlaria, Chile, Fiji, India, Indonesia, Japan (Honshu, Shikoku, Kyushu, Nansei Isls.), Kenia, Kuwait, Malaysia, Micronesia, New Caledonia, New Zealand, Oman, Philippines, Taiwan, Thailand, Vietnam etc.
L. japnica var. *japonica*	Rounded	150–280 µm	150–300 µm	Hawaii, Japan (Pacific Ocean), Philippines
L. japnica var. *kajimurae*	Rounded	70–150 (–170) µm	70–150 µm	Japan (Sea of Japan), Korea
L. minisakaii	Rounded	135–185 µm	155–205 µm	Japan (Okinawa)
L. ohkuboana	Blunt	470–710 µm	470–1420 µm	China, Japan (Pacific Ocean), Korea, New South Wales, Oman, Papua New Guinea, Taiwan
L. sakaii	Blunt	60–150 µm	60–250 µm	California, Japan (Hokkaido, Honshu, Shikoku, Kyushu), Korea, Philippines, Taiwan, Vietnam

* Womersley (1984), ** Guiry and Guiry (2019)

from Japan. On the other hand, most algae in the mesophotic zone is uncommon in the Japanese Archipelago, because of few influence of the currents from Asia. There is a possibility that the mesophotic algal flora in Ogasawara Islands were derived from Oceania or the South Pacific Ocean.

Presently seven species and one variety of *Lychaete* are dispersed throughout Japan, though their exact distribution may not be accurate because they are so similar each other in outward morphology. To clarify the whole distribution of *L. bainesii*, anatomical observations and molecular analyses on more samples from various fields and more specimens in various herbaria are required.

Key to the species of *Lychaete* in Japan (based on van den Hoek and Chihara, 2000)

1a. Basal cross wall of lateral branches absent, leaving the lateral and parent cell in open connection .....*L. herpestica*
1b. Basal cross wall of lateral branches present at or near junction of cells.....2
2a. Apical cells less than 340 µm in diameter 3
2b. Apical cells 470–710 (–930) µm in diameter .....*L. ohkuboana*
3a. Thalli forming spreading pompon-like tufts up to 7 cm in height. Basal stipes short, mostly one-celled (to two-celled).....4
3b. Thalli forming erect tufts up to 30 (–40) cm in height. Basal stipes elongated, 2 or more cells 5
4a. Apical cells relatively long, 135–185 µm in diameter. Basal cells relatively narrow, 170–205 µm in

diameter.....*L. minisakaii*
4b. Apical cells relatively short, 160–340 µm in diameter. Basal cells relatively thick, 400–700 µm in diameter..... *L. dotyana*
5a. Apical cells thin, 15–25(–35) µm in diameter, having an obtuse to acute tip .....*L. bainesii*
5a. Apical cells thick, 50–300 µm in diameter, having a blunt or round tip 6
6a. Apical cells (50–) 60–150 µm in diameter. Basal cells much less conspicuous, 170–250(–300) µm in diameter.....*L. sakaii*
6b. Apical cells 70–280 µm in diameter. Basal cells conspicuous, 580–1100 µm in diameter ..... 7. *L. japonica*
7a. Apical cells 150–280 µm in diameter. Basal cells 700–1100 µm in diameter ..... *L. japonica* var. *japonica*
7b. Apical cells 70–150 µm in diameter. Basal cells 580–800 µm in diameter ..... *L. japonica* var. *kajimurae*

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