

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

Taiju Kitayama

Department of Botany, National Museum of Nature and Science,
4–1–1 Amakubo, Tsukuba, Ibaraki 305–0005, Japan
E-mail: kitayama@kahaku.go.jp

(Received 18 August 2019; accepted 25 September 2019)

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 Ogasawara 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* Kützinger. 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 nine

teen 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 transferred 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 referred 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 Kuroshio 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	
<i>L. bainesii</i> *	Obtuse to mucronate	14–25(–35) μm	15–300 μm	South Australia, Tasmania, Victoria Japan (Ogasawara Isls.)
<i>L. bainesii</i> (the present study)	Obtuse to acute	15–23 μm	18–120 μm	
<i>L. dotyana</i>	Rounded	160–340 μm	180–700 μm	Fiji, Hawaii, Japan (Miyake-jima Isl., Misaki, Oki Isl., Philippines, Queensland, South Africa, Tai- wan, Tanzania)
<i>L. herpestica</i> *	Rounded	240–370 μm	240–370 μm	Australia, Chile, Fiji, India, Indo- nesia, Japan (Honshu, Shikoku, Kyushu, Nansei Isls.), Kenia, Kuwait, Malaysia, Micronesia, New Caledonia, New Zealand, Oman, Philippines, Taiwan, Thailand, Vietnam etc.
<i>L. japnica</i> var. <i>japonica</i>	Rounded	150–280 μm	150–300 μm	Hawaii, Japan (Pacific Ocean), Philippines
<i>L. japnica</i> var. <i>kajimurae</i>	Rounded	70–150 (–170) μm	70–150 μm	Japan (Sea of Japan), Korea
<i>L. minisakaii</i>	Rounded	135–185 μm	155–205 μm	Japan (Okinawa)
<i>L. ohkuboana</i>	Blunt	470–710 μm	470–1420 μm	China, Japan (Pacific Ocean), Korea, New South Wales, Oman, Papua New Guinea, Taiwan
<i>L. sakaii</i>	Blunt	60–150 μm	60–250 μm	California, Japan (Hokkaido, Hon- shu, 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 diameter3
- 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 cells5
- 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 tip6
- 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*

Acknowledgments

I am grateful to Mr. Yoshiyasu Takase, the Ogasawara-jima Fisheries Cooperative for collecting the material by dredging with his ship. I thank Mr. Masataka Kikuchi, the union representative of the Ogasawara-jima Fisheries Cooperative for permission and cooperation for collecting, and Kotaro Seno and Mr. Miyazaki, the Ogasawara Fisheries Center, Tokyo Metropolitan for providing me the facilities to process the specimens. This study was supported by Grants-in-Aid for Scientific Research (No. 16K07496) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

- Boedeker, C., Leliaert, F. and Zuccarello, G. C. 2016. Molecular phylogeny of the Cladophoraceae (Cladophorales, Ulvophyceae) with the resurrection of *Acrocladus* Nägeli and *Willella* Borgesen, and the description of *Lurbica* gen. nov. and *Pseudorhizoclonium* gen. nov. *Journal of Phycology* 52: 905–928.
- Guiry, M. D. and Guiry, G. M. 2019. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org> (accessed on 16 August 2018).
- Harvey, W. H. 1859. *Phycologia Australica*. Vol. 2. Lovell Reeve & Co, London, pl. 112.
- Hoek, C. van den 1963. Revision of the European species of *Cladophora*. Brill, Leiden, pp. 1–248, plate 1–55.
- Hoek, C. van den and Chihara, M. 2000. A taxonomic revision of the marine species of *Cladophora* (Chlorophyta) along the coasts of Japan and the Russian Far-East. National Science Museum Monographs No. 19. 242 pp. Tokyo.
- Hoek, C. van den and Searles, R. B. 1988. *Cladophora pseudobainesii* nov. spec. (Chlorophyta): An addition to the N.W. Atlantic species of *Cladophora*. *Botanica Marina* 31: 521–524.
- Kitayama, T. 2012. First record of *Discosporangium mesarthrocarpum* (Meneghini) Hauck (Phaeophyceae, Ochrophyta) from the Ogasawara Islands, Japan. *Bulletin of the National Museum of Nature and Science, Series B (Botany)* 38: 147–152.
- Kitayama, T. 2013. Morphology of *Zosterocarpus ogasawaraensis* sp. nov. (Phaeophyceae, Ochrophyta), a new marine deep-water brown alga from the Ogasawara Islands, Japan. *Bulletin of the National Museum of Nature and Science, Series B (Botany)* 39: 159–164.
- Kitayama, T. 2014. Morphology of *Aneurianna ogasawaraensis* sp. nov. (Rhodomelaceae, Rhodophyta), a new marine deep sublittoral red alga from the Ogasawara Islands, Japan. *Bulletin of the National Museum of Nature and Science, Series B (Botany)* 40: 133–138.
- Kitayama, T. 2017. First record of genuine *Codium mammosum* Harvey (Codiales, Ulvophyceae) from Japan. *Bulletin of the National Museum of Nature and Science, Series B (Botany)* 43: 93–98.
- Womersley, H. B. S. 1956. A critical survey of the marine algae of southern Australia. I. Chlorophyta. *Australian Journal of Marine and Freshwater Research*, 7: 343–383.
- Womersley, H. B. S. 1984. *The Marine Benthic Flora of Southern Australia. Part I. Government Printer, Adelaide, South Australia*. 329 pp.
- Wynne, M. J. 2017. The reinstatement of *Lychaete* J.Agardh (Ulvophyceae, Cladophoraceae). *Notulae Algarum* 31: 1–4.