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First Record of *Callithamniella tingitana* (Schousboe ex Bornet) Feldmann-Mazoyer (Ceramiaceae, Rhodophyta) from Japan

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Abstract A marine red alga, *Callithamniella tingitana* (Schousboe ex Bornet) Feldmann-Mazoyer (Ceramiaceae, Ceramiales, Rhodophyta) was collected from the coast of Chichi-jima Island, Ogasawara Islands, Japan. This species is the type species of the genus *Callithamniella* and differs from all other members of the genus in having determinate axes, laterals branched dichotomously from the third proximal cells on indeterminate axes and ellipsoidal tetrasporangia borne on unicelled pedicels on indeterminate axes. This is the first record of the genera and species from Japan and also the first report on this species from the Pacific Ocean.

Key words: *Callithamniella tingitana*, Ceramiaceae, Japan, Ogasawara Islands, red alga.

The red algal genus *Callithamniella* (Ceramiaceae, Ceramiales, Rhodophyta) was established by Feldmann-Mazoyer (1938) on the basis of "*Callithamnion tingitana*" Schousboe ex Bornet (Bornet, 1892) as a new genus having minute dorsiventral thalli, which are composed of simple erect determinate axes and *Callithamnion*-like erect indeterminate axes arising from prostrate indeterminate axes. In this genus, there are five current species in the world (Guiry and Guiry, 2015): *C. tingitana* (Schousboe ex Bornet) Feldmann-Mazoyer (Feldmann-Mazoyer, 1938) (type species), *C. capensis* Simons (Simons, 1970), *C. flexilis* Baardseth (Baardseth, 1941), *C. pacifica* Abbott et R.E. Norris (Abbott and Norris, 1993), *C. silvae* Searles in Searles et Schneider (Searles and Schneider, 1989). Most species of them, *C. tingitana*, *C. capensis*, *C. flexilis* and *C. silvae*, were recorded from the Atlantic Ocean and the neighboring waters, while in Pacific Ocean only one species, *C. pacifica*, was found by Abbott and Norris (1993), who described this as an endemic species to Hawaii. Although Kim and Lee (1991) described a new species, "*C. koreana* H.-S.Kim et I.K.Lee" based on the alga from Korea, it was synonymized into *C. pacifica* later by Kim and Lee (2012) because of their similarity in morphology. Thus the distribution of *Callithamniella* had been regarded as separating into the four atlantic species and one pacific species so far. However, information about the pacific species is few because of its difficulty of collecting and identification and is insufficient for discussing about the distribution of this genus.

Ogasawara Islands (= Bonin Islands) are oceanic islands located ca. 1,000 km south of Tokyo Metr., Japan. In the investigations of algal flora around the Islands, several rare algae were found from the deep sublittoral zone using dredge: for example, *Aneurianna ogasawaraensis* Kitayama (Kitayama, 2014), *Zosterocarpus ogasawaraensis* Kitayama (Kitayama, 2013). There is a possibility that the Ogasawara Islands has a unique algal flora different from any area of the Japanese Archipelago. Recently, in addition, a small alga referable to *Callithamniella* was collected from Chichi-jima island, main island of Ogasawara Islands. In this study, to confirm the

identity of this present alga from the Island and reconsideration on the distribution of *Callithamniella* in the Pacific Ocean, the author made anatomical observations on the material using a microscope.

Materials and Methods

The red algal material referable to the genus *Callithamniella* was collected from the subtidal zone (1–2 m in depth) of the coast of Futami Bay, Chichi-jima Island in the Ogasawara Islands (= Bonin Islands), Japan by snorkeling on 13 July 2013. 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

Order Ceramiales Oltmanns, 1904
Family Ceramiaceae Dumortier, 1822
Tribe Dohrnielleae Feldmann-Mazoyer, 1941

Callithamniella tingitana (Schousboe ex Bornet) Feldmann-Mazoyer

Comptes Rendus Hebdomadaires des Séances de l'Académie des Science, Paris 207: 1119 (1938) [Figs. 1–11]

Basionym: *Callithamnion tingitana* Schousboe ex Bornet, 1892: 329 [Type locality: Tangier, Morocco (Schneider and Searles, 1997). Holotype: PC (Schneider, 1984: 458)]

Synonym: *Callithamnion aegagrophila* Funk, 1922: 236, table V, f. 15, 16.
Callithamniella capensis sensu Stegenga, 1988: 376.
Grallatoria tingitana (Schousboe ex Bornet) Abbott, 1976: 148.

Habitat: Grew on other benthic marine algae (e.g., *Champia*, *Dictyota*, *Padina*) in the subtidal zone (1–2 m in depth).

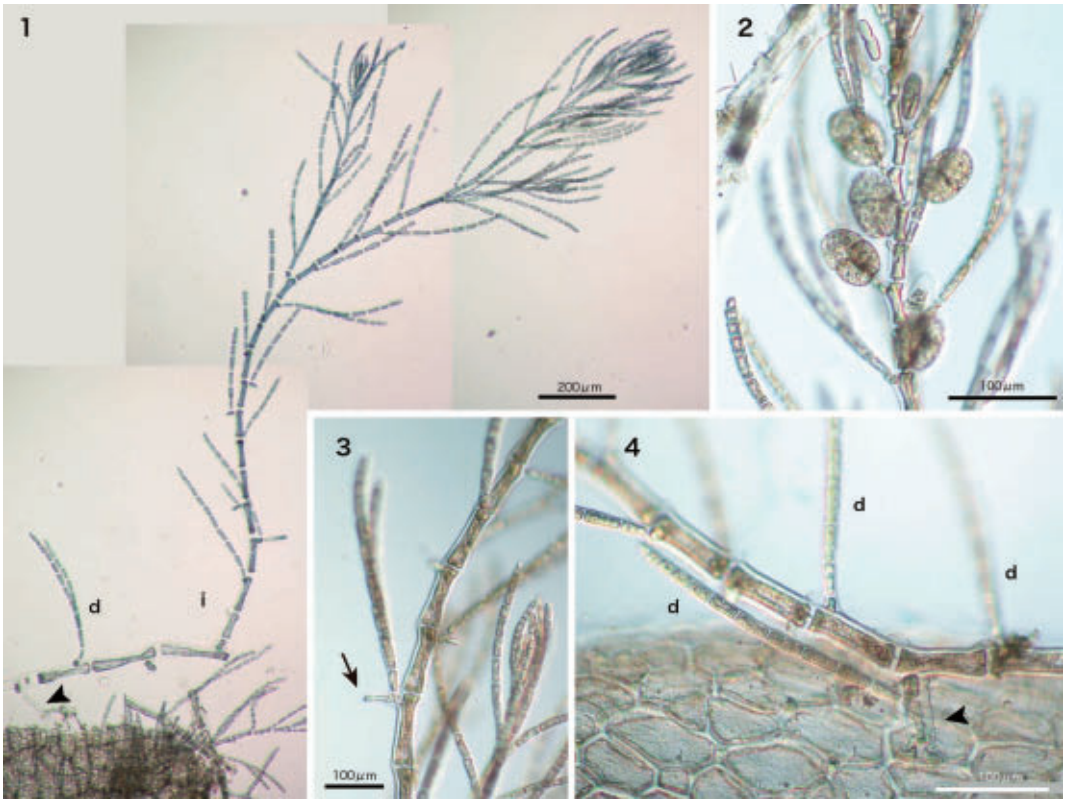
Vegetative morphology: Plants are epiphytic, minute, up to 2 mm in height, filamentous and bright red in color. The thalli are dorsiventral, organized with prostrate axes and erect indeterminate and determinate axes arising irregularly from the prostrate axes (Fig. 1). All axes are uniseriate and ecorticate (Figs. 2–4). Prostrate axes are cylindrical, 30–55 μm in diameter. Each cell of the prostrate axes is straight, 60–320 μm in length, producing an erect axes and a ventral rhizoid or a hapteron from a basal cell. Rhizoids are colorless, uniseriate, unicellular or multicellular, elongate, up to 400 μm in length, 16–24 μm in diameter (Fig. 3, arrow). Haptera are colorless, unicellular, discoidal to digitate (Figs. 1, 4, arrowheads, 11 h). Erect determinate axes are short, 11–13 celled, branched dichotomously once or twice from the 3rd proximal cells, curved slightly toward axes. Erect inderminate axes are elongate, issuing alternately determinate laterals in spiral and few indeterminate laterals, terminated an apical cell (Fig. 5). Cells of the erect indeterminate axes are cylindrical, 45–84 μm in length, 18–40 μm in diameter in the lower portion, tapering to the top, 6–15 μm in length, 4–10 μm in diameter in the terminal portion. Determinate laterals are similar to erect determinate axes, 10–13 celled, curved slightly toward axes, branched dichotomous, once or twice from the 3rd proximal cells (Fig. 6).

Reproductive morphology: Tetrasporangia are formed on one celled pedicels on erect indeterminate axes, adjacent to the basal cells of determinate laterals (Figs. 2, 6). Immature tetrasporangia are long ovate (Figs. 7, 8). Mature tetrasporangia are ovate or ellipsoidal, 30–54 μm in diameter, 48–72 μm in length, devided cruciately (Figs. 6, 9, 10). Sexual organs were not observed.

Specimens examined: "Koyo-walls" in front of the Ogasawara Fisheries Center, Futami Bay, Chichi-jima Island, Ogasawara Islands, Japan (27°5′50″N, 142°11′56″E); 13 July 2013; leg. T. Kitayama (TNS-AL 198288–198290).

Japanese name: Hai-kinu-ito (nom. nov.).

Distribution: *Atlantic Ocean and Mediterranean Sea*: Europe, Africa, Atlantic Islands, North



Figs. 1–4. *Callithamniella tingitana* from Chichi-jima Island, Ogasawara Islands, Japan. 1. Habit showing a dorsiventral thallus composing of an erect determinate axis (d) and indeterminate axis (i) arising from the prostrate axis with a holdfast (arrowhead). 2. Erect indeterminate axis with mature tetrasporangia. 3. Erect indeterminate axis showing a rhizoid (arrow) from the basal cell of determinate lateral. 4. Prostrate indeterminate axis with erect determinate axes (d) and a holdfast (arrowhead) on the surface of *Champia*.

America, Western Atlantic, South America (Guiry and Guiry, 2015); *Pacific Ocean*: Japan (Ogasawara Islands, the present study).

The four specific characters that distinguished *C. tingitana* from other members of the genus are shown in Table 1. The material from the Ogasawara Isls. agrees well with *C. tingitana*, except the range of branching position in erect determinate laterals: Schneider and Searles (1991, p. 735) stated that *C. tingitana* has the branching occurring from the 3rd–5th proximal cells of the laterals.

Discussion

The red alga collected from the Ogasawara Islands possesses completely generic characteristics of *Callithamniella* Feldmann-Mazoyer: the dorsiventral thalli composed of erect indeterminate and determinate axes arising from prostrate axes; determinate laterals issued alternately or spirally from the erect indeterminate axes; tetrasporangia borne on pedicels adjacent to the determinate laterals. In Japan, this is the first record for this genus, which may have been mistaken for juvenile plants of *Callithamnion* before.

Furthermore, it is not easy to carry out species identification within the genus because there are few considerable differences among the five current species in the world. Comparisons of a few characteristics of determinate axes and laterals and tetrasporangia among them (Table 1) resulted barely in the key to the species of the genus (see below), in which the present alga from Ogasawara Islands can be treated as *Cal-*

Table 1. Comparisons of the four characteristics among the species of the *Callithamniella*

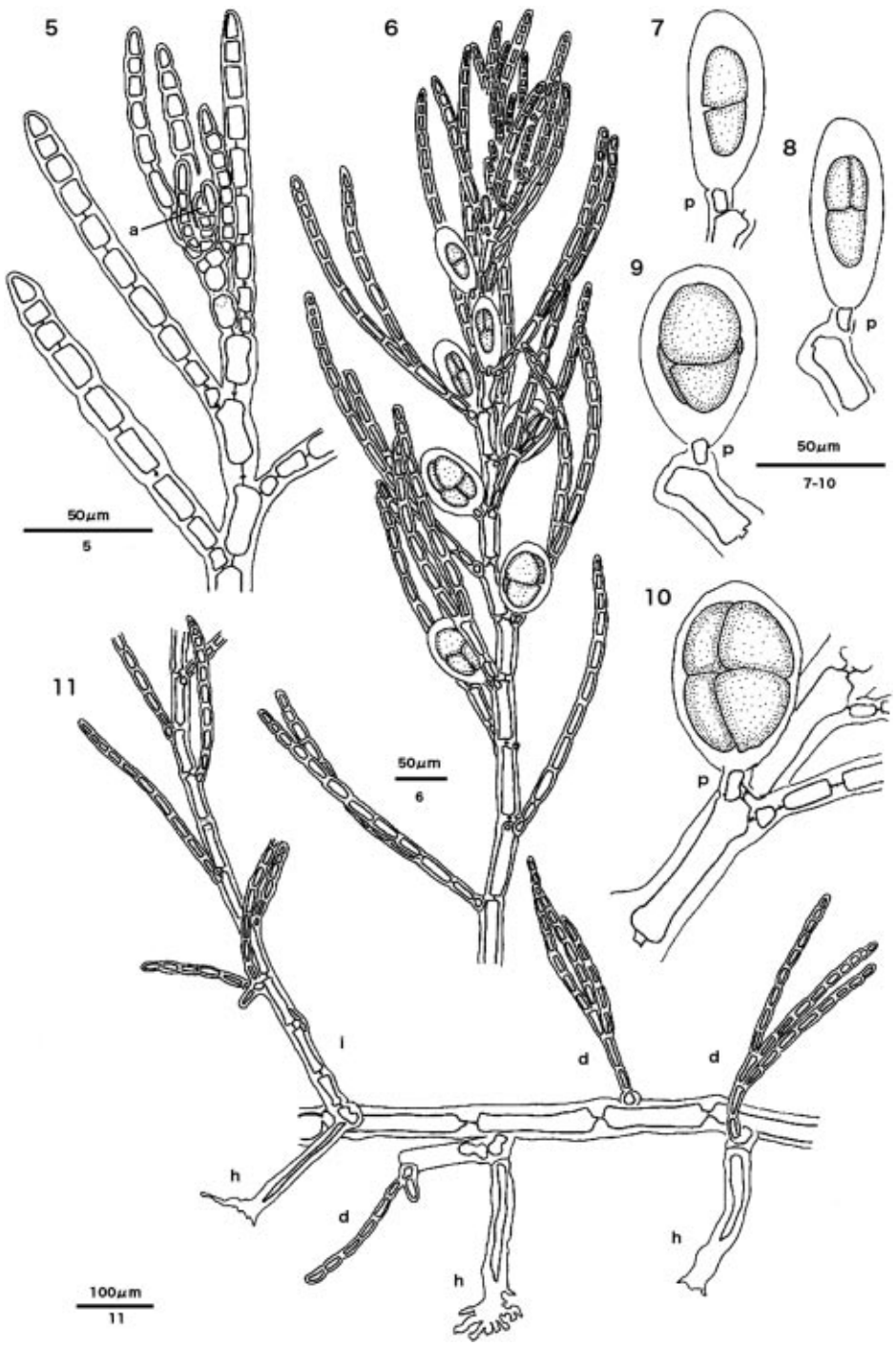
	Branching position of determinate erect axes and laterals	Tetrasporangia		
		Position	Pedicels	Shape and lenght
C. capensis (Simons, 1970)	Unbranched*	On the indeterminate erect axes	1–2 cells	Ellipsoidal, up to 75 μm*
C. flexilis (Secilla, 2012)	Unbranched	On the indeterminate erect axes	1–2 (3) cells	Ellipsoidal, 27–43 μm
C. pacifica (Abbott and Norris, 1993)	From the 3rd proximal cells**	On the indeterminate erect axes	1–3 cells	Long ovate, up to 90 μm
C. pacifica (Kim and Lee, 2012)	From the 3rd proximal cells***	On the indeterminate erect axes	1–2 (3) cells***	Ellipsoidal, 60–65 μm
C. silvae (Searles and Schneider, 1989)	"In upper portion" (from the 6–7th proximal cells****)	On the proximal cells of determinate laterals	1 (2) cells	Ellipsoidal, 27–45 μm
C. tingitana (Schneider, 1984; Searles and Schneider, 1989)	From the 3rd–5th proximal cells	On the indeterminate erect axes	A single cell	Ellipsoidal, 38–55 μm
C. tingitana (the present study)	From the 3rd proximal cells	On the indeterminate erect axes	A single cell	Ellipsoidal, ovate, 48–72 μm

* Judging from fig. 6 in Simons (1970). ** Judging from fig. 17 in Abbott and Norris (1993). *** Judging from fig. 47 in Kim and Lee (2012). **** Judging from figs. 5 and 6 in Searles and Schneider (1989).

lithamniella tingitana (Schousboe ex Bornet) Feldmann-Mazoyer. In particular, the present alga from Ogasawara Islands is similar strikingly in morphology to the Feldmann-Mazoyer (1940)'s alga and Schneider (1984)'s alga of *C. tingitana* from North Carolina, U.S.A.; on the other hand, it differs from the Schneider and Searles (1997)'s alga of *C. tingitana* from Bermuda in having many unbranched determinate laterals.

The alga from the Ogasawara Islands also doesn't agree with *C. pacifica*, which is known as the only species distributed to the Pacific Ocean (Abbott and Norris, 1993) in morphology of reproductive organs. Abbott and Norris (1993, p. 459) noted "*C. pacifica* sp. nov. is widely separated geographically (from the Atrantic species), but this should not be the basis for describing new species". As a strong characteristic for the new species, they featured "very large tetrasporangia, up to 90 μm long" (Abbott and Norris, 1993) and "to 22 by 90 μm including wall layers" (Abbott, 1999), which are surely different from any species of the genus including the present alga from Ogasawara Islands. Additionally, tetrasporangia of *C. pacifica* have "1–3 cells long" pedicles (Abbott and Norris, 1993), while ones in most of other species have unicelled or 1–2 celled pedicels except *C. flexilis* (Secilla, 2012). Kim and Lee (2012) also observed Korean alga of *C. pacifica*, which was identical to "*C. koreana*" described informally by Kim and Lee (1991), and observed 1–2 (3) celled pedicels (they illustrated three celled pedicel in fig. 47B). According to their description, however, teterasporangia of the Korean alga are not so long ovate and under 65 μm in length. It is probable that this size exclude wall layers, for most of the ones showed in their illustration (fig. 47A–E) are mesurable as 50–120 (150) μm in lengh.

Although reality of the species endemic to the Pacific Ocean is an unresolved problem because of morphological variation in the Atlantic species, the alga from Ogasawara Islands is identified with *C. tingitana* at the present time. As a result, it is considered that the two species of *Callithamniella*, *C. pacifica* (Hawaii and Korea) and *C. tingitana* (Japan), are distributed to the Pacific Ocean. To clarify the relationship among the *Callithamniella tingitana* and other species of the genus *Callithamniella*, and to redefine its generic circumscription, obervations of sexual reproductive organs and molecular analyses on the new materials from Ogasawara Islands are required.



Figs. 5–11. *Callithamniella tingitana* from Chichi-jima Island, Ogasawara Islands, Japan. 5. Apex of erect indeterminate axis with apical cell (a), issuing alternately determinate laterals. 6. Erect indeterminate axis with determinate laterals and tetrasporangia. 7–10. Various stages of tetrasporangia on unicellular pedicels (p). 7–8. Immature terasporangia. 9. Side view of mature tetrasporangium. 10. Front view of mature tetrasporangium. 11. Prostrate indeterminate axis bearing an erect indeterminate axes (i), three erect determinate axes (d) and three holdfasts with haptera (h).

Key to the species of *Callithamniella*

1a. Determinate axes and laterals unbranched 2
1b. Determinate axes and laterals often branched dichotomous 3
2a. Tetrasporangia 27–43 μm in length ..... *C. flexilis*
2a. Tetrasporangia up to 75 μm in length ..... *C. capensis*
3a. Branching of determinate axes occurring from the 6–7th proximal cells; tetrasporangia on the proximal cells of determinate laterals ..... *C. silvae*
3b. Branching of determinate axes occurring from the 3rd–5th proximal cells; tetrasporangia on the indeterminate axes 4
4a. Tetrasporangia long ovate, 22–90 μm in length, borne on 1–3 celled pedicels ..... *C. pacifica*
4b. Tetrasporangia ovate or ellipsoidal, 38–72 μm in length, borne on 1 celled pedicels ..... *C. tingitana*

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