

# First Record of *Compsopogon caeruleus* (Balbis ex C. Agardh) Montagne (Compsopogonophyceae, Rhodophyta) from Ogasawara Islands, Japan

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**Abstract** A benthic freshwater red alga, *Compsopogon caeruleus* (Balbis ex C. Agardh) Montagne (Compsopogonophyceae, Rhodophyta) was recorded from Ogasawara Islands, Japan, for the first time. This species differs from the other species of the genus *Compsopogon*, in having cortex of less than three cell-layer, without spinous or curling branchlets, though the size of monosporangia is not considered to be a useful taxonomic character in this genus. Finding of *C. caeruleus* from the extraordinary isolated islands suggested that this alga has any means of dispersion other than flooding of the river's water (e.g., remnant of marine regression, transportation by migratory birds).

**Key words:** *Compsopogon caeruleus*, Compsopogonales, Compsopogonophyceae, Ogasawara Islands, red algae.

A freshwater red alga referable to *Compsopogon caeruleus* (Balbis ex C. Agardh) Montagne (Compsopogonales, Compsopogonophyceae, Rhodophyta) was collected from the stream on Chichi-jima Island, the largest island in Ogasawara Islands (=Bonin Islands), Japan. This species has a wide distribution in the world: Europe, North America, Caribbean Islands, Western Atlantic, Asia, Australia, Hawaiian Islands, Vanuatu (Guiry and Guiry, 2011), though this is the first report from the Ogasawara Islands. In Japan, "*Compsopogon oishii* Okamura" had been used for this alga (Nakamura, 1993), which was believed to be endemic to Japan for a long time since its original description by Okamura (1915). He described the new species based on the plants collected by Yoshizo Oishi from "the mouth of Tamagawa River, Haneda-mura" (Haneda, Ota Ward, Tokyo) and "Yanokuchi, Prov. Musashi" (Komae City, Tokyo). But Vis *et al.* (1992) synonymized *C. oishii* under the cosmopolitan species, *C. caeruleus* as *C. coeruleus* (This spe-

cific epithet is often spelled "*coeruleus*", though C. Agardh (1824: 122) used "*Conferva caerulea*" (Guiry in Guiry and Guiry, 2006)). Since 2000, however, the Ministry of the Environment of Japan and the International Union for the Conservation of Nature treat this alga as a threatened species (Vulnerable) (Brodie *et al.*, 2009), because in recent years the habitats of this alga are being lost by rapid urbanization of the rural districts including isolated islands. It is also expected that addition of the Ogasawara Islands to UNESCO's list of the natural "World Heritage Site" on June 24, 2011 will have any influence on the habitat of the alga.

The genus *Compsopogon* Montagne (1846, p. 152) is a macroscopic genus placed under the family Compsopogonaceae with another macroscopic genus *Compsopogonopsis* Krishnamurthy (1962) and a microscopic genus *Pulvinaster* West, Zuccarello *et al.* (2007). *Compsopogon* is distinguished from *Compsopogonopsis* in lacking rhizoidal cortication throughout thallus. The

delimitation of these genera in this family is not so disputed, while there are differing views upon the number of species in the *Compsopogon*. Vis *et al.* (1992) recognized only two species of the genus, *Compsopogon caeruleus* (Balbis ex C. Agardh) Montagne (as *C. coeruleus*) and *C. prolificus* Yadava et Kumano, using multivariate morphometrics and image analyses for compsopogonalean taxa in North America and examining the type specimens of seven taxa of the genus. On the other hand, Seto and Kumano (1993) also examined type specimens of almost the same taxa of the genus and reappraised the several species of the genus: *C. aeruginosus* (J. Agardh) Kützing (1849), *C. corticrassus* Chihara et Nakamura (1980), *C. chalybeus* Kützing (1849).

In this study, to confirm the identity of the present plants collected from Ogasawara islands and to clarify the morphological characters for the species of *Compsopogon* in Japan, anatomical observations were made on the material using a microscope. For preservation, the material was dried on sheets of paper or fixed in 10% formalin-seawater. Voucher specimens were deposited in the algal herbarium of the National Museum of Nature and Science (TNS). In addition, to define geographical distribution of the species in Japan, the dried specimens were investigated in the herbaria of Department of Botany, TNS and Hokkaido University Museum (SAP).

### Description

Order Compsopogonales Skuja, 1939

Family Compsopogonaceae Schmitz in  
Engler et Prantl, 1897

#### ***Compsopogon caeruleus*** (Balbis ex C. Agardh)

Montagne in Durieu De Maisooneuve, Exploration scientifique de l'Algérie pendant les années 1840, 1841, 1842. Sciences physiques. Botanique. Cryptogamie **1**: 154 (1846).

Basionym: *Conferva caerulea* Balbis ex C. Agardh, Systema algarum: 122 (1824) [Type locality: Puerto Rico, Antilles, Caribbean (Seto

and Kumano, 1993)].

Synonyms: *Conferva chalybeus* Kützing, Species algarum: 432 (1849); *Conferva cornaldii* Kützing, Tabulae Phycologicae **7**: 35 (1857); *Conferva oishii* Okamura, Icones of Japanese Algae **3**: 128 (1915).

[Figs. 1–7]

Plants bluish green or reddish brown in color, entangled, epilithic on stone or epiphytic on withered branches of tree in the stream (Fig. 1). Thalli filamentous, slender, branched repeatedly and profusely, up to 40 cm in length and 25–360  $\mu\text{m}$  in width (Figs. 2, 3). Young laterals uniseriate, rounded at the apex, acute angle with the main branch (Fig. 4). Mature branches uniaxial, corticated, composed of an axial cell and 1–2 celled cortical layers, without rhizoidal filaments on the surface (Fig. 5). Axial cells colorless, barrel-shaped. Cortical cells small, spherical to cuboidal, 12–32  $\mu\text{m}$  in width  $\times$  15–48  $\mu\text{m}$  in length in surface view. Spinous or curing branchlets absent.

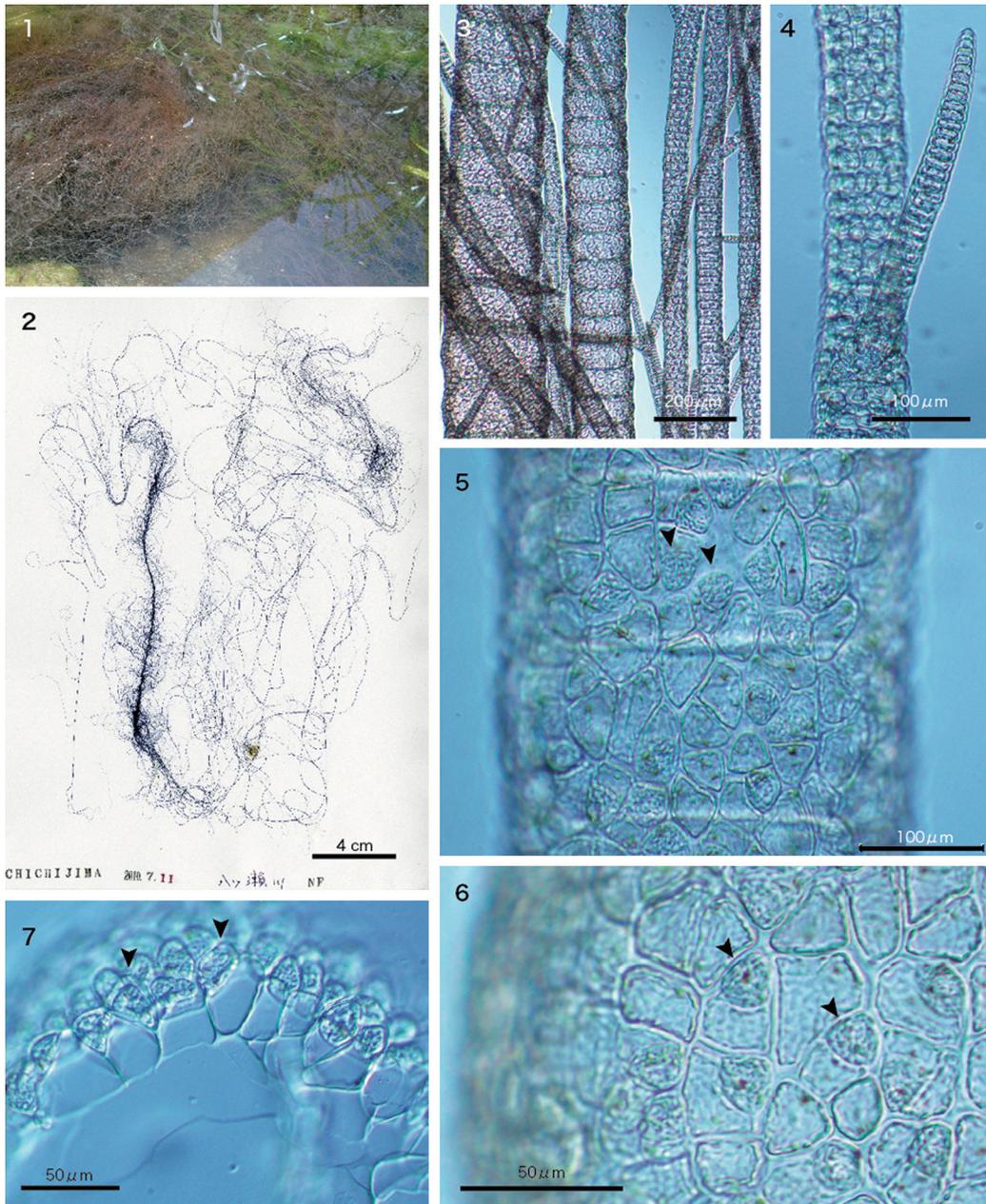
Monosporangia pigmented, scattered over mature branches, spherical or triangle to polygonal, 12–16  $\mu\text{m}$  in width in surface view (Fig. 6). The sporangia embedded in the cortical layer, formed by dividing unequally from the upper side of the cortical cell (Fig. 7).

Specimens examined: Near Ose-bashi Bridge, Yatsuse-gawa River, Kominato, Chichi-jima Island, Ogasawara Isls., Japan (27°03'34"N, 142°12'18"E), 11 July 2010, leg. T. Kitayama (TNS-AL 17302–17304).

Distribution: *Asia*: Japan (Fig. 8), China (Hu and Wei, 2006); *Oceania*: Hawaii (Sherwood, 2004), Vanuatu (West *et al.*, 2007); *Australia*: Lord Howe Island (Millar and Kraft, 1993); *North America*: Florida (Taylor, 1960), Louisiana (Taylor, 1960); *Central America*: Dominica (Taylor, 1969); *Africa*: Algeria (Krishnamurthy, 1962); *Europe*: England (Krishnamurthy, 1962).

### Discussion

The present *Compsopogon* plants from Chichi-jima Island, Ogasawara Islands, are identified as



Figs. 1–7. *Compsopogon caeruleus* (Balbis ex C.Agardh) Montagne from Chichi-jima Island, Ogasawara Isls., Japan. 1. Habitat. 2. Habit. (TNS-AL 17302). 3. Erect filaments. 4. Young uniseriate lateral on mature branches. 5, 6. Surface view of erect filament showing cortical cells with monosporangial cells (arrowheads) on barrel-shaped axial cells. 7. Transverse section of erect filament showing monosporangia (arrowheads) produced from cortical cells by unequal cell division.

*C. caeruleus* because of the frequent ramification in erect filaments, formation of a few cell-layers in cortex, lacking spinous or curling branchlets.

These characters also agree mostly to the description in *C. oishii*, which has been recorded from many sites of main land of Japan since

Okamura (1915).

However, the plants from Chichi-jima Island have small monosporangia, which are 12–16  $\mu\text{m}$  in width, while size of monosporangia or monospores of *C. caeruleus* (or *C. oishii*) had been described large as 15–21  $\mu\text{m}$  in diameter (Nakamura, 1984), 7.5–27.5  $\mu\text{m}$  in length (Vis *et al.*, 1992), (16–)20–23  $\mu\text{m}$  in diameter (Seto and Kumano, 1993). According to Seto and Kumano (1993) and Kumano (2002), *C. chalybeus*, which is European species, has small monospores, 10–16  $\mu\text{m}$  in diameter. In their system for *Compsopogon*, the Chichi-jima's plants can be identified as *C. chalybeus*. There was no record of *C. chalybeus* in Asia including Japan, but recently Liu and Wang (2004) reported this species from Pingtung County, Taiwan, following Kumano (2002)'s system. The plants from Taiwan are also similar to the plants of the Chichi-jima Island in having small monosporangia, which are 12–16  $\mu\text{m}$  in diameter. In India, Ratha *et al.* (2007) reported three ecotypes of *C. caeruleus* (as *C. coeruleus*), whose monosporangia differ in size, depending on difference of water habitats (e.g., water temperature, pH, conductivity, salinity): the first ecotype, 16.4–22.3  $\mu\text{m}$  in diameter; the second, 10–18.3  $\mu\text{m}$  in diameter; the third 8.6–14  $\mu\text{m}$  in diameter. In Japan, it was observed that the seasonality made a difference to size of monospores in the plants of *C. caeruleus* (as *C. oishii*) living in the little irrigation canal in Katori City, Chiba Pref. in 1992: Diameters of monospores from the same population were measured as 13.2–16.8  $\mu\text{m}$  on 29 May 1992, and then 17.2–22.1  $\mu\text{m}$  on 23 October 1992 (Yamaoka, unpublished). Thus I consider that size of monospore and monosporangia is not so useful as a taxonomic character for *Compsopogon* and treat the alga from Chichi-jima as *C. caeruleus* provisionally until the system of the genus will be stabilized.

Fig. 8 shows the geographical distribution of *Compsopogon caeruleus* in Japan based on the herbarium specimens deposited in SAP and TNS, and literature data. It suggests that habit of this alga has a tendency to be close to seacoasts or es-

tuaries along the Pacific side of the Japan Archipelago. Thaxter (1900) collected *Compsopogon* spp. from Cocoanut Grove, along the shores of Biscane Bay, Florida and Taylor (1960) noted that *C. caeruleus* is often abundant in tidal creeks near the coast of Florida and Louisiana. Ratha *et al.* (2007) collected *C. caeruleus* from the channel of an estuary and Chilika lagoon in the Orissa state, India. There is a possibility that *Compsopogon caeruleus* is a brackish and freshwater alga. Nozawa (1971) studied the effect of salinity on the germination of monospores in *C. caeruleus* (as *C. oishii*) and showed that formation and liberation of monospores was stimulated in between 0.8–16.6‰ (max in 6.8‰). He concluded that the reproduction and distribution of this alga might have connection with seawater or saline water. Also Glazer *et al.* (1994) showed that *C. caeruleus* (as *C. coeruleus*) has a capability to grow and reproduce in salinities up to 35‰ and a possibility of its being adapted secondarily to freshwater from marine habitats. Finding of the alga from Chichi-jima Island, where is a volcano island formed around 46–48 million years ago (Ishizuka *et al.*, 2006) and isolated geographically from main lands extraordinarily, suggests that this alga has any means of dispersion other than flooding of the water between two rivers. Thus two hypotheses are possible: 1) remnants of the algal habitats by marine regression in geological eras, and 2) recent transportation of the algal plants among the islands or continents by migratory birds. In particular, it is suspected that long distant migrants living on both rivers and seacoasts (e.g., Scolopacidae, Charadriidae) are movers for the alga. Judging from the distribution clustering to Pacific side of Japan, if migratory birds flying from the South Pacific carry its plants or spores, there may be also a possibility of that the habitats of *C. caeruleus* are rest areas for them. More information on distribution of the species is required for verifying these hypotheses.

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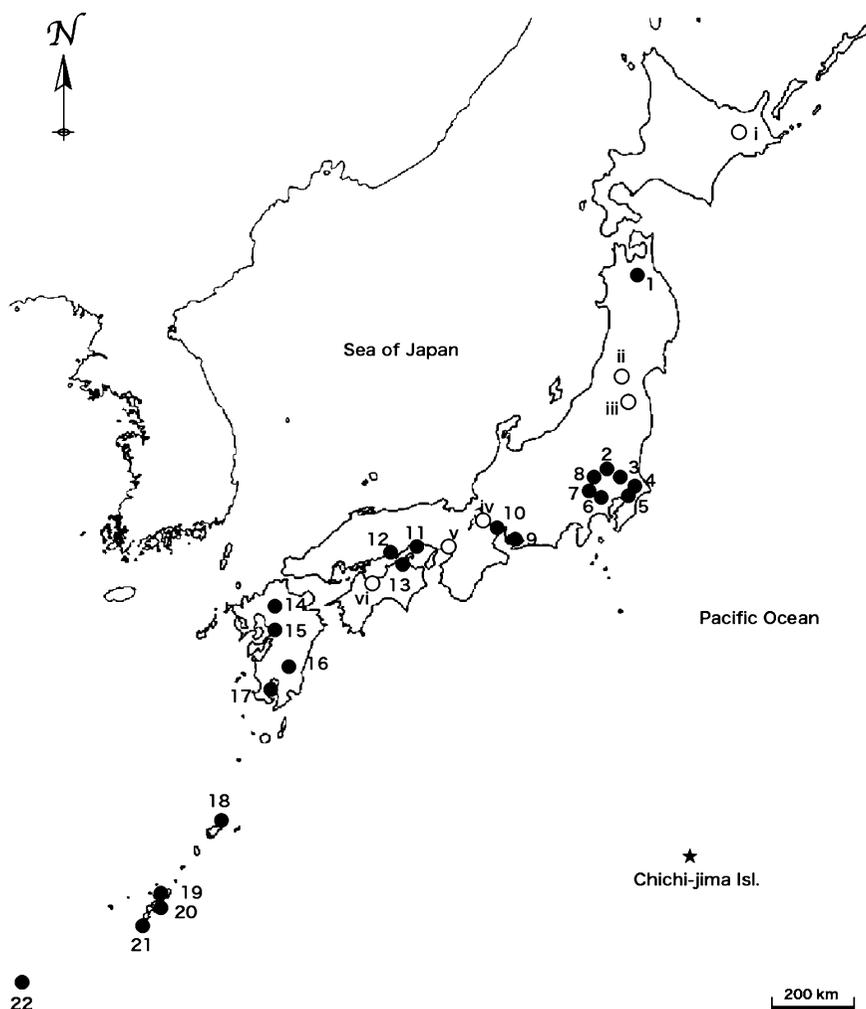


Fig. 8. Geographical distribution of *Compsopogon caeruleus* (Balbis ex C. Agardh) Montagne in Japan based on dried specimens from the herbaria (SAP, TNS) and literatures.

Filled circles (●): specimens investigated. 1. Yamatosawa, Hirosaki, Aomori Pref., 19 Feb. 2008, leg. Y. Ishitoya (TNS-AL 163530). 2. Tatebayashi, Gunma Pref., 23 Sep. 1971, leg. M. Chihara (TNS-AL 152359). 3. Mitsukaido, Ibaraki Pref., 14 May 2004, leg. A. Higa (TNS-AL 164542). 4. Yorogo, Katori, Chiba Pref., 10 Aug. 1991, leg. Y. Yamaoka (TNS-AL 173605). 5. Yachiyo, Chiba Pref., 15 Dec. 2001, leg. M. Suzuki (TNS-AL 166738). 6. Omiya, Tokyo Metr., 3 Jan., leg. K. Hisauchi (TNS-AL 166014). 7. Honjo, Saitama Pref., 19 Nov. 1972, leg. T. Hashimoto (TNS-AL 157097). 8. Sakai, Gumma Pref., 20 Aug. 1969, leg. M. Hasei (TNS-AL 24055). 9. Akamatsu, Anjo, Aichi Pref., 1951 (?), leg. Anonymous (TNS-AL 157116). 10. Imafuku, Ogaki, Gifu Pref., 26 Oct. 2001, leg. S. Arai (TNS-AL 164286). 11. Okada, Himeji, Hyogo Pref., 13 Dec. 1952, leg. H. Kiyose (TNS-AL 157117). 12. Kojima Lake, Okayama Pref., 8 Aug. 1974, leg. Anonymous (TNS-AL 157099). 13. Gobo River, Takamatsu, Kagawa Pref., 4 Dec. 1985, leg. R. Seto (TNS-AL 157122). 14. Hiratsuka River, Amagi, Fukuoka Pref., 2 Nov. 2004, leg. T. Yoshida (SAP 101406). 15. Imizu, Kumamoto Pref., 15 Feb. 2004, leg. T. Yoshida (SAP 97970). 16. Takaharu, Nishimorokata, Miyazaki Pref., 18 Dec. 1999, leg. T. Minamiya (TNS-AL 164284). 17. Campus of Kagoshima University, Kagoshima, Kagoshima Pref., 13 Apr. 1974, leg. K. Nozawa (TNS-AL 157110). 18. Tatsugo, Amami-oshima, Kagoshima Pref., 3 May 2005, leg. S. Arai (TNS-AL 164399). 19. Onna, Okinawa Pref., 9 Mar. 2004, leg. S. Arai (TNS-AL 164350). 20. Oyama, Okinawa Pref., 10 May 1957, leg. S. Kamura (TNS-AL 157109). 21. Osato, Ito-man, Okinawa Pref., 6 Apr. 1977, leg. R. Seto (TNS-AL 157107). 22. Kabira, Ishigaki Isl. Okinawa Pref., 19 May 2007, leg. Suda (TNS-AL 164463). Open circles (○): literature data. i. Lake Akan, Hokkaido (Kumano, 2000). ii. Lake Hakuryu, Yamagata Pref. (Ohnuma and Hara, unpublished). iii. Marsh Yunuma, Urabandai, Fukushima Pref. (Kumano, 2000). iv. Ohmi-hachiman, Shiga Pref. (Kumano, 2000). v. Maikata, Osaka Pref. (Kumano, 2000). vi. Doi, Ehime Pref. (Kobayashi, 2003). Star (★): the present alga.

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