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Research note

Morphology and life history of *Coelocladia arctica* (Dictyosiphonales, Phaeophyceae), new to Japan*

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SUMMARY

The occurrence of *Coelocladia arctica* Rosenvinge (Dictyosiphonales, Phaeophyceae) is reported for the first time in the Pacific Ocean, from Oshoro, Hokkaido, Japan. The field material was approximately 30 mm in height, up to 300 μm in diameter, 2–3 times irregularly branched and provided with phaeophycean hairs and plurilocular sporangia. The thallus was composed of several (usually four) large, hyaline, rounded, isodiametric inner cells, with smaller subcortical and pigmented cortical cells. The plurilocular sporangia were 3–4 celled, often branched, and protruded from the cortical cells, arranged in a crown-shaped complex. In culture, the plurispores germinated unipolarly leaving an emptied original spore wall, and developed into a branched protonema. Cells of the protonema as well as the erect thallus contained several disc-shaped chloroplasts with pyrenoids. Uniseriate erect filaments arose from the protonema, then became polystichous and formed branches. Unilocular sporangia were never observed in the field or in cultured material. Erect thalli were formed under culture conditions of 5–15°C, and developed a thick parenchyma at 5–10°C, irrespective of the day length.

Key words: *Coelocladia arctica,* Dictyosiphonales, life history, morphology, Phaeophyceae.

INTRODUCTION

Coelocladia arctica Rosenvinge, a dictyosiphonalean brown alga, was described by Rosenvinge (1893) based on specimens collected from Ujarasgssuk on Disko Island at Vaigattet, West Greenland. Since then, there have been very few records of the species (Rosenvinge 1898 as *Kjellmania subcontinua* Rosenvinge; Zinova 1957; Jaasund 1965; Pedersen 1976). Among them, as suggested by Pedersen (1976), the identification of the material from North Norway (Jaasund 1965) was doubtful because the morphology of the plurilocular sporangia was not typical of *C. arctica.* The report from East Siberian Sea (Zinova 1957) was also not convincing as the identification was based on sterile material (Jaasund 1965). The third report of the species from West Greenland (Godthåbsfjorden) was based on cultured material obtained from a crude culture of a *Dictyosiphon* species. Nevertheless, Pedersen (1976) identified the material as *C. arctica,* and placed it in his new family Coelocladiaceae in the order Dictyosiphonales. Thus, there have been no substantial field collections of *C. arctica* since the original description. In the present paper, the morphology and life history of this little known species is described based on material collected at Oshoro, Hokkaido, Japan, a new record from the Pacific Ocean.

Field observations and collections were made at Oshoro, Hokkaido, Japan (43°16′N, 140°52′E) on 1 May and 24 May 1988. Morphological observations by light microscopy were made on living material, as well as material preserved in 3–5% formaldehyde–seawater. Photomicrographs were taken using Nomarski optics, or after staining with dilute aniline blue (in 50% Caro Syrup).

Erect thalli were found in a small sheltered bay, mixed with *Scytosiphon lomentaria* (Lyngbye) Link and *Sphaerotrichia divaricata* (C. Agardh) Kylin. They grew on shells or pebbles in the upper subtidal zone 1–2 m below LLW, solitary or in groups. They resembled *Stictyosiphon soriferus* (Reinke) Rosenvinge in appearance and could hardly be distinguished by the naked eye. The erect thalli were up to approximately 30 mm in height and 300 μm in diameter, and were sparsely cylindrical and 2–3 times irregularly branched (Figs 1–4), and yellowish brown in color. The basal parts of the erect thalli were composed of rhizoidal filaments forming a small, cushion-shaped holdfast (Fig. 2) attached to the substrate. In cross section, the thallus was composed of several (usually four) large, hyaline, rounded,

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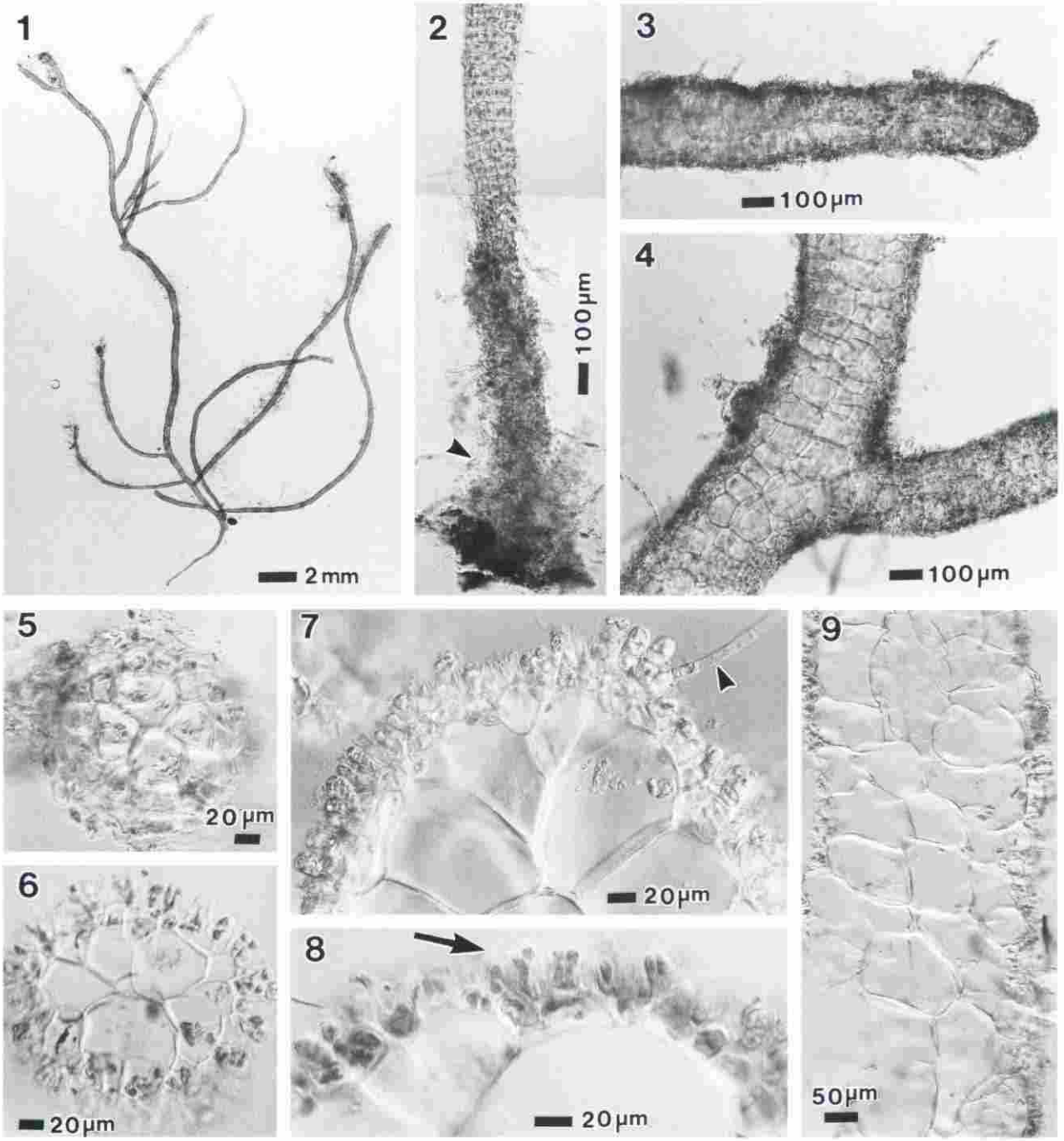
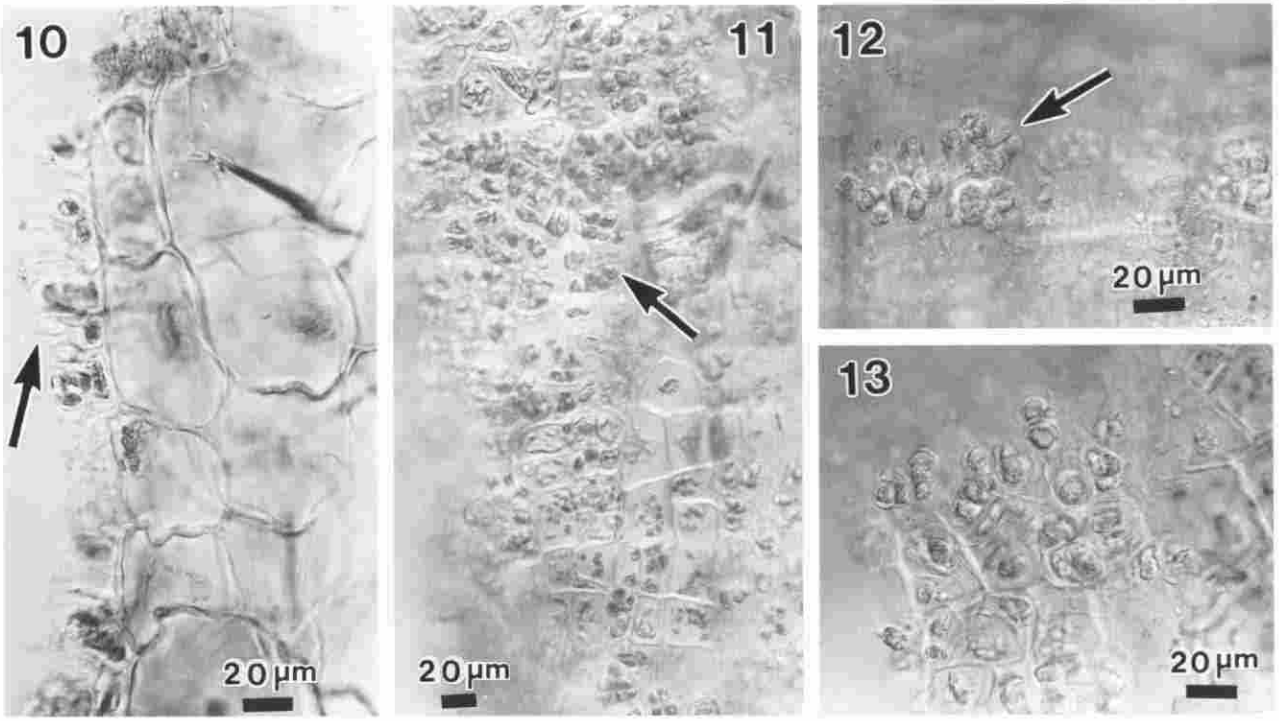


Figs 1–9. *Coelocladia arctica* Rosenvinge. Morphology of the field material from Oshoro, Hokkaido. 1. Habit of the whole thallus. 2. Rhizoidal holdfast (arrowhead) and lower part of the thallus. 3. Terminal part of a parenchymatous branch. 4. Branching. The plane of focus is in the interior of the main axis showing the round inner isodiametric cells. 5. Uppermost part of the erect thallus in cross section. 6. Thin fertile branch in cross section. 7, 8. Thick fertile branches in cross section. Arrowhead shows a phaeophycean hair; arrow shows plurilocular sporangia. 9. Thick main axis in longitudinal section.

isodiametric inner cells (88–128 × 72–100 µm), a single layer of subcortical cells and pigmented cortical cells (up to 20 µm in thickness; Figs 5–8). The length of the inner cells was shorter than the width in longitudinal section (Fig. 9). Phaeophycean hairs (8–16 µm in diameter) arose among the cortical cells (Fig. 7). The plurilocular sporangia were formed in sori (Figs 11, 13), later covering most of the thallus surface (Figs 6–8). They were 3–4 celled, up to 20 µm in length, often branched, and later protruded from the cortical cells, arranged in a crown-shaped complex (Figs 7, 10, 12). The tip of each of the sporangia formed a release pore.

Cultures were started from zoids released from plurilocular sporangia on erect thalli collected on 24 May 1988. The zoids were pipetted onto glass slides and cultured in glass vessels containing 200 mL of PESI



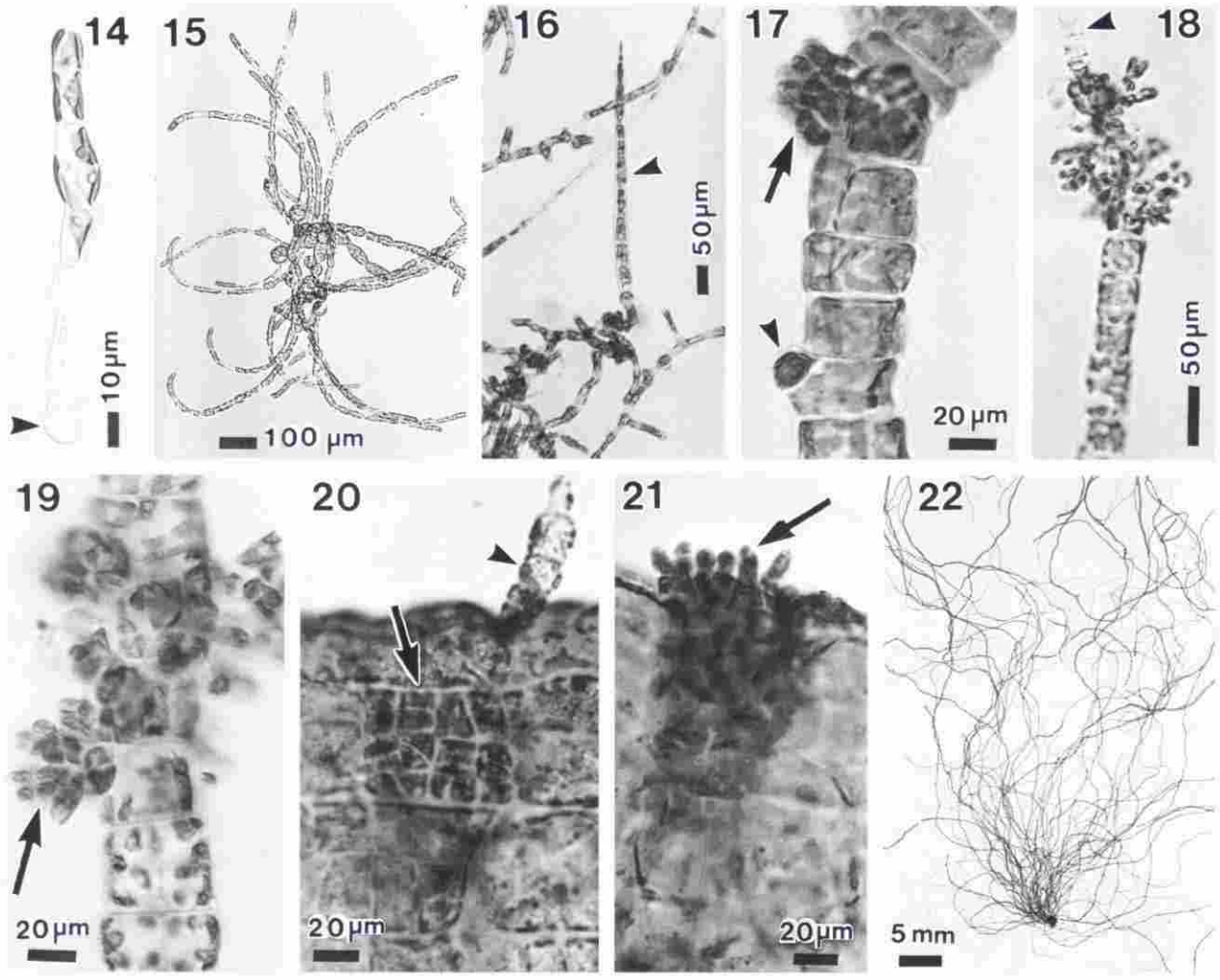
Figs 10–13. *Coelocladia arctica* Rosenvinge. Morphology of the plurilocular sporangia in field material. 10. Partly emptied plurilocular sporangia (arrow) in longitudinal section. 11. Surface view of vegetative and fertile parts of the main axis. Arrow shows plurilocular sporangia. 12, 13. Fertile, protruded plurilocular sporangia (arrow) in surface view.

medium (Tatewaki 1966). The sets of culture conditions used were: 5 °C SD (short day, 8:16 h L:D), 5 °C LD (long day, 16:8 h L:D), 10 °C SD, 10 °C LD, 15 °C SD, 15 °C LD, 20 °C SD and 20 °C LD, under daylight-type white fluorescent lighting of approximately 30 µmol $m^{-2}s^{-1}$ (5 °C) or 50 µmol $m^{-2}s^{-1}$ (10 °C, 15 °C, 20 °C). The culture strain of the material from West Greenland (Pedersen G-154) studied by Pedersen (1976) was also cultured under 10 °C LD for morphological comparisons.

The plurispores (zoids) released from the plurilocular sporangia of the mature, field-collected material were flagellated normally (long anterior flagellum and short posterior flagellum), contained a chloroplast with a stigma, and showed positive phototaxis. They showed a green flagellar autofluorescence in the posterior flagellum (Kawai 1988, 1992). They germinated unipolarly leaving an emptied original spore wall (Fig. 14), and developed into branched, uniseriate prostrate filaments (Fig. 15). Cells of the prostrate filaments contained several disc-shaped chloroplasts with pyrenoids (Fig. 14). No hairs or reproductive structures were formed on the prostrate filaments. Uniseriate erect filaments with a terminal hair arose on the prostrate filaments (Fig. 16). The erect filaments gradually became polystichous in the middle–upper portions (Fig. 17), and occasionally formed branches. Cells of erect thalli contained several disc-shaped chloroplasts with pyrenoids (Fig. 17). These cells were larger and more highly vacuolated than those of the prostrate filaments. Plurilocular sporangia were formed on the parenchymatous portion of erect thalli, in crown-shaped arrangements (Figs 17–19). The plurilocular sporangia did not protrude from the thicker parenchymatous portions of the thallus when young (Fig. 20), but later became protruded (Fig. 21). Terminal (Fig. 18) and lateral (Fig. 20) hairs without an obvious sheath were present on the erect thalli. Well-grown erect thalli were up to approximately 60 mm in height (Fig. 22). The erect thalli developed under 5–15 °C culture conditions, but were rare at 20 °C, irrespective of the photoperiod. The thalli became thicker and polystichous under lower temperatures (5, 10 °C), but tended to stay uniseriate at higher temperatures (15 °C). Unilocular sporangia were not formed under all of the culture conditions examined.

The type specimen of *C. arctica* housed in the Botanical Museum, Copenhagen, was examined for comparison. The gross morphology and the presence of the distinctive, crown-shaped plurilocular sporangia in the Japanese material agree well with the original description (Rosenvinge 1893) and the type specimen of *C. arctica*. The Japanese specimens were somewhat smaller than the type (3 cm *vs* 10 cm). However, such features are generally rather variable depending on environmental conditions, and furthermore, the Japanese material grew up to 6 cm in culture. Therefore, I identify the Japanese material as *C. arctica*.

In culture, Japanese *C. arctica* showed a direct type of life history repeating the polystichous erect thalli that form plurilocular sporangia. The prostrate filaments



Figs 14–22. *Coelocladia arctica* Rosenvinge in culture. 14. Three-celled germling of a plurispore with emptied original spore wall (arrowhead). 15. Branched prostrate filaments (protonema). 16. Young erect thallus (arrowhead) from the protonema. 17. Partly polystichous erect thallus forming plurilocular sporangia (arrow). Arrowhead shows initial of plurilocular sporangia. 18. Plurilocular sporangia formed at the terminal part of a uniseriate erect thallus, terminated with a phaeophycean hair (arrowhead). 19. Protruded plurilocular sporangia in crown-shaped arrangement (arrow) formed on a uniseriate erect thallus. 20. Young, flat plurilocular sporangia formed on a thick parenchymatous thallus (arrow) and a phaeophycean hair (arrowhead). 21. Fertile, protruding plurilocular sporangia (arrow) on a thick parenchymatous thallus. 22. Habit of a well-developed erect thallus in culture.

never formed reproductive structures in any of the culture conditions examined and, therefore, appear to be protonemata. This life-history pattern and the morphology of the vegetative and reproductive structures agree well with the culture results of Pedersen (1976) on Greenland material, and are confirmed by the present experiments.

Pedersen (1976) pointed out the morphological resemblance of the plurilocular sporangia of *Litosiphon subcontinus* (Rosenvinge) S. Lund 1959 (=*K. subcontinua* Rosenvinge 1898) and *C. arctica*, and concluded that the former taxon is an unbranched form or a fragmentary thallus of the latter.

As pointed out by Kawai (1991), the plurilocular sporangia illustrated in figs 1–3 of Yamada (1953) and figs 15 and 16 of Arasaki and Nozawa (1953) of *Kjellmania arasakii* Yamada (=*S. soriferus* [Reinke] Rosenvinge, Kawai [1991]) collected in Tokyo Bay were distinctive in their crown-shaped morphology. They resembled those of *C. arctica* or *L. subcontinus* (Rosenvinge) S. Lund (= *C. arctica* after Pedersen 1976), rather than those of *Stictyosiphon* or *Kjellmania*. Therefore, if those materials are indeed identical to *C. arctica*, the southern distributional boundary of this species would be warm temperate in the Pacific coast.

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