

## *Plocamium serrulatum* (Plocamiaceae), a red algal species newly recorded in Korea

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**Abstract:** A marine red algal species was collected from Uljin, located on the eastern coast of Korea, during a survey of marine algal flora. This alga shares the generic features of *Plocamium*, and is characterized by linear, flat and thin thalli with narrow axes, branches developing in alternating pairs from margins of the axes, two to four times alternately pinnately branching, linear or occasionally adaxially curved lowermost branchlets and distinctly and compactly clustered stichidia. In a phylogenetic tree based on *rbcL* sequences, the Korean alga nests in the same clade as *P. serrulatum*. The genetic distance between both sequences within the clade was calculated as 0.0–0.2%. Based on the morphological and molecular data, this Korean species is identified as *P. serrulatum* described originally from Taiwan. This is the first record of *P. serrulatum* in Korean marine algal flora.

**Keywords:** *Plocamium serrulatum*, red alga, morphological and molecular data, Korea

## INTRODUCTION

*Plocamium* Lamouroux (1813), which is a red algal genus currently thought to contain 45 species, is widely distributed throughout the world's oceans. However, it is most diverse in the southern hemisphere (Cremades *et al.* 2011; Guiry and Guiry 2020). Silva *et al.* (1996) reported 16 species from the Red Sea. Some of these also have distributions more or less restricted to South Africa, whereas several others are known only from western Australia (Wynne 2002). In Korea, six species of *Plocamium* have been recorded (Kim *et al.* 2013).

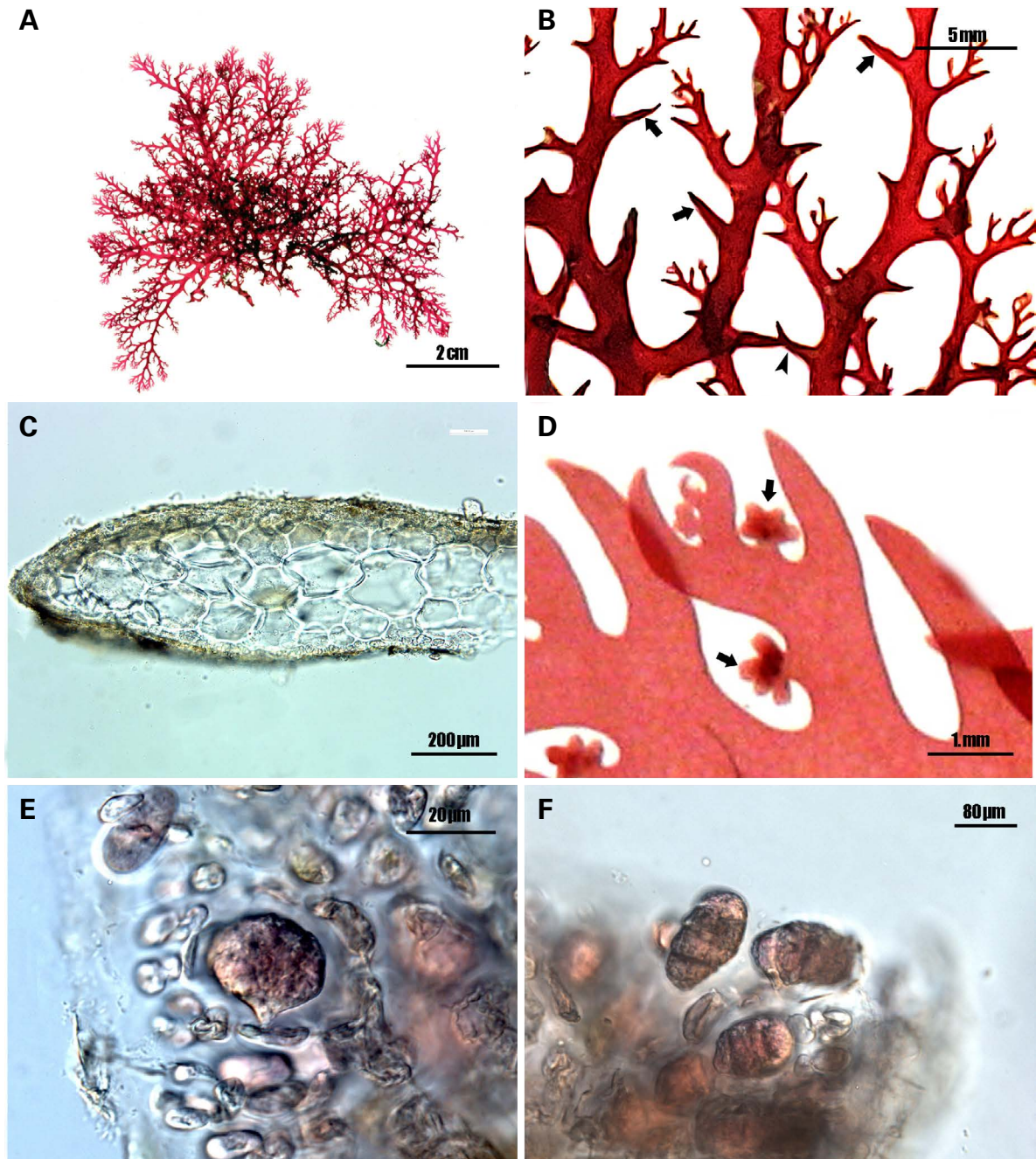
Traditional taxonomy distinguishes between *Plocamium* species largely on the basis of the number of ramuli in alternating series, the morphology of the lower ramuli, the length, width, color and consistency of the thallus, and the morphology and arrangement of tetrasporangial stichidia and cystocarps (Simons 1964; Womersley 1971; South

and Adams 1979; Gabrielson and Scagel 1989; Cremades *et al.* 2011).

During the indigenous survey of marine algal flora, a species belonging to *Plocamium* was collected from Uljin in Korea. This is identified based on morphological and molecular data, and is newly recorded in Korea herein.

## MATERIALS AND METHODS

Specimens for this study were collected from Onyang-ri, Uljin located in the eastern coast of Korea. Taxonomic data were obtained from fresh, liquid-preserved and herbarium specimens. Liquid-preserved material was stored in a 10% solution of Formalin/seawater. Blades dissected from the cleared materials were hand sectioned, transferred to a slide with distilled water, and mounted in pure glycerin. For permanent slides, the glycerin was exchanged with 10–20%



**Fig. 1.** *Plocamium serrulatum* Okamura. A. Habit of vegetative plants with narrow axes. B. Details of branches developing in alternating pairs from margins of the axes with linear (arrows) or occasionally adaxial curving lowermost branchlets (arrowhead). C. Transverse section of main branch. D. Distinct and compact clustered stichidia (arrows). E. Young tetrasporangium cut off from cortical cell of stichidium. F. Fully developed tetrasporangia divided zonately.

corn syrup.

Total genomic DNA was extracted from silica-gel-preserved sample using the DNeasy Plant Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's pro-

ocol. Before extraction, dried material was crushed with liquid nitrogen using a mortar and pestle. Extracted DNA was used for amplification of ribulose-1, 5-bisphosphate carboxylase large subunit (*rbcL*) regions. For *rbcL*, the gene

was amplified in three overlapping parts with the primer pairs *FrbcL* start (5'-TGTGTTGTCGACATGTCTA-  
ACTCTGTAGAAG-3') - R753 (5'-GCTCTTTCATA-  
CATATCTTCC-3'), F492 (5'-CGTATGGATAAATTTG-  
GTCG-3') - R1150 (5'-GCATTTGTCCGCAGT-  
GAATACC-3'), and F993 (5'-GGTACTGTTGTAGG-  
TAAATTAGAAGG-3') - *RrbcS* (5'-TGTGTTGCGGC-  
CGCCCTTGTGTT AGTCTCAC-3') (Freshwater and  
Rueness 1994). PCR amplifications were performed in  
a TaKaRa PCR Thermal Cycler Dice (TaKaRa Bio Inc.,  
Otsu, Japan). PCR was performed with an initial dena-  
turation step at 94°C for 4 min, followed by 35 cycles of 1  
min at 94°C, 1 min at 50°C, and 2 min at 72°C, with a final  
7-min extension at 72°C. The PCR products were moved  
to Macrogen Sequencing Service for sequencing (Mac-  
rogen, Seoul, Korea). Sequences for the *rbcL* region were  
aligned using BioEdit (Hall 1999). Phylogenetic analyses

were performed using maximum-likelihood methods.  
Bootstrap values were calculated with 1,000 replications.  
*RbcL* sequences of other species were obtained from Gen-  
Bank. *Sarcodia montagneana* (J.D. Hooker & Harvey) J.  
Agardh was used as an outgroup.

## RESULTS AND DISCUSSION

### *Plocamium serrulatum* Okamura 1932

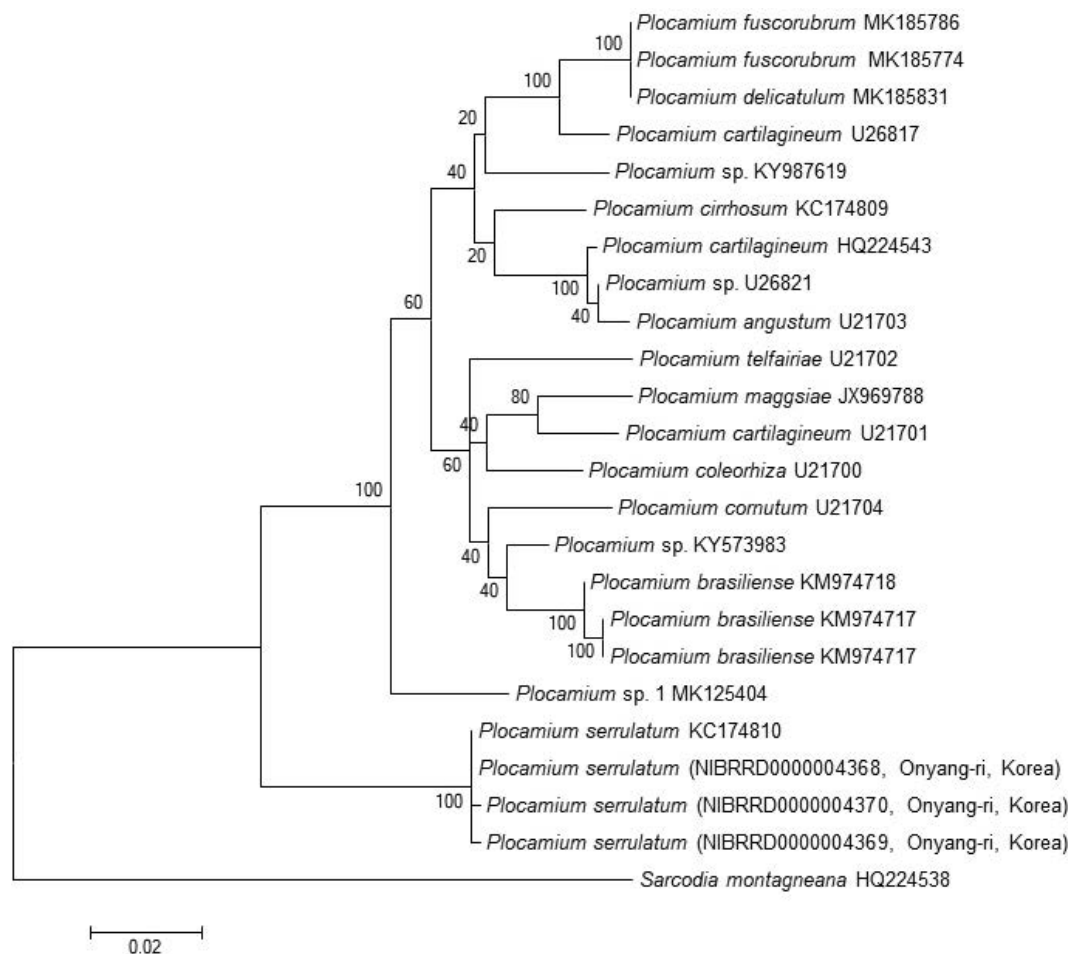
Korean name: Yal-beun-gop-seu-ri nom. nov.

(신칭: 얇은곱슬이)

Type locality: Kotosho, Taiwan (Aoki, Segawa) (Guiry and  
Guiry 2020).

Specimens examined: NIBRRD0000004368–NIBRRD  
0000004370 (Onyang-ri, Uljin: 26.viii.2014).

Habitat: Epilithic near upper to lower intertidal.



**Fig. 2.** Phylogenetic tree of *Plocamium* species obtained from maximum-likelihood method based on *rbcL* sequences. Bootstrap proportion values (1,000 replicates samples) are shown above branches. Scale bar = 0.02 substitutions/site.

Morphology: Thalli erect, 5–10 cm in height, linear, flat, bright red in color, attached by a conspicuous holdfast; main axes narrow, 1–2 mm wide, narrowing to 0.5 mm distally, thin membranous, 800–900 µm thick; branches developing in alternating pairs from margins of the axes, with 2–4 times alternately pinnately branched; proliferous branchlets formed mainly in the lower part of lateral branches; lowermost branchlet linear, occasionally adaxially curved; tetrasporangial initial cut off from cortical cell of stichidium; tetrasporangial stichidia distinct and compact clustered, stellate, cylindrical or branched divaricately, scattered among the branches of the proliferations; tetrasporangia divided zonately. Sexual thalli were not collected.

The first dichotomy patterns, such as the ramuli in alternating pairs or alternating series of three to four (or more), are considered to be significant in most keys to species of *Plocamium* (Simons 1964; Womersley 1971, 1994; South and Adams 1979; Yoshida 1998). In addition, the width of the main axes is also be useful (Wynne 2002; Yano *et al.* 2004). According to the original description from Kotosho, Taiwan (Okamura 1932), *Plocamium serrulatum* appears to fall into the former branching type with narrow axes rather than the latter dichotomy pattern with broad axes. These features are basically found in Korean alga collected from Uljin in the present study (Fig. 1A, B). In gross morphology together with the branching pattern, the Korean entity is similar to *Plocamium serrulatum*. It has linear, flat and thin thalli with narrow axes and two to four times pinnate alternating pairs in branching (Fig. 1A, B) as reported by Okamura (1932).

Lowermost branchlet shape is also important for distinguishing between *Plocamium* species (Yano *et al.* 2004). *P. serrulatum* appears to be an adaxial curving type based on the original description (Okamura 1923, p. 189, pl. 198, f. 1–4, as *P. costatum*). However, both types of adaxial curving and linear shape in the branchlets are observed in Korean alga, even though the former shape only occurs occasionally (Fig. 1B).

The position of tetrasporangial stichidia varies among *Plocamium* species (Womersley 1971; Gabrielson and Scagel 1989). *P. serrulatum* shows distinctly and compactly clustered stichidia of divaricate and stellate shape in the usual form (Okamura 1932). This feature is also found in the Korean alga (Fig. 1D).

In the phylogenetic tree based on *rbcl* sequence, the sequence of the Korean alga nests in the same clade as that of *P. serrulatum* from the type locality (Taiwan) with a genetic distance of 0.0–0.2% (Fig. 2). These morphological

and molecular evidence suggests that this Korean species should be identified as *P. serrulatum*. This is the first record of the *Plocamium serrulatum* in Korea.

## ACKNOWLEDGEMENTS

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