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A new species of marine algae from Korea based on morphology and molecular data: *Gelidium palmatum* sp. nov. (Gelidiales, Rhodophyta)

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Two species of the agar-yielding genus *Gelidium*, *G. galapagense* and *G. isabelae*, have previously been reported from Korea but their occurrence has not been confirmed with molecular data. We intensively collected samples of *Gelidium* from Jeju Island, where the two species were reported, and the southern coast of Korea. Phylogenetic analyses based on *cox1* and *rbcL* sequences revealed that only a single species occurred in Korea. The Korean species was distantly related to *G. galapagense* and *G. isabelae* from the Galápagos Islands, and formed a clade with *G. microdonticum*, *G. millarianum*, and *G. pakistanicum*. A new species, *G. palmatum*, is described for those specimens that were previously recognized as either *G. galapagense* or *G. isabelae* from Korea. *G. palmatum* is small in size (up to 0.7 cm), with compressed, lanceolate axes, irregular, digitate to palmate branches, abundant rhizines in the medulla, tetrasporangial sori without sterile margins, and rounded bilocular cystocarps borne subapically on palmate branchlets.

Key Words: agar-yielding algae; *cox1*; *Gelidium galapagense*; *Gelidium isabelae*; morphology; phylogeny; *rbcL*; systematics

INTRODUCTION

Gelidium, the most speciose genus in the order Gelidiales, comprises 145 species that are found worldwide in intertidal and subtidal zones of cold-temperate to tropical coasts (Freshwater and Rueness 1994, Boo et al. 2014, Guiry and Guiry 2019). This genus is a unique marine source for agarose gel for molecular work, and agar, a medium for microbiological studies; rhizine fibers are harvested for the industrial development of nanocomposites (Callaway 2015, Chen et al. 2016).

Small-sized *Gelidium* species are so simple in morphology that DNA analysis is needed for the correct identification. Molecular studies have shown that widespread

species actually comprise hidden local species, or that geographically isolated local species turned out a single widespread species. For example, *G. crinale* (Hare ex Turner) Gaillon was confirmed to be a cosmopolitan species distributed throughout the Atlantic and Pacific waters, while *G. pusillum* (Stackhouse) Le Jolis is endemic to the north Atlantic (Freshwater and Rueness 1994, Millar and Freshwater 2005, Kim and Boo 2012).

Sohn and Kang (1978) were the first to study *Gelidium* from Korea, reporting nine species, and Lee (1988) studied the morphology of six species from Jeju Island. Lee (1994) and Lee and Kim (1995) provided descriptions of



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eight species with a key to enable species identification. Lee et al. (2005) first reported the occurrence of *G. galapagense* W. R. Taylor at Geumneung, Jeju Island. Kim and Hwang (2015) reported 17 species of *Gelidium* including *G. isabelae* W. R. Taylor from Jeju Island. Recent molecular studies have revealed many new species of *Gelidium* from Korea. Kim et al. (2011, 2012) described five new species, *G. coreanum* K. M. Kim, J. K. Park, I. K. Hwang, H. S. Yoon & S. M. Boo, *G. eucorneum* K. M. Kim, J. K. Park, I. K. Hwang & S. M. Boo, *G. jejuense* K. M. Kim, J. K. Park, I. K. Hwang, H. S. Yoon & S. M. Boo, *G. minimum* K. M. Kim, J. K. Park, I. K. Hwang, H. S. Yoon & S. M. Boo, and *G. prostratum* K. M. Kim, J. K. Park, I. K. Hwang, H. S. Yoon & S. M. Boo. Boo et al. (2014) confirmed the occurrence of *G. johnstonii* Setchell & N. L. Gardner, which was considered as misidentified in Korea, and Boo et al. (2016b) added *G. longiramulosum* (Y. P. Lee & B. S. Kim) G. H. Boo and *G. yoshidae* G. H. Boo & R. Terada, which were previously attributed to the genus *Acanthopeltis*. On the other hand, Boo et al. (2013) transferred *G. divaricatum* G. Martens to the genus *Gelidiophycus*.

Reports of *G. galapagense* and *G. isabelae* from Korea have been questionable because of their simple and homoplastic morphologies. Lee et al. (2005) recognized Korean *G. galapagense* on the basis of characteristics of tetrasporangial stichidia, which arise on fan- or digitate tips of branches with short pedicels. This species has been included in seaweed floras of Korea (Lee 2008, Kim and Hwang 2015). However, Boo et al. (2016a) reported that Korean *G. galapagense* was very close to *G. millarianum* G. H. Boo, Hughey, K. A. Miller & S. M. Boo from Australia and might be assigned as a new species. Kim and Hwang (2015) proposed that *G. isabelae* from Korea was previously misapplied as *G. pusillum* by Lee (1988) and *G. pusillum* var. *pacificum* W. R. Taylor by Lee and Kim (1995). Korean *G. isabelae* was recognized on the basis of the visible decussate lines by resulting of uneven thickness of the pigmented cortical cell layer in the flattened, distal portions of erect branches. However, recent analysis of mitogenomes from type specimens of *G. galapagense* and *G. isabelae* raised questions about reports of these two species outside the Galápagos Islands (Boo et al. 2016a).

The objectives of this study were to investigate the occurrence of *G. galapagense* and *G. isabelae* in Korea and to provide a phylogeny to clarify the identities of Korean species. We intensively collected specimens that were morphologically similar to the descriptions of Korean *G. galapagense* and *G. isabelae* provided by Lee et al. (2005), Lee (2008) and Kim and Hwang (2015). We analyzed two

molecular markers, mitochondrial *cox1* and plastid *rbcL*, from specimens for which we observed the anatomy and morphology. On the basis of morphological features and phylogenetic relationships, we recognize a new species of *Gelidium* from Korea.

MATERIALS AND METHODS

Specimens were collected in the intertidal zone at Goheung and Wando on the southern coast of Korea, and at Jeju Island (Supplementary Table S1). They were mounted on herbarium sheets and subsamples were dehydrated in silica gels for DNA sequencing. For anatomical observation, plants were sectioned using razor blades and were stained with 1% aqueous aniline blue. Photographs were taken with a DP-71 camera (Olympus, Tokyo, Japan) mounted on a BX-51 microscope (Olympus). Holotype, isotype and paratype specimens are housed at the Herbarium of the Department of Biology, Chungnam National University, Daejeon, Korea (CNUK) (Thiers 2019).

DNA extraction, polymerase chain reaction amplification, and sequencing were performed as described in Boo et al. (2013). The primers used for amplifying and sequencing were F7, F645, R753, and RrbcS start for *rbcL* (Freshwater and Rueness 1994, Lin et al. 2001, Gavio and Fredericq 2002), and COXI43F and COXI1549R for *cox1* (Geraldino et al. 2006). Sequences of the forward and reverse strands were determined for all taxa, and the electropherograms were edited using MEGA7 (Kumar et al. 2016) and checked manually. Newly generated sequences were deposited in GenBank. Sequences were aligned using the MUSCLE algorithm in MEGA7 with default parameters and the alignment was manually adjusted. Three outgroup species representing three other genera in the Gelidiaceae (Boo et al. 2016b), *Capreolia implexa* Guiry & Womersley, *Gelidiophycus freshwateri* G. H. Boo, J. K. Park & S. M. Boo, and *Ptilophora spongiophila* G. H. Boo, L. Le Gall, I. K. Hwang, K. A. Miller & S. M. Boo, were included in the alignment.

Phylogenies of *cox1* and *rbcL* datasets were reconstructed using maximum likelihood (ML) and bayesian inference (BI). The best-fitting nucleotide substitution model was selected using jModelTest v2.1.10 (Darriba et al. 2012) with Akaike Information Criteria. The ML analyses were performed using the Pthreads version of RAxML v8.0.X (Stamatakis 2014) set as follows: a rapid bootstrap analysis and search for the best-scoring ML tree in one single program run with 1,000 bootstrap replicates under GTR + G + I model. The BI analyses were performed for

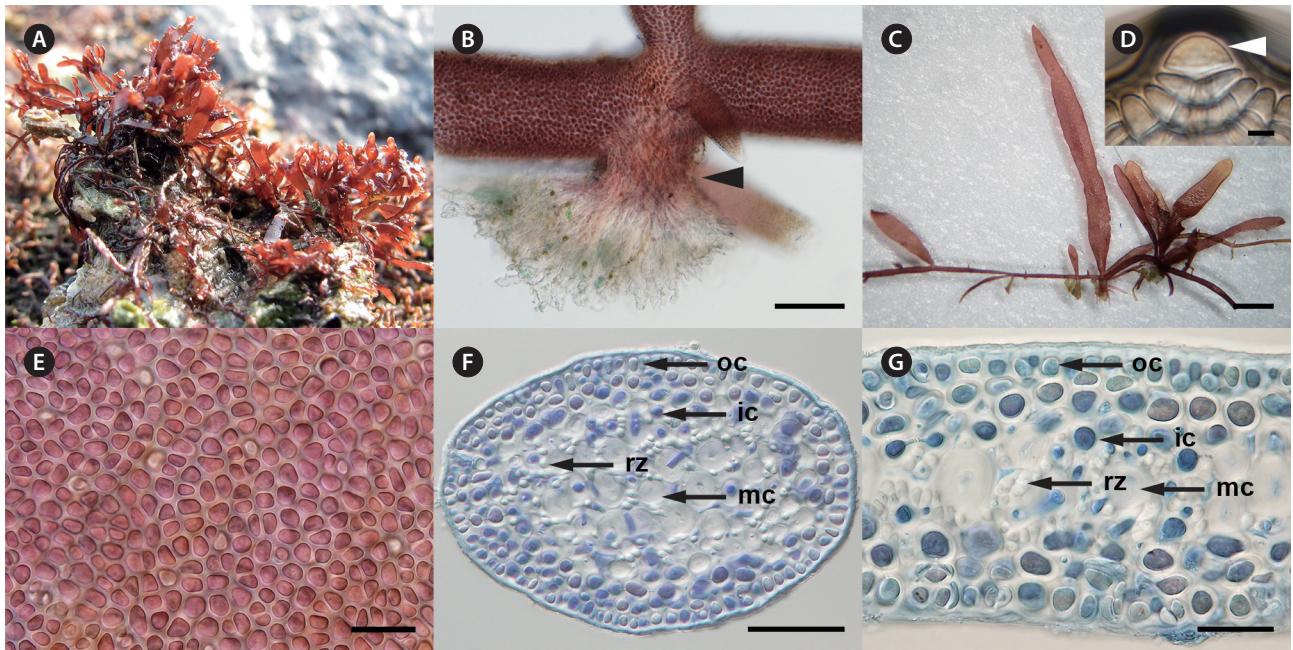


Fig. 1. Vegetative structure of *Gelidium palmatum* sp. nov. (A) Plants growing on rock in the intertidal zone at Donggori, Wando, Korea on Jul 14, 2014. (B) A brush-like hapteron (arrowhead) (CNU059012). (C) Simple branching pattern of vegetative thallus (CNU059012). (D) A dome-shaped apical cell at the tip of a branchlet (arrowhead) (CNU059022). (E) Surface view of outermost cortical cells showing their irregular arrangement (CNU059022). (F) Transverse section of a terete prostrate stolon showing outermost cortical cells (oc), inner cortical cells (ic), rhizines (rz), and medullary cells (mc) (CNU059012). (G) Transverse section of flattened erect axis showing outermost cortical cells (oc), inner cortical cells (ic), rhizines (rz), and medullary cells (mc) (CNU059012). Scale bars represent: B, 100 µm; C, 1 mm; D, 5 µm; E & G, 20 µm; F, 50 µm. [Colour figure can be viewed at <http://www.e-algae.org>].

individual datasets with MrBayes v.3.2.1 (Ronquist et al. 2012) using the Metropolis-coupled Markov Chain Monte Carlo (MC3) with the GTR + G + I model. For each matrix, four million generations of two independent runs were performed with four chains and sampling trees every 100 generations. The burn-in period was identified graphically by tracking the likelihoods at each generation to determine whether they reached a plateau. Twenty-five percent of saved trees were removed, and the remaining trees were used to infer Bayesian posterior probabilities (BPP).

RESULTS

Gelidium palmatum G. H. Boo & K. M. Kim sp. nov. (Figs 1 & 2)

Description. Thallus light to dark red, up to 0.7 cm high, forming a turf on upper intertidal rocks (Fig. 1A), with terete prostrate branches attached by brush-like holdfasts (Fig. 1B). Erect branches cylindrical at base, becoming compressed, 0.1–0.3 mm in width, lanceolate

to clavate (Fig. 1C), with longitudinal striations. Apices mostly obtuse with a prominent apical cell (Fig. 1D); surface cells rounded, arranged irregularly (Fig. 1E); cortex consisting of 3–5 layers in prostrate portions (Fig. 1F), 3–4 layers of globose to elliptical cells in compressed branches (Fig. 1G); rhizines abundant in medulla (Fig. 1F & G). Tetrasporangial sori without sterile margins arising on ultimate branchlets, tetrasporangia irregularly arranged (Fig. 2A), up to 12–34 × 33–61 µm (Fig. 2B). Spermatangia in terminal sori on strongly compressed branchlets with rounded apices (Fig. 2C & D). Cystocarps 310–450 µm in diameter, spherical to ovoid on subapical parts of palmate branches, bilocular (Fig. 2E & F), with one ostiole on each surface.

Holotype. CNU059012, Jul 14, 2014, G. H. Boo, a tetrasporangial specimen; deposited in CNUK, Herbarium of Chungnam National University, Daejeon, Korea.

Type locality. Donggori, Wando, Korea (34°19'57.32" N, 126°53'00.59" E).

Isotypes. CNU059009, CNU059010, CNU059011, and CNU059013 in CNUK, Korea.

Etymology. The specific epithet refers to the hand-shaped branches and branchlets.

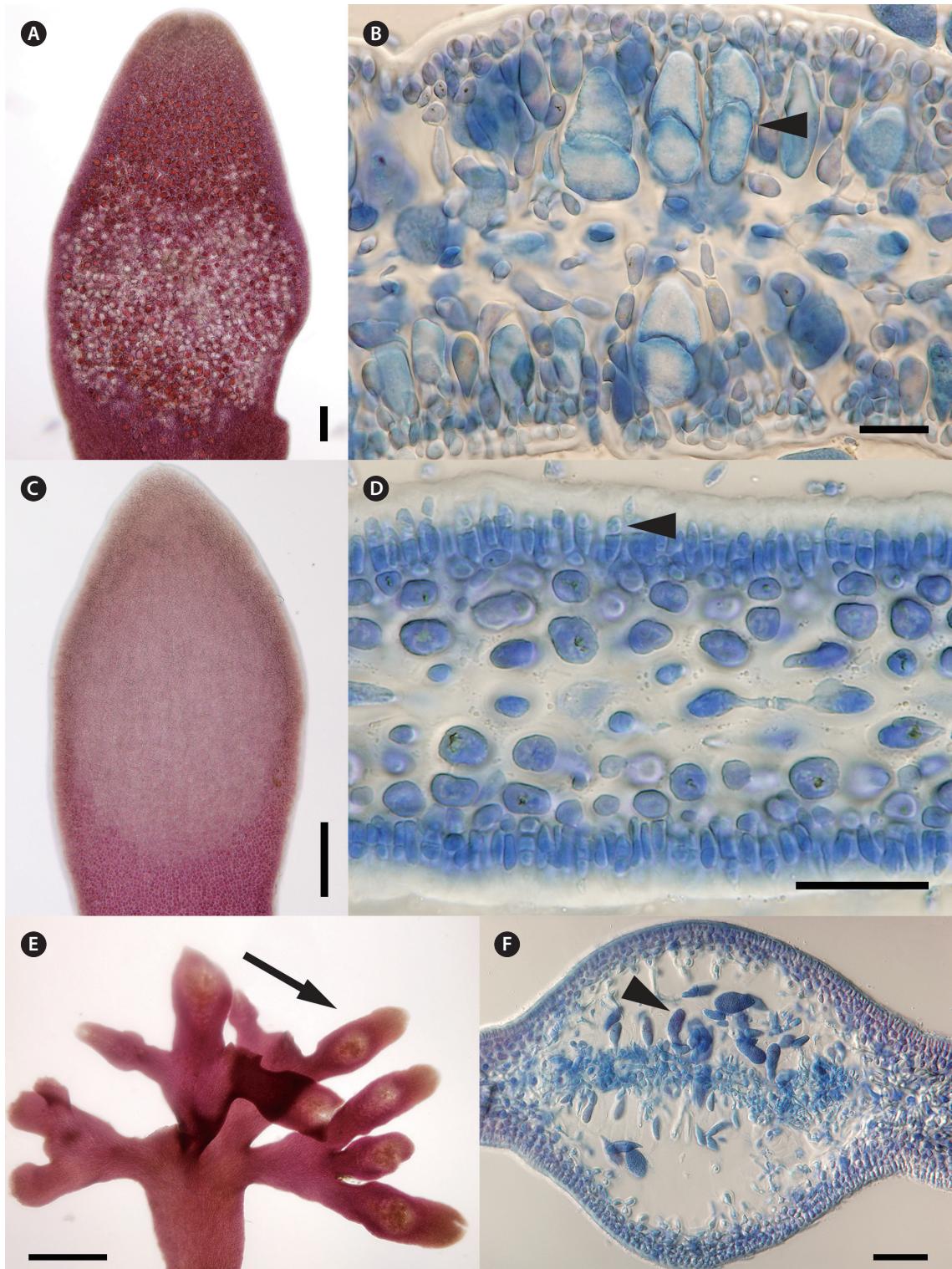


Fig. 2. Reproductive structures of *Gelidium palmatum* sp. nov. (A) Tetrasporangial stichidium-like branch (CNU059021). (B) Transverse section of tetrasporangial sorus with tetrasporangia (arrowhead) (CNU059024). (C) Thallus with spermatangial sorus (CNU059009). (D) Transverse section of spermatangial branchlet with spermatangia (arrowhead) (CNU059009). (E) Thallus bearing cystocarps (arrow) (CNU059007). (F) Transverse section of bilocular cystocarp with carpospores (arrowhead) (CNU059007). Scale bars represent: A & C, 100 µm; B & D, 20 µm; E, 500 µm; F, 50 µm. [Colour figure can be viewed at <http://www.e-algae.org>].

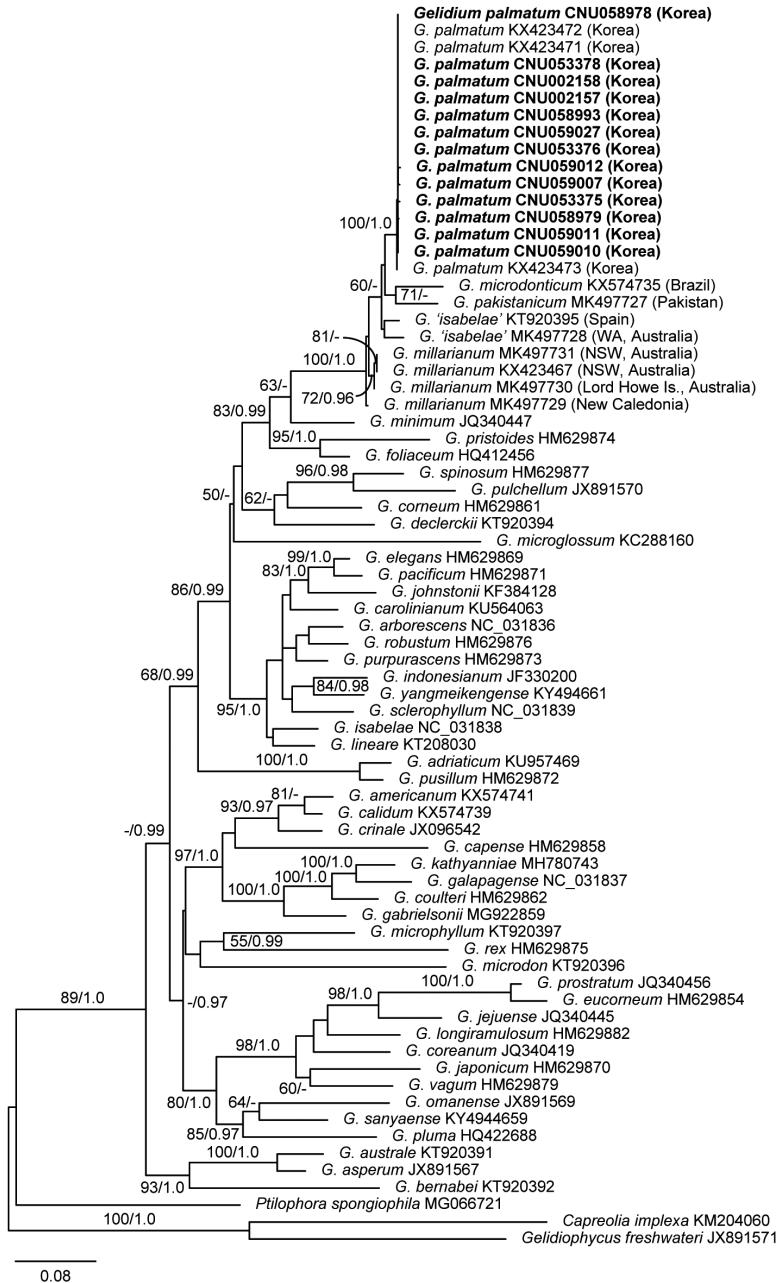


Fig. 3. Maximum likelihood (ML) phylogeny based on mitochondrial *cox1* sequences of the genus *Gelidium*. ML bootstrap values ($\geq 50\%$) and Bayesian posterior probabilities (≥ 0.90) are shown at branches. Dashes indicate values < 50 or < 0.90 . Bold letters indicate newly generated sequences in this study.

DNA sequences of type specimens. For the holotype, MN784142 (*cox1*) and MN784151 (*rbcL*); for isotypes, MN784140 and MN784141 (*cox1*), and MN784150 (*rbcL*).

Additional herbarium specimens observed. CNU-053375, CNU053376 (Sorokdo, Goheung, Korea; Mar 26, 2010); CNU059007, CNU059008, CNU059021, CNU059022, CNU059024, CNU059027 (Donggori, Wando, Korea; Jul 14, 2014); CNU058978, CNU058979, CNU058993 (My-

eongsasipri, Wando, Korea; Jul 13, 2014); CNU002157, CNU002158 (Munseom, Jeju Island, Korea; May 16, 2011); CNU053378 (Pyeongdae, Jeju Island, Korea; Mar 29, 2010); CNU053479 (Doduri, Jeju Island, Korea; Jun 17, 2008); CNU053379, CNU054668 (Geumneung, Jeju Island, Korea; Mar 30, 2010); CNU052132 (Gwideokri, Jeju Island, Korea; Oct 19, 2007).

Distribution and habitat. This species was confirmed

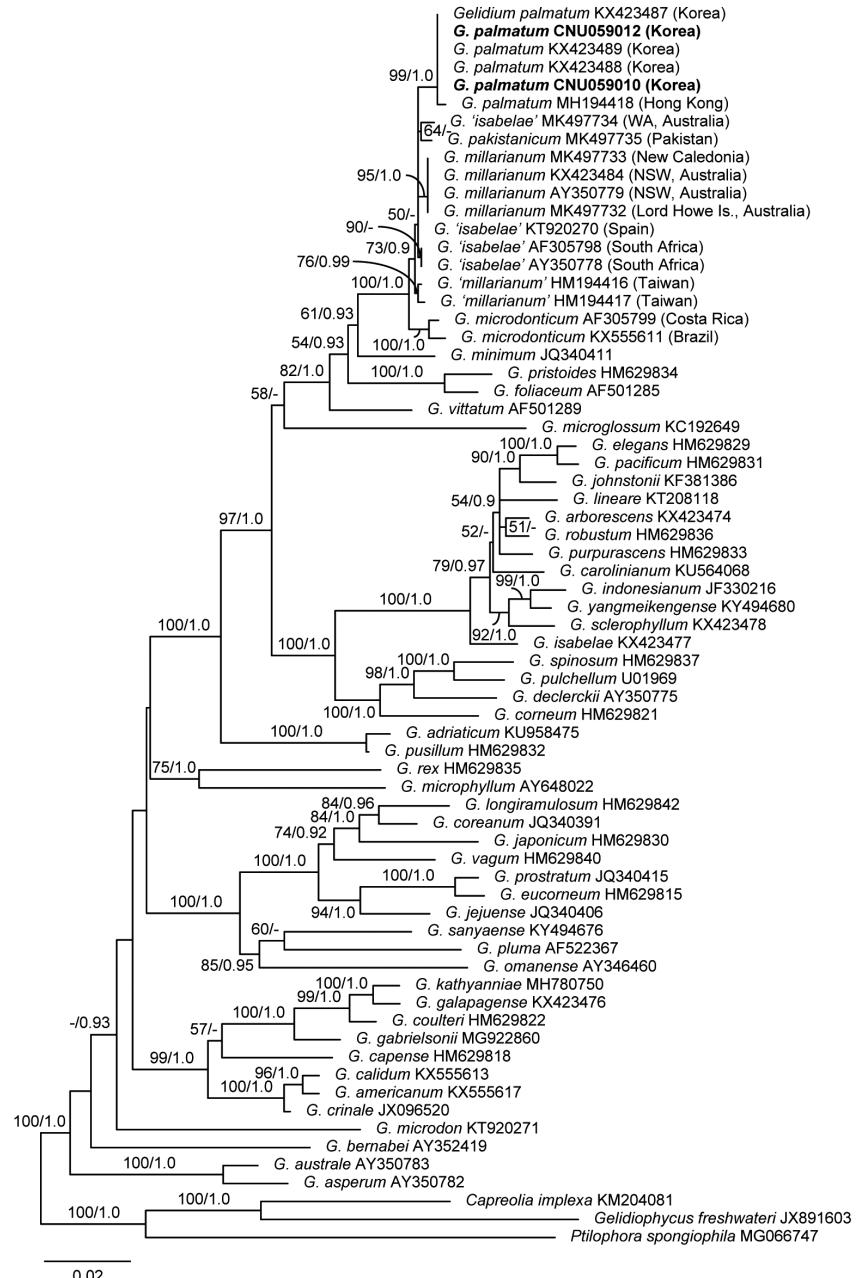


Fig. 4. Maximum likelihood (ML) phylogeny based on plastid *rbcL* sequences of the genus *Gelidium*. ML bootstrap values ($\geq 50\%$) and Bayesian posterior probabilities (≥ 0.90) are shown at branches. Dashes indicate values < 50 or < 0.90 . Bold letters indicate newly generated sequences in this study.

on the southern coast (Goheung and Wando), and on Jeju Island, Korea. Its range extends to Stanley Bay, Hong Kong, where specimens were identified with sequence by Lin et al. (2018). It grows on upper intertidal rocks and in shaded rocky crevices, forming short turfs often mixed with *Gelidiophycus freshwateri* and / or *Caulacanthus okamurae* Yamada in Korea (Fig. 1A).

Phylogenetic analyses

Fifteen sequences were generated in this study, 13 *cox1* and two *rbcL*. A total of 73 *cox1* sequences were aligned with 60 previously published sequences of *Gelidium* from GenBank including our three outgroups (Supplementary Table S1). The Korean taxon, which we describe here as *Gelidium palmatum* sp. nov., was distinct from

other species in the genus (Fig. 3). *G. palmatum* formed a fully supported clade with *G. microdonticum*, *G. millarianum*, *G. pakistanicum*, *G. 'isabelae'* from Spain and *G. 'isabelae'* from Western Australia (100% ML, 1.0 BPP). The intraspecific divergences of *G. palmatum* were up to 0.4%. *G. palmatum* was distinct enough to be segregated from other species of *Gelidium*; pairwise divergences of *G. palmatum* were 2.7-3.2% with *G. millarianum*, 4.8-5.0% with *G. pakistanicum*, 5.1-5.4% with *G. microdonticum*, 2.6-3.5% with *G. 'isabelae'* from Spain, and 3.5-3.7% with *G. 'isabelae'* from Western Australia.

The *rbcL* phylogeny (Fig. 4) confirmed the strong monophyly of the genus *Gelidium* (100% ML, 1.0 BPP). Five *rbcL* sequences from Korean *Gelidium palmatum* formed a distinct clade that also contained *G. 'millarianum'* from Hong Kong (100% ML, 1.0 BPP). *G. palmatum* formed a strongly supported clade with *G. microdonticum*, *G. millarianum*, *G. pakistanicum*, *G. 'isabelae'* from Western Australia, *G. 'isabelae'* from South Africa, *G. 'isabelae'* from Spain, and *G. 'millarianum'* from Taiwan (99% ML, 1.0 BPP). The intraspecific divergence between specimens from Korea and Hong Kong was 0.2%. Inter-specific divergences between *G. palmatum* and the other species in the *G. millarianum* complex ranged from 0.4% (vs. *G. 'isabelae'* from Spain) to 0.9% (vs. *G. millarianum*).

DISCUSSION

Our analyses of mitochondrial *cox1* and plastid *rbcL* sequences, with morphological observations, clearly revealed the occurrence of a new species, *G. palmatum* from Korea. *Gelidium palmatum* is characterized by a combination of the following features: small size (about 0.7 cm high), compressed to lanceolate erect axes, irregularly digitate or palmate branches, rhizines abundant in the medulla, tetrasporangial sori without sterile margins, and rounded bilocular cystocarps born subapically on palmate to digitate branches. Phylogenetic analyses of both *rbcL* and *cox1* sequences consistently demonstrated a marked difference between *G. palmatum* and other species in the genus. *Gelidium palmatum* occurs in Korea and Hong Kong, the latter being based on a *rbcL* sequence in GenBank. However, without molecular analysis, one should hesitate to identify *G. palmatum* from other countries. Our results support the proposal of Boo et al. (2016a) that reports of *G. galapagense* and *G. isabelae* from sites outside the Galápagos Islands are the result of misidentifications of other species. Additional collections and analyses will probably extend the known distri-

bution of *G. palmatum* to other sites in East Asia.

G. palmatum is well segregated from the *G. millarianum* species complex by pairwise divergences of *cox1* (2.6-5.0%) and *rbcL* (0.4-0.9%). These values are similar to those between closely related species of *Gelidium* (Freshwater et al. 2010, Boo et al. 2014, Freshwater and Shahnaz 2019). For example, *rbcL* pairwise divergence, estimated from GenBank sequences, between *G. linoides* Kützing and *G. tenuifolium* Shimada, Horiguchi & Masuda from Japan was 0.3% (Boo et al. 2014). The *cox1* divergences between related species are reported to be 2.7-5.4% (Freshwater et al. 2010, Boo et al. 2014, Freshwater and Shahnaz 2019). Mitochondrial *cox1* sequence is a useful tool for identification of closely related species, because its sequence is more variable, with larger barcoding gaps, than the conserved *rbcL*, which is less informative (Freshwater et al. 2010, Boo et al. 2016b).

A comparison of *G. palmatum* with morphologically similar species is given in Table 1. In practice, it is not easy to delimit small sized species of *Gelidium* by a few diagnostic characteristics, as many cryptic species (molecularly distinguishable but morphologically indistinguishable) have been revealed by recent molecular studies (Boo and Hughey 2019, Brunelli et al. 2019, Perrone et al. 2019). Boo et al. (2016a) reported that Korean *G. galapagense*, herein described as *G. palmatum*, having lanceolate tetrasporangial branches without sterile margins is different from *G. millarianum* having tetrasporangial branches with retuse tips and a sterile margin. Kim and Hwang (2015) recognized Korean *G. isabelae* on the basis of longitudinal striations on the surface of branches. However, increased sampling in the present study revealed that both of tetrasporangial stichidium and longitudinal striations are not key characters of *G. palmatum*. Instead, both tetrasporangial stichidia, arising on fan- or digitate tip of a branch with a short pedicel, and rhizines abundant in medulla are considered as key characteristics of *G. palmatum*. However, rather than a few diagnostic characteristics, a combination of several morphological characteristics is more practical for recognizing *G. palmatum* from other small sized species of *Gelidium*.

G. galapagense (type locality: Banks Bay, Isla Isabela, Galápagos Islands) is distinguished by stichidium-like tetrasporangial branches that are irregularly palmately or digitately expanded from a constricted base (Taylor 1945). The previous use of tetrasporangial characters for Korean *G. 'galapagense'* (Lee et al. 2005, Lee 2008) is unreliable. All sequences in GenBank and in our personal *Gelidium* sequence library (G. H. Boo, unpublished) re-

Table 1. A comparison of morphological characteristics of *Gelidium palmatum* sp. nov. and similar species

Feature	<i>G. palmatum</i> sp. nov.	<i>G. galapagense</i>	<i>G. isabae</i>	<i>G. miliarium</i>	<i>G. pakistanicum</i>
Type locality	Donggori, Wando, Korea	Banks Bay, Isla Isabela, Galápagos Islands, Ecuador	Pt. Albermarle, Isla Isabela, Galápagos Islands, Ecuador	Neds Beach, New South Wales, Australia	Gadani, Karachi, Pakistan
Habitat	Turf-forming, on upper tidal rock and in rocky crevices, mixed with <i>Gelidiophycus feroxwarei</i> and / or <i>Caulanthus ustulatus</i>	On rocks	On rocks, with mixed filamentous algae	Turf-forming, on intertidal rock	Turf-forming, lower littoral
Height (cm)	Up to 0.7	Up to 1	Up to 1	Up to 1	Up to 1.1
Color	Light to dark red	Dark purplish	Dull purplish	Light to dark red	Blackish maroon
Shape of thallus	Terete prostrate branches, becoming erect, terete at base and compressed above, digitate to palmate branches	Short creeping terete stolons, becoming erect foliar branches, terete at base and flattened above	Fleshy, small, creeping, terete or a little compressed, erect, flat, stipitate foliar branches, ligulate to spatulate or lanceolate, obtuse	Terete prostrate axes becoming erect flattened branches, lanceolate to clavate	Tough but not rigid, creeping, terete, becoming erect, terete at base and compressed to flattened, clavate to linear
Longitudinal striations	Present	NA	Present	Present	Absent
Branching pattern	Simple, irregular	Simple to irregularly marginal, sometimes re-divided	Simple or sparingly pinnate, no regular order	Up to three orders of dichotomous branching	Primarily lateral
Rhizines	Abundant in medulla	Few in the outer part of medulla	In the subcortical region	In the inner cortex and medulla	Abundant below the cortex
Tetrasporangial sori	On ultimate palmate branches without sterile margins	In branch tips or occupying the whole extent of small stichidium-like branches, irregularly palmately expanded or digitately divided above	In the upper ends of ordinary branches	On secondary branches with sterile margins	At the tip of erect axes or in stichidium-like structure
Tetrasporangia	Irrregularly arranged, 12–34 × 33–61 µm	No definite arrangement	No definite arrangement	Irregularly arranged, up to 28 µm in diameter	Irregularly arranged, up to 43 × 31 µm
Spermatangia	Sori on palmate branches, strongly compressed with rounded apices	NA	NA	NA	NA
Cystocarps	On subapical parts of palmate branches, round, two ostioles, bilocular	NA	NA	On upper branches, spherical to ovoid, two ostioles, bilocular	NA
Distribution	Korea, Hong Kong	Isla Isabela	Isla Isabela	Australia	Pakistan
Reference	This study	Taylor (1945)	Taylor (1945)	Millar and Freshwater (2005), Boo et al. (2016a)	Afaq-Husain and Shameel (1997, 1999)

NA, not applicable.

veal that *G. galapagense* is restricted to the Galápagos Islands.

G. isabelae (type locality: Pt. Albemarle, Isla Isabela, Galápagos Islands) has a creeping, firm thallus, simple or occasionally sparingly pinnate branches, and rhizines congested in the subcortical layer (Taylor 1945). Recently, Boo et al. (2016a) analyzed sequences from the type specimen of *G. isabelae* and concluded that it is endemic to the Galápagos Islands. Kim and Hwang (2015) reported *G. 'isabelae'* from Jeju Island based on the description of *G. pusillum* *sensu* Lee (1988) and *G. pusillum* var. *pacificum* *sensu* Lee and Kim (1995). They agreed with Millar and Freshwater (2005) and N'Yeurt and Payri (2010) that the visible decussate lines are a key character of *G. 'isabelae'* from Australia and French Polynesia. However, Boo et al. (2016a) identified the Australian plants as *G. millarianum*. Since the morphology and distribution of *G. pusillum* *sensu* Lee (1988) and *G. pusillum* var. *pacificum* *sensu* Lee and Kim (1995) are similar to our collections at five locations in Jeju Island, we here conclude that *G. 'isabelae'* from Jeju Island is *G. palmatum*.

A taxonomic revision is urgently needed for specimens identified as *G. isabelae* from French Polynesia, Japan, the Philippines, Spain, South Africa, and Western Australia (Silva et al. 1987, Yoshida 1998, Millar and Freshwater 2005, N'Yeurt and Payri 2010). Some of those specimens analyzed for *cox1* had a close relationship with *G. millarianum* (Boo et al. 2016a, Freshwater and Shahnaz 2019).

G. millarianum (type locality: Neds Beach, New South Wales, Australia) is up to 1 cm high and has flattened lanceolate to clavate main axes with three orders of distichous branches, rhizines abundant in both the subcortical layer and the medulla, and tetrasporangial sori with a sterile margin on secondary branches (Millar and Freshwater 2005, Boo et al. 2016a). *G. millarianum* occurs in New South Wales, Australia and New Caledonia. Lin et al. (2018) reported *G. millarianum* in Hong Kong and Taiwan based on *rbcL* sequences. The specimen of *G. millarianum* from Hong Kong was nested in our *G. palmatum* clade and the *rbcL* pairwise divergence was 0.2%, within the intraspecific-level variation reported in previous studies (Freshwater et al. 1995, 2010, Boo et al. 2013, 2014). The *rbcL* divergences of Australian and Taiwanese specimens differed by 0.4-0.5%. Based on the *rbcL* phylogeny and pairwise divergences, the Taiwanese specimens may be re-examined morphologically and with additional analyses of mitochondrial *cox1* sequences.

G. pakistanicum (type locality: Gadani, Karachi, Pakistan) is small in size (up to 1 cm) and main axes are terete, becoming compressed to flattened, lacking basal

constrictions, and with primarily lateral branches (Afaq-Husain and Shameel 1997, 1999). Freshwater and Shahnaz (2019) noted that the *rbcL* variation between *G. pakistanicum* and *G. millarianum* was lower than values generally considered as differentiating species.

In conclusion, our study reveals that the Korean reports of two *Gelidium* species with type localities in the Galápagos Islands result from misidentifications due to their small size and simple morphology. Our newly described *G. palmatum*, proposed for these misidentified specimens, commonly occurs on the southern coast of Korea and has been verified from Hong Kong. This study highlights the need for additional work on small, morphologically simple species in the agar-yielding genus *Gelidium*.

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SUPPLEMENTARY MATERIALS

Supplementary Table S1. Information on specimens included in molecular analyses. Bold indicates sequences generated in this study (<https://e-algae.org>).

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