Parviphycus, a new genus in the Gelidiellaceae
(Gelidiales, Rhodophyta)

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Abstract — A new genus of marine red algae, Parviphycus (Gelidiales), is proposed to accommodate those species previously assigned to Gelidiella that have the following features: distichous patterns of apical division in erect and prostrate axes, axial and periaxial cells in distinctive transverse rows, especially in upper and middle parts of the plants, and stichidia with few and regularly arranged rows of sporangia produced by periaxial cells. The type species is Parviphycus adnatus (Dawson) comb. nov. (basionym: Gelidiella adnata Dawson). Three other nomenclatural combinations are proposed: P. antipai (basionym: Gelidiella antipai Celan), P. tenuissimus (basionym: Gelidiella tenuissima Feldmann et Hamel) and P. womersleyanus (basionym: Gelidiella womersleyana Kraft et Abbott).

Algae / Geliales / Gelidiellaceae / Parviphycus / Rhodophyta

1. It is a pleasure to dedicate this work to my dear friend Izzie Abbott, on her 85th birthday.

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INTRODUCTION

Taxonomic confusion at the specific and generic levels characterize the present circumscription of the genus *Gelidiella*. Between 20 and 25 generally small-sized, turfy species are included in this genus (Ganzon-Fortes, 1994), but about half of them are known only from one or two geographic localities. Single collections often provide limited insights into morphological variation, and thereby may have led to an artificially high number of described *Gelidiella* species. In fact, authors working with this genus (e.g. Dawson, 1956; Egerod, 1971; Santelices, 1977, 2002; Hatta & Prud'homme van Reine, 1991; Norris, 1992; Kraft & Abbott, 1998) have often remarked on the difficulties encountered when distinguishing species.

While reviewing the type materials of *Gelidiella adnata* Dawson, Santelices (2002) recognized that the pattern of apical division, the internal structure of the thallus and the structure of the stichidium of this species were conspicuously different from the respective patterns exhibited by the type species, *G. acerosa*. Therefore he recognized the need for a new genus in the Gelidiellaceae to accommodate the smallest-sized species similar to *G. adnata*. Later, additional morphological and molecular evidence were added that supported the proposal of heterogeneity within *Gelidiella* (Rico *et al*., 2002). However, the examination of additional species seemed advisable before proposing a new genus. The study of another three, small species of *Gelidiella* (*G. antipai* Celan, *G. tenuissima* Feldmann *et al* and *G. womersleyana* Kraft *et al*.) has now been completed and corroborates their close morphological similarity with *G. adnata*, their dissimilarity with *G. acerosa* and thereby the need to include these species in a different genus. This study first summarizes the historical evidence supporting the recognition of a new genus, and reports on the morphological studies with the three additional small-sized species of *Gelidiella*. Then the new taxon is described and new nomenclatural combinations are proposed.

MATERIALS AND METHODS

General procedures followed those described in previous morphological studies (e.g. Santelices, 1991a, 1991b, 2002; Santelices & Hommersand, 1997). The herbarium specimens of the species examined are listed in Table 1. All specimens were first examined under a stereomicroscope. Representative thalli were gradually rehydrated avoiding tissue damage, and fixed in a 10% formaldehyde solution in seawater. Axes and branches were cut 20-30 µm thick to avoid tissue destruction, using a Leitz freezing microtome. Sections were stained with 1% aniline blue and mounted in 50% Karo corn syrup. Photomicrographs were taken with a Nikon Biophot Microscope. Slides with transections are deposited in the algal collection of the Sala de Sistemática, Pontificia Universidad Católica de Chile (SS/UC).
The genus *Gelidiella* was established by Feldmann & Hamel (1934) to replace *Echinocaulon* Kützing (1843), a name already used for a genus in the Polygonaceae (Angiosperm). Since *Echinocaulon* Kützing was a later homonym, *Gelidiella* Feldmann *et* Hamel was proposed as its replacement. The species in *Echinocaulon* were characterized by the presence of an apical cell and the lack of thick-walled, delicate fibers (rhizines) in the cortex or medulla, a character that Feldmann & Hamel maintained as distinctive of the genus *Gelidiella*. Later, Fan (1961) suggested the lack of a known sexual generation as an additional characteristic of this genus.

Intrageneric heterogeneity was suspected since Feldmann’s early characterization of *Gelidiella* (= *Echinocaulon*; Feldmann, 1931a, 1931b, 1931c). While he recognized species such as *Echinocaulon rigidiusculum* (Grunow) Feldmann, *E. setaceum* Feldmann and *E. nigrescens* Feldmann as congeneric, he also thought that *Gelidium bornetti* Weber-van Bosse (= *Gelidiella bornetti* (Weber-van Bosse) Feldmann) and *Gelidium pannosum* Bornet non Grunow (= *Gelidiella tenuissima* Feldmann *et* Hamel) may not belong to the same genus. Even though Feldmann & Hamel (1934) included all the above taxa in the genus *Gelidiella*, they recog-

Comparing the largest and one of the smallest species of *Gelidiella* (*G. acerosa* (Förskal) Feldmann *et* Hamel and *G. adnata* Dawson, respectively), Santelices (2002) found 80-100-fold differences in axis length and 10-15-fold differences in axis diameter between both species. More importantly, these species differed in their respective patterns of apical division, external and internal structure of the axis, stichidial construction and tetrasporangial formation. Later, Rico *et al.* (2002) also found that the spermatangial morphology of *G. acerosa* differed from that of the small-sized species, *G. tenuissima*. Authors in the two above mentioned studies suggested that the described morphological differences may be interpreted as generic differences, but that examination of an additional number of species seemed necessary before suggesting taxonomic changes.

Together with their spermatangial studies, Rico *et al.* (2002) also performed molecular analysis (LSU and *rbcL*) to assess the relationship of *Gelidiella tenuissima* with *G. acerosa*. They found that both species represented different lineages within the genus, a result also found by Shimada & Masuda (2000) using small subunit ribosomal DNA sequences. Thus, current molecular data suggests that there may be two lineages in the genus, but more molecular studies are needed to better support the idea.

Examination of species with “pannosa-type” stichidia

As indicated earlier, “pannosa-type” stichidia have been described for 10 species of *Gelidiella* (Ganzon-Fortes, 1994). Four of these were examined in this study, including *G. adnata*, already examined by Santelices (2002); *G. antipai* Celan, extensively described by Boudouresque (1972) and considered to include *G. stichidiospora* Dawson; *G. tenuissima*, recently reviewed and cultivated by Rico *et al.* (2002) and *G. womersleyana*, described by Kraft & Abbott (1998).

A morphological comparison of the above 4 species with individuals of *Gelidiella acerosa* verified the differences already described between *G. acerosa* and *G. adnata* (Santelices, 2002) and simultaneously emphasizes the similarities between *G. adnata* and the other three studied small-sized species. Thus, while the thallus length of *G. acerosa* can easily reach 6-10 cm, axis length in the other species infrequently reaches beyond 6 mm (Figs 1-5).
The new genus *Parviphycus*

Figs 1-5. External habit of 5 species of *Gelidiella*. Fig. 1. *Gelidiella acerosa*, scale = 4 mm. Fig. 2. *Gelidiella adnata*, scale = 300 µm. Fig. 3 *Gelidiella antipai*, scale = 130 µm. Fig. 4. *Gelidiella tenuissima*, scale = 400 µm. Fig. 5. *Gelidiella womersleyana*, scale = 150 µm.
All the species of *Gelidiella* studied here grow by the activity of an apical cell that divides transversely (Figs 6-11). In the case of *G. acerosa*, cell divisions of the subapical and subsequent cells in the axial filament occur at right angles to each other in a short alternating series forming a clearly decussate pattern (Figs 6, 7). As a consequence, the central axial filament is visible only a short distance below the apex and axes and branches are cylindrical in outline. In the case of the other 4 species (Figs 6-11), the subapical cells have longitudinal divisions in 2 directions in the same plane, cutting off 2 periaxial cells and 2 lateral cells, which cut off further cells. This pattern of division is much closer to a distichous pattern than to a decussate pattern and the resulting erect and prostrate axes and branches are slightly compressed, especially close to the tips.

Internal thallus structure (Figs 12-17) also differed between *Gelidiella* acerosa and the 4 small-sized species of *Gelidiella* studied. A transection through the middle part of a young erect axis of *G. acerosa* shows several layers of pigmented cortical cells that grade into a medulla of globose cells (Fig. 12). Axial cells and periaxial derivatives can not be identified in cross section (Fig. 13). Transections through the erect axes of the other 4 species of *Gelidiella* (Figs 14-17) show a few (1-3) layers of cortical cells and 1-3 layers of medullary cells. In these species, axial and periaxial cells are produced in a distinctive transverse row of thick-walled cells that remain evident in most plant parts. These differences in internal structure between *G. acerosa* and the small-sized species studied here is apparent even when the transverse sections are made the same distance back from the apical cell.

Differences in sporangia arrangement between *G. acerosa* and the other 4 species of *Gelidiella* (Figs 18-22) constitute an additional taxonomic difference. As already noted by Feldmann & Hamel (1934), the sporangia are abundant, compact and irregularly disposed in *Gelidiella acerosa*, without forming transverse rows, although they may exhibit a clear acropetal development. The other 4 species, on the contrary, exhibit stichidia with few, regularly arranged rows of sporangia formed from the apex. Longitudinal and cross sections through the sporangia of these species (Figs 23-26) indicate that in *G. acerosa* the sporangia frequently originate from internal cortical cells and less often from medullary cells. The position of the cells generating the sporangia is not fixed because internal cortical and external medullary cells are abundant in any branch, all seemingly have the capacity to differentiate sporangia and their original position can change by thallus growth (Fig. 23). In the cases of *G. adnata*, *G. antipai* and *G. tenuissima* (Figs 24-26) the sporangia originate from the periaxial cells flanking the axial cells on each side. In these species, therefore, spore production is restricted to cells with a fixed position in the plant and the number of spores produced in each mature transverse row of the stichidia is a function of the number of periaxial cells on each side of the thallus.

All the above morphological differences suggest the need for a new genus for those species previously assigned to *Gelidiella* that possess distichous patterns of apical division, axial and periaxial cells of upper and middle parts of the plant in distinctive transverse rows, and stichidia with few and regularly arranged rows of sporangia produced by periaxial cells. None of the existing genera of either the Gelidiaceae or the Gelidiellaceae seems able to accommodate the above species. The name *Parviphycus* is proposed for this new genus, a name that emphasizes the small size of the species included therein.
The new genus *Parviphycus*

Fig. 6-11. Tip of erect axes of 5 species of *Gelidiella* showing the pattern of division of the apical (arrows) and subapical cells. Figs 6, 7. *Gelidiella acerosa*, scales 100 µm in Fig. 6 and 20 µm in Fig. 7. Fig. 8. *Gelidiella adnata*, scale 30 µm. Fig. 9. *Gelidiella antipai*, scale 20 µm. Fig. 10. *Gelidiella tenuissima*, scale 30 µm and Fig. 11. *Gelidiella womersleyana*, scale 20 µm.
Figs 12-17. Cross section through the axes of 5 species of Gelidiella. Arrow heads indicate axial cells while long arrows indicate periaxial cells. Figs. 12, 13. Gelidiella acerosa. Fig. 12 shows the internal structure of erect axes, scale = 100 µm. Fig. 13 is a close up of a central medullary region, scale = 10 µm, with no evidence of axial or periaxial cells. Figs. 14, 15, 16 and 17 show respective transections through erect axes of G. adnata (scale = 20 µm), G. antipai (scale = 20 µm), G. tenuissima (scale = 25 µm) and G. womersleyana (scale = 20 µm).

Figs 18-22. Surface view of tetrasporangial stichidia in 5 species of Gelidiella. Fig. 18. Gelidiella acerosa, scale = 500 µm. Fig. 19. Gelidiella adnata, scale = 200 µm. Fig. 20. Gelidiella antipai, scale = 200 µm. Fig. 21. Gelidiella tenuissima, scale = 150 µm and Fig. 22. Gelidiella womersleyana, scale = 100 µm.
The new genus *Parviphyicus*
Taxonomic propositions

**Parviphycus Santelices, gen. nov.**

Plantae saepe teretes formant usque ad 2 cm alti. Thalli ex uno vel variis ramis erectis formantur qui ex superficie dorsali levantur ramorum postrorum. Axes postrati incrementum habent vagum, cum una cellula apicali quae in sensu transversali dividitur. Cellula subapicalis divisiones longitudinales monstrat in duas directiones, 2-4 cellulas periauxiales originantes, quae posterius cellulas laterales generant. Hic modus divisionis subdicotomicus est et axes demissi rotundi sunt aut debiliter compressi, usque ad 180 mm diametri, subtracto adhaesi per rizoidis unicellularibus aut paucis cellulis, quod unum per cellulan efficitur ex tegumento magis extremon vel ex duobus tegumentis magis externis cellularum corticales. Rizoides mensuram habent usque ad 10 mm diametri atque 300 mm longitudinis, interclusi uni ex aliis, rizoidium velum formantes contiguorum vel rizoidium lineas

Figs 23-26. Transection through mature stichidia of 4 species of *Gelidiella*. Note the sporangia produced by cortical cells in *G. acerosa* (Fig. 23) while in the other three species the sporangia are produced by the periauxial (medullary) cells (Fig. 24 = *G. adnata*. Fig. 25 = *G. antipai*. Fig. 26 = *G. tenuissima*). Arrow heads in Figs 24, 25 and 26 indicate axial cell. In all figures the arrows indicate the pit connection between the sporangia and the cells originating them. (Scale in all figures = 20 µm.)
formantes interclusorum. Cellulae corticales in ramis iuvenibus cum axe maiore transversaliter ordinato in directionem rami principalis. Medulla cum 4 ad 6 cursibus transversalibus cellularum cylindricarum.

Axes stoloniferi axes lineales efficiunt sine constrictionibus vel tantum cum constrictionibus debilibus in base, generaliter simplicibus sed interdum derivatibus in forma irregulari, cum aut sine pilis in earum portionibus apicabilibus et saepe cum fissura et evidentia incrementi rami. Rami erecti ex superficie surgunt normaliter oppositi illi qui rizoides producit. Aliqui horum axium erectorum possunt postea in axes stoloniferi transformari, adhaesiones rizoidales producentes et obventitie etiam novos axes producentes.

Axes erexit usque 20 mm longitudinis atque 180 mm diametri, cum basibus divisionis apicalis et constructio thali similaris axibus raptantibus, sed cum cellulis corticalibus brevioribus, longitudinaliter ordinatis aut in forma irregulari. In sectione transversali, axes erecti formati videntur 1-3 cursibus cellularum corticalium atque 1-5 cursibus cellularum medullarium in cursibus dispositarum transversalibus. Hae sunt cellulae axiales (vel filamentum axiale centrale) collocatae inter varias cellulas peraxiales ad unumquodque latus cellulae axialis et quae ordinantur horizontali modo cum hac. Tetrasporangia in stichidiis lanceolatis originata, globosis, cylindricis vel extensis super brevibus pedicellibus positis vel in apice ramorum terminalium; semper stichium per pedicellum vel ramum. Tetrasporangia in sequentia regulari formata ex apice (exempli gratia: 6, 8, 12, per segmentum), cellulis periaxialibus formata quae sunt ad laterem filamenti axialis. Tetrasporangia circumdata uno vel duobus tegumentis cellularum corticalium quarum continuitas interrumpitur in mensura in qua sporangia crescit atque maturat. Tetrasporangiae subspherae sunt, in forma crucifera divisae vel tetraedrica, usque 40 mm diametri. Cognosciunt tantum structuram marium et tantum pro una speciei (P. tenuissimus). Sori spermatangiales apparent utpote splenia incoloria in ramis terminalibus, vel terminent axem erectum vel se disponant lateraliter respectu ad axem principalem. Cellulae quae spermacia producunt cellulis corticalibus formantur. Spermacia forma sunt pyramidalis, 3-4 mm alti.

Plants often forming a low-stature turf, up to 2 cm. tall. Thalli formed by one to many upright branches arising from the dorsal side of prostrate branches. Prostrate axis with indeterminate growth, with a single apical cell that divides transversally. The sub-apical cell with longitudinal divisions in two directions, cutting off 2-4 periaxial cell which later cut off further cells laterally. Pattern of division subdistichous and creeping axes rounded or slightly compressed, up to 180 µm diameter, attached to the undersurface by unicellular or few-celled rhizoids that originate one per cell from the most external or the two most external layers of cortical cells. Rhizoids are up to 10 µm diam. and 300 µm long, developing separately one from the other, forming a fringe of contiguous or bundles of isolated rhizoids. Cortical cells in young regions with long axis arranged transversally on branches. Medulla with elongated cylindrical cells in 4-6 transverse rows.

Stoloniferous axes give rise to basally unconstricted or slightly constricted linear axes, usually simple but sometimes irregularly branched, with or without hairs in their apical portions and often truncated with apparent evidence of renewed blade growth. Upright branches normally arise from the face of the axis opposing the fringe of rhizoids. Some of these uprights may later become stoloniferous axes, developing rhizoidal attachments and, eventually, also originating new axes.

Erect axes are up to 20 mm long and 180 µm diameter, with patterns of apical division and thallus construction similar to the creeping axes, but with smaller cortical cells aligned longitudinally or irregularly. In cross section, the erect
axes are formed by 1 to 3 layers of cortical cells and 1 to 5 layers of medullary cells arranged in transverse rows. These are the axial cells (or the central axial filament) flanked by one or several horizontally aligned periaxial cells on each side of the axial cell.

**Tetrasporangia** borne on lanceolate, globose, cylindrical or terete stichidia located on short pedicels or in the apices of terminal branches; always one stichidium per pedicel or branch. Tetrasporangia formed in regular sequence from the apex (e.g. 6, 8, 12 per segment) by periaxial cells flanking the axial filament. Tetrasporangia surrounded by one or two layers of cortical cells in which the continuity is disrupted as the sporangia grow and mature. Tetrasporangia subspherical, cruciatelly to tetrahedrally divided, up to 40 µm diam. Only male reproductive structures known and only for one species (*P. tenuissimus*). **Spermatangial sori** appear as colorless patches in ultimate unbranched branchlets, either terminally in erect axes or laterally from the main axes. Spermatangial initials are formed from cortical cells. Spermatangia pyramidal in outline, 3-4 µm high.

**Type species:** *Parviphycus adnatus* (Dawson) Santelices

**New combinations**

*Parviphycus adnatus* (Dawson) Santelices, comb. nov.

- **Basionym:** *Gelidiella adnata* Dawson [Marine plants in the vicinity of the Institut Océanographique de Nha Trang, Viet Nam. *Pacific Science* 8: 422, fig. 33 f (1954)].
- **Type locality:** Nha Trang, Viet Nam.
- **Known geographic distribution:** Viet Nam, Isla San Benedicto, Revillagigedo Archipelago, Arno Atoll in the Marshall Islands and Hawaii. The species has been confused with *G. antipai* and may occur in areas where *G. antipai* has been described.

*Parviphycus antipai* (Celan) Santelices, comb. nov.

- **Basionym:** *Gelidiella antipai* Celan [Note sur la flore algologique du littoral roumain de la mer Noire IV. *Bull. Sect. Scientifique de l’Académie Roumaine* 19: 3 (1938)].
- **Synonym:** *Gelidiella stichidiospora* Dawson (1953).
- **Type locality:** Cape Kaliakra on the Bulgarian coast of the Black Sea.
- **Known geographic distribution:** the Mediterranean, Baja California, Natal (South Africa) and southern Australia.
- **References:** Celan, 1938; Boudouresque, 1972; Norris, 1992; Womersley & Guiry, 1994.

*Parviphycus tenuissimus* (Feldmann et Hamel) Santelices comb. nov.

- **Synonyms:** *Gelidium pannosum* Grunow (Bornet, 1892); *Gelidium pannosum* Bornet, non Grunow (Weber van Bosse, 1921); *Echinocaulen pannosum* Feldmann (1931a); *Gelidiella pannosa* (Feldmann) Feldmann et Hamel (Fan, 1961); *Gelidiella tenuissima* (Thuret) Feldmann et Hamel (Boudouresque, 1969).
- **Type locality:** Biarritz, France.
**Known geographic distribution:** Great Barrier Reef, Australia, Thailand, Viet Nam, Indonesia, the Yeayama Islands in Japan, the Marshall Islands, Puerto Rico, the Canary Islands, Portugal, Morocco, Atlantic France, the Mediterranean, Senegal, Mauritania, Aldabra, Bangladesh, India, Kenya and the Seychelles.


**Parviphycus womersleyanus** (Kraft et Abbott) Santelices comb. nov.

**Basionym:** Gelidiella womersleyana Kraft et Abbott [Gelidiella womersleyana (Gelidiales, Rhodophyta), a diminutive new species from the Hawaiian Islands. Botanica Marina 41: 56 (1998)].

**Type locality:** Kaiwi Point, ca 1 Km north of the harbor at Kailua-Kona, Hawaii Island, at 7-9 m deep.

**Geographical distribution:** known only from the type locality.


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