

## Two new species and two new records of *Pterocliadiella* (Gelidiales) from Malaysia based on analyses of *rbcL* and *coxI* gene sequences

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Five species of *Pterocliadiella* (Gelidiales) are reported from Malaysia, identified using a combination of morphological data and partial *rbcL* (chloroplast) and *coxI* (mitochondrial) gene sequences. Two new species, *Pterocliadiella phangiae* sp. nov. and *Pterocliadiella megasporangia* sp. nov., are proposed based on phylogenetic analyses and distinct morphological features. *Pterocliadiella phangiae* sp. nov. showed a sister relationship with *P. caerulescens*, *P. beachiae*, *P. psammophila* and *P. australafricanensis*. *Pterocliadiella megasporangia* sp. nov. formed a monophyletic clade with *P. bartlettii* and *P. melanoidea* with strong support in all analyses. Two other species are reported as new records for Malaysia and Southeast Asia. *Pterocliadiella beachiae* grouped robustly with *P. beachiae* from the Caribbean Sea; *P. bartlettii* was resolved in a clade among sequences of *P. bartlettii* from the Caribbean Sea and Texas, USA. The identity of *P. caerulescens*, which had previously been reported from Malaysia based on morphological features, was verified by *rbcL* and *coxI* gene analyses as well as morphological studies. This study provides 22 new *rbcL* gene sequences and 18 new *coxI* sequences for the genus *Pterocliadiella*, documents detailed morphological data for the relevant specimens and increases the number of *Pterocliadiella* species known in Malaysia from two to six, including two new species.

KEY WORDS: Molecular systematics, Morphology, Pterocliadiaceae, *Pterocliadiella phangiae*, *Pterocliadiella megasporangia*

### INTRODUCTION

The Gelidiales is an order of red algae including economically important species used for agar and agarose production. The Gelidiaceae, the largest family in the modern Gelidiales, was originally established by Kützing (1843) in the order Nemaliales (Hommersand & Fredericq 1988). The family was later elevated to the order Gelidiales by Kylin (1923) based on its diplobiontic life cycle and absence of functional auxiliary cells in the fertilization process (Santelices 1988). Fan (1961) reviewed the order Gelidiales, recognized eight genera in the Gelidiaceae and established a new family, the Gelidiellaceae, for the single genus *Gelidiella*.

J. Agardh (1851) used the unilocular structure of the cystocarp as the main character to distinguish his new genus *Pterocladia* from *Gelidium*, which has bilocular cystocarps. Although the type species, *Pterocladia lucida* (Brown ex Turner) J. Agardh, has unilocular cystocarps, two unequally developed locules were subsequently found in the cystocarp of some *Pterocladia* species such as *P. capillacea* (S.G. Gmelin) Bornet (Fan 1961; Santelices 1991a, b; Hommersand & Fredericq 1996), which indicated that a segregate genus was required for these species (Santelices 1991a, b). Subsequently the genus *Pterocliadiella* [type species *P. capillacea* (S.G. Gmelin) Santelices & Hommersand] was established by Santelices & Hommersand (1997) for species

forming two unequal locules with intercalary carpogonia, a virtually solid cylinder around the central axis, cystocarps usually attached to the cystocarp floor and chains of carposporangia on the remaining three sides. Several studies of the reproductive and vegetative characteristics of the Gelidiales (Santelices 1998, 1999; Santelices & Hommersand 1997) supported the establishment and validity of *Pterocliadiella*, to which most species of *Pterocladia* and some species of *Gelidiella* and *Gelidium* were transferred (Santelices & Hommersand 1997; Santelices 1998, 2007). In recent years, various studies using a combination of morphological and molecular data have supported the monophyly of *Pterocliadiella* (Bailey & Freshwater 1997; Freshwater & Bailey 1998; Shimada & Masuda 2000, 2002; Thomas & Freshwater 2001; Millar & Freshwater 2005; Nelson *et al.* 2006; Tronchin & Freshwater 2007).

The new family Pterocliadiaceae was established for *Pterocladia* and *Pterocliadiella* (Perrone *et al.* 2006), based on the peg-like attachment system in these genera, while *Gelidium* with brush-like tufts of rhizoids and *Gelidiella*, with unicellular rhizoids, were retained in the Gelidiaceae and Gelidiellaceae, respectively. There are currently 17 recognized species in *Pterocliadiella* (Guiry & Guiry 2012), of which four, *P. caerulescens* (Kützing) Santelices & Hommersand, *P. caloglossoides* (M.A. Howe) Santelices, *P. capillacea* and *P. taylorii* (Joly) Santelices, have been reported from Southeast Asia (Pham-Hoàng 1969; Silva *et al.* 1987, 1996; Abbott *et al.* 2002; Tsutsui *et al.* 2005; Phang *et al.* 2007, 2008, 2010; Santelices 2007). Of these, only *P.*

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