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Taxonomic studies of the diatom genus *Halamphora* (Bacillariophyceae) from the mountainous regions of southwest China, including the description of two new species

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Abstract

In this study, we describe two new *Halamphora* species (*Halamphora subfontinalis* and *H. hezhangii*) and identify three species newly recorded in China (*H. elongata*, *H. submontana* and *H. tenella*) and two others previously recorded from China (*H. montana* and *H. dusenii*), as well as make preliminary observations on three interesting and unnamed *Halamphora* species. For all ten taxa observations were made using light microscopy and for the new taxa scanning electron microscopical observations were also made. Comparisons of morphological features are made with similar, previously-described taxa. All of these *Halamphora* species were found in alkaline waters (7.2 < pH < 9.7) in the mountainous regions of southwest China, including Tibet, Yunnan and Guizhou Provinces. In addition, we list in *Halamphora* twenty taxa previously recorded from China in the genus *Amphora*, resulting in two new combinations.

Key words: diatoms, Bacillariophyceae, *Halamphora*, *Amphora*, China, new species, taxonomy, new combinations

Introduction

Mountainous regions of southwest China are located on the southeast margin of the Qinhai–Tibet plateau. Mountains in these regions are usually arranged from north to south and have complicated topographies and unique natural environments. These areas boast considerable biological richness and are recognized together as one of the world's "biodiversity hotspots" (Boufford & Dijk 2000, Zhang *et al*. 2008).

The diatom genus *Halamphora* (Cleve 1895: 117) Levkov (2009: 165) was recently elevated and recognized as a separate genus by Levkov (2009), after being considered a subgenus of *Amphora* Ehrenberg ex Kützing (1844: 108) by Cleve (1895). *Halamphora* is typified by *Halamphora coffeaeformis* (Agardh 1827: 627) Levkov (2009: 179) which was previously described as *Frustulia coffeaeformis* Agardh. The features that help to separate *Halamphora* from *Amphora* include: *Halamphora* species may have a raphe ledge on the dorsal side only, uni- or biseriate striae, external foramina of areolae that are usually simple, rarely with short finger–like processes at the margins, and internal openings of areolae occluded by hymens. *Amphora* species possess a raphe ledge on both sides of the raphe, uniseriate striae, external foramina of areolae sometimes with short finger–like processes at the margins, and internal openings of areolae occluded by vela (Levkov 2009).

Halamphora is a relatively large, widely distributed genus, with most of the species being found in marine or brackish water habitats; only a few species occur in freshwater. Levkov (2009) lists 79 species in *Halamphora* from Europe, Asia, Africa, North America and South America. Most *Halamphora* species were described originally as *Amphora* taxa, and then transferred to *Halamphora*. Wachnicka & Gaiser (2007) reported ca. 13 new *Halamphora* species (as *Amphora* sp. at that time) in marine and coastal environments of South Florida, USA. Stepanek & Kociolek (2013) detailed the history of *Amphora* and *Halamphora*, and reported four new *Halamphora* species from inland waters of the western USA. Kociolek *et al*. (2014) described four new species of *Halamphora* from Lake Sediments in the western USA. Three new species were described from North Dakota, USA, by Stepanek & Kociolek (2015). Three new species were described from the Midwest of the United States by Stepanek & Kociolek (2015). Blanco *et al*. (2013) and Álvarez-Blanco & Blanco (2014) described two new *Halamphora* species, as well as transferred four

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Halamphora sabiniana (Reimer) Levkov (2009: 219)
Basionym: *Amphora sabiniana* Reimer in Patrick & Reimer (1975: 79) (Shi 2013: 20)

Halamphora tenerrima (Aleem & Hustedt) Levkov (2009: 235)
Basionym: *Amphora tenerrima* Aleem & Hustedt (1951: 16, 17) (Cheng *et al*. 1993: 54)

Halamphora thumensis (A. Mayer) Levkov (2009: 236)
Basionym: *Amphora coffeaeformis* var. *thumensis* A. Mayer (1919: 208) (Shi 2013: 21)

Halamphora transcaspica (Petersen) Q-M. You & J.P. Kociolek, *comb*. *nov*., *stat*. *nov*.
Basionym: *Amphora coffeaeformis* var. *transcaspica* Petersen, *Dansk Botanisk Arkiv Udgivet af Dansk Botanisk Forening* 6(6): 48, Fig. 8, 1930.

Halamphora veneta (Kützing) Levkov (2009: 242)
Basionym: *Amphora veneta* Kützing (1844: 108) (Zhu & Chen 2000: 202)

A comprehensive investigation of the genus *Halamphora* for China is lacking. At present, with the addition of *Halamphora* taxa examined in this study, only 25 taxa have been reported from China, and most of them (21 taxa) have been found in inland waters. A total of 6 taxa only, including *Halamphora acutiuscula*, *H*. *coffeaeformis*, *H*. *costata*, *H*. *cymbifera*, *H*. *exigua* and *H*. *tenerrima*, were found in coastal and marine waters.

In the last five years, nearly 30 new species of *Halamphora* have been described. These new taxa have been 'discovered' in relatively unexplored areas, such as mountainous regions of southwest China, in study as well as part of floras from better studied areas (Europe, Levkov 2009, United States, Stepanek & Kociolek 2013, 2015, Kociolek *et al*. 2014; Antarctic Region, Van de Vijver *et al.* 2014). A closer examination of habitats with elevated pH and alkalinity will undoubtedly yield a more comprehensive study of *Halamphora* biodiversity and ecological distributions in China and around the world.

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