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The biogeographic distribution of *Cavinula* (Bacillariophyceae) in North America with the descriptions of two new species

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Abstract

Cavinula Mann & Stickle is small genus presently comprising 25 taxa distinguished by the linear to round-elliptical valve shape, uniseriate striae, presence of nodules and distinctive terminal pores. Most often the species from the genus have been reported from colder northern or alpine oligotrophic aquatic systems, or moist sub-aerial habitats. Observation of samples from different localities reveals fourteen *Cavinula* taxa are distributed across North America. Descriptions of confirmed species including designated types are provided with regard to their taxonomy, autecology, and distribution in Canada and USA. Light and Scanning Electron Microscope observations of different samples and type material reveal high morphological variation within some of the taxa. Two and three morphotypes are recognized within *C. cocconeiformis* and *C. pseudoscutiformis. Cavinula kernii* and *C. maculata* are recognized as new species and formal description and differential diagnosis are presented. The biogeography of the genus *Cavinula* in North America is represented by three groups of species. The first group comprises taxa with more restricted distribution in oligotrophic, cold and/or alpine environments from the Arctic Archipelago and the Rocky Mountains in western North America. The second group comprises more tolerant species with broader distributions across a wider range of ecological conditions. The third group from south-eastern North America, represented by *C. maculata*, is found in low pH and specific conductance conditions with low nutrients. Globally, forty-one percent of the known taxa are present in North America. This number is subject to change after a better understanding of the different morphotypes and global taxa distributions.

Key words: Diatoms, *Cavinula*, North America, Biogeography, pH, TP, DOC, Conductivity

Introduction

The genus *Cavinula* Mann & Stickle (in Round *et al.* (1990: 665) was erected to identify small isovalvar, round to elliptical valves with uniseriate striae composed of round to elliptical areolae (Round *et al.* 1990). *Cavinula* has a distinct chloroplast composed of simple plates positioned adjacent to the valve face which are connected by an H-shaped pyrenoid bridge across the center of the cell (Cox 1996). One or two H-shaped plastids may be present. In the original description of the genus, the external raphe was described as linear with enlarged central pores and terminal fissures deflected to one side, but often short (Round *et al.* 1990). Internally, the areolae are positioned between thickened costae (interstrial) ridges and each areola is covered by a fine weakly domed hymen. The sternum is thickened internally and the terminal raphe fissures are associated with helictoglossae, while the central raphe fissures have small to non-distinct elevated nodules. The valve mantle is generally narrow with a few aligned areolae near the valve face, but devoid of areolae along the lower mantle margin. The cingulum is composed of 2–4 open copular bands, each band with two rows of fine pores on the pars exterior.

Features like valve shape, nodules and distinctive terminal pores can distinguish the species; a common, but not exclusive, feature appears to be the alternating long and short striae around the central area and, for some taxa, the connection of the terminal raphe fissure to an adjacent stria.

Cavinula is known mainly from oligotrophic aquatic systems, or moist sub-aerial habitats. Species are typically observed in colder northern or alpine environments, although *C. scutelloides* (W. Smith) Lange-Bertalot (in Lange-Bertalot & Metzeltin 1996: 31; basionym: *Navicula scutelloides* W. Smith 1856: 91) is found in more alkaline waters. In

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Ellesmere Island, Nunavut. At present the majority of the *Cavinula* species are found in the Northern Hemisphere with habitats ranging from sub-terrestrial moss environments to benthic aquatic systems. General water conditions can vary, but typically for the majority of species in North America, pH's range from 7.0–8.3, conductance 8–212 µS/cm, and TP from 8–14 µg/L (except *C. scutelloides*).

The more general, cosmopolitan distribution of many *Cavinula* species (estimated 41% of taxa represented in North America) is surprising for a genus with such a small number of species. This is even more interesting, given the isolated northern and alpine distributions for many of the species. However, it could be argued that the majority of the global land mass is in the northern hemisphere and subsequently more interconnected, therefore it should not be surprizing that species from "harsher" environments can have larger distributions across the northern hemisphere (Verleyen *et al.* 2009). Currently, only a few taxa (3) including *C. pseudoscutiformis*, have been documented from the Antarctic region of the southern hemisphere (Kellogg & Kellogg 2002). The limited knowledge about diatom diversity across India and Asia limits the discussion about validated distributions globally. *C. pusio* is an interesting taxon with warm, lower altitude (290 m ASL) presence in New Zealand, a higher altitude subalpine distribution in Europe and confirmed identifications from the alpine (cold, high altitude) and Arctic Archipelago (cold, low altitude) regions in North America. Discussion over global distribution becomes even more difficult considering the large morphological variability observed within some of the taxa. The presence of morphotypes within the cosmopolitan taxa *C. cocconeiformis*, *C. cocconeiformis* f. *elliptica* and *C. pseudoscutiformis* suggest that allopatric speciation maybe evident. Establishing new species from the observed morphotypes (two within *C. cocconeiformis* and three within *C. pseudoscutiformis*) is tempting, but at present not warranted due to unsolved questions regarding species specific phenotypic plasticity. Therefore, the current picture on the global distribution of *Cavinula* species is subject to change when a better understanding of species boundaries is achieved and questions on the presence of [semi]cryptic species is resolved. At present we are uncertain whether *C. thoroddsenii* is present in North America, however, it is likely distributed in low numbers across the Arctic Archipelago. The apparent cosmopolitan distribution of some species may change if morphotypes are found to represent separate species. For instance, *C. cocconeiformis* sensu stricto and *C. pseudoscutiformis* sensu stricto may turn out to have more restricted ecological preferences.

In the establishment of the genus *Cavinula*, Mann & Stickle state that this genus has no close relatives, although they suggest that a more complete investigation of *Navicula* species may result in a better understanding of this genus and its allies. At present, *Cavinula* has a very superficial association with *Cosmioneis* with respect to plastid formation, valve shape, uniseriate round to elliptical areolae and often alternating long and short areolae around the central area. *Cosmioneis* valves have wider mantles, the mantle depth at the apex is reduced, the raphe ends are never deflected in opposite directions, the proximal raphe ends are positioned within a distinct depression, the internal central raphe ends are T-shaped and there is a specialized pore on the valvocopula at the apex. Surprisingly, some species from the two genera can be found in the same types of habitats. DNA studies should clarify the association between these genera.

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