

Short Communications

Skeletonema (Bacillariophyceae) in Indian waters: A reappraisal

R K Naik¹, D Sarno², W H C F Kooistra², P M D'Costa¹ & A C Anil^{1,*}

¹National Institute of Oceanography, Council of Scientific and Industrial Research, Dona
Paula, Goa, 403 004, India

²Stazione Zoologica Anton Dohrn, Villa Comunale, 80121, Naples, Italy
*[E-mail: acanil@nio.org]

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The planktonic diatom genus *Skeletonema* is common in Indian coastal waters. Recent taxonomic studies have uncovered high diversity in this genus, and it is expected that several species occur also in the highly diverse marine habitats along the Indian coastline. In the present study, material of a culture raised from a specimen isolated from a water sample taken from Goa and material from two Lugol fixed samples, one from the Bay of Bengal and one from the Arabian Sea, were examined. Samples were examined in LM and SEM. The culture strain from Goa was also characterized using its LSU rDNA sequence. Results revealed that the above strain belongs to *S. costatum sensu stricto*. The sample from the Bay of Bengal contained *S. grevillei* and the sample from the Arabian Sea, *S. tropicum*.

[**Keywords:** *Skeletonema costatum sensu stricto*, *S. grevillei*, *S. tropicum*, Indian waters]

The diatom genus *Skeletonema* Greville emend. Sarno et Zingone is common in the plankton of coastal marine habitats throughout the tropical and temperate regions¹⁻⁴. The first species to be described in this genus is *S. costatum* (Greville) Cleve⁵ and in most studies, the genus is considered synonymous with this species. However, such a treatment constitutes a serious underestimation of the generic diversity because several species have been recognized in *Skeletonema*. These are: *S. ardens* Sarno et Zingone⁶, *S. costatum* (Greville) Cleve emend. Zingone et Sarno (*sensu stricto*; *s.s.*)⁷, *S. dohrnii* Sarno et Kooistra⁸, *S. grethae* Zingone et Sarno⁸, *S. grevillei* Sarno et Zingone^{6,7}, *S. japonicum* Zingone et Sarno⁸, *S. marinoi* Sarno et Zingone⁸, *S. menzelii* Guillard, Carpenter and Reimann⁹, *S. potamos* (Weber) Hasle^{10,11}, *S. pseudocostatum* Medlin emend. Zingone et Sarno^{8,12}, *S. tropicum* Cleve¹³ and *S. subsalsum* (A. Cleve) Bethge^{14,15}. The taxonomic treatment of *Skeletonema* is a work in progress because some of the proposed species are not well separated genetically and/or morphologically¹⁶⁻²⁰. Moreover, cryptic diversity abounds in *S. menzelii* and *S. tropicum*²⁰.

In a recent biogeographical study, molecular and morphological approaches were integrated to identify numerous strains of *Skeletonema* collected from all over the world²⁰. Results indicated

that although most *Skeletonema* species appear to be widely distributed, none seems to be truly cosmopolitan. However, tropical regions were severely underrepresented and Indian waters were missing in their survey.

In Indian waters, Subrahmanyam²¹ reported *S. costatum*. The genus has since then been reported throughout the year, both in the Arabian Sea and the Bay of Bengal²²⁻²⁹. Along the west coast of India, *Skeletonema* blooms during the onset of the south-west monsoon after an intermittent break, when salinity is low and nutrient concentrations are higher compared to other months of the year^{26,30}. Along the east coast, *Skeletonema* dominates the phytoplankton community in the northern part of the Bay of Bengal during the south-west monsoon and it does likewise at the onset of the north-east monsoon at Kalpakkam, in the southern part of Bay of Bengal, when salinity and nutrient concentrations are low^{28,31}. These lower nutrient concentrations associated with dominance of *Skeletonema* in the Bay of Bengal are in contrast to the elevated nutrient concentrations associated with *Skeletonema* blooms along the west coast of India. In spite of these apparent differences, all these blooms are believed to consist of *S. costatum*. However, this treatment does not take into account the recent taxonomic appraisal of the genus. The goal of the present study is to give a first account

of *Skeletonema* species diversity in Indian waters according to the updated taxonomy.

To accomplish this goal, we examined one culture strain and two preserved phytoplankton samples. The culture strain was isolated from the waters of Dona Paula Bay, Goa, along the west coast of India in May 2007. It was maintained in f/2 medium³² at 25°C with 12 h : 12h L :D cycle and transferred to fresh f/2 medium every 10 days. It is presently in the culture collection of Marine Corrosion and Materials Research Division (MCMRD), National Institute of Oceanography, Goa, India. The preserved phytoplankton samples were collected from the east coast (Bay of Bengal; 21°01'N, 88°13'E; October 2006) and west coast (Arabian Sea; 15°27'N, 73°48'E; August 2007) of India. Culture and the preserved samples were prepared for LM and SEM following Sarno *et al.*⁸. Samples were observed using an Axiophot (Carl Zeiss, Oberkochen, Germany) and a JEOL JSM-6700F field emission scanning microscope.

The culture strain was also examined utilizing a molecular approach. DNA extraction, PCR amplification and sequencing of the first ca. 700 base pairs of the large subunit nuclear ribosomal RNA coding region (LSU rDNA), and alignment of this marker with other sequences was carried out as described in Sarno *et al.*⁸

Culture strain was identified as *S. costatum* s. s. based on molecular and morphological results, whereas *S. grevillei* and *S. tropicum* were identified based on morphological characters in samples from the east and west coast of India respectively.

Skeletonema costatum (Figures 1 and 2): Cells are 4-12 µm in diameter and contain 1-2 chloroplasts. In terminal valves, fuloportulae have open processes that end with a claw-like protrusion (Figure 1). In intercalary valves, processes of fuloportulae are closed, with a small hole often visible at their base and a longitudinal suture running from the hole towards the process end (Figure 2). Each process generally connects to two processes of the sibling valve (1:2 junction). In both intercalary and terminal valves, the rimoportula is located near the marginal ring of fuloportulae and has a long external process (Figure 2). The morphological features of this strain corresponded to those reported in Zingone *et al.*⁷, which re-examined the type material of the species, and in Sarno *et al.*⁶ which observed the species as live material. Results of the molecular identification procedure showed that the partial LSU rDNA

sequence of the culture strain was identical to those of *S. costatum* strains B and C (Lagoa dos Patos, Brazil, Genbank numbers EF423397 and EF423398) and strain SZN-B212 (Montevideo, Uruguay, Genbank number EF423396).

Skeletonema grevillei (Figures 3-6): Cells are 5-8 µm in diameter and contain 1-2 chloroplasts. The external parts of fuloportulae are open along their entire length in both terminal and intercalary valves. In terminal valves, processes of fuloportulae are irregularly truncated at their tips and pointed at their lateral ends (Figure 3). In intercalary valves, the processes of the fuloportulae are long (7-8 µm), each joining one process of the adjacent cells (1:1 junction) with a knuckle-like connection (Figures 4, 6). Several series of siliceous ridges link the bases of the processes to each other and to the valve mantle, delimiting a series of bigger, oval holes between the fuloportulae and a series of smaller, circular holes at the external base of the fuloportulae (Figures 3-5). In terminal valves of the colony the rimoportula is located close to the valve face margin, near the marginal ring of fuloportulae, and it bears a long process. The morphological features of some specimens found in the East coast (Figure 5) show a larger development of the silica ridges compared to the original description of the species⁷.

Skeletonema tropicum (Figures 7-9): Cells are 9-15 µm in diameter and contain several chloroplasts (1-7). Tips of the fuloportulae of terminal processes are irregularly truncated or, more often, show a claw-like projection (Figure 7). The processes of the intercalary fuloportulae connect tightly to those of the next cell (Figure 8). The junction is generally of the 1:1 type, but occasionally 1:2 junctions are visible (Figure 9). Processes of the fuloportulae are straight (Figure 8) or curved (Figure 9). Both types of processes have been observed in a single colony. Rimoportula of the terminal valves has a long external process, located midway between the annulus and the valve margin (Figure 7). Hasle¹ showed spiraling processes connecting sibling cells in specimens from Peru and from Atlantida (Uruguay) identified as *S. costatum*. Kooistra *et al.*²⁰ uncovered cryptic diversity in *S. tropicum*. However, in the present study, we did not have access to genetic information for this material.

Skeletonema costatum s. s. and *S. grevillei* have a wide geographical range, occurring in both temperate and tropical waters^{6,20}. The third species, *S. tropicum*, has been reported by Kooistra *et al.*²⁰ in tropical locations as well as in the Mediterranean

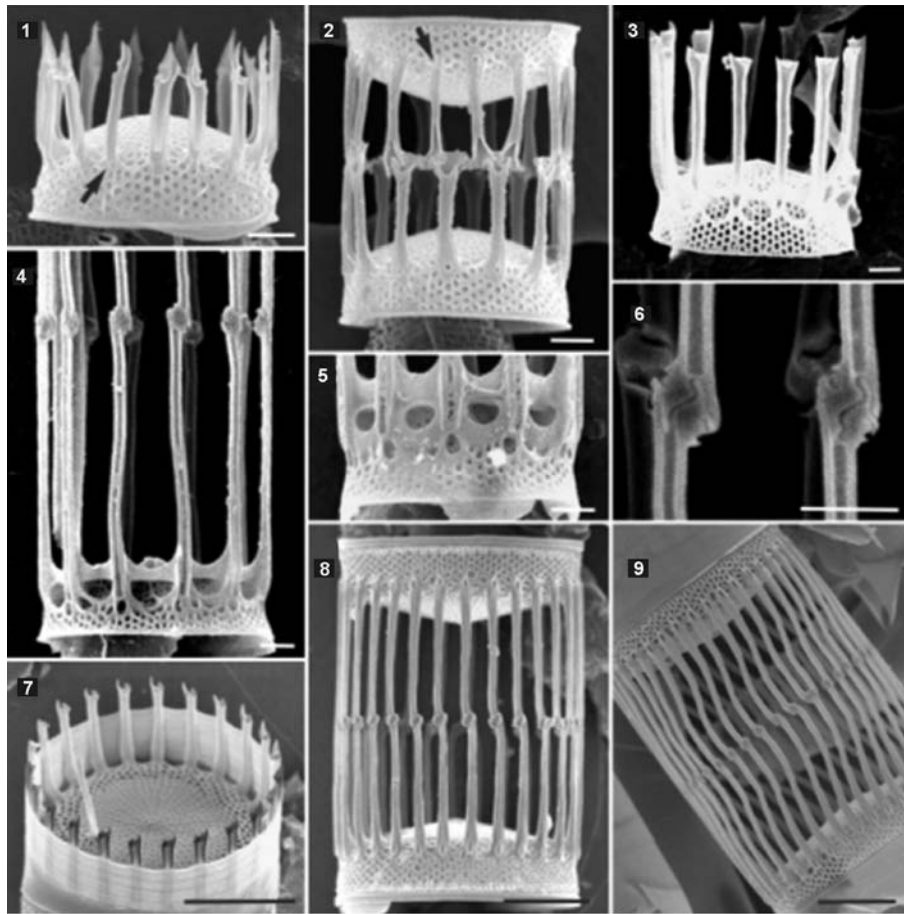


Plate 1

Plate 1— General morphology of *Skeletonema* (SEM pictures). (1) *S. costatum*, terminal valve with the marginal terminal rimoportula process (arrow). Scale bar = 1 μm . (2) *S. costatum*, intercalary valve with the long rimoportula process (arrow). Scale bar = 1 μm . (3) *S. grevillei*, terminal valve. Scale bar = 1 μm . (4) *S. grevillei*, intercalary valve. (5) *S. grevillei*, detail of an intercalary valve showing the well expanded silica ridges joining the bases of the intercalary fultoportula processes. Scale bar = 1 μm . (6) *S. grevillei*, detail of knuckle-like junction. Scale bar = 1 μm . (7) *S. tropicum*, terminal valve with fultoportula processes and subcentral rimoportula process. Scale bar = 5 μm . (8, 9) *S. tropicum*, intercalary valve. Scale bar = 5 μm

Sea, the East China Sea and in southern Brazil during summer and autumn.

The observation of two other *Skeletonema* species (*S. grevillei* and *S. tropicum*) in addition to *S. costatum* s. s. in this study highlights the need for ultrastructural and molecular taxonomic studies to unravel the diversity of *Skeletonema* in Indian waters. Regular monitoring is needed to uncover not only the diversity of this genus, but also habitat preferences and seasonal variation of the detected species.

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