

MORPHOLOGY OF TWO SPECIES OF THE MARINE PLANKTONIC DIATOM GENUS *Cerataulina* H. PERAGALLO *Ex* SCHÜTT (BACILLARIOPHYTA) FROM THE TROPICAL MEXICAN PACIFIC, INCLUDING A NEW RECORD FOR THE AREA

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ABSTRACT: The diatom genus *Cerataulina* is represented by only four taxonomically accepted species of marine, truly planktonic affinity. Although its species may not be so frequent or abundant, one species, *Cerataulina pelagica*, may be abundant in coastal zones and may form harmful blooms in some parts of the world. Based on material collected by net during various oceanographic cruises and other surveys, along coasts of the Mexican Pacific, especially the tropical portion, marine phytoplankton samples were analyzed, from which two species of *Cerataulina*, namely *Cerataulina dentata* and *C. pelagica*, were studied by LM and SEM. *Cerataulina dentata* is a new record in the area. Observations made here confirm previous descriptions including various morphological details such as the shape of cells and chains, connections between sibling valves, valve face areolation, the projections of the valve poles which are costate ocelli, which may be winged and bearing a spine at the end, a single rimoportula, centrally (or subcentrally) or marginally located (depending of the species), and the structure of the copulae of the cingulum. *Cerataulina pelagica* is widely distributed whereas *C. dentata* is more restricted to tropical areas. Finally, morphological and distributional differences are discussed for the main three species of the genus.

Key words: Diatoms, Mexican Pacific, Morphology, New record, Phytoplankton.

RESUMEN: La diatomea del género *Cerataulina* está representado por solo cuatro especies taxonómicamente aceptadas, las cuales son formas marinas y planctónicas. Las especies de este género no son frecuentes o abundantes, y solo una especie, *Cerataulina pelagica*, puede ser abundante en la zona costera y llega a formar proliferaciones nocivas en algunas partes del mundo. Este trabajo está basado en el análisis de muestras de fitoplancton marino, colectadas con red durante varios cruceros oceanográficos y otros medios a lo largo de costas del Pacífico mexicano, especialmente en la porción tropical. En algunas muestra aparecieron las especies de *Cerataulina*, *C. dentata* y *C. pelagica* las cuales fueron estudiadas con ML y MEB. *Cerataulina dentata* es un nuevo registro en el área. Las presentes observaciones confirman las descripciones previas, incluyendo detalles morfológicos como la forma de células y cadenas, las conexiones entre valvas adyacentes, la areolación valvar, las proyecciones de los polos valvares que son ocelli costados (costate ocelli) que pueden tener alas y espinas al final, una rimoportula central (o subcentral) o marginal (dependiendo de la especie), y la estructura de las copulae del cingulum. Mientras que *Cerataulina pelagica* está ampliamente distribuida en todo el Pacífico mexicano, *C. dentata* está más restringida a áreas tropicales. Se discuten finalmente las diferencias morfológicas y de distribución de tres especies de *Cerataulina*.

Palabras clave: Diatomeas, Fitoplancton, Morfología, Nuevo registro, Pacífico mexicano.

INTRODUCTION

Diatoms constitute the most diverse and often the most productive taxonomic group within the marine phytoplankton all over the world. Numerous diatom species are predominant in coastal areas, as they respond to different enrichment processes, such as upwelling and river discharges, and some of them may produce innocuous blooms, except blooms caused by potentially toxic species of the genus *Pseudo-nitzschia* H. Peragallo.

Among important members of the marine planktonic diatoms, species of the genus *Cerataulina* H. Peragallo

ex Schütt, are common part of the “cosmopolitan” phytoplankton community, especially *Cerataulina pelagica* (Cleve) Hendeny. The genus comprises usually cylindrical, chain-forming species, with cells twisted about pervalvar axis, connected by two elevations with or without wings at poles of the valves (CUPP 1943; ROUND *et al.* 1990; HASLE & SYVERTSEN 1997). There are 13 species names within the genus, of which only 5 have been flagged as accepted taxonomically (GUIRY & GUIRY 2020). However, *Cerataulina daemon* (Greville) Hasle, listed as an entity taxonomically accepted (GUIRY & GUIRY 2020), should be regarded as a synonym of

Cerataulina bicornis (Ehrenberg) Hasle (HASLE & SIMS 1985), in which case there would be only four species fully recognized. *Cerataulina zhongshaensis* Guo, Ye et Zhou was described in 1978 (GUO 2003) from waters of southern China; it is a very rare, characteristic, and not fully studied species. The currently accepted type species is *Cerataulina pelagica* (synonym: *Cerataulina bergonii* (H. Peragallo) Schütt).

There are few modern morphological and taxonomic studies of *Cerataulina*, one very important was made by HASLE & SYVERTSEN (1980), where they characterized morphologically three species using light and electron microscopy, and then HASLE & SIMS (1985) showed some details of *Cerataulina bicornis* by SEM and stated the synonymy of this species with *C. daemon*. Later, RIVERA *et al.* (2003), SUNESEN & SAR (2007) and SUNESEN *et al.* (2009) have studied morphological details of two species of the genus, *Cerataulina dentata* and *C. pelagica*, from South American waters.

Cerataulina pelagica was reported to form blooms, which were associated with the death of benthic shellfish and bony fish in New Zealand, attributed to anoxia and clogging of the gills (TAYLOR *et al.* 1985). The other species appear not so regularly in the phytoplankton and may be considered to have a more warm-water distribution, and are rather scarce and definitely not so frequent nor abundant.

In this paper, the morphology of two species, *Cerataulina dentata* and *C. pelagica*, occurring in the phytoplankton from the Mexican Pacific, is studied by Light Microscopy (LM) and Scanning Electron Microscopy (SEM), with a new record in the area for *C. dentata*. Also, a comparison among all species is discussed.

MATERIAL AND METHODS

This study is based on material collected during various oceanographic surveys along coasts of the central Mexican Pacific, especially during the oceanographic cruise “MareaR VI” carried out from 10-21 June, 2014. Net samples (mesh 64 μm) were obtained by vertical hauls, the hauling depths depending on the depth of the fixed stations; a set of samples were fixed with formalin (4%) and another set with ethanol (70%). One sample obtained from 40 m depth to surface from station 42 (in front of Acapulco, Guerrero State, located at 16° 49' N, 99° 53' W), and the preliminary microscopical analysis

yielded a number of tropical forms of diatoms, including *Cerataulina* species.

Either raw or rinsed samples were analyzed by Light Microscopy (LM, Olympus BX 40, attached camera Hitachi KP-D50 Color digital), where preliminary identifications, measurements and microphotographs were made. Whole rinsed samples or isolated specimens were additionally studied by Scanning Electron Microscopy (SEM, JEOL JSM6360LV) after air-drying and coating with gold.

Terminology for diatoms and the genus *Cerataulina* follows that recommended by ROUND *et al.* (1990) and HASLE & SYVERTSEN, (1997).

RESULTS AND OBSERVATIONS

Cerataulina pelagica (Cleve) Hendey (Figures 1-9)

Synonym: *Cerataulina bergonii* (H. Peragallo) Schütt

References: HUSTEDT, 1930, p. 869, fig. 517 (including resting spores of *Cerataulina bicornis*); CUPP, 1943, p. 167, fig 117; HENDEY, 1964, p. 113, pl. 6, fig. 4; HASLE & SYVERTSEN, 1980, p. 82, figs. 1-29, 95; TAKANO 1990, p. 272, figs. A-F; HASLE & SYVERTSEN, 1997, p. 171, pl. 32, table 38; BÉRRARD-THERIAULT *et al.*, 1999, p. 32, pl. 17 b, c, e; RIVERA *et al.* 2003, p. 652; figs. 1 A-L; SUNESEN & SAR, 2007, p. 500, figs. 4 A-G; SUNESEN *et al.*, 2009, p. 80, figs. 17 A-D; HOPPENRATH *et al.*, 2009, p. 68, figs. 29 a-h; JAMESON & HALLEGRAEFF, 2010, p. 49, figs 2.2 E-G.

Description: Cells cylindrical, arranged in straight, short to long chains, twisted about the central axis of the chain, with very narrow, rectangular apertures between valves, and with the pervalvar axis usually twice or three times the diameter (Figs. 1, 2). Some solitary cells were rarely found. There are numerous small and round to elongate chloroplasts in each cell (Figs. 1, 2). Cells with valves slightly convex, connected in the chain by two short projections on each valve (Figs. 1, 2).

The valves have a relative low mantle and show two short projections (ocelli) at opposite poles, with a single, centric or slightly eccentric rimoportula (Figs. 3-5). Each ocellus has a number (7-8) of short tangential bars (costate ocelli), and is surrounded by a wing which becomes a spine at the end (Figs. 5-7). The external part of the rimoportula is oblique to the ocelli, with a slit-like shape, and is located at the center of a depressed annulus

(Figs. 5, 6, 8). The areolae of the valves are arranged in radiating costae (Fig. 6), closed by fine porous cribra of certain complexity (Figs. 8, 9). The cingulum is composed of numerous copulae, very indistinct, split, with ligulae and antiligulae (Figs. 1, 2, 5).

Dimensions: Diameter of valve 18-36 μm , and perivalvar axis (25) 70-120 μm .

Distribution: A neritic planktonic species considered "cosmopolitan", but common in temperate and subtropical waters. The distribution of this species is wide all along coasts of the Mexican Pacific.

Cerataulina dentata Hasle in Hasle et Syvertsen (Figs 10-19)

References: HASLE & SYVERTSEN, 1980, p. 87, figs. 65, 72-94, 97; TAKANO 1990, p. 270, figs. A-E; HASLE & SYVERTSEN, 1997, p. 171, pl. 33, table 38; SUNESEN & SAR, 2007, p. 499, figs. 3 A-G.

Description: The cells are cylindrical, forming straight, short to long chains, although few solitary cells were detected, and are twisted about the central axis of the chain, leaving no aperture, or extremely narrow, between valves, and with the perivalvar axis usually more than three times the diameter (up to 10 times) (Figs. 10-12). The bands of the cingulum are very conspicuous (Figs. 10-12). Numerous small and round chloroplasts are present in each cell (Fig. 12). The cells are connected in the chain by two very short projections on each valve, with the valves slightly convex (Figs. 12, 13).

The valves show a very low mantle and two short ocelli at opposite poles, with a single, marginal rimoportula (Fig. 14). There are several knobs with minute dentate structures, at the valve margin opposite to the rimoportula, and fewer at its sides (Fig. 15). The external part of the rimoportula is an open circular structure (Fig. 16). The costate ocelli have numerous (up to 10) short tangential bars, with no wing nor spine (Fig. 17). The areolae of the valves radiate from the annulus where the marginal rimoportula is situated (Fig. 14). These are covered by fine and simple porous cribra (Fig. 18). The cingulum consists of numerous, very distinctive copulae, which are split and have ligulae and antiligulae (Fig. 19).

Dimensions: Diameter 18-25 μm , and perivalvar axis 55-120 μm .

Distribution: Species found in coastal warm water regions. This is the first record of this species in the

Mexican Pacific: it was found only in places (Acapulco) of the tropical part of the Mexican Pacific.

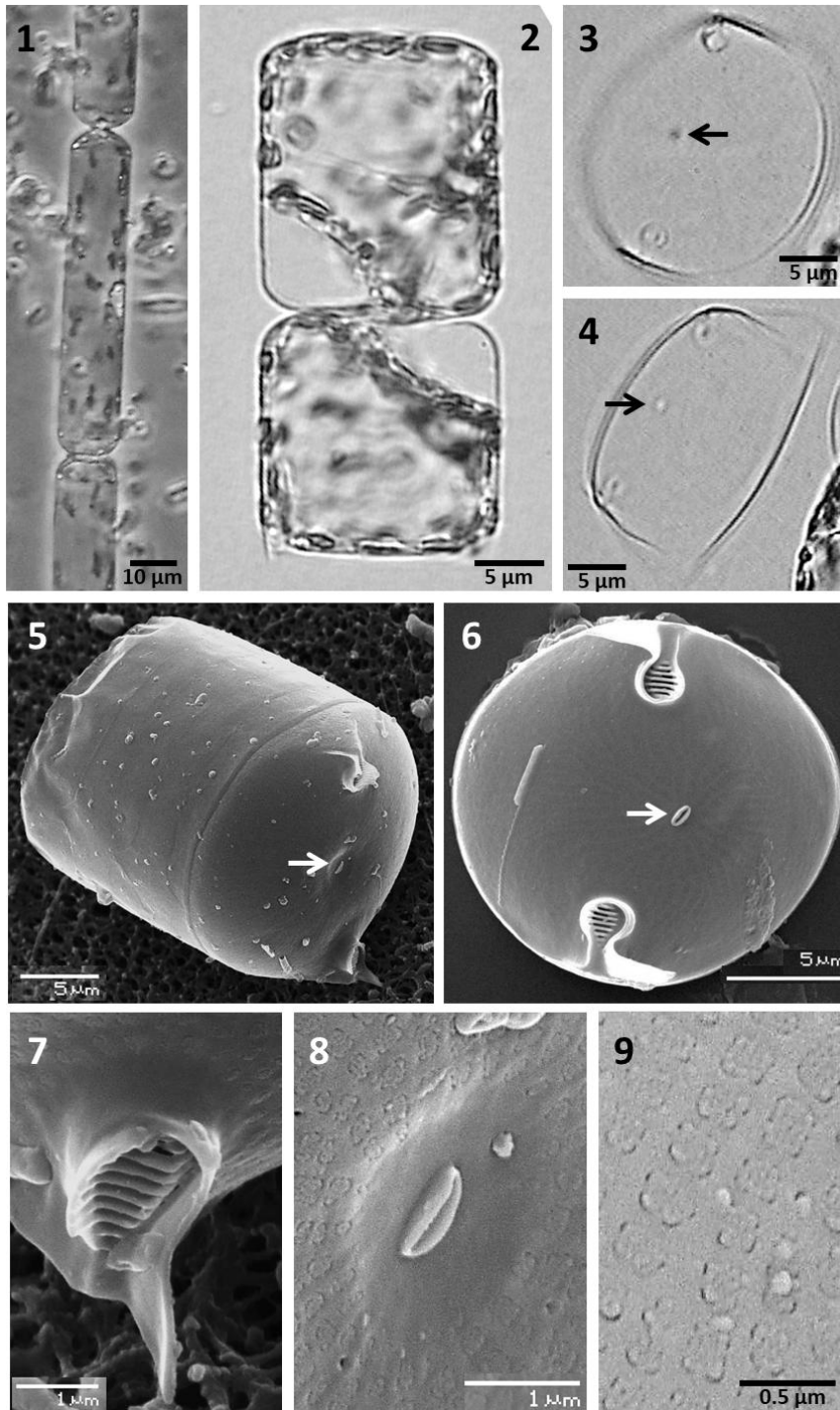
DISCUSSION

The two species of *Cerataulina* studied in this paper are truly marine planktonic, although *Cerataulina pelagica* has been reported since its original description, widely distributed in temperate and subtropical waters around the world. Consequently, it has been well-known and studied, and its records include blooms, some of them considered to be harmful (TAYLOR *et al.* 1985).

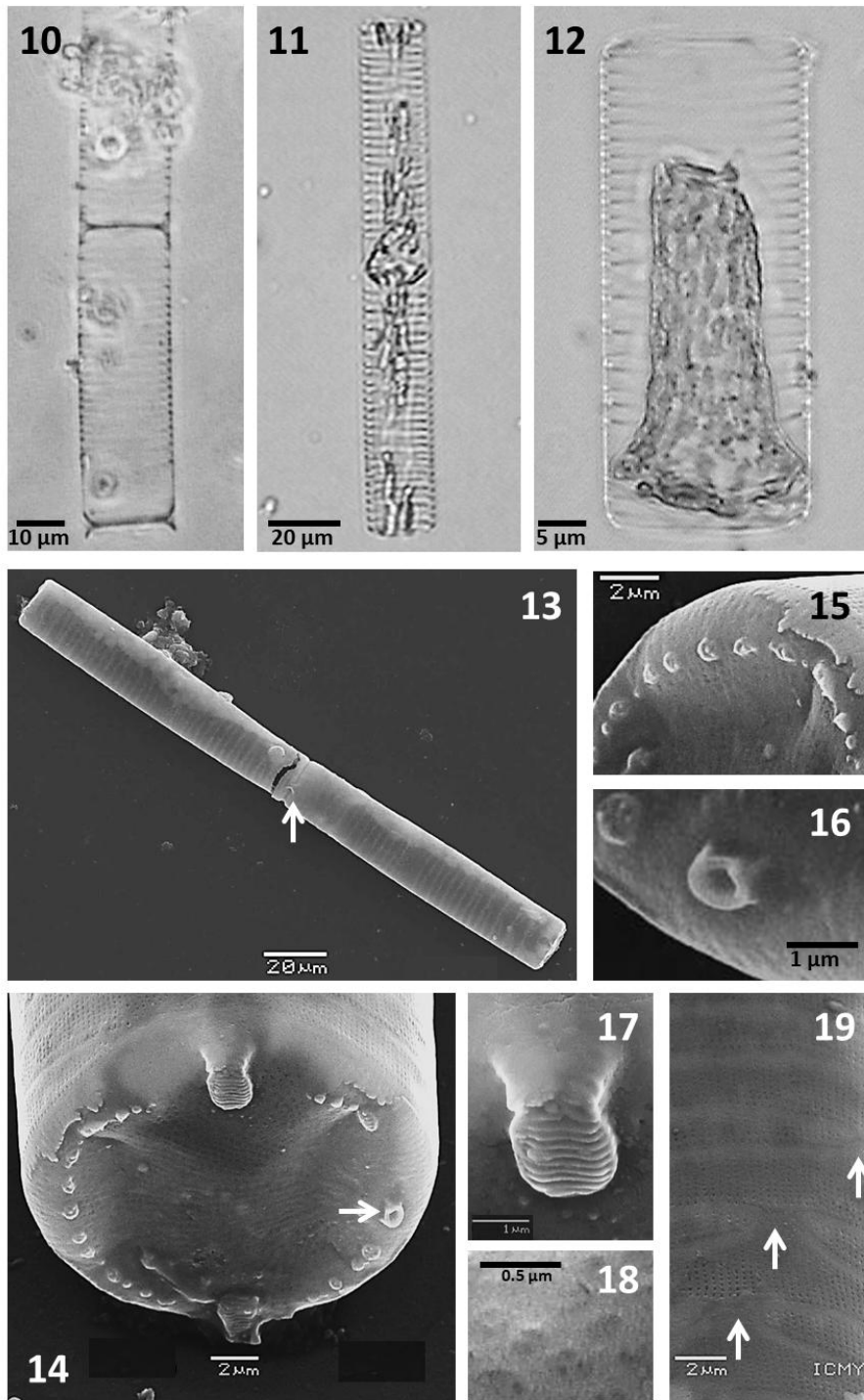
The morphology of the *Cerataulina* species is relatively simple, but characteristic, having the costate ocelli as the main feature within diatoms. Differences among all the species of the genus include the development of these costate ocelli, more elevated and with large and conspicuous (even by LM) wings and spines, and the position of the rimoportula, which is centrally or subcentrally situated in *C. pelagica*, whereas in *C. bicornis* and *C. dentata* is located at the margin (HASLE & SYVERTSEN 1997). However, *Cerataulina dentata* may be easily identified as it has a more visible morphological character that may be seen by LM and refers to the cingulum bands, which are very conspicuous. The only known species forming resting spore is *C. bicornis* (*Syringium bicornis* Ehrenberg) (HASLE & SIMS 1985).

Most of the morphological details shown in this paper confirm previous observations of the species performed in other parts of the world (HASLE & SYVERTSEN 1980; TAKANO 1990, RIVERA *et al.* 2003; SUNESEN & SAR 2007; HOPPENRATH *et al.* 2009). SUNESEN & SAR (2007) showed only details of the valves (externally and internally viewed) of *Cerataulina dentata*, but not of the chains of the species and especially the cingulum copulae; here these observations are added.

There are ecological differences in the species of the genus, including of course the world distribution, with *Cerataulina bicornis* and *C. dentata* having a distribution in warm-water regions, compared with *C. pelagica*, being widely distributed all over the world seas, as previously mentioned; it is considered to be a "cosmopolitan" species. Finally, about the fourth "taxonomically accepted" species, *Cerataulina zhongshaensis*, it has been reported only from waters of the south of China (GUO 2003). This species needs to be studied in detail for its morphology and phylogenetic



Figures 1-9. *Cerataulina pelagica*, LM and SEM. Fig. 1. Part of a twisted chain with three cells showing the connection and aperture between sibling valves. Fig. 2. Two whole living cells in a short chain. Figs. 3, 4. Individual, loose valves showing the ocelli and the central rimoportula (arrow). Fig. 5. A complete frustule, showing the cingulum, and the valve face with the two ocelli and the central rimoportula (arrow). Fig. 6. Valve view with the two costate ocelli and rimoportula (arrowed). Fig. 7. Detail of one costate ocellus with a terminal spine. Fig. 8. Detail of the external part of the central rimoportula. Fig. 9. Detail of the areolae of the valve face.



Figures 10-19. *Cerataulina dentata*, LM and SEM. Fig. 10. Part of a chain showing conspicuous cingulum bands. Figs. 11, 12. Two individual, solitary cells with cellular content and visible cingulum bands. Fig. 13. A chain of two complete frustules, with the connection between sibling valves by one projection (ocellus) (arrow). Fig. 14. Valve view showing the two costate ocelli at opposite poles, the marginal rimoportula (arrow) and the dentate knobs. Figs. 15, 16. Details of marginal dentate knobs and rimoportula, respectively. Fig. 17. Detail of one costate ocellus. Fig. 18. High magnification of the areolae arrangement. Fig. 19. Details of copulae of the cingulum, with ligulae (arrows).

relationships, as it appears to be different from the other three of the genus.

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