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Morphological study of the marine planktonic diatom *Chaetoceros okamurai* (Chaetocerotales, Bacillariophyceae) from the Gulf of Mexico

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SUMMARY

Despite the numerous works on phytoplankton in the Gulf of Mexico, there are new records of species made continually, especially diatoms and dinoflagellates in this area. The presence of the planktonic diatom *Chaetoceros okamurai* Ikari, originally described by Ikari in 1928 from Japanese Pacific waters, is reported from the Gulf of Mexico. This species appeared occasionally in net samples from the southern Gulf of Mexico. Its morphology was studied by light and scanning electron microscopy. Some morphological characteristics are useful to distinguish *C. okamurai* from closely related species: the form of the chains (slightly twisted and heteropolar); the shape of the aperture (typically rhombical); and the shape of the valves. A single rimoportula, centrally placed, is present in every valve of the chain. *Chaetoceros okamurai* belongs to the subgenus *Chaetoceros* (*Phaeoceros*) and the section Borealia, and seems to be closely related to the species *Chaetoceros borealis* Bailey, *Chaetoceros densus* Cleve, *Chaetoceros eibenii* Grunow and *Chaetoceros octagonus* Hernández-Becerril. This is the first record of *C. okamurai* since its original description, and a new record in the Gulf of Mexico (Atlantic Ocean). The distribution of the species is poorly known, but apparently it is a tropical to subtropical form.

Key words: *Chaetoceros okamurai*, diatoms, distribution, Gulf of Mexico, morphology, plankton.

INTRODUCTION

The planktonic diatom *Chaetoceros okamurai* Ikari was originally described by Ikari (1928) from Japanese Pacific waters (Seto area), based on *Peragallia meridiana* Schütt *sensu* Okamura (1907), which is now regarded as a synonym. Since then, the species has not been recorded elsewhere, although it is cited by Yamaji (1966) in his compilation of plankton of Japan. This lack of records may be due to misidentification, because in fact, superficial resemblances exist between *C. okamurai* and other species widely distributed and often reported, such as *Chaetoceros borealis* Bailey, *Chaetoceros densus* Cleve and *Chaetoceros eibenii* Grunow, as well as the recently described species *Chaetoceros octagonus* Hernández-Becerril (all of them belonging to the subgenus *Chaetoceros*). Consequently, no detailed observations have been made on the species.

There are numerous papers on phytoplankton in the Gulf of Mexico, but still new records of species (diatoms and dinoflagellates) are continually made. During a survey of phytoplankton in the southern Gulf of Mexico, more than 40 taxa of the diatom genus *Chaetoceros* were recorded (D. Hernández-Becerril and Flores Granados, unpubl. data). A morphological study of *C. okamurai* is presented here, based on samples from the same area, including comments on its systematics and distribution.

MATERIALS AND METHODS

Preserved samples, collected by phytoplankton nets (54 μm mesh) during 11 cruises (1983–1989) from various points in the southern Gulf of Mexico, were analyzed. All materials were preserved in 4% formaldehyde. Table 1 shows locations of samples where *C. okamurai* was found.

The species was studied by light (Olympus CH) and scanning electron microscopy (SEM; JEOL-JMS 35 and Phillips 501, usually operated at 10–12 kV), using either rinsed (with distilled water) or cleaned material (following oxidation of organic material and acid treatment; Hasle 1978). Fresh and permanent slides were prepared for light microscopy, from which identification was made and measurements were taken. Preparation of aluminium stubs were made for SEM: drops of rinsed or cleaned material or specimens isolated were placed onto coverslips, air-dried and coated with gold.

Terminology follows classical references (Anonymous 1975; Ross *et al.* 1979), as well as considerations by

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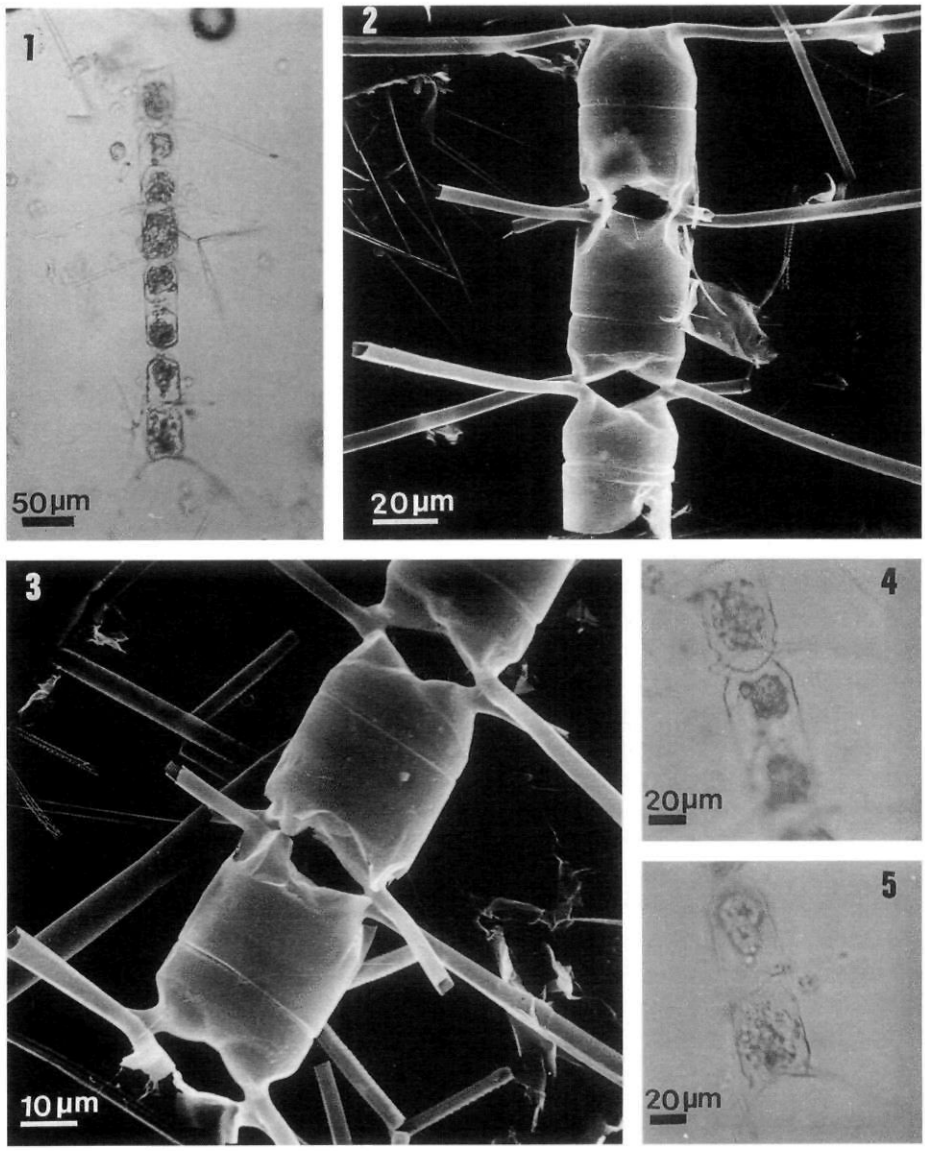
Table 1. Location of samples in which *Chaetoceros okamurai* was found

Sample	Station	Location (Gulf of Mexico)	Cruise/date
40	VIII-B-35	20°25'N 90°50'W	YUCATAN IV (13-24/V, 85)
24	80-160	22°30'N 90°30'W	JS 8702 (15-27/IX, 87)
18	100-150	21°30'N 91°00'W	Argos 89-1 (24/VI-3/VII, 89)
26	80-170	22°30'N 90°00'W	Argos 89-1 (24/VI-3/VII, 89)



Figs 1–5. *Chaetoceros okamurai*. 1. A complete, twisted chain, showing six cells, two of which are in division (LM). 2. Two complete cells and one sibling valve of the anterior end of a chain (SEM). 3. Middle part (three cells) of one chain (SEM). 4. Detail of the anterior end of a chain (LM). 5. Posterior end of the same chain (LM).

Rines and Hargraves (1988) and Hernández-Becerril (1991, 1996) on the genus *Chaetoceros*.

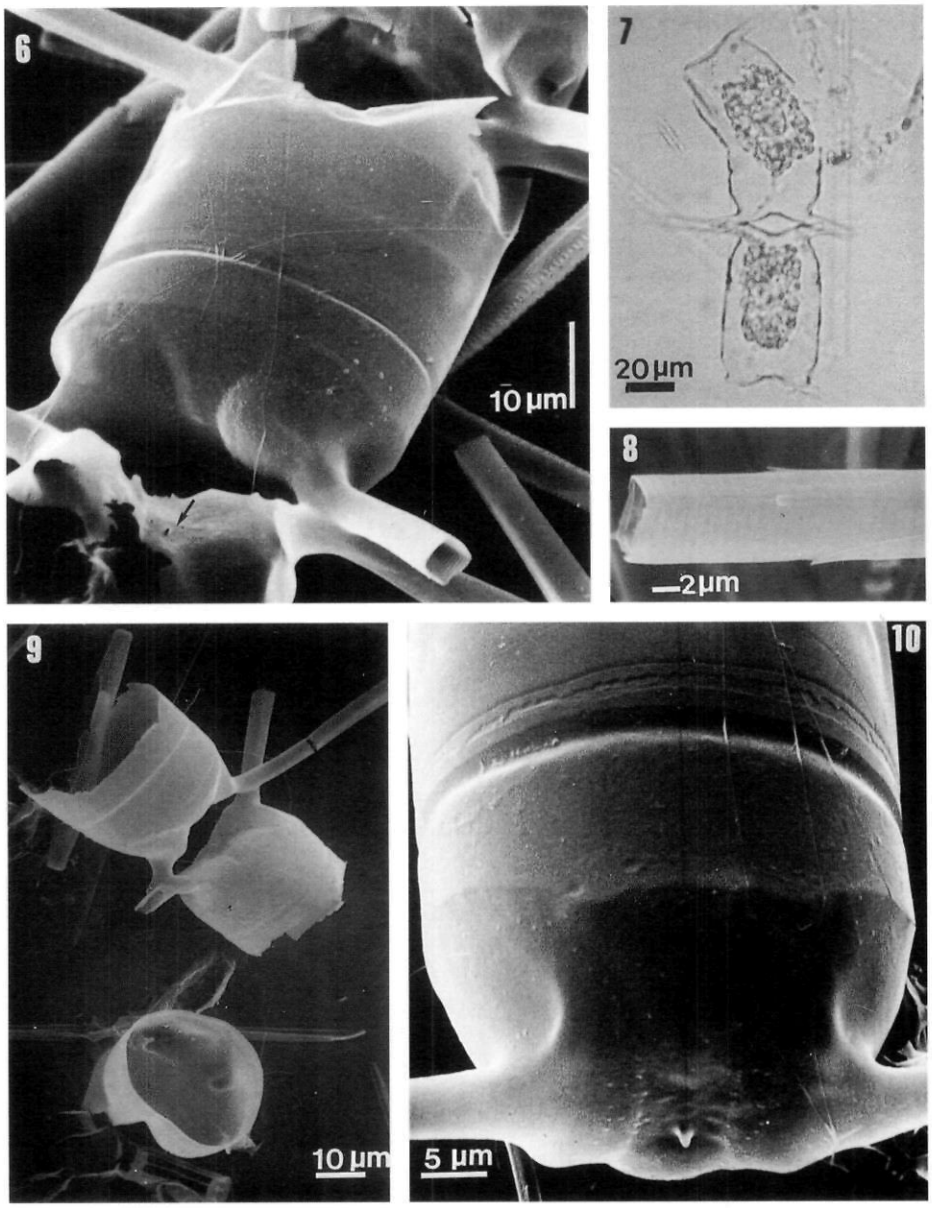
RESULTS

Selected references

Chaetoceros okamurai Ikari 1928, p.248, fig. 2a–e.
Peragallia meridiana auct. non Schütt: Okamura, 1907, p.100, pl. 6, fig. 65.

Description

Chaetoceros okamurai is a robust species which forms chains that are medium-sized to relatively long (5–10 cells per chain), heteropolar (with the two ends distinct: anterior and posterior ends, respectively) and twisted (Fig. 1). The apertures are relatively large and lenticular to typically rhombical (Figs 2–4, 7). The cells are cylindrical (the pervalvar axis longer than the apical one) with an octagonal shape, and the corners of the cells are inside the valve margin (Figs 2–5). The setae are



Figs 6–10. *Chaetoceros okamurai*. 6. Detail of a complete intercalary cell: the external aperture of the rimoportula is arrowed (SEM). 7. Two cells of a chain, showing the rhombical aperture (LM). 8. An intercalary seta (four-sided), exhibiting transverse costae and spines on the edges (SEM). 9. Two sibling valves and another loose valve viewed internally (SEM). 10. Detail of a terminal valve showing the external flattened projection of the rimoportula (SEM).

thick and coarse, straight (the anterior terminal setae are slightly curved) and all directed toward one end (Figs 1–3). Chloroplasts are small, rounded, occurring in both the main body of the cells and setae (Fig. 1).

Intercalary valves are convex (Figs 2–5, 7), while terminal valves are slightly convex or flat (Figs 2, 10). The valve face is reduced and the valve mantle is high to relatively high in all cells (Figs 6, 10). In valve view, the valves are elliptical to subcircular (Fig 9). The valves are heavily silicified, perforated irregularly by small poroids (Figs 6, 10). No marked annulus was apparent in the valve face. At least three girdle bands are present in the cells (Figs 3, 6). There is an evident constriction at the point where the mantle meets the girdle (Figs 2, 3, 6, 10).

The setae arise from the apices of the valves well inside the valve margin; the sibling setae fuse together immediately (Figs 2–7). The bases of the setae are raised structures that occupy most of the valve face leading to the rhombical shape of the aperture (Figs 6, 9). They are circular in cross-section at their very base (Figs 6, 9), becoming four-sided distally (Figs 3, 6, 8). All setae bear transversal costae and rows of poroids in between these (Fig. 8). Spines are also present on the edges of the sides (Fig. 8). No significant differences are found between terminal and intercalary setae, apart from the slight curvation of the terminal setae (Figs 1, 5).

A single rimoportula occurs on each valve face at the centre (Figs 6, 10). On terminal valves, there is a short flattened tube projected externally from the rimoportula, diagonally orientated and centrally located (Fig. 10). Intercalary valves show no clear projection (Fig. 6).

Specimens measured yielded 28–39 µm apical axis, 40–47 µm pervalvar axis, 6–8 µm aperture, and 3.5–4.8 µm width of setae.

Distribution

Chaetoceros okamurai appeared in a few locations in the study area (Table 1), as an occasional to common form but never abundant. It is not clearly neritic nor oceanic in habitat, as it was found in samples of both regions. The species seems to have no defined temporal distribution, for it appeared in various seasons.

DISCUSSION

Morphology

The morphology of *C. okamurai* is similar to other species of the subgenus *Chaetoceros* (*Phaeoceros*), especially the section Borealia: robust chains, heavily silicified frustules, valves simply perforated by small pores, thick and polyedric setae with costae and spines, and one rimoportula per valve in the chain (Evensen and Hasle 1975; Koch and Rivera 1984; Hernández-Becerril 1996).

Several characteristics, however, differentiate the species from others of the same section (Borealia), such as the shape of the chains (heteropolar and twisted), and the shape of the valves (especially the raised bases of setae) and apertures (typically rhombical), which are considered sufficient to separate *C. okamurai* from closely related species.

The original description and illustration include no comment of twisted chains, a feature evident in this study. Moreover, the characteristic of numerous girdle bands or 'costations on the girdle' in some specimens described originally by Ikari (1928) was not observed in the specimens studied here, although this fact also occurs in specimens of *Chaetoceros denticulatus* Lauder, often illustrated in the original description and other literature with several girdle bands and found in the Mexican Pacific with no extensions of the girdle (Hernández-Becerril 1996).

Despite the fact that Ikari's original material of the species was not observed, all other characteristic features and figures show that the species described in this study belongs to *C. okamurai*. Probably the typical rhombical shape of the aperture is the most significant feature that aids positive identification.

Additionally, no specimen of the var. *tetraseta* Ikari was encountered in the samples, in which two pairs of setae per valve occur.

Taxonomy

Chaetoceros okamurai certainly belongs to the subgenus *Chaetoceros*, within the section *Borealia*, although originally Ikari (1928) did not include the species in any section. It is closely related to the species *C. borealis*, *C. densus*, *C. eibenii* and *C. octagonus*, species already studied by electron microscopy (Evensen and Hasle 1975; Koch and Rivera 1984; Hernández-Becerril 1992, 1996; Table 2).

Table 2. Morphological characteristics of *Chaetoceros okamurai* and closely related species

Species	Chains	Aperture	Valves	Rimoportula	Setae	Remarks
Chaetoceros borealis[a]	Straight, long	Oval, large	Costae	No external protrusion	4–5 sided, 2 striae/2 costae	—
Chaetoceros densus[b]	Straight, long	Lanceolate, narrow	Weak costae	No external protrusion	4 sided, 1 stria/2 costae	*
Chaetoceros eibenii[c]	Straight, long	Hexagonal, large	Costae	External protrusion	4–6 sided, ?	**
Chaetoceros octagonus[d]	Straight, short	Hexagonal, narrow	No costae	No external protrusion	4 sided, 1 stria/2 costae	***
Chaetoceros okamurai[e]	Twisted, heteropolar	Rhombical, large	No costae	External protrusion, terminal valves	4 sided, 2 striae/2 costae	****

[a]Evensen and Hasle (1975); [b]Hernández-Becerril (1996); [c]Koch and Rivera (1984); [d]Hernández-Becerril (1992); [e]Ikari (1928) and this study.
*Internal poroid mesh in bases of setae; **production of resting spores; ***external bases of setae distinctly raised; ****external bases of setae raised.

All five species form relatively long chains, although only *C. okamurai* exhibits twisted or straight and heteropolar chains, the rest showing straight chains (Table 2). The general appearance of the chains of *C. borealis*, *C. eibenii* and *C. okamurai* is similar, including the relatively narrow aperture and the shape of the cells. It may be slightly difficult to differentiate these species if not taking into account specific characters, therefore misidentifications have probably been made. *Chaetoceros eibenii*, however, is a unique species of the subgenus *Chaetoceros* in producing resting spores.

Chaetoceros borealis is mainly distributed in cold waters, *C. densus* and *C. eibenii* are widely distributed in temperate and subtropical areas. *Chaetoceros octagonus* is so far known only from tropical–subtropical regions, for it is a recently described species (Hernández-Becerril 1992).

Distribution

This appears to be the first documented record after its original description. Consequently, this is the first record of *C. okamurai* in the Gulf of Mexico and the Atlantic Ocean. Yamaji (1966) has reported this species for the plankton of Japan, but apparently it was cited for a compilation rather than observed from samples, and his illustrations were taken from those of Ikari (1928).

The species seems to be distributed in tropical–subtropical waters of the Pacific and Atlantic Oceans. Probable misidentification may have led to ignoring its real distribution.

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