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Morphological description of *Cyclotella atomus* var. *marina* (Bacillariophyceae): newly reported in Korean waters

Mi Hee Chung¹, Won Duk Yoon¹ and Joon-Baek Lee^{2,*}

¹National Fisheries Research and Development Institute, Busan 619-705, Korea

²Department of Earth and Marine Sciences, Marine and Environmental Research Institute, Jeju National University, Jeju 690-756, Korea

A variety of *Cyclotella atomus* were discovered among the epiphytic diatoms on eelgrass (*Zostera marina* L.) in Korean waters. *Cyclotella atomus* var. *marina* has a flat and disc-shaped valve, and is clearly differentiated into a striate marginal zone and a smooth central zone. The valves have a very small diameter ranging from 3.1-3.4 μm . This small diatom does not have any central ornamentation. The marginal striate zone has numerous granules toward the mantle. The valves have five or six marginal fultoportulae with two satellite pores and a single marginal rimoportula.

Key Words: *Cyclotella*; *Cyclotella atomus* var. *marina*; diatom; eelgrass; epiphytic

INTRODUCTION

Genus *Cyclotella* comprises a large complex of centric diatoms, which have been divided into different groups (Håkansson 2002). This genus was first introduced by Kützing (1833) as a subgenus of *Frustulia* Ag., which included one species, *Frustulia operculata* Ag. Brébisson (1838) adopted the *Cyclotella* group of Kützing as a new genus, which included two species: *Cyclotella ovalis* and *C. operculata*. However, no generitype was designated by Brébisson. *C. operculata*, the monotype of the subgenus, automatically became the generitype of the genus. *Cyclotella* (Kütz.) Brébisson was predominantly a freshwater genus in the family Stephanodiscaceae Makarova and highly diverse with more than 100 species (van Landingham 1969).

Cyclotella has been widely reported in various habitats including terrestrial fossil species, freshwater species, brackish or marine water species, and even attached species on phytoplankton and macrophyte (Sullivan 1982, Chang and Steinberg 1988, Håkansson et al. 1993, Hasle

and Syvertsen 1997). However, description of *Cyclotella* attached to seagrass has been rare.

Some taxonomical studies on *Cyclotella* have been carried out in Korea (Lee and Lee 1988, Lee et al. 1994, Lee et al. 1995b, Cho 1996). Several *Cyclotella* species, such as *C. badanica*, *C. comta*, *C. meneghiniana*, *C. stelligera*, *C. striata*, *C. striata* var. *ambigua*, and *C. stylorum*, were reported as the benthic diatom from the coastal areas (Choi 1990) and 15 *Cyclotella* species were reported as the plankters from the freshwater, brackish and marine waters of Korea (Lee et al. 1995b).

Presently, we describe the newly reported variety *Cyclotella atomus* var. *marina* in Korean waters based on scanning electron microscopy (SEM) observation.

MATERIALS AND METHODS

Eelgrass (*Zostera marina* L.) samples were collected

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*Corresponding Author

E-mail: jblee@jejunu.ac.kr

Tel: +82-64-754-3435, Fax: +82-64-725-2461

Fig. 1. A map showing the sampling site.

for epiphytic diatom research from the region of Yulim-ri (34°36'N, 127°47'E) (Fig. 1), Yeosu City, Korea, in July 1998. The site has densely populated eelgrass beds, and is a small, semi-closed bay with narrow openings. Eelgrass sampling was carried out during ebb tide. The eelgrass samples were randomly collected in the upper 1 cm of sediments in a 10 × 10 cm quadrat, and then refrigerated and moved to the laboratory (Heijs 1985, Moncreiff et al. 1992). The epiphytic diatoms on eelgrass were rinsed with distilled water, and removed with a nylon brush and a rubber knife. The collected epiphytic diatoms were cleaned with HNO₃ and H₂SO₄, and mounted on cover slips for observing with SEM (TOPCON sm-300; Topcon, Co., Tokyo, Japan) as described previously (Hasle 1983).

The diameter of this species was measured on 50 frustules using Optimas V. 6.5 image analysis software (Media Cybernetics, Silver Spring, MD, USA). The valve structure elements were also measured using the software and as described previously (Genkal and Kiss 1993), using the formula:

$$\tau = 10n/\pi D$$

where τ is number of striae in 10 μ m; n , the number of striae on circumference of valve face; and D , the diameter of the valve. Terminology is according to Anonymous (1975) and Lee et al. (1995a).

Nutrient factors were measured by the method of Strickland and Parsons (1972), and water temperature and salinity was recorded using a YSI MODEL 33 SCT me-

ter (Yellow Springs Instrument Co. Inc., Yellow Springs, OH, USA).

RESULTS

Observation

Cyclotella atomus var. *marina* Tanimura, Nagumo et Kato 2004

Present study Figs 2-21

Tanimura et al. (2004) Figs 3-15

Description: According to Håkansson (2002), Lowe (1975), and Servant-Vildary (1984), we describe in detail *Cyclotella atomus* var. *marina*.

The cells are solitary and disc-shaped. The valves are circular, flat, but those with a slight undulation can be found. The diameter of valves range from 3.1 to 3.4 μ m.

The details of the central area, the marginal area, the mantle and the girdle band of the external view (Figs 2-7, Figs 18-21) are as follows. The central zone is smooth without any depressions and surrounded by striae. The striae (점무늬열) consist of 15 or 16 areola in 10 μ m and have a simple alveolate structure. Each alveolus (벌집구멍) is opened externally by means of rows. In the marginal area, the fulcportulae (strutted process, 받침돌기) number 5 or 6 for every cell. The external pores of the fulcportulae range from 0.07-0.11 μ m in diameter. Towards the mantle the regular rows gradually increase in number to 4-6 before reaching the margin of the shallow mantle. The striate zone has numerous granules toward the mantle. The girdle is composed of several bands, which are open (Figs 6, 7 & 14-17).

The internal view with the central area, marginal area, the mantle fulcportulae with their satellite pores, the rimoportula (labiate process, 입술돌기) and the position (Figs 8-17) are as follows. The valve shows the alveoli, with one of the costae bearing the rimopotula and the costa bearing a fulcportula. The central area of the silica has no visible structure internally and extends over to nearly two-thirds the length of the costae and alveoli. The marginal fulcportulae are arranged at every second or third interstria with two satellite pores, and close to the mantle margin. They number 5 or 6 for every cell. The internal pores of the fulcportulae range from 0.14-0.18 μ m. There is one marginal rimoportula per cell. This is situated on a recessed costa on the very short mantle in nearly the same or slightly over position as one of the fulcportulae, and is externally visible as an elongated opening. The

Figs 2-7. *Cyclotella atomus* var. *marina* SEM photos. Figs 2 & 3. External view, showing marginal fultoportula (Fu.) and rimoportula (Ri.). Figs 4 & 5. 3-4 rows areolae in each stria. Figs 6 & 7. External girdle view, showing girdle folded in several bands. Each scale is shown in each photo.

Figs 8-13. *Cyclotella atomus* var. *marina* SEM photos (Fu., Fultoportula; Ri., Rimoportula; s.p., satellite pore). Fig. 8. Six fultoportulae with two satellite pores arranged at every third cost, while one rimoportula is located beside one fultoportula. Figs 9-11. Five fultoportulae arranged at every third costa. Figs 12 & 13. One rimoportula in the ring of fultoportulae. Each scale is shown in each photo.

Figs 14-17. *Cyclotella atomus* var. *marina* SEM photos; internal valve view. Fig. 14. Five fultoportulae and one rimoportula. Fig. 15. Details of Fig. 14, showing rimoportula (Ri.), fultoportula (Fu.) with two satellite pores (s.p.) and open girdle band (arrow). Figs 16 & 17. Rimoportula (Ri.), fultoportula (Fu.) with two satellite pores (s.p.) and open girdle band (arrow). Each scale is shown in each photo.

internal lips are small and vertical to the proximal costa.

Iconotypes: Figs 2-21 in the present study

Type locality: Yulim-ri, Dolsan Island of Yeosu, Korea

Habitat: metaphytic which means to be epiphytic or planktonic form, and abundant in marine waters around 26 psu salinity (Table 1).

DISCUSSION

A system of infrageneric classification of *Cyclotella* was initially proposed by Lowe (1975) and further extended

by Servant-Vildary (1984). Apart from the criteria used by Lowe's classification, which are 1) presence and spacing of marginal fultoportulae, 2) presence and spacing of fultoportulae on the valve face, 3) presence and number of rimoportulae, 4) presence of spines, 5) other special features such as granulae and structure of striae, Servant-Vildary (1984) has further emphasized the importance of the structure of the alveoli. According to this diagnostic features proposed by Lowe and Servant-Vildary, we compared *Cyclotella atomus* var. *marina* with other species of *Cyclotella* (Table 2). All the compared species represent the following characteristics; a) a simple alveolus structure, b) presence of marginal rimoportula with simple internal lips, c) marginal fultoportula with simple external

Figs 18-21. *Cyclotella atomus* var. *marina* SEM photos; showing various morphology of external valve. Each scale is shown in each photo.

and internal pores. *C. atomus* var. *marina* in this paper, *C. atomus* in Trigueros et al. (2000) (Figs 12-15), and *C. atomus* var. *atomus* in Genkal and Kiss (1993) (Fig. 13), have also similar fultoportulae, which have short tubes and the two satellite pores range parallel to the alveolae on the internal valve face. However, *C. atomus* var. *marina* in this paper differs from the other species in the absence of any central structure including pore, fultoportulae, and rimoportula. In contrast, *C. atomus*, *C. atomus* var. *atomus* and *C. atomus* var. *gracilis* have a central pore and fultoportulae.

In addition, it is very difficult to discern the morphological features in detail by light microscopy observation because of very small size. However, it can be seen that there is no fultoportula on the valve face and a simple al-

Table 1. The physico-chemical factors of the sampling site in July 1998

Factors	Value	Range in 1998-1999 ^a
NO ₂ (μM)	26.99	0.09-26.99
NO ₃ (μM)	9.12	0.03-83.09
NH ₄ (μM)	1.14	1.14-93.61
PO ₄ (μM)	3.44	0.08-3.44
TN (μM)	37.25	6.62-134.26
SiO ₂ (μM)	1.18	0.10-3.87
p-SiO ₂ (μM)	0.08	0.03-0.50
Water temperature (°C)	23	8.5-28.3
Salinity (psu)	26	14.3-26.0

^aTaken from Chung (2003).

Table 2. Comparison of diagnostic features between *Cyclotella atomus* var. *marina* and other varieties of *Cyclotella atomus*

	<i>C. atomus</i> var. <i>marina</i> in the present study	<i>C. atomus</i> var. <i>marina</i> in Tanimura et al. (2004)	<i>C. atomus</i> in Håkansson and Clarke (1997)	<i>C. atomus</i> var. <i>atomus</i> in Genkal and Kiss (1993)	<i>C. atomus</i> var. <i>gracilis</i> in Genkal and Kiss (1993)
Habitat	Marine	Marine	Freshwater-brackish	Freshwater	Freshwater
Forms of central area	F	F	F or SU	SU	SU
Diameter of valves (μm)	3.1-3.4	3-4.5	3.5-8.0	no data	5.0-7.5
Central fuloportula	×	×	○	○	○
Marginal fuloportula	○	○	○	○	○
Number of satellite pore	2	2	2-3	2-3	2-3
Marginal rimoportula	○	○	○	○	○

F, Flat; SU, Slightly undulated.

veolate structure at the margin.

The cell structure and size of *C. atomus* var. *marina* in this paper are similar to only *C. atomus* var. *marina* reported by Tanimura et al. (2004). Both have a similar size, a number of marginal fuloportula and rimoportula, and do not have any central structure.

C. atomus var. *marina* was first recorded by Tanimura et al. (2004) in Tokyo Bay, Japan. This species grows abundantly at a salinity of around 30 psu salinity and is abundant in water with higher nutrients, such as in bays. The presently-described *C. atomus* var. *marina* was also found in nutrient-rich marine waters (Table 1).

C. atomus var. *marina* described in this study was found among epiphytic diatom on eelgrass, but Tanimura et al. (2004) reported this species in the water column of Tokyo Bay. Actually, it seems to be not a true epiphyta because we could not find any attaching material. This species may not be a true epiphytic, but rather a meta-phytic diatom that exists in both benthic and/or planktonic forms (Håkansson personal communication).

According to this ecological and morphological evidence, we believe that the species in the present study is identical with the *C. atomus* var. *marina* described as a new variety by Tanimura et al. (2004). This is the first report of this species in Korean waters.

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