JOURNAL OF
ECOLOGY AND ENVIRONMENT
http://www.jecoenv.org

Research Paper
J. Ecol. Environ. 36(4): 407-419, 2013

Taxonomic study on the euryhaline *Cyclotella* (Bacillariophyta) species in Korea

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Abstract

Cyclotella species were collected at 51 sites from July 2010 to June 2013 in Korean coastal waters. A total of five *Cyclotella* species (*C. atomus* var. *marina, C. baltica, C. litoralis, C. meduanae,* and *C. meneghiniana*) were identified in this study. The diagnostic characteristics for five *Cyclotella* species are described, focusing on the spacing, position, number of satellite pores of the mantle fultoportula and valve face fultoportula. In addition, we put the salinity ranges of five species of *Cyclotella* together. Of the five *Cyclotella* species, *C. baltica, C. litoralis* and *C. meduanae* are newly recorded in Korea.

Key words: Bacillariphyceae, *Cyclotella*, euryhaline diatom, new to Korea

INTRODUCTION

The genus *Cyclotella* (Kützing) Brébisson is represented primarily in freshwater habitats, but many species, such as *C. atomus* Hustedt, *C. baltica* (Grunow) Håkansson, *C. caspia* Grunow, *C. choctawhatcheeana* Prasad, *C. cryptica* Reimann, Lewin *et* Guillard, *C. desikacharyi* Prasad, *C. litoralis* Lange *et* Syvertsen, *C. meneghiniana* Kützing, *C. scaldensis* Muylaert *et* Sabbe, *C. striata* (Kützing) Grunow and *C. stylorum* Brightwell occur in marine or brackish waters (Håkansson 2002, Prasad and Nienow 2006, Tanaka 2007).

Cyclotella are characterized by having circular valves with different ornamentation between the central area and the marginal area of the valve face. Due to the morphological similarity among species and high intra-specific variation, taxonomic discriminations of the *Cyclotella* species are hard to unravel (Håkansson and Kling 1994, Meyer and Håkansson 1996). In addition, further taxonomic confusion is caused by the small size of the cells and numerous similarities among the species belonging to *Cyclotella* sensu lato. Recently Håkansson (2002) published the genus *Puncticulata* Håkansson from nine *Cyclotella* species based on the central area of valve faces, as well as the particular locations of fultoportulae and rimoportulae. Houk and Klee (2004) established the genus *Discostella* Houk *et* Klee from all stelligeroid *Cyclotella* taxa according to the position of the mantle fultoportulae and rimoportula on marginal striae.

In Korea, Lee and Lee (1988) firstly examined six *Cyclotella* species from southern and western coastal waters of Korea using scanning electron microscopy. Lee et al. (1994) studied the fine structure of *Cyclotella pseudostelligera* Hustedt. Lee et al. (1995a) reported 15 *Cyclotella* species of diatoms in Korea. Lee et al. (1995b) originally described *Cyclotella orientalis* from the Nakdong River. Lee (1995) made a check-list and added two *Cyclotella* species in Korean waters. Cho (1996) founded nine *Cyclotella* species at Nakdong River, *C. woltereckii* Hustedt was firstly reported in Korea. Recently, Chung et al. (2010) first reported *Cyclotella atomus* var. *marina* from a diatom assemblage attached to an eelgrass sample at the Yeosu

http://dx.doi.org/10.5141/ecoenv.2013.407

Received 29 October 2013, **Accepted** 19 November 2013

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Table 1. Sampling information of *Cylcotella* in the Korean coastal waters

Date	Station	Locality	Latitude (N)	Longitude (E)
28 Aug 2010	[1]ES-01	Dogu-ri, Donghae-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do	35°59.801	129°27.470
28 Aug 2010	ES-02	Duho-dong, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°03.812	129°23.258
29 Aug 2010	ES-03	Wolpo-ri, Cheongha-myeon, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°12.491	129°22.553
29 Aug 2010	ES-04	Ganggu-ri, Ganggu-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°21.560	129°23.141
29 Aug 2010	ES-05	Gusan-ri, Giseong-myeon, Uljin-gun, Gyeongsangbuk-do	36°45.614	129°28.335
29 Aug 2010	ES-06	Geumjin-ri, Okgye-myeon, Gangneung-si, Gangwon-do	37°39.151	129°03.107
30 Aug 2010	ES-07	Bongpo-ri, Toseong-myeon, Goseong-gun, Gangwon-do	38°15.050	128°34.055
30 Aug 2010	ES-08	Oho-ri, Jugwang-myeon, Goseong-gun, Gangwon-do	38°19.474	128°31.598
30 Aug 2010	ES-09	Gajin-ri, Jugwang-myeon, Goseong-gun, Gangwon-do	38°22.366	128°30.558
15 Nov 2010	[2]SS-01	Guseong-ri, Sani-myeon, Haenam-gun, Jeollanam-do	34°43.205	126°23.178
15 Nov 2010	SS-02	Sin-gi-ri, Doam-myeon, Gangjin-gun, Jeollanam-do	34°31.685	126°46.390
16 Nov 2010	SS-03	Gyoryang-dong, Suncheon-si, Jeollanam-do	34°54.535	127°30.316
09 Jun 2011	SS-04	Noil-ri, Gwayeok-myeon, Goheung-gun, Jeollanam-do	34°40.893	127°19.043
10 Jun 2011	SS-05	Hwagye-ri, Idong-myeon, Namhae-gun, Gyeongsangnam-do	34°46.528	127°56.565
02 Nov 2012	SS-06	Jumun-ri, Yonghyeon-myeon, Sacheon-si, Gyeongsangnam-do	34°59.530	128°03.058
02 Nov 2012	SS-07	Galsa-ri, Geumseong-myeon, Hadong-gun, Gyeongsangnam-do	34°56.658	127°46.882
02 Nov 2012	SS-08	Annam-ri, Daeseo-myeon, Goheung-gun, Jeollanam-do	34°44.881	127°18.794
22 Jul 2010	[3]YS-01	Jeongwang-dong, Siheung-si, Gyeonggi-do	37°19.572	126°39.282
22 Jul 2010	YS-02	Jeon-gok-ri, Seosin-myeon, Hwaseong-si, Gyeonggi-do	37°11.209	126°39.109
22 Jul 2010	YS-03	Gungpyeong-ri, Seosin-myeon, Hwaseong-si, Gyeonggi-do	37°06.951	126°40.618
22 Jul 2010	YS-04	Hanjin-ri, Songak-eup, Dangjin-si, Chungcheongnam-do	36°58.248	126°46.993
22 Jul 2010	YS-05	Hwagok-ri, Daesan-eup, Seosan-si, Chungcheongnam-do	37°00.185	126°27.201
23 Jul 2010	YS-06	Chang-ri, Buseok-myeon, Seosan-si, Chungcheongnam-do	36°37.465	126°22.003
23 Jul 2010	YS-07	Yeongbo-ri, Ocheon-myeon, Boryeong-si, Chungcheongnam-do	36°19.689	126°30.603
23 Jul 2010	YS-08	Dodun-ri, Seo-myeon, Seocheon-gun, Chungcheongnam-do	36°09.481	126°30.023
23 Jul 2010	YS-09	Dasa-ri, Biin-myeon, Seocheon-gun, Chungcheongnam-do	36°05.867	126°36.869
23 Jul 2010	YS-10	Sinchang-ri, Janghang-eup, Seocheon-gun, Chungcheongnam-do	36°00.403	126°41.874
23 Jul 2010	YS-11	Sutong-ri, Buri-myeon, Geumsan-gun, Chungcheongnam-do	35°38.287	126°27.771
23 Jul 2010	YS-12	Anseong-ri, Dongjin-myeon, Buan-gun, Jeollabuk-do	35°47.250	126°44.897
23 Jul 2010	YS-13	Simpo-ri, Jinbong-myeon, Gimje-si, Jeollabuk-do	35°51.406	126°41.940
24 Jul 2010	YS-14	Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°56.146	126°31.672
24 Jul 2010	YS-15	Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°43.670	126°31.759
24 Jul 2010	YS-16	Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°41.283	126°31.922
24 Jul 2010	YS-17	Sinsido-ri, Okdo-myeon, Gunsan-si, Jeollabuk-do	35°43.732	126°31.916
14 Oct 2010	YS-18	Wolgot-dong, Siheung-si, Gyeonggi-do	37°23.247	126°44.413
14 Oct 2010	YS-19	Jeongwang-dong, Siheung-si, Gyeonggi-do	37°20.725	126°41.265
14 Oct 2010	YS-20	Sa 2-dong, Sangrok-gu, Ansan-si, Gyeonggi-do	37°17.509	126°49.289
14 Oct 2010	YS-21	Manho-ri, Poseung-eup, Pyeongtaek-si, Gyeonggi-do	36°57.666	126°50.000
14 Oct 2010	YS-22	Gwongwan-ri, Hyeondeok-myeon, Pyeongtaek-si, Gyeonggi-do	36°55.031	126°54.394
14 Oct 2010	YS-23	Daeeum-ri, Inju-myeon, Asan-si, Chungcheongnam-do	36°51.157	126°51.278
14 Oct 2010	YS-24	Unjeong-ri, Sinpyeong-myeon, Dangjin-si, Chungcheongnam-do	36°53.385	126°49.573
14 Oct 2010	YS-25	Seopo-ri, Napo-myeon, Gunsan-si, Jeollabuk-do	36°02.165	126°47.043
14 Oct 2010	YS-26	Soryong-dong, Gunsan-si, Jeollabuk-do	35°58.019	126°37.032
15 Oct 2010	YS-27	Seonyeon-ri, Okseo-myeon, Gunsan-si, Jeollabuk-do	35°53.158	126°37.737
15 Oct 2010	YS-28	Woryeon-ri, Hoehyeon-myeon, Gunsan-si, Jeollabuk-do	35°53.180	126°43.653
15 Oct 2010	YS-29	Geumgwang-ri, Hoehyeon-myeon, Gunsan-si, Jeollabuk-do	35°53.351	126°46.013
15 Oct 2010	YS-30	Anseong-ri, Dongjin-myeon, Buan-gun, Jeollabuk-do	35°47.238	126°44.822
15 Oct 2010	YS-31	Gyehwa-ri, Gyehwa-myeon, Buan-gun, Jeollabuk-do	35°47.634	126°38.629
15 Nov 2010	YS-32	Ogam-dong, Mokpo-si, Jeollanam-do	34°47.803	126°26.097
15 Apr 2011	YS-33	Busu-ri, Sinpyeong-myeon, Dangjin-si, Chungcheongnam-do	36°54.605	126°48.900
17 Apr 2011	YS-34	Gung-ri, Seobu-myeon, Hongseong-gun, Chungcheongnam-do	36°35.608	126°27.347

[1]ES, East Sea; [2]SS, South Sea; [3]YS, Yellow Sea.

coast in Korea.

Although 21 species of *Cyclotella* diatom have been recorded in Korea (Lee et al. 1995a, Lee 1995, Cho 1996, Chung et al. 2010), several *Cyclotella* species have been transferred into the other cyclotelloid genera, such as *Discostella* and *Puncticulata*, following the recent complication of cyclotelloid diatoms (Håkansson 2002, Houk and Klee 2004): four *Cyclotella* species (*C. bodanica* Eulenstein, *C. comta* (Ehrenberg) Kützing, *C. comta* var. *glabriuscula* Grunow, *C. radiosa* (Grunow) Lemmermann) were transferred into the genus *Puncticulata*; five *Cyclotella* species (*C. comta* var. *glabriuscula* Grunow, *C. orientalis* Lee, Chung et Gotoh, *C. pseudostelligera* Hustedt, *C. stelligera* (Cleve et Grunow) Van Heurck, *C. woltereckii* Hustedt) were transferred into the genus *Discostella*.

We present the fine structure, description, distribution and taxonomic remarks of five *Cyclotella* species in Korean waters. Of the five species discussed in this paper, we include three species which are newly recorded in Korea.

MATERIALS AND METHODS

Sample collections were carried out at 51 sites from July 2010 to June 2013 in Korean coastal waters (Table 1). Phytoplankton were collected using a 20 μm mesh net by horizontal and/or vertical towing. Samples were immediately fixed with neutralized formalin (5% final concentration). Using a method presented by Hasle and Fryxell (1970), organic matter in the diatom cell was removed. Prepared diatom material was observed under a light microscope (Axioskop 40; Carl Zeiss, Oberkochen, Germany) and a scanning electron microscope (JSM-5600LV; JEOL, Tokyo, Japan), and was photographed with an MRc5 camera (Carl Zeiss). Diatom size analysis was completed with image calculation software (AxioVision AC version 4.5; Carl Zeiss). The general terminology was adopted from the proposals on Diatom Terminology (Anonymous 1975, Ross et al. 1979), and some special terms for *Cyclotella* followed Håkansson (2002) and Tanaka (2007).

RESULTS AND DISCUSSION

A total of five *Cyclotella* were identified in the present study, we present keys for five *Cyclotella* species based on morphological characteristics, such as the space, position, number of satellite pores of the mantle fultoportula and valve face fultoportula (Table 2).

Key to 5 *Cyclotella* species in Korea

1a. Two satellite pores on mantle fultoportula 2
1b. Three satellite pores on mantle fultoportula 4
2a. No central fultoportula .....*C. atomus* var. *marina*
2b. Several central fultoportula 3
3a. Mantle fultoportula on recessed interstria ...*C. litoralis*
3b. Mantle fultoportula on thickened interstria...*C. baltica*
4a. Space of mantle fultoportula on every 2nd interstria .....*C. meduanae*
4b. Space of mantle fultoportula on every interstria ....*C. meneghiniana*

Description of species

***Cyclotella atomus* var. *marina* Tanimura, Nagumo *et* Kato 2004 (Fig. 1)**

Description: Valves are 2.8-5.0 μm in diameter. The central area is flat to slightly tangentially undulate without colliculate ornamentation (Fig. 1A and 1B). The marginal striae density is 20-25 in 10 μm. Valve face fultoportula is absent. Mantle fultoportulae located on every 2nd to 3rd interstria (Fig. 1A-1D), internally the tubulus is surrounded by two satellite pores (Fig.1C and 1D). A single rimoportula located on the ring of mantle fultoportulae, internally the rimoportula has a narrow sessile labium (Fig. 1C and 1D).

Distribution: *Cyclotella atomus* var. *marina* was found from a diatom assemblage attached to an eelgrass sample taken from waters with a salinity of approximately 26, in the region of Yulimri, Yeosu City, Korea in July 1998 (Chung et al. 2010). However, the species occurred total 5 times as a planktonic in this study and reported once and four times from the South Sea and the Yellow Sea, respectively (Table 3).

Remarks: *Cyclotella atomus* var. *marina* is distinguished from other variety of *C. atomus* by the absence of a valve face fultoportula (Chung et al. 2010).

***Cyclotella baltica* (Grunow) Håkansson 2002 (Fig. 2)**

Basionym: *Cyclotella striata* var. *baltica* Grunow in Van Heurck 1882, pl. 92, figs 13-15, non *Cyclotella litoralis* Lange et Syvertsen sensu Håkansson 1996.

Description: Valves are 13.9-37.0 μm in diameter. The central area tangentially undulate with a slightly colliculate ornamentation (Fig. 2A-2C and 2E). The marginal striae density is 10-15 in 10 μm. Valve face fultoportula number two to nine (Fig. 2C-2F), internally surrounded by three satellite pores (Fig. 2D and 2F). Mantle fultoportulae located on every 2nd to 3rd interstria (Fig. 2G and

http://dx.doi.org/10.5141/ecoenv.2013.407

Table 2. Morphological information of 5 *Cyclotella* species in the present study

Species	Diameter (μm)	Valve face	Central area ornamentation	Marginal striae in 10 μm	Central fultoportula		Mantle fultoportula		Rimoportula			Spines
					Number	Satellite pores	Space	Satellite pores	Position	External shape	Internal shape	
C. atomus var. *marina*	2.8-5.0	flat to slightly tangentially undulate	smooth	20-25	0	NA	every 2nd to 3rd interstria	2	between the mantle fultoportulae	slit-like opening	sessile labium	spinules
C. baltica	13.9-37.0	tangentially undulate	slightly colliculate	10-13	2-9	3	every 2nd to 3rd interstria	2	slightly above the ring of mantle fultoportulae	slit-like opening	sessile labium	granules
C. litoralis	23.0-63.0	tangentially undulate	colliculate	8-12	5-20	3	every 2nd interstria or sometimes a pair	2	lower from the mantle fultoportulae	slit-like opening	sessile labium	granules on interstriae toward mantle
C. meduanae	6.21-7.79	flat to slightly undulate	smooth	12-15	0	NA	every 2nd or sometimes every interstria	3	between the mantle fultoportulae	slit-like opening	sessile labium	granules
C. meneghiniana	8.0-30.3	slightly tangentially undulate	smooth	8-10	1-7	3	every interstria	3	between the mantle fultoportulae	slit-like opening	stalked and often bent labium	spines

NA: not applicable.

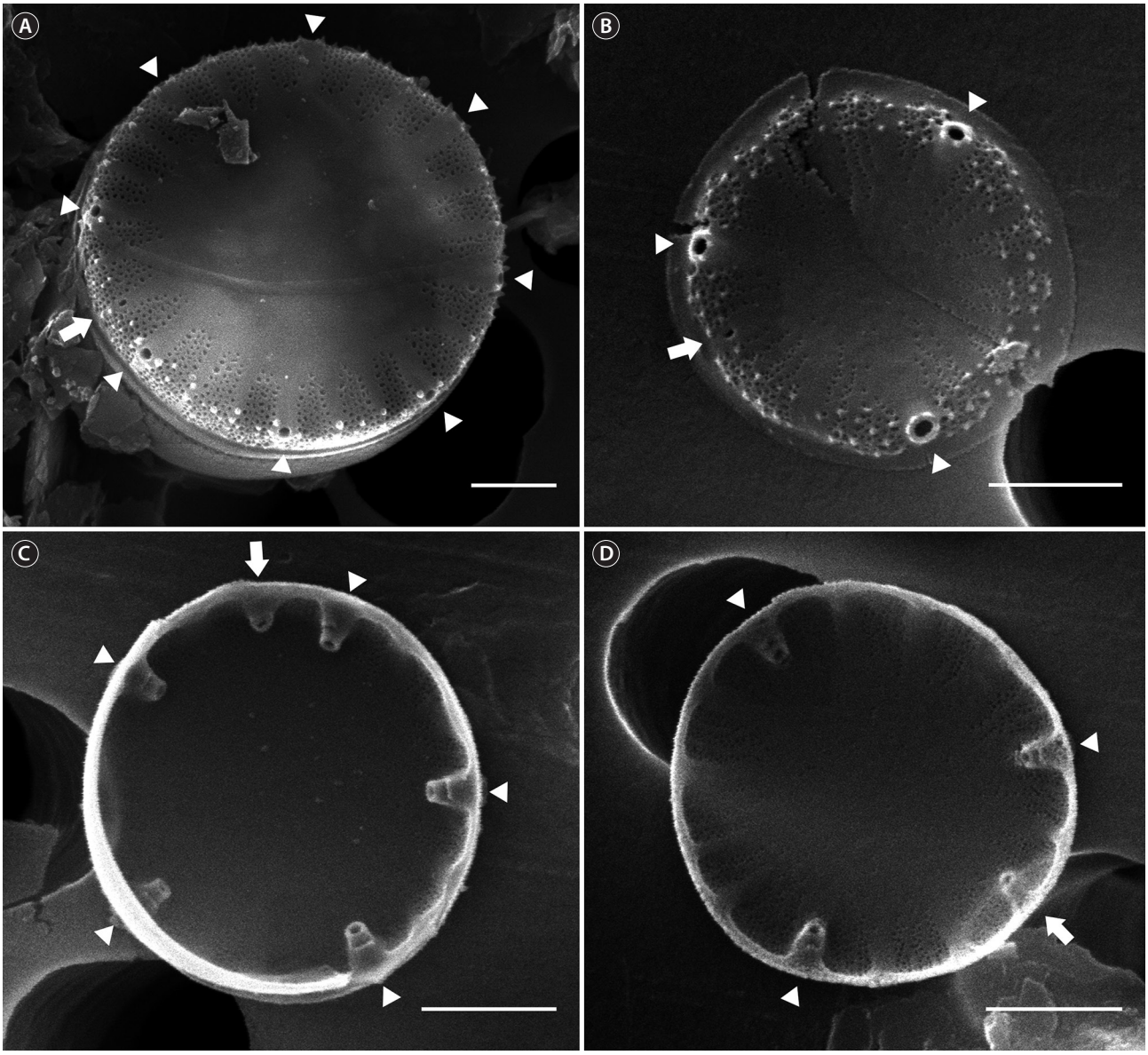

Fig. 1. *Cyclotella atomus* var. *marina* Tanimura, Nagumo et Kato. Arrow and arrowheads indicate the rimoportula and the fultoportula respectively. (A-B) External valve view, (C-D) Internal valve view. Scale bars,1 μm.

2H), internally the tubulus is surrounded by two satellite pores (Fig. 2H). A single rimoportula located slightly above the ring of the mantle fultoportulae, internally the rimoportula has a sessile labium (Fig. 2H).

Distribution: Grunow (1882) collected *C. baltica* from the Baltic. Tanaka (2007) collected this species from Hokkaido to Kyushu in Lake Abshiri, Mikawa Bay, and regarded as a brackish to marine water species. *Cyclotella baltica* occurred total 11 times in this study, and was observed as a planktonic from the East Sea (one time) and the Yellow Sea (10 times), there was no occurrence from the South Sea (Table 3). This species is firstly recorded in the present study.

Remarks: Håkansson (2002) placed *C. striata* var. *baltica* in *C. baltica* according to the absence of the valve face fultoportula, and stated that the species were regarded as *C. striata* previously (Hustedt 1928, Cleve-Euler 1951, Helmcke and Krieger 1954, Helmcke et al. 1974, Takano 1976, Prasad et al. 1990) was in fact *C. baltica*. Tanaka (2007) described *C. baltica* from Japanese specimens. However, the Japanese material showed some differences from the lectotype of Håkansson (2002): a valve diameter

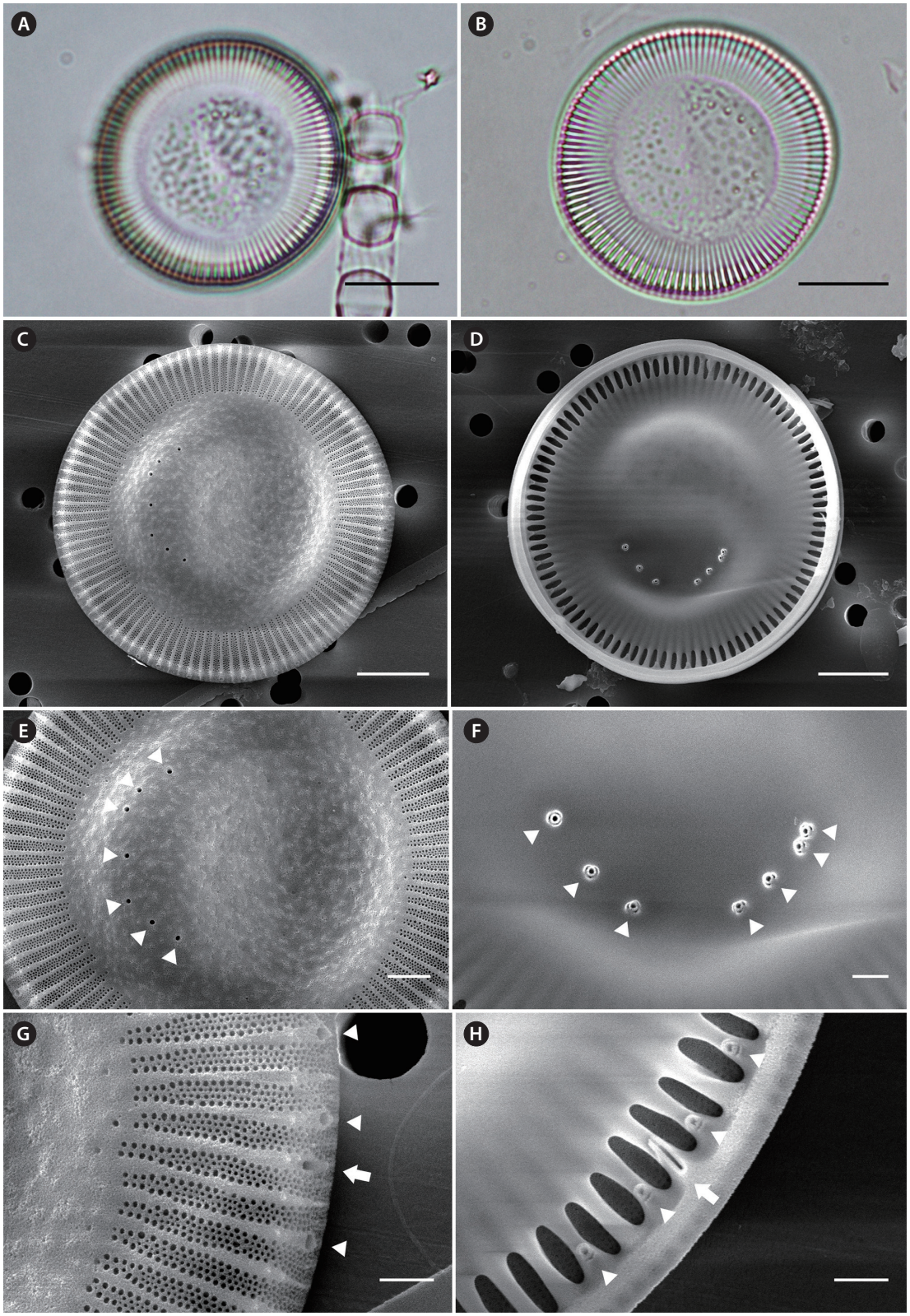

Fig. 2. *Cyclotella baltica* (Grunow) Håkansson. Arrow and arrowheads indicate the rimoportula and the fultoportula, respectively. (A) External valve view, (B) Internal valve view, (C) Central area with 7 fultoportulae in the external valve view, (D) Seven fultoportulae with 3 satellite pores on the central area of valve face in the internal valve view, (E) Externally striated marginal area with mantle fultoportulae and rimoportula, (F) Internally alveolated marginal area with mantle fultoportulae and rimoportula. Scale bars represent: A, B, 10 μm; C, D, 5 μm; E, 2 μm; G, H, 1 μm.

Table 3. Check-list of 5 *Cyclotella* species in Korean coastal waters

Sea	Station	Salinity (psu)	*C. atomus* var. *marina*	*C. baltica*	*C. litoralis*	*C. meduanae*	*C. meneghiniana*
East Sea	ES-01	33.45					+
	ES-02	29.88					+
	ES-03	33.71					+
	ES-04	33.57					+
	ES-05	33.95			+		+
	ES-06	32.36					+
	ES-07	31.73		+			
	ES-08	26.72					+
	ES-09	27.84					+
South Sea	SS-01	1.90					+
	SS-02	30.87			+		
	SS-03	0.04					+
	SS-04	34.80			+		
	SS-05	29.79			+		
	SS-06	28.01	+		+		
	SS-07	28.88			+		
	SS-08	27.37					
	SS-09	30.88			+		
Yellow Sea	YS-01	30.13		+	+		+
	YS-02	21.50			+		
	YS-03	27.80			+		
	YS-04	29.31			+		
	YS-05	31.32			+		
	YS-06	15.93			+		+
	YS-07	31.17			+		
	YS-08	30.61		+	+		
	YS-09	27.25			+		
	YS-10	23.05					+
	YS-11	30.68			+		
	YS-12	10.17	+	+		+	+
	YS-13	16.55		+			+
	YS-14	29.84		+			+
	YS-15	29.66			+		
	YS-16	29.79			+		
	YS-17	28.54			+		
	YS-18	24.56			+		+
	YS-19	26.43			+		
	YS-20	19.73	+				+
	YS-21	26.04			+		+
	YS-22	23.22			+		+
	YS-23	0.20					+
	YS-24	23.98			+		
	YS-25	0.10					+
	YS-26	18.78					+
	YS-27	21.88	+	+			+
	YS-28	22.70	+	+	+	+	+
	YS-29	13.20		+		+	+
	YS-30	15.32		+	+		+
	YS-31	26.27		+	+		+
	YS-32	30.80					+
	YS-33	23.77					+
	YS-34	33.97			+		
Total occurences			5	11	29	3	30

and the position of external opening of rimoportula. The morphological characteristics in Korean specimens agree with the description of *C. baltica* in Håkansson (2002): a valve diameter, the external position of rimoportula, the striae dense and the spacing of mantle fultoportulae. Although Korean specimens show well-developed alveoli in the internal valve view (Fig. 2B and 2F), the variation of alveoli development within *Cyclotella* species have been reported (Beszteri et al. 2005). Therefore, we regarded the Korean specimens as *C. baltica*.

***Cyclotella litoralis* Lange *et* Syvertsen 1989 (Fig. 3)**

Description: Valves are 23.0-63.0 μm in diameter. The central area tangentially undulates with colliculate ornamentation (Fig. 3A-3C and 3E). The marginal striae density is 8-12 in 10 μm. Valve face fultoportula is eight to twelve (Fig. 3C and 3D), internally surrounded by three satellite pores (Fig. 3F). Mantle fultoportulae located on every 2nd (Fig. 3G and 3H), or sometimes, on a pair (Fig. 3G), internally the tubulus is surrounded by two satellite pores (Fig. 3H). A single rimoportula is located on the fultoportulae below the mantle, internally the rimoportula has a sessile labium (Fig. 3H).

Distribution: Lange and Syvertsen (1989) originally described as *C. litoralis* from the south western Atlantic, and Tanaka (2007) described this species in Isahaya Bay, Nagasaki Prefecture, Japan. This species was observed 29 times from all of the Sea as a planktonic in this study (Table 3). Although *C. litoralis* is firstly recorded in this study, Lee and Lee (1988) already observed *Cyclotella* sp. A from Gwangyang Bay and Jinhae Bay. However, since then there was no additional study for identification of the species.

Remarks: *Cyclotella litoralis* have been confused with *C. striata* complex (e.g., *C. baltica*, *C. striata*, *C. stylorum*): This species have been distinguished from *C. baltica* based on the spacing of the mantle fultoportulae (Håkansson 2002), as well as the number of central fultoportula (Prasad and Nienow 2006). In this study, the presence of the recessed costa is an additional characteristic for distinguishing between the two species (Fig 2B and 3B). *Cyclotella striata* can be distinguished from *C. litoralis* based on the absence of a valve face fultoportula (Håkansson 2002). The spacing of mantle fultoportula can be used to distinguish between *C. litoralis* and *C. stylorum* (Lange and Syvertsen 1989).

***Cyclotella meduanae* Germain 1981 (Fig. 4)**

Description: Valves are 6.2-7.8 μm in diameter. The central area is flat to slightly tangentially undulate, without colliculate ornamentation (Fig. 4A and 4B). The marginal striae density is 12-15 in 10 μm. Valve face fultoportula is absent (Fig. 4A-4C). Marginal fultoportulae are located on every 2nd to 3rd interstria (Fig. 4A-4D), internally the tubulus is surrounded by three satellite pores (Fig. 4D). A single rimoportula is located on the ring of marginal fultoportulae, internally the rimoportula has a narrow sessile labium (Fig. 4D).

Distribution: *Cyclotella meduanae* originally described from Mayenne, France (Germain 1981). Tanaka (2007) examined the Japanese specimen from Inba Pond, Chiba Prefecture and mentioned that *C. meduanae* has been found mainly in eutrophic water and freshwater. In the present study, *C. meduanae* is newly recorded and was found 3 times as a planktonic (Table 3).

Remarks: *Cyclotella meduanae* has been noted to have morphological similarity with *C. meneghiniana* (Håkansson 2002). Håkansson (2002) mentioned that the only difference between both species is the absence or presence of the valve face fultoportula. However, we found an additional difference in the spacing of the mantle fultoportulae between *C. meduanae* and *C. meneghiniana*: in the first one, the mantle fultoportulae was located on every second interstria, while the latter on every interstria (compare Fig. 4C with Fig. 5B).

***Cyclotella meneghiniana* Kützing 1844 (Fig. 5)**

Synonyms: *Surirella melosiroides* G.G.A. Meneghini ms. 1844; *Cyclotella kuetzingiana* var. *meneghiniana* (Kützing) Brun 1880; *Stephanocyclus meneghiniana* (Kützing) Skabichevskii 1975.

Description: Valves are 8.0-30.3 μm in diameter. The central area is slightly tangentially undulate and without colliculate ornamentation (Fig 5A-5E). The marginal striae density is 8-10 in 10 μm. Valve face fultoportula is one to seven (Fig. 5A-5F), internally surrounded by three satellite pores (Fig. 5F). Marginal fultoportulae are located on every interstria (Fig. 5G and 5 H), internally the tubulus is surrounded by three satellite pores (Fig. 5H). A single rimoportula located on the ring of marginal fultoportulae, internally the rimoportula has a stalked, and often bent, sessile labium (Fig. 5H).

Distribution: *Cyclotella meneghiniana* have been found in varied habitats including brackish water, and both eutrophic and oligotrophic freshwater (Håkansson 2002, Tanaka 2007). In Korea, Lee and Lee (1988) firstly recorded *C. meneghiniana* in the Han River and Ulsan Bay near Taehwa River estuary. Cho (1996) described *C. meneghiniana* from the Nakdong River. *Cyclotella meneghiniana* was most frequently observed in this study. This species

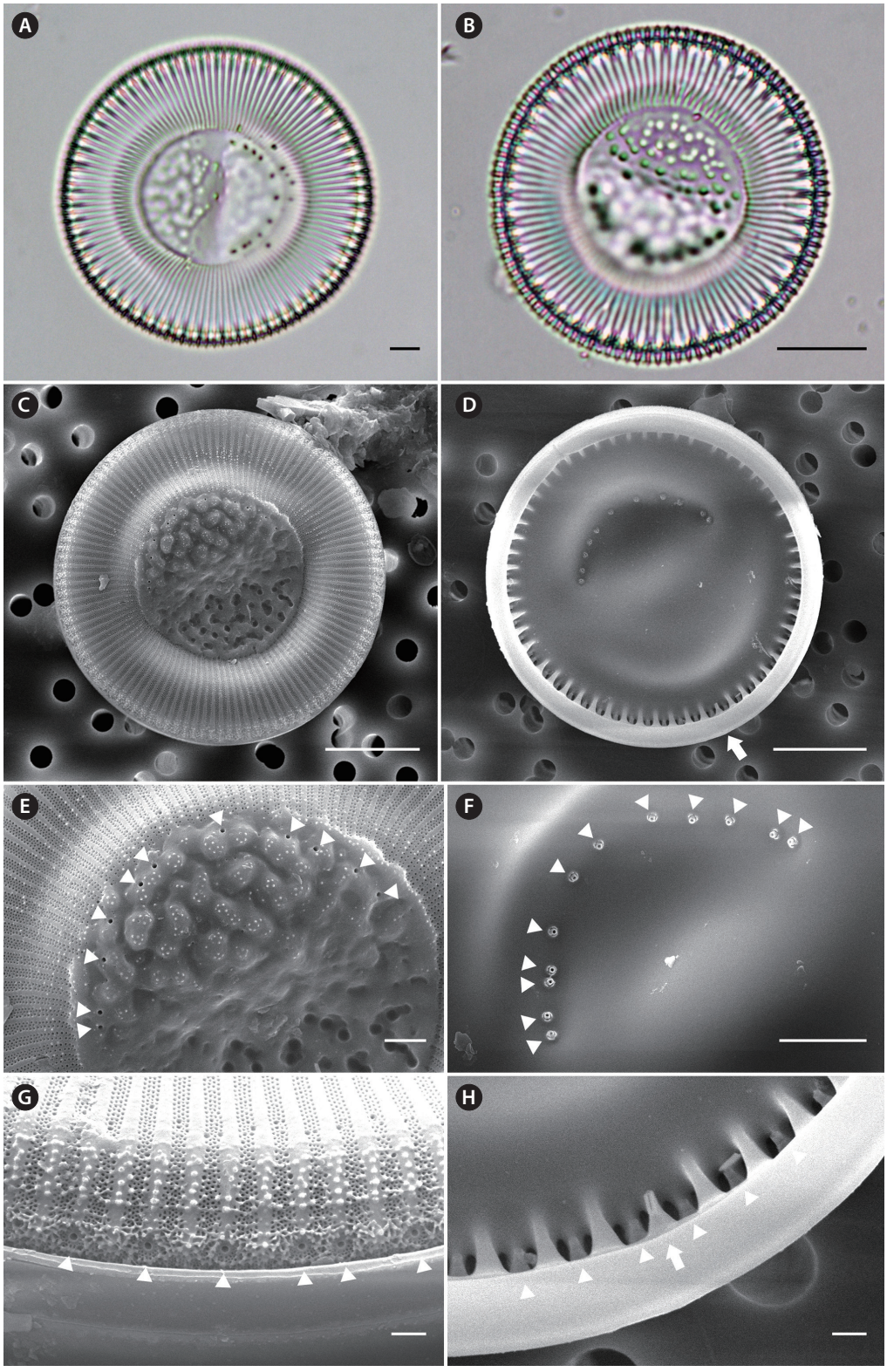

Fig. 3. *Cyclotella litoralis* Lange et Syvertsen. Arrow indicates the rimoportula. (A) External valve view, (B) Internal valve view, (C) Central area with 10 fultoportulae (arrowheads) in the external valve view, (D) Twelve fultoportulae (arrowheads) with 3 satellite pores on the central area of valve face in the internal valve view, (E) Externally striated marginal area with mantle fultoportulae (arrowheads) and rimoportula, (F) Internally marginal area with mantle fultoportulae (arrowheads) on the recessed interstria and a sessile rimoportula between two fultoportulae. Scale bars represent: A-D, 10 μm; E, 1 μm; F, 5 μm; G, H, 1 μm.

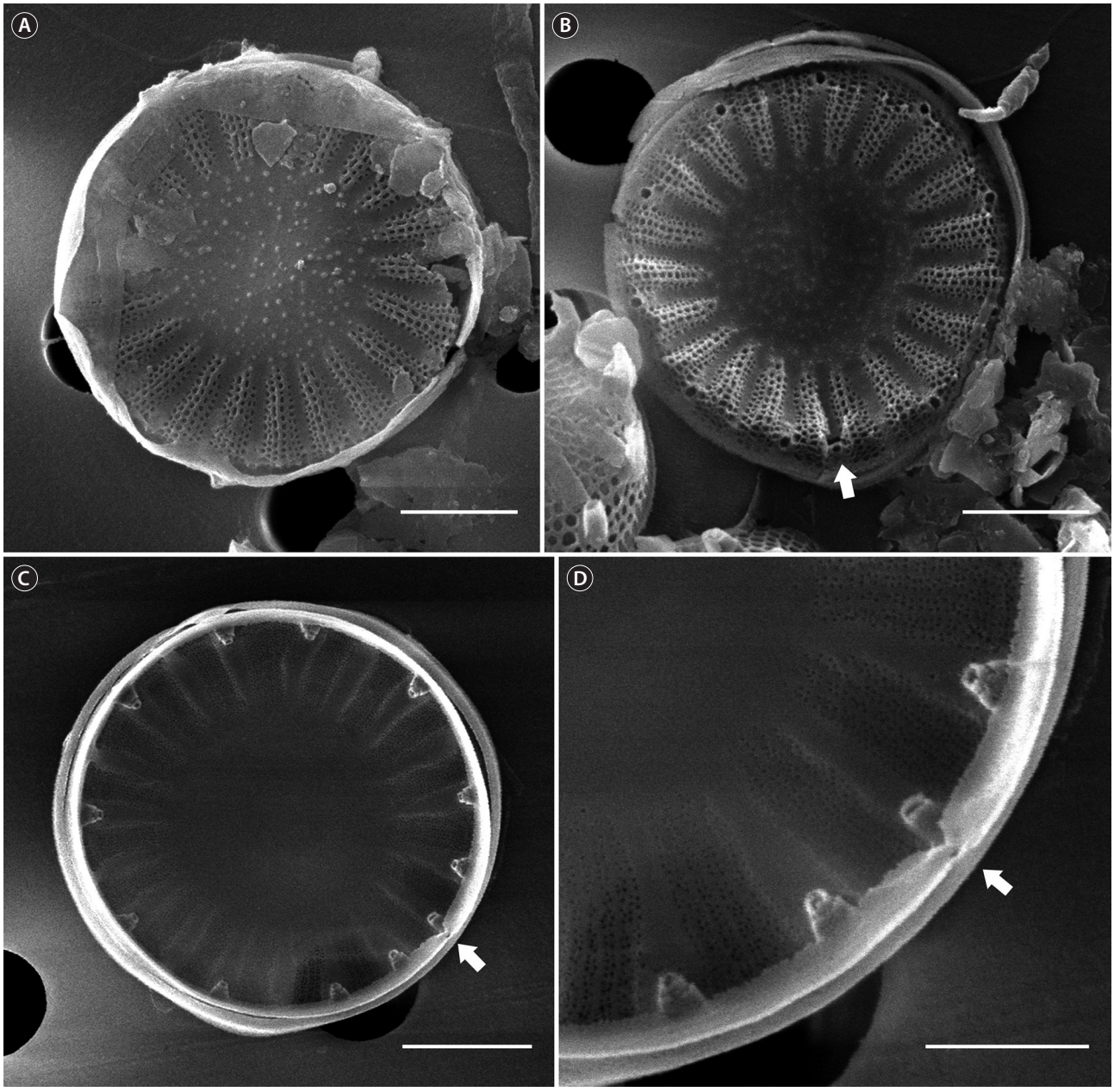

Fig. 4. *Cyclotella meduanae* Germain. Arrow indicates the rimoportula. (A-B) External valve view, (C) Internal valve view, (D) Internal mantle fultoportulae on every interstria and sessile rimoportula between two mantle fultoportulae. Scale bars represent: A-C, 2 μm; D, 1 μm.

was reported total 30 times in this study, 8 times from the East Sea, 2 times from the South Sea, and 20 times from the Yellow Sea as a planktonic (Table 3).

Remarks: *Cyclotella meneghiniana* has been known to have a wide ecological distribution (Håkansson 2002, Finlay et al. 2002), and highly variable frustule (Håkansson and Chepurnov 1999).

Therefore, this species has been confused with several *Cyclotella* species such as *C. ceylonica* Holsinger, *C. pratii* Toman, *C. kuetzingiana* Thwaites (Håkansson 2002). Recently, Beszteri et al. (2007) investigated the cryptic diversity of *C. meneghiniana* based on nuclear and plastid genes. Although this study did not analyze the molecular sequences, it is needed to understand the cryptic diversity of *C. meneghiniana* in Korea.

Occurrence of *Cyclotella* species according to the salinity

This study present the salinity range of five *Cyclotella*

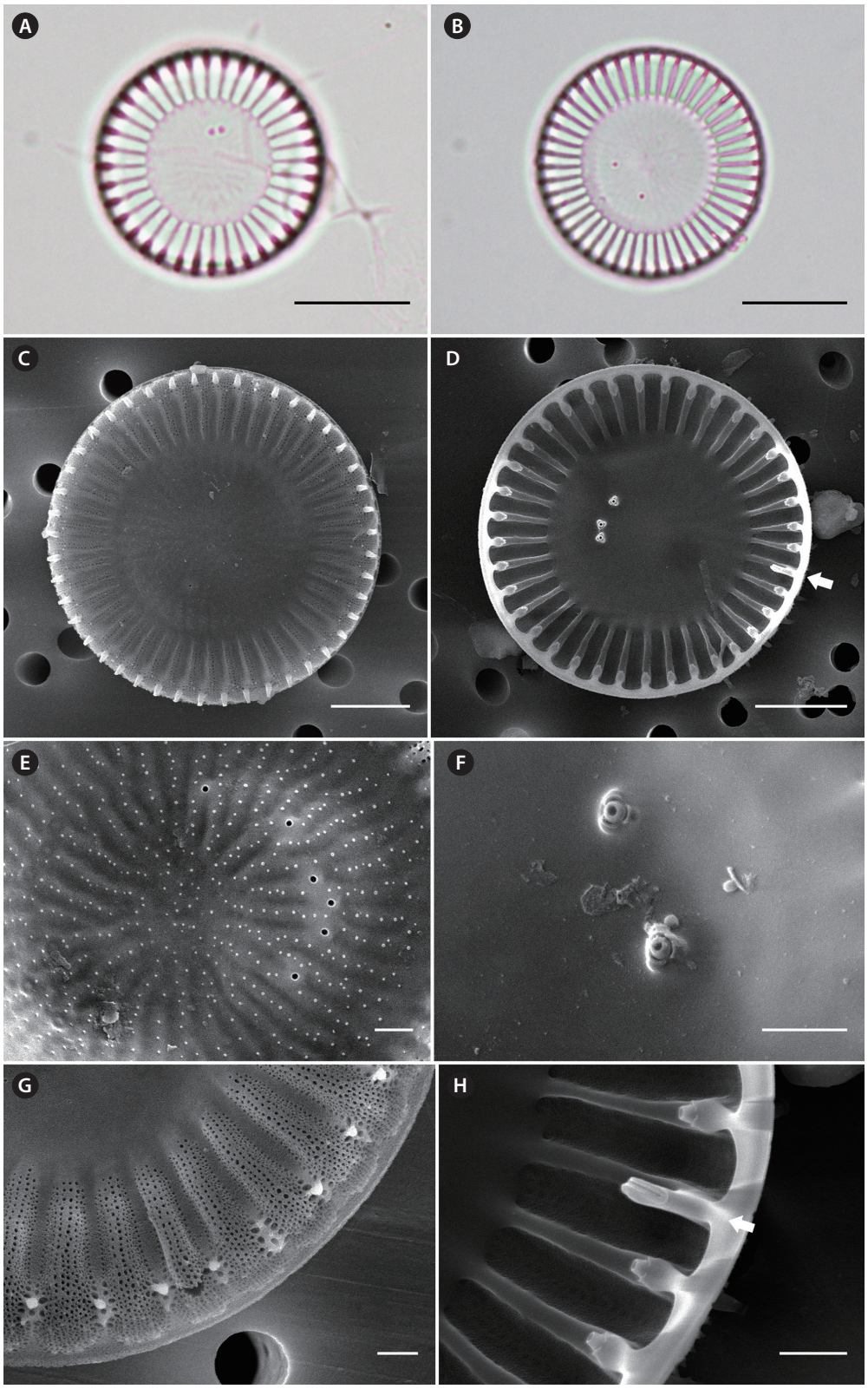

Fig. 5. *Cyclotella meneghiniana* Kützing. Arrow indicates the rimoportula. (A) External valve view, (B) Internal valve view, (C) Central area with 6 fultoportulae in the external valve view, (D) Two fultoportulae with 3 satellite pores on the central area of valve face in the internal valve view, (E) Externally striated marginal area with mantle fultoportulae, (F) Internally marginal area with mantle fultoportulae on the interstria and a sessile rimoportula between two fultoportulae. Scale bars represent: A, B, 10 μm; C, D, 5 μm; E-H, 1 μm.

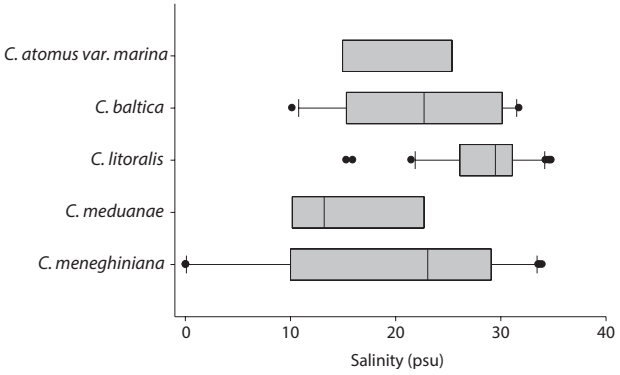

Fig. 6. Box plot of data of salinity range from five *Cyclotella* species in Korea.

species in the Korean coastal waters (Fig. 6). *Cyclotella atomus* var. *marina* occurred in a range of 10.17-28.01 psu from five sites; *C. baltica* was collected at 11 sites in a range of 10.17-31.73 psu*; C. litoralis* was reported in a range of 15.32-34.80 psu at 29 sites; *C. meduanae* have a salinity range of 10.17-22.70 psu from 3 sites; *C. meneghiniana* occurred in a range of 0.04-34.95 psu from 30 sites. Most of species occur a wide range of 10-30 psu, which indicate the leakage of *Cyclotella* species into the coastal waters may be more diverse than previous consideration. (Round and Sims 1980).

ACKNOWLEDGMENTS

This work was supported by a grant from the National Institute of Biological Resources (NIBR), as funded by the Ministry of Environment (MOE) of Republic of Korea (NIBR No. 2013-01-001), and by a 2013 Research Grant from Sangmyung Universtiy.

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