



Newly recorded diatom species in marine and fresh water of Korea

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Abstract

A study on indigenous diatoms was carried out at 71 sites during the period from April 1999 to August 2014 in marine and fresh water in Korea. Forty species of diatoms are new to Korea and they are divided into three classes, six subclasses, 13 orders, 19 families, and 28 genera. The nomenclatures, references, dimensions, specimens examined, local habitat, distribution in Korea, and photograph are reported here. The 40 species found in marine and fresh water showed species-specific habitats.

Key words: Bacillariophyta, indigenous diatoms, Korea, new records

INTRODUCTION

A project entitled "Survey and Excavation of Korean Indigenous Species" started in 2006 under the National Institute of Biological Resources (NIBR), an organization of the Ministry of Environment of Korea. A number of diatom species have been newly reported to Korea and the species richness of the diatom gradually increases in the meantime. Lee et al. (2012) added 60 new diatom species occurring in the coastal area to the diatom floristic study of Korea. In addition, some genus assemblages of diatoms were intensively studied, and a number of species were newly reported; many naviculoid and *Hantzschia* species in the intertidal sand flats of the Nakdong River estuary (Joh 2013, 2014a), some *Achnanthes* and *Cyclotella* ones from the coastal area (Lee et al. 2013, Park et al. 2013), and *Stauroneis* species from the mountain peatlands (Joh 2014b). Additionally, Park et al. (2014) studied planktonic pennate diatoms, and they added 20 species to the diatom checklist of Korea. Despite continuous efforts to understand the diversity of diatoms from Korea, many such

diatoms remain undescribed. This is the third publication in the species diversity project, and forty diatom species are newly reported with their distributional patterns.

MATERIALS AND METHODS

The materials were collected at 71 sites during the period from April 1999 to August 2014 from fresh and marine coastal waters of Korea (Table 1 and Fig. 1). All samples were collected using 20- μ m-mesh plankton nets with vertical and/or horizontal towing. Diatom samples were immediately fixed with 4% neutralized formalin. To examine the fine structures and specific characteristics of each diatom, cell organelles and organic matter were removed with concentrated HCl and saturated KMnO_4 (Hasle and Fryxell 1970). The permanent slides were observed at $\times 400$ to $\times 1000$ magnification using a light microscope (Eclipse 80i; Nikon, Tokyo, Japan) with a digital

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Fig. 1. Sampling sites in the present study. The abbreviated words indicate as follows: East Sea, ES; Yellow Sea, YS; South Sea, SS; Freshwater, FW.

camera (DS-Fi1; Nikon, Tokyo, Japan). The other cleaned samples were attached to aluminum stubs, coated with gold-palladium, and examined using a scanning electron microscope (JSM-5600LV; JEOL, Tokyo, Japan).

Diatom identifications were mainly based on Hendey (1964), Round et al. (1990), Hasle and Syvertsen (1996), and a number of other references including the original descriptions listed for each taxon.

RESULTS AND DISCUSSION

Forty species of diatoms were newly recorded from marine and fresh water in Korea. As shown in the following, diatom taxa were composed of three classes, six subclasses, 13 orders, 19 families, and 28 genera based on the system of Round et al. (1990) and Medlin and Kaczmarska (2004). We described the taxonomic information of diatoms, illustrations, classifications, references, basionyms, synonyms, and distributions.

Class Coscinodiscophyceae Round & Crawford 1990

Subclass Coscinodiscophycidae Round & Crawford 1990

Order Asterolamprales Round 1990

Family Asterolampraceae Smith 1872

Genus *Asteromphalus* Ehrenberg 1844

1. *Asteromphalus hyalinus* Karsten 1905
2. *Asteromphalus parvulus* Karsten 1905

Order Coscinodiscales Round 1990

Family Hemidiscaceae Hendey ex Hasle 1964

Genus *Pseudoguinaridia* von Stosch 1986

3. *Pseudoguinaridia recta* von Stosch 1985

Genus *Actinocyclus* Ehrenberg 1837

4. *Actinocyclus exiguus* Fryxell & Semina 1981
5. *Actinocyclus* sp.

Family Heliopeltaceae Smith 1872

Genus *Actinoptychus* Ehrenberg 1843

6. *Actinoptychus aster* Brun 1892

Genus *Schuetitia* De Toni 1894

7. *Schuetitia annulata* var. *minor* (Grunow in Van Heurck) De Toni 1894

Table 1. Sampling information in this study

| Sites | Locality | Latitude (N) | Longitude (E) | Date |
|---------|--|--------------|---------------|---|
| YS-01 | Daecheong-myeon, Ongjin-gun, Incheon, Korea | 37°51'16" | 124°42'48" | 11 Aug 2014 |
| YS-02 | Oepo-ri, Naega-myeon, Ganghwa-gun, Incheon, Korea | 37°42'00" | 126°22'23" | 24 Oct 2006 |
| YS-03 | Janghwa-ri, Hwado-myeon, Ganghwa-gun, Incheon, Korea | 36°40'36" | 129°27'14" | 29 Aug 2010 |
| YS-04 | Choji-ri, Gilsang-myeon, Ganghwa-gun, Incheon, Korea | 37°37'02" | 126°28'17" | 02 Apr 2010 24 Oct 2006 |
| YS-05 | Songdo-dong, Yeonsu-gu, Incheon, Korea | 37°24'32" | 126°35'41" | 17 Feb 2010 22 Oct 2010 |
| YS-06 | Wolgot-dong, Siheung-si, Gyeonggi-do, Korea | 37°23'15" | 126°44'25" | 14 Oct 2010 |
| YS-07 | Sangrok-gu, Ansan-si, Gyeonggi-do, Korea | 37°17'31" | 126°49'17" | 14 Oct 2010 |
| YS-08 | Daebunam-dong, Danwon-gu, Ansan-si, Gyeonggi-do, Korea | 37°17'37" | 126°35'33" | 25 Aug 2006 |
| YS-09 | Busu-ri, Sinpyeong-myeon, Dangjin-si, Chungcheongnam-do, Korea | 36°54'36" | 126°48'54" | 15 Apr 2011 |
| YS-10 | Hanjin-ri, Songak-eup, Dangjin-si, Chungcheongnam-do, Korea | 36°58'14" | 126°46'55" | 04 Mar 2014 23 Jul 2010 |
| YS-11 | Jangmi-dong, Gunsan-si, Jeollabuk-do, Korea | 36°59'20" | 126°43'05" | 16 Apr 2011 |
| YS-12 | Banggal-ri, Wonbuk-myeon, Taean-gun, Chungcheongnam-do, Korea | 36°53'50" | 126°12'10" | 15 Jul 2011 |
| YS-13 | Mohang-ri, Sowon-myeon, Taean-gun, Chungcheongnam-do, Korea | 36°47'11" | 126°08'22" | 15 Jul 2011 02 Nov 2011 |
| YS-14 | Pado-ri, Sowon-myeon, Taean-gun, Chungcheongnam-do, Korea | 36°34'33" | 126°18'38" | 10 May 2012 16 Apr 2011 03 Oct 2012 |
| YS-15 | Janggok-ri, Gonam-myeon, Taean-gun, Chungcheongnam-do, Korea | 36°24'34" | 126°22'30" | 03 Oct 2012 05 Nov 2011 |
| YS-16 | Ocheon-myeon, Boryeong-si, Chungcheongnam-do, Korea | 36°22'55" | 126°23'36" | 05 Mar 2014 |
| YS-17 | Buseok-myeon, Seosan-si, Chungcheongnam-do, Korea | 36°37'29" | 126°22'01" | 17 Apr 2011 |
| YS-18 | Gung-ri, Seobu-myeon, Hongseong-gun, Chungcheongnam-do, Korea | 36°35'36" | 126°27'21" | 17 Apr 2011 |
| YS-19 | Janghang-eup, Seocheon-gun, Chungcheongnam-do, Korea | 36°00'24" | 126°41'46" | 16 Jan 2014 |
| YS-20 | Soryong-dong, Gunsan-si, Jeollabuk-do, Korea | 35°58'11" | 126°37'02" | 14 Oct 2010 |
| YS-21 | Gunsan-si, Jeollabuk-do, Korea | 35°55'18" | 126°36'24" | 14 Apr 2007 |
| YS-22 | Hoehyeon-myeon, Gunsan-si, Jeollabuk-do, Korea | 35°53'21" | 126°46'01" | 15 Oct 2010 |
| YS-23 | Simpo-ri, Jinbong-myeon, Gimje-si, Jeollabuk-do, Korea | 35°51'24" | 126°41'56" | 23 Jul 2010 |
| YS-24 | Anseong-ri, Dongjin-myeon, Buan-gun, Jeollabuk-do, Korea | 35°47'15" | 126°44'54" | 23 Jul 2010 |
| YS-25 | Okdo-myeon, Gunsan-si, Jeollabuk-do, Korea | 35°50'29" | 126°29'21" | 16 Apr 2011 |
| YS-26 | Byeonsan-myeon, Buan-gun, Jeollabuk-do, Korea | 35°43'40" | 126°31'46" | 23 Jul 2010 |
| YS-27 | Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do, Korea | 35°41'55" | 126°33'19" | 16 Apr 2011 |
| YS-28 | Seogechado-ri, Jodo-myeon, Jindo-gun, Jeollanam-do, Korea | 34°15'33" | 125°54'42" | 08 Nov 2013 |
| ES-01 | Dogu-ri, Donghae-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do, Korea | 35°59'50" | 129°27'29" | 21 Jan 2009 |
| ES-02 | Namjeong-myeon, Yeongdeok-gun, Gyeongsangbuk-do, Korea | 36°15'40" | 129°22'30" | 22 Jan 2009 |
| ES-03 | Ganggu-ri, Ganggu-myeon, Yeongdeok-gun, Gyeongsangbuk-do, Korea | 36°21'34" | 129°23'08" | 29 Aug 2010 |
| ES-04 | Daetan-ri, Yeongdeok-eup, Yeongdeok-gun, Gyeongsangbuk-do, Korea | 36°26'30" | 129°26'00" | 29 Aug 2010 |
| ES-05 | Chuksan-ri, Chuksan-myeon, Yeongdeok-gun, Gyeongsangbuk-do, Korea | 36°30'28" | 129°26'59" | 29 Aug 2010 |
| ES-06 | Daecheong-myeon, Ongjin-gun, Incheon, Korea | 36°35'54" | 129°24'54" | 22 Jan 2009 |
| ES-07 | Gusan-ri, Giseong-myeon, Uljin-gun, Gyeongsangbuk-do, Korea | 36°45'37" | 129°28'20" | 29 Aug 2010 |
| ES-08 | Jukbyeon-ri, Jukbyeon-myeon, Uljin-gun, Gyeongsangbuk-do, Korea | 37°03'29" | 129°25'18" | 29 Aug 2010 |
| ES-09 | Daejin-dong, Donghae-si, Gangwon-do, Korea | 37°34'55" | 129°6'43" | 23 Jan 2009 |
| ES-10 | Okgye-myeon, Gangneung-si, Gangwon-do, Korea | 37°39'09" | 129°03'06" | 29 Aug 2010 |
| ES-11 | Jeongdongjin-ri, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea | 37°41'10" | 129°02'34" | 23 Jan 2009 |
| ES-12 | Anhyeon-dong, Gangneung-si, Gangwon-do, Korea | 37°47'49" | 128°54'08" | 18 Apr 2014 |
| ES-13 | Sacheon-myeon, Gangneung-si, Gangwon-do, Korea | 37°50'16" | 128°52'36" | 29 Aug 2010 |
| ES-14 | Namae-ri, Hyeonnam-myeon, Yangyang-gun, Gangwon-do, Korea | 37°56'39" | 128°47'19" | 30 Aug 2010 |
| ES-15 | Jucheong-ri, Ganghyeon-myeon, Yangyang-gun, Gangwon-do, Korea | 38°07'23" | 128°37'58" | 23 Jan 2009 |
| ES-16 | Geumho-dong, Sokcho-si, Gangwon-do, Korea | 38°13'12" | 128°35'24" | 18 Apr 2014 |
| ES-17 | Daejin-dong, Donghae-si, Gangwon-do, Korea | 38°19'36" | 128°31'42" | 23 Jan 2009 |
| ES-18 | Dokdo-ri, Ulleung-eup, Ulleung-gun, Gyeongsangbuk-do, Korea | 37°14'21" | 131°52'04" | 22 Apr 2013 |
| SS-01 | Sin-gi-ri, Doam-myeon, Gangjin-gun, Jeollanam-do, Korea | 34°31'41" | 126°46'23" | 15 Nov 2010 |
| SS-02 | Annam-ri, Daeseo-myeon, Goheung-gun, Jeollanam-do, Korea | 34°44'53" | 127°18'48" | 02 Nov 2012 |
| SS-03 | Geumseong-myeon, Hadong-gun, Gyeongsangnam-do, Korea | 34°56'39" | 127°46'53" | 02 Nov 2012 |
| SS-04 | Nambyeon-ri, Namhae-eup, Namhae-gun, Gyeongsangnam-do, Korea | 34°48'40" | 127°50'08" | 10 Jun 2011 |
| SS-05 | Hwagye-ri, Idong-myeon, Namhae-gun, Gyeongsangnam-do, Korea | 34°46'32" | 127°56'34" | 10 Jun 2011 |
| SS-06 | Jahye-ri, Seopo-myeon, Sacheon-si, Gyeongsangnam-do, Korea | 34°59'32" | 128°03'04" | 02 Nov 2012 |
| SS-07 | Daebang-dong, Sacheon-si, Gyeongsangnam-do, Korea | 34°55'59" | 128°03'02" | 10 Jun 2011 |
| SS-08 | Seo-dong, Sacheon-si, Gyeongsangnam-do, Korea | 34°55'28" | 128°04'19" | 03 Feb 2012 |
| SS-09 | Korea Straits | 34°31'45" | 128°37'09" | 15 Sep 2012 |
| SS-10 | Jung-dong, Haeundae-gu, Busan, Korea | 35°09'32" | 129°11'19" | 01 Sep 2005 |
| Jeju-01 | Hagwi-ri, Aewol-eup, Jeju-si, Jeju-do, Korea | 33°29'10" | 126°24'28" | 11 Mar 2012 |
| Jeju-02 | Mara-ri, Daejeong-eup, Seogwipo-si, Jeju-do, Korea | 33°07'20" | 126°16'11" | 24 Jun 2014 |
| FW-01 | Wando-gun, Jeollanam-do, Korea | 34°22'01" | 126°42'52" | 07 Feb 2008 |
| FW-02 | Gwangyeong-dong, Gwangyang-si, Jeollanam-do, Korea | 34°59'51" | 127°43'10" | 24 Apr 1999 |
| FW-03 | Okgu-eup, Gunsan-si, Jeollabuk-do, Korea | 35°33'14" | 128°24'52" | 28 Oct 2007 |
| FW-04 | Namcheon-myeon, Gyeongsan-si, Gyeongsangbuk-do, Korea | 35°45'39" | 128°44'04" | 22 Feb 2007 |
| FW-05 | Gyeongju-si, Gyeongsangbuk-do, Korea | 35°49'44" | 129°13'34" | 21 Feb 2008 |
| FW-06 | Riv. Geumgang | 36°22'18" | 126°59'26" | 21 Oct 2007 |
| FW-07 | Munmak-eup, Wonju-si, Gangwon-do, Korea | 37°18'33" | 127°48'28" | 27 Apr 2002 |

Class Mediophyceae (Jousé & Proshkina-Lavrenko) Medlin & Kaczmarska 2004
Subclass Biddulphiophycidae Round & Crawford 1990

- Order Anaulales Round & Crawford 1990
Family Anaulaceae (Schütt) Lemmermann 1899
Genus *Eunotogramma* Weisse 1855
8. *Eunotogramma marinum* (Smith) Peragallo & Peragallo 1908
Order Biddulphiales Krieger 1954
Family Biddulphiaceae Kützing 1844
Genus *Terpsinoë* Ehrenberg 1843
9. *Terpsinoë americana* (Bailey) Ralfs 1861
Genus *Trigonium* Cleve 1867
10. *Trigonium arcticum* var. *japonica* (Grunow) Desikachary & Sreelatha 1989
Order Toxariales Round 1990
Family Toxariaceae Round 1990
Genus *Toxarium* Bailey 1854
11. *Toxarium hennedyanum* (Gregory) Pelletan 1889

Subclass Chaetocerotophycidae Round & Crawford 1990

- Order Chaetocerotales Round & Crawford 1990
Family Chaetoceraceae Ralfs 1861
Genus *Chaetoceros* Ehrenberg 1844
12. *Chaetoceros lorenzianus* var. *solitaries* Proshkina-Lavrenko 1955
13. *Chaetoceros octagonus* Hernandez-Becerril 1992
14. *Chaetoceros simplex* Ostenfeld 1901

Subclass Thalassiosirophycidae Round & Crawford 1990

- Order Thalassiosirales Glezer & Makarova 1986
Family Stephanodiscaceae Makarova 1986
Genus *Cyclotella* (Kützing) Brébisson 1838
15. *Cyclotella choctawhatcheeana* Prasad 1990
16. *Cyclotella cryptica* Reimann, Lewin & Guillard 1963
17. *Cyclotella scaldensis* Muylaert & Sabbe 1996
Family Thalassiosiraceae Hasle 1973
Genus *Shionodiscus* Alverson, Kang & Theriot 2006
18. *Shionodiscus endoseriatus* (Hasle & Fryxell) Alverson, Kang & Theriot 2006
19. *Shionodiscus poro-irregularis* (Hasle & Heimdal) Alverson, Kang & Theriot 2006

Class Bacillariophyceae Haeckel 1878
Subclass Fragilariaceae Round & Crawford 1990

- Order Fragilariales Silva 1962
Family Fragilariaceae Greville 1833
Genus *Asterionellopsis* Round 1990
20. *Asterionellopsis socialis* (Lewin & Norris) Crawford & Gardner 1997
Genus *Fragilaria* Lyngbye 1819
21. *Fragilaria capucina* var. *austriaca* (Grunow) Lange-Bertalot 1980
Genus *Synedra* Ehrenberg 1830
22. *Synedra tabulata* var. *obtusa* (Pantocsdk) Hustedt 1932
Order Tabellariales Round 1990
Family Tabellariaceae Kützing 1844
Genus *Tabellaria* Ehrenberg ex Kützing 1844
23. *Tabellaria* sp.
Order Licmophorales Round 1990
Family Licmophoraceae Kützing 1844
Genus *Licmophora* Agardh 1827
24. *Licmophora juergensii* Agardh 1831

Subclass Bacillariophycidae Mann 1990

- Order Achnanthales Silva 1962
Family Achnanthidiaceae Mann 1990
Genus *Achnanthidium* Kützing 1844
25. *Achnanthidium* sp.
Family Cocconeidaceae Kützing 1844
Genus *Anorthoneis* Grunow 1868
26. *Anorthoneis* sp.
Order Cymbellales Mann 1990
Family Cymbellaceae Greville 1833
Genus *Encyonema* Kützing 1834
27. *Encyonema neogracile* Krammer 1997
Genus *Encyonopsis* Krammer 1997
28. *Encyonopsis leei* Krammer 2003
Family Gomphonemataceae Kützing 1844
Genus *Gomphonema* Ehrenberg 1832
29. *Gomphonema olivaceoides* var. *densestriata* Foged 1963
30. *Gomphonema parvulum* f. *saprophilum* Lange-Bertalot & Reichardt 1991
31. *Gomphonema productum* (Grum.) Lange-Bertalot & Reichardt 1991
Order Naviculales Bessey 1970
Family Naviculaceae Kützing 1844
Genus *Amphipleura* Kützing 1844
32. *Amphipleura lindheimeri* Grunow 1862

Genus *Caloneis* Cleve 1894

33. *Caloneis alpestris* (Grunow) Cleve 1894

Genus *Pseudogomphonema* Medlin 1986

34. *Pseudogomphonema monicae* Witkowski, Metzeltin & Lange-Bertalot 1996

Family Scoliotropidaceae Mereschowsky 1903

Genus *Progonoia* Schrader 1969

35. *Progonoia mirabilis* (Leuduger-Fortmorel) Schrader 1971

Family Pleurosigmataceae Mereschowsky 1903

Genus *Gyrosigma* Hassall 1845

36. *Gyrosigma littorale* (Smith) Griffith & Henfrey 1856

Genus *Pleurosigma* Smith 1852

37. *Pleurosigma amara* Stidolph 1992

38. *Pleurosigma strigosum* Smith 1852

39. *Pleurosigma tenuiforme* von Quillfeldt 2000

40. *Pleurosigma inscriptura* Harper 2009

1. *Asteromphalus hyalinus* Karsten 1905 (Fig. 2)

References: Karsten 1905, p. 90, pl. 8, fig. 15; Hasle and Syvertsen 1996, pp 135, 139–140; Lange-Bertalot 2003, p. 30, pl. 64, figs. 1, 2, pl. 65, figs. 1–4, pl. 66, figs. 1, 2.

Dimension: diameter 32.7–35.8 μm , 7 hyaline rays, sector areolae 5–6 in 10 μm .

Type locality: unknown.

Distribution: Hasle and Syvertsen (1996) considered *A. hyalinus* may be present the Norwegian water, the Barants Sea and the North Pacific.

Korea distribution: This species was observed one time in the East Sea of Korea on 22 Jan 2009 (ES-02).

2. *Asteromphalus parvulus* Karsten 1905 (Fig. 3)

References: Karsten 1905, p. 90, pl. 8, fig. 14; Hasle and Syvertsen 1996, pp 135, 139–140; Lange-Bertalot 2003, p. 43, pl. 66.

Dimension: diameter 32.7–35.8 μm , 6 hyaline rays, sector areolae 9 in 10 μm .

Type locality: unknown.

Distribution: Hasle and Syvertsen (1996) mentioned *A. parvulus* as a southern cold water species.

Korea distribution: This species was observed one time in the East Sea of Korea on 29 Aug 2010 (ES-14).

3. *Pseudoguardia recta* von Stosch 1985 (Fig. 4)

References: Von Stosch 1985, pp 307, 312–314, figs. 7–11; Hasle and Syvertsen 1996, p. 130, pl. 22.

Dimension: diameter 46.8 μm , peralvar axis 44.3 μm .

Type locality: Port Phillip Bay, Victoria, Australia.

Korea distribution: This species was observed one time

in the freshwater of Korea on 21 Feb 2008 (FW-05).

4. *Actinocyclus exiguus* Fryxell & Semina 1981 (Fig. 5)

References: Fryxell and Semina 1981, p. 442, figs. 1–10; Hasle and Syvertsen 1996, p. 122; Lange-Bertalot 2003, pl. 62, fig. 2.

Dimension: diameter 19.6 μm , 10 areolae in 10 μm at the valve face, 12 areolae in 10 μm at the valve margin, 19 areolae in 10 μm at the valve mantle.

Type locality: the southern Indian and Atlantic Oceans on 18 Apr 1976 (49°19.0' E, 46°4.75' S).

Korea distribution: This species was observed in the Yellow Sea on 10 May 2012 (YS-13).

5. *Actinocyclus* sp. (Fig. 6)

Dimension: diameter 58.9–59.8 μm , areolae 6–7 in 10 μm at the centre, 8–9 in 10 μm at the margin, 17 in 10 μm at the valve mantle, distance between rimoportula 10.3 μm .

Korea distribution: This species was observed one time in the Yellow Sea of Korea on 05 Mar 2014 (YS-15).

Remark: The measurement and areolation of this species is similar to the nominate variety of *Actinocyclus octonarius*, but the internal structure of rimoportula is different between both species. The rimoportula of *A. octonarius* internally has the long neck and the labium slit is parallel to the valve face, while one of our *Actinocyclus* specimen has the short neck and the labium slit is fairly curved toward the abvalvar. The variation of internal structure of rimoportula in *A. octonarius* has not known yet, we temporarily consider this species as unknown status until other evident characters reveal.

6. *Actinoptychus aster* Brun 1892 (Figs. 7 and 8)

References: Schmidt 1892, pl. 173, fig. 2; Siqueiros-Beltrones and López-Fuerte 2006, pl. 6, fig. 7.

Dimension: diameter 39.3–66.2 μm , areolae 2–4 in 10 μm at the centre, 3–5 in 10 μm at the margin, marginal ribs 4–5 in the valve margin.

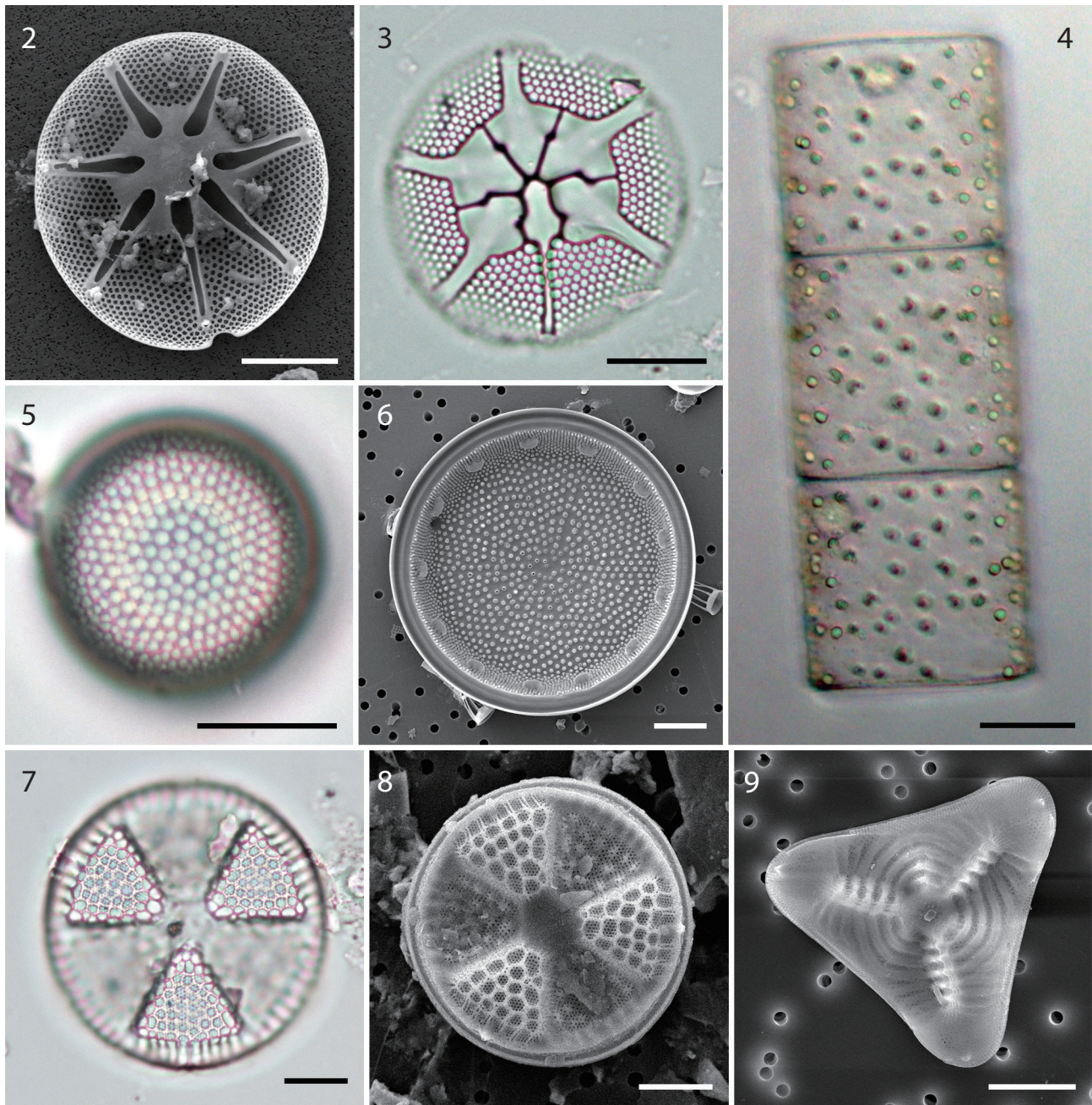
Type locality: Sendai, Japan.

Korea distribution: This species has been mainly observed in the Yellow Sea: on 02 Apr 2010 (YS-03), 15 Oct 2010 (YS-21), 15 Apr 2011 (YS-08), and 11 Aug 2014 (YS-01).

7. *Schuetzia annulata* var. *minor* (Grunow in Van Heurck) De Toni 1894 (Fig. 9)

Basionym: *Actinoptychus annulatus* var. *minor* Grunow in Van Heurck 1883.

References: Van Heurck 1883, pl. 124, fig. 13; De Toni



Figs. 2–9. Fig. 2. Internal valve of *Asterionellopsis hyalina* in SEM. Fig. 3. *Asterionellopsis parvula* in LM. Fig. 4. *Pseudoguillardia recta* in LM. Fig. 5. *Actinocyclus exiguus* in LM. Fig. 6. Internal valve of *Actinocyclus* sp. Fig. 7. *Actinoptychus aster* in LM. Fig. 8. External valve of *Actinoptychus aster* in SEM. Fig. 9. External valve of *Schuettia annulata* var. *minor*. Scale bars represent: Figs. 2, 3 & 5–10, 10 μ m; Fig. 4, 20 μ m.

1894, p. 1396.

Dimension: length between two corner 35.8 μ m, striae 7 in 10 μ m at the valve face, areolae 19 in 10 μ m at the stria.

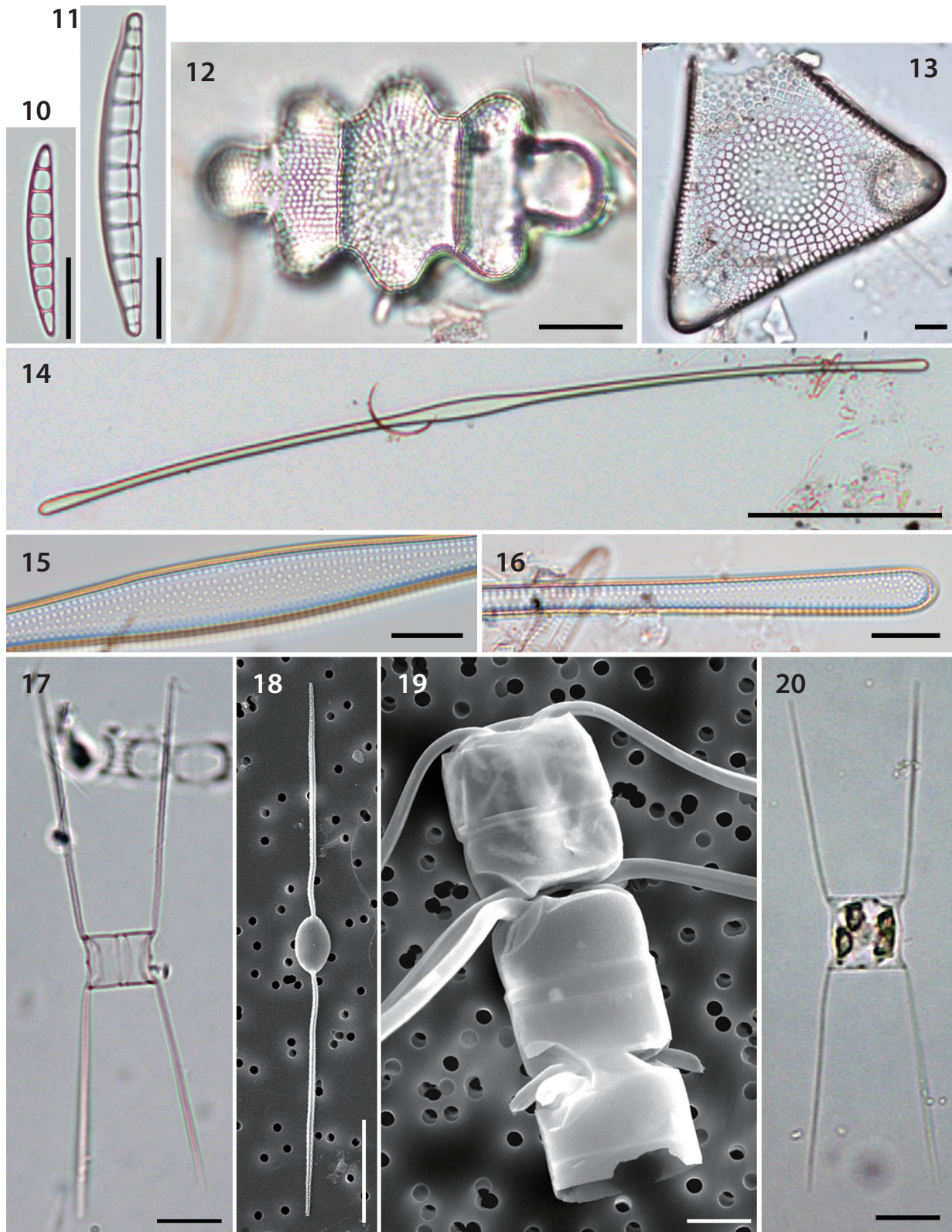
Korea distribution: This species was observed one time in the Yellow Sea of Korea on 22 Oct 2010 (YS-04).

8. *Eunotogramma marinum* (Smith) Peragallo & Peragallo 1908 (Figs. 10 and 11)

Basionym: *Himantidium marinum* W. Smith 1857.

Synonym: *Smithiella marina* (W. Smith) Peragallo & Peragallo 1901.

References: Peragallo and Peragallo 1908, p. x, pl. 32, fig. 36.



Figs. 10–20. Figs. 10, 11. *Eunotogramma marinim* in LM. Fig. 12. *Terpsinoë Americana* in LM. Fig. 13. *Trigonium arcticum* var. *japonica* in LM. Figs. 14–16. *Toxarium hennedyanum* in LM. Fig. 14. Whole cell in the valve view. Fig. 15. Central area. Fig. 16. Apical area. Fig. 17. *Chaetoceros lorenzianus* var. *solitarius* in the girdle view in LM. Fig. 18. *Chaetoceros lorenzianus* var. *solitarius* in the valve view in SEM. Fig. 19. *Chaetoceros octagonus* in SEM. Fig. 20. *Chaetoceros simplex* in the girdle view in LM. Scale bars represent: Figs. 11–13, 15–17, 19 & 20, 10 μ m; Fig. 14, 100 μ m; Fig. 18, 20 μ m.

Dimension: length 15.4–40.1 μm , width 3.1–5.0 μm , 7–12 transverse costae.

Type locality: Biarritz, France.

Korea distribution: This species has been mainly observed in the East Sea on 29 Aug 2010 (ES-07), 29 Aug 2010 (ES-11), and 30 Aug 2010 (ES-15).

9. *Terpsinoë americana* (Bailey) Ralfs in Pritchard 1861 (Fig. 12)

Basionym: *Tetragramma americana* Bailey 1854

Synonyms: *Terpsinoë americana* (Bailey) Grunow 1867, *Triceratium americanum (americana)* (Bailey) Cleve-Euler 1951.

References: Bailey 1854, p. 7, figs. 1, 2; Pritchard 1861, p. 859; Grunow 1867, p. 23.

Dimension: length 47.8–48.6 μm , width 25.1 μm , 13–16 areolae in 10 μm at the valve centre.

Type locality: Sebastian River near St. Augustine, Florida.

Korea distribution: This species was observed one time in the South Sea of Korea on 15 Nov 2010 (SS-01).

10. *Trigonium arcticum* var. *japonica* (Grunow) Desikachary & Sreelatha 1989 (Fig. 13)

Basionym: *Triceratium arcticum* var. *japonica* Grunow in Schmidt et al. 1882.

Synonym: *Biddulphia arctica* var. *japonica* (Grunow in Schmidt et al.) Mills 1933.

References: Schmidt 1882, pl. 79, figs. 10, 11; Desikachary and Sreelatha 1989, p. 271, pl. 143, figs. 3, 4.

Dimension: length between two corner 94 μm , 4 areolae in 10 μm .

Type locality: Tokyo Bay, Yokohama, Japan.

Korea distribution: This species was observed one time from the coastal water of Jeju Island in Korea on 11 Mar 2012 (Jeju-01).

11. *Toxarium hennedyanum* (Gregory) Pelletan 1889 (Figs. 14–16)

Basionym: *Synedra hennedyana* Gregory 1857

References: Gregory 1857, p. 534, pl. 14, fig. 108; Pelletan 1889, p. 54; Hasle and Syvertsen 1996, p. 252–253; Stidolph et al. 2012, pl. 16, fig. 95.

Dimension: length 465.5 μm , width 10.6 μm , 10 areolae in 10 μm at the valve centre.

Type locality: Lamlash Bay, Scotland.

Korea distribution: This species was observed one time from the coastal water of Jeju Island in Korea on 24 Jun 2014 (Jeju-02).

12. *Chaetoceros lorenzianus* var. *solitarius* Proschkina-Lavrenko 1955 (Figs. 17 and 18)

References: Proschkina-Lavrenko 1955, p. 145, pl. 59, figs. 1–6.

Dimension: apical axis 11.1 μm , transapical axis 7.0 μm .

Type locality: Black Sea.

Korea distribution: This species was observed in the Yellow Sea on 23 Jul 2010 (YS-22) and 23 Jul 2010 (YS-23).

13. *Chaetoceros octagonus* Hernández-Becerril 1992 (Fig. 19)

References: Hernández-Becerril 1992, pp 218–219, figs. 1, 3–15.

Dimension: apical axis 12.9 μm .

Type locality: Baja California coasts

Korea distribution: This species was observed in the South Sea of Korea on 15 Sep 2012 (SS-09).

14. *Chaetoceros simplex* Ostenfeld 1901 (Fig. 20)

References: Ostenfeld 1901, p. 137, fig. 8; Hendeby 1964, p. 137, pl. 19, fig. 2; Hasle and Syvertsen 1996, p. 223.

Dimension: apical axis 12.9 μm , perivalvar axis 11.1 μm

Type locality: the Caspian Sea.

Korea distribution: This species was observed in the South Sea of Korea on 01 Sep 2005 (SS-10).

15. *Cyclotella choctawhatcheeana* Prasad 1990 (Figs. 21 and 22)

References: Prasad et al. 1990, p. 419, figs. 2–26; Lange-Bertalot 1996, pl. 41; Lange and Tiffany 2002, fig. 5.

Dimension: diameter 6.9–8.2 μm , 23–25 marginal striae in 10 μm .

Type locality: Choctawhatchee Bay of Florida, Gulf of Mexico (30°30' N, 80°06' W).

Korea distribution: This species has been observed from the Yellow Sea and the South Sea: on 17 Feb 2010 (YS-04), 15 Oct 2010 (YS-21), and 02 Nov 2012 (SS-03).

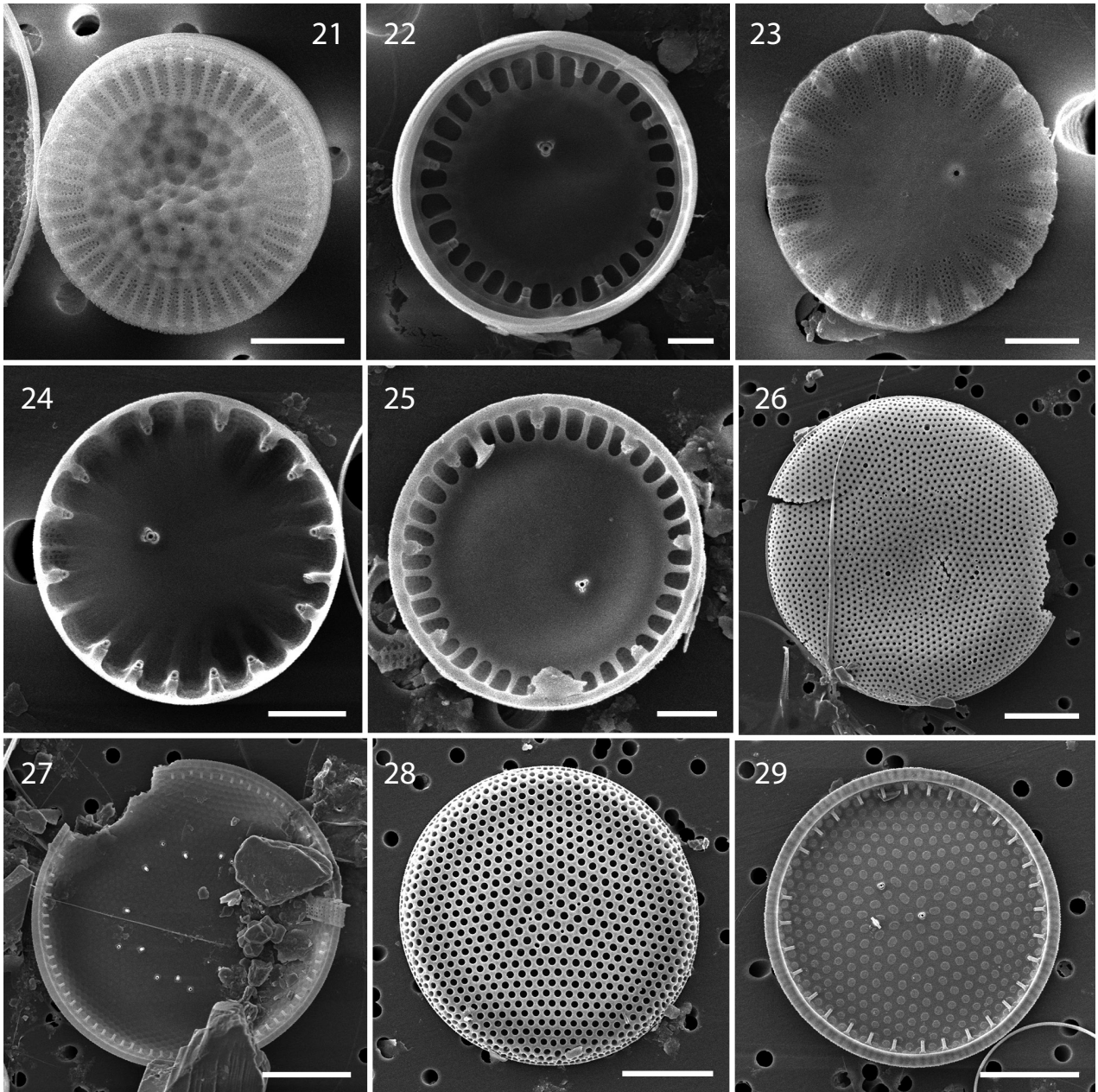
16. *Cyclotella cryptica* Reimann, Lewin & Guillard 1963 (Figs. 23 and 24)

References: Reimann et al. 1963, p. 75–84, figs. 4–11; Hasle and Syvertsen 1996, p. 31; Germain 1981, p. 36; Kobayashi 2006, p. 31, pl. 43, figs. 1–8; Houk et al. 2010, p. 17, pl. 148, figs. 1–14, pl. 149, figs. 1–6.

Dimension: diameter 6.2–10.3 μm , 10 marginal striae in 10 μm .

Type locality: West Tisbury Great Pond, Martha's Vineyard, Massachusetts, US.

Korea distribution: This species has been observed in



Figs. 21–29. Figs 21, 22. *Cyclotella choctawhatcheeana*. Fig. 21. External valve view. Fig. 22. Internal valve view. Figs. 23, 24. *Cyclotella cryptica*. Fig. 23. External valve view. Fig. 24. Internal valve view. Fig. 25. *Cyclotella scaldensis* in the internal valve view. Figs. 26, 27. *Shionodiscus endoseriatus*. Fig. 26. External valve view. Fig. 27. Internal valve view. Figs. 28, 29. *Shionodiscus poro-irregularatus*. Fig. 28. External valve view. Fig. 29. Internal valve view. Scale bars represent: Fig. 21, 5 μm ; Fig. 22, 1 μm ; Figs. 23–25, 2 μm ; Figs. 26–29, 10 μm .

the Yellow Sea and East Sea: on 23 Jul 2010 (YS-23), 14 Oct 2010 (YS-06), 15 Oct 2010 (YS-21), 18 Apr 2014 (ES-13), and 18 Apr 2014 (ES-17).

17. *Cyclotella scaldensis* Muylaert & Sabbe 1996 (Fig. 25)

References: Muylaert and Sabbe 1996, pp 336, 338, figs. 1-15; Lange and Tiffany 2002, figs. 85, 86; Houk et al. 2010, p. 19, pl. 155, figs. 1–15, pl. 156, figs. 1–6, pl. 157, figs. 1–6.

Dimension: diameter 14.3–41.6 μm , 10 marginal striae in 10 μm .

Type locality: Temse, Schelde estuary, Belgium.

Korea distribution: This species has been observed in the Yellow Sea and East Sea on 23 Jan 2009 (ES-16), 23 Jul 2010 (YS-23), 14 Oct 2010 (YS-05), 14 Oct 2010 (YS-19), 15 Apr 2011 (YS-08), and 17 Apr 2011 (YS-17).

18. *Shionodiscus endoseriatus* (Hasle & Fryxell) Alverson, Kang & Theriot 2006 (Figs. 26 and 27)

Basionym: *Thalassiosira endoseriata* Hasle & Fryxell in Fryxell & Hasle 1977.

References: Fryxell and Hasle 1977, p. 78, pl. 8, figs. 45–49; Hernández-Becerril and Peña 1995, p. 548, figs. 21, 22; Mahood et al. 1986, p. 146, fig. 91; Sar et al. 2001, p. 208, figs. 23–25; Alverson et al. 2006, p. 259.

Dimension: diameter 35.9–41.6 µm, 11–12 areolae in 10 µm at the valve centre, 14 areolae in 10 µm at the valve margin, 9–10 marginal fultoportulae in 10 µm.

Type locality: Pacific Ocean between Ecuador and the Galapagos Islands (03°07′–03°12′ S, 84°42′–84°54′ W).

Korea distribution: This species was observed in the Yellow Sea on 08 Nov 2013 (YS-27) and 16 Jan 2014 (YS-18).

19. *Shionodiscus poro-irregulatus* (Hasle & Heimdal) Alverson, Kang & Theriot 2006 (Figs 28 and 29)

Basionym: *Thalassiosira poro-irregulata* Hasle & Heimdal 1970.

References: Johansen and Fryxell 1985, p. 175, fig. 11; Rivera 1981, p. 113, figs. 317–339; Alverson et al. 2006, p. 260.

Dimension: diameter 18.8–65.3 µm, 6–11 areolae in 10 µm at the valve centre, 8–15 areolae in 10 µm at the valve margin, 4–6 marginal fultoportulae in 10 µm.

Type locality: Talcahuano (Bahía de Concepción), Chile.

Korea distribution: This species has been frequently observed in the coastal waters of Korea: 10 Jun 2011 (SS-04), 10 Jun 2011 (SS-05), 10 Jun 2011 (SS-07), 03 Feb 2012 (SS-08), 02 Apr 2010 (YS-03), 14 Oct 2010 (YS-05), 25 Aug 2006 (YS-07), 04 Mar 2014 (YS-09), 16 Apr 2011 (YS-10), 15 Jul 2011 (YS-11), 15 Jul 2011 (YS-12), 17 Apr 2011 (YS-16), 16 Jan 2014 (YS-18), 16 Apr 2011 (YS-24), 16 Apr 2011 (YS-26), 08 Nov 2013 (YS-27), 22 Apr 2013 (ES-19), 29 Aug 2010 (ES-03), 29 Aug 2010 (ES-04), 29 Aug 2010 (ES-05), 29 Aug 2010 (ES-08), and 29 Aug 2010 (ES-09).

20. *Asterionellopsis socialis* (Lewin & Norris) Crawford & Gardner 1997 (Figs. 30 and 31)

Basionym: *Asterionella socialis* Lewin & Norris 1970.

Synonym: *Licmophora socialis* Hanna mss. Thayer 1935.

References: Lewin and Norris 1970, p.145, figs. 5, 6, 13, 14, 18; Crawford and Gardner 1997, p. 48, figs. 20–21.

Specimen examined: NIBRDI0000134570 in National Institute of Biological Resources (NIBR), Incheon.

Dimension: length 29.9–48.8 µm, width 5.1–6.1 µm, 46–53 transapical striae in 10 µm.

Type locality: the west coast of the Olympic Peninsula, State of Washington, US.

Korea distribution: This species was observed in the Yellow Sea on 04 Mar 2014 (YS-09).

21. *Fragilaria capucina* var. *austriaca* (Grunow) Lange-Bertalot 1980 (Fig. 32)

Basionym: *Synedra austriaca* Grunow in Van Heurck 1881.

Synonym: *Synedra amphicephala* var. *austriaca* Grunow in Van Heurck 1881.

References: Van Heurck 1881, pl. 39, figs. 16A–B; Lange-Bertalot 1980, p. 748; Krammer and Lange-Bertalot 2004a, p. 126, pl. 109, figs. 21–24, pl. 113, figs. 3–5.

Dimension: length 49 µm, width 4 µm, 10 transapical striae in 10 µm.

Type locality: unknown.

Korea distribution: This species was observed one time at the stream of Namcheon on 22 Feb 2007 (FW-04).

22. *Synedra tabulata* var. *obtusa* (Pantocsdk) Hustedt 1932 (Figs. 33–35)

Basionym: *Synedra affinis* var. *obtusa* Arnott ex Van Heurck 1881.

Synonym: *Synedra tabulata* var. *obtusa* (Arnott) Cleve-Euler 1953; *Synedra tabulata* var. *obtusa* (Arnott in Van Heurck) Ross 1947.

References: Hustedt 1932, p. 219, fig. 710h; Simonsen 1987, p. 49.

Dimension: length 105–125 µm, width 6 µm, 13–14 transapical striae in 10 µm.

Type locality: unknown.

Korea distribution: This species was observed in the South Sea of Korea on 07 Feb 2008 (FW-01).

23. *Tabellaria* sp. (Figs. 36 and 37)

Dimension: length 34.1–35.2 µm, width 3 µm, 34–35 transapical striae in 10 µm.

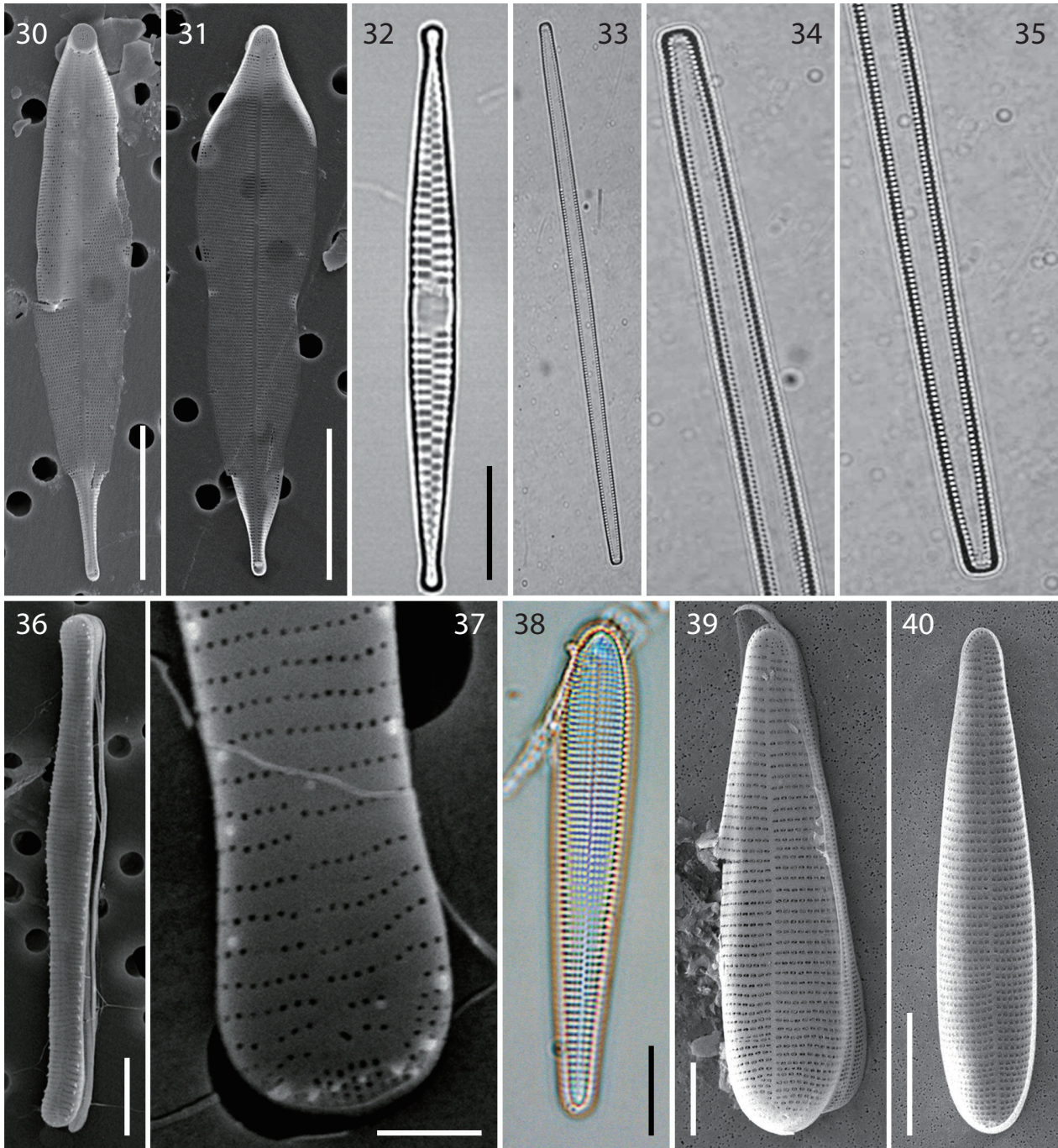
Korea distribution: This species was observed in the Yellow Sea on 24 Oct 2006 (YS-03).

Remark: In our knowledge, there is no identical species in this specimen. Therefore, we temporarily consider this species as unidentified status, and further investigation should be performed.

24. *Licmophora juergensii* Agardh 1831 (Figs. 38–40)

Synonym: *Podosphenia juergensii* (Agardh) Kützing 1844.

References: Agardh 1831, p. 42; Henedy 1964, p. 168, pl. 26, fig. 14; Honeywill 1998, p. 231, fig. 2a–h.



Figs. 30–40. Figs. 30, 31. *Asterionellopsis socialis*. Fig. 30. External valve view. Fig. 31. Internal valve view. Fig. 32. *Fragilaria capucina* var. *austriaca* in LM. Figs. 33–35. *Synedra tabulata* var. *obtusa*. Fig. 33. Whole cell. Figs. 34, 35. Apical area. Figs. 36, 37. *Tabellaria* sp. Fig. 36. Whole cell. Fig. 37. Apical area. Figs. 38–40. *Licmophora juergensii*. Fig. 38. Whole cell in LM. Fig. 39. External valve view in SEM. Fig. 40. Internal valve view in SEM. Scale bars represent: Figs. 30–32, 38 & 40, 10 μ m; Figs. 36 & 39, 5 μ m; Fig. 37, 1 μ m.

Specimen examined: NIBRDI0000134571 in National Institute of Biological Resources (NIBR), Incheon.

Dimension: length 35.8–54.3 μ m, width 8.2–11.2 μ m, 13–16 transapical striae in 10 μ m, 20–22 transverse areolae in 10 μ m.

Type locality: unknown.

Korea distribution: This species has been mainly observed in the East Sea on 21 Jan 2009 (ES-01), 22 Jan 2009 (ES-06), 23 Jan 2009 (ES-10), 23 Jan 2009 (ES-12), and 23 Jan 2009 (ES-18).

25. *Achnanthydium* sp. (Fig. 41)

Dimension: length 10.5 μm , width 4.7 μm , 20 transapical striae in 10 μm .

Korea distribution: This species was observed in the Yellow Sea on 24 Oct 2006 (YS-02).

Remark: The biseriate striae and the unilaterally deflected terminal raphe fissures are related to the genus *Planothydium*, but there are no identical species in the genus in our knowledge. Round and Bukhtiyarova (1996) transferred some *Achnanthydium* species having the multiseriate striae into *Planothydium*, but they did not transfer all multiseriate *Achnanthydium* species at that time. Therefore we primarily consider this species as *Achnanthydium* species, and further study is needed to decide its taxonomic position.

26. *Anorthoneis* sp. (Fig. 42)

Dimension: long 21.6–24.3 μm , 18.5–21.7 μm .

Korea distribution: This species has been mainly observed in the Yellow Sea on 15 Jul 2011 (YS-11), 02 Nov 2011 (YS-12) and 05 Nov 2011 (YS-14).

Remark: This species differ from the other *Anorthoneis* species by the biseriate areolation in the margin of raphid valve. Until the fine structure from two types of valve is revealed, we temporarily consider this species as unknown status.

27. *Encyonema neogracile* Krammer 1997 (Fig. 43)

References: Krammer 1997, pp 177–178, pl. 82, figs. 1–13, pl. 83, figs. 1–3, pl. 85, figs. 7–10, pl. 86, figs. 9–12, pl. 90, fig. 6, pl. 91, figs. 1–2.

Dimensions: apical axis 47 μm , transapical axis 7.5 μm , transapical striae 12 in 10 μm .

Type locality: Laguna Santarem, Brazilian Amazon.

Korea distribution: This species was observed in the Upo Wetland on 28 Oct 2007 (FW-03).

28. *Encyonema leei* (Krammer) Ohtsuka, Hanada & Nakamura 2004 (Fig. 44)

Basionym: *Encyonemopsis leei* Krammer 2003.

References: Krammer 2003, p. 147, 170, pl. 162, figs. 15–19; Ohtsuka et al. 2004, p. 150, figs. 1–24.

Dimensions: apical axis 28.5 μm , transapical axis 7 μm , transapical striae 10 in 10 μm .

Type locality: Kwangcheon River, Uljin country, Korea.

Korea distribution: This species was observed in the Geumgan River on 21 Oct 2007 (FW-06).

29. *Gomphonema olivaceoides* var. *densestriata* Foged 1963 (Fig. 47)

References: Foged 1963, p. 40, pl. 6, fig. 5.

Dimensions: apical axis 18–35 μm , transapical axis 5–6 μm , transapical striae 10–12 in 10 μm .

Type locality: lake in Djursland.

Korea distribution: This species was observed in the Sumgang River on 27 Apr 2002 (FW-07).

30. *Gomphonema parvulum* f. *saprophilum* Lange-Bertalot & Reichardt in Lange-Bertalot 1993 (Fig. 48)

References: Lange-Bertalot 1993, p. 69; Krammer and Lange-Bertalot 2004b, pl. 76, figs. 8–13, pl. 77, figs. 5–9.

Dimensions: apical axis 14 μm , transapical axis 6.5 μm , transapical striae 18 in 10 μm .

Type locality: unknown.

Korea distribution: This species was observed one time at the stream of Namcheon on 22 Feb 2007 (FW-04).

31. *Gomphonema productum* (Grunow) Lange-Bertalot & Reichardt in Lange-Bertalot 1993 (Fig. 49)

Basionym: *Gomphonema angustatum* var. *productum* Grunow in Van Heurck 1880.

References: Van Heurck 1880, pl. 24, figs. 52–55; Lange-Bertalot 1993, p. 7, pl. 73, figs. 14–17, pl. 74, figs. 1–3; Krammer and Lange-Bertalot 2004b, pl. 74, figs. 15–22.

Dimensions: apical axis 29 μm , transapical axis 8 μm , transapical striae 12 in 10 μm .

Type locality: unknown.

Korea distribution: This species was observed one time at the stream of Namcheon on 22 Feb 2007 (FW-04).

32. *Amphipleura lindheimeri* Grunow 1862 (Fig. 45)

Synonyms: *Amphipleura pellucida* var. *lindheimeri* (Grunow) Cleve 1894; *Amphiprora lindheimeri* (Grunow) Wolle 1890; *Berkeleya lindheimeri* (Grunow) Giffen 1970; *Amphipleura pellucida* var. *lindheimeri* (Grunow) O'Hara 1889.

References: Grunow 1862, p. 469, pl. 11, fig. 11; Germain 1981, p. 137.

Dimensions: apical axis 120–330 μm , transapical axis 23–27 μm , transapical striae 26–28 in 10 μm .

Type locality: the mighty waters of America borealis.

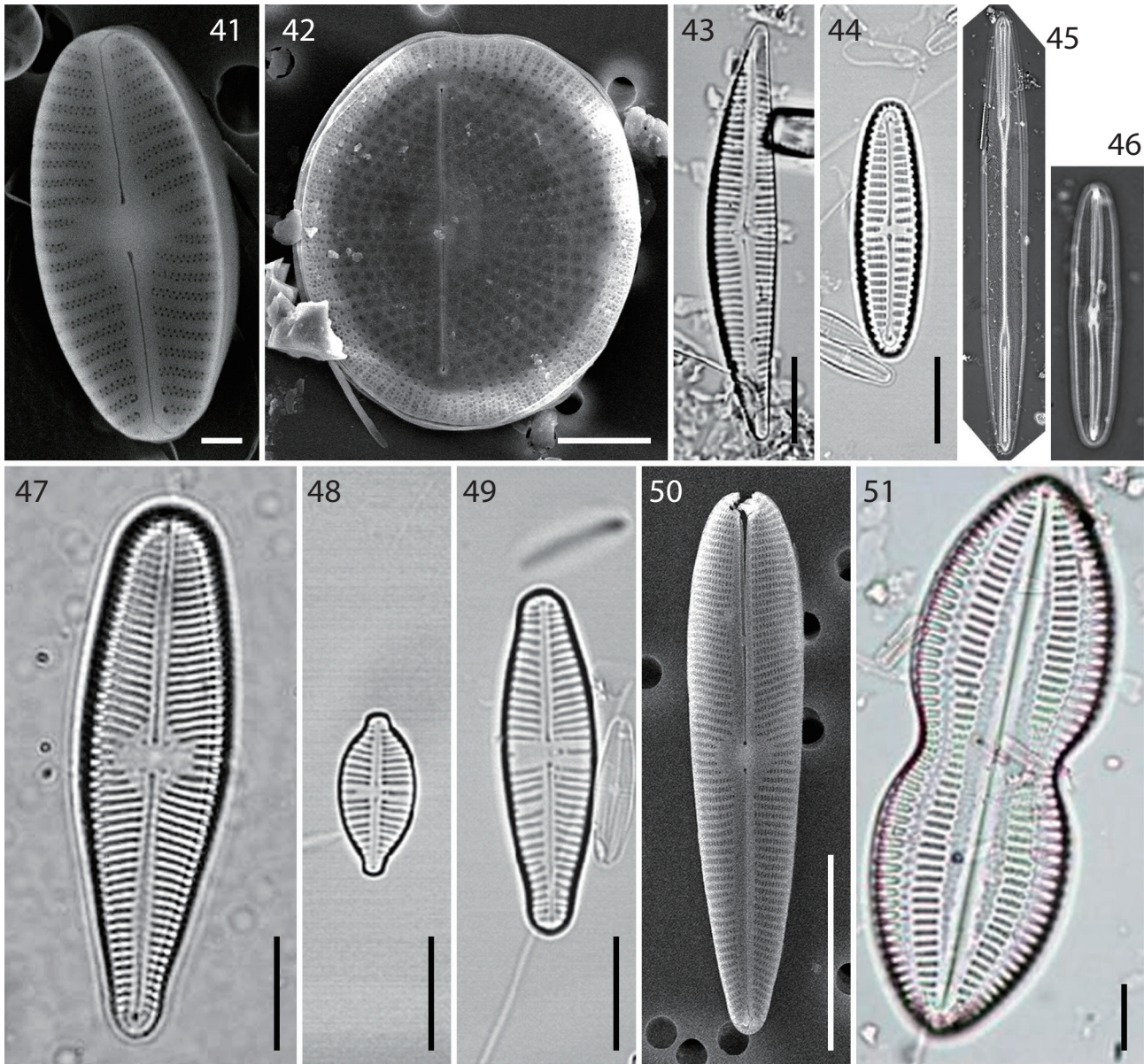
Korea distribution: This species was observed one time at the stream of Sueocheon on 24 Apr 1999 (FW-02).

33. *Caloneis alpestris* (Grunow) Cleve 1894 (Fig. 46)

Basionym: *Navicula alpestris* Grunow 1860.

Synonym: *Schizonema alpestre* (Grunow) Kuntze 1898.

References: Cleve 1894, p. 53; Germain 1981, p. 238;



Figs. 41–51. Fig. 41. *Achnanthisdium* sp. in the external valve view in SEM. Fig. 42. *Anorthoneis* sp. in the external valve view in SEM. Fig. 43. *Encyonema neogratile*. Fig. 44. *Encyonema leei*. Fig. 45. *Amphipleura lindheimeri*. Fig. 46. *Caloneis alpestris*. Fig. 47. *Gomphonema olivaceoides* var. *densestriata*. Fig. 48. *Gomphonema parvulum* f. *saprophilum*. Fig. 49. *Gomphonema productum*. Fig. 50. *Pseudogomphonema monicae*. Fig. 51. *Progonoia mirabilis*. Scale bars represent: Fig. 41, 1 μm ; Fig. 42, 5 μm ; Figs. 43, 44 & 47–51, 10 μm .

Lange-Bertalot 1996, pl. 24.

Dimensions: apical axis 45–92 μm , transapical axis 6–15 μm , transapical striae 20–24 in 10 μm .

Type locality: stream in Alps, Austria.

Korea distribution: This species was observed one time at the Sueo stream on 24 Apr 1999 (FW-02).

34. *Pseudogomphonema monicae* Witkowski, Metzeltin & Lange-Bertalot 1996 (Fig. 50)

References: Metzeltin and Witkowski 1996, pp 25–26,

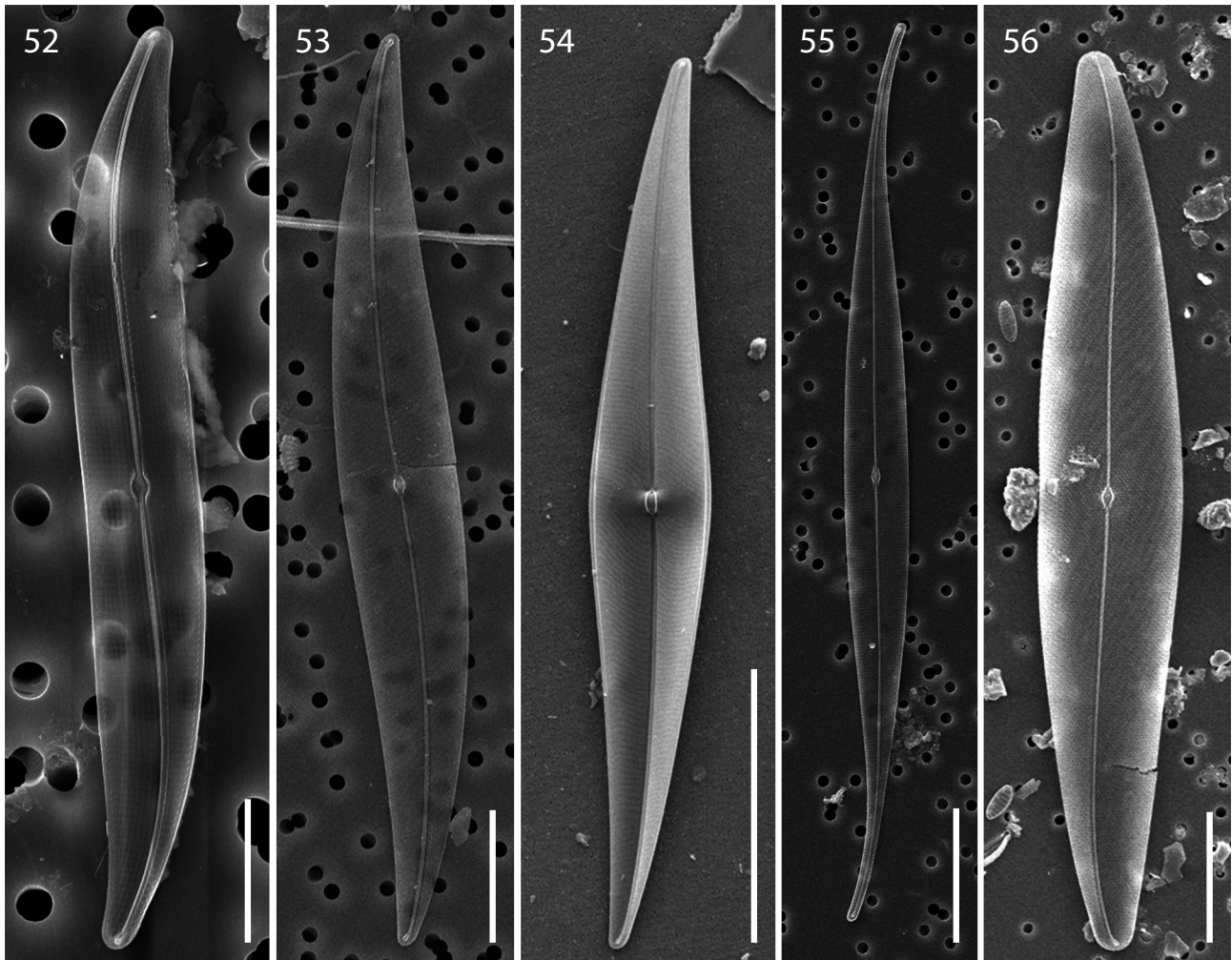
pl. 57, fig. 2, pl. 58, figs. 11–22, pl. 80, figs. 1–4, pl. 81, fig. 2; Lange-Bertalot 1996, pl. 57–58, 80–81.

Specimen examined: NIBRDI0000134572 in National Institute of Biological Resources (NIBR), Incheon.

Dimension: apical axis 28.0 μm , transapical axis 5.6 μm , 25 transapical striae 25 in 10 μm .

Type locality: sediment in Bear Island, Wadden Sea.

Korea distribution: This species was observed one time in the Yellow Sea on 16 Apr 2011 (YS-13).



Figs 52–56. Fig. 52. *Gyrosigma littorale* in the internal valve view. Fig. 53. *Pleurosigma amara* in the internal valve view. Fig. 54. *Pleurosigma strigosum* in the internal valve view. Fig. 55. *Pleurosigma tenuiforme* in the internal valve view. Fig. 56. *Pleurosigma inscriptura* in the internal valve view. Scale bars represent: Fig. 52, 10 μm ; Figs. 53, 55 & 56, 20 μm ; Fig. 54, 50 μm .

35. *Progonoia mirabilis* (Leuduger-Fortmorel) Schrader 1971 (Fig. 51)

Basionym: *Navicula mirabilis* Leuduger-Fortmorel 1879.

Synonym: *Caloneis musca* var. *mirabilis* (Leuduger-Fortmorel) Cleve 1894; *Navicula musca* var. *mirabilis* (Leuduger-Fortmorel) Fricke 1902.

References: Schrader 1971, p. 921.

Dimension: length 86.3 μm , width 29.6 μm , 7 transapical striae in 10 μm .

Type locality: unknown.

Korea distribution: This species was observed one time from the coastal water of Jeju Island in Korea on 11 Mar 2012 (Jeju-01).

36. *Gyrosigma littorale* (Smith) Griffith & Henfrey 1856 (Fig. 52)

Basionym: *Pleurosigma littorale* (*litorale*) Smith 1852.

Synonyms: *Scalprum* (*Scalptrum*) *litorale* (Smith) Kuntze 1891; *Gyrosigma litorale* (Smith) Cleve 1894.

References: Griffith and Henfrey 1856, p. 356, pl. 11, fig. 19; Hendey 1964, p. 250.

Dimension: length 62.9–65.0 μm , width 8.1–8.6 μm , 28 areolae in 10 μm , 22 transapical striae in 10 μm .

Type locality: coast of Sussex, England.

Korea distribution: This species has been observed two times in the Yellow Sea and the South Sea on 03 Oct 2012 (YS-13) and 02 Nov 2012 (SS-02), respectively.

37. *Pleurosigma amara* Stidolph 1992 (Fig. 53)

References: Stidolph 1992, p. 349, figs. 44–51, 64–76.

Dimension: length 155–271 µm, width 21–27 µm, 22–25 oblique striae in 10 µm, 16–24 transverse striae in 10 µm.

Type locality: Westshore, Napier, North Island, New Zealand; in salt marsh.

Korea distribution: This species was observed one time in the South Sea of Korea on 2 Nov. 2012 (SS-06).

38. *Pleurosigma strigosum* W. Smith 1852 (Fig. 54)

Synonyms: *Gyrosigma strigosum* (Smith) Griffith & Henfrey 1856; *Pleurosigma angulatum* var. *strigosa* (*strigosum*) (Smith) Van Heurck 1885.

References: Smith 1852, p. 7, pl. 1, fig. 6; Hendey 1964, p. 246; Lange and Tiffany 2002, fig. 41.

Dimension: length 134–170 µm, width 20–24 µm, 19–25 oblique striae in 10 µm, 17–22 transverse striae in 10 µm.

Type locality: coast of Sussex, England.

Korea distribution: This species was observed one time in the Yellow Sea on 14 Apr 2007 (YS-20).

39. *Pleurosigma tenuiforme* von Quillfeldt 2000 (Fig. 55)

References: von Quillfeldt 2000, p. 222, figs. 1–7.

Dimension: length 135 µm, width 11 µm, 26 oblique striae in 10 µm, 28 transverse striae in 10 µm.

Type locality: Barents Sea (76°45'76" N, 23°00'11" E).

Korea distribution: This species was observed one time in the Yellow Sea on 17 Feb 2010 (YS-04).

40. *Pleurosigma inscriptura* Harper 2009 (Fig. 56)

References: Harper et al. 2009, p. 343, figs. 18–22.

Dimension: length 139 µm, width 22.6 µm, 19 oblique striae in 10 µm, 21 transverse striae in 10 µm.

Type locality: Island Bay, Wellington, New Zealand.

Korea distribution: This species was observed one time in the Yellow Sea on 03 Oct 2012 (YS-14).

Korean distribution of newly recorded diatoms

Most taxa have been rarely observed in the specific areas, except for *Shionodiscus poro-irregulatus*, *Cyclotella choctawhatcheeana*, *C. cryptica*, *C. scaldensis*, and *Gyrosigma littorale* (Table 2). The occurrence of species was related to their preferred habitat and reflected the habitat features: In the Yellow Sea, 14 species were observed, and they mainly consisted of the benthic diatoms, such as *Actinocyclus*, *Anorthoneis*, *Pleurosigma*, and *Pseudogomphonema*. In the South Sea, four species were observed; of these, two species (*Chaetoceros octagonus* and *C. simplex*) were planktonic and two species (*Pleurosigma amara* and *Terpsinoë Americana*) were benthic diatoms.

In the East Sea, four species were observed; of these, two *Asteromphalus* species were planktonic and the other two species (*Eunotogramma marinum* and *Licmophora juergensii*) were epiphytic. On Jeju Island, *Progonioia mirabilis*, *Toxarium hennedyanum*, and *Trigonium arcticum* var. *japonica* were typical planktonic diatoms, and these species were not observed at high latitudes in Korea. In the freshwater regions, 10 species were observed, and they were typical freshwater diatoms. The co-occurrence of planktonic and benthic diatoms in the Yellow and

Table 2. Checklist of occurrence of 40 species from the Yellow Sea (YS), South Sea (SS), East Sea (ES), Jeju Island (Jeju) and the freshwater regions (FW); each value indicate the number of occurrence from the sites in each area

| Species | YS | SS | ES | Jeju | FW |
|---|----|----|----|------|----|
| <i>Achnantheidium</i> sp. | 1 | | | | |
| <i>Actinocyclus exiguus</i> | 1 | | | | |
| <i>Actinocyclus</i> sp. | 1 | | | | |
| <i>Actinocyclus aster</i> | 4 | | | | |
| <i>Amphipleura lindheimeri</i> | | | | | 1 |
| <i>Anorthoneis</i> sp. | 3 | | | | |
| <i>Asterionellopsis socialis</i> | 1 | | | | |
| <i>Asteromphalus hyalinus</i> | | | 1 | | |
| <i>Asteromphalus parvulus</i> | | | 1 | | |
| <i>Caloneis alpestris</i> | | | | | 1 |
| <i>Chaetoceros lorenzianus</i> var. <i>solitarius</i> | 2 | | | | |
| <i>Chaetoceros octagonus</i> | | 1 | | | |
| <i>Chaetoceros simplex</i> | | 1 | | | |
| <i>Cyclotella choctawhatcheeana</i> | 2 | 1 | | | |
| <i>Cyclotella cryptica</i> | 3 | | 2 | | |
| <i>Cyclotella scaldensis</i> | 5 | | 1 | | |
| <i>Encyonema neogratile</i> | | | | | 1 |
| <i>Encyonopsis lei</i> | | | | | 1 |
| <i>Eunotogramma marinum</i> | | | 3 | | |
| <i>Fragilaria capucina</i> var. <i>austriaca</i> | | | | | 1 |
| <i>Gomphonema olivaceoides</i> var. <i>densestriata</i> | | | | | 1 |
| <i>Gomphonema parvulum</i> f. <i>saprophilum</i> | | | | | 1 |
| <i>Gomphonema productum</i> | | | | | 1 |
| <i>Gyrosigma littorale</i> | 1 | 1 | | | |
| <i>Licmophora juergensii</i> | | | 5 | | |
| <i>Pleurosigma amara</i> | | 1 | | | |
| <i>Pleurosigma inscriptura</i> | 1 | | | | |
| <i>Pleurosigma strigosum</i> | 1 | | | | |
| <i>Pleurosigma tenuiforme</i> | 1 | | | | |
| <i>Progonioia mirabilis</i> | | | | 1 | |
| <i>Pseudogomphonema monicae</i> | 1 | | | | |
| <i>Pseudoguinardia recta</i> | | | | | 1 |
| <i>Schuetitia annulata</i> var. <i>minor</i> | 1 | | | | |
| <i>Shionodiscus endoseriatus</i> | 2 | | | | |
| <i>Shionodiscus poro-irregulatus</i> | 13 | 4 | 6 | | |
| <i>Synedra tabulata</i> var. <i>obtusa</i> | | | | | 1 |
| <i>Tabellaria</i> sp. | 1 | | | | |
| <i>Terpsinoë americana</i> | | 1 | | | |
| <i>Toxarium hennedyanum</i> | | | | | 1 |
| <i>Trigonium arcticum</i> var. <i>japonica</i> | | | | | 1 |

South Seas might have been due to the tidal effect, and the epiphytic taxa from the East Sea might have been opportunely detached from seaweed at the intertidal zone.

Shionodiscus poro-irregulatus, *Cyclotella choctawhatcheeana*, *C. cryptica*, *C. scaldensis*, and *Gyrosigma littorale* have been frequently observed in the coastal waters of Korea. Given the frequent occurrence of these species, why are they firstly reported in the present study? Park et al. (2014) mentioned three reasons explaining why the taxa have not been recorded in Korea: (1) high species diversity in a single genus, (2) misidentification due to confusion with similar taxa, and (3) species-specific habitats. *Shionodiscus poro-irregulatus* might be misidentified as other thalassiosiroid diatoms, such as *S. oestrupii* var. *venrickae* due to its valve face rimoportula or *Thalassiosira eccentrica* due to its coarse areolae and tangential areolation. *Cyclotella* and *Gyrosigma* are the most species-rich groups of diatoms, and the numbers of species are estimated at approximately 177 and 89, respectively (Guiry and Guiry 2015). The four newly recorded species in both genera might be overlooked or misidentified as other *Cyclotella* or *Gyrosigma* species. Both genera require intensive study to understand the species diversity in Korea.

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