



Taxonomic study of the genus *Achnanthes* (Bacillariophyta) in Korean coastal waters

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Abstract

A study on the fine structure of the genus *Achnanthes* species (Bacillariophyceae) is carried out at 92 stations for taxonomic purposes from January 2009 to April 2013 in Korean marine water, freshwater and brackish water. Twelve *Achnanthes* species are identified based on a variety of taxonomic characters by means of light microscopy and scanning electron microscopy. Of these, seven species, *Achnanthes cocconeoides*, *A. groenlandica*, *A. javanica*, *A. kuwaitensis*, *A. parvula*, *A. pseudolongipes*, and *A. yaquinensis*, are newly recorded in Korean waters. All 12 species are documented concerning a taxonomic key, description, distribution, seasonality, remarks and photographs. Twenty three *Achnanthes* taxa are identified in the survey.

Key words: *Achnanthes*, Bacillariophyceae, diatoms, new to Korea

INTRODUCTION

The genus *Achnanthes* Bory comprises a group of monoraphid heterovalvar diatoms with *Achnanthes adnata* as the type species (Bory 1822). More than 500 species have been described in the genus *Achnanthes* in marine, fresh- and brackish waters (VanLandingham 1967). Recent studies on the monoraphid diatom have subdivided into new genera that include *Achnanthidium* Kützing (Round et al. 1990), *Psammothidium* Bukhtiyarova & Round, *Karayevia* Round & Bukhtiyarova ex Round, *Kolbesia* Round & Bukhtiyarova ex Round, *Rossithidium* Round & Bukhtiyarova (Round and Bukhtiyarova 1996) and *Pogoneis* Round & Basson (Round and Basson 1997).

Toyoda et al. (2006) pointed out that there is no taxonomic information of the type and revised the type of the genus as *Achnanthes brevipes* Agardh through the examination of the lectotypus of Bory. The definition of *Achnanthes* sensu stricto has been revisited, and there are now probably fewer than 100 species and infraspecific taxa in

the genus (Toyoda et al. 2006). *Achnanthes* sensu stricto differs from other achnanthoid diatoms in areolae, raphe, girdle and palstid structure (Round et al. 1990). The presence of cribrate areolae on both the valves and copulae is one of the most important features for discriminating between *Achnanthes* sensu stricto and other achnanthoid species (Toyoda et al. 2005a). Living material of *Achnanthes* species, with two or many peripheral chloroplasts, contrasts with other achnanthoid genera, which usually contain a single chloroplast (Toyoda et al. 2005b).

Thirty six taxa of *Achnanthes* species have been identified in Korea from the early 1930's to the mid-1990's (Lee 1995, Lee et al. 1995). Of these, only 14 species are the current valid name, 18 taxa of listed species are transferred into the other genera, two species are changed concerning the status or the author of the species, and two taxa are uncertain species name (Table 1). Although the number of *Achnanthes* species in Korea has been recorded, no

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taxonomic study has provided descriptions, illustrations or monographs, which has hampered the exact identification of the recorded species of *Achnanthes* sensu stricto. The aim of this study is to reveal the genus *Achnanthes* species focused on the fine structure during a survey conducted from January 2009 to April 2013 in marine, fresh- and brackish waters of Korea.

MATERIALS AND METHODS

Achnanthes species were collected at 92 stations in marine, fresh- and brackish waters of Korea from Jan 2009 to Apr 2013 (Appendix 1). Samples were collected by vertical or horizontal towing using a 20 µm mesh-size plankton net. Net samples were immediately fixed with neutralized formalin (final concentration 4%), glutaraldehyde (final concentration 2%) or Lugol's solution (Sournia 1968). To examine the fine structure and taxonomic characteristics of the species, samples were cleaned of organic matter with concentrated HCl and saturated KMnO₄ following the Hasle and Fryxell (1970)'s modified method. Permanent slides were made with the acid-cleaned materials, as follows. A drop of cleaned sample was put on a cover slip and dried using low heat. Pleurax mountant was put

on each sample on a cover slip. The cover slip was put face-down on a slide glass and slightly heated using an alcohol lamp to evaporate the solvent. All specimens were observed using an Eclipse 80i light microscope equipped with bright-field and differential interference contrast optics (Nikon, Tokyo, Japan) with a DS-Fil digital camera (Nikon). Some cleaned specimens were individually dropped onto an aluminum stub and coated with gold-palladium. Coated samples were examined using a JSM-5600LV scanning electron microscope (JEOL, Tokyo, Japan). Sizes of the diatom species were analyzed with Axio Vision AC v. 4.5 image calculation software (Carl Zeiss, Oberkochen, Germany). Terminology followed general proposals by Anonymous (1975), Ross et al. (1979) and Toyoda et al. (2003).

RESULTS AND DISCUSSION

Twelve *Achnanthes* species were identified in the present study. Taxonomic information of all species included synonym, description, morphometric data (Table 2), distribution, reference, seasonality, taxonomic remarks and illustrations about respective species.

Table 1. List of *Achnanthes* species in Korea

Species name in previous study	Valid species name	Literature
<i>Achnanthes brevipes</i> var. <i>brevipes</i>	<i>Achnanthes brevipes</i> var. <i>brevipes</i>	Lee et al. 1995; Lee 1995; This study
<i>Achnanthes brevipes</i> var. <i>intermedia</i>	<i>Achnanthes brevipes</i> var. <i>intermedia</i>	Lee et al. 1995; this study
<i>Achnanthes clevei</i> var. <i>rostrata</i> Hustedt	<i>Achnanthes clevei</i> var. <i>rostrata</i> Hustedt	Lee et al. 1995
<i>Achnanthes coarctata</i>	<i>Achnanthes coarctata</i>	Lee et al. 1995; this study
<i>Achnanthes cocconeoides</i>	<i>Achnanthes cocconeoides</i>	This study
<i>Achnanthes convergens</i> Kobayasi	<i>Achnanthes convergens</i> Kobayasi	Lee et al. 1995
<i>Achnanthes crenulata</i> Grunow	<i>Achnanthes crenulata</i> Grunow	Lee et al. 1995
<i>Achnanthes groelandica</i>	<i>Achnanthes groelandica</i>	This study
<i>Achnanthes inflata</i> (Kützing) Grunow	<i>Achnanthes inflata</i> (Kützing) Grunow	Lee et al. 1995
<i>Achnanthes javanica</i>	<i>Achnanthes javanica</i>	This study
<i>Achnanthes koreana</i> Skvortzow	<i>Achnanthes koreana</i> Skvortzow	Lee et al. 1995
<i>Achnanthes kuwaitensis</i>	<i>Achnanthes kuwaitensis</i>	This study
<i>Achnanthes lapidosa</i> var. <i>lanceolata</i> Hustedt	<i>Achnanthes lapidosa</i> var. <i>lanceolata</i> Hustedt	Lee et al. 1995
<i>Achnanthes longipes</i>	<i>Achnanthes longipes</i>	Lee et al. 1995; Lee 1995; This study
<i>Achnanthes marginulata</i> Grunow	<i>Achnanthes marginulata</i> Grunow	Lee et al. 1995
<i>Achnanthes parvula</i>	<i>Achnanthes parvula</i>	This study
<i>Achnanthes pseudolongipes</i>	<i>Achnanthes pseudolongipes</i>	This study
<i>Achnanthes subconstricta</i>	<i>Achnanthes subconstricta</i>	Lee et al. 1995; Lee 1995; This study
<i>Achnanthes subhudsonis</i> Hustedt	<i>Achnanthes subhudsonis</i> Hustedt	Lee et al. 1995; Lee 1995
<i>Achnanthes subhudsonis</i> var. <i>kraeuselii</i> (Cholnoky) Cholnoky	<i>Achnanthes subhudsonis</i> var. <i>kraeuselii</i> (Cholnoky) Cholnoky	Lee et al. 1995
<i>Achnanthes temperi</i> Peragallo	<i>Achnanthes temperi</i> M. Peragallo	Lee et al. 1995
<i>Achnanthes trinodis</i> (Ralfs) Grunow	<i>Achnanthes trinodis</i> (Ralfs) Grunow	Lee et al. 1995
<i>Achnanthes yaquinensis</i>	<i>Achnanthes yaquinensis</i>	This study

Table 2. Morphological characteristics of *Achnanthes* species

	Dimension		Valve				RV		ARV		Internal costae	Spines	Marginal ridge	Terminal orbiculi on ARV
	Length (µm)	Width (µm)	Outline	Middle part	Apices	Rows of striae	Striae in 10 µm	Rows of striae	Striae in 10 µm					
<i>Achnanthes brevipes</i> var. <i>brevipes</i>	35.8-59.8	10.8-28.4	linear-elliptical	slightly constricted	cuneate	1	10	1	9	present ^a	absent	absent	absent	
<i>Achnanthes brevipes</i> var. <i>intermedia</i>	26.7-43.3	9.2-11.3	linear-elliptical	slightly constricted	rounded	1	11-12	1	10	ND	absent	absent	absent	
<i>Achnanthes coarctata</i>	26.7	7.3	linear-elliptical	constricted	narrowed rostrate	1	10-12	1	10	absent ^b	absent	absent	absent	
<i>Achnanthes cocconetodes</i>	18.5-22.4	6.9-11.8	elliptical	broad	rounded	1	9-10	1	10-11	ND	absent	absent	absent	
<i>Achnanthes groenlandica</i>	24.7-33.3	3.8-5.3	linear	slightly convex	bluntly rounded	1	12	1	13	absent ^b	absent	absent	absent	
<i>Achnanthes javanica</i>	61.7-89.5	23.3-31.4	linear-elliptical	slightly broad	cuneate	2-3	5-6	2-3	5-6	present	absent	present	absent	
<i>Achnanthes kuwaitensis</i>	33.7-66.2	8.3-8.9	nearly linear	slightly constricted	smoothly rounded	1	9-11	1	10-11	present	absent	absent	present	
<i>Achnanthes longipes</i>	36.1-103	11.2-23.1	linear	slightly constricted	cuneate	2	6-12	2	6-8	present	absent	absent	absent	
<i>Achnanthes parvula</i>	10-25	4.7-9.2	linear-elliptical	slightly broad	rounded	1	15-16	1	10-11	absent	absent	absent	present	
<i>Achnanthes pseudolongipes</i>	65-115	20.8-29.1	linear-elliptical	constricted	cuneate	1	8-9	2-3	6-7	present ^b	absent	absent	present	
<i>Achnanthes substricta</i>	30-69.2	13.3-26.9	linear-elliptical	constricted	cuneate	2-3	5-6	2-3	4-5	present	present	present	present	
<i>Achnanthes yaquimensis</i>	33.9-45.2	9.2-27.2	nearly rhombus	smoothly rounded	cuneate	1	8-9	1	8-8.5	present	present	present	present	

^aAlfinito 1983; ^bCox 2006; ND, No Data.

Key to genus *Achnanthes* species

- 1a. One row of striae on the raphid valve (RV) and araphid valve (ARV)2
- 1b. Multi-rows of striae on the RV and ARV9
- 2a. Spines and marginal ridge on the valves
..... *A. yaquinensis*
- 2b. No spines and marginal ridge on the valves3
- 3a. Cuneate valve apices *A. brevipes* var. *brevipes*
- 3b. No cuneate valve apices4
- 4a. Terminal obiculi on the ARV5
- 4b. No terminal obiculi on the ARV6
- 5a. Internal costae inner valve *A. kuwaitensis*
- 5b. No internal costae inner valve *A. parvula*
- 6a. Narrowed rostrate valve apices *A. coarctata*
- 6b. Rounded rostrate valve apices7
- 7a. Broad middle part of the valve*A. cocconeoides*
- 7b. Not broad middle part of the valve8
- 8a. Striae in 10 µm on the RV more than the ARV
..... *A. brevipes* var. *intermedia*
- 8b. Striae in 10 µm on the RV less than the ARV
..... *A. groenlandica*
- 9a. Terminal obiculi on the ARV 10
- 9b. No terminal obiculi on the ARV.....11
- 10a. Rows of striae on the RV differ the ARV.....
..... *A. pseudolongipes*
- 10b. Rows of striae on the RV same the ARV
..... *A. subconstricta*
- 11a. Marginal ridge of the valve *A. javanica*
- 11b. No marginal ridge of the valve *A. longipes*

Descriptions of species

Achnanthes brevipes var. *brevipes* Agardh (Fig. 1A-1E, Fig. 3A)

Synonym: *Achnanthidium brevipes* (Agardh) Cleve 1895; *Achnantella brevipes* (Agardh) Gaillon 1833; *Achnanthidium brevipes* (Agardh) Heiberg 1863.

Description: Valves linear-elliptical, slightly constricted in the middle, cuneate at the apices. In girdle view, valve slightly curved geniculately with a convex ARV and a concave RV. 35.8-59.8 µm long, 10.8-28.4 µm wide. Striae uniseriate on both valves (ARV and RV) with nine striae in 10 µm on the ARV, and 10 striae in 10 µm on the RV. Internal valves with thickened transverse costae. Transapical striae slightly radial. Cells without spines and marginal ridge. Both valves without terminal obiculi.

Distribution: *A. brevipes* var. *brevipes* is found all coastal areas and in salterns (Hustedt 1931), is common in estuaries or harbours and has been reported on the south

and east coasts of Britain (Hendey 1964). Presently, *A. brevipes* var. *brevipes* was present 14 times in Korean coastal waters in planktonic environments: ES-01 (21 Jan 2009), ES-02 (21 Jan 2009), ES-19 (23 Jan 2009), ES-24 (16 Feb 2009), ES-32 (29 Aug 2010), ES-37 (29 Aug 2010), ES-40 (29 Aug 2010), ES-51 (30 Aug 2010), ES-53 (21 Apr 2013), YS-12 (24 Jul 2010), SS-01 (15 Nov 2010), SS-06 (16 Nov 2010), SS-09 (9 Jun 2011), SS-21 (26 Feb 2013).

References: Agardh 1824, p 1; Gaillon 1833, p 10; Heiberg 1863, p 118; Cleve 1895, p 193; Hendey 1951, p 41, pl. 16, figs. 9, 10.

Remarks: This species possesses the thickened transverse costae on the internal valves (Alfinito 1983), although it was not examined in this study. *A. brevipes* var. *brevipes* is dissimilar to *A. brevipes* var. *intermedia* in possessing more narrowed valve ends.

Achnanthes brevipes var. *intermedia* (Kützing) Cleve (Fig. 1I-1K)

Basionym: *Achnanthes intermedia* Kützing 1833.

Synonym: *Achnanthes intermedia* Kützing 1833; *Achnanthes subsessilis* Kützing 1833; *Achnanthidium brevipes* var. *intermedia* '(Kützing) Cleve' VanLandingham 1967.

Description: Valves linear-elliptical, sometimes slightly constricted in the middle, rounded at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 26.7-43.3 µm long, 9.2-11.3 µm wide. Striae uniseriate on both valves (ARV and RV) with 10 striae in 10 µm on the ARV and 11-12 striae in 10 µm on the RV. Transapical striae slightly radial. Cells without spines and marginal ridge. Both valves without terminal obiculi.

Distribution: *A. brevipes* var. *intermedia* are widely distributed and lives in waters of lower salt concentration (Hustedt 1931). McIntire and Reimer (1974) found the species from Yaquina Estuary, Oregon, in Aug 1968, Oct 1968 and Jul 1969. Presently, *A. brevipes* var. *intermedia* was recorded 16 times as a planktonic diatom of East Sea and Yellow Sea: ES-04 (22 Jan 2009), ES-08 (22 Jan 2009), ES-14 (22 Jan 2009), ES-30 (28 Aug 2010), ES-34 (29 Aug 2010), ES-37 (29 Aug 2010), ES-38 (29 Aug 2010), ES-39 (29 Aug 2010), ES-41 (29 Aug 2010), ES-42 (29 Aug 2010), ES-48 (30 Aug 2010), YS-04 (22 Jul 2010), YS-05 (22 Jul 2010), YS-08 (23 Jul 2010), YS-11 (23 Jul 2010), YS-14 (24 Jul 2010).

References: Cleve 1895, p 193; Kützing 1833, p 576, figs. 55, 56; VanLandingham 1967, p 70; McIntire and Reimer 1974, p 171, pl. II, fig. 8a-b, pl. III, fig. 2a-b.

Remarks: Thickened transverse costae of *A. brevipes* var. *intermedia* was not examined in this study.

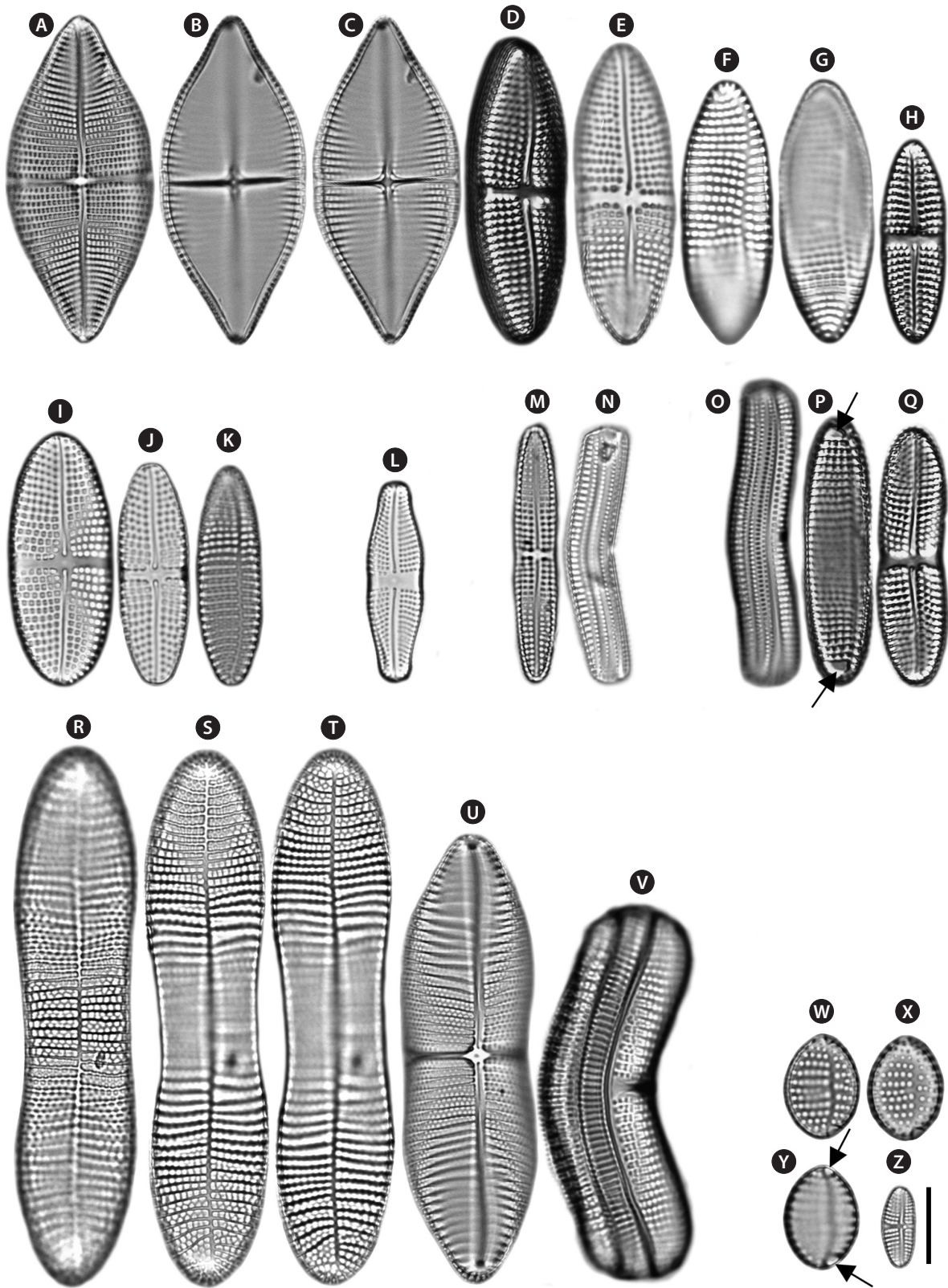


Fig. 1. LM microphotographs of the *Achnanthes* spp. (A-E) RV of the *A. brevipes* var. *brevipes*. (I-K) RV of the *A. brevipes* var. *intermedia*. (L) RV of the *A. coarctata*. (M) RV of the *A. groenlandica*. (N) Girdle view of the *A. groenlandica*. (O) Girdle view of the *A. kuwaitensis*. (P) ARV with terminal obiculi (arrows) of the *A. kuwaitensis*. (Q) RV of the *A. kuwaitensis*. (R-T) ARV of the *A. longipes*. (U) RV of the *A. longipes*. (V) Girdle view of the *A. longipes*. (W-Y) ARV with terminal obiculi (arrows) of the *A. parvula*. (Z) RV of the *A. parvula*. Scale bar, 10 μ m.

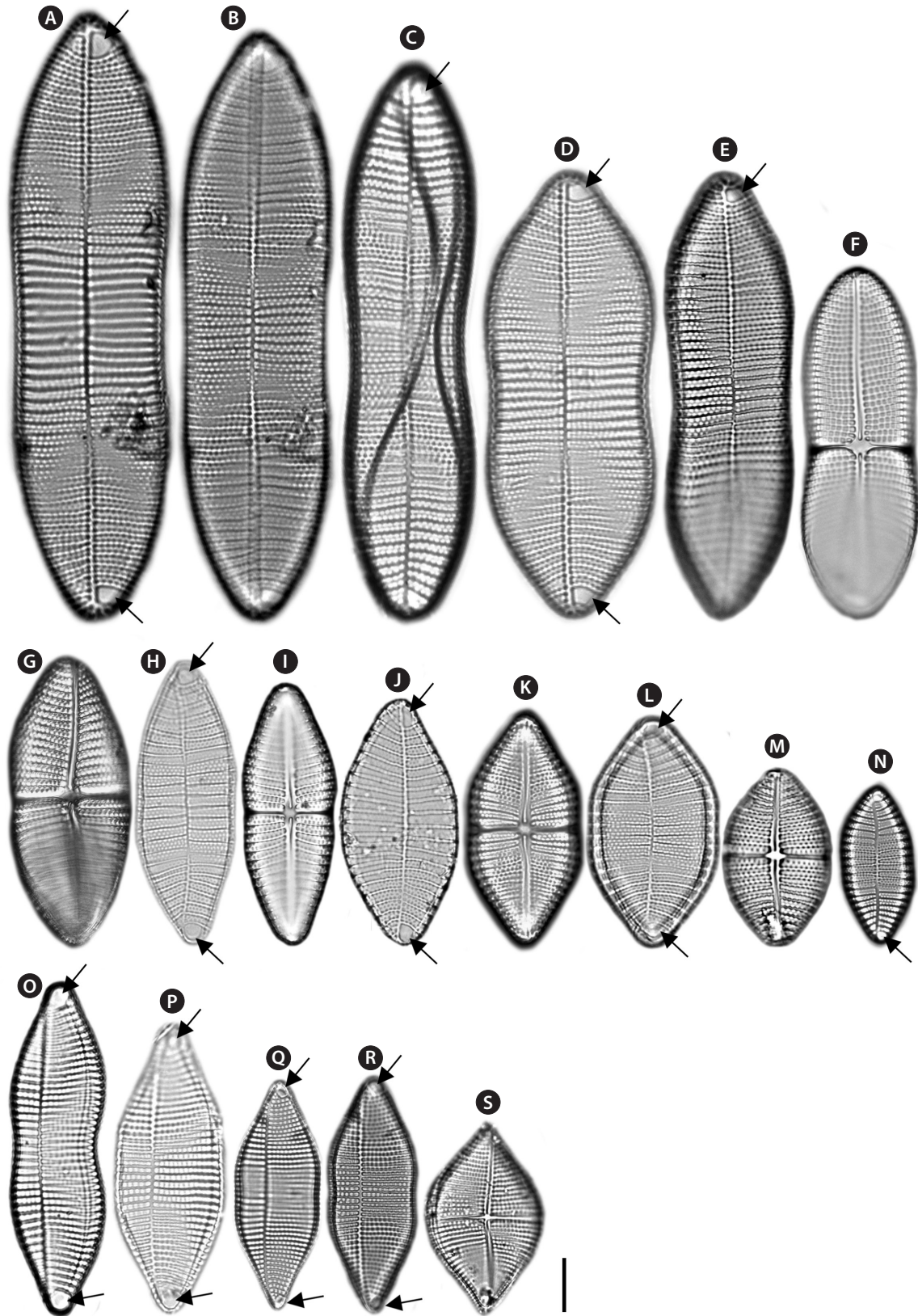


Fig. 2. LM microphotographs of the *Achnanthes* spp. (A-E) ARV with terminal obiculi (arrows) of the *A. pseudolongipes*. (F) RV of the *A. pseudolongipes*. (G, I, K & M) RV of the *A. subconstricta*. (H, J, L & N) ARV with terminal obiculi (arrows) of the *A. subconstricta*. (O-R) ARV with terminal obiculi (arrows) of the *A. yaquinensis*. (S) RV of the *A. yaquinensis*. Scale bar, 10 μ m.

***Achnanthes coarctata* (Brébisson ex Smith) Cleve & Grunow (Fig. 1L)**

Basionym: *Achnantheidium coarctatum* Brébisson ex Smith 1855.

Synonym: *Achnantheidium coarctatum* Brébisson ex Smith 1855.

Description: Valves linear-elliptical, constricted in the middle, with narrowed rostrate at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 26.7 µm long, 7.3 µm wide. Striae uniseriate on both valves (ARV and RV) with 10 costae in 10 µm on the ARV and 10-12 costae in 10 µm on the RV. Internal valves without thickened transverse costae. Transapical striae slightly radial. Cells without the spines and marginal ridge. Both valves without terminal obiculi.

Distribution: Hustedt (1931) found this species commonly in drainage ditches and on wet rocks from northern Europe. Cox (2006) examined *A. coarctata* on a SEM stub from Kinloch Rannoch, Perthshire, Scotland in Jul 2002. This study, *A. coarctata* was found in planktonic environment of East Sea only: ES-45 (29 Aug 2010).

References: Smith 1855, p 8, pl. 1, fig. 10; Cleve and Grunow 1880, p 121.

Remarks: Cox (2006) supposed it may be present spines or ridges at the face-mantle junction of the ARV such as *A. yaquinensis*; this was not examined presently. This species does not possess thickened transverse costae on the internal valves (Cox 2006), although it was not examined in this study.

***Achnanthes cocconeoides* Riznyk (Fig. 3B-3C)**

Description: Valves elliptical, broad in the middle, rounded at the apices. In girdle view, the valve is nearly flat. 18.5-22.4 µm long, 6.9-11.8 µm wide. Striae uniseriate on the both valves (ARV and RV) with 10-11 striae in 10 µm on the ARV and 9-10 striae in 10 µm on the RV. Transapical striae slightly radial. Cells without spines and marginal ridge. Both valves without terminal obiculi.

Distribution: McIntire and Reimer (1974) recorded *A. cocconeoides* from the Yaquina Estuary, Oregon, in Aug 1968, Oct 1968, Feb 1969, May 1969, and Jul 1969. Presently, *A. cocconeoides* was identified as a planktonic diatom once from East Sea only: ES-35 (29 Aug 2010).

References: Riznyk 1973, p 114, 115, pl. I, figs. 8, 9, pl. 18, figs. 1, 2; McIntire and Reimer 1974, p 172, pl. II, fig. 7a-b, pl. IV, fig. 2a-b.

Remarks: The shape of the central area and the lack of terminal orbiculi distinguish this species from *A. groenlandica* and *A. parvula*. In addition, *A. cocconeoides* is characterized by its nearly flat raphe valve. This taxon is

newly identified in Korea. Thickened transverse costae of *A. cocconeoides* was not examined in this study.

***Achnanthes groenlandica* Cleve & Grunow (Fig. 1M, 1N, Fig. 3D-3F)**

Basionym: *Achnantheidium groenlandicum* Cleve 1873.

Synonym: *Achnantheidium groenlandicum* Cleve 1873; *Achnanthepeyla groenlandica* Peragallo 1921.

Description: Valves linear, slightly convex in the middle, bluntly rounded at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 24.7-33.3 µm long, 3.8-5.3 µm wide. Striae uniseriate on both valves (ARV and RV) with 13 striae in 10 µm on the ARV and 12 striae in 10 µm on the RV. Internal valves without thickened transverse costae. Transapical striae slightly radial. Cells without spines and marginal ridge. Both valves without terminal obiculi.

Distribution: Cox (2006) examined *A. groenlandica* on a SEM stub collected in south of Cape Columbine, Cape Province, South Africa, in Jul 2002. Presently, *A. groenlandica* was recorded seven times as a planktonic diatom in Korean coastal waters: ES-08 (22 Jan 2009), ES-17 (23 Jan 2009), ES-20 (23 Jan 2009), ES-32 (29 Aug 2009), ES-33 (29 Aug 2010), ES-40 (29 Aug 2009), YS-18 (15 Oct 2010), SS-11 (9 Jun 2011), SS-12 (10 Jun 2011), SS-17 (10 Jun 2011).

References: Cleve and Grunow 1880, p 20; Peragallo 1921, p 10; Cleve 1873, p 25, pl. 4, fig. 23.

Remarks: Cox (2006) supposed the striae pores of this taxon on the ARV may be markedly larger than on the RV. This was not examined in the present study. This species was newly recorded in Korean coastal waters. This species does not possess thickened transverse costae on the internal valves (Cox 2006), although it was not examined in this study.

***Achnanthes javanica* Cleve & Grunow (Fig. 4A-4C)**

Description: Valves linear-elliptical, slightly broad in the middle, cuneate at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 61.7-89.5 µm long, 23.3-31.4 µm wide. Striae bi- or triseriate on the both valves (ARV and RV) with 5-6 striae in 10 µm on the ARV and 5-6 striae in 10 µm on the RV. Internal valves with thickened transverse costae. Transapical striae slightly radial. Cells with the marginal ridge but no spines. Both valves without terminal obiculi.

Distribution: Toyoda et al. (2003) examined *A. javanica* from the littoral area in Yonehara-Beach, Okinawa, Japan, in Mar 1996. Cox (2006) studied this species with a slide from Java. This study, *A. javanica* was present twice times in planktonic environments of the East Sea only: ES-10

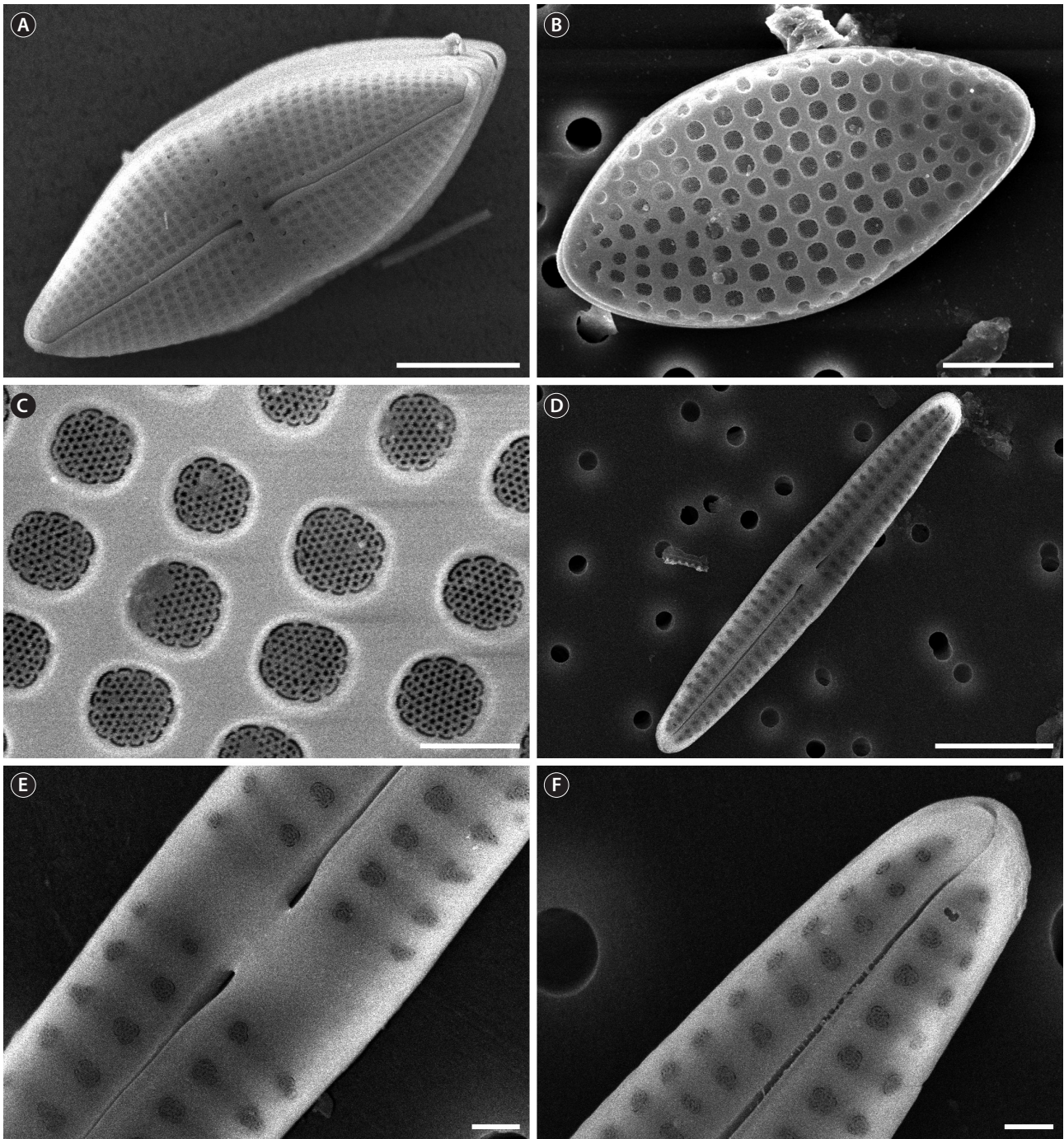


Fig. 3. SEM microphotographs of the *Achnanthes* spp. (A) RV of the *A. brevipes* var. *brevipes*. (B) Cribrate areolae on the RV of the *A. cocconeoides*. (C) Striae of the *A. cocconeoides*. (D) RV of the *A. groenlandica*. (E) Central area of RV of the *A. groenlandica*. (F) Terminal end of ARV of the *A. groenlandica*. Scale bars represent: A, D, 10 μ m; B, 5 μ m; C, E, F, 1 μ m.

(22 Jan 2009), ES-11 (22 Jan 2009).

References: Cleve and Grunow 1880, p 18; Toyoda et al. 2003, p 367, figs. 5-10, 21-28.

Remarks: *A. javanica* was newly recorded in Korean coastal waters.

Achnanthes kuwaitensis Hendey (Fig. 10-1Q, Fig. 4D-4F)

Synonym: *Achnanthidium kuwaitensis* 'Hendey' Van-Landingham 1967.

Description: Valves nearly linear, slightly constricted in the middle, smoothly rounded at the apices. In girdle

view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 33.7-66.2 μm long, 8.3-8.9 μm wide. Striae uniseriate on both valves (ARV and RV) with 10-11 striae in 10 μm on the ARV and 9-11 striae in 10 μm on the RV. Internal valves with thickened transverse costae. Transapical striae nearly linear. Cells without marginal ridge and spines. Terminal orbiculi with both ends of the ARV but not on the RV.

Distribution: McIntire and Reimer (1974) reported this species from the Yaquina Estuary, Oregon (U.S.A.) in Aug 1968, Oct 1968, and Jul 1969. Presently, *A. kuwaitensis* was recorded eight times as a planktonic diatom from East Sea and Yellow Sea: ES-11 (22 Jan 2009), ES-13 (22 Jan 2009), ES-31 (29 Aug 2010), ES-32 (29 Aug 2010), ES-52 (26 Feb 2013), YS-16 (24 Jul 2010), YS-18 (15 Oct 2010), SS-21 (26 Feb 2013).

References: Hendey 1958, p 55, pl. 6, figs. 8-10; VanLandingham 1967, p 73; McIntire and Reimer 1974, p 173, pl. II, fig. 6a-c, pl. III, fig. 4a-b.

Remarks: This taxon can be easily distinguished from other linear shaped *Achnanthes* species by the terminal orbiculi on the ends of ARV.

Achnanthes longipes Agardh (Fig. 1R-1V, Fig. 4H-4K)

Synonym: *Achnantella longipes* Gaillon 1833.

Description: Valves linear, slightly constricted in the middle, wedged at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 36.1-103 μm long, 11.2-23.1 μm wide. Striae biseriate on both valves (ARV and RV) with 6-8 striae in 10 μm on the ARV and 6-12 striae in 10 μm on the RV. Internal valves with thickened transverse costae. Transapical striae nearly linear or slightly radial. Cells without marginal ridge and spines. Both valves without terminal orbiculi.

Distribution: Cox (2006) studied *A. longipes* collected from Java. Presently, *A. longipes* was present 39 times in planktonic environments of Korean coastal waters: ES-01 (21 Jan 2009), ES-02 (21 Jan 2009), ES-03 (22 Jan 2009), ES-05 (22 Jan 2009), ES-06 (22 Jan 2009), ES-07 (22 Jan 2009), ES-08 (22 Jan 2009), ES-09 (22 Jan 2009), ES-15 (23 Jan 2009), ES-18 (23 Jan 2009), ES-19 (23 Jan 2009), ES-20 (23 Jan 2009), ES-21 (23 Jan 2009), ES-22 (16 Feb 2009), ES-23 (16 Feb 2009), ES-24 (16 Feb 2009), ES-25 (16 Feb 2009), ES-27 (16 Feb 2009), ES-28 (16 Feb 2009), ES-29 (28 Aug 2010), ES-30 (28 Aug 2010), ES-31 (29 Aug 2010), ES-34 (29 Aug 2010), ES-40 (29 Aug 2010), ES-41 (29 Aug 2010), ES-43 (29 Aug 2010), ES-44 (29 Aug 2010), ES-45 (29 Aug 2010), ES-46 (29 Aug 2010), ES-47 (29 Aug 2010), ES-49 (30 Aug 2010), ES-53 (21 Apr 2013), YS-16 (24 Jul 2010), YS-17 (14 Oct 2010), SS-09 (9 Jun 2011), SS-15 (10 Jun 2011), SS-

16 (10 Jun 2011), SS-17 (10 Jun 2011), SS-18 (11 Jun 2011).

References: Agardh 1824, p 1; Gaillon 1833, p 10.

Remarks: *A. longipes* and *A. pseudolongipes* have large, longitudinal, panduriform valves and form long colonies attached to a long stalk, but lack ridges and spines. There is little difference between the two species, with the exception of an extra row of striae between the transverse costae on the RV.

Achnanthes parvula Kützing (Fig. 1W-1Z, Fig. 5A)

Synonym: *Achnanthes brevipes* var. *parvula* (Kützing) Cleve 1895; *Achnanthidium brevipes* var. *parvulum* (Kützing) Cleve' VanLandingham 1967; *Achnanthidium brevipes* var. *parvulum* (Kützing) Mereschowsky 1901.

Description: Valves linear-elliptical, slightly broad in the middle, rounded at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 10-25 μm long, 4.7-9.2 μm wide. Striae uniseriate on both valves (ARV and RV) with 10-11 striae in 10 μm on the ARV and 15-16 striae in 10 μm on the RV. Internal valves without thickened transverse costae. Transapical striae nearly linear or slightly radial. Cells without marginal ridge and spines. Terminal orbiculi with both ends of the ARV but not on the RV.

Distribution: McIntire and Reimer (1974) recorded *A. parvula* from the Yaquina Estuary, Oregon in Aug 1968, Oct 1968, Feb 1969, May 1969, and Jul 1969. This study, *A. parvula* was recorded 6 times from planktonic environments of East Sea only: ES-01 (21 Jan 2009), ES-08 (22 Jan 2009), ES-09 (22 Jan 2009), ES-16 (23 Jan 2009), ES-17 (23 Jan 2009), ES-32 (29 Aug 2010).

References: Kützing 1844, p 76, pl. 21, fig. 5; Cleve 1895, p 193; VanLandingham 1967, p 71; Mereschowsky 1901, p 31.

Remarks: This taxon ostensibly resembles *A. groenlandica*, but is easily distinguished by the terminal orbiculi, which are lacking in *A. groenlandica*. The more precise name for this taxon is still uncertain. We are currently investigating this problem and intend to report on it in the near future. *A. parvula* was a newly record species in this study.

Achnanthes pseudolongipes Toyoda & Nagumo in Toyoda et al. (Fig. 2A-2F)

Description: Valves linear-elliptical, constricted in the middle, cuneate at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 65-115 μm long, 20.8-29.1 μm wide. Striae bi- to triseriate with 6-7 striae in 10 μm on the ARV, uniseriate with 4-5 striae in 10 μm on the RV. Internal valves with

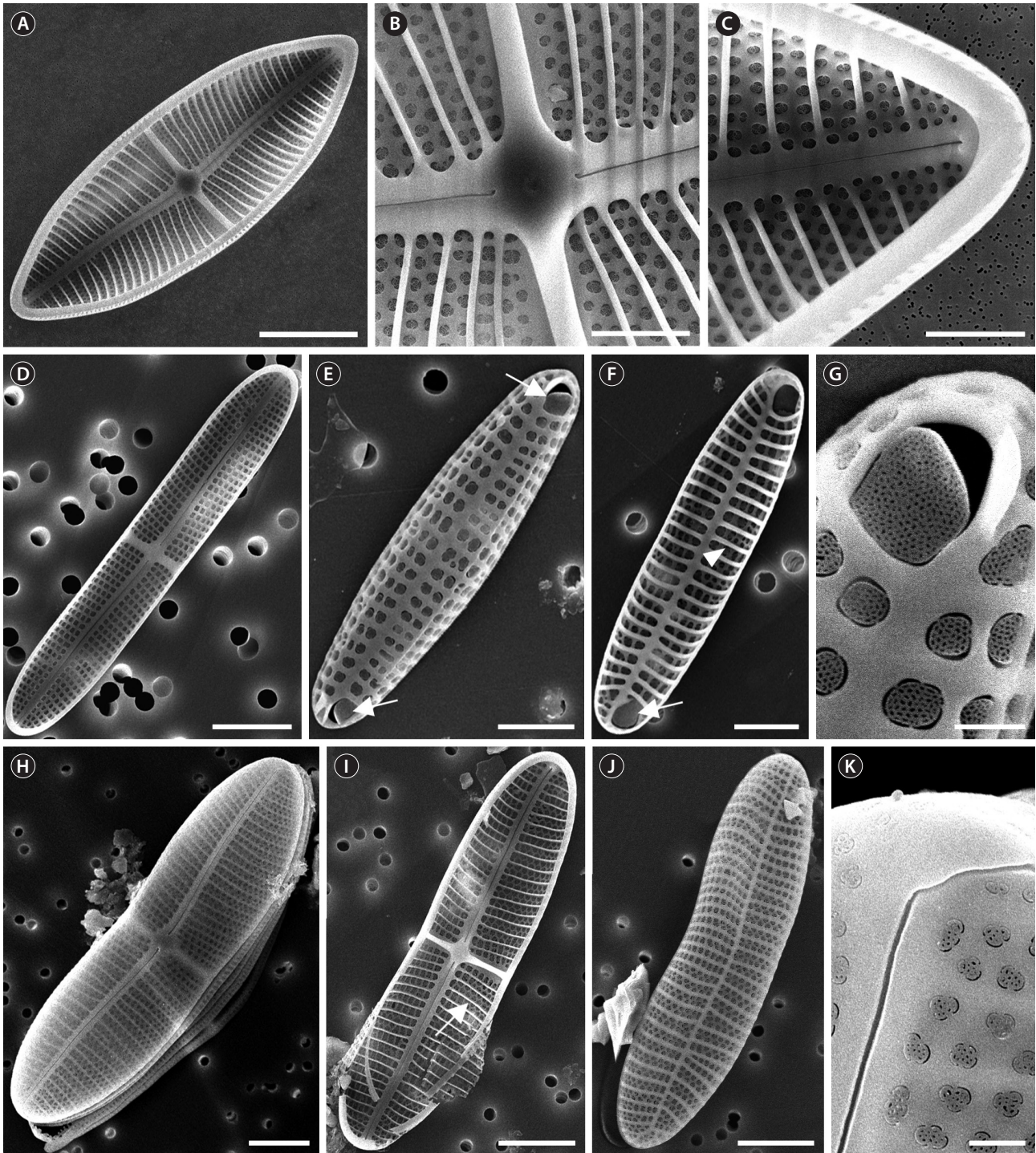


Fig. 4. SEM microphotographs of the *Achnanthes* spp. (A) Internal view of RV of the *A. javanica*. (B) Central area (stauros) of RV of the *A. javanica*. (C) Terminal end and costae of RV of the *A. javanica*. (D) Internal RV of the *A. kuwaitensis*. (E) ARV with terminal obiculi (arrows) of the *A. kuwaitensis*. (F) Internal ARV with terminal obiculi (arrows) and costae (arrowhead) of the *A. kuwaitensis*. (G) Terminal obiculi of the *A. kuwaitensis*. (H) RV of the *A. longipes*. (I) Internal RV with costae (arrow) of the *A. longipes*. (J) External RV of the *A. longipes*. (K) Raphe ending of the *A. longipes*. Scale bars represent: A, 20 μm ; B, C, E, F, 5 μm ; D, H-J, 10 μm ; G, K, 1 μm .

thickened transverse costae. Transapical striae slightly radial. Cells without the marginal ridge and spines. Terminal orbiculi at both ends of the ARV but not on the RV.

Distribution: Toyoda et al. (2010) found *A. pseudolongipes* from a fishery buoy off the coast of Japan. Presently, *A. pseudolongipes* was present six times as a planktonic diatom from the East Sea only: ES-09 (22 Jan 2009), ES-16 (23 Jan 2009), ES-18 (23 Jan 2009), ES-40 (29 Aug 2010), ES-44 (29 Aug 2010), ES-50 (30 Aug 2010).

References: Toyoda et al. 2010, p 186, figs. 1-28.

Remarks: *A. pseudolongipes* is the only species known so far in *Achnanthes sensu stricto* to possess a different pattern of seriate striae; the ARV will have the same striae pattern (Toyoda et al. 2003, Toyoda and Williams 2004, Toyoda et al. 2005a). *A. pseudolongipes* is easily separated from these taxa by its plastid structure as well as the uniseriate striae of its RV (Toyoda et al. 2010). This species was newly recorded in this study. This species possesses thickened transverse costae on the internal valves (Cox 2006), although it was not examined in this study.

***Achnanthes subconstricta* (Meister) Toyoda (Fig. 2G-2N, Fig. 5B-5F)**

Basionym: *Achnanthes javanica* var. *subconstricta* Meister 1932.

Description: Valves linear-elliptical, constricted in the middle, with cuneate at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 30-69.2 μm long, 13.3-26.9 μm wide. Striae bi- to tetraseriate on the both valves (ARV and RV) with 4-5 striae in 10 μm on the ARV and 5-6 striae in 10 μm on the RV. Internal valves with thickened transverse costae. Transapical striae slightly radial. Cells with the marginal ridge and spines on the both terminal ends and marginal ridge of the valve. Terminal orbiculi with both ends of the ARV but not on the RV.

Distribution: McIntire and Reimer (1974) recorded the species from the Yaquina Estuary, Oregon, in Aug 1968, and Jul 1969. Toyoda et al. (2003) examined *A. subconstricta* from littoral area of marine in Ohhara, Chiba, Japan in Mar, 1999 and littoral area of brackish in Kamegasaki, Chiba, Japan in Sep, 1999. Presently, *A. subconstricta* was recorded 38 times in planktonic environments of Korean coastal waters: ES-05 (22 Jan 2009), ES-06 (22 Jan 2009), ES-08 (22 Jan 2009), ES-10 (22 Jan 2009), ES-16 (23 Jan 2009), ES-21 (23 Jan 2009), ES-22 (16 Feb 2009), ES-29 (28 Aug 2010), ES-34 (29 Aug 2010), ES-36 (29 Aug 2010), ES-37 (29 Aug 2010), ES-39 (29 Aug 2010), ES-52 (26 Feb 2013), YS-01 (22 Jul 2010), YS-02 (22 Jul 2010), YS-03 (22 Jul 2010), YS-04 (22 Jul 2010), YS-05 (22 Jul 2010), YS-06 (23 Jul 2010),

YS-07 (23 Jul 2010), YS-08 (23 Jul 2010), YS-09 (23 Jul 2010), YS-10 (23 Jul 2010), YS-13 (24 Jul 2010), YS-15 (24 Jul 2010), SS-01 (15 Nov 2010), SS-02 (15 Nov 2010), SS-03 (15 Nov 2010), SS-04 (16 Nov 2010), SS-05 (16 Nov 2010), SS-06 (16 Nov 2010), SS-07 (17 Nov 2010), SS-08 (9 Jun 2011), SS-10 (9 Jun 2011), SS-13 (10 Jun 2011), SS-14 (10 Jun 2011), SS-19 (11 Jun 2011), SS-20 (11 Jun 2011), SS-21 (26 Feb 2013).

References: Toyoda et al. 2003, p 369; Meister 1932, p 40, pl. 14, fig. 113.

Remarks: This taxon is very similar in shape to *A. longipes*, particularly the larger cells. It is best distinguished by the single rows of areolae and particularly by the terminal orbiculi which are absent in *A. longipes*. Toyoda et al. (2003) suggested that *A. javanica* and *A. subconstricta* could be recognized as separate species. The most significant distinguishing character is the presence of terminal orbiculi in *A. subconstricta*.

***Achnanthes yaquinensis* McIntire & Reimer (Fig. 2O-2S, Fig. 5G-5I)**

Description: Valves nearly rhombus, smoothly rounded in the middle, cuneate at the apices. In girdle view, the valve is slightly curved geniculately, with a convex ARV and a concave RV. 33.9-45.2 μm long, 9.2-27.2 μm wide. Striae uniseriate on the both valves (ARV and RV) with 8-8.5 striae in 10 μm on the ARV and 8-9 striae in 10 μm on the RV. Internal valves with thickened transverse costae. Transapical striae nearly linear or slightly radial. Cells with the marginal ridge and spines on the both terminal ends of the valve. Terminal orbiculi with both end of the ARV but not on the RV.

Distribution: McIntire and Reimer (1974) found *A. yaquinensis* from Yaquina Estuary, Oregon (U.S.A.) in Aug 1968, Oct 1968, May 1969, and Jul 1969. Toyoda et al. (2005b) found this species from the coast of Japan in Apr 1994, Nov 2001, and Jun 2001. This study, *A. yaquinensis* was found three times as a planktonic diatom from the East Sea only: ES-12 (22 Jan 2009), ES-26 (16 Feb 2009), ES-27 (16 Feb 2009).

References: McIntire and Reimer 1974, p 174, pl. II, fig. 1a-b, pl. III, fig. 1a-b.

Remarks: This taxon is very similar in shape to *A. longipes*, particularly the larger cells. It is best distinguished by the single rows of areolae and particularly by the terminal orbiculi which are absent in *A. longipes*. Also, this species resembles *A. subconstricta*; the valves are panduriform and the ARV has terminal orbiculi. However, the taxa can be easily distinguished by the number of rows of areolae between the costae. *A. yaquinensis* has a single row, while *A. subconstricta* has more than three. In addi-

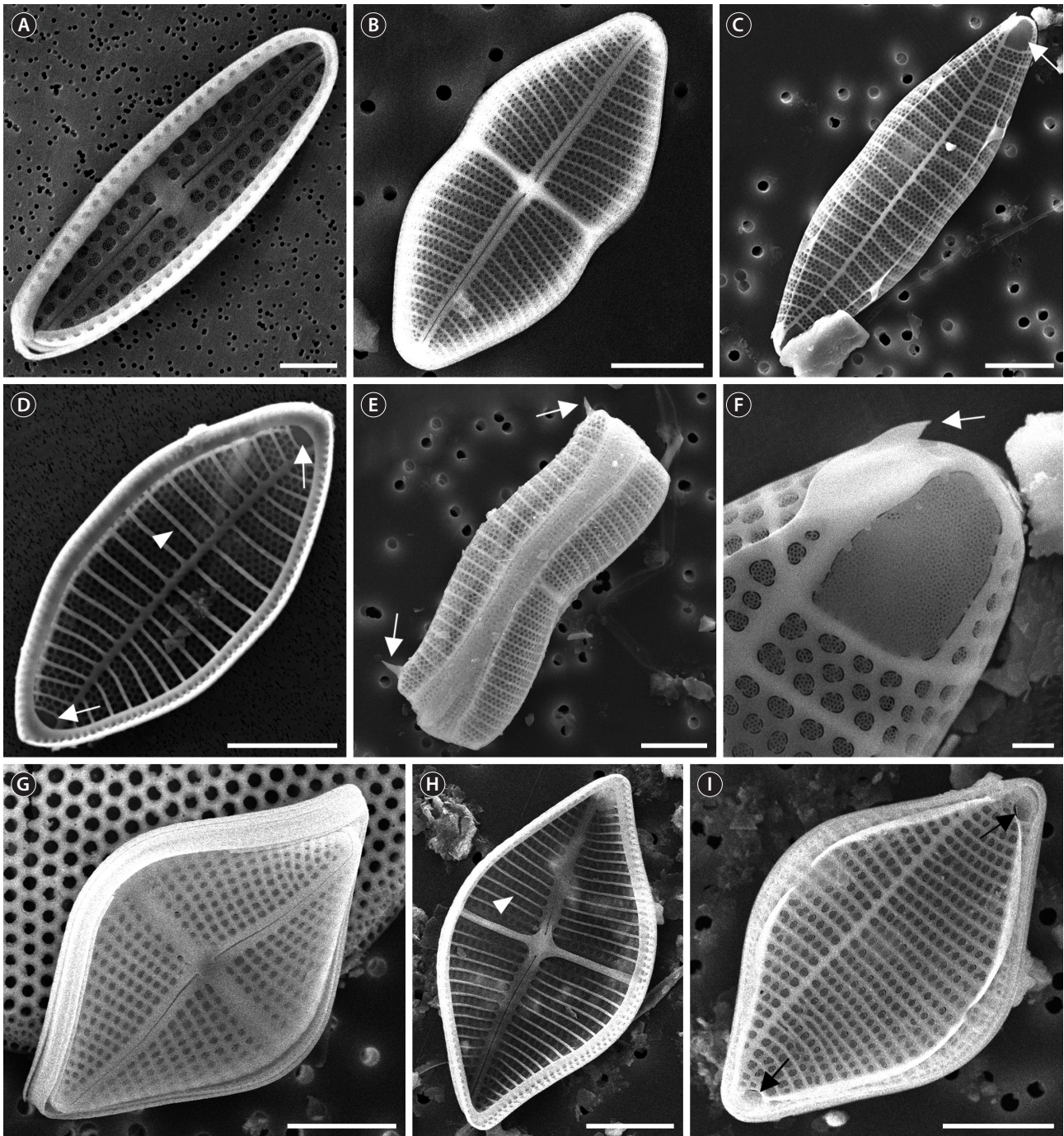


Fig. 5. SEM microphotographs of the *Achnanthes* spp. (A) Internal RV of the *A. parvula*. (B) RV of the *A. subconstricta*. (C) ARV with terminal obiculi (arrow) of the *A. subconstricta*. (D) Internal ARV with terminal obiculi (arrows) and costae (arrowhead) of the *A. subconstricta*. (E) Girdle view with terminal spines (arrows) of the ARV of the *A. subconstricta*. (F) Terminal obiculi and spine (arrow) of the *A. subconstricta*. (G) RV of the *A. yaquinensis*. (H) Internal RV with costae (arrow) of the *A. yaquinensis*. (I) ARV with terminal obiculi (arrows) of the *A. yaquinensis*. Scale bars represent: A, 2 μm ; B-E & G-I, 10 μm ; F, 1 μm .

tion, *A. subconstricta* usually has some marginal spines that develop from the marginal ridge, while *A. yaquinensis* has only two terminal spines, one at each end of the ARV. This species was new record species in this study.

CONCLUSION

Twelve *Achnanthes* species including the seven newly recorded species (*A. cocconeoides*, *A. groenlandica*, *A. javanica*, *A. kuwaitensis*, *A. parvula*, *A. pseudolongipes*, and *A. yaquinensis*) were obtained in marine and brackish waters of Korea. They are assigned to the genus *Achnanthes* based on 11 key characteristics.

Most of *Achnanthes* species possessed the same rows of striae on RV and ARV, but *A. pseudolongipes* had the different rows of striae each valve. Internal costae were found in *A. brevipes* var. *brevipes*, *A. javanica*, *A. kuwaitensis*, *A. longipes*, *A. pseudolongipes*, *A. subconstricta* and *A. yaquinensis*, although *Achnanthes coarctata*, *A. groenlandica* and *A. parvula* had not internal costae of the valve. Internal costae of *A. brevipes* var. *intermedia* and *A. cocconeoides* were not confirmed in this study and other references. Spines and marginal ridge on the valve were found the both *A. subconstricta* and *A. yaquinensis*, but *A. javanica* had only the spines on the valve. Terminal obiculi on the valve were possessed *A. kuwaitensis*, *A. parvula*, *A. pseudolongipes*, *A. subconstricta* and *A. yaquinensis*. Therefore, *A. subconstricta* and *A. yaquinensis* possess internal costae, spines, marginal ridge on the valves and terminal obiculi on the ARV.

We present the distribution of *Achnanthes* species in this study. All *Achnanthes* species were found the East Sea, six species were recorded from the Yellow Sea, and four species were obtained from the South Sea. All unrecorded species were found from the East Sea, three unrecorded species were examined in the Yellow Sea, and three unrecorded species were found from the South Sea. From 92 sites, the most frequent species was *A. longipes* and *A. subconstricta* (39 times for each) and the least frequent species were *A. coarctata* and *A. cocconeoides* (once each), while the *A. cocconeoides* was the least common unrecorded species (once). Of the 92 stations, the site that involved the largest number of species ($n = 5$) in Korea was ES-08. Four species were obtained from ES-32 and three species each from ES-01, ES-09, ES-16, ES-34 and ES-37. One or two species were present in most sites. Of the newly recorded species, the sites that involved the large number of species in Korea were ES-08, ES-16 and ES-32 (three species at each site). *Achnanthes* species

were more found from the East Sea than from the Yellow Sea or South Sea.

Consequently, valid nomenclatural-named *Achnanthes* taxa were 23 species including the seven unrecorded species in this study (Table 1). Further in-depth taxonomic studies of the other genera should be examined in marine, brackish and fresh water of Korea, although this paper will suffice to reestablish the taxonomic status of *Achnanthes* species in Korea.

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Appendix 1. Sampling sites in coastal waters of Korea

Date	Station	Locality	Latitude	Longitude
21 Jan 2009	ES ¹ -01	Dogu-ri, Donghae-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do	35°59.839N	129°27.479E
21 Jan 2009	ES-02	Daebo-ri, Homigot-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do	36°04.793N	129°33.596E
22 Jan 2009	ES-03	Duho-dong, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°03.703N	129°23.300E
22 Jan 2009	ES-04	Wolpo-ri, Cheongha-myeon, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°12.485N	129°22.496E
22 Jan 2009	ES-05	Jangsa-ri, Namjeong-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°15.673N	129°22.493E
22 Jan 2009	ES-06	Samsa-ri, Ganggu-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°21.430N	129°23.058E
22 Jan 2009	ES-07	Chuksan-ri, Chuksan-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°30.505N	129°26.945E
22 Jan 2009	ES-08	Byeonggok-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°35.907N	129°24.905E
22 Jan 2009	ES-09	Gusan-ri, Giseong-myeon, Uljin-gun, Gyeongsangbuk-do	36°45.369N	129°28.168E
22 Jan 2009	ES-10	Mangyang-ri, Giseong-myeon, Uljin-gun, Gyeongsangbuk-do	36°51.147N	129°25.673E
22 Jan 2009	ES-11	Sanpo-ri, Geunnam-myeon, Uljin-gun, Gyeongsangbuk-do	36°57.907N	129°24.889E
22 Jan 2009	ES-12	Jukbyeon-myeon, Uljin-gun, Gyeongsangbuk-do	37°01.961N	129°24.936E
22 Jan 2009	ES-13	Imwon-ri, Wondeok-eup, Samcheok-si, Gangwon-do	37°13.523N	129°20.481E
22 Jan 2009	ES-14	Gungchon-ri, Geundeok-myeon, Samcheok-si, Gangwon-do	37°19.630N	129°16.119E
23 Jan 2009	ES-15	Jeongha-dong, Samcheok-si, Gangwon-do	37°19.630N	129°16.116E
23 Jan 2009	ES-16	Daejin-dong, Donghae-si, Gangwon-do	37°34.924N	129°06.719E
23 Jan 2009	ES-17	Jeongdongjin-ri, Gangdong-myeon, Gangneung-si, Gangwon-do	37°41.163N	129°02.570E
23 Jan 2009	ES-18	Sacheonjin-ri, Sacheon-myeon, Gangneung-si, Gangwon-do	37°41.162N	129°02.569E
23 Jan 2009	ES-19	Namea-ri, Hyeonnam-myeon, Yangyang-gun, Gangwon-do	37°41.162N	129°02.569E
23 Jan 2009	ES-20	Dongmyeong-dong, Sokcho-si, Gangwon-do	38°12.640N	128°25.771E
23 Jan 2009	ES-21	Oho-ri, Jugwang-myeon, Goseong-gun, Gangwon-do	38°19.607N	128°31.708E
16 Feb 2009	ES-22	Gwangan-dong, Suyeong-gu, Busan	35°08.317N	129°06.867E
16 Feb 2009	ES-23	Ilgwang-myeon, Gijang-gun, Busan	35°21.313N	129°21.255E
16 Feb 2009	ES-24	Seosaeng-myeon, Ulju-gun, Ulsan	35°21.315N	129°21.256E
16 Feb 2009	ES-25	Hwangseong-dong, Nam-gu, Ulsan	35°37.113N	129°27.009E
16 Feb 2009	ES-26	Jeongja-dong, Buk-gu, Ulsan	35°41.585N	129°28.522E
16 Feb 2009	ES-27	Oryu-ri, Gampo-eup, Gyeongju-si, Gyeongsangbuk-do	35°52.679N	129°31.136E
16 Feb 2009	ES-28	Yangpo-ri, Janggi-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do	38°13.200N	128°35.406E
28 Aug 2010	ES-29	Dogu-ri, Donghae-myeon, Nam-gu, Pohang-si, Gyeongsangbuk-do	35°59.801N	129°27.470E
28 Aug 2010	ES-30	Duho-dong, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°03.812N	129°23.258E
29 Aug 2010	ES-31	Cheongha-myeon, Buk-gu, Pohang-si, Gyeongsangbuk-do	36°12.491N	129°22.553E
29 Aug 2010	ES-32	Ganggu-ri, Ganggu-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°21.560N	129°23.141E
29 Aug 2010	ES-33	Daetan-ri, Yeongdeok-eup, Yeongdeok-gun, Gyeongsangbuk-do	36°26.505N	129°26.006E
29 Aug 2010	ES-34	Chuksan-ri, Chuksan-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°30.464N	129°26.975E
29 Aug 2010	ES-35	Byeonggok-ri, Byeonggok-myeon, Yeongdeok-gun, Gyeongsangbuk-do	36°35.949N	129°24.907E
29 Aug 2010	ES-36	Hupo-ri, Hupo-myeon, Uljin-gun, Gyeongsangbuk-do	36°40.606N	129°27.230E
29 Aug 2010	ES-37	Gusan-ri, Giseong-myeon, Uljin-gun, Gyeongsangbuk-do	36°45.614N	129°28.335E
29 Aug 2010	ES-38	Sanpo-ri, Geunnam-myeon, Uljin-gun, Gyeongsangbuk-do	36°51.151N	129°25.644E
29 Aug 2010	ES-39	Eumnam-ri, Uljin-eup, Uljin-gun, Gyeongsangbuk-do	36°59.076N	129°24.630E
29 Aug 2010	ES-40	Jukbyeon-ri, Jukbyeon-myeon, Uljin-gun, Gyeongsangbuk-do	37°03.487N	129°25.303E
30 Aug 2010	ES-41	Wondeok-eup, Samcheok-si, Gangwon-do	37°13.782N	129°20.715E
30 Aug 2010	ES-42	Chogok-ri, Geundeok-myeon, Samcheok-si, Gangwon-do	37°18.584N	129°17.645E
30 Aug 2010	ES-43	Jeongha-dong, Samcheok-si, Gangwon-do	37°26.315N	129°11.261E
30 Aug 2010	ES-44	Daejin-dong, Donghae-si, Gangwon-do	37°34.804N	129°06.825E
26 Feb 2013	ES-45	Geumjin-ri, Okgye-myeon, Gangneung-si, Gangwon-do	37°39.151N	129°03.107E
21 Apr 2013	ES-46	Aninjin-ri, Gangdong-myeon, Gangneung-si, Gangwon-do	37°44.078N	128°59.224E
22 Jul 2010	ES-47	Sacheonjin-ri, Sacheon-myeon, Gangneung-si, Gangwon-do	37°50.261N	128°52.605E
22 Jul 2010	ES-48	Susan-ri, Sonyang-myeon, Yangyang-gun, Gangwon-do	38°04.627N	128°40.431E
22 Jul 2010	ES-49	Jucheong-ri, Ganghyeon-myeon, Yangyang-gun, Gangwon-do	38°07.385N	128°37.942E
22 Jul 2010	ES-50	Bongpo-ri, Toseong-myeon, Goseong-gun, Gangwon-do	38°15.050N	128°34.055E
22 Jul 2010	ES-51	Jugwang-myeon, Goseong-gun, Gangwon-do	38°19.474N	128°31.598E
23 Jul 2010	ES-52	Yangbuk-myeon, Gyeongju-si, Gyeongsangbuk-do	35°51.805N	128°55.622E
23 Jul 2010	ES-53	Jeodong-ri, Ulleung-eup, Ulleung-gun, Gyeongsangbuk-do	37°29.712N	130°54.471E

Appendix 1. Continued

Date	Station	Locality	Latitude	Longitude
23 Jul 2010	YS ² -01	Jeongwang-dong, Siheung-si, Gyeonggi-do	37°19.572N	126°39.282E
23 Jul 2010	YS-02	Jeon-gok-ri, Seosin-myeon, Hwaseong-si, Gyeonggi-do	37°11.209N	126°39.109E
23 Jul 2010	YS-03	Gungpyeong-ri, Seosin-myeon, Hwaseong-si, Gyeonggi-do	37°06.951N	126°40.618E
23 Jul 2010	YS-04	Hanjin-ri, Songak-eup, Dangjin-gun, Chungcheongnam-do	36°58.248N	126°46.993E
24 Jul 2010	YS-05	Hwagok-ri, Daesan-eup, Seosan-si, Chungcheongnam-do	37°00.185N	126°27.201E
24 Jul 2010	YS-06	Buseok-myeon, Seosan-si, Chungcheongnam-do	36°37.465N	126°22.003E
24 Jul 2010	YS-07	Gung-ri, Seobu-myeon, Hongseong-gun, Chungcheongnam-do	36°35.572N	126°27.209E
24 Jul 2010	YS-08	Dodun-ri, Seo-myeon, Seocheon-gun, Chungcheongnam-do	36°09.481N	126°30.023E
24 Jul 2010	YS-09	Dasa-ri, Biin-myeon, Seocheon-gun, Chungcheongnam-do	36°05.867N	126°36.869E
14 Oct 2010	YS-10	Sutong-ri, Buri-myeon, Geumsan-gun, Chungcheongnam-do	35°38.287N	126°27.771E
15 Oct 2010	YS-11	Simpo-ri, Jinbong-myeon, Gimje-si, Jeollabuk-do	35°51.406N	126°41.940E
15 Nov 2010	YS-12	Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°56.146N	126°31.672E
15 Nov 2010	YS-13	Okdo-myeon, Gunsan-si, Jeollabuk-do	35°49.387N	126°28.352E
15 Nov 2010	YS-14	Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°43.670N	126°31.759E
16 Nov 2010	YS-15	Daehang-ri, Byeonsan-myeon, Buan-gun, Jeollabuk-do	35°41.283N	126°31.922E
16 Nov 2010	YS-16	Sinsido-ri, Okdo-myeon, Gunsan-si, Jeollabuk-do	35°43.732N	126°31.916E
16 Nov 2010	YS-17	Wolgot-dong, Siheung-si, Gyeonggi-do	37°23.247N	126°44.413E
17 Nov 2010	YS-18	Sangrok-gu, Ansan-si, Gyeonggi-do	35°47.634N	126°38.629E
09 Jun 2011	SS ³ -01	Ogam-dong, Mokpo-si, Jeollanam-do	34°47.803N	126°26.097E
09 Jun 2011	SS-02	Sani-myeon, Haenam-gun, Jeollanam-do	34°43.205N	126°23.178E
09 Jun 2011	SS-03	Yulpo-ri, Hoecheon-myeon, Boseong-gun, Jeollanam-do	34°39.894N	127°04.991E
30 Aug 2010	SS-04	Duwon-myeon, Goheung-gun, Jeollanam-do	34°42.801N	127°16.017E
30 Aug 2010	SS-05	Gyoryang-dong, Suncheon-si, Jeollanam-do	34°54.535N	127°30.316E
30 Aug 2010	SS-06	Geumseong-myeon, Hadong-gun, Gyeongsangnam-do	34°56.406N	127°47.424E
30 Aug 2010	SS-07	Nambu-myeon, Geoje-si, Gyeongsangnam-do	34°44.157N	128°40.512E
26 Feb 2013	SS-08	Wondong-ri, Gunoe-myeon, Wando-gun, Jeollanam-do	34°23.575N	126°38.907E
21 Apr 2013	SS-09	Hoejin-ri, Hoejin-myeon, Jangheung-gun, Jeollanam-do	34°28.843N	126°56.460E
22 Jul 2010	SS-10	Yulpo-ri, Hoecheon-myeon, Boseong-gun, Jeollanam-do	34°40.052N	127°05.815E
11 Jun 2011	SS-11	Noil-ri, Gwayeok-myeon, Goheung-gun, Jeollanam-do	34°40.893N	127°19.043E
11 Jun 2011	SS-12	Soho-dong, Yeosu-si, Jeollanam-do	34°44.793N	127°39.501E
11 Jun 2011	SS-13	Nambyeon-ri, Namhae-eup, Namhae-gun, Gyeongsangnam-do	34°48.658N	127°50.135E
26 Feb 2013	SS-14	Hwagye-ri, Idong-myeon, Namhae-gun, Gyeongsangnam-do	34°46.528N	127°56.565E
11 Jun 2011	SS-15	Daebang-dong, Sacheon-si, Gyeongsangnam-do	34°55.978N	128°03.033E
11 Jun 2011	SS-16	Pangok-ri, Samsan-myeon, Goseong-gun, Gyeongsangnam-do	34°56.423N	128°18.433E
11 Jun 2011	SS-17	Anjeong-ri, Gwangdo-myeon, Tongyeong-si, Gyeongsangnam-do	34°56.246N	128°25.711E
26 Feb 2013	SS-18	Galgot-ri, Nambu-myeon, Geoje-si, Gyeongsangnam-do	34°44.145N	128°40.558E
11 Jun 2011	SS-19	Noksan-dong, Gangseo-gu, Busan	35°01.687N	128°48.856E
11 Jun 2011	SS-20	Dadae-dong, Saha-gu, Busan	35°02.913N	128°58.260E
11 Jun 2011	SS-21	Suyeong-dong, Suyeong-gu, Busan	35°09.691N	129°08.297E

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