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New records of two *Amphora* taxa from Ulleungdo and Dokdo, Korea

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A study was conducted to investigate the species diversity of the genus *Amphora* in relation to environmental settings in Ulleungdo and Dokdo. Although *Amphora* is one of the most speciose genera in marine habitats, its recorded diversity in Korean waters has been relatively low compared to similar ecosystems. In this study, light microscopy (LM) and scanning electron microscopy (SEM) were employed to examine the morphology and ultrastructure of *Amphora* taxa. Specimens were collected from four stations across intertidal and subtidal habitats. As a result, *Amphora arcuata* and *Amphora bigibba* var. *interrupta* were documented for the first time in Korean waters. *Amphora arcuata* was found at two subtidal sites (20 m depth), whereas *A. bigibba* var. *interrupta* occurred at all four stations, including one intertidal location (0 m depth). These findings contribute to a more comprehensive understanding of *Amphora* biodiversity in Ulleungdo and Dokdo, which harbor unique island ecosystems.

Keywords: *Amphora arcuata*, *Amphora bigibba* var. *interrupta*, diatom, taxonomy, Ulleungdo and Dokdo

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Introduction

Ulleungdo and Dokdo are among the most geologically isolated islands in Korea. Ulleungdo is located 130.3 km from the mainland, while Dokdo is 216.8 km away (Jung *et al*., 2013; Bang *et al*., 2022). Due to their geopolitical significance in the middle of the East Sea, numerous studies have been conducted on these islands (Cha *et al*., 2010; Jung *et al*., 2013; Kim and Kwon, 2013; Hwang and Lee, 2021; Bang *et al*., 2022). However, research on diatoms—the foundation of marine ecosystems—remains limited.

Diatoms contribute to more than 40% of primary production in marine environments (Tréguer *et al*., 2018) and serve as a primary food source for various herbivores, such as gastropods and copepods (Friedrichs *et al*., 2013). To date, over 10,000 diatom species have been identified, with an estimated global diversity exceeding 200,000 species (Mann and Droop, 1996). *Amphora sensu lato* is one of the most species-rich genera in benthic environments, occurring in epiphytic, epipellic, and epilithic habitats (Round *et al*., 1990; Levkov *et al*., 2009).

In Korea, marine *Amphora* was first reported by Choi (1990), and additional species have since been continuously recorded in Korean waters (Park and Koh, 2012; Joh, 2017). *Amphora* species have also been documented in numerous diatom flora studies (Lee *et al*., 1999; Park, 2011; Pandey *et al*., 2018; Kim, 2020). They are widely distributed and commonly found in Korean marine benthic environments.

In the present study, two *Amphora* taxa were recorded for the first time in Korean waters. Detailed observations using light microscopy (LM) and scanning electron microscopy (SEM) were conducted to describe their morphological characteristics.

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Materials and Methods

Sediment samples were collected from Ulleungdo and Dokdo by scraping the top 0−0.5 cm of sediment with a stainless-steel spatula and transferring it into 50 mL Falcon tubes (Fig. 1, Table 1). The samples were immediately fixed with 4% formaldehyde and transported to the laboratory for further processing.

To extract diatom frustules, the sediment samples were sonicated three times to detach the frustules from the sediment matrix. The samples were then treated with hydrochloric acid (HCl) and hydrogen peroxide (H_2O_2) to remove calcium carbonate and organic matter.

The cleaned diatom frustules were dried onto glass coverslips and mounted on glass slides using Naphrax resin to prepare permanent slides. Observations were conducted using a BX53 light microscope (Olympus, Tokyo, Japan), and images were captured with a ZEISS Axiocam 208c digital camera (Carl Zeiss, Oberkochen, Germany). Additionally, a few drops of cleaned frustules were dried onto aluminum stubs, coated with gold, and examined using a field emission scanning electron microscope (FE-SEM, MIRA-3, Tescan, Brno, Czech Republic).

For each station, a total of 500 diatom valves were examined under LM to assess the relative abundance of taxa. Based on this evaluation, representative frustules were selected for high-resolution imaging using LM and SEM to document diagnostic features.

Environmental parameters such as temperature, salinity, and pH were not measured during the sampling process.

Results

This study presents the first record of *Amphora arcuata* and *Amphora bigibba* var. *interrupta* in Korea. Structural features such as outline, raphe system, and striae density of both *Amphora* taxa were examined under light microscopy (LM) at 1000× magnification. Additionally, the ultrastructure of both *A. arcuata* and *A. bigibba* var. *interrupta* was analyzed using scanning electron microscopy (SEM).

Amphora arcuata A.W.F.Schmidt, 1875

Reference. A.W.F.Schmidt, 1875. pl. 26: figs. 27−29.
Description. Valve semi-lanceolate with dorsal margin convex with narrow fascia, ventral margin moderate, valve ends acute and bent dorsal margin with length of 60−68.5 µm and width of 16 µm, Raphe acute follow ventral margin, Striae slightly radiate with 18 per 10 µm, compose with a round to oblong areolae (Fig. 2).

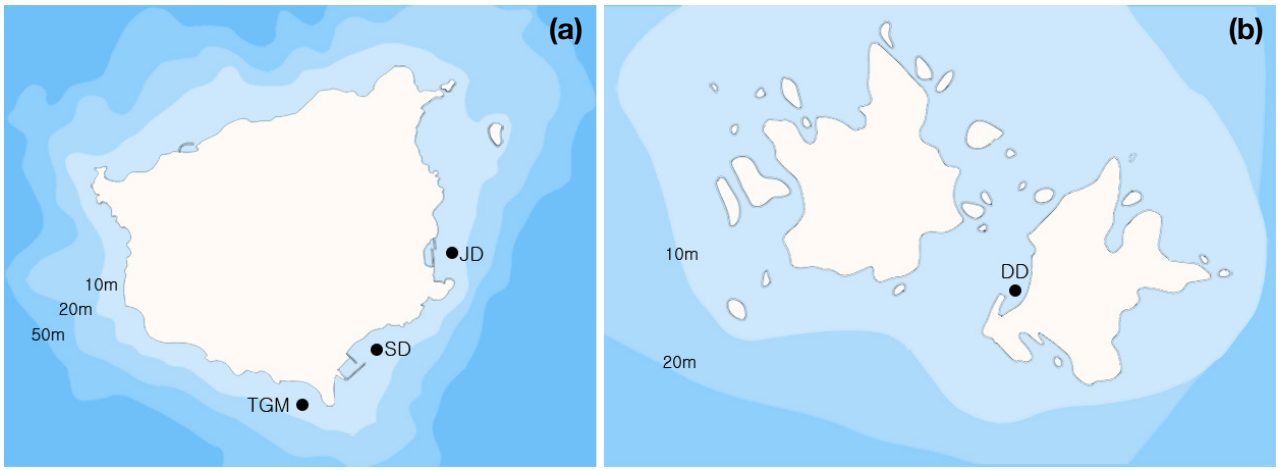

Fig. 1. Map showing the sampling locations on the Ulleungdo (a) and Dokdo (b) where *Amphora bigibba* var. *interrupta* and *A. arcuata* were observed.

Table 1. List of samples which have been analyzed in the present study.

Sampling date	Sites	Location	Latitude (N)	Longitude (E)	Depth (m)	*Amphora arcuata*	*A. bigibba* var. *interrupta*
Nov. 11, 2013	JD	Jeodong-ri, Gyeongsangbuk-do, Korea	37°29′49″	130°55′06″	20	v	v
Nov. 11, 2013	TGM	Namyang-ri, Gyeongsangbuk-do, Korea	37°27′20″	130°52′02″	20		v
Nov. 11, 2013	SD	Sadong-ri, Gyeongsangbuk-do, Korea	37°28′17″	130°53′25″	20	v	v
Jul. 07, 2018	DD	Dokdo-ri, Gyeongsangbuk-do, Korea	37°14′22″	131°52′05″	0		v

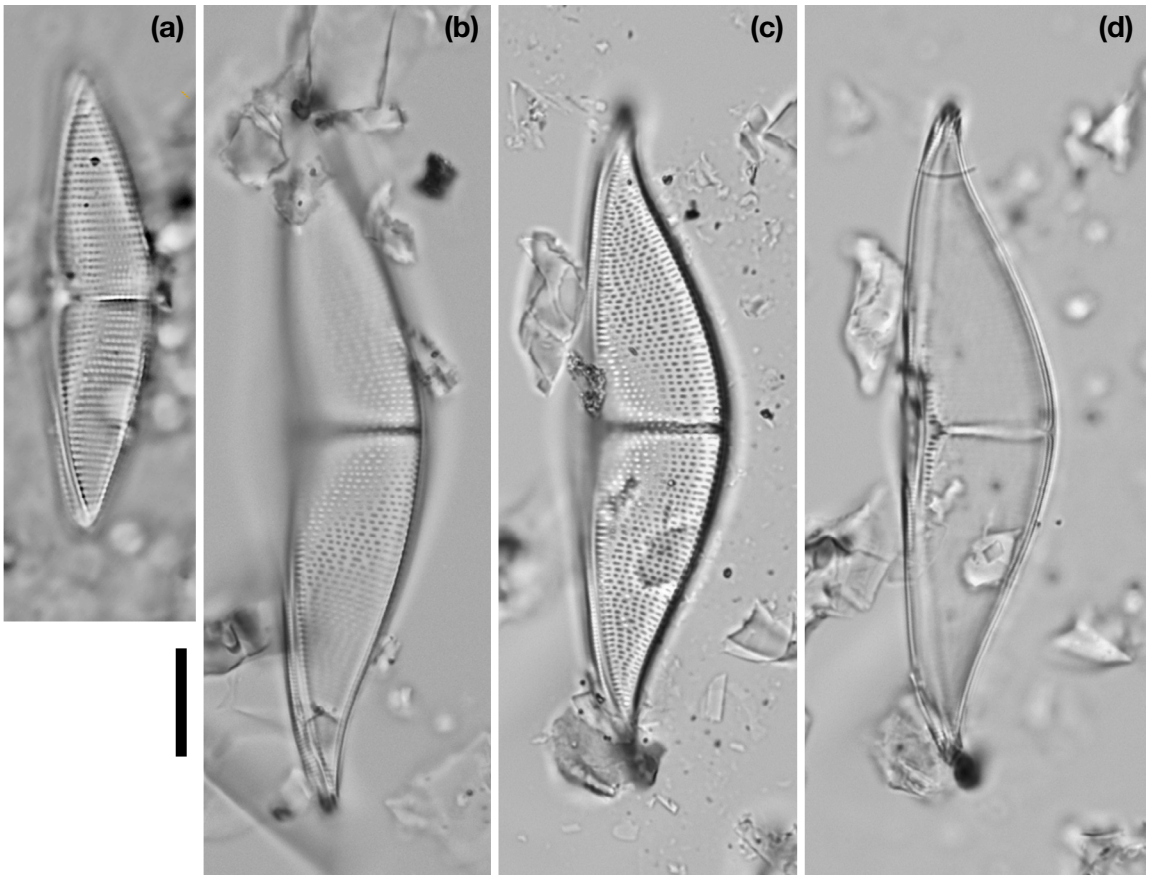

Fig. 2. Light microscope photographs of *Amphora arcuata* from Ulleungdo and Dokdo (a–d). Scale bar: 10 μm.

Taxonomic remarks. *Amphora arcuata* is similar to *A. aspera* Petit with slight differences in valve outline. However, *A. arcuata* has a dorsal valve fascia, whereas *A. aspera* lacks a fascia.

Distribution. *A. arcuata* has been reported from Philippines (Mann, 1925; Martinez-Goss, 2021), Guam (Lobban *et al*., 2012), Britain (Hartley *et al*., 1986), and U.S.A. (Wachnicka and Gaiser, 2007). In the present study, *A. arcuata* was observed from 2 stations in Ulleungdo subtidal zone.

Amphora bigibba var. *interrupta* (Grunow) Cleve, 1895

Reference. Cleve, 1895. pl. 25: fig. 65.

Description. Valves are semi-lanceolate with dorsal margin convex, constricted in middle, with ventral margin straight, protracted in middle, with rostrated apice with length of 17.5–33.5 μm and width of 2.7–3.3 μm (Figs. 4, 5A, C), Raphe straight with both central and terminal fissures hooked toward the dorsal margin in external view (Fig. 3B), whereas internally, the raphe ends simple (Fig. 5C, D). Striae parallel, 20–24 in 10 μm, with areolae that are not resolved under LM (Fig. 4A–F).

Taxonomic remarks. *Amphora bigibba* var. *interrupta* is similar to the original species *A. bigibba*, which also exhibits constriction in the middle of the dorsal margin. However, *A. bigibba* var. *interrupta* has distinctive protraction in the middle ventral margin, yet *A. bigibba*'s ventral margin is straight.

Distribution. *A. bigibba* var. *interrupta* has been recorded from warm water coast in Bosnia-Herzegovina (Hafner *et al*., 2018), U.S.A. (Wachnicka and Gaiser, 2007; López-Fuerte *et al*., 2020), Mexico (López-Fuerte and Siqueiros-Beltrones, 2016), Turkey (Kaleli and Akçaalan, 2021), India (Gupta and Das, 2020), and New Zealand (Harper *et al*., 2012). In the present study, *A. bigibba* var. *interrupta* was observed from 4 stations in Ulleungdo and Dokdo.

Discussion

This study reports two *Amphora* taxa, *Amphora bigibba* var. *interrupta* and *Amphora arcuata*, previously unrecorded in Korean coastal waters. According to the 2024 edition of the Korean National Species List (NIBR, 2024), 59 taxa

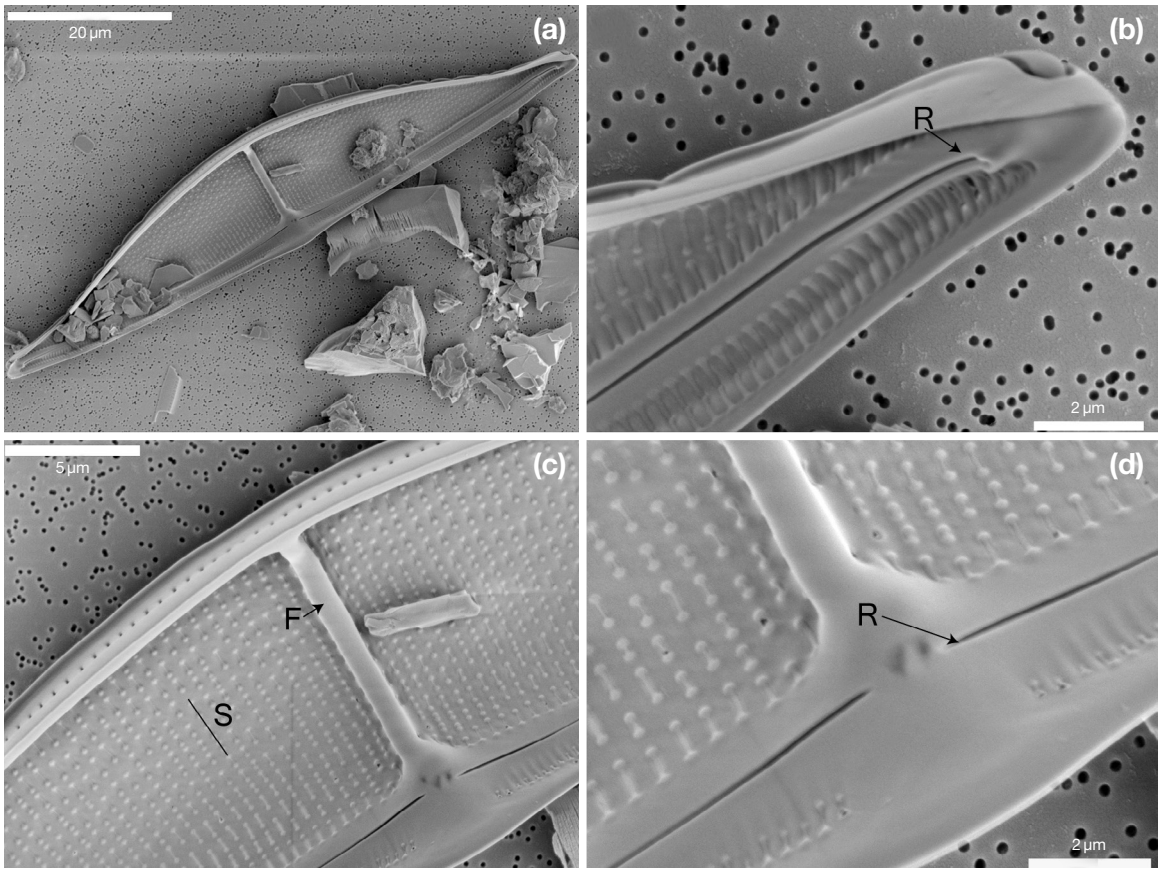

Fig. 3. Scanning electron micrographs of *Amphora arcuata*. (a) Internal view of the entire valve. (b) Terminal raphe fissure, labeled R, showing dorsal deflection. (c) Dorsal fascia (F) and parallel striae (S). (d) Central raphe endings, labeled R, at the mid-valve region.

Table 2. Morphological differences between *A. arcuata* and the related species *A. aspera*.

Characteristic	*A. arcuata*	*A. aspera*
Valve outline	Semi-lanceolate	Semi-lanceolate, gibbous
Valve length (μm)	17.5–33.5	40–85
Valve width (μm)	2.7–3.3	12–18
Dorsal fascia	Present	Absent
Raphe	Straight; ends hooked dorsally (external)/simple internally	Straight, slightly dorsally deflected
Striae orientation	Parallel	Slightly radiate
Striae density (10 μm)	20–24	15–16 (dorsal), 22–24 (ventral)
Areolae resolution in LM	Not resolved	Not resolved
Source	This study	Literature

of *Amphora* have been documented. With the addition of the two taxa described in this study, the total number increases to 61, highlighting the ongoing need to explore and document diatom diversity in Korea's subtidal habitats. Both taxa were identified based on detailed morphological observations using light microscopy (LM) and scanning electron microscopy (SEM), enabling accurate taxonomic resolution.

Amphora bigibba var. *interrupta* was observed at all four sampling stations, including both subtidal sites (JD, TGM, SD) and an intertidal site (DD). This broad spatial distribution suggests that the taxon tolerates a range of ecological conditions. Its occurrence at Dokdo, a site with no apparent subtidal zone, supports previous records that re-

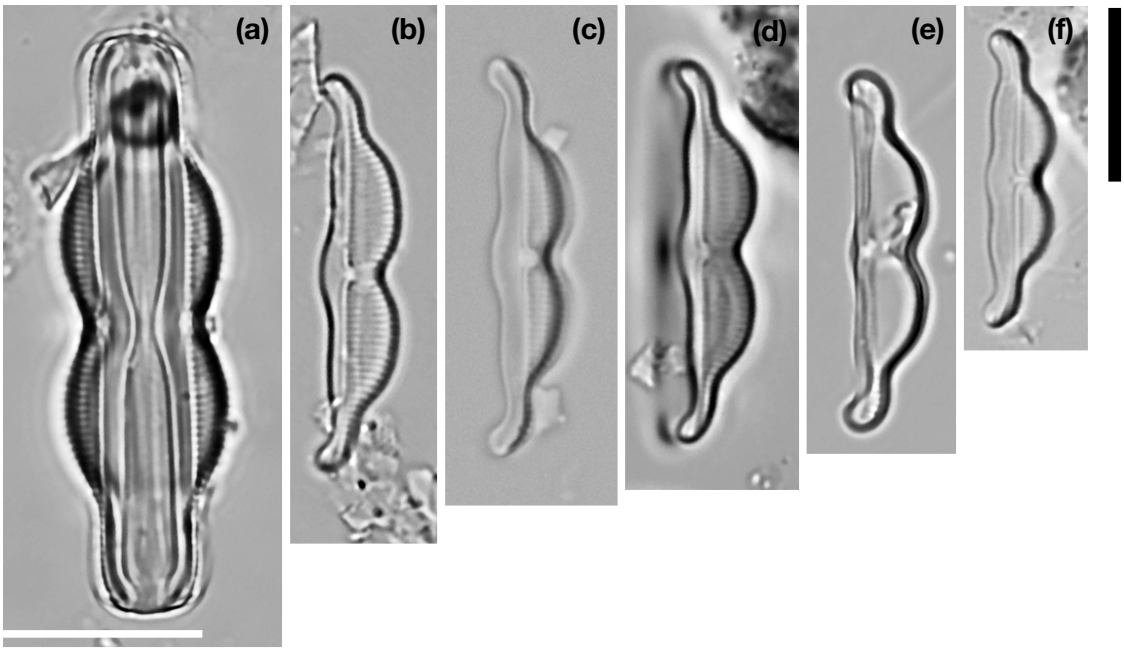

Fig. 4. Light microscope photographs of *Amphora bigibba* var. *interrupta* from Ulleungdo and Dokdo (a–f). Scale bar: 10 μm.

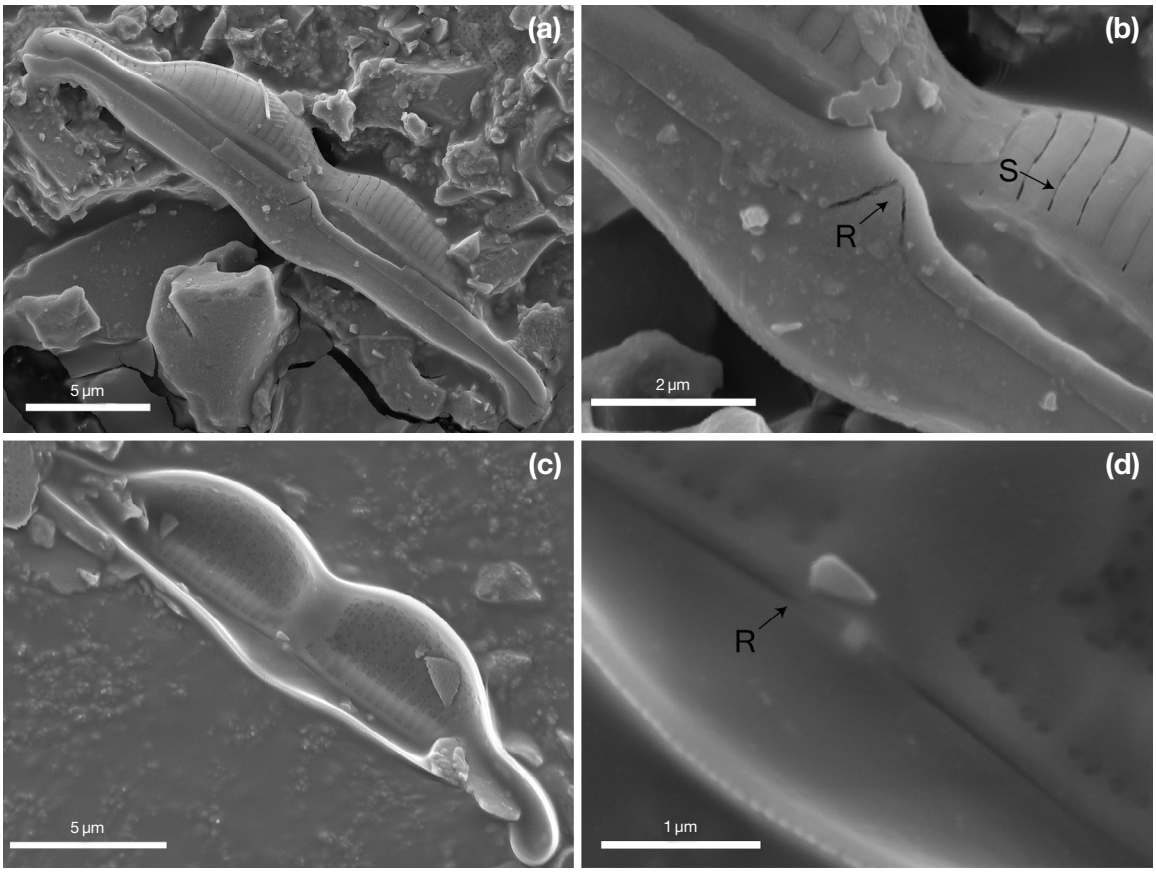

Fig. 5. Scanning electron micrographs of *Amphora bigibba* var. *interrupta*. (a) External view of the entire valve. (b) Terminal raphe fissure (R) and parallel striae (S) on the external valve surface. (c) Internal view of the entire valve. (d) Central raphe endings, labeled R, on the internal valve surface.

gard this taxon as a warm-water species (Witkowski *et al*., 2000). This finding may reflect the influence of the East Korea Warm Current, which transports warm waters northward along the eastern coast of Korea and contributes to the presence of warm-affinity diatoms in offshore areas. The presence of *A. bigibba* var. *interrupta* across diverse habitats, including intertidal zones, may also suggest ecological shifts influenced by regional warming. Such occurrences align with broader trends in diatom biogeography responding to ocean warming, and warrant further investigation under a climate change context.

In contrast, *Amphora arcuata* was found only at two subtidal stations (JD and SD), both sampled at a depth of 20 m. While this distribution suggests a potential ecological association with subtidal environments, the limited number of sites precludes definitive conclusions regarding habitat specificity. Further observations across a broader range of depths and seasons are necessary to clarify its ecological niche. Morphologically, *A. arcuata* closely resembles *A. aspera* Petit, but differs in the presence of a dorsal fascia and a slightly narrower valve outline.

These distinctions support its recognition as a separate taxon and demonstrate the value of high-resolution SEM in distinguishing among closely related *Amphora* species.

Overall, the discovery of *A. bigibba* var. *interrupta* and *A. arcuata* underscores the underappreciated diversity of benthic diatoms in Korean waters, particularly within subtidal environments. This study reinforces the importance of integrating fine-scale morphological techniques and ecological context in taxonomic research, and calls for continued diatom monitoring efforts to uncover additional unrecorded taxa in Korean coastal ecosystems.

It should be noted that no environmental variables such as water temperature, salinity, or nutrient concentrations were recorded during sampling. As a result, interpretations regarding the ecological tolerance or habitat specificity of the identified species remain preliminary. Future studies incorporating environmental data are essential for a more robust understanding of benthic diatom distribution in Korean coastal waters.

Conflicts of Interest

The authors of this paper have no affiliation with any interests and are solely responsible for the paper.

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