

New Records of Diatoms (Bacillariales, Rhopalodiales & Surirellales) with Ultrastructure Details from the Black Sea Coast of Turkey

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ABSTRACT

Diatoms associated with the order Bacillariales, Rhopalodiales and Surirellales are well known to be present in marine and brackish waters. In this study, diatoms in the western Black Sea coasts of Turkey were investigated with ultrastructure details. Species belonging to the Bacillariales, Rhopalodiales and Surirellales were subject to light microscopy (LM) and scanning electron microscopy (SEM) analysis, and a total of twenty-four taxa were investigated. This study examines details on the morphology and biogeography of the taxa with remarks on their distribution in Turkey. The results revealed that four species were reported on the Turkish coasts for the first time. These species were *Nitzschia liebethruthii*, *N. volvendirostrata*, *Epithemia guettingeri* and *Campylodiscus scalaris*.

Keywords: Bacillariophyceae, biodiversity, diatoms, scanning electron microscopy, the Black Sea

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INTRODUCTION

Diatoms make essential contributions to primary productivity and the photosynthesis rate (Salleh & McMinn, 2011; Witkowski, Bohaty, Edgar & Harwood, 2014). Benthic diatom taxonomy studies determine the flora of the observed area and are useful for further research, e.g. ecology and monitoring. The Black Sea has brackish water characteristics like the Baltic Sea and the Caspian Sea. Unlike the Caspian Sea, the Black Sea and Baltic Sea show some morphological similarities. The Baltic Sea is connected to the North Sea via the Kiel strait; the Black Sea is connected to the Mediterranean via the Dardanelles and the Bosphorus straits; however, water flow is relatively lower. The low rate of saline water flowing through the straits to the Black Sea is one reason for this habitat to show brackish characteristics. However, it has a high rate of river discharge along its coasts. Compared to waters with similar characteristics, the Baltic Sea has been the most studied in recent years. Diatom distribution in the Baltic Sea has been studied by several researchers

(Witkowski, 1991; Vilbaste, Sundback, Nilsson & Truu, 2000; Hällfors, 2004).

There have been several studies in marine habitats from the Black Sea. One of the pioneering studies was performed by Mereschkowsky (1902) and Proshkina-Lavrenko (1955, 1963). However, in the last decade, there have been more papers published on the composition and distribution of diatoms of the Black Sea. Most of these studies were performed in the northern part of the Black Sea (Petrov, Nevrova, Terletskaia, Milyukin & Demchenko, 2010; Nevrova, Witkowski, Kulikovskiy, Lange-Bertalot & Kociolek, 2013; Snigireva & Kovaleva, 2015; Nevrova, 2016). Along the southern coasts, studies were limited to a few published papers (Baytut, Gönülol & Koray, 2005; Kaleli, Kulikovskiy & Solak, 2017).

The latest studies reported significant numbers of diatom taxa in the southern Black Sea. However, there is still insufficient data. The diatom flora of the Baltic Sea is an example of taxa that can be used as a comparison for the south



Black Sea. Nevertheless, brackish species have been a challenge for researchers in the past. Some taxa may be confused as being marine, brackish or even as a freshwater species. Monographs, including the brackish taxa (Krammer & Lange-Bertalot, 1988; Witkowski, Lange-Bertalot & Metzeltin, 2000; Hofmann, Werum & Lange-Bertalot, 2011) are good ways of identifying these taxa. According to some authors, certain environmental parameters (e.g., salinity, temperature) are necessary to identify the taxa. Ultrastructural studies can contribute to the knowledge of the diatom structure in the observed area, even though data is lacking in the Black Sea apart from a few studies in the north (Witkowski, Kulikovskiy, Nevrova, Lange-Bertalot & Gogorev, 2010; Nevrova et al., 2013; Nevrova & Petrov, 2019). When compared to the illustrated fine structure of the freshwater diatoms, marine diatoms have slightly less available data.

Members of the Bacillariaceae family have the highest number of taxa with the Naviculaceae (Kociolek et al., 2021); *Nitzschia*, *Rhopalodia*, and *Surirella* making up many brackish taxa. These brackish conditions, e.g. low saline coasts or electrolyte-high waters, can show high biodiversity. Therefore, diatoms from the Bacillariaceae family are of interest in this paper. Here we present some Bacillarioideae diatoms through the fine structure from the Black Sea coast of Ereğli and report 24 taxa from the *Nitzschia*, *Surirella*, *Rhopalodia*, *Tryblionella*, and *Psammodictyon* genera. This paper focuses on the species which are known to be found in marine-brackish waters. This paper discusses taxa on morphology data provided with Scanning electron microscopy (SEM) analysis and comments on their biogeography.

MATERIAL AND METHODS

Ereğli Bay in Zonguldak province is one of the important industrial zones on Turkey's Black Sea coast. The material used in this study was collected from Ereğli Bay (41°16'56" N 31°24'48" E), during benthic marine diatom sampling of the Black Sea coasts in August 2017 (Fig. 1). Sampling was performed by scraping the submerged stones and rocks at the port.



Figure 1. Sampling site location, Ereğli, Zonguldak province, Turkey.

Samples were treated with 10% HCl, then with H₂O₂ to remove the organic material and were then washed with distilled water four times. Permanent slides were prepared with air-dried clean valves and mounted with Naphrax®. Observations in the light micro-

scope (LM) were performed with an Olympus BX-51 microscope at Kütahya Dumlupınar University. SEM observations were performed by Tescan Mira3 XMU at the Sivas Cumhuriyet University Advanced Technology Application and Research Center. Valve measurements were made using ImageJ software. Taxonomic classification and nomenclatural updates followed that of Maraşlıoğlu & Gönüloğlu (2021), Guiry & Guiry (2021) and Kociolek et al., (2021).

RESULTS AND DISCUSSION

Bacillariales Hendey

Cylindrotheca Rabenhorst

Cylindrotheca closterium (Ehrenberg) Reimann & Lewin
Fig. 4: 26, 27

Basionym: *Ceratoneis closterium* Ehrenberg

Synonym(s): *Ceratoneis closterium* Ehrenberg, *Nitzschiella curvirostris* var. *closterium* (Ehrenberg) De Toni, *Nitzschia longissima* var. *closterium* (Ehrenberg) Peragallo & Peragallo, *Nitzschiella tenuirostris* Mereschkowsky.

References: Hasle & Syvertsen (1996)

Dimensions: Length 52 µm, width 3.9 µm.

Remarks: *Cylindrotheca closterium* was found to be cosmopolitan in marine phytoplankton. The species is also known to be harmful algae (Hasle & Syvertsen, 1996).

Distribution & biogeography: The taxon was identified in different locations in Turkey (Maraşlıoğlu & Gönüloğlu, 2021), it is a cosmopolitan and widespread species of marine coasts (Guiry & Guiry, 2021).

Nitzschia Hassall

Nitzschia amabilis H. Suzuki Fig. 3: 16-19

Synonym: *Nitzschia laevis* Hustedt 1939

References: Witkowski et al. (2000), Suzuki et al. (2010)

Dimensions: Length 10-12.1 µm, width 4.6-4.9 µm, striae 38-40 in 10 µm, costae 14-16 in 10 µm.

Remarks: Valves are elliptic, the median fibula is distinct, internally the raphe is slightly undulated, terminal raphe endings extend to the apices. In external valves, hymenes were observed internally.

Distribution & biogeography: Hustedt (1939) identified taxa from the coasts of Germany as *Nitzschia laevis* (non *N. laevis* Frenquelli). It is a widespread species (Guiry & Guiry, 2021) and has been reported and documented on the Aegean coast of Turkey (Kaleli, et al., 2020).

Nitzschia incognita Legler & Krasske Fig. 2: 4

References: Legler & Krasske (1940), Witkowski et al. (2000).

Dimensions: Length 48 µm, width 3 µm, costae 12 in 10 µm.

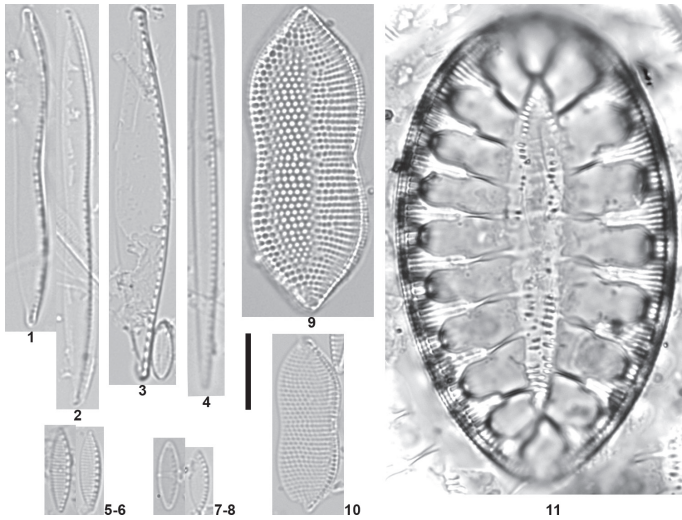


Figure 2. Scale bar: 10 µm. 1, 2. *Nitzschia* cf. *traheiformis*; 3. *N. lanceolata*, 4. *N. incognita*, 5, 6. *N. liebethruthii*; 7, 8. *N. inconspicua*, 9. *Psammodictyon panduriforme* var. *continuum*; 10. *Tryblionella coarctata*, 11. *Surirella fastuosa*. Scale bar: 10 µm.

Remarks: Striae are indiscernible in LM, median distant fibula exist, valve endings are narrowed apiculate.

Distribution & biogeography: *Nitzschia incognita* is a brackish water species that was identified in Lake Van, Turkey (Legler & Krasske, 1940), and observed in the temperate waters of Europe (Guiry & Guiry, 2021) and the Mediterranean Sea (Witkowski et al., 2000).

***Nitzschia inconspicua* Grunow Fig. 2: 7, 8**

Synonym(s): *Nitzschia frustulum* var. *inconspicua* (Grunow) Grunow, *Homoeocladia inconspicua* (Grunow) Kuntze, *Nitzschia perpusilla* var. *inconspicua* Grunow

References: Rovira et al (2015).

Dimensions: Length 7.2-12.5 µm, width 2.3-2.9 µm, costae 14-20 in 10 µm.

Remarks: The taxon resembles *N. frustulum*; however, transapical striae are indistinct in LM, and the valves are broader-lanceolate than the former taxa. It is a widespread brackish-freshwater species (Guiry & Guiry, 2021).

Distribution & biogeography: Species was reported and documented from the Aegean streams and is also common in Turkey (Maraşlıoğlu & Gönülol, 2021). *Nitzschia inconspicua* is a widespread freshwater species also occurring in brackish water (Guiry & Guiry, 2021).

***Nitzschia lanceolata* W. Smith Fig. 2: 3**

Synonym: *Homoeocladia lanceolata* (W. Smith) Kuntze

References: Witkowski et al (2000).

Dimensions: Length 47.5 µm, width 7.1 µm, costae 8 in 10 µm.

Remarks: One valve of *Nitzschia lanceolata* was observed. Valves are broadly lanceolate; fibulae are unevenly distributed.

Distribution & biogeography: *Nitzschia lanceolata* was identified in streams in the Aegean and the Black Sea region; however, the taxon was not documented before in marine coasts of Turkey. It is a cosmopolitan marine-brackish species that was reported in the Mediterranean and the Black Sea (Witkowski et al., 2000; Guiry & Guiry, 2021).

***Nitzschia liebethruthii* Rabenhorst**

Fig. 2: 5, 6; Fig. 3: 15

Synonym: *Homoeocladia liebethruthii* (Rabenhorst) Kuntze

References: Krammer & Lange-Bertalot (1988); Witkowski et al. (2000).

Dimensions: Length 11.4-12.4 µm, width 2.7 µm, fibulae 16-18 in 10 µm.

Remarks: Valves are lanceolate, striae are distinct in LM. *N. liebethruthii* valves were observed with higher fibulae density (Witkowski et al., 2000; 11-12 in 10 µm). The taxon is close to *N. frustulum*, and small valves resemble *N. inconspicua*.

Distribution & biogeography: The species was reported inland of the Antalya and Euphrates regions. This is the first time the species was identified in Turkish coasts. It is a cosmopolitan species

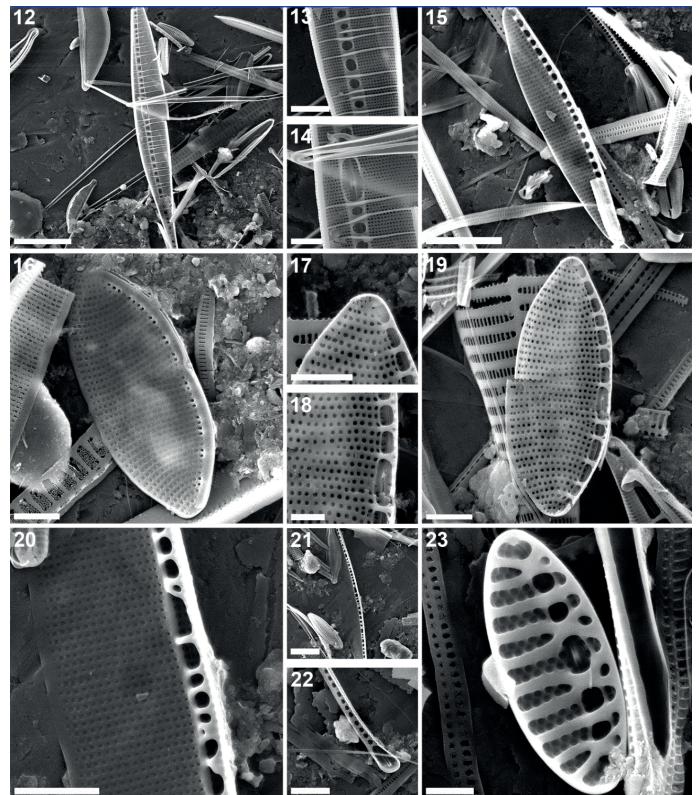


Figure 3. 12-14. *Nitzschia ventricosa*; 15. *N. liebethruthii*; 16-19. *N. amabilis*; 20-22. *N. reversa*; 23. *N. valdestriata*. Scale bars: 17,18,23: 1 µm; 13,14,16,20,22: 2 µm; 15,19,21: 5 µm; 12: 10 µm.

reported in the Mediterranean Sea (Witkowski et al., 2000) and also occurs in brackish-freshwater habitats (Guiry & Guiry, 2021).

Nitzschia cf. traheaformis Chunlian Li, Witkowski & Yu
Fig. 2: 1, 2; Fig. 4: 30

References: Witkowski et al. (2016).

Dimensions: Length 28.7-36.3 µm, width 3.6-3.9 µm, striae 34-40 in 10 µm.

Remarks: Valves are slightly constricted in the middle with apiculate apices. Specimens are similar in valve outline to the following species; however, observed specimens were smaller in size compared to *N. hybrida* (48-103 µm) and *N. pellucida* (55-70 µm; Witkowski et al., 2000). The valves showed more resemblance to *N. traheaformis*, which was 17-54 µm long and 3-4.7 µm wide (Witkowski et al., 2016), and more dubiatae than the other species. Here the valves have higher striae than *N. traheaformis* (32-34 in 10 µm). Therefore we commit the taxa as *N. cf. traheaformis* for further observation.

Distribution & biogeography: *Nitzschia traheaformis* was found in the Red and Yellow Sea and the Indian Ocean. It is necessary to observe the taxon in the Black Sea in detail to confirm before addressing and expanding its biogeography.

Nitzschia reversa Smith **Fig. 3: 20-22**

Synonym: *Nitzschia longissima* var. *reversa* Grunow

References: Snoeijs & Potapova (1995), Witkowski et al. (2000).

Dimensions: Length 89.8 µm, width 4.2 µm, striae 52 in 10 µm, costae 16 in 10 µm.

Remarks: *Nitzschia reversa* can be distinguished by its apices which deflect in opposite directions. It is a cosmopolitan species, found in phytoplankton, identified in inland saline waters (Witkowski et al., 2000; Kociolek et al., 2021).

Distribution & biogeography: The taxon was identified by Ersanlı & Gönülol (2003) in Simenit Lake; however, this is the first time it was documented in Turkish coasts. It is cosmopolitan and widespread (Guiry & Guiry, 2021), found in marine phytoplankton (Witkowski et al., 2000).

Nitzschia ventricosa Kitton **Fig. 3: 12-14**

Synonym: *Homoeocladia ventricosa* (Kitton) Kuntze

References: Witkowski et al. (2000), Lobban et al. (2012).

Dimensions: Length 160.6 µm, width 6 µm, striae 48 in 10 µm, fibulae 8 in 10 µm.

Remarks: Valve is long with rostrate endings, fibulae and costae are irregular, central nodule exits, central raphe endings form helictoglossae.

Distribution & biogeography: This is the first time this species was observed in the coasts of the Sea of Marmara in Turkey (in

print). Species is widespread in the warm waters of the oceans and observed in the Mediterranean Sea (Guiry & Guiry, 2021).

Nitzschia vidovichii (Grunow) Grunow **Fig. 4: 24, 25**

Basionym: *Homoeocladia vidovichii* Grunow

References: Navarro (1982), Navarro & Lobban (2009).

Dimensions: Length 103.8 µm, width 7.6 µm, striae 28 in 10 µm.

Remarks: The specimen observed here conforms with the micrographs of Navarro (1982), Navarro & Lobban (2009). Taxon resembles *Nitzschia scalpelliformis*, showing similar dimensions; however, raphe is centrally formed.

Distribution & biogeography: It is a widespread marine species (Guiry & Guiry, 2021). Species was reported from Homa Lagoon in the Aegean Sea (Çolak-Sabancı & Koray, 2010).

Nitzschia volvendirostrata Ashworth, Dabek & Witkowski
Fig. 4: 28

References: Witkowski et al. (2016).

Dimensions: Length 12.1 µm, width 2.8 µm, striae 52 in 10 µm, costae 10 in 10 µm.

Remarks: Valve has a linear outline and rostrate apices, fibulae irregular. The taxon resembles *Nitzschia nanodissipata*, in terms of its outline. Witkowski et al. (2016) described the species with the dimensions of 7-11.5 µm length and 3-3.5 µm width. Here, valve dimensions are slightly higher and resemble *N. volvendirostrata* (striae 52-54 in 10 µm, 8-9 costae in 10 µm) in terms of striae numbers.

Distribution & biogeography: Taxon was identified in the Red Sea (Witkowski et al., 2016). This is the first time it has been identified in Turkish coastal waters.

Psammodictyon D.G. Mann

Psammodictyon panduriforme var. *continuum* (Grunow) Snoeijs
Fig. 2: 9

Basionym: *Nitzschia panduriformis* var. *continua* Grunow

Synonym: *Nitzschia panduriformis* var. *continua* Grunow

References: Krammer & Lange-Bertalot (1988), Snoeijs & Balashova (1998).

Dimensions: Length 18.5-22.5 µm, width 7.5-8 µm, striae 18-19 in 10 µm.

Remarks: Taxon is slightly panduriform, valves are smaller than *Tryblionella coarctata* and have higher striae numbers in the observed material.

Distribution & biogeography: It is a brackish-marine waters species identified in the Baltic Sea (Snoeijs & Balashova, 1998). Species was formerly observed in the Aegean Sea coasts in Turkey (Kaleli et al., 2020).

Tryblionella W. Smith**Tryblionella compressa** (Bailey) Poulin **Fig. 4: 32, 33**

Basionym: *Pyxidicula compressa* Bailey

Synonym(s): *Pyxidicula compressa* Bailey, *Dinopyxis compressa* (Bailey) Stein, *Exuviaella compressa* (Bailey) Ostenfeld, *Nitzschia compressa* (Bailey) C.S. Boyer, *Prorocentrum compressum* (Bailey) T.H. Abé ex J.D. Dodge.

References: Poulin et al. (1990), Witkowski et al. (2000), Witon & Witkowski (2006).

Dimensions: Length 33.1 µm, width 21.9 µm, striae 9 in 10 µm.

Remarks: Valve is lanceolate, slightly inflated in the middle, with produced apices. Striae are punctate and equal to fibulae numbers.

Distribution & biogeography: *Tryblionella compressa* is a marine, brackish species and widespread on the coasts (Guiry & Guiry, 2021).

Tryblionella coarctata (Grunow) Mann **Fig. 2: 10**

Basionym: *Nitzschia coarctata* Grunow

Synonym(s): *Nitzschia coarctata* Grunow, *Homoeocladia coarctata* (Grunow) Kuntze, *Nitzschia punctata* var. *coarctata* (Grunow) Hustedt

References: Snoeijis & Balashova (1998), Witkowski et al. (2000).

Dimensions: Length 31.6-40 µm, width 14-15 µm, striae 12 in 10 µm.

Remarks: Valves are panduriform with apiculate endings. *Tryblionella coarctata* possess punctate aerolation similar to *Psammodyctyon*. Furthermore, *T. coarctata* differs from *P. panduriforme* var. *continuum*, by the hyaline valve face in one half of the valve in LM micrographs. Also, *P. panduriforme* var. *continuum* has lower striae density.

Distribution & biogeography: It is a cosmopolitan species inhabiting marine (Guiry & Guiry, 2021) and brackish waters (Snoeijis & Balashova 1998). It was formerly reported from the Mediterranean Sea (Witkowski et al., 2000) and the Dardanelles Strait (Yildiz, 2018).

Tryblionella cf. coarctata var. densestriata Álvarez-Blanco & S. Blanco **Fig. 4: 31**

References: Blanco & Blanco (2014).

Dimensions: Length 10.7 µm, width, 5.1 µm, striae 34 in 10 µm.

Remarks: One small specimen was observed, the valve is slightly panduriform with a higher striae count (Blanco & Blanco, 2014; 22-30 in 10 µm). Blanco & Blanco (2014) listed the striae numbers from different authors, and here the specimen was closer to the valves observed from Murcia.

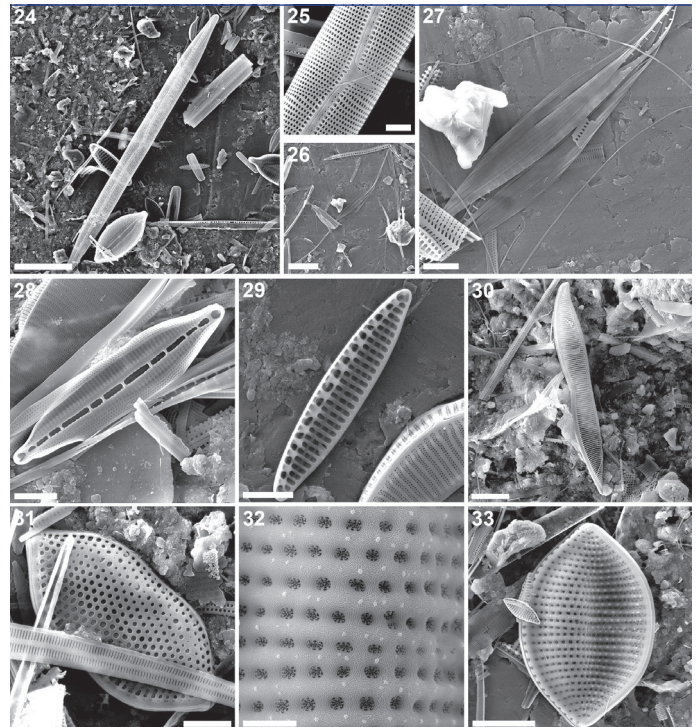


Figure 4. 24, 25. *Nitzschia vidovichii*; 26, 27 *Cylindrotheca closterium*; 28. *Nitzschia volvendirostrata*; 29. *Nitzschia* sp.1; 30. *N. cf. traheiformis*; 31. *Tryblionella cf. coarctata* var. *densestriata*; 32, 33. *Tryblionella compressa*. Scale bars: 25,27,28,29,31,32: 2 µm; 30: 5 µm; 24,26,33: 10 µm.

Distribution & biogeography: Taxon was described in the Mediterranean Sea (Blanco & Blanco, 2014).

Rhopalodiales D.G. Mann**Protokeelia C.W. Reimer & J.J. Lee****Protokeelia sp. Fig. 5: 36, 43**

Dimensions: Length 7.2-11.2 µm, width 2.5-3.5 µm, striae 32-36 in 10 µm, 35 coastae in 10 µm.

Remarks: Valves are semi lunate to weakly convex and some valves are constricted slightly in the middle, almost straight at the ventral margin. Valve endings are acute and rounded, not produced, areolation are biseriate, raphe terminates slightly before the apices, and is expanded. Central endings are near, slightly bent on the dorsal side in the external valve. In the internal view, fibulae are regular and rounded. Central median fibulae exist with an open gap, however, just one valve was observed and more valves might reveal if it is an opening or broken part of the fibulae. The ventral margin girdle band is placed with two rows oblong of areolae. Taxa resemble genus *Protokeelia* with its characteristics. Some differences were found though, like the ventral side of the specimens resemble mostly *P. hottingeri* (Reimer & Lee, 1984; Lee et al., 1989); the structure of the keel and biseriate areolae are similar, although fibulae structure are different, or ventral margin of *P. spinifera*, *P. aculeata* and *P. cholnokyii*

are concave (Round & Basson, 1995a,b), while *Protokeelia* sp. has straight margins. Therefore we commit the taxa to *Protokeelia* sp. for further studies.

Epithemia Kützing

Epithemia guettingeri (Krammer) Lobban & J.S. Park Fig. 5: 37-39

References: Krammer (1988), Park et al. (2018).

Dimensions: Length 19.9-26.5 μm , width 8-8.3 μm , 40 striae in 10 μm , 11-16 costae in 10 μm .

Remarks: Valves are dorsiventral, and straight at the ventral margin. Apices are acute and rounded, raphe terminates at the apices. Central endings are bent on the dorsal side of the valve. Costae are regularly distributed, and striae are biseriate. In the specimens, flabelli-like structure was observed on the areolae. Fibulae are irregular, and median central raphe was observed. Apical costae in the middle of the valve were observed in the external valve view; however, in the internal view, it was not observed, which is in line with Krammer (1988). Park et al. (2018) indicated *Epithemia guettingeri* and *E. pacifica* resemble, and the median costae differs, both existed and were observed in internal and external valves in *E. guettingeri*, while in *E. pacifica* it was observed in the internal valve. Here, areolae presence on the apical band conforms with SEM images of Park et al. (2018). Taxon has recently been proposed to be transferred back to the genus *Epithemia* (Park et al., 2018).

Distribution & biogeography: It is a marine species which was reported in temperate waters of the oceans (Guiry & Guiry 2021). It is reported for the first time in the Turkish coasts.

Epithemia pacifica (Krammer) Lobban & J.S. Park Fig. 5: 40-42

References: Lange-Bertalot & Krammer (1987), Witkowski et al. (2000).

Dimensions: Length 40 μm , width 8.7 μm , striae 18 in 10 μm , costae 8 in 10 μm .

Remarks: Valve is strongly dorsiventral and slightly concave at the ventral margin. Areolae are circular, striae are biseriate, raphe terminates at the produced rostrate apices. In the fine structure of the broken valve, the median apical hyaline band was observed. Recently taxa were proposed as *Epithemia pacifica* (Park et al., 2018).

Distribution & biogeography: It is a marine species described from the Pacific Ocean (Guiry & Guiry, 2021) and also was observed in the Mediterranean Sea (Hafner et al., 2018). It is observed for the first time in the Sea of Marmara coasts in Turkey (in print).

Rhopalodia O. Müller

Rhopalodia cf. brebissonii Krammer Fig. 5: 34, 35

References: Lange-Bertalot & Krammer (1987), Witkowski et al. (2000).

Dimensions: Length 19 μm , width 4.3 μm , 30 striae in 10 μm , 5 costae in 10 μm .

Remarks: Valve is dorsally convex, ventrally straight. Areolae are square-oblong, here apices were not produced and acutely apiculate. In Lange-Bertalot & Krammer (1987) valves have produced endings and are bent at the ventral margin, differed from the specimen observed and striae 30 in 10 μm (Lange-Bertalot & Krammer, 1987; 17-22 in 10 μm) are higher than described. Ruck et al. (2016) proposed the transfer of *Rhopalodia* species into *Epithemia*, therefore, after further analysis to confirm specimen belongs to *R. brebissonii* it can be proposed to move into *Epithemia*.

Distribution & biogeography: It is a freshwater taxon (Guiry & Guiry, 2021), reported from the Baltic Sea (Snoeijs & Balashova, 1998).

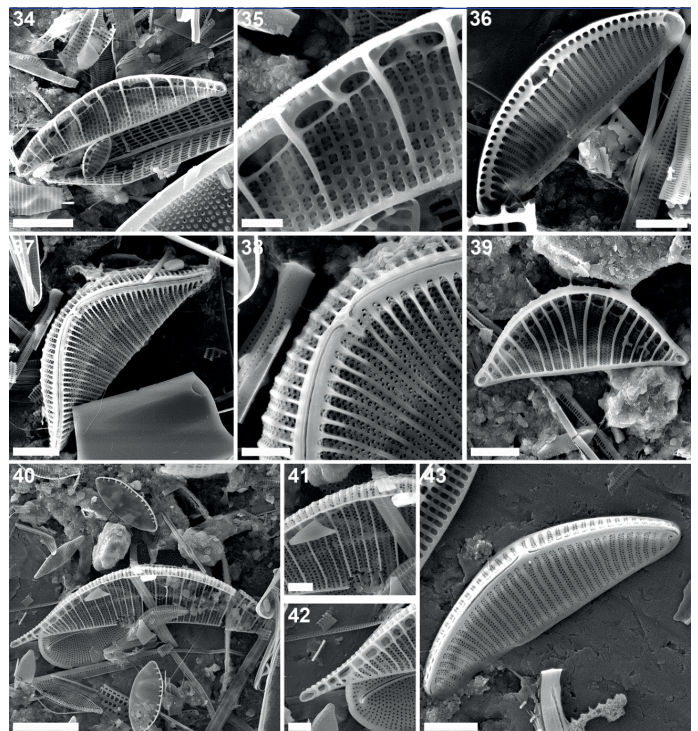


Figure 5. 34, 35. *Rhopalodia cf. brebissonii*; 36. *Protokeelia* sp.1; 37-39. *Epithemia guettingeri*; 40-42. *E. pacifica*, 43. *Protokeelia* sp.1. Scale bars: 34,37,39: 5 μm ; 35: 1 μm ; 36,38,41,42,43: 2 μm ; 40: 10 μm .

Surirellales D.G. Mann

Campylodiscus Ehrenberg ex Kützing

Campylodiscus scalaris (Giffen) Lobban & Park Fig. 6: 44-46

Basionym: *Surirella scalaris* Giffen

References: Giffen (1967), Navarro (1983), Lobban et al (2012), Park et al. (2018)

Dimensions: Length 22.2 μm , width 22 μm .

Remarks: SEM images of *Campylodiscus scalaris* showing that external valve is depressed, the central area is connected to margins by canals, double branched near the margin. In internal view, areolae were small, oblong, and formed a mixed distribution. Warts cover the branches and the occluded area in between. Giffen (1967) described taxa as *Surirella scalaris*, Lobban et al. (2012) proposed a transfer of the species into *Campylodiscus* (see, *C. scalaris* non Tempère & Brun 1889 for different species).

Distribution & biogeography: This is the first record for the Turkish flora, reported from the Pacific Ocean and the Adriatic Sea (Guiry & Guiry, 2021).

Campylodiscus* aff. *bicostatus W. Smith ex Roper **Fig. 6: 47**

Synonym: *Campylodiscus clypeus* var. *bicostata* (W. Smith ex Roper) Hustedt

References: Peragallo & Peragallo (1897-1908)

Dimensions: Length 22.1 µm, width 19.3 µm.

Remarks: Valve consists of a large hyaline area in the centre and irregular punctae are located at the margin between the ribs. Drawings of Peragallo & Peragallo (1897-1908) and Hustedt (1985) resemble the valve found here. However, more specimens should be observed to dedicate the taxa to *C. bicostatus*.

Distribution & biogeography: *C. bicostatus* was reported from different locations, formerly reported from the Sankum lagoon and freshwater lakes (Maraşlıoğlu & Gönülol, 2021 and references therein). It is a cosmopolitan freshwater species (Guiry & Guiry, 2021).

Campylodiscus* cf. *thureti Brébisson **Fig. 6: 54**

References: Romagnoli et al. (2014), Kulikovskiy et al. (2016), Schmidt (1874-1959)

Dimensions: Length 32 µm, width 24.5 µm.

Remarks: Valve is oval, composing triseriate striae crossed by ribs and emerges near the margin. Ribs are more further apart, similar to Romagnoli et al. (2014). Our specimen resembles *C. cf. thuretii* in Romagnoli et al. (2014). Before committing the specimen into *C. thuretii*, more valves should be observed.

Distribution & biogeography: *C. thuretii* has not been recorded in Turkey before, it has been reported from the temperate waters of marine coasts (Guiry & Guiry, 2021) and the Mediterranean Sea (Romagnoli et al., 2014).

***Surirella* Turpin**

Surirella* cf. *brebissonii* var. *kuetzingii Krammer & Lange-Bertalot **Fig. 6: 51-53**

References: Krammer & Lange-Bertalot (1987), Schmidt (1874-1959).

Dimensions: Length 28.3-34.9 µm, width 12.1-13 µm, 31striae in 10 µm.

Remarks: Valves are wedge-shaped and broadly rounded in headpole and narrower and rounded in the foot pole. Striae are parallel to radiate at the endings and biseriate. Taxon resembles *Surirella brebissonii* var. *kuetzingii* in terms of its valve outline (Krammer & Lange-Bertalot, 1987), however in SEM *S. brebissonii* var. *kuetzingii* composed triseriate-quadriseperate striae (English & Potapova, 2011). In LM striae are discernible in the centre of the valve face. Species also resemble *S. suevica* Zeller (Krammer & Lange-Bertalot, 1987; fig. 46,47) and Schmidt (1874-1959; pl.23: 60-65). Further observation is needed from the material.

Distribution & biogeography: It was reported from different regions of inland waters. (Guiry & Guiry, 2021).

Surirella fastuosa (Ehrenberg) Kützing **Fig. 2: 11; Fig. 6: 48-50**

References: Peragallo & Peragallo (1897-1908), Witkowski et al. (2000).

Dimensions: Length 60.1 µm, width 34.9 µm.

Remarks: *Surirella fastuosa* shows a wide range of valve morphology; valves are elliptic-ovate with rounded apices in general, due to this character taxon is similar to *S. armoricana* in valve outline. Our specimen resembles *S. armoricana* Peragallo, with wider costae at the margin. Illustrations of Hendey (1974, Pl. 40:6) and Foged (1975, Pl.30:5) match our specimen; however, the drawings and description of *S. armoricana* in Peragallo & Peragallo (1897-1908) revealed that the central area is panduriform. Therefore we commit our specimen to *S. fastuosa*.

Distribution & biogeography: Taxa was reported from temperate waters of the coasts of oceans (Guiry & Guiry, 2021).

In this study, members of the Bacillariales, Rhopalodiales and Surirellales from the coast of the Black Sea were investigated, which have a more complex structure such as fibula or keel. A total of 24 species were observed and of these, 22 taxa were investigated with fine structure. Taxa were discussed with regards to taxonomy and biogeographical distribution. Fifteen species were observed from the Bacillariales including *Cylindrotheca*, *Nitzschia*, *Psammodictyon* and *Tryblionella*; while four taxa from the Rhopalodiales showed distribution with *Protokeelia*, *Rhopalodia* and finally the Surirellales were composed of five taxa belonged to *Campylodiscus*, and *Surirella*. Taxa observed here have marine-brackish habitat preferences. Some taxa (*Tryblionella compressa*, *Surirella* cf. *brebissonii* var. *kuetzingii*, *Rhopalodia* cf. *brebissonii*) presented here showed a wide range of distribution in the coasts and lakes of Turkey (Maraşlıoğlu & Gönülol, 2021).

Amongst the species, several of them were formerly reported from the Black Sea, including *Cylindrotheca closterium*, *Nitzschia liebethruthii*, *N. inconspicua*, *N. liebethruthii*, *Psammodictyon panduriforme* var. *continuum*, *Surirella fastuosa*, *Tryblionella compressa* and *T. coarctata* (Nevrova, 2016; Nevrova & Petrov, 2019). In the Aegean Sea coasts, common species were *Campylodiscus scalaris*, *Epithemia guettingeri*, *Nitzschia amabilis*, *N. liebethruthii*, *N. inconspicua* (Louvrou, 2007). Similarly, species

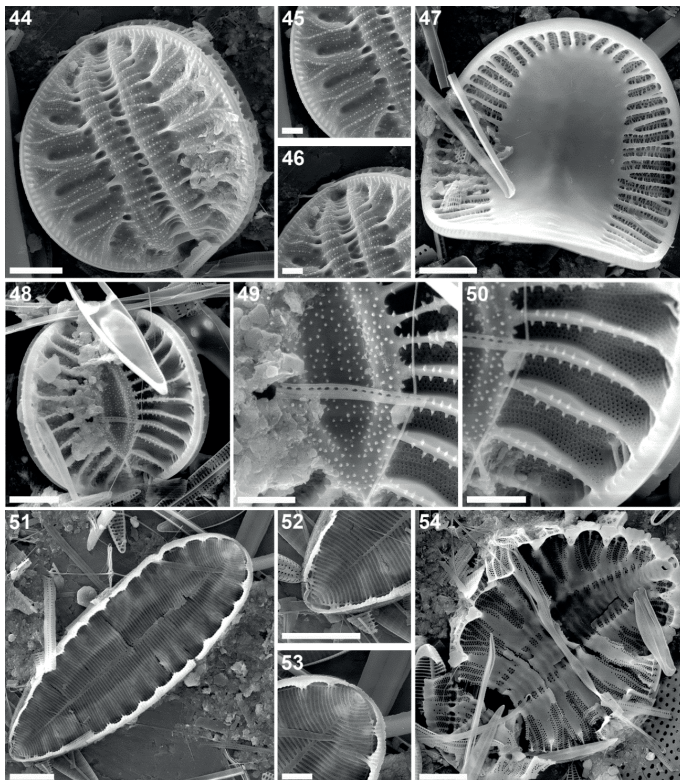


Figure 6. 44-46. *Campylodiscus scalaris*; 47. *C. cf. bicostatus*; 48-50. *Surirella fastuosa*; 51-53. *Surirella cf. brebissonii* var. *kuetzingii*; 54. *Campylodiscus cf. thuretii*. Scale bars: 45,46,49,50,52,53: 2 μ m; 44,47,48,51,54: 5 μ m.

numbers were higher in the lower saline waters of the Black Sea (Nevrova & Petrov, 2019). While marine diatom ecology has been given less attention, and limited data is present on the autecology of the species, in *Campylodiscus scalaris* an example which was described from the South African coasts, our findings in the Black Sea expanded the biogeographic range of the species in lower saline waters of the Black Sea. This could suggest that with the help of the ultrastructural view, more species could be introduced to the Black Sea flora and contribute to their habitats.

Marine benthic diatoms are important components of the coastal areas; nevertheless, low salinity levels could yield such challenging environments and could be suitable both for brackish and freshwater taxa to survive (Petrov & Nevrova, 2007; Barinova et al., 2019). Recently benthic diatom communities in the Black Sea have become intensively studied in the north due to observing the diatoms' adaptation to environmental changes. On the other hand, Black Sea flora consisted mostly of the presented taxa, particularly in the Northern Black Sea (Petrov & Nevrova, 2007; Nevrova & Petrov, 2019) showed the high biodiversity presence of Bacillariaceae. Although diatom biodiversity of diatoms from the Turkish coasts has not been studied in depth before, some of the previous studies (Baytut & Gönülol, 2016; Kaleli et al., 2017) devoted to benthic diatom flora found that biodiversity could be even higher than that which has been investigated so far on the Black Sea coasts. Also previously, freshwater taxa were

reported from the coasts or lagoons in the Black Sea (Soylu et al. 2011; Kaleli & Akçaalan, 2021 and references therein).

The current study represented some of the taxa with SEM. Although the ultrastructure of the valves is a more reliable way of identification, some taxa (*C. thuretii*, *C. bicostatus*, *R. brebissonii*) should be investigated further from the location. Due to the lack of specimens, some taxa could not be defined at the species level. Therefore, for those, there is a need to observe more valves in LM and SEM. Finally, ultrastructure analysis revealed that *Nitzschia liebethruthii*, *N. volvendirostrata*, *Epithemia guettingeri* and *Campylodiscus scalaris* were reported for the first time in the coastal waters of Turkey and contributed to the knowledge of marine benthic diatoms.

CONCLUSION

Eregli Bay, located on the southwestern coasts of the Black Sea, is a moderately populated industrial zone. The taxa discussed above contributed to the knowledge of Turkish diatom flora as well as the Black Sea. The characteristics of the Black Sea could allow a wide range of diatom communities in terms of habitat preference (Nevrova, 2016; Barinova et al., 2019). In addition to this, some studies in the coastal lakes and lagoons in the Turkish Black Sea coast indicated that the diatom community in these areas could be also composed of several freshwater forms (Soylu et al. 2010, 2011). This study brings comprehensive data on the marine and brackish forms which could grow on the hard substrates of the bays in the Southern Black Sea coasts. Further studies would provide data both for the taxonomical aspect and extend the biogeography of the taxa for the Black Sea. Even when the species are taken into consideration under family or order classification, the Turkish coasts of the Black Sea presented a high level of biodiversity, and this could be useful to understand the biodiversity of diatoms and provide data for further studies in the region.

Conflict of Interest

The authors declare no conflict of interest.

Ethics committee approval: Ethics committee approval is not required.

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