Taxonomy and distribution of diatoms on the Turkish Mediterranean Coast, Dalyan (Muğla)

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Abstract

Diatoms are one of the components in the littoral zone and the most productive in terms of O₂ production and primary production. Despite their importance in these coastal ecosystems, the diatoms of littoral zones of Turkish coastlines have been understudied. In this report, we document the littoral diatoms from Dalyan Iztuzu Beach at the southeast coasts of Aegean Sea. Samples were collected from 6 stations in Dalyan Beach between 2012 and 2016. We report here on the occurrence of 9 genera including, Catenula Mereschkowsky, Cymatosira Grunow, Dimeregramma Ralfs, Diplomenora Blazé, Eunotogramma Weisse, Meloneis Louvrou, Danielidis & Economou-Amilli, Neohuttonia Kuntze, Plagiogramma Greville and Tetramphora Mereschkowsky, as well as 40 taxa as newly-recorded from Turkey. The newly-recorded diatoms are characterized in terms of their morphology and illustrated with light micrographs. For each species, their habitat and geographic distribution along the coasts are discussed.

Keywords: Benthic; Diatom; Marine; New Records; The Mediterranean Sea; Turkish coast.

Introduction

The marine littoral zone is an important area in the oceans due to its high primary productivity, O₂ production and for the determination of the ecological status of the coasts (Desrosiers et al., 2013). Diatoms are one of the components in the littoral zone and the most productive in terms of O₂ production and the primary production (Coelho et al., 2007).

Previous studies in Turkey indicated that diatoms are generally the most abundant group amongst phytoplankton (Bat et al., 2007; Taş, 2014). Taş (2014) indicated that in the Daşça Peninsula, diatoms and dinoflagellates were found as dominants in the phytoplankton. The other records from the Sea of Marmara revealed that diatoms were one of the major groups in the phytoplankton (Deniz & Taş, 2009; Balkıs & Teklu-Ahçiç, 2014; Balkıs & Taş, 2016). Also, a few studies (e.g. Özman-Say & Balkıs, 2012) were carried out in the Mediterranean Sea, with similar results.

A pioneering study on Turkish marine benthic diatoms was performed in the first half of 19th Century by Ehrenberg (1844). His interest in Turkish marine diatoms concerned the Sea of Marmara and Bosphorus (Istanbul) regions. Ehrenberg described three new species from the Sea of Marmara (Achnanthes bacillaris, Cocconeis margaritifera, and Navicula decussata) and one new species from Bosphorus (Gallionella asperula). Then, in the early 20th Century, Hustedt (1930-1966) described Achnanthes orientalis (=Karayevia amoena (Hustedt) Bukhtiyarova), Stauroeis decipiens Hustedt and Nitzschia capitellata Hustedt from the Sea of Marmara. Hustedt also published some diatom records from Golden Horn, Bosphorus, which included the presence of Melosira dubia Kützing, M. nummuloides Agardh, Cocconeis notata Petit and Mastogloia pumila Cleve (Hustedt, 1930-1966). Recently, research on the diatoms from Western Turkey was initiated and this activity resulted in the publication of several diatom checklists (Koray 2001; Balkıs, 2004; Ayssel, 2005; Taş & Okuş, 2006). These checklists included some benthic diatoms but they were primarily dedicated to planktonic forms. Additionally, research on the benthic diatom composition from Homa Lagoon, İzmir province, resulted in some species being recorded for the first time for the Turkish marine flora, including species from Cocconeis, Fogedia, Mastogloia, Seminavis, Syndra and Trachysphenia (Coşk Sabanci, 2013; Coşk Sabanci et al., 2010, 2014). More recently, 31 new records
of marine diatoms from the Black Sea coast at Sinop were published by Kaleli et al. (2017).

Turkey has coasts on several seas (Black Sea, Marmara, and the Mediterranean Sea), each differing from one another in terms of environmental conditions. The significant factors differing throughout the year between the marine coasts are salinity and water temperature (Tsimplis et al., 2004; Coll et al., 2010). The study area for the present report is part of the southeastern Aegean Sea coasts. This area has been shown to be a marine biodiversity hotspot, exposed to alien species via the Suez Canal (Coll et al., 2010).

The aim of this study is to document the diatom species observed for the first time on the Turkish Mediterranean coasts of Dalyan, expand biogeographical knowledge of marine diatoms, and contribute to a fuller understanding of the Turkish marine diatom flora. For certain taxa treated here, we also indicate specific relationships between taxa and their habitats.

Material and Methods

Dalyan Iztuzu Beach (36° 42′02″ N, 28° 41′31″ E) is located on the southeastern coast of the Aegean Sea (Fig. 1). The Iztuzu Coast, which is 4.7 km long, is one of the protected areas of the Turkish coasts, due to the presence of nesting grounds of Caretta caretta (Linnaeus, 1758), the loggerhead sea turtle. In the southern part of the coast, Sülüklü Lake is present. This lake is shallow and has a mostly sandy bottom (Kaleli, 2019). In the northern part of the coast, the Dalyan River reaches the coast via the Delta of Dalyan.

Sampling was carried out between 2012-2016 from 6 different locations along the coast of Dalyan. Epilithic diatom samples were collected from stones and rocks from the southern coast by brushing, and epiphytic samples were collected from both the northern and southern parts of the beach by using plastic bags to collect host plants and dislodge the epiphytes. Sand samples were taken from the shoreline. Epipelic samples from Sülüklü Lake was collected with a spoon.

Samples were treated with 10% HCl and washed several times with distilled water in order to remove carbonates. Then, the samples were prepared by boiling with H_2O_2 and washed with distilled water. Frustules were air-dried and mounted with Naphrax. Light microscopic (LM) observations were performed with Olympus BX-51 microscope in the Biology Department and Nikon Eclipse Ci-E microscope at Advanced Research Center (DPU-ILTEM) of Kütahya Dumlupınar University.

Diatom identification was aided with the following references: Peragallo & Peragallo (1897-1908), Hustedt (1930-1966), Hendey (1964), Simonsen (1987), Hartley et al. (1996), Loir & Novarino (2014), Witkowski et al. (2000), Witon & Witkowski (2006a), Wachnicka & Gaiser (2007), Riberio (2010), and Álvarez-Blanco & Blanco (2014).

Taxonomic classification and nomenclatural updates on genera and taxa names were checked with Fourtanier & Kociolek (2011), Guiry & Guiry (2019) and Kociolek et al. (2019). Previously published phytoplankton check-
Table 1. New recorded taxa list according to their presence in the substrates observed.

| Taxa / Habitat | Epilithon | Epiphyton | Epipsammon |
|----------------|-----------|------------|------------|
| *Achnanthes danica* (Flögel) Grunow | + | | |
| *Amphora cymbamphorica* Cholnoky | | + | |
| *Anorthoneis vortex* Sterrenburg | + | + | |
| *Ardissonea crystallina var. dalmatica* (Kützing) Mills | + | | |
| *Brachysira estonarium* Witkowski, Lange-Bertalot & Metzeltin | + | | |
| *Caloneis libera* (Smith) Cleve | + | | |
| *Catenula adhaerens* (Mereshchowsky) Mereshchowsky | + | | |
| *Cocconeis diaphana* Smith | + | | |
| *Cocconeis dirupta* Gregory | + | | |
| *Cocconeis pelta* Schmidt | + | | |
| *Cocconeis peloides* Hustedt | + | + | |
| *Cymatosira belgica* Grunow | + | | |
| *Cymatosira lorenziana* Grunow | + | | |
| *Delphineis minutissima* (Hustedt) Simonsen | + | | |
| *Dimeregramma minus var. nanum* (Gregory) Van Heurck | + | + | |
| *Diplomenora cocconeiformis* (Schmidt) Blazé | + | | |
| *Eunotogramma marinum* (Smith) H. Peragallo & M. Peragallo | + | + | |
| *Fallacia pseudony* (Hustedt) Mann | + | + | |
| *Fallacia schaeferae* (Hustedt) Mann | + | | |
| *Grammatophora angulosa var. mediterranea* Grunow | + | + | |
| *Licmophora ehrenbergii f. grunovii* (Mereshchowsky) Witkowski | + | | |
| *Mastogloia crucicula* (Grunow) Cleve | + | | |
| *Mastogloia emarginata* Hustedt | + | | |
| *Mastogloia ovalis* A. Schmidt | + | + | |
| *Meloneis mimallis* Louvrou, Danielidis & Economou-Amilli | + | + | |
| *Navicula arenaria var. rostellata* Lange-Bertalot | + | | |
| *Navicula lusoria* Giffen | + | | |
| *Neohuttonia reichardtii* (Grunow) Hustedt | + | + | |
| *Nitzschia aequorea* Hustedt | + | + | |
| *Nitzschia amabilis* Suzuki | + | | |
| *Nitzschia nanodissipata* Chunlian Li & Witkowski | + | | |
| *Nitzschia valdestrata* Aleem & Hustedt | + | | |
| *Plagiogramma pulchellum var. pygmaeum* (Greville) H. Peragallo & M. Peragallo | + | | |
| *Plagiogramma tenuissimum* Hustedt | + | + | |
| *Pinnothidium lilljeborgei* (Grunow) Witkowski, Lange-Bertalot & Metzeltin | + | | |
| *Proschkinia bulnheimii* (Grunow) Karayeva | + | | |
| *Psammodictyon panduriforme var. continentum* (Grunow) Snoeijs | + | | |
| *Tetramphora sulcata* (Brébisson) Stepanek & Kociolek | + | | |
| *Trachysphenia acuminata* Peragallo | + | | |
| *Tryblionella marginulata* (Grunow) Mann | + | | |
lists by Koray (2001), Balkis (2004), Taş & Okuş (2006) and Gönülol (2018) were compared for the new records.

Results

This is the first study on benthic diatoms carried out in the region. As a result, taxa belonging to 9 genera, including *Catena* Mereschkowsky, *Cymatosira* Grunow, *Dimeregramma* Ralfs, *Diplomenora* Blazé, *Eunotogramma* Weisse, *Meloneis* Louvrou, Danielidis & Econo-mou-Amilli, *Neohuttokia* Kuntze, *Plagiogramma* Greville, and *Tetramphora* Mereschkowsky and a total of 40 species were identified as new records for marine benthic flora of Turkish coasts. Descriptions and micrographs of the diatoms follow below with information, including habitat distributions (Table 1). For each taxon, valves were measured and individual (n) valves are given in the dimensions.

Description of the Taxa

*Biddulphiaceae*

*Neohuttokia* Kuntze, 1898

*Neohuttokia reichardtii* (Grunow) Hustedt (Fig. 2. A)

**Basionym:** *Cerataulus reichardtii* Grunow

**References:** Hustedt (1930-1966/I), p. 863, fig. 514; Hustedt (1955), p. 4, pl. 24; Witkowski et al. (2000), p. 33, pl. 3: 12, 13; Al-Yamani & Saburova (2011), p. 55, pl. 19: a-d

**Dimensions:** Valve length 23.3-37.0 μm, breadth 9.0-11.9 μm and 9-10 pervalvar rows in 10 μm. (n=3).

**Remarks:** Found in rock scrape (epilithon) and sand (epipsammon) samples. The taxon was first described from the Adriatic Sea by Grunow (*Cerataulus reichardtii*), later observed at Milos Island, South Aegean Sea (Louvrou, 2007). The distribution of *N. reichardtii* from the Mediterranean was expanded to other oceans with reports from the Virgin Islands and the Caribbean Sea by Boyer (1927) and tropical and subtropical waters by Witkowski et al. (2000).

*Eunotogramma* Weisse, 1854

*Eunotogramma marinum* (Smith) H. Peragallo & M. Peragallo (Fig. 2. B)

**Basionym:** *Himantidium marinum* Smith

**References:** Peragallo & Peragallo (1897-1908), p. 343, pl. 82:36; Witkowski et al. (2000), p. 32, pl. 10: 1-3

**Dimensions:** Valve length 20.5-26.3 μm, breadth 3.8 μm, 4 septa in 10 μm. (n=2).

**Remarks:** A few valves observed in the materials. Valves semi-lanceolate and transapical ribs observed both in girdle and valve view. The species was described from the Atlantic coasts of France (Peragallo & Peragallo, 1897-1908) and also reported from western Baltic Sea by Witkowski et al. (2000). Hendey (1974) reported the species from the British coasts, and it was reported from Guadeloupe Island in the western Atlantic coast (Loir, 2011-2014).

*Plagiogrammaceae*

*Dimeregramma* Ralfs, 1861

*Dimeregramma minus var. nanum* (Gregory) Van Heurck (Fig. 2. C)

**Basionym:** *Denticula nana* Gregory

**References:** Hustedt (1930-1966/II), p. 119, fig. 641; Witkowski et al. (2000), p. 29, pl. 11:3-9; Li et al. (2015).

**Dimensions:** Valve length 6.2-12.8 μm, breadth 3.5-5.6 μm and 10-15 striae in 10 μm. (n=5).

**Remarks:** Observed in epilithon. Valves rhombic with sternum broader than in the nominate variety, also differ in size. Here, the number of transapical striae (10-15 in 10 μm) is lower than the values given by Hustedt (1930-1966) and Witkowski et al. (2000) (14 in 10 μm). Distributed widespread in the oceanic coasts and the Mediterranean; Japan (Sato et al., 2008), South Africa (Giffen, 1975), Atlantic Ocean, Québec, (Poulin et al., 1984), and the Mediterranean, (Hustedt 1930-1966; Louvrou, 2007).

*Plagiogramma* Greville, 1859

*Plagiogramma pulchellum var. pygmaeum* (Greville) H. Peragallo & M. Peragallo (Fig. 2 D)

**Basionym:** *Plagiogramma pygmaeum* Greville

**References:** Peragallo & Peragallo (1897-1908), p. 338, pl. 82:3; Hustedt (1930-1966/II), p. 104, fig. 634; p. 338, pl. 82:3; Witkowski et al. (2000), p. 38, pl. 10:13; 11:29, 30

**Dimensions:** Valve length 21 μm, breadth 6.4 μm 7 striae in 10 μm. (n=1).

**Remarks:** Rarely occurred in the epilithic samples. Differs from the nominate variety by the smaller size. The taxon was reported from the Persian Gulf (Hendey, 1970), observed by Peragallo & Peragallo (1897-1908) from the Balearic Sea in the Mediterranean and Hustedt (1930-1966/II), from Oman and New Caledonia by Witkowski et al. (2000).

*Plagiogramma tenuissimum* Hustedt (Fig. 2. E)

**References:** Hustedt (1956), p. 106, fig. 6-8

**Dimensions:** Valve length 7.3-14.7 μm, breadth 2.0-2.7 μm, which is in accordance with original description by Hustedt (1956). (n=11).

**Remarks:** A few valves occurred in epilithon and epipsammon. Valves elliptical, in girdle view rectangular. Two internal, transapical ribs (pseudosepta) visible in both valve and girdle view. Hustedt (1956) described this species from Lago Maracaibo in Venezuela. Witkowski et al. (2000), p. 23, pl. 10: 33-35, identified this diatom as *Anaulus minutus* Grunow. *Plagiogramma tenuissimum* is recorded from the type habitat, Lago Maracaibo, Venezuela, a coastal lagoon that connects with the Caribbean Sea (Hustedt, 1956; Rodriguez, 2001) but also as an epiphyte from Brazilian coastal lagoons (Da Rosa & Garcia, 2015). Recently recorded for the first time for Black Sea flora from Crimea (Nevrova, 2016)

*Cymatosiraceae*

*Cymatosira* Grunow, 1862

*Cymatosira belgica* Grunow (Fig. 2. F)
**References:** Peragallo & Peragallo (1897-1908), p. 337, pl. 82:25; Witkowski et al. (2000), p. 27, pl. 10:18-22; Dąbek et al. (2017) fig. S1.: b.

**Dimensions:** Valve length 10.1-19.9 μm, breadth 3.1-5.0 μm and 11-13 striae in 10 μm. (n=11).

**Remarks:** Observed in epilithon. Marine and brackish water species (Kociółek et al., 2019). Possibly cosmopolitan species in marine coasts and brackish waters. It was reported from different coasts like Belgium, France (Peragallo & Peragallo, 1897-1908), Adriatic Sea (Vilicic et al. 2002), and the Atlantic coasts of Argentinian and Brazil (Garibotti et al., 2011; Garcia, 2016).

**Cymatosira lorenziana** Grunow (Fig. 2 G)

**References:** Peragallo & Peragallo (1897-1908), p. 337, pl. 82:24; Foged (1984), p. 31, pl. 28:1-3; Witkowski et al. (2000), p. 27, pl. 11:12-15; Al-Yamani & Saburova (2011), p. 56, pl. 20: e-g; Dąbek et al. (2017), fig. S1: c.

**Dimensions:** Valve length 12.3-24.3 μm, breadth 7.6-9.6 μm and 8-11 striae in 10 μm. (n=9).

**Remarks:** Found in epilithic samples. Differs from *C. belgica* by size and rhombic valve outline with acute endings. Species was described from the Adriatic Sea by Grunow and reported by Hafner et al. (2018a) also in the

**Fig. 2:** A. *Neohuttonia reichardtii* (Grunow) Hustedt; B. *Eunotogramma marinum* (Smith) H. Peragallo & M. Peragallo; C. *Dimeregramma minus* var. *nanum* (Gregory) Van Heurck; D. *Plagiogramma pulchellum* var. *pygmaeum* (Greville) H. Peragallo & M. Peragallo; E. *Plagiogramma tenuissimum* Hustedt; F. *Cymatosira belgica* Grunow; G. *Cymatosira lorenziana* Grunow; H. *Grammatophora angulosa* var. *mediterranea* Grunow; I. *Licmophora ehrenbergii* f. *grunowii* (Mereschkowsky) Hustedt; J. *Trachysphenia acuminata* Peragallo; K. *Delphineis minutissima* (Hustedt) Simonsen. Scale bar =10 μm.
Mediterranean observed by Hustedt (1930-1999/II) and Peragallo & Peragallo (1897-1908) from Villefranche coasts and reported from Kuwait (Hendey, 1970; Al-Yamani & Saburova, 2011) and Aegean Sea (Economou-Amilli, 1980; Foged, 1986). Taxa also have distribution in river estuary found in the USA (Manoylov & Dominy, 2013).

**Grammatophoraceae**

*Grammatophora* Ehrenberg, 1840

*Grammatophora angulosa var. mediterranea* Grunow (Fig. 2: H)

**References:** Peragallo & Peragallo (1897-1908), p. 358, pl. 88:18

**Dimensions:** Valve length 9.3-14.4 μm, breadth 9.3-16.8 μm in girdle view and 15-17 striae in 10 μm. (n=14).

**Remarks:** Found in epiphytic samples. Differs from the nominate variety by the striae density. This taxon is similar to *G. hamulifera*. However, in the latter taxon undulating septa end with a ridge in the middle. In *G. angulosa var. mediterranea* septa undulation is continuous. Observed valves agree with the description given by Peragallo & Peragallo (1897-1908).

**Licmophoraceae**

*Licmophora* Agardh, 1827

*Licmophora ehrenbergii f. grunowii* (Mereschkowsky) Hustedt (Fig. 2 I)

**Basionym:** *Licmophora grunowii* Mereschkowsky

**References:** Hustedt (1930-1966 / II), p. 70, fig. 594;

**Dimensions:** Valve length 84.1 μm, breadth 15.1 μm and 9 striae in 10 μm. (n=1).

**Remarks:** This taxon occurred as an epiphyte on seaweeds. Differs from *L. ehrenbergii* in terms of size and blunt wedge-shaped head pole. In the material studied, the nominate forma of *L. ehrenbergii* was found in epilithon samples and separated from *L. ehrenbergii* f. *grunowii* by wide wedge-shaped head-pole and larger size. Honeywill (1998) mentioned that the nominate forma of *L. ehrenbergii* has cuneate valve shape in girdle view and spathulate and robust valves. Taxa reported from the Black Sea, the Adriatic Sea and the Mediterranean Sea (Guiry & Guiry, 2019). Giffen (1971) found the species from the Atlantic Ocean coasts of South Africa, New Zealand and Australia (Giffen, 1966; Foged, 1978, 1979). Needs further biogeographic investigation for the Mediterranean, can be confused with *Neodetonia superba* (C. Janisch) S. Blanco.

**Fragilariaceae**

*Trachysphenia* Petit, 1877

*Trachysphenia acuminata* Peragallo (Fig. 2. J)

**References:** Hustedt (1955), p. 14, pl. 4:50-54; Witkowski et al. (2000), p. 84, pl. 24: 17-19

**Dimensions:** Valve length 11.5-17.8 μm, breadth 3.6-4.2 μm and 14-16 striae in 10 μm. (n=2).

**Remarks:** A few valves observed in epilithic samples. This taxon is distinguishable by produced rostrate apices and rhombic valves. According to Hustedt (1955), valve shape is characteristic and separates this species from *T. australis*. Reported from Mexican coasts (López-Fuerte & Siqueiros-Beltrones, 2016).

**Rhaphoneidaceae**

*Delphineis* Andrews, 1977

*Delphineis minutissima* (Hustedt) Simonsen (Fig. 2. K)

**Basionym:** *Rhaphoneis minutissima* Hustedt

**References:** Simonsen (1987), p. 252, pl. 374:10-16; Witkowski et al. (2000), p. 45, pl. 22: 11-14; Watanabe et al. (2013), fig. 1-15

**Dimensions:** Valve length 7.6 μm, breadth 6 μm, 12 transapical striae in 10 μm. (n=1).

**Remarks:** A few valves were observed. Valves are oblong with a very narrow sternum, transapical striae are punctate. It is easily overlooked due to the very small size. Taxa were described by Hustedt from North Sea (1939) and distributed to brackish waters of UK (Watanabe et al., 2013) to Atlantic coasts of Argentina (Sar et al., 2007)

*Delphineis* Andrews, 1977

*Delphineis cocconeiformis* (A. Schmidt) Blazé (Fig. 3. A)

**Basionym:** *Coscinodiscus cocconeiformis* Schmidt

**References:** Witkowski et al. (2000), p. 46, pl. 22:1, 2; 23:8-11; Al-Yamani & Saburova (2011), p. 62, Pl. 24: a-f

**Dimensions:** Valve diameter 18.2-23.3 μm and 13-15 striae in 10 μm. (n=6).

**Remarks:** Found in epilithic and epiphytic materials. Hendey (1970) observed the species from Kuwait and pointed out that the specimens he studied were almost circular. Reported from the same location by Al-Yamani & Saburova (2011), and from the oceanic coasts of South Africa, New Zealand and Australia (Giffen, 1966; Foged 1978, 1979). Needs further biogeographic investigation for the Mediterranean, can be confused with *Neodetonia superba* (C. Janisch) S. Blanco.

*Meloneis* Louvrou, Danielidis & Economou-Amilli, 2013 (Fig. 3. B)

*Meloneis mimallis* Louvrou, Danielidis & Economou-Amilli

**References:** Louvrou et al. (2012), p. 2, Figs. 1: A-E; 2: A-E

**Dimensions:** Valve length 19.6-30.4 μm, breadth 13.1-18 μm and 7-9 striae in 10 μm. (n=22).

**Remarks:** Observed on seaweeds but also in epilithon. This species has been described from the Greek coasts of the Aegean Sea (Louvrou et al., 2012). Valves observed have broader morphological distribution on the Turkish coast of the Aegean Sea. Reported from the Mallorca in the Mediterranean (Álvarez-Blanco & Blanco, 2014).

*Ardissoneaceae*

*Ardissonea* De Notaris, 1870

*Ardissonea crystallina* var. *dalmatica* (Kützing) Mills (Fig. 3. C)

**Basionym:** *Synedra dalmatica* Kützing

**Heterotypic synonym:** *Ardissonea fulgens* var. *dalmatica* *Kützing* Mills 1933

**References:** Peragallo & Peragallo (1897-1908), p. 311, pl. 79:4

**Dimensions:** Valve length 129.1-129.8 μm, breadth 8.0-10.8 μm and 16-18 striae in 10 μm. (n=2).
Remarks: Found in epilithic samples. In the material studied *A. crystallina* var. *dalmatica* accompanied *A. crystallina*. *Ardissonea crystallina* was observed and illustrated on İzmir region coasts by Aktan (2001) and Sabanci (2008). *Ardissonea crystallina* var. *dalmatica* differs from the nominate variety by the stria density. In the Mediterranean coasts, reported from Naples (Peragallo & Peragallo, 1897-1908).

*Achnanthes* Bory, 1822

*Achnanthes danica* (Flögel) Grunow (Fig. 3. D)

Basionym: *Cocconeis danica* Flögel

References: Peragallo & Peragallo (1897-1908), p. 7, pl. 2:1, 2; Witkowski *et al.* (2000), p. 88, pl. 51:23-25

Dimensions: Valve length 29.0-35.8 μm, breadth

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**Fig. 3:** A. *Diplomenora cocconeiformis* (Schmidt) Blaz̄e; B. *Meloneis mimallis* Louvrou, Danielidis & Economou-Amilli; C. *Ardissonea crystallina* var. *dalmatica* (Kützing) Mills; D. *Achnanthes danica* (Flögel) Grunow; E. *Planothidium lilljeborgei* (Grunow) Witkowski, Lange-Bertalot & Metzeltin; F. *Anorthoneis vortex* Sterrenburg; G. *Cocconeis diaphana* W. Smith; H. *Cocconeis dirupta* Gregory; I. *Cocconeis pelta* Schmidt; J. *Cocconeis peltoides* Hustedt. Scale bar = 10 μm.
11.0-11.5 μm and in SV (sternum view) 14 striae in 10 μm. (n=2).

**Remarks:** Found in the epilithical samples. The species is very similar to *Achnanthes fimbriata*. *A. fimbriata* has lanceolate valves with acutely rounded apices while *A. danica* has elliptic-lanceolate valves with slightly produced valve endings. In Witkowski *et al.* (2000) valve dimensions are given higher than *A. fimbriata* and *A. danica* has less stria in SV. Reported from the northern European coasts (Witkowski *et al.*, 2000).

**Planothidium Round & Bukhtiyarova, 1996**

**Planothidium lillicjeborgei** (Grunow) Witkowski, Lange-Bertalot & Metzeltin (Fig. 3. E)

**Basionym:** *Achnanthes lillicjeborgei* Grunow

**References:** Schmidt (1874-1959), pl. 420:8, 9; Peragallo & Peragallo (1897-1908), p. 8, pl. 2:6; Witkowski *et al.* (2000), p. 121, pl. 49:1, 51:27-29; Witon & Witkowski (2006a), figs.156, 157

**Dimensions:** Valve length 13.7-22.7 μm, breadth 6.4-8.8 μm and 10-13 striae in 10 μm. (n=4).

**Remarks:** Found in the epilithon. Only SV was observed. Distinct with a wide sterna covered by puncta. Loir (2010-2014) reported this taxon from the Adriatic Sea coast of Greece. Found in the Faeroe Islands (Witon *et al.*, 2006b), Northern European coasts (Hustedt & Al- eem, 1951).

**Cocconeidaceae**

**Anorhoneis** Grunow, 1868

**Anorhoneis vortex** Sterrenburg (Fig. 3. F)

**References:** Witkowski *et al.* (2000), p. 98, pl. 42:23-25; Lobban *et al.* (2012), p. 286, pl. 39:5

**Dimensions:** Valve length 12.4-13.8 μm, breadth 11.6-11.8 μm and 16-18 striae in 10 μm. (n=3).

**Remarks:** Observed both in epilithic and epiphytic samples. This species is similar to *Anorhoneis excen- trica* in valve outline and hyaline central area, however, *A. vortex* is smaller. A marine, euryhaline species, it has been reported from Guan (Lobban *et al.*, 2012), Baltic Sea (Snoeijfs & Vilbaste, 1994) and British Islands by Hendey (1964) and as *A. excen- trica* as mentioned in Witkowski *et al.* (2000).

**Cocconeis** Ehrenberg, 1836

**Cocconeis diaphana** Smith (Fig. 3. G)

**References:** Smith (1853), p. 22; fig. 254; Álvarez-Blanco & Blanco (2014), p. 18, pl. 22:9; 23: 21-25

**Dimensions:** Valve length 19.5-24.0 μm, breadth 6.1-7.3 μm and 12-14 striae in 10 μm. (n=2).

**Remarks:** Marine species. Striae barely visible in LM. In the material studied, only SV was observed. Reported from the Atlantic coasts of France (Smith, 1853) and Murcia in Spain by Álvarez-Blanco & Blanco (2014). This taxon resembles *Cocconeis molestula* Kützing. However, *C. molestula* has narrower valves (7-8 μm broad, Witkowski *et al.*, 2000; Riaux-Gobin & Compère, 2008) as compared to *C. diaphana*. Type material illustrations of *C. molestula* in Riaux-Gobin & Compère (2008) reveals distinctly bent raphe endings whereas *C. diaphana* the raphe endings are straight in SV.

**Cocconeis dirupta** Gregory (Fig. 3. H)

**References:** Schmidt A. (1874-1959), pl. 191, fig. 55; Hustedt (1930-1966 / II), p.354, fig. 809; Witkowski *et al.* (2000), p. 105, pl. 39: 1-5; 51: 5-8

**Dimensions:** Valve length 20.2 μm, breadth 11.4 μm and 23 striae in 10 μm. (n=3).

**Remarks:** A few valves were observed in the material studied. This species resembles *C. diaphana*, but its RV (raphe view) is characterized by the presence of a sigmoid raphe, and transverse fascia. Widespread in the Faeroe Islands (Witon *et al.*, 2006b) and more broadly, in the Atlantic Ocean (Stidolph, 2012). In the Adriatic reported by Hafner *et al.* (2018b).

**Cocconeis petlu Schmidt (Fig. 3. I)**

**References:** Schmidt A. (1874-1959), pl. 191, fig. 6; Giffen (1970), p. 271, fig. 27, 28; Witkowski *et al.* (2000), p. 111, pl. 41: 7-10

**Dimensions:** Valve length 17.3 μm, breadth 12.3 μm and 22 striae in 10 μm. (n=1).

**Remarks:** Only one SV valve was observed. It has a wide sternum. This taxon is spread across warmer waters (Giffen 1970; fig. 27) and also from the Baltic Sea (Witkowski *et al.*, 2000). This taxon also resembles *Cocco- neis germainii* Riaux-Gobin, Witkowski & Romero. *C. germainii* valves are small, narrower and elliptic (length: 9.7-13.2 μm, breadth: 5.7-4.2 μm; length: 11.5-2 μm, breadth: 5.8-8.5 μm) (Riaux-Gobin *et al.*, 2007, 2011, respectively), material observed in this study has broader valves but striae counts are similar to *C. germainii* (SV: 22.5-27 in 10 μm and 19.6-23.5 in 10 μm) Riaux-Gobin et al., 2007, 2011, respectively). Sar *et al.* (2003) observed the species with lower striae count (14-18 in 10 μm).

**Cocconeis petluoides** Hustedt (Fig. 3. J)

**References:** Snoeijfs & Vilbaste (1994), p. 31, fig. 119; Hartley *et al.* (1996), p.122, pl. 53:1; Witkowski *et al.* (2000), p. 112, pl. 38:1-9; Al-Yamani & Saburova (2011), p. 83, pl. 53: g, h

**Dimensions:** Valve length 9.0-10.4 μm, breadth 6.1-7.3 μm and 12-14 striae in 10 μm. (n=13).

**Remarks:** This is a cosmopolitan marine species. In SV valves the transapical striae are crossed by longitudinal lines between the valve middle and the margin. In the material studied here, the striae count was 12-14 in 10 μm, which is slightly lower than given in Witkowski *et al.* (2000). Hendey (1964, 1970) observed this species in mud, on dead seaweeds or attached to sand grains. In Dalyan, this taxon was observed in the epilithon and epipsammon. In the Mediterranean observed in Neum Bay, Bosnia & Herzegovina (Hafner *et al.*, 2018b).

**Sellaphoraceae**

**Fallacia** Stickle & Mann, 1990

**Fallacia pseudony** (Hustedt) Mann (Fig. 4. A)

**Basionym:** *Navicula pseudony* Hustedt

**References:** Hustedt (1955), p. 22, pl. 8:6,7; Simon- sen (1987), p. 408, pl. 611:20-24; Round *et al.* (1990) p. 669, Witkowski *et al.* (2000), p. 210, pl. 71:23-30
Atlantic Ocean and elsewhere (e.g., Riberio, 2010). This species has a very broad distribution in the habitat was Beaufort Bay, East Coast of the United States with lower stria density (21 in 10 μm.). Hustedt’s type the species on the coasts of South Africa found the taxon forms (2000) agree F. pseudony F. oculi-

1966) (28-32 in 10 μm). It was previously recorded in the lower than indicated in the description of Hustedt (1930-1966) LM. In valves illustrated here, the stria density is slightly

9.1 μm and 26 striae in 10 μm. (n=5).

Remarks: Valves were found in the epipsammon. Transapical striae of this species are difficult to resolve in LM. In valves illustrated here, the stria density is slightly lower than indicated in the description of Hustedt (1930-1966) (28-32 in 10 μm). It was previously recorded in the North Sea (Hustedt 1930-1966) and from the Mediterranea

...nean Sea (Witkowski et al., 2000).

Mastogloia crucicula (Grunow) Cleve (Fig. 4. C)

Basionym: Orthoneis crucicula Grunow

References: Cleve (1895), p.148; Hustedt (1955), p. 19, pl. 6:12; Hendey (1970); p. 145, pl.1:8; Witkowski et al. (2000), p. 242, pl. 75:3; Lobban et al. (2012), p. 270, pl. 26:6-7; 27:1; Loir & Novarino (2014), p. 25 pl. 6: b

Dimensions: Valve length 9.9-18.6 μm, breadth 6.1-8.4 μm and 18-21 striae in 10 μm. (n=7).

Remarks: Commonly occurred in epiphytic samples from the Dalyan beach and Süliklü Lake. This taxon possesses a distinct transverse fascia in the middle which reaches the valve margins. Partecta interrupted in the middle, 4 partecta in 10 μm observed. Reported by Loir (2010-2014) from the Greek Islands and Louvrou (2007) from Milos Island. Foged (1986) observed reported taxa from the Aegean coasts of Greece. In the Adriatic Coasts found by Hafner et al. (2018a) and in the Mediterranean by Loir (2011-2014).

Mastogloia emarginata Hustedt (Fig. 4. D)

References: Hustedt (1930-1966 / II), p. 476, fig. 896; Simonsen (1987), p. 94, pl. 134:5-7

Witkowski et al. (2000), p. 245, pl. 77: 9-12

Dimensions: Valve length 19.8 μm, breadth 9.5 μm and 23 striae in 10 μm. (n=1).

Remarks: This taxon was observed in the epilithon. Partecta is weakly silicificated. The raphe is slightly undulating. Witkowski et al. (2000) indicated in Hustedt’s drawings and Simonsen’s micrographs there are two different taxa present. Here, our specimens agree with the micrographs in Witkowski et al. (2000). The species was previously reported from the Aegean Sea by Loir (2010-2014) and Foged (1986).

Mastogloia ovalis Schmidt (Fig. 4. E)

References: Witkowski et al. (2000), p. 255, pl. 75:11-13; Lobban et al. (2012), p. 279, pl. 33:4-6; Loir & Novarino (2014), p. 39, pl. 17: a

Dimensions: Valve length 14.5-17.1 μm, breadth 8.2-9.8 μm and 16-19 striae in 10 μm. (n=9).

Remarks: Observed both in the epilithic and epiphytic samples. Valves elliptic, partecta in the middle, 3 in 10 μm. Reported from the Mediterranean by Hustedt (1930-1966) and Aegean Sea (Foged, 1986; Loir, 2010-2014).

Brachysiraceae

Brachysira Kützing, 1836

Brachysira estonianum Witkowski, Lange-Bertalot & Metzeltin (Fig. 4. F)

References: Witkowski et al. (2000), p. 160, pl. 134:1-4

Dimensions: Valve length 19.6-26.4 μm, breadth 3.6-4.0 μm. (n=4).

Remarks: This taxon was observed in epilithic samples. This is a marine to brackish water species. This taxon resembles B. aponina; however, B. estonianum valves are smaller and narrower (Witkowski et al. 2000 indicated B. aponina 14-35 μm long and 4-5.5 μm wide and B. estonianum 11.5-29 μm long and 3-3.5 μm wide). Striae of both species are not resolvable in LM. This species was observed from Estonia and Mississippi Delta by Witkowski et al. (2000), Karstic wetlands of Central America (La Hee, 2010) and in samples from the Adriatic Sea surrounding the Dubrovnik area (Witkowski & Car, unpublished observations).

Naviculaceae

Caloneis Cleve, 1894

Caloneis liber (Smith) Cleve (Fig. 4. G)

Basionym: Navicula liber Smith

Heterotypic Synonyms: Navicula maxima Gregory 1855, Navicula liber var. maxima (Gregory) Grunow 1867, Caloneis liber var. maxima (Gregory) Jørgensen 1905, Caloneis liber var. maxima (Gregory) Frenguelli 1939

References: Cleve (1894-1895), p. 54; Peragallo & Peragallo (1897-1908), p. 71, pl. 9:5; Hendey (1964), p.229, pl. 29:2; Hartley et al. (1996), p. 102, pl. 43:1; Witkowski et al. (2000), p.166, pl.152-9

Dimensions: Valve length 49.7-51.4 μm, breadth 8.5-8.9 μm and 18 striae in 10 μm. (n=2).

Remarks: This taxon was found in the material studied. The species is considered cosmopolitan, an inhabitant of the marine littoral zone. This species has been reported from the Aegean Sea by Economidou-Amillii (1980). In the Adriatic Sea reported by Hafner et al. (2018b). Caloneis liber var. linearis was observed in the brackish Homa Lagoon in central Aegean coasts of Turkey (Çolak Sabancı, 2008).
Navicula Bory, 1822
Navicula arenaria var. rostellata Lange-Bertalot (Fig. 4. H)

References: Witkowski et al. (2000), p. 267, pl. 116: 18-20; 129: 29

Dimensions: Valve length 32.1 μm, breadth 7.5 μm and 9 striae in 10 μm. (n=1).

Remarks: This taxon is differentiated by having a large central area where transapical striae are interrupted at the margins. Navicula arenaria var. rostellata differs from the nominate variety by the linear-lanceolate valves. It occurred in epilithon samples in the present study and was previously reported from Crete by Loir (2010-2014).

Navicula lusoria Giffen (Fig. 4. I)

References: Giffen (1975), p. 84, figs. 75-77; Witkowski et al. (2000), p. 289, pl. 129: 11-14

Dimensions: Valve length 24.3 μm, breadth 7.8 μm and 13 striae in 10 μm. (n=1).

Remarks: Valves are elliptical, with transapical striae in the middle strongly radiate. This taxon was described from South Africa Giffen (1975) and has also been reported from Mexico (López-Fuerte & Siqueiros-Beltrones, 2016), from Crete (Loir, 2010-2014) and the Aegean Sea (Louvrour, 2007).

Proschkiniaeae
Proschkinia Karayeva, 1978
Proschkinia bulnheimii (Grunow) Karayeva (Fig. 4. J)
Basionym: Navicula bulnheimii Grunow

References: Witkowski et al. (2000), p. 340, pl. 147: 14-17

Dimensions: Valve length 28.9 μm, breadth 4 μm. (n=1).

Remarks: This taxon was found in the epilithic material, but scarce. In the central area, a fistula is resolvable from the nominate variety by the linear-lanceolate valves. This species was observed widely, but was somewhat more abundant in epilithon samples. Valves are lanceolate with weakly capitulate endings, while the transapical striae are discernible in LM. This species resembles N. amabilis Suzuki in terms of valve outline. However, N. amabilis is less constricted in the middle, and the valve endings are short, rostrate, while in P. rudum the apices are roundly produced.

Catenulaceae
Amphora Ehrenberg ex Kützing, 1844
Amphora cymbamphora Cholnoky (Fig. 4. K)

References: Witkowski et al. (2000), p. 136, pl. 164: 26-28

Dimensions: Valve length 33.5-36.5 μm, breadth 5.9-7.0 μm and 12-13 dorsal striae in 10 μm. (n=6).

Remarks: This species was observed in epipsammic samples, inhabiting brackish to marine waters. Distinct with the narrow axial area and straight ventral margin. Valves observed here are slightly longer than reported by Witkowski et al. (2000). Also, it was observed in the brackish Sülüklü Lake near the coast of Dalyan. Louvrour (2007) reported the species from the Aegean Sea.

Catenula Mereschkowsky, 1903
Catenula adhaerens (Mereschkowsky) Mereschkowsky (Fig. 4. L)

Basionym: Navicula adhaerens Mereschkowsky

References: Witkowski et al. (2000), p. 168, pl. 170: 1-12

Dimensions: Valve length 16.0-18.3 μm, breadth 2.0-2.5 μm. (n=4).

Remarks: This taxon was observed in epilithon samples. Valves are semi-elliptic in shape. Striae discernible in LM. Sabbe & Vyverman (1995) and Tremaarin & Ludwig (2008), reported on the occurrence of C. adhaerens in estuarine sites. Widespread taxa (Guiry & Guiry, 2019).

Tetramphora Mereschkowsky, 1903
Tetramphora sulcata (Brébisson) Stepanek & Kociolek (Fig. 4. M)

Basionym: Amphora sulcata Brébisson

References: Peragallo & Peragallo (1897-1908), p. 213, pl. 47:7; Wachnicka & Gaiser (2007), p. 418, figs. 113-115; Stepanek & Kociolek (2016), p. 128, figs. 22-30

Dimensions: Valve length 27.7 μm, breadth 5.3 μm and 20 dorsal striae in 10 μm. (n=1).

Remarks: This taxon was observed in samples from the epilithon. Specimens observed in this study are slightly smaller than given by Stepanek & Kociolek (2016, 35-58 μm long). However, other characters, including arched dorsal margin and bi-arcuate raphe, agree well with the description of Stepanek & Kociolek (2016) and illustration in Peragallo & Peragallo (1897-1908).

Bacillariaceae
Nitzschia Hassall, 1845
Nitzschia aequorea Hustedt (Fig. 4. N)

References: Simonsen (1987), p. 262, pl. 382:15-20; Witkowski et al. (2000), p. 367, pl. 210: 14, 15

Dimensions: Valve length 18.1-22.9 μm, breadth 3.1-3.8 μm and 15-16 fibulae in 10 μm. (n=4).

Remarks: This taxon was observed widely, but was somewhat more abundant in epilithon samples. Valves are lanceolate with weakly capitulate endings, while the transapical striae are discernible in LM. Reported from South African coasts by Cholnoky (1961) and Giffen (1975).

Nitzschia amabilis Suzuki (Fig. 4. O)

Heterotypic Synonym: Nitzschia laevis Hustedt 1939, non Nitzschia levis (laevis) Frenquelli 1923

References: Witkowski et al. (2000), p. 387, pl. 190:1-6; Suzuki et al. (2010), p. 223; Rivera & Cruces (2011), p. 95, fig. 1

Dimensions: Valve length 14.4-15.6 μm, breadth 4.5-5.8 μm and 9-10 fibulae in 10 μm. (n=2).

Remarks: This taxon was found in epilithon samples. This species resembles Psammodium cyanum in terms of valve outline. However, N. amabilis is less constricted in the middle, and the valve endings are short, rostrate, while in P. cyanum the apices are roundedly produced. A new name was proposed by Hid. Suzuki in Suzuki et al. (2010) for this taxon. Reported from Chile coasts (Rivera & Cruces, 2011). Widespread marine species (Witkowski et al., 2000).
**Nitzschia nanodissipata** Chunlian Li & Witkowski

**References:** Witkowski *et al.* (2016), p. 188, fig. 3-d

**Dimensions:** Valve length 13.7 μm, breadth 2.7 μm and 8 fibulae in 10 μm. (n=1).

**Remarks:** This taxon occurred in the epiphytic material. It may be confused with *Nitzschia dissipata*; however, *N. nanodissipata* is much smaller. Dimensions of specimens studied here conform to those of *N. nanodissipata* (Witkowski *et al.*, 2016).
Nitzschia valdestriata Aleem & Hustedt (Fig. 4. Q)

References: Aleem & Hustedt (1951), p. 19, fig. 5; Simonsen (1987), pl. 551:9-13; Snoeijis & Vilbaste (1994), p. 86, fig. 174; Hartley et al. (1996), p. 402, pl. 193:3; Witkowski et al. (2000), p. 407, pl. 203:19-21; 207:14-16

Dimensions: Valve length 4.3-16.8 μm, breadth 2.1-2.8 μm and 16-19 striae in 10 μm. (n=120).

Remarks: This taxon was observed in epilithon and epiphyton samples, but dominant in the epiphytic samples. This taxon is characterized as a cosmopolitan marine to freshwater species (Guiry & Guiry, 2019).

Psammodictyon D.G.Mann, 1990

Psammodictyon panduriforme var. continuum (Grunow) Snoeijis (Fig. 4. R)

Basionym: Nitzschia panduriformis var. continua Grunow

Heterotypic synonym: Nitzschia panduriformis var. continua Grunow 1880

References: Krammer & Lange-Bertalot (1988), fig. 38:6, 7; Snoeijis & Balashova (1998), p. 88; Witkowski et al. (2000), p. 398, pl. 183:6

Dimensions: Valve length 12.2-17.1 μm, breadth 4.9-6.3 μm and 20-21 striae in 10 μm. (n=3).

Remarks: This taxon was observed in epilithon samples. It differs from the nominate variety by its smaller size and panduriform valve shape (Witkowski et al., 2000). Snoeijis & Balashova (1998) reported taxa from the Baltic Sea, also found in the Adriatic (Hafner, 2018) and the Black Sea (Nevrova, 2016).

Tryblionella Wm.Smith, 1853

Tryblionella marginulata (Grunow) D.G.Mann (Fig. 4. S)

Basionym: Nitzschia marginulata Grunow

References: Round et al. (1990), p. 678; Witkowski et al. (2000), p. 392, pl. 183:4, 5

Dimensions: Valve length 35 μm, breadth 10.7 μm and 16 striae in 10 μm. (n=1).

Remarks: This taxon was observed in epilithic samples. It is a marine to brackish-water species. It was reported previously from Aegean coasts (Loir, 2010-2014) and Black Sea (Nevrova, 2016).

Discussion

Marine benthic diatom taxonomy of Turkish coastal waters is a relatively new area of research. Some previous studies and checklists regarding marine diatoms have been prepared; however, the number of taxa reported so far is relatively low. Checklists (Koray 2001; Balkis, 2004; Aysel, 2005; Taş & Okuş, 2006) and some other taxonomical research (Ehrenberg, 1844; Hustedt, 1930-1966; Çolak Sabanci, 2013; Çolak et al., 2010, 2014; Kaleli et al., 2017) revealed that 65 centric diatoms and 249 pinnate diatoms (for a total of 304 taxa) have been documented for the Turkish coasts so far. In these surveys, the Black Sea and Sea of Marmara were the areas where most taxa have been reported. Navicula (46 taxa), Nitzschia (30 taxa) and Mastogloia (22 taxa) are the genera with the highest numbers of taxa represented. This study contributes additional taxa to the checklist of marine diatoms of Turkey for these genera: 2 for Navicula, 4 for Nitzschia and 3 for Mastogloia. Additionally, this study adds nine additional genera to the list of Turkish marine benthic diatoms. However, insufficient data from the region has been a difficulty for comparisons of species distributions in the Aegean Sea. The present report is the first study of marine diatoms from the Dalyan region. On the other hand, there have been a few previous studies on marine diatoms (Çolak, 2008) from Turkey, and from the other side of the Aegean Sea (Economou-Amili, 1980; Foged, 1986; Louvrou et al., 2012; Loir, 2010-2014). In these studies, some taxa were discussed biogeographically and taxonomically. Although there were not many records of diatoms from the region, some species habitat information was mentioned as additional data in these studies.

From a biogeographic point of view, Neohuttonia richarditi was reported from the tropics and subtropics (in Kuwait by Al-Yamani & Saburova (2011) and in Tanzania by Foged (1975). Cymatosira belgica and C. lorenziana were found in the epilithon in Dalyan coasts. These taxa were previously reported from the Mediterranean (Alvez-Blanco & Blanco, 2014) and Greece (Loir, 2010-2014), being more abundant from warm waters (Witkowski et al. 2000). Meloneis mimallis was described from Aegean coasts of Greece (Louvrou et al. 2012); this is the second record of that species from the Aegean Sea. Planothidium lilljeborgei has been reported from Faeroe Islands Fjords (Witon & Wittkowski, 2006a) extending its biogeography to cold waters. Other species also reported by Witon & Wittkowski (2006a,) such as Cocconeis dirupta, were also observed at Dalyan.

A number of the recorded taxa and their distributions, in general, reveal that this coastline integrates species from both warm water environments as well as cold water environments. That might indicate that the flora could be quite extensive; unique not in new species, but unique in community composition, supporting species from very different temperature regimes.

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