

New records and rare taxa for the freshwater algae of Turkey from the Tatar Dam Reservoir (Elazığ)

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Received: 28.10.2017 • Accepted/Published Online: 03.04.2018 • Final Version: 24.07.2018

Abstract: Recently, the number of algological studies in Turkish inland waters has increased remarkably. However, taxonomic and floristic studies on algae in the Euphrates basin are still scarce. This study contributes new information to the knowledge of the Turkish freshwater algal flora. Phytoplankton samples were collected from the Tatar Dam Reservoir in the Euphrates Basin between January 2016 and December 2016. Two taxa were recorded for first time and 14 rare taxa for the freshwater algae of Turkey were identified in this study. The new records belong to the phylum Bacillariophyta, whereas taxa considered as rare belong to the phyla Chlorophyta, Cyanobacteria, Rhodophyta, Charophyta, Euglenophyta, and Bacillariophyta. The morphology and taxonomy of these taxa are briefly described in the paper and original light microscopy illustrations are provided.

Key words: Freshwater algae, new records, rare taxa, Tatar Dam Reservoir, Turkey

1. Introduction

Algae are the undisputed primary producers in aquatic ecosystems. They play also an important role in biological monitoring programs since these organisms reflect the health of their environment through their abundance and diversity. Therefore, they are widely used as indicators of water quality and the pollution status of freshwater ecosystems (Stevenson et al., 1996).

The number of algological studies in inland waters of Turkey has seen a marked increase in recent years (Varol and Fucikova, 2015). In the checklist of the freshwater algae of Turkey (Aysel, 2005), a total of 2030 taxa were reported. Later, new records of freshwater algae from new localities have been continuously added (Sevindik et al., 2011; Varol and Fucikova, 2015; Solak et al., 2018). The Euphrates and Tigris basins are among the most important regions of Turkey in terms of floristics and environmental conservation. However, taxonomic and floristic studies on algae in these basins are still scarce. The aim of the present study was to contribute to knowledge of the freshwater algal flora of Turkey, with special attention to new records and rare taxa of algae from the Tatar Dam Reservoir in the Euphrates Basin.

2. Materials and methods

2.1. Study area

The Tatar Dam Reservoir is located on the border of Elazığ and Tunceli provinces in eastern Anatolia (Figure 1). The dam reservoir was formed on the Peri Stream, which is a tributary of the Euphrates River. It has a surface area of 10.83 km² and a volume of 299.57 × 10⁶ m³. The Tatar Dam was erected for hydroelectric power generation in 2013.

2.2. Sampling and identification

Phytoplankton samples were taken monthly from five sampling stations in the Tatar Dam Reservoir between January 2016 and December 2016. The samples were collected using a plankton net with a mesh size of 55 µm and fixed with formaldehyde in the field. Permanent slides for detailed diatom observation, together with temporary slides for identification of other algal groups were prepared and examined microscopically with an Olympus BX53 microscope. Photographs were taken using Kameram 5 CMOS digital camera. Identified algal species were checked with the checklist published by Aysel (2005) and the database of Turkish algae (Gönülol, 2017), and determined as new records or rare taxa for Turkish freshwater algal flora. Relevant taxonomic sources are noted for each taxon. The nomenclature follows Guiry and Guiry (2017).

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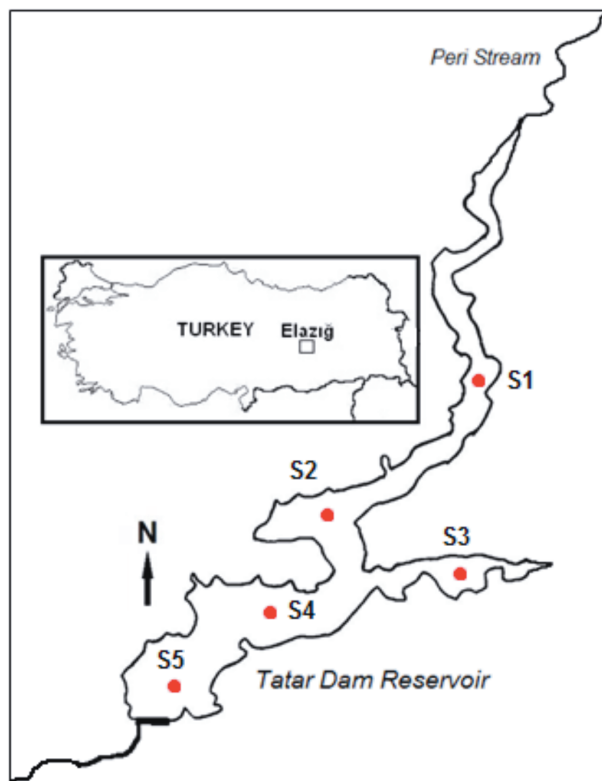


Figure 1. Map showing study area and sampling stations.

Turkey has highly diverse inland waters, such as lakes, ponds, reservoirs, canals, rivers, and streams. There are 25 river basins, 120 natural lakes, and 706 dam reservoirs within the borders of Turkey. In the present study, taxa identified in a limited number of freshwater locations are categorized as rare taxa. There are studies reporting algal flora of more than 200 freshwater locations and rare taxa are defined as taxa identified in less than 5% of these locations.

3. Results

A total of 16 species, of which two are new records and 14 are rare taxa for the freshwater algae of Turkey, were identified in this study. General information on the morphology and taxonomy of these taxa is given below.

3.1. Taxa belonging to the phylum Cyanobacteria

Class: Cyanophyceae

Subclass: Nostocophycidae

Order: Nostocales

Family: Nostocaceae

Genus: *Anabaena* Bory de Saint-Vincent & Flahault

Species: *Anabaena minderi* Huber-Pestalozzi (Figures 2a–2c)

Reference: Komarek (2013)

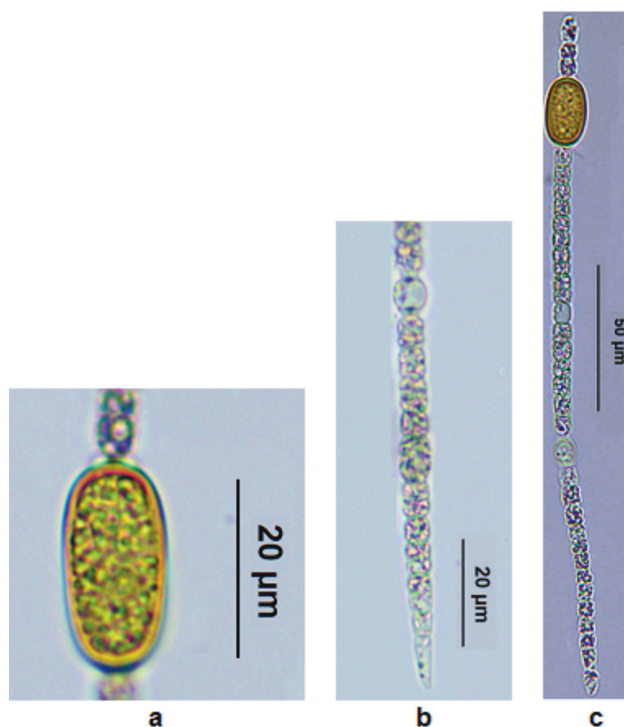


Figure 2. The shape of akinete (a), terminal cell and heterocyte (b), and trichome (c) of *Anabaena minderi*.

Heterotypic Synonym: *Anabaena bergii* var. *limnetica* Couté & Preisig

Description: Trichome length 240 µm, akinete length 22 µm × 12 µm width, heterocyte diameter 6–7 µm. Akinetes were brownish-green, with smooth walls, shape elongated oval. Trichomes had 1–2 heterocytes. Heterocytes were almost spherical.

Distribution in Turkey: Hirfanlı Dam Lake (Baykal and Açıkgöz, 2004), Menzelet, Tahtalı, and Porsuk reservoirs, and Eğirdir Lake (Köker et al., 2017).

3.2. Taxa belonging to the phylum Bacillariophyta

Subphylum: Bacillariophytina

Class: Bacillariophyceae

Subclass: Bacillariophycidae

Order: Cymbellales

Family: Gomphonemataceae

Genus: *Gomphonema* Ehrenberg

Species: *Gomphonema subclavatum* var. *mexicanum* (Grunow) R.M.Patrick (Figures 3a, 3b)

Reference: Kociolek (2011)

Basionym: *Gomphonema commutatum* var. *mexicanum* Grunow

Homotypic Synonym: *Gomphonema commutatum* var. *mexicanum* Grunow

Heterotypic Synonym: *Gomphonema mexicanum* Grunow

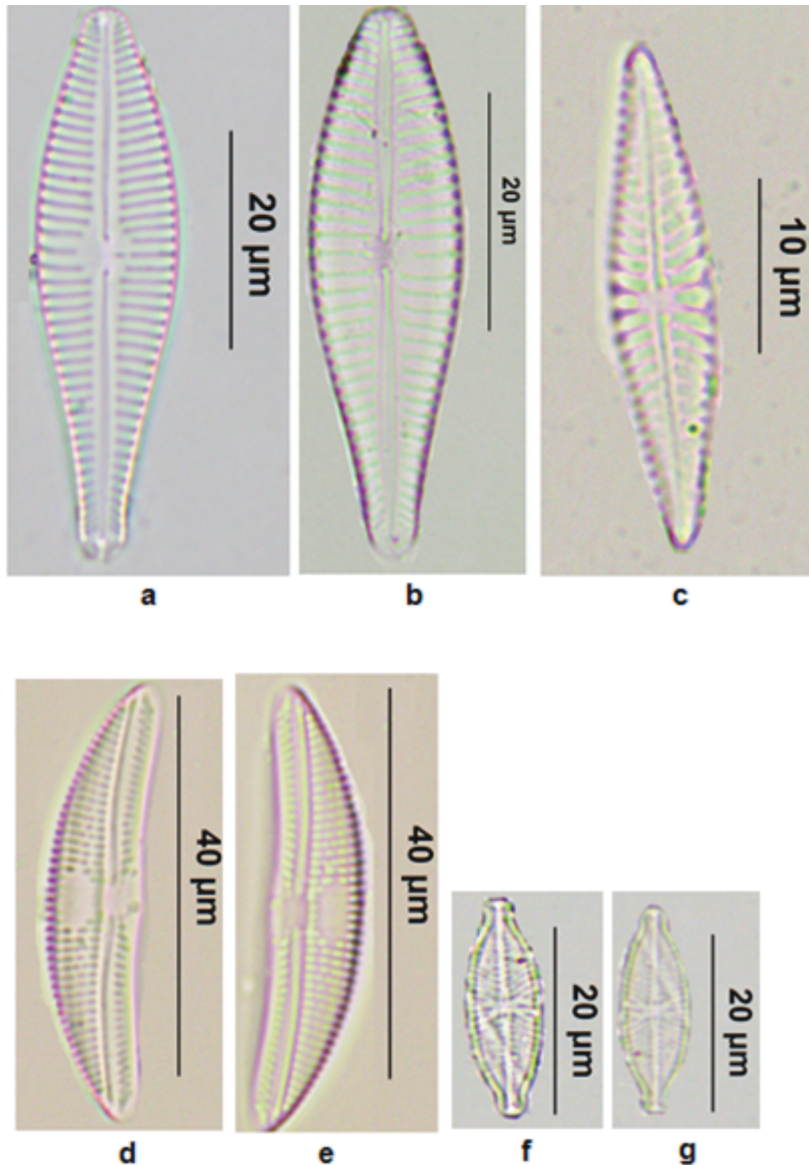


Figure 3. *Gomphonema subclavatum* var. *mexicanum* (a, b), *Hippodonta jakubii* (c), *Amphora copulata* (d, e), *Navigeia decussis* (f, g).

Description: Length 47–49 µm, breadth 12 µm, striae number 10 in 10 µm. Valves are elliptical-clavate with the headpole produced slightly and broadly rostrate and footpole rounded. A single stigma is present in the central area.

Distribution in Turkey: Uzungöl (Şahin, 1998).

Subphylum: Bacillariophytina

Class: Bacillariophyceae

Subclass: Bacillariophycidae

Order: Naviculales

Suborder: Naviculineae

Family: Naviculaceae

Genus: *Hippodonta* Lange-Bertalot, Witkowski & Metzeltin

Species: *Hippodonta jakubii* Kulikovskiy, Lange-Bertalot & Metzeltin (Figure 3c)

Reference: Kulikovskiy et al. (2012)

Description: Length 26 µm, breadth 6 µm, striae number 12 in 10 µm. Frustules rectangular, valves rhombic-lanceolate with long-protracted, narrowly rounded valve ends, striae coarse, strongly radiate at middle, becoming clearly convergent toward valve ends.

Notes: The single individual depicted here does not fit exactly with the type specimen described in the protologue of this species, particularly regarding the shape of the poles and the striation pattern. The conspecificity between *H. jakubii* and *H. arkonensis*, as suggested by Pavlov et al. (2013), can be ruled out (compare Lange-Bertalot et al.,

1996, p. 252, Fig. 4: 11–18 with Kulikovskiy et al., 2012, p. 414, Fig. 66: 28–32)

Distribution in Turkey: New record.

Subphylum: Bacillariophytina

Class: Bacillariophyceae

Subclass: Bacillariophycidae

Order: Thalassiosiphales

Family: Catenulaceae

Genus: *Amphora* Ehrenberg ex Kützing

Species: *Amphora copulata* (Kützing) Schoeman & R.E.M. Archibald (Figure 3d, 3e)

Reference: Stepanek and Kociolek (2011)

Basionym: *Frustulia copulata* Kützing

Homotypic Synonym: *Frustulia copulata* Kützing

Description: Valves semilanceolate to semielliptical, length 46 µm, breadth 8 µm, striae number 14 in 10 µm, dorsal and ventral fascia present, raphe positioned near the ventral margin.

Distribution in Turkey: New record.

Subphylum: Bacillariophytina

Class: Bacillariophyceae

Subclass: Bacillariophycidae

Order: Naviculales

Suborder: Naviculineae

Family: Naviculaceae

Genus: *Navigeia* L.N. Bukhtiyarova

Species: *Navigeia decussis* (Østrup) Bukhtiyarova (Figure 3f, 3g)

Reference: Potapova (2009)

Basionym: *Navicula decussis* Østrup

Homotypic Synonym: *Navicula decussis* Østrup, *Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin

Description: Valves elliptical-lanceolate with rostrate to capitate apices. Short and long striae alternate in the central valve, striae radiate, usually bent. Length 23 µm, breadth 7 µm, 16 striae in 10 µm.

Distribution in Turkey: Aras River (Altuner, 1988), Hirfanlı Dam Lake (Baykal and Açıkgöz, 2004), Karagöl (Açıkgöz and Baykal, 2005), Felent Creek (Solak et al., 2012), Tigris River (Varol and Şen, 2014).

Subphylum: Coscinodiscophytina

Class: Coscinodiscophyceae

Subclass: Melosirophyceae

Order: Melosirales

Family: Paraliaceae

Genus: *Ellerbeckia* R.M. Crawford

Species: *Ellerbeckia arenaria* (G. Moore ex Ralfs) R.M. Crawford (Figure 4a, 4b)

Reference: Bahls (2012)

Basionym: *Melosira arenaria* G. Moore ex Ralfs

Homotypic Synonyms: *Melosira arenaria* G. Moore ex Ralfs, *Lysigonium arenarium* (Moore) Trevisan, *Orthoseira arenaria* (G. Moore ex Ralfs) W. Smith, *Gaillonella arenaria* (Moore) Pelletan, *Paralia arenaria* (Moore) Moisseeva

Description: 62–65 µm diameter. It has robust, drum-shaped frustules that are linked by their valve faces to form long filamentous colonies. The interlocking ridges and grooves on linking valves extend to the valve margin.

Distribution in Turkey: Lake Çıldır (Akbulut and Yıldız, 2002), Karagöl (Açıkgöz and Baykal, 2005), Lake Abant (Çelekli and Küllköylüoğlu, 2006), Sakarya River catchment (Solak et al., 2018).

Subphylum: Coscinodiscophytina

Class: Coscinodiscophyceae

Subclass: Coscinodiscophycidae

Order: Coscinodisciales

Family: Coscinodiscaceae

Genus: *Lindavia* (Schütt) De Toni & Forti

Species: *Lindavia praetermissa* (Lund) T. Nakov et al. (Figure 4c)

Reference: Bahls (2013)

Basionym: *Cyclotella praetermissa* J.W.G. Lund

Homotypic Synonyms: *Cyclotella praetermissa* J.W.G. Lund, *Handmannia praetermissa* (J.W.G. Lund) Kulikovskiy & Solak

Description: Cells are cylindrical with shallow mantles, 14 µm diameter. The valve face is nearly flat, with a marginal ring of short striae and a central area of many scattered, uniform-sized, and evenly-spaced areolae.

Distribution in Turkey: Lake Abant (Çelekli and Küllköylüoğlu, 2006), Sakarya River basin (Solak and Kulikovskiy, 2013), Marmara River catchment (Solak et al., 2018).

Subphylum: Bacillariophytina

Class: Mediophyceae

Subclass: Thalassiosirophyceae

Order: Stephanodiscales

Family: Stephanodiscaceae

Genus: *Stephanodiscus* Ehrenberg

Species: *Stephanodiscus neoastreae* Håkansson & Hickel (Figure 4d)

Reference: Håkansson (2002)

Description: Valves are circular and large, 27 µm diameter. The structure of the valve edge is irregular. The central valve face areolae are irregularly arranged. The spines are present and they occur irregularly.

Distribution in Turkey: Çaygören and İkizcetepeler reservoirs (Sevindik et al., 2011), Pulur Creek (Fakioğlu et al., 2012), Akarçay River catchment (Solak et al., 2018).

Subphylum: Bacillariophytina

Class: Mediophyceae

Subclass: Thalassiosirophyceae

Order: Stephanodiscales

Family: Stephanodiscaceae

Genus: *Cyclotella* (Kützing) Brébisson

Species: *Cyclotella cretica* var. *cyclopuncta* (H. Håkansson & J.R. Carter) R. Schmidt (Figure 4e, 4f)

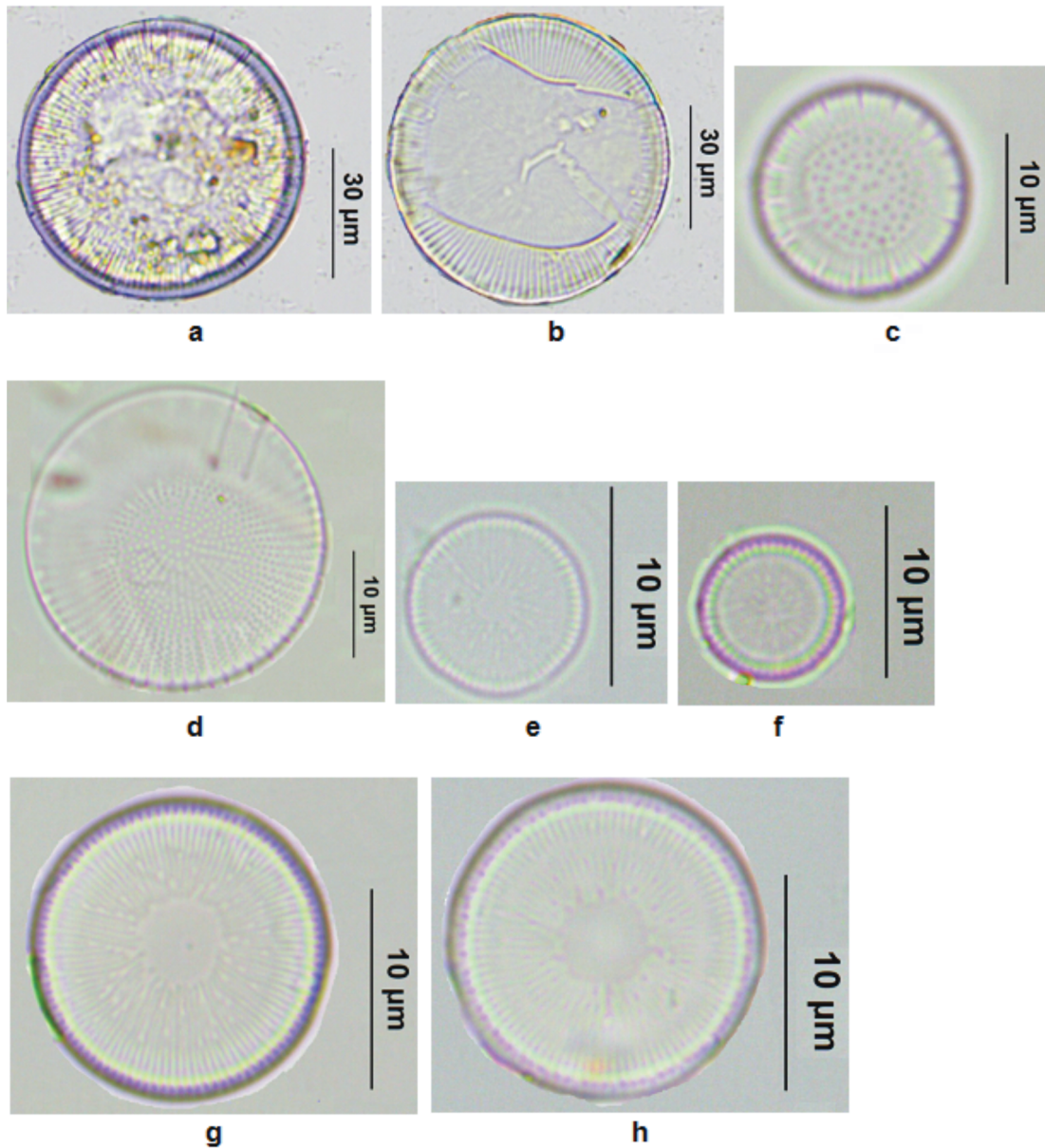


Figure 4. *Ellerbeckia arenaria* (a, b), *Lindavia praetermissa* (c), *Stephanodiscus neoastraea* (d), *Cyclotella cretica* var. *cyclopuncta* (e, f), *Pantocsekiella iranica* (g, h).

Reference: Hakansson (2002)

Basionym: *Cyclotella cyclopuncta* Håkansson & J.R.Carter

Homotypic Synonym: *Cyclotella cyclopuncta* Håkansson & J.R.Carter

Description: 8 µm diameter. The central area has one single, eccentrically placed fultoportula. The marginal striae and interstriae are of slightly unequal length, about 20 in 10 µm. The most important morphological character is the hollows in the marginal area, close to the valve face/mantle junction.

Distribution in Turkey: Tigris River (Varol and Şen, 2014).

Subphylum: Bacillariophytina

Class: Mediophyceae

Subclass: Thalassiosirophyceidae

Order: Stephanodiscales

Family: Stephanodiscaceae

Genus: *Pantocsekiella* K.T.Kiss & E.Ács

Species: *Pantocsekiella iranica* (T.Nejadsattari, S.Kheiri, S.Spaulding & M.Edlund) K.T.Kiss, L.Ector & E.Ács (Figure 4g, 4h)

Reference: Kheiri et al. (2013)

Basionym: *Cyclotella iranica* T.Nejadsattari, S.Kheiri, S.Spaulding & M.Edlund

Homotypic Synonyms: *Cyclotella iranica* T.Nejadsattari, S.Kheiri, S.Spaulding & M.Edlund, *Lindavia iranica* (T.Nejadsattari, S.Kheiri, S.Spaulding & M.Edlund) T.Nakov et al.

Description: Frustules cylindrical, valves disc-shaped, valve face smooth, flat with alveolate multiseriatae striae on margin; 15 µm in diameter. Striae vary in length, extending to mantle, 21 in 10 µm.

Distribution in Turkey: Sakarya and Gediz river catchments (Solak et al., 2018).

3.3. Taxa belonging to the phylum Chlorophyta

Subphylum: Chlorophytina

Class: Chlorophyceae

Order: Sphaeropleales

Family: Hydrodictyaceae

Genus: *Lacunastrum* H.A.McManus

Species: *Lacunastrum gracillimum* (West & G.S.West) H.McManus (Figure 5a)

Reference: Kim and Kim (2012)

Basionym: *Pediastrum duplex* var. *gracillimum* West & G.S.West

Homotypic Synonyms: *Pediastrum duplex* var. *gracillimum* West & G.S.West, *Pediastrum gracillimum* (West & G.S.West) Thunmark

Description: Coenobia 100–110 µm across; the colony is composed of 16 cells; marginal cells similar or with two horn-like processes. Cell walls smooth. Marginal cells 18–20 µm long, 16–18 µm in diameter; inner cells 15–20 µm long, 16–22 µm in diameter.

Distribution in Turkey: Yeniçağa Lake (Kılınç, 2003), Çaygören Reservoir (Sevindik, 2010), Buldan Dam Lake (Ustaoğlu et al., 2010), Eğirdir Lake (Coşkun and Ertan, 2016).

Subphylum: Chlorophytina

Class: Chlorophyceae

Order: Sphaeropleales

Family: Scenedesmaceae

Subfamily: Scenedesmoidea

Genus: *Westella* De Wildeman

Species: *Westella botryoides* (West) De Wildeman (Figure 5b)

Reference: John et al. (2011)

Basionym: *Tetracoccus botryoides* West

Homotypic Synonym: *Tetracoccus botryoides* West

Description: Coenobia 60–76 µm across; cells spherical, 5–10 µm wide.

Distribution in Turkey: Gaga Lake (Taş, 2012), Lake Uluabat (Dalkıran et al., 2016).

3.4. Taxa belonging to the phylum Charophyta

Class: Conjugatophyceae

Order: Desmidiiales

Family: Gonatozygaceae

Genus: *Gonatozygon* De Bary

Species: *Gonatozygon kinahanii* (W.Archer) Rabenhorst (Figure 5c)

Reference: Kim (2012)

Basionym: *Leptocystinema kinahanii* W.Archer

Homotypic Synonym: *Leptocystinema kinahanii* W.Archer

Description: Cells elongated cylindrical, straight or sometimes slightly curved, 370–410 µm long, 16–20 µm wide. Cell walls always smooth.

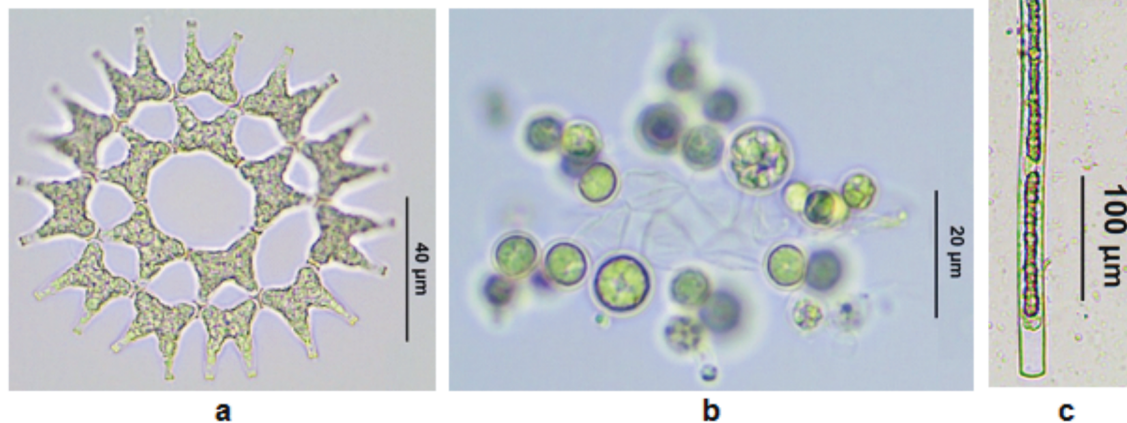


Figure 5. *Lacunastrum gracillimum* (a), *Westella botryoides* (b), *Gonatozygon kinahanii* (c).

Distribution in Turkey: Erfelek Reservoir (Ersanlı and Hasırcı, 2013), Dodurga Reservoir (Mustak and Ersanlı, 2015), Karagöl Lake (Akar and Şahin, 2014).

3.5. Taxa belonging to the phylum Euglenophyta

Subphylum: Euglenoida

Class: Euglenophyceae

Order: Euglenales

Family: Euglenaceae

Genus: *Trachelomonas* Ehrenberg

Species: *Trachelomonas volvocinopsis* Svirenko (Figure 6a)

Reference: Brosnan et al. (2005)

Description: Lorica spherical, 22–24 µm in diameter, walls smooth, reddish-brown.

Distribution in Turkey: Lake Akgöl (Ersanlı et al., 2006).

3.6. Taxa belonging to the phylum Rhodophyta

Subphylum: Eurhodophytina

Class: Bangiophyceae

Subclass: Bangiophycidae

Order: Bangiales

Family: Bangiaceae

Genus: *Bangia* Lyngbye

Species: *Bangia atropurpurea* (Mertens ex Roth) C.Agardh (Figure 6b–6d)

Reference: Eloranta and Kwandrans (2012)

Basionym: *Conferva atropurpurea* Mertens ex Roth

Homotypic Synonyms: *Conferva atropurpurea* Mertens ex Roth, *Oscillatoria atropurpurea* (Mertens ex Roth) C.Agardh, *Bangia fuscopurpurea* var. *atropurpurea* (Roth) Lyngbye, *Girardia fuscopurpurea* var. *atropurpurea* (Mertens ex Roth) S.F.Gray, *Bangiella atropurpurea* (Mertens ex Roth) Gaillon, *Diadenus atropurpureus* (Mertens ex Roth) Kuntze, *Bangiadulcis atropurpurea* (Mertens ex Roth) W.A.Nelson

Description: Thalli dark red, composed of multiseriate cells. Filaments unbranched, 70–90 µm wide.

Notes: Although marine and freshwater populations of *Bangia* have been considered to belong to the same species for a long time under the name *Bangia atropurpurea*, differences have been found between marine and freshwater populations on the basis of karyological and molecular data. Based on these findings, the species epithet of *B. atropurpurea* was recognized to represent freshwater populations of *Bangia*, while the name *B. fuscopurpurea* should be used to represent marine populations (Shea et al., 2014).

Distribution in Turkey: Susurluk River basin and North Aegean river basin (Aysel, 2005).

Subphylum: Eurhodophytina

Class: Florideophyceae

Subclass: Nemaliophycidae

Order: Acrochaetiales

Family: Acrochaetiaceae

Genus: *Audouinella* Bory

Species: *Audouinella chalybea* (Roth) Bory (Figure 6e, 6f)

Reference: Eloranta and Kwandrans (2012)

Basionym: *Conferva chalybea* Roth

Homotypic Synonyms: *Conferva chalybea* Roth, *Ectocarpus chalybeus* (Roth) Lyngbye, *Chantransia chalybea* (Roth) Fries, *Pseudochantransia chalybea* (Roth) Brand

Heterotypic Synonyms: *Trentepohlia aeruginosa* C.Agardh, *Trentepohlia pulchella* f. *chalybea* C.Agardh

Description: Cells with blue chloroplasts; narrow branch angles, cell length/width ratio > 3.

Distribution in Turkey: Tigris River (Varol and Fucikova, 2015).

4. Discussion

Floristic studies on freshwater microalgae are of great interest since they provide a scientific basis for the validation of biogeography and biodiversity models within microorganisms. They are also a source of ecological data used in the implementation of biomonitoring networks such as those performed under the requirements of environmental authorities for ecosystem health diagnosis in aquatic habitats. The recent literature confers great importance to the biogeography of these algae (Padisak et al., 2016). In particular, diatoms have been traditionally considered as cosmopolitan organisms; however, this hypothesis has been questioned in some studies (Kociolek and Spaulding, 2000). For instance, Coste and Ector (2000) assessed the presence in European rivers of diatom taxa that were virtually absent in modern floras. Due to their fast proliferation in several basins in France and other European countries, some of them can be considered as invasives. The recent dispersion of certain diatoms such as *Didymosphenia geminata* (Lyngbye) M.Schmidt is a matter of current concern provided the aggressive ecological behavior of this species, causing large environmental impacts worldwide (Blanco and Ector, 2007). The biogeographical patterns of exotic and introduced diatoms are still poorly understood. Some studies report the presence of nonindigenous species in many freshwater ecosystems (Bertrand and Coste, 1994). The distribution and progression of selected taxa were investigated by Coste and Ector (2000), who revealed the presence of new species for the local flora, some of them found in large populations in certain locations. These authors recognize three types of exotic diatoms: i) tropical or subtropical diatoms, ii) rare taxa with restricted distribution areas, and iii) invasive species.

In this regard, algal diversity is still not very well known in many regions of Turkey. However, the number of new

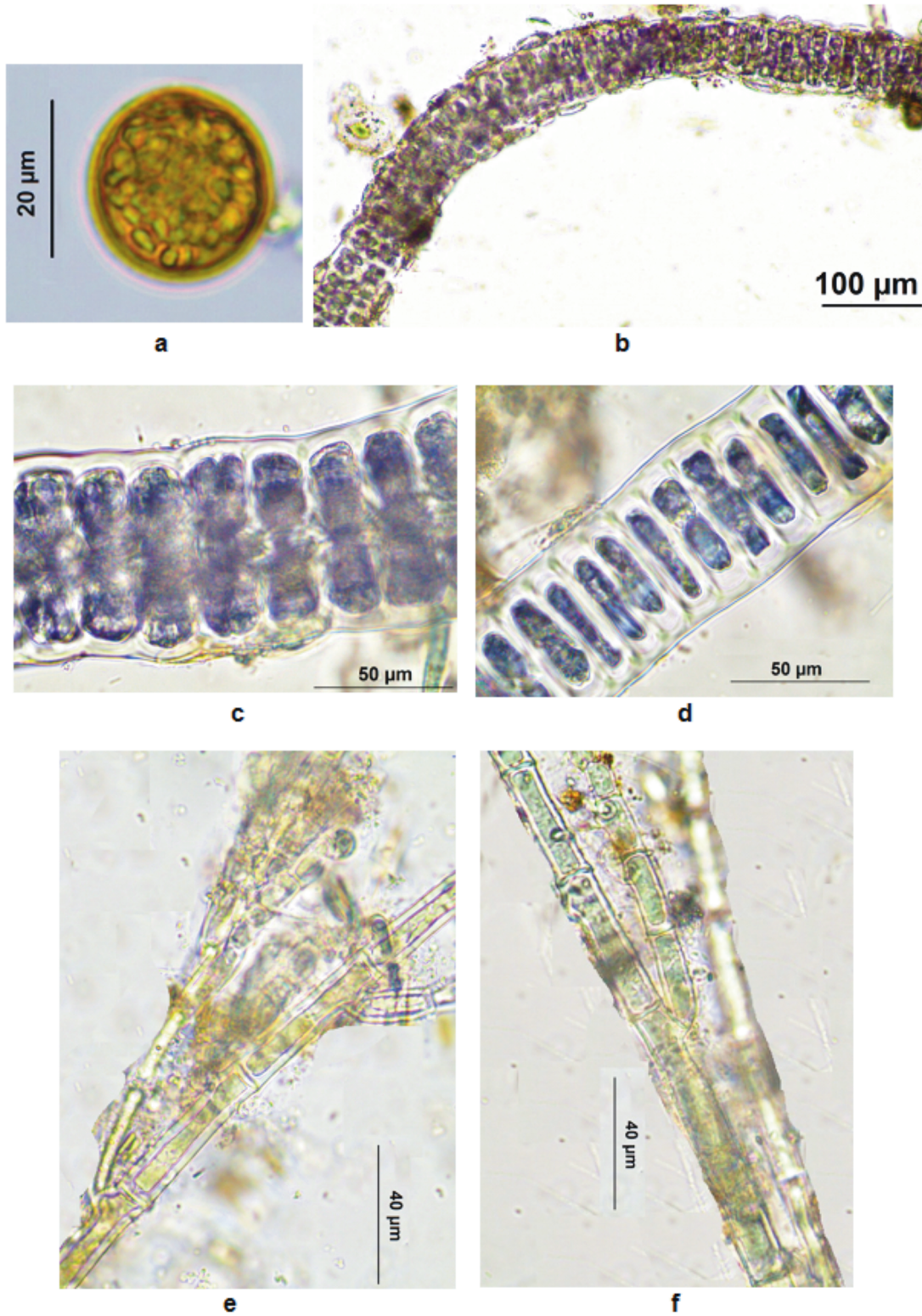


Figure 6. *Trachelomonas volvocinopsis* (a), *Bangia atropurpurea* (b-d), *Audouinella chalybea* (e, f).

records will increase when previously surveyed regions are revisited or new localities are examined. This study reports two new records and 14 rare taxa for the freshwater algae of Turkey from the Tatar Dam Reservoir in the Euphrates Basin. Most of rare taxa and new records found in the Tatar Dam Reservoir are well known worldwide. However, *Hippodonta jakubii* is only reported from the Lake Baikal in Russia (Kulikovskiy et al., 2012), while *Pantocsekiella iranica* is only reported from the Karaj River in Iran (Kheiri et al., 2013) and the Gediz and Sakarya rivers in Turkey (Solak et al., 2018). Thus, this study offers an important contribution to characterize Turkey's freshwater algae.

The appearance of several rare algal species within this geographical area reveals one of the aspects of the biogeographic particularities of the Turkish aquatic habitats. From a floristic point of view, the present work confirms the presence of a noticeable algal taxa richness in this region. The considerable extension of their catchment areas, together with the strong lithological, hydrodynamic, and landscape heterogeneity in its watercourses, contributed to this diversity.

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