New records for the freshwater algae of Turkey (Tigris Basin)

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Abstract: Samples were collected from different habitats (plankton, epipelon, epiphyton, and epilithon) at 20 stations situated on rivers and dam systems in the Tigris Basin between December 2004 and November 2005. Twenty-five new records were identified for the Turkish freshwater algae. They belong to the following divisions: 3 to Cyanobacteria, 1 to Rhodophyta, 1 to Euglenozoa, 2 to Myzozoa, 1 to Ochrophyta, 9 to Chlorophyta, and 8 to Charophyta.

Key words: Algae, new record, freshwater, Dicle Reservoir, South-East Anatolian region

Introduction

Unlike in the past, today freshwater algae research is progressing rapidly in Turkey. However, long-term monitoring of changes in algal diversities and population studies are rarely done. Therefore, 2 different studies were planned in this research to determine the algal flora of the South-East Anatolian region Euphrates and Tigris basins. Recently, since many studies on the diversity and ecology of diatoms have been done (Atıcı & Obalı, 2010; Kıvrak & Uygun, 2012; Solak et al., 2012), new records of algae except Bacillariophyta are greater in number in Turkey (Çelekli et al., 2007; Çevik et al., 2007; Baykal et al., 2009; Sevindik et al., 2010; Sevindik et al., 2011). To date, except in Devegeçidi Reservoir and the Euphrates Basin (Aysel, 2005; Baykal et al., 2009), there have been no records pertaining to the algal flora of the region (Gönülol & Öztürk, 1996; Şen et al., 1997; Aysel, 2005).

Structures such as hydro-electric plants, and agricultural and irrigation systems built on the Tigris River can lead to serious ecological variations. Being the first of its kind in the region, this study is therefore very important in addition to contributing to providing new records of species for the freshwater algae of Turkey. The algae of the region were investigated at 20 sampling stations. The general view of the area and the sampling stations are shown in Figure 1. The names of the stations are indicated in the Table.

Materials and methods

Sampling materials were collected from 20 stations in the Tigris River and its tributaries and from 4 dam reservoirs on the river (Figure 1). For taxonomic analysis, samples were taken using plankton nets of 30 and 55 µm and 2 L fibreglass containers and those
of epipelic on sediments using a glass rod 0.5-0.8 cm in diameter. Epiphytic and epilithic samples were taken by scratching the surfaces of submerged plants and stones, respectively. All samples were fixed in 4% formaldehyde and organisms were identified on both temporary and permanent slides. Water temperature, pH, conductivity, salinity, and dissolved O₂ were measured in situ, using a YSI model (55/25 FT, 30/25 FT) and Thermo/Orion (210 model) portable probes, respectively. Other physical and chemical analyses were done at the Aquatic Products Laboratory of Fırat University, Elazığ.

Photographs were taken using a Nikon research microscope and are shown in Figures 2-11. Taxonomic identifications were carried out according to the works by Huber-Pestalozzi (1938, 1941, 1950, 1955, 1982, 1983), Bourrelly (1972), Prescott (1975), Korshikov (1987), Komarek and Anagnostidis (1999), John et al. (2002), and Wehr and Sheath (2003). The arrangement of the phyla follows that of AlgaeBase (Guiry, 2012).
Results and discussion

A total of 364 algal taxa were identified in the Tigris Basin, with 25 being new records for the Turkish freshwater algal flora.

Phylum: Cyanobacteria
Class: Cyanophyceae
Subclass: Synechococcophycideae
Order: Synechococcales
Family: Chamaesiphonaceae
Genus: Geitleribactron Komárek, 1975


(Komarek & Anagnostidis, 1999, pp. 360-361).

Description: Cells solitary or dense, with blue green homogeneous contents, periphytic layers on the substrate, giving a blue-green colour to the latter. Cells straight and cylindrical, rounded at the apex, generally short with colourless mucilaginous pads at the base. Cells 1.3-2.7 µm wide and 4-7 µm long; during reproduction, 1 or 2 new young cells found at the ends (Figure 2).

Found at station 8 in plankton (Epiphytic on Oedogonium species).

Phylum: Cyanobacteria
Class: Cyanophyceae
Subclass: Synechococcophycideae
Order: Pseudanabaenales
Family: Pseudanabaenaceae
Genus: Limnothrix Meffert, 1987


(Basionym: Oscillatoria redekei van Goor
Homotypic Synonym: Oscillatoria redekei van Goor 1918

Figure 2. a, b- Geitleribactron periphyticum, c- Limnothrix redekei, d- Phormidium okenii (Scale bars = 10 µm).
Description: Trichome straight, not attenuated at the ends. Cells 1.2-2.1 µm wide, 6.5-8.5 µm long; narrowed at cross walls, appearing rectangular. Gas vacuoles seen on both sides of the cross walls (Figure 2).

Identified at stations 2, 6, 7, 9-11 in plankton, 12 in epiphyton, 1, 3, 4, 7, and 12 in epilithon.

Phylum: Cyanobacteria
Class: Cyanophyceae
Subclass: Oscillatoriophycidea
Order: Oscillatoriales
Family: Phormidiaceae
Genus: *Phormidium* Kützing ex Gomont, 1892


(Huber-Pestalozzi, 1938, p. 224).
Basionym: *Oscillatoria okenii* C.Agardh
Homotypic Synonyms: *Oscillatoria okenii* C.Agardh ex Gomont 1892

*Lyngbya okenii* (C.Agardh) Hansgirg 1884.
Heterotypic Synonym: *Oscillatoria okenii* C.Agardh ex Gomont 1892.

Description: Trichome straight, only slightly attenuated and twisted (or curved). Cells 6-8.5 µm wide, 3-3.5 (4.5) µm long, cross walls slightly narrowed, without adjacent granules, end cells weakly conical or round (Figure 2).

Found at station 9 in plankton.

Phylum: Rhodophyta
Class: Florideophyceae
Subclass: Nemaliophycidae
Order: Acrochaetiales
Family: Acrochaetiaceae
Genus: *Audouinella* Bory de Saint-Vincent, 1823


(John et al., 2002, p. 128).
Basionym: *Conferva hermannii* Roth

Homotypic Synonyms: *Conferva hermannii* Roth 1797.
*Chantransia hermannii* (Roth) Desvaux 1809.
*Chantransia chalybea* var. *hermannii* (Roth) Trevisan 1842.

Heterotypic Synonyms: *Audouinella miniata* Bory de Saint-Vincent 1823.
*Chantransia violacea* Kützing 1845.
*Audouinella violacea* (Kützing) Hamel 1924.
*Rhodochorton violaceum* (Kützing) K.M.Drew 1935.

Description: Cylindrical cells with several parietal, ribbon-like chloroplasts and mature forms violet-green colour, 7.5-10 µm wide, and 30-50 µm long. Some of the short lateral branches have ovoid monosporangia, singly or in clusters, 10-12.5 µm wide, up to 30-50 µm long. Some short branch ends have carposporangia. Ends of branches are generally round but sometimes tapering side branches are found (Figures 3 and 4).

Figure 3. a, b- *Audouinella hermannii* (Scale bars = 10 µm).
Found at stations 2, 15, and 19 in plankton, and at 2 and 19 in epiphyton.

**Phylum:** Euglenozoa  
**Class:** Euglenophyceae  
**Order:** Euglenales  
**Family:** Euglenaceae  
**Genus:** *Euglena* Ehrenberg, 1830

5. **Species:** *Euglena spirogyra* var. *abrupte-acuminata* Lemmermann 1913.  
(Huber-Pestalozzi, 1955, pp. 101-102).

**Description:** Cells 20-25 µm wide, up to 137.5 µm long (including tail); longitudinally flattened, with sides nearly parallel; anterior apex slightly narrow, rounded, posterior apex wide, tapering to a short point; pellicle with regularly arranged rows of external bead granules; chloroplasts numerous, disk-shaped, without pyrenoids; rectangular paramylon granules present, one lying anterior to nucleus and another posterior to nucleus; eyespot large and prominent, with motional euglenoid (Figure 4).

Found at station 11 in epilithon.

**Phylum:** Myzozoa  
**Class:** Dinophyceae  
**Subclass:** Peridiniphycidae  
**Order:** Gonyaulacales  
**Family:** Ceratiaceae  
**Genus:** *Ceratium* F. Schrank, 1793

6. **Species:** *Ceratium hirundinella* f. *austriacum* (Zederbauer) Bachmann 1911.  
(Huber-Pestalozzi, 1950, pp. 263-268).

**Description:** Cells broad, 55-58 µm wide, 142-168 µm long; epitheca sharply converging from just above...
the transverse furrow, then narrow more gradually to form a long horn (85-87 µm long). Transverse furrow relatively narrow; hypotheca is divided into 3 antapical horns, central horn the longest (approximately 50 µm) and the others are 27-28 µm and 14-16 µm (the given as the figure, apical horn is shown broken). The antapical horns are shorter than the apical horn. The apical horn and antapical horns are in parallel erection, but some antapical horns are extended outward. Epitheca is depressed, conical and slightly flattened compared to the hypotheca (Figure 5).

Found at stations 1-4, and 7 in plankton.

7. Species: Ceratium hirundinella var. carinthiacum Zederbauer 1911.

(Huber-Pestalozzi, 1950, pp. 263-268).

Description: Cells 48-60 µm wide, 150-166 (175) µm long; dorsal/apical horn is longer than ventral horns, 80-88 µm long; ventral horns are of different lengths, the longest 45 µm, with the short one protruding (3-5 µm). Apical horn and the longest antapical horn are more or less on the same axis (Figure 5).

Found at stations 2 and 3 in plankton.

Phylum: Ochrophyta
Class: Chrysophyceae
Order: Chromulinales
Family: Dinobryaceae
Genus: Dinobryon Ehrenberg, 1834


Basionym: Dinobryon stipitatum F.Stein

Description: Lorica is conically shaped; V-shaped, enlarging towards apex forming a colony. Lorica 37.5 µm long, 7.5 µm wide, broadest at mouth 8-9 µm wide (Figure 6).

Identified at stations 1-3 in plankton.

Phylum: Chlorophyta

Figure 5. a- Ceratium hirundinella var. carinthiacum, b- Ceratium hirundinella f. austriacum (Scale bars = 10 µm).

Figure 6. a- Dinobryon sociale var. stipitatum, b, c- Actinastrum aciculare f. africanum (Scale bars = 10 µm).
Class: Trebouxiophyceae
Order: Chlorellales
Family: Chlorellaceae

**Genus:** *Actinastrum* Lagerheim, 1882


**Description:** Coenobial form made of 8 cells, all radiating from a central point. Cells 5-5.5 (6) \(\mu\)m in diameter, 30-40 \(\mu\)m long. From the middle, cells become narrow to end and cylindrical towards centre. Chloroplast with a single pyrenoid, often reaching extremes of cells (Figure 6).

Found at stations 7 and 11 in epipelon.

**Phylum:** Chlorophyta
Class: Trebouxiophyceae
Order: Chlorellales
Family: Chlorellaceae

**Genus:** *Micractinium* Fresinius, 1858


**Basionym:** *Richteriella quadriseta* Lemmermann 1898.

**Homotypic Synonyms:** *Richteriella quadriseta* Lemmermann 1898.

**Richteriella botryoides var. quadriseta** (Lemmermann) West.

**Description:** Coenobia tetrahedral, consisting of a 4-angled central space and 4-celled group, localised at the angles radially, without a mucilage sheath; cells 5.5-7 \(\mu\)m wide, 7-8 \(\mu\)m long, angular ovoid, with bluntly rounded ends and weakly convex, bearing 2-4 spines, about 1-1.5 \(\mu\)m wide, 7-8 \(\mu\)m, up to 48 \(\mu\)m long (Figure 7).

Found at station 3 in plankton.

**Phylum:** Chlorophyta
Class: Chlorophyceae
Order: Chaetophorales
Family: Aphanochaetaceae

**Genus:** *Aphanochaete* A.Braun, 1851

11. **Species:** *Aphanochaete repens* A.Braun 1850. (Bourrelly, 1972, p. 315; John et al., 2002, p. 434).

**Homotypic Synonym:** *Herposteiron repens* (A.Braun) Wittrock 1872.

**Heterotypic Synonyms:** *Aphanochaete confervicola* (Nägeli ex Kützing) Rabenhorst; *Gonatoblaste rostrata* Huber

**Description:** Filaments linear, partly branched and epiphytic. Cells 7.5 \(\mu\)m wide, 15-16 \(\mu\)m long, each bearing a single (rarely 2) unsheathed bristle; chloroplast parietal with one pyrenoid (Figure 7).

Found on green algae in warm and shallow waters.

Found at stations 2 in epiphyton and 11 in epipelon.

**Phylum:** Chlorophyta
Class: Chlorophyceae

![Figure 7. a- Micractinium quadrisetum, b- Aphanochaete repens, c, d- Coenocystis planktonica (Scale bars = 10 \(\mu\)m).](image-url)
Order: Sphaeropleales
Family: Radiococcaceae
Genus: Coenocystis Korshikov, 1953.


Synonym: Coenochloris korshikovii Hindak.

Description: In colonies 4 or 8 cells localised near the centre. Cells globose or ovoid, (8) 9-11 µm wide, with smooth and thin walls. There is 1 parietal, thickened at the apex, indistinct pyrenoid (Figure 7).

Found at stations 2, 3, 6, and 9 in plankton, and at 11 in epiphyton.

Phylum: Chlorophyta
Class: Chlorophyceae
Order: Sphaeropleales
Family: Scenedesmaceae

Genus: Coelastrum Nägeli, 1849.


Basionym: Sphaerastrum verrucosum Reinsch.
Homotypic Synonym: Sphaerastrum verrucosum Reinsch.
Heterotypic Synonym: Coelastrum morus West & G.S. West 1896.

Description: Coenobia spherical, 8-16 celled, up to 20-27 µm diameter. Cells 7-14 µm wide, spherical with 6-12 pointed protuberances, connecting with neighbouring cells (Figure 8).

Found at stations 8 in plankton, and at 2 and 15 in epiphyton.

Phylum: Chlorophyta
Class: Chlorophyceae

![Figure 8. a- Coelastrum verrucosum, b, c- Monoraphidium fontinale, d- Scenedesmus flavescens, e- Sphaerobotrys fluviatilis (Scale bars = 10 µm).](image_url)
Order: Sphaeropleales  
Family: Selenastraceae  

Description: Cells solitary, 5-5.5 µm wide, 42-57.5 µm long, spindle-oblong, nearly straight to curved. Chloroplast trough-shaped, no pyrenoid. 4 or 8 autospores per cell (Figure 8).  
Found at station 3 in plankton.

Phylum: Chlorophyta  
Class: Chlorophyceae  
Order: Sphaeropleales  
Family: Scenedesmaceae  
Genus: Scenedesmus Meyen, 1829.

15. Species: Scenedesmus flavescens Chodat 1913.  
(John et al., 2002, p. 393).  
Heterotypic Synonym: Scenedesmus tenuispina Chodat 1913.  
Description: Coenobia of (2-) 4 linearly arranged cells. Cells 5-5.5 µm wide, 12-13 µm long, slightly cylindrical to ovoid with rounded ends. Marginal cells bear 2 short equatorial spines on sides and longer spines on the polar ends. Inner cells are straight and carry 1 or 2 spines each at both ends (Figure 8).  
Found at stations 1, 5, 9, 11, and 12 in epiphyton.

Phylum: Chlorophyta  
Class: Chlorophyceae  
Order: Chlorophyceae incertae sedis  
Family: Chlorophyceae familia incertae sedis  
Genus: Sphaerobotrys Butcher, 1932.

Description: Cells attached to remains of mother cell walls enclosed within a thin mucilaginous envelope and about 5.5 µm wide, 6.5-7 µm long; slightly disc or pear-shaped, ventral view round, arranged in oblique rows; chloroplast parietal with a single pyrenoid (Figure 8).  
Found at station 3 in plankton and epiphyton.

Phylum: Chlorophyta  
Class: Trebouxiophyceae  
Order: Chlorophyceae incertae sedis  
Family: Klebsormidiaceae  
Genus: Klebsormidium

(John et al., 2002, pp. 447-448).  
Basionym: Hormidium crenulatum Kützing 1845  
Homotypic Synonym: Chlorhormidium crenulatum (Kützing) Komaromy 1976.  
Description: Filaments long, cells 9-20 µm wide (including mucilage sheath), 0.5 times longer than wide or equal, cylindrical barrel-shaped. Cell walls
thin and smooth, some filaments markedly thickened, stratified, H-shaped segments occasionally present. Chloroplasts plate or girdle-shaped, covering almost 80% of cell circumference (sometimes covering completely), with 1, rarely 2, or 3 prominent pyrenoids (Figure 9).

Found at stations 4 in plankton and epiphyton and 13 in epiphelon.

**Phylum:** Charophyta  
**Class:** Coleochaetophyceae  
**Order:** Coleochaetales  
**Family:** Coleochaetaceae  
**Genus:** Coleochaete Brébisson, 1844.

19. **Species:** *Coleochaete pulvinata* A.Braun in Kützing 1849.  

![Figure 9](image.png)  
Figure 9. a- *Geminella interrupta*, b, c- *Klebsormidium crenulatum*, d- *Coleochaete pulvinata* (Scale bars = 10 µm).

**Description:** Filament forming hemispherical, cushion-like growths (2-3 mm across) of irregularly branched erect filaments radiating from a common centre. Cells 18-24 µm wide, up to 70 µm long, irregularly cylindrical, typically bearing bristles (Figure 9).

Found at stations 1 in epilithon and at 2 and 12 in epiphyton.

**Phylum:** Charophyta  
**Class:** Zygnematophyceae  
**Order:** Zygnematales  
**Family:** Zygnemataceae  
**Genus:** *Mougeotia* C.Agardh, 1824.

20. **Species:** *Mougeotia abnormis* Kisselev 1927.  

**Description:** Cells 18-20 µm wide, 90-120-(135) µm long; chloroplast filling the length of a cell with 6-8 pyrenoids. Zygospores in a triangular tube, triangular-ovoid with concave walls 25 µm wide, 38 µm long; median wall smooth (Figure 10).

Found at stations 2 in epiphyton and at 7 in plankton, epiphyton, and epilithon.

21. **Species:** *Mougeotia genuflexa* (Dillwyn) C.Agardh 1824.


Basionym: *Conferva genuflexa* Dillwyn

Homotypic Synonym: *Conferva genuflexa* Dillwyn.

Heterotypic Synonym: *Mesocarpus pleurocarpus* De Bary 1858.

**Description:** Cells 23-28.5 µm wide, 60-125 µm long. Chloroplasts broad, ribbon-like, almost covering complete cell circumference, with 6-8 pyrenoids usually in irregular series; conjugation lateral, zygospores formed in conjugation tube, quadrate-ovoid (Figure 10).

Found at stations 1 in epiphyton and 20 in plankton.

**Phylum:** Charophyta

**Class:** Zygnematoiphyceae

**Order:** Zygnematales

**Family:** Zygnemataceae

**Genus:** *Spirogyra* Link, 1820.

22. **Species:** *Spirogyra rhizobrachialis* Jao 1936.

(Prescott, 1975, p.320).

![Figure 10. a- Mougeotia abnormis, b, c- Mougeotia genuflexa, d- Spirogyra rhizobrachialis (Scale bars = 10 µm).](image)
Description: Cells 37.5-50 µm wide, 240-312.5 µm long, with plain end walls. Chloroplasts crenate and deeply toothed on the margins, broad, 2.5-3.5 (4.5) turns. Fertile cells cylindrical and sterile ones frequently forming tubes that develop highly branched rhizoidal processes at their ends. Zygospores ellipsoidal, brown, 42.5-72.5 µm wide, 90-95 µm long (Figure 10).

Found at stations 11 and 17 in plankton, and at 7, 14, and 16 in epilithon.

Phylum: Charophyta
Class: Zygnematophyceae
Order: Zygnematales
Family: Zygnemataceae
Genus: Zygogonium Kützing, 1843.


Heterotypic Synonym: Zygnema ericetorum (Kützing) Hansgirg 1886.

Description: Filaments simple or rarely branched. Cells 25-27.5 µm wide, 50-53 µm long, cylindrical, or slightly constricted at the crosswalls, usually with purple cell sap. Has 2 pillow-shaped chloroplasts knotted in the middle, each with a central pyrenoid (Figure 11).

Found at station 7 in epiphyton.

Phylum: Charophyta
Class: Zygnematophyceae
Order: Zygnematales
Family: Desmidiaceae
Genus: Cosmarium Corda ex Ralfs, 1848.


(Huber-Pestalozzi, 1982, p. 277).

Heterotypic Synonym: Cosmarium subtumidum var. minor J.Sampaio 1922.

Description: Cells 14.5-22.5 µm wide, 18-27.5 µm long, about 1-2 times as long as wide (L/W:1.2-1.24), with a deep sinus, linearly and closed until the end of an extension. Half cells rounded, trapezoidal with broadly rounded basal angles and lateral margins. Convex, not straight, apex broad and flat, trimmed or slightly convex. In apical view elliptic oblong, slightly swollen on the sides, circular in lateral view. Walls with fine pores in half cells. Centre and at the apex somewhat thickened. Chromotrophes half monocentric with a pyrenoid in each half-cell (Figure 11).

Found at stations 1, 2, and 7 in epiphyton.


(Huber-Pestalozzi, 1982, p. 278).

Heterotypic Synonym: Cosmarium subtumidum f. minus Cedergren 1938.

Description: Cells are very small, but relatively long, 10.5-13 µm wide and 15-17 µm long (L/W: 1.25), resembling 2 joined spheres; apical view...
swollen. Chromatophores monocentric, furcoid with a central pyrenoid-like structure in every half-cell (Figure 11).

Found at stations 1 and 12 in plankton, at 7 in epiphyton, and at 1, 2, and 3 in epilithon.

Generally, eutrophic species are found in Turkish freshwaters. However, Tortum Lake (Altuner & Aykulu, 1987), Aygır and Bâlkılıgöl lakes (Şahin, 2000), and Yedigöller (Şahin, 2002) are oligotrophic, while Hazar Lake is in a state of transition from oligotrophic to mesotrophic (Şen, 1988). Dam reservoirs are said to have more mesotrophic characteristics (Baykal et al., 2009; Açıklgöz et al., 2011).

The surface temperature values of running waters and dam reservoirs recorded in the region were 6.2-31.7 °C (average 16.6 °C), pH was 6.8-9.2 (average 7.8), and dissolved oxygen was 3.5-13.9 (average 9.2) mg L\(^{-1}\). Among the changing physical and chemical properties, temperature, light transmission, and nutrients had more effects on algal growth. Filamentous species such as *Klebsormidium crenulatum*, *Audouinella hermannii*, *Mougeotia genuflexa*, and *Spirogyra rhizobrachialis* were identified in Batman, Botan-Beyazsu, Karasu, and Hezil streams, respectively. Most of the other species were identified in more plankton and epipelon in the reservoirs on the Tigris River and its main tributary. Species identified were generally observed to be widespread and sometimes rare in mesotrophic and eutrophic media in European and American waters (John et al., 2002; Wehr & Sheath, 2003).

**Conclusion**

In recent years, multifaceted studies about algae have been conducted in Turkey. However, systematic studies that require long and exhausting investigations have started to decline. This study is considered a critical contribution toward determining the algal flora of Turkey.

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