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STUDY OF THE DIATOM GENERA ENCYONEMA, CRATICULA, AND CYMATOPLEURA (BACILLARIOPHYTA) IN THE WESTERN RIVERS OF LAKE URMIA, IRAN

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This study is the first attempt to investigate some diatom species in the western rivers of Lake Urmia. The study presents the details of *Encyaonema*, *Craticula,* and *Cymatopleura* at the lowest taxonomic level to provide information in terms of species taxonomy, morphology and ecology. In order to determine the morphological similarities in species level of the aforementioned genera, 14 sites were repeatedly sampled along the rivers from September 2021 to August 2022. The results showed a high diversity of diatoms including *Encyonema caespitosum*. *Encyonema silesiacum*, *Encyonema prostratum*, *Craticula cuspidata*, *Craticula ambigua*, *Cymatopleura solea*, *Cymatopleura apiculata*, *Cymatopleura hibernica* and *Cymatopleura elliptica*. The taxonomic and ecological study of the observed species from the western rivers of Lake Urmia indicates diatom assemblage closely integrated with the limnology and ecological status of the rivers. Indeed, the results infer that the rivers undergo a transition from freshwater to brackish, particularly where the rivers terminate at Lake Urmia.

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Keywords: Lake Urmia; rivers; diatom taxonomy; *Encyonema*; *Craticula*; *Cymatopleu*

مطالعه دیاتومه‌های سرده‌های Encyonema، Craticula و Cymatopleura (Bacillariophyta) در رودخانه‌های غربی دریاچه ارومیه، ایران

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این مطالعه اولین گزارش برای بررسی برخی از گونه‌های دیاتومه در رودخانه‌های غربی دریاچه ارومیه است. این مطالعه جزئیات جنس‌های Encyaonema، Craticula و Cymatopleura را در پایین‌ترین سطح طبقه‌بندی ارائه می‌کند تا اطلاعاتی از نظر تاکسونومی، مورفولوژی و اکولوژی گونه‌ها بدست آید. به منظور تعیین شباهت‌های مورفولوژیکی در سطح گونه‌های جنس‌های فوق الذکر، از ۱۴ ایستگاه در طول رودخانه‌ها به طور مکرر از سپتامبر ۲۰۲۱ تا آگوست ۲۰۲۲ نمونه‌برداری شد. نتایج نشان‌دهنده تنوع بالای دیاتومه‌ها از جمله Encyonema caespitosum, Encyonema silesiacum، Encyonema prostratum، Craticula cuspidata، Craticula ambigua، Cymatopleura solea، Cymatopleura apiculata، Cymatopleura hibernica و Cymatopleura elliptica بود. بررسی تاکسونومیکی و اکولوژیکی گونه‌های مشاهده‌شده از تمامی رودخانه‌های غربی دریاچه ارومیه نشان می‌دهد که تجمع دیاتومه‌ها کاملا مرتبط با لیمنولوژی و وضعیت اکولوژیکی این

رودخانه‌ها است. در واقع، نتایج چنین بیان می‌کنند که رودخانه‌ها به ویژه در حوالی مناطقی که به دریاچه ارومیه منتهی می‌شوند، از آب شیرین به لب شور تبدیل می‌شوند.

INTRODUCTION

Biogeography, in defining the relationship between the distribution pattern of biodiversity and their environmental condition, is the most important characteristic of the biological community. Diatom biodiversity and assemblages reflect the function and ecological processes of the riverine ecosystems. Recently, research on diatoms has extensively progressed so that these studies not only focus on taxonomy and morphology but also focus on biomonitoring and diatom-based indices for evaluation of ecological condition of riverine ecosystems (Chessman & al. 2007; Atazadeh & al. 2021). The taxonomic composition of benthic diatom communities has been widely used for monitoring of water quality (Lowe & Pan 1996; Chessman & al. 2007).

Until now, there is no clear checklist of diatoms of Iran. However, some studies were conducted over the past few decades including Algues des dèserts d'Iran (Compère 1981), Anzali Lagoon (Nejadsattari & al. 2005), Lake Neure (Nejadsattari 2005), Gharasou River (Atazadeh & al. 2007), Ramsar rivers (Soltanpour-Gargari & al. 2011), Karaj and Marbareh Rivers (Kheiri & al. 2018a, 2018b), Zayandeh-Rood (Shams-Kahrizsangi & al. 2012), Balikhli River (Panahy-Mirzahasnlou & al. 2018), and Taleghan River (Naseri & al. 2022**)**.

The genus *Encyonema* was first established by Kützing in 1833 (Kützing 1833). All over the mid-20th century, a number of taxa were added (e.g. Frenguelli 1942; Mayer 1947), which indicates not using the name of the genus *Encyonema*, whereas *Cymbella* was used. The genus *Encyonema* was later distinguished from *Cymbella* by D.G. Mann in 1981, Kociolek and Stoermer in 1988 and Krammer in 1997. *Encyonema* was different from *Cymbella* due to its organ features and raphe deviations and the shape of valves. *Encyonema* is a relatively large genus, with more than 150 species suggested by Krammer in 1997 (Liu & al. 2021b). Cells are dorsiventral, the central raphe ends are turned to dorsal. While the distal raphe ends sharply curved to ventral. Cells are forming colonies through mucous tubes, occasionally solitary. Furthermore, chloroplast solitary, expanding under both valves towards the dorsal side of the girdle, with the center opposite its ventral side. Globally distributed freshwater genus in different ecosystems in terms of trophy and pH (Kulikovskiy & al. 2016).

The genus *Craticula* Grunow was described based on the species *C. perrotettii* Grunow and was forgotten for a long time until Mann & Stickle (Mann & Stickle 1991) re-established the genus and provided a more detailed description based on ultrastructural and sexual characteristics (Levkov & al. 2016). Most members of this genus were previously part of the *Navicula*. One of the reasons for naming this genus is due to the presence of "craticula" (Levkov & al. 2016). The valves are lanceolate with narrowly protruding or capitate-deposed ends, with a straight raphe fissure. Inner frustules can be formed, or valves with alternating radial stripes instead of roughly parallel ones (Hofmann & al. 2011). Cells are solitary and naviculoid. Furthermore, they have two chloroplasts, curved like a boat, adjacent to the girdle, opposite each other, with one or more pyrenoids on each (Kulikovskiy & al. 2016). The species of the genus are mostly marine. However, they can be found in freshwater ecosystems from acidic to alkaline and from oligotrophic to eutrophic.

The genus *Cymatopleura* was first introduced by W. Smith in 1851 (Smith 1851). The frustrates have canal raphes that run around the valve at the mantle edge. Very coarse frustules are formed on the valve view, the crests and troughs of which are clearly visible in valve view and girdle view under light microscope. In the valve view, the valves are not interrupted in the area of the median line (Hofmann & al. 2011). The cells are solitary, in the preparation as is visible from the girdle. Valves are isopolar, occasionally twisted along the longitudinal axis. Species of the genus are distributed in different types of ecosystems around the world.

Studying diatom taxonomy, biodiversity and biogeography around the rivers of the world second hypersaline lake is greatly important due to the region is facing tremendous threats of degradation by human activities and anthropogenic stressors. This is first study in the western rivers of Lake Urmia, Iran. The present study contributes to our diatom knowledge in terms of taxonomic and morphological diversity of *Encyonema*, *Craticula*, and *Cymatopleura* in the western rivers of Lake Urmia. In addition, the available data were compared with earlier work from different geographic regions. Furthermore, careful observation can provide important information about the ecological status of the rivers.

MATERIALS AND METHODS

Study area

Lake Urmia, the largest saline lake in northwestern Iran, has severe restrictions on water resources and is becoming more saline and dry these days (Fig. 1a-d). The continuous decline in water flowing into the lake has caused a significant shrinkage in the lake's surface area since 1995 (USGS 2022). A number of the rivers that discharge into Lake Urmia are Talkherood (Aji-Chay), Zarrinehrood, Lilan, Mordagh, Siminehrood, Mahabadrood, Baranduz-Chay, Nazlou-Chay, Rouzeh-Chay, Zola-Chay, Shahr-Chay, Sufi-Chay, etc.

Nazlu-Chay is located on the northwest of Lake Urmia. Nazlu-chay is formed by joining of several small tributaries that flow from the surrounding high mountains, especially the mountains border of Iran and Turkey. The main tributary of this river is Sero-Chay. The length of the Nazlu-Chay is 95 km with the catchment area of 1960 km^2 (Fig. 1b; Table 1).

Rouzeh-Chay is a 65 km long river, which originates 23 km west of Urmia city and flows to the northeast, then merges with the Nazlu-Chay and discharges into Lake Urmia. The water level of this river has decreased significantly due to human activities (Fig. 1b; Table 1).

Shahr-Chay river is formed by the joining of several small tributaries in a reservoir called Shahr-Chay Dam and passes through the village of Band and the city of Urmia along its route and finally flows into Lake Urmia in an area called Cape Hesar. It should be noted that Shahr-Chay is a permanent river which passes through the city of Urmia and it supplies water for urban and agricultural usage. (Fig. 1b; Table 1).

Baranduz-Chay originates from border of Iran and Turkey. After receiving various tributaries which join together in an area called Haftavan. From this area onwards, it is known as Baranduz-Chay. This river flows into Lake Urmia after passing through several villages in the southern part of Urmia city. The catchment lies to the south of the city of Urmia and covers an area of approximately 1019 km^2 (Fig. 1b; Table 1).

Sampling and laboratory techniques

Algal periphyton samples were collected (three replicates) from emergent and submerged surfaces including cobbles, pebbles or rocks, woody debris, aquatic plants and mud at points within each of the established sampling sites where the water velocity was relatively low. The algal periphyton was scraped from an area of 20-30 cm^2 of a substrate using a soft toothbrush. The sample was washed into a plastic tray with river water and the resulting algal suspension rinsed into a 250 mL collection bottle. Samples were digested with 35% hydrogen peroxide in a beaker at 90°C on a hotplate for 2 hours, after which two drops of 35% hydrochloric acid were added.

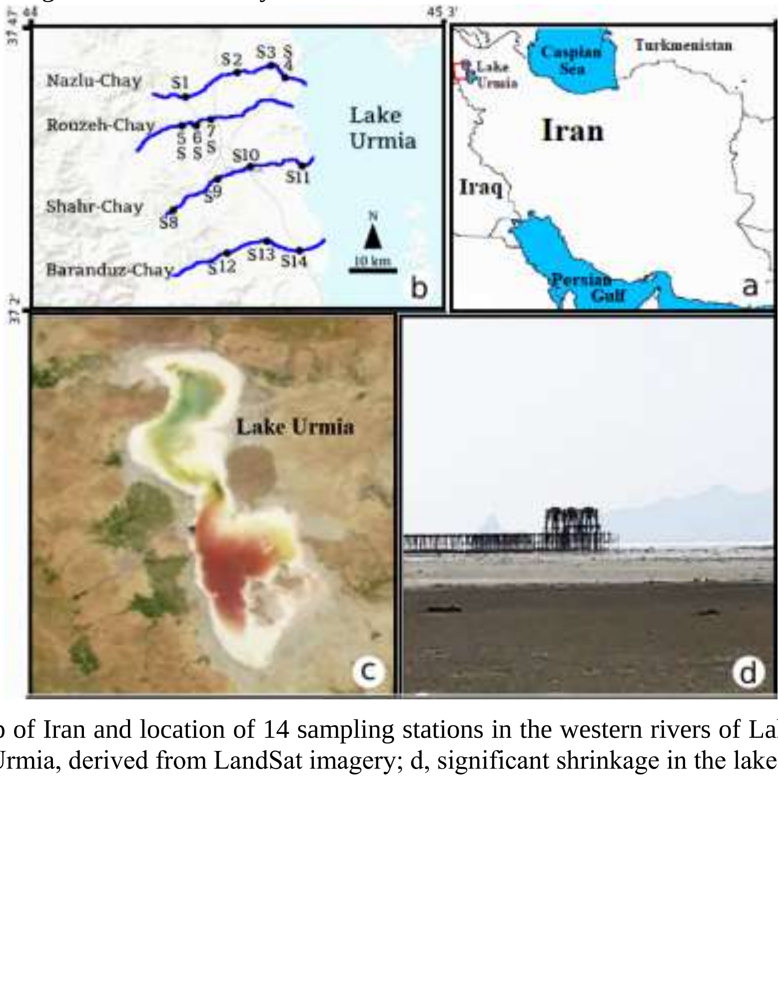


Fig. 1. a-b, Map of Iran and location of 14 sampling stations in the western rivers of Lake Urmia; c, current status of Lake Urmia, derived from LandSat imagery; d, significant shrinkage in the lake's surface.

The beakers were filled with distilled water and left to settle overnight after which the supernatant was discarded (Atazadeh & al. 2014). This process was repeated four times. Subsamples of 800 µl were air-dried on coverslips and mounted using Naphrax. Then permanent slides were studied under optical microscopes (Zeiss Axioskop 40' with integrated DP 450 camera) and (Olympus CH-2, Japan) capable of 1000X magnification. For scanning electron microscopy (SEM), the rinsed samples were resuspended in a solution of deionized water for 30 minutes and rinsed three times in distilled water. Diatom suspensions were dried directly on 22 mm aluminum stubs and gold coated with a Dynavac Xenosput sputter coater. Images were taken in a TESCAN VEGA3 field-emission scanning electron microscope, with a working voltage of 2.0 kV and spot size 2.

Diatoms were identified in the laboratory using global and regional identification keys (Kulikovskiy & al. 2016; Hofmann & al. 2011; Krammer & Lange-Bertalot 1986, 1988; Krammer & Lange-Bertalot 1991a; Krammer & Lange-Bertalot 1991b; Bishop & al. 2017; Blanco 2020). The North American Diatom and Algae-Base and Diatom-Base websites were also used for a more examinations (Guiry 2022; Kociolek & al. 2022; Spaulding 2022).

Table 1. Sampling sites including names of rivers, geographical coordinates and ecological characteristics.

Site No.	Site name	River name	Latitude	Longitude	Altitude (m a.s.l)	pH	Conductivity $mS.cm^{-1}$	TDS $g.L^{-1}$
S1	Nazlu	Nazlu-Chay	37°40'25"	44°58'27"	1373	7.6-9.4	0.35-1.45	0.17-0.71
S2	Baghestan	Nazlu-Chay	37°42'46"	45°05'21"	1226	7.7-8.8	0.42-0.72	0.2-0.35
S3	Tala-tappe	Nazlu-Chay	37°43'18"	45°10'40"	1370	7.3-8.1	0.38-0.58	0.18-0.29
S4	Osalu	Nazlu-Chay	37°42'33"	45°12'38"	1280	7.8-7.95	0.37-0.5	0.18-0.24
S5	Tiz-kharab	Rouzeh-Chay	37°37'29"	44°59'12"	1415	6.9	0.74	0.36
S6	Gajin	Rouzeh-Chay	37°37'20"	45°00'06"	1400	-	-	-
S7	Balow	Rouzeh-Chay	37°38'12"	45°02'02"	1370	8.3	0.59	0.29
S8	Nushan-sofla	Shahr-Chay	37°27'55"	44°56'17"	1510	8-8.7	0.24-0.42	0.11-0.2
S9	Daneshjo Park	Shahr-Chay	37°31'41"	45°03'10"	1353	7.9-9.2	0.25-0.47	0.12-0.23
S10	Aghche-Galee	Shahr-Chay	37°32'50"	45°07'35"	1310	4.9-7.5	0.24-1.04	0.12-0.5
S11	Keshtiban	Shahr-Chay	37°33'11"	45°14'45"	1297	7-8.2	0.25-2.49	0.12-1.24
S12	Baranduz	Baranduz-Chay	37°24'05"	45°05'36"	1322	7.2-8.2	0.31-0.77	0.15-0.38
S13	Dizaj Tekiyeh	Baranduz-Chay	37°25'09"	45°10'23"	1308	6.9-7.9	0.36-1.04	0.17-0.52
S14	Arablou	Baranduz-Chay	37°24'06"	45°14'45"	1295	7.8-8	0.41-0.59	0.2-0.29

RESULTS

Encyonema Kütz.

Classification: Chromista, Bacillariophyta, Bacillariophyceae, Bacillariophycidae, Cymbellales, Cymbellaceae, *Encyonema*

Encyonema caespitosum Kützing, 1849 (Figs. 3-4, Table 2)

Synonyms: *Encyonema prostratum* sensu Kützing 1844, *Encyonema caespitosum* var. *ovata* Grunow 1875, *Cymbella caespitosa* (Kützing) Brun 1880, *Encyonema auerswaldii* Rabenhorst 1853

Morphology: Valves dorsiventral, dorsal side convex, ventral slightly convex. The ends are slightly drawn on the ventral side, widely rounded. Length 22-46 µm, width 9-13 µm. Axial area strongly offset ventrally. Central area missing, relatively pronounced, rounded. Proximal end of raphe curved dorsally. As is generally characteristic of this genus, the central ends curve dorsally. Striae weakly radial, 10–12 in 10 µm.

Ecology: Lives in mesotrophic alkaline water bodies, and freshwater with medium electrolyte content, in flowing habitats rarer, particularly in large streams and rivers (Kulikovskiy & al. 2016; Hofmann & al. 2011).

Distribution: Cosmopolitan (Kulikovskiy & al. 2016). Frequent to very frequent (Hofmann & al. 2011).

Occurrence in sampling sites: S8, S12

Encyonema silesiacum (Bleish) D.G. Mann 1990 (Fig. 5, Table 2)

Basionym: *Cymbella silesiaca* Bleisch 1861-1882.

Synonym: *Cymbella minuta* var. *silesiaca* (Bleisch) Reimer 1975.

Morphology: Valves strongly dorsiventral, semi-lanceolate, dorsal side strongly convex, ventral straight, slightly convex in the central part. The ends are narrowly rounded, inclined to the ventral side. Length 16-42 µm, width 6-10 µm. The axial area is narrow, located closer to the ventral side. The central area is weakly expressed. Striae 10-13 in 10 µm.

Ecology: Mainly in the mountains, oligotrophic and mesotrophic water bodies with a low or moderate level of mineral (Kulikovskiy & al. 2016; Hofmann & al. 2011).

Distribution: In Central Europe rather frequent and occasionally abundant, furthermore in Germany, in running waters in alpine and sub-alpine regions (Hofmann & al. 2011).

Occurrence in sampling sites: S8, S9, S11, S12, S13

Fig. 2. Pictures of some sampling sites: a, Baghestan; b, Nushan-sofla; c, Daneshjo-Park; d, Aghche-Galee; e, Keshtiban; f, Baranduz.

Table 2. The species details and measurements of the genus *Encyonema* in the studied sites.

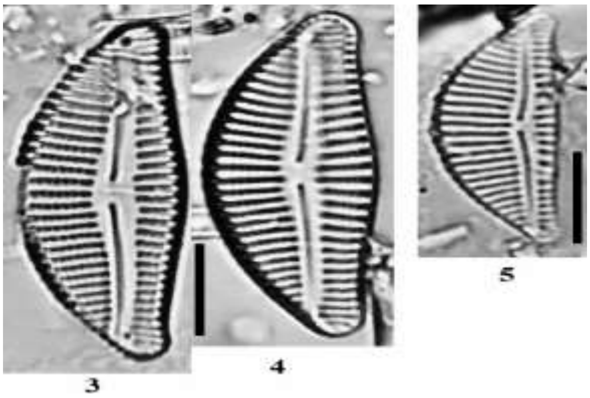
Figs	Species	Length (µm)	Width (µm)	Striae (#/10µm)
3	*Encyonema caespitosum*	37.4	12.2	10
4	*Encyonema caespitosum*	35.9	12.6	11
5	*Encyonema silesiacum*	25.4	9	12

Table 3. The details and measurements of *Encyonema prostrata* in the studied sites.

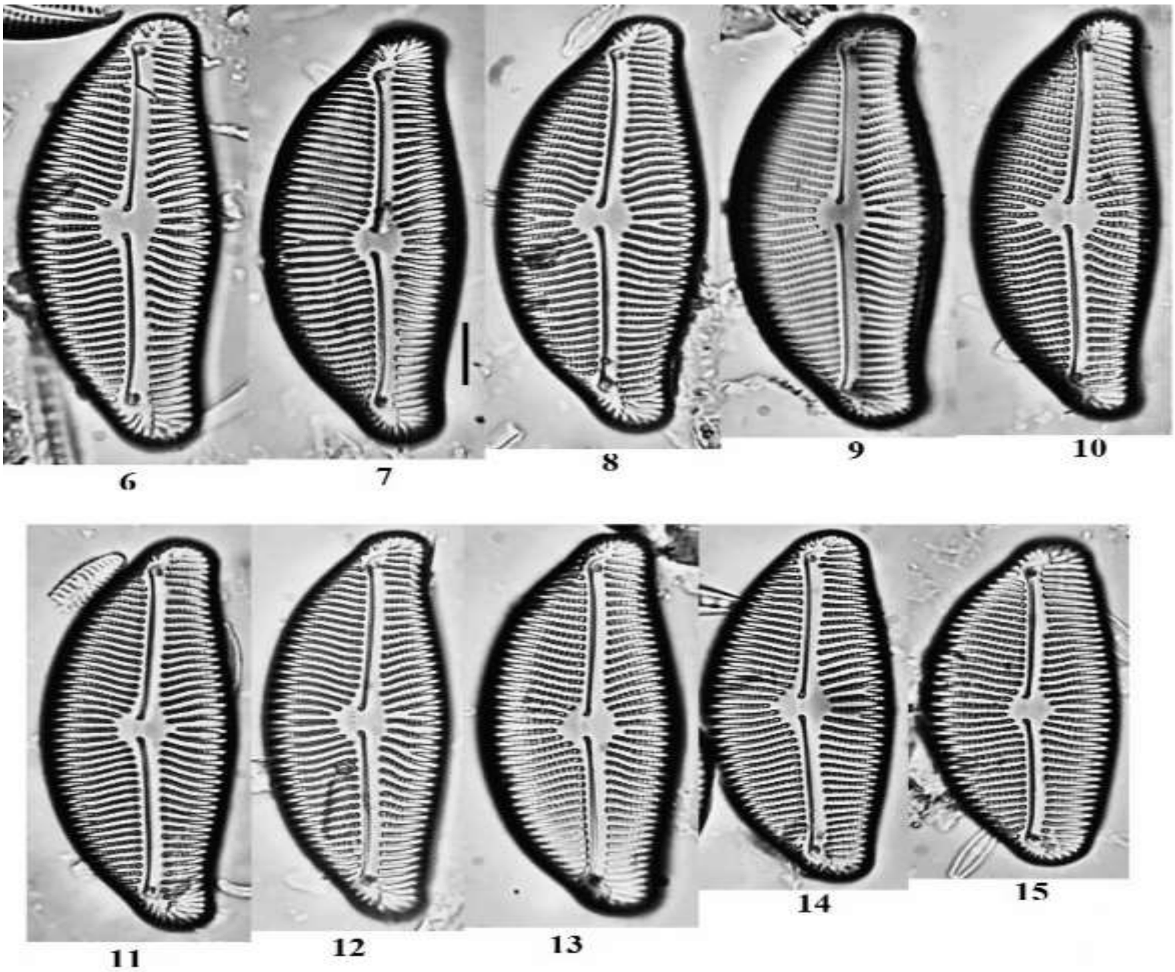
Figs	Species	Length (µm)	Width (µm)	Striae (#/10µm)	Areolae (#/10µm)
6	*Encyonema prostratum*	70.8	23.8	6	16
7	*Encyonema prostratum*	67.6	24.5	6	16
8	*Encyonema prostratum*	66.9	25	6	16
9	*Encyonema prostratum*	66.4	25.4	6	16
10	*Encyonema prostratum*	65.8	22.7	7	16
11	*Encyonema prostratum*	63.4	23.4	7	16
12	*Encyonema prostratum*	63.4	22.3	7	16
13	*Encyonema prostratum*	62.3	24.5	7	16
14	*Encyonema prostratum*	56	23.8	7	16
15	*Encyonema prostratum*	53.2	23.4	7	16

Table 4. The details and measurements of *Craticula cuspidata* in the studied sites.

Figs	Species	Length (μm)	Width (μm)	Striae (#/10μm)
16	*Craticula cuspidata*	116.1	28.8	11
17	*Craticula cuspidata*	115.3	27.9	11



Figs. 3-4. *Encyonema caespitosum*, LM valve view. Fig 5: *Encyonema silesiacum* LM valve view. Scale bar = 10 μm.



Figs. 6-15. *Encyonema prostratum*. LM valve view. Scale bar = 10 μm.

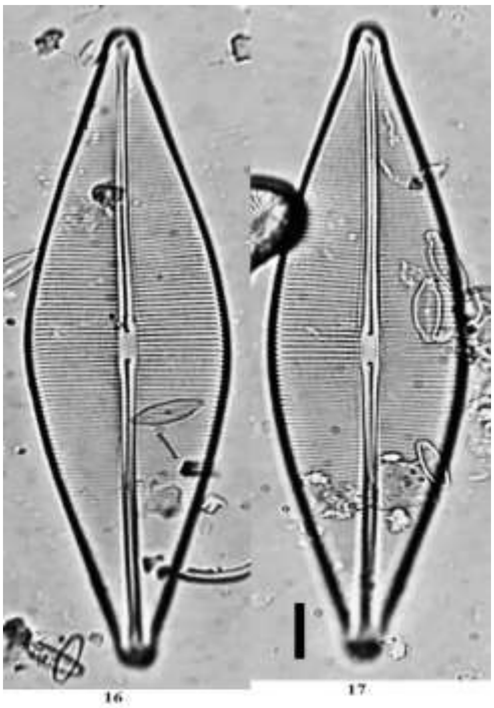
Encyonema prostratum (Berkeley) Kützing 1844 (Figs. 6-15, Table 3)
Basionym: *Monema prostratum* Berkeley 1833.
Synonym: *Encyonema paradoxum* Kutzing 1833, *Encyonema maximum* Wartmann 1862, *Cymbella encyonema* Heiberg 1863, *Cymbella prostrata* (Berkeley) P. T. Cleve 1894.
Morphology: Valves strongly dorsiventral, semi-lanceolate; dorsal side convex; ventral side convex in middle part. The ends are broadly rounded, slightly curved on the ventral side. Length 38-94 µm, width 16-25 µm. Axial area moderately narrow. The central area is small, rounded. Striae radial, 7-10 in 10 µm. Areolae 16 in 10 µm.
Ecology: Eutrophic reservoirs and freshwater (Kulikovskiy & al. 2016).
Distribution: Cosmopolitan (Kulikovskiy & al. 2016).
Occurrence in sampling sites: S2, S8, S9, S11, S12, S13

Craticula Grunow 1868.
Classification: Chromista, Bacillariophyta, Bacillariophyceae, Bacillariophycidae, Naviculales, Stauroneidaceae, *Craticula*

Craticula cuspidata **(**Kützing) DG Mann 1990 (Figs 16-17, Table 4)
Basionym: *Frustulia cuspidata* Kützing 1833.
Synonyms: *Navicula cuspidata* (Kützing) Kützing 1844.
Morphology: Valves rhombic-lanceolate to broadly lanceolate. The ends are narrowly rounded, relatively capitated or sub-capitated. Length 65-170 µm, width 17-36 µm. The axial area is narrow. The central area is weakly expressed, slightly expanded. Striae parallel, rarely slightly radial, relatively converging at the ends, 11-15 in 10 µm.
Ecology: Fresh and brackish waters (Kulikovskiy & al. 2016), frequently recorded from inland habitats with high conductivity and brackish waters (Hofmann & al. 2011).
Distribution: Cosmopolitan (Kulikovskiy & al. 2016).
Occurrence in sampling sites: S2, S9, S11, S13

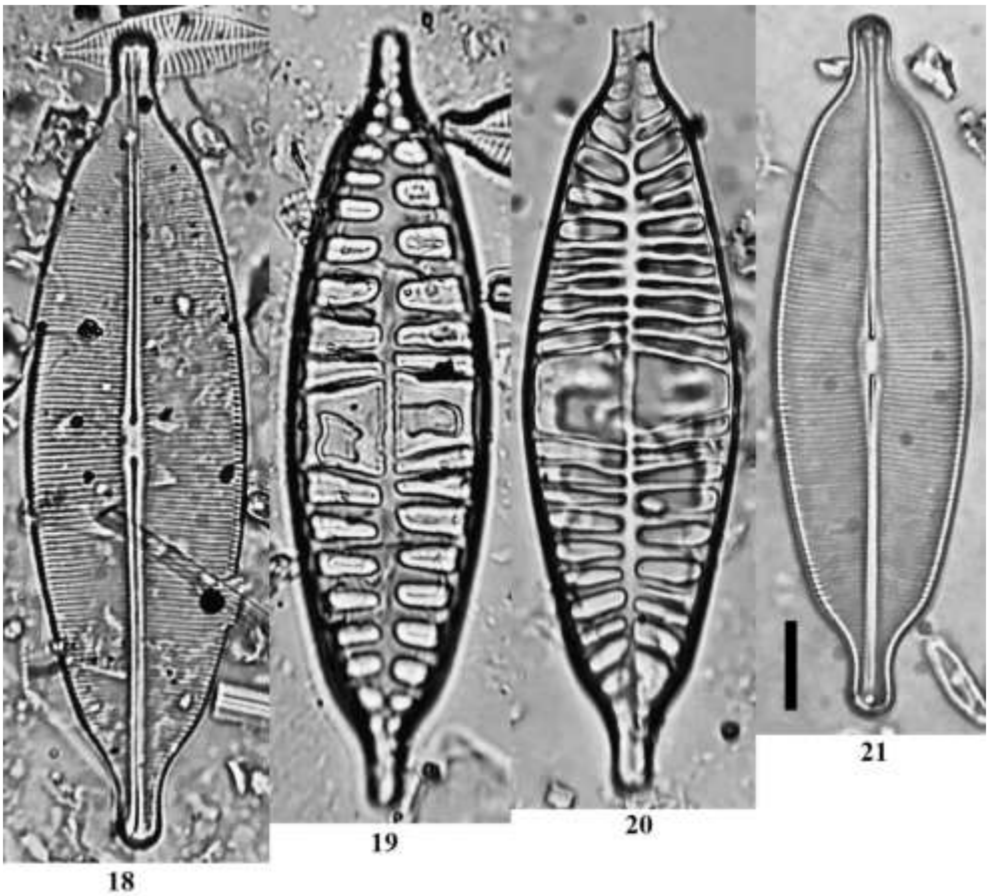
Table 5. The details and measurements of *Craticula ambigua* in the studied sites.

Figs	Species	Length (µm)	Width (µm)	Striae (#/10µm)	Areolae (#/10µm)
18	*Craticula ambigua*	93	25.3	14	30
19	*Craticula ambigua*	88.3	23.3	No data	No data
20	*Craticula ambigua*	89	25	No data	No data
21	*Craticula ambigua*	79.8	22.2	14	30



Figs. 16-17. *Craticula cuspidata* LM valve view. Scale bar = 10 µm.

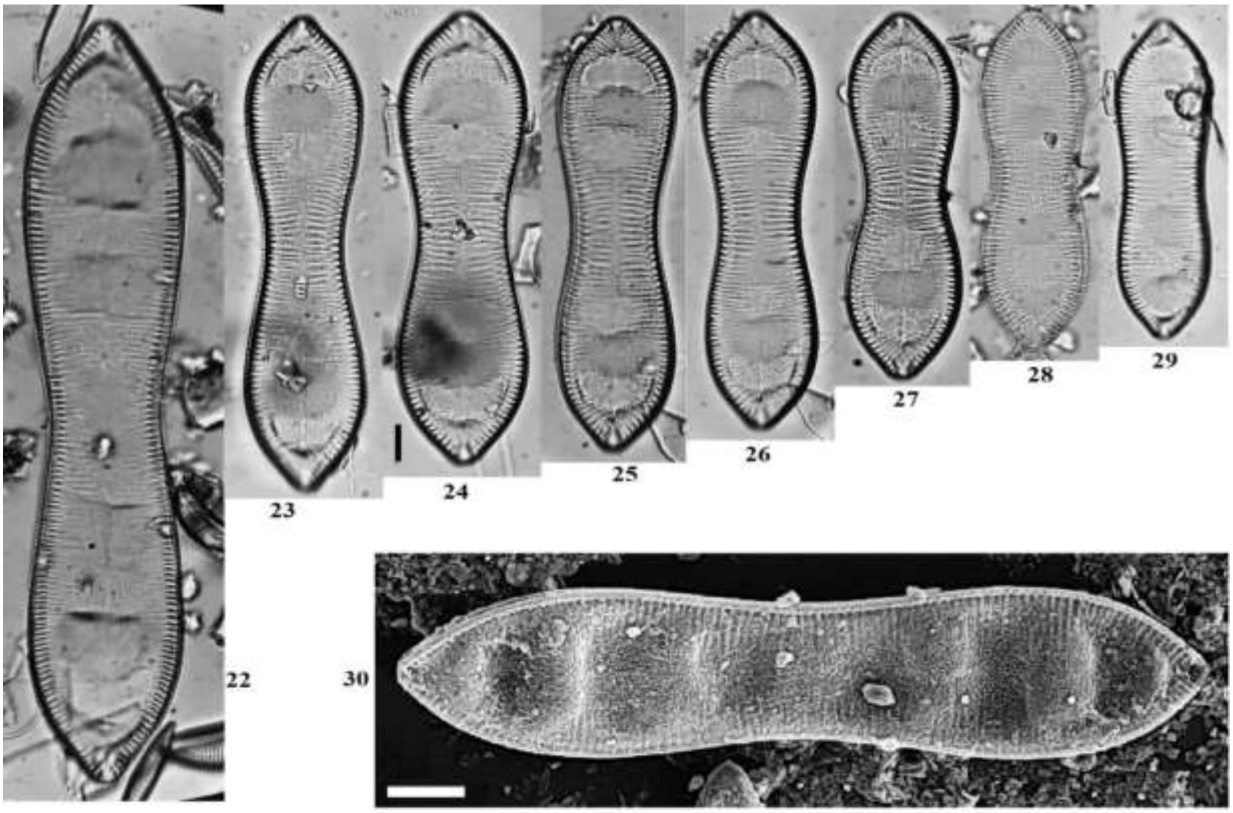
Craticula ambigua (Ehrenberg) DG Mann 1990 (Figs 18-21, Table 5)
Basionym: *Navicula ambigua* Ehrenberg 1843.
Synonyms: *Navicula cuspidata* var. *ambigua* (Ehrenberg) Kirchner 1878.
Morphology: Valves elliptical-lanceolate. The ends are attenuated, from sub-capitate to capitate. Length 38-95 µm, width 12-24 µm. The axial area is narrow, linear. The central area is weakly expressed, slightly expanded, and may be absent. Striae are very weakly radial, converging at ends, 15–18 in 10 µm. Areolae about 30 in 10 µm.
Ecology: Eutrophic and mesotrophic water bodies, moderately or strongly conductivity (Kulikovskiy & al. 2016; Hofmann & al. 2011). It usually appears in eutrophic, alkaline freshwater or slightly brackish waters.
Distribution: Cosmopolitan (Kulikovskiy & al. 2016).
Occurrence in sampling sites: S2, S13
Cymatopleura W Smith 1851.
Classification: Chromista, Bacillariophyta, Bacillariophyceae, Bacillariophycidae, Surirellales, Surirellaceae, *Cymatopleura*.
***Cymatopleura solea* (Brébisson)** W. Smith 1851 (Figs 22-30, Table 6)
Basionym: *Cymbella solea* Brébisson 1835.
Synonyms: *Navicula librile* Ehrenberg 1832, *Cymatopleura librile* (Ehrenberg) Pantocsek 1902.
Morphology: Valves broadly linear, narrowed in middle part. The ends are wedge-shaped, rounded. Length 30-300 µm, width at the ends 10-45 µm. Fibulae 7-8 in 10 µm. The striae are 28-29 in 10 µm.
Ecology: Mesotrophic and eutrophic fresh or brackish water bodies (Kulikovskiy & al. 2016; Hofmann & al. 2011).
Distribution: Cosmopolitan (Kulikovskiy & al. 2016), in Central Europe widely distributed (Hofmann & al. 2011).
Occurrence in sampling sites: S2, S3, S4, S5, S7, S8, S10, S11, S12, S13, S14



Figs. 18-21: *Craticula ambigua*. LM valve view. Scale bar = 10 µm.

Table 6. The details and measurements of *Cymatopleura solea* in the studied sites.

Figs	Species	Length (µm)	Width (µm)	Fibulae (#/10µm)	Striae (#/10µm)
22	*Cymatopleura solea*	210.5	26.7	6	28
23	*Cymatopleura solea*	131.8	18.4	6	28
24	*Cymatopleura solea*	125	22.8	6	28
25	*Cymatopleura solea*	119.7	20.9	7	28
26	*Cymatopleura solea*	115.2	19.1	7	29
27	*Cymatopleura solea*	100.8	19.3	6	28
28	*Cymatopleura solea*	93.8	20.8	7	29
29	*Cymatopleura solea*	88.5	18.4	7	29
30	*Cymatopleura solea*	83.4	20	7	28



Figs. 22-30. *Cymatopleura solea*, Figs 22-29 LM valve view, Fig 30 SEM valve view. Scale bar = 10 µm.

Cymatopleura apiculata (Brébisson) W. Smith 1853 (Figs 31-32, Table 7)

Synonyms: *Cymatopleura solea* var. *apiculata* (W.Smith) Ralfs 1861, *Surirella librile* (W.Smith) Descy 1983.

Morphology: The valves are broadly linear, narrowed in the middle part. The ends are wedge-shaped, rounded in small specimens. Length 38-125 µm, width at the ends 15-21 µm. Fibulae 7-8 in 10 µm. Striae are 28-29 in 10 µm.

Ecology: Mesotrophic and eutrophic fresh or brackish water bodies (Kulikovskiy & al. 2016).

Distribution: Cosmopolitan (Kulikovskiy & al. 2016).

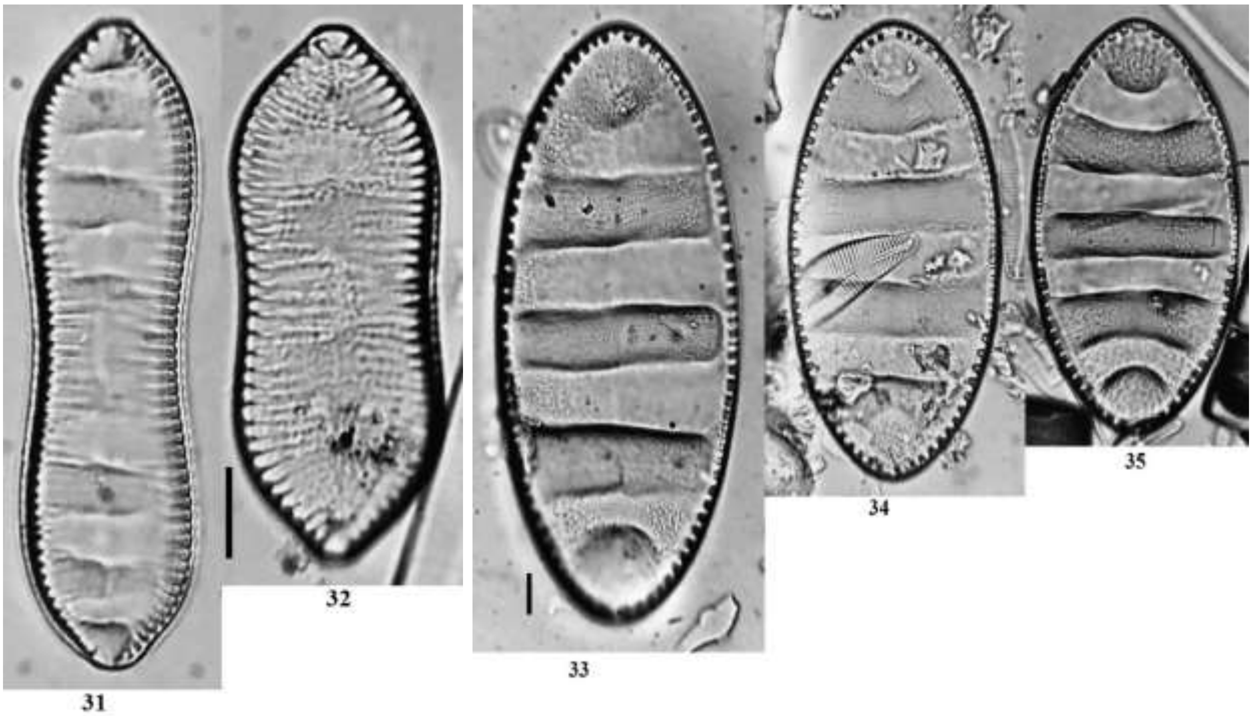
Occurrence in sampling sites: S8, S12, S13, S14

Table 7. The details and measurements of *Cymatopleura apiculata* in the studied sites

Figs	**Species**	**Length (µm)**	**Width (µm)**	**Fibulae (#/10µm)**	**Striae (#/10µm)**
31	*Cymatopleura apiculata*	72.7	15.5	7	29
32	*Cymatopleura apiculata*	60	20.1	7	No data

Table 8. The details and measurements *Cymatopleura hibernica* in the studied sites.

Figs	**Species**	**Length (µm)**	**Width (µm)**	**Fibulae (#/10µm)**
33	*Cymatopleura hibernica*	141.9	67.7	4
34	*Cymatopleura hibernica*	113	58.9	3
35	*Cymatopleura hibernica*	102.6	58.8	3



Figs. 31-32. *Cymatopleura apiculata*, LM valve view. Scale bar = 10 µm Figs. Figs 33-35: *Cymatopleura hibernica*, LM valve view. Scale bar = 10 µm.

Cymatopleura hibernica W. Smith 1851 (Figs 33-35, Table 8)

Synonyms: *Surirella plicata* Ehrenberg 1854, *Cymatopleura nobilis* Hantzsch 1860, *Cymatopleura elliptica* var. *rhomboides* Grunow 1862, *Cymatopleura elliptica* var. *ibernica* (W. Smith) Van Heurck 1881, *Cymatopleura elliptica* var. *ibernica* (W. Smith) Van Heurck 1896, *Cymatopleura plicata* (Ehrenberg) Pantocsek 1902, *Cymatopleura elliptica* var. *nobilis* (Hantzsch) Hustedt 1912. **Morphology:** The valves are rhombic-elliptical. The ends are sharply rounded or wedge-shaped. The frustules possess canal raphes which run around valves at the mantle margin. Length 60-190 µm, width 48-71 µm. Fibulae 3-5 in 10 µm.

Ecology: Fresh and brackish waters (Kulikovskiy & al. 2016).

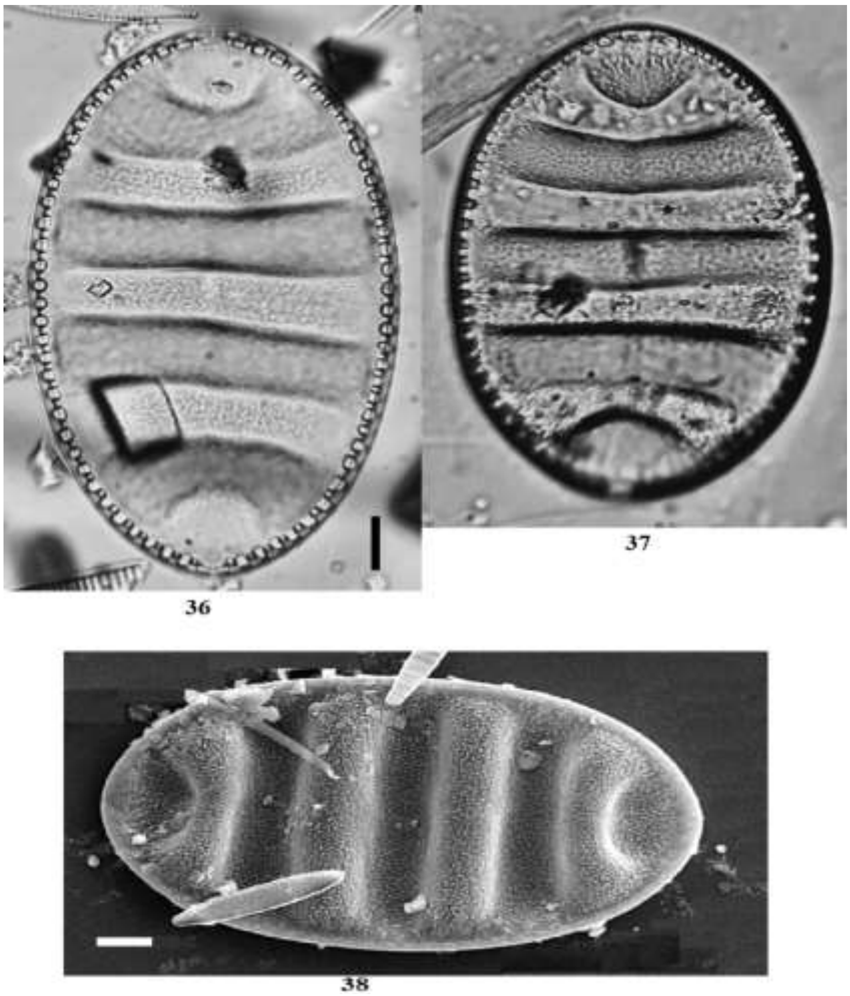
Distribution: Cosmopolitan (Kulikovskiy & al. 2016).

Occurrence in sampling sites: S2, S3, S8, S12, S13, S14

Cymatopleura elliptica (Brébisson) W. Smith 1851 (Figs 36-38, Table 9)
Basionym: *Surirella elliptica* Brébisson ex Kützing 1844.
Morphology: The valves are broadly elliptical. The ends are bluntly rounded to broadly rounded or flatted. The frustules possess canal raphes which run around valves at the mantle margin. Length 60-220 µm, width 30-90 µm. Fibulae 3-4 in 10 µm.
Ecology: Fresh and brackish waters (Kulikovskiy & al. 2016).
Distribution: Widely distributed in Central Europe but always in small numbers (Hofmann & al. 2011).
Occurrence in sampling sites: S1, S2, S4, S7, S8, S12, S13

Table 9. The details and measurements of *Cymatopleura elliptica* in the studied sites

Figs	Species	Length (µm)	Width (µm)	Fibulae (#/10µm)
36	*Cymatopleura elliptica*	103.9	58.9	3
37	*Cymatopleura elliptica*	90.4	61	3
38	*Cymatopleura elliptica*	97.5	60.2	-



Figs. 36-38. *Cymatopleura elliptica*, Figs 36-37 LM valve view, Fig 38 SEM external valve view. Scale bar = 10µm.

Overall, the results showed high diversity of diatoms species which in present study focused on 9 species from 3 genera including *Encyonema*, *Craticula* and *Cymatopleura*. The taxonomic and ecological study of the observed species from all the western rivers of Lake Urmia indicate diatom assemblage closely integrated with the limnological and ecological status of the rivers.

DISCUSSION

Lake Urmia resembles the Great Salt Lake (USA) in terms of geomorphology and water chemistry characteristics (Kelts & Shahrabi 1986). Lake Urmia, a UNESCO designated Biosphere Reserve and listed in Ramsar sites, is one of the most important lakes in the world and the second hypersaline lake (salinity ranging from 217 to more than 300 $g.L^{-1}$) in the world (Sharifi & al. 2018). This lake has suffered from a significant water shortage in recent years due to human activities, anthropogenic use and climate changes. The western rivers of the lake have less conductivity particularly in upstream sites, however, the conductivity gradually increased in down streams close to Lake Urmia which affect the diversity and species richness. It is noteworthy that observing and identifying species in such a condition can transmit relevant information about the species composition and their tolerance to conductivity. The upper reaches of the Nazlu-chay, Rouzeh-Chay, Shahr-chay, and Baranduz-chay rivers have fresh and relatively fresh water. In addition, the Aji-Chay has much less water, and only in certain months of the year, due to low rainfall, it comes dry completely.

In the present study, nine species were carefully analyzed. The genera *Encyonema*, *Craticula*, and *Cymatopleura* have already been reported in Iran. 3 species of *Encyonema* including *E. caespitosum*, *E. silesiacum*, and *E. prostratum*, 2 species of *Craticula* and they including *C. ambigua*, and *C. hibernica*, 4 species of *Cymatopleura* that includes *C. solea*, *C. apiculata*, *C. hibernica*, and *C. elliptica*, were observed. The comparison of studied specimens with other regions of Iran showed that *Encyonema caespitosum* was reported in Karaj river (Kheiri & al. 2018a), in addition, *Encyonema silesiacum* has been reported in Balikhli River (Panahy-Mirzahasnlou & al. 2018), Kashkan River (Safiallah & al. 2020), and Taleghan River (Naseri & Noroozi 2021). At the same time, *Encyonema prostratum* has been reported in Gavkhuni wetland (Zarei-Darki 2011). Similarly, *Craticula cuspidata* has been documented in the Balikhli River (Panahy-Mirzahasnlou & al. 2018), and the Anbaran Chay river (Panahy & al. 2020), in addition to which *Craticula ambigua* has been reported in the Gavkhuni wetland (Zarei-Darki 2011).

Like the two mentioned genera, the taxa *Cymatopleura solea* from Iran has been reported in the National Botanical Garden (Nezhadsatari & al. 2007), Ramsar streams (Soltanpour-Gargari & al. 2011), Zayandehrud (Zarei Darki & al. 2013), Boujagh National Park (Noroozi & al. 2009), Shahroud river (Sharifinia & al. 2016), Caspian Sea (Tahami & al. 2018), Marbareh river (Kheiri & al. 2018b), Kordan river (Adl & al. 2020), Jajrood (Jamalou & al. 2005), and Aras (Ghaffari & al. 2020; Mohebbi & al. 2012). In addition, *Cymatopleura elliptica* has been reported from Iran in Ramsar streams (Soltanpour-Gargari & al. 2011), Boujagh National Park (Noroozi & al. 2009), Golestan province (Ahmadi Musaabad & al. 2019), Kordan river (Adl & al. 2020), and Balikhli river (Panahy-Mirzahasnlou & al. 2018).

Due to the similarities between the species, especially in diatoms, their comparison provides a broad view and classified information, which at the same time increases the accuracy of the study. The species of *Encyonema*, especially *E. silesiacum* and *E. caespitosum*, were compared in Table 10 due to their morphological similarity. As it can be seen, both mentioned species have a complete overlap with their previous reports in terms of size and number of striae. *Encyonema silesiacum* overlaps with *E. caespitosum*, *E. ventricosum*, *E. lange-bertalotii*, and *E. procerum* in terms of length, while it is larger than *E. montana*. In terms of width, *E. silesiacum* only overlaps with *E. caespitosum* and is larger than other species. It is noteworthy that the amount of striae of our studied species is consistent only with *E. caespitosum* and *E. procerum* and is different from other species. The length of *Encyonema caespitosum* only overlaps relatively with *E. procerum*, but its width does not fit with any of the species in the Table 10.

Encyonema prostratum was compared with their similar species in terms of its morphology in Table 11. The *E. prostratum* in this study has shown a high similarity. In terms of length, it is completely consistent with *E. leibleinii*, *E. yellowstonianum*, *E. nicafei*, *E. latum*, *E. reimeri*, and is different from other species. Also, in terms of width, it completely fits with *E. latum*, and *E. reimeri*, and has little overlap with *E. leibleinii*, and *E. yellowstonianum*. In addition, the number of striae in the *E. prostratum* is completely overlapping with *E. latum*, and relatively overlapping with *E. leibleinii*.

Craticula cuspidata, and *Craticula ambigua* were compared with their similar species in terms of their morphological characteristics in Table 12. The *C. cuspidata* in this study has shown a complete overlap with its previous reports, and *C. ambigua* in this study has shown a high overlap with its previous reports, and in terms of width, it has a small discrepancy that can be ignored. The *C. cuspidata* and *C. ambigua* in this study are completely consistent with *C. johnstoniae*, and *C. acidoclinata* in terms of length. They also completely overlap in width with only *C. acidoclinata* and are completely different from the rest of the species. It should be noted that the number of striae in *C. hibernica* only overlaps with *C. acidoclinata*, and also *C. ambigua* with *C. johnstoniae*, and *C. acidoclinata* completely fits.

Cymatopleura solea and *Cymatopleura apiculata* were compared with their similar species in terms of appearance similarity in Table 13. *Cymatopleura solea*, and *C. apiculata* in this study showed complete overlap with previous reports. The *C. solea* in this study has shown complete overlap with almost all species in terms of length and width. The *C. apiculata* in this study, is consistent with *C. rugosa*, *Surirella dongtingensis*, and *Surirella librile* in terms of length, and in terms of width, it overlaps with almost all the species in the table. *C. solea,* and *C. apiculata* in this study do not match with *Surirella dongtingensis* in terms of the number of fibulae, and due to the lack of detailed information on fibulae in other species, it is not possible to compare in this regard.

Cymatopleura elliptica and *Cymatopleura hibernica* were compared with their two similar species in terms of morphological similarity (Table 14). *Cymatopleura elliptica* and *C. cuspidate* in this study showed complete overlap with previous reports. The *C. elliptica* in this study has shown a complete overlap with *Surirella undulata* in terms of length and width. Also, the *C. cuspidata* in this study is relatively consistent with *Surirella undulata* in terms of length and width. In terms of the number of fibulae, *C. cuspidata* is consistent with *Surirella undulata*, and due to the lack of data in *Cymatopleura internationale*, it cannot be compared.

We examined the morphology and ecology of *Encyonema caespitosum. Encyonema silesiacum*, *Encyonema prostratum*, *Craticula cuspidata*, *Craticula ambigua*, *Cymatopleura solea*, *Cymatopleura apiculata*, *Cymatopleura hibernica* and *Cymatopleura elliptica* and demonstrated that these species have a wide geographic distribution with a broad ecological tolerance, from fresh to brackish water. Clearly, additional work on diatom taxonomy and environmental drivers of biodiversity deserves further attention in the region. It should be acknowledged the more investigations will bring great information about diatom community structure and their response to drying rivers and lake due to human activities (e.g. construction of dams and reservoirs) and climate variability and changes particularly in arid and semi-arid regions.

Table 10. Comparison of *Encyonema silesiacum* and *Encyonema caespitosum* with similar species. Asterisk (*) indicates the specimen in western rivers of Lake Urmia.

	E. silesiacum*	***E. caespitosum****	***E. silesiacum***	***E. caespitosum***	***E. ventricosum***	***E. lange-bertalotii***	***E. procerum***	***E. montana***
Length (µm)	25.4	35.9-37.4	16-42	22-57	9-29	17-31	20-36	15-22
Width (µm)	9	12.2-12.6	6-10	9-15	4.5-7	6-8	5-8	6-8
Striae (#/10µm)	12	10-11	10-13	9-12	14-19	14-16	8-13	11-12
Source	This Study	This Study	Kulikovskiy 2016	Hofmann 2011	Kulikovskiy 2016	Bahls 2016a	Bahls 2016b	Bahls 2018

Table 11. Comparison of *Encyonema prostratum* with similar species. Asterisk (*) indicates the specimen in western rivers of Lake Urmia.

	E. prostratum*	***E. prostratum***	***E. lange-bertalotii***	***E. auerswaldii***	***E. leibleinii***	***E. yellowstonianum***	***E. nicafei***	***E. latum***	***E. reimeri***
Length (µm)	53.2-70.8	38-94	17-31	22-32	40-65	39-75	56-76	50-84	30-89
Width (µm)	22.3-25.4	16-25	6-8	9-10	16-23	17-23	16-19	22-27	16-26
Striae (#/10µm)	6-7	7-10	14-16	10-12	7-10	10-11	9	6-8	10
Areolae (#/10µm)	c. 16	16	c. 30-35	c. 25	16-20	16	18	12-14	14-16
Source	This Study	Kulikovskiy 2016	Bahls 2016a	Lowe 2015	Alexson 2014	Spaulding 2010d	Spaulding 2010b	Spaulding 2010a	Spaulding 2010c

Table 12. Comparison of *Craticula hibernica* and *Craticula ambigua* with similar species. Asterisk (*) indicates the specimen in western rivers of Lake Urmia.

	C. hibernica*	***C. ambigua****	***C. ambigua***	***C. cuspidata***	***C. accomodiformis***	***C. riparia***	***C. halophila***	***C. johnstoniae***	***C. acidoclinata***
Length (µm)	115.3-116.1	79.8-93	38-95	65-170	30-36	29-48	33-52	78-105	94-168
Width (µm)	27.9-28.8	22.2-25.3	12-24	17-36	9-13	8-10	8-12	18-19	22-29
Striae (#/10µm)	11	14	13-21	11-15	23-25	17-19	17-19	14-17	12-14
Areolae (#/10µm)	No data	c. 30	30	20-26	No data	No data	No data	No data	No data
Source	This Study	This Study	Kulikovskiy 2016; LaLiberte & al. 2015	Kulikovskiy 2016; Hofmann 2011	Bishop & Burge 2015	Burge & Bishop 2015	Bahls 2012b	Bahls 2012c	Bahls 2012a

Table 13. Comparison of *Cymatopleura solea* and *Cymatopleura apiculata* with similar species. Asterisk (*) indicates the specimen in western rivers of Lake Urmia.

	C. solea*	***C. apiculata****	***C. solea***	***C. apiculata***	***C. laticeps***	***C. nyansae***	***C. rugosa***	***C. clavata***	***Surirella dongtingensis***	***S. librile***
Length (µm)	83.4-210.5	60-72.7	30-300	38-125	130-166	138-245	52.5-100	110-240	56-93	56-280
Width (µm)	18.4-26.7	15.5-20.1	10-45	15-21	24-50	18-59.5	12-20	19-43	13-18	13-36
Fibulae (#/10µm)	6-7	7	6-9	No data	No data	No data	No data	No data	8-9	No data
Striae (#/10µm)	28-29	c. 29	28	28-29	>20	29	31	55-60	No data	29-34
Source	This Study	This Study	Kulikovskiy 2016	Kulikovskiy 2016	Cocquyt & John 2014	Cocquyt & John 2014	Cocquyt & John 2014	Cocquyt & John 2014	Liu & al. 2021a	Kociolek 2011

Table 14. Comparison of *Cymatopleura elliptica* and *Cymatopleura hibernica* with similar species. Asterisk (*) indicates the specimen in western rivers of Lake Urmia.

	*C. elliptica**	*C. hibernica**	*C. elliptica*	*C. hibernica*	*C. internationale*	*Surirella undulata*
Length (µm)	90.4-103.9	102.6-141.9	60-220	60-190	54-72	64-133
Width (µm)	58.9-61	58.8-67.7	30-93	48-71	31-39	45-67
Fibulae (#/10µm)	3	4-3	No data	No data	No data	4-5
Source	This Study	This Study	Kulikovskiy 2016	Kulikovskiy 2016	Bahls 2012d	Hatcher 2018; Liu & al. 2021

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REFERENCES

Adl, M. M., Iranbakhsh, A., Noroozi, M., Asri, Y., & Saadatmand, S. 2020: Epipelic Diatoms Flora Of Kordan River, Alborz Province In Iran. -Modern Phytomorphology 14: 40-48.

Ahmadi Musaabad, L., Panahy Mirzahasanlou, J., G Mahmoodlu, M., & Bahlakeh, A. 2019: Diatom Flora In Three Springs Of Golestan Province. -Journal Of Phycological Research 3(2): 432–442.

Alexson, E. 2014: Encyonema Leibleinii. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Leibleinii (Accessed August 17, 2022).

Atazadeh, I., Edlund, M. B., Van Der Vijver, B., Mills, K., Spaulding, S. A., Gell, P. A., Crawford, S., Barton, A. F., Lee, S. S., & Smith, K. E. L. 2014: Morphology, Ecology And Biogeography Of Stauroneis Pachycephala PT Cleve (Bacillariophyta) And Its Transfer To The Genus Envekadea. -Diatom Research 29(4): 455–464.

Atazadeh, E., Gell, P., Mills, K., Barton, A., Newall P. 2021: Community Structure And Ecological Responses To Hydrological Changes In Benthic Algal Assemblages In A Regulated River: Application Of Algal Metrics And Multivariate Techniques In River Management. -Environmental Science And Pollution Research 28 (29): 39805-39825.

Atazadeh, I., Sharifi, M., & Kelly, M. G. 2007: Evaluation Of The Trophic Diatom Index For Assessing Water Quality In River Gharasou, Western Iran. -Hydrobiologia 589(1): 165–173. Https://Doi.Org/10.1007/S10750-007-0736-0

Bahls, L. 2012a: Craticula Acidoclinata. In Diatoms Of North America. Https://Diatoms.Org/ Species/Craticula_Acidoclinata (Accessed August 17, 2022).

Bahls, L. 2012b: Craticula Halophila. In Diatoms Of North America. Https://Diatoms.Org/ Species/Craticula_Halophila_Sensu_Llb (Accessed August 17, 2022).

Bahls, L. 2012c: Craticula Johnstoniae. In Diatoms Of North America. Https://Diatoms.Org/ Species/Craticula_Johnstoniae (Accessed August 17, 2022).

Bahls, L. 2012d: Cymatopleura Internationale. In Diatoms Of North America. Https://Diatoms.Org/ Species/Cymatopleura_Internationale (Accessed August 17, 2022).

Bahls, L. 2016a: Encyonema Lange-Bertalotii. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Lange-Bertalotii (Accessed August 17, 2022).

Bahls, L. 2016b: Encyonema Procerum. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Procerum (Accessed August 17, 2022).

Bahls, L. 2018: Encyonema Montana. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema-Montana (Accessed August 17, 2022).

Bishop, I., Burge, D. 2015: Craticula Accomodiformis. In Diatoms Of North America. Https://Diatoms.Org/Species/Craticula_Accomodiformis (Accessed August 17, 2022).

Bishop, I. W., Esposito, R. M., Tyree, M., & Spaulding, S. A. 2017: A Diatom Voucher Flora From Selected Southeast Rivers (USA). -Phytotaxa 332(2): 101–140.

Blanco, S. 2020: Diatom Taxonomy And Identification Keys BT - Modern Trends In Diatom Identification: Fundamentals And Applications (G. Cristóbal, S.

Blanco, & G. Bueno (Eds.) -Springer International Publishing: 25-38. Https://Doi.Org/10.1007/978-3-030-39212-3_3

Burge, D., Bishop, I. 2015: Craticula Riparia. In Diatoms Of North America. Https://Diatoms.Org/ Species/Craticula_Riparia (Accessed August 17, 2022).

Chessman B. C., Bate N., Gell P. A. & Newall P. 2007: A Diatom Species Index For Bioassessment Of Australian Rivers. -Marine And Freshwater Research 58: 542–557

Compère P. 1981: Algues Des Deserts D'iran. -Bulletin Du Jardin Botanique National De Belgique/Bulletin Van De National Plantentuin Van België 51: 3–40.

Cocquyt, C. & Jahn, R. 2014: A Re-Investigation Of Otto Müller's Cymatopleura Taxa (Bacillariophyta) From East Africa. -Plant Ecology And Evolution 147(3): 412-425.

Frenguelli, J. 1942: XVII Contribución Al Conocimiento De Las Diatomeas Argentinas. Diatomeas Del Neuquén.(Patagonia). -Revista Del Museo De La Plata 5(18): 73–219.

Ghaffari, S., Razeghi, J., Ramazannejhad Ghadi, R., Dabagh Mohamadi Nasab, A., & Masoudi, M. 2020: Study Of Population Structure And Biodiversity Of Algae In Aras River. -Journal Of Wetland Ecobiology 11(4): 105–115.

Guiry, M. 2022: Algaebase. Https://Www.Algaebase. Org/ (Accessed August 17, 2022).

Hatcher, K. 2018: Surirella Undulata. In Diatoms Of North America. Https://Diatoms.Org/ Species/Surirella-Undulata (Accessed August 17, 2022).

Hofmann, G.; Werum, M.; Langebertalot, L.-B. 2011: Diatomeen Im Süsswasser-Benthos Von Mitteleuropa. Bestimmungsflora Kieselalgen Für Die Ökologische Praxis. Über 700 Der Häufigsten Arten Und Ihre Ökologie. Rugell,: ARG Gantner Verlag. :1-908.

Jamalou, F., Falahian, F. A., Nezhadsatari, T., & Majd, A. 2005: Study Of Diatoms Flora Of Jajrood River. - Environmental Science And Technology (26): 98-112.

Kelts, K., & Shahrabi, M. 1986: Holocene Sedimentology Of Hypersaline Lake Urmia, Northwestern Iran. -Palaeogeography, Palaeoclimatology, Palaeoecology 54(1): 105–130. Https://Doi.Org/Https://Doi.Org/10.1016/0031-0182(86)90120-3

Kheiri, S., Solak, C. N., Edlund, M. B., Spaulding, S., Nejadsattari, T., Asri, Y., & Hamdi, S. M. M. 2018a: Biodiversity Of Diatoms In The Karaj River In The Central Alborz, Iran. -Diatom Research 33(3): 355–380.

Kheiri, S., Tavakoli, M., & Oraghi Ardebili, Z. 2018b: Diatom Flora Of Marbareh River, Dez Catchment, Lorestan, Iran. -Journal Of Plant Research (Iranian Journal Of Biology) 31(3): 516–528. Https://Www.Sid.Ir/En/Journal/Viewpaper.Aspx?ID=768823

Kociolek, P. 2011: Surirella Librile. In Diatoms Of North America. Https://Diatoms.Org/ Species/Surirella-Librile (Accessed August 17, 2022).

Kociolek, J.P.; Blanco, S.; Coste, M.; Ector, L.; Liu, Y.; Karthick, B.; Kulikovskiy, M.; Lundholm, N.; Ludwig, T.; Potapova, M.; Rimet, F.; Sabbe, K.; Sala, S.; Sar, E.; Taylor, J.; Van De Vijver, B.; Wetzel, C.E.; Williams, D.M.; Witkowski, A.; Witkowsk, J. 2022: Diatombase. Https://Doi.Org/10.14284/504 (Accessed August 17, 2022).

Krammer K. & Lange-Bertalot H. 1986: Bacillariophyceae, 1. Teil: Naviculaceae In: Suswasserflora Von Mitteleuropa (Ed. By H. Ettl, J. Gerloff, H. Heynıg & D. Mollenhauer), Vol. 2/1. G. Fischer Verlag, Stuttgart & New York. :876pp.

Krammer K. & Lange-Bertalot H. 1988: Bacillariophyceae, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In: Süßwasserflora Von Mitteleuropa. (Ed. By H. Ettl, J. Gerloff, H. Heynıg, D. Mollenhauer), Vol. 2/2. G. Fischerverlag, Stuttgart & New York. :596pp.

Krammer K & Lange-Bertalot H. 1991a: Bacillariophyceae, 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. In: Süßwasserflora Von Mitteleuropa (Ed. By H. Ettl, J. Gerloff,H. Heynıg, D. Mollenhauer), Vol. 2/3. G. Fischer Verlag,Stuttgart & New York. :576 Pp.

Krammer K. & Lange-Bertalot H. 1991b: Bacillariophyceae, 4. Teil: Achnanthaceae. Kritische Erganzungen -Zu Navicula (Lineolatae) Und Gomphonema, Gesamtliteraturverzeichnis. In: Süswasserflora Von Mitteleuropa (Ed. By H. Ettl, J. Gerloff, H. Heynıg, D. Mollenhauer), Vol 2/4. G. Fischer Verlag, Stuttgart & New York. :437pp.

Kulikovskiy, M. S., Glushchenko, A. M., Genkal, S. I., & Kuznetsova, I. V. 2016: Identification Book Of Diatoms From Russia. Filigran, Yaroslavl.

Kützing, F.T. 1833: Synopsis Diatomacearum Oder Versuch Einer Systematischen Zusammenstellung Der Diatomeen. -Linnaea 8(5): 529-620, Pls. XIII-XIX.

Laliberte, G., Vaccarino, M., Main, S. 2015: Craticula Ambigua. In Diatoms Of North America. Https://Diatoms.Org/Species/Craticula_Ambigua (Accessed August 17, 2022).

Levkov, Z., Tofilovska, S., & Mitic-Kopanja, D. 2016:

Species Of The Diatom Genus Craticula Grunow (Bacillariophyceae) From Macedonia. Contributions. -Section Of Natural, Mathematical & Biotechnical Sciences 37(2).

Liu, B., Kociolek, J. P., & Ector, L. 2021a: Surirella Dongtingensis Sp. Nov. And Ultrastructure Of S. Undulata (Bacillariophyta) From China. -Botany Letters, 168(1): 32-41 DOI: 10.1080/23818107.2020.1756908

Liu, Q., Li, J., Wang, Q., Kociolek, J. P., & Xie, S. 2021b: Encyonema Oblonga (Bacillariophyta, Cymbellaceae), A New Species From Shanxi Province, China. -Phytotaxa 480(3): 284–290.

Lowe, R. 2015: Encyonema Auerswaldii. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Auerswaldii (Accessed August 17, 2022).

Lowe R. L. & Pan Y. 1996: Benthic Algal Communities As Biological Indicators. In R. J. Stevenson, M. L. Bothwell, And R. L. Lowe, Editors. -Algal Ecology. Freshwater Benthic Ecosystems Academic Press, San Diego :705-739

Mann, D. G., & Stickle, A. J. 1991: The Genus Craticula. -Diatom Research 6(1): 79–107.

Mayer, A. 1947: Die Bayerischen Encyonema Und Cymbella Arten Mit Ihren Formen. -Berichte Der Bayerischen Botanischen Gesellschaft (Zur Erforschung Der Heimischen Flora) 27: 226–239.

Mirzahasanlou, J. P., Nejadsattari, T., Ramezanpour, Z., NAMIN, J. I., & Asri, Y. 2018: The Epilithic And Epipelic Diatom Flora Of The Balikhli River, Northwest Iran. -Turkish Journal Of Botany 42(4): 518–532.

Mohebbi, F., Mohsenpour Azari, A., & Asem, A. 2012: Phytoplankton Population And Its Indices In Aras Dam Reservoir. -Iranian Journal Of Biology 25(2): 316–328.

Naseri A., Noroozi M., Asri Y., Iranbakhsh A., Saadatmand S. & Atazadeh E. 2022: Diatom taxonomy and environmental drivers of biodiversity in the Taleghan River and reservoir in Central Alborz, Iran, -Diatom Research. DOI: 10.1080/0269249X.2022.2123049.

Nezhadsatari, T., SHARIAT, M. Z., & Jamzad, Z. 2007: A Study On Diatoms Of The Artificial Ponds And Lakes Of The National Botanical Garden, Iran.

Nejadsattari T. 2005: The Diatom Flora Of Lake Neure, Iran. -Diatom Research 20: 313–333.

Nejadsattari T., Noroozi M. & Fallahi M. 2005: The Composition Andseasonal Distribution Of Epiphytic Algae In Anzali Lagoon, Iran. -Cryptogamie, Algol 26: 387–398.

Noroozi, M., Naqunezhad, A., & Mehrvarz, S. S. 2009: Algal Flora In First Iranian Land-Marine The Boujagh National Park. -International Journal On Algae 11(3): 276-288.

Panahy Mirzahasanlou, A., Fataei, E., & Panahy Mirzahasanlou, J. 2020: Investigation Of Diatoms In Anbaran Chay River Of Ardabil Province In Relation To Water Quality As Bio Indicators. -Journal Of Wetland Ecobiology 12(2): 37–48.

Safiallah, S., Saadatmand, S., Kheiri, S., & Iranbakhsh, A. 2020: Biodiversity Of Diatoms In The Kashkan River In The Zagros Mountains, Western Iran. -Iranian Journal Of Botany 206(2): 141–161.

Shams-Kahrizsangi M., Afsharzadeh S. & Atici T. 2012: Seasonal Variations In Phytoplankton Communities In Zayandeh-Rood Dam Lake (Isfahan, Iran). -Turkish Journal Of Botany. 36: 715–726.

Sharifi, A., Shah-Hosseini, M., Pourmand, A., Esfahaninejad, M., & Haeri-Ardakani, O. 2018: The Vanishing Of Urmia Lake: A Geolimnological Perspective On The Hydrological Imbalance Of The World’s Second Largest Hypersaline Lake -Springer Berlin Heidelberg: 1-38 Https://Doi.Org/10.1007/698_2018_359

Sharifinia, M., Mahmoudifard, A., Gholami, K., Namin, J. I., & Ramezanpour, Z. 2016: Benthic Diatom And Macroinvertebrate Assemblages, A Key For Evaluation Of River Health And Pollution In The Shahrood River, Iran. -Limnology 17(1): 95–109.

Smith, W. 1851: Notes On The Diatomaceae: With Descriptions Of British Species Included In The Genera Campylodiscus, Surirella And Cymatopleura.-Annals And Magazine Of Natural History 7(2): 1-14.

Soltanpour-Gargari, A., Lodenius, M., & Hinz, F. 2011: Epilithic Diatoms (Bacillariophycae) From Streams In Ramsar, Iran. -Acta Botanica Croatica 70(2): 167–190.

Spaulding, S. 2010a: Encyonema Latum. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Latum (Accessed August 17, 2022).

Spaulding, S. 2010b: Encyonema Nicafei. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyonema_Nicafei (Accessed August 17, 2022).

Spaulding, S. 2010c: Encyonema Reimeri. In Diatoms Of North America. Https://Diatoms.Org/ Species/Encyononema_Reimeri (Accessed August 17, 2022).

Spaulding, S. 2010d: Encyonema Yellowstonianum. In Diatoms Of North America. Https://Diatoms.Org/Species/Encyonema_Yellowstonianum (Accessed August 17, 2022).

Spaulding, S. A. 2022: Diatoms Of North America. Https://Diatoms.Org (Accessed August 17, 2022).
Tahami, F., Eslami, F., & Rahmati, R. 2018: The Study On Diatoms In The Estuary Of The Major Rivers Of The Caspian Sea (Iran Waters). -Environmental Researches 8(16): 177–186. Http://Www.Iraneiap.Ir/Article_63811.Html
USGS. 2022: Earth Resources Observation And Science (EROS) Center. Https://Eros.Usgs.Gov/Image-Gallery/Earthshot/Lake-Urmia-Iran (Accessed August 17, 2022).
Zarei-Darki, B. 2011: Species Composition And Ecology Of The Diatoms In The Gavkhuni Wetland (Iran). -Вісник Харківського Національного Аграрного Університету. Серія: Біологія, 1: 110–117. Http://Nbuv.Gov.Ua/UJRN/Vkhnau_Biol_2011_1_13
Zarei Darki, B., Zarei Darki, L., Akkafi, H. R., & Mirzai, M. 2013: Taxonomic Composition Of Algae And Its Indicator Role In The Ecosystem Of The Zayandehrud River, Iran. -Inland Water Biology 6(4): 285–293.