https://tbj.ui.ac.ir
Taxonomy and Biosystematics
E-ISSN: 2322-2190
Document Type: Research Paper
Vol. 16, Issue 3, No. 60, (2024), P:35-44
Received: 29/05/2024 Accepted: 24/08/2024

Reaearch Paper

Study of genus *Reimeria* (Bacillariophyta) in the Kordan and Hazarband Rivers in the Central Alborz, Northern Iran

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Abstract
Reimeria Kocioleck & Stoermer is a small cosmopolitan genus introduced in 1987 by Kocioleck & Stoermer within Gomphonemataceae family. Species of *Reimeria* are biraphid and longitudinally asymmetrical with dorsiventral shape and a single stigma. For decades, only *R. sinuata* was reported from various localities in Iran. In the present study, the biodiversity of the genus was investigated in the Kordan and Hazarband rivers. The sampling process was carried out in 2019 with a total of five samples collected at five locations. A total of five species including *Reimeria capitata* (A.Cleve) Levkov & Ector, *R. fontinalis* Levkov & Ector, *R. ovata* (Hustedt) Levkov & Ector, *R. sinuata* (W.Greg.) Kociolek & Stoermer *and R. uniseriata* Sala, Guerrero & Ferrario were identified, three of which are new records for the diatom flora of Iran. Additionally, *R. uniseriata* Sala, Guerrero & Ferrario was the only taxon common to all sites and *R. capitata* (A.Cleve) Levkov & Ector was the least common one. *R. sinuata* (W.Greg.) Kociolek & Stoermer was consistently found in multiple locations across various sampling sites in Iran, but always in low abundance. Considering the species diversity observed at each investigated site, the distributional evenness of *Reimeria* species did not exceed 20 percent in any given location. The same applies to neighboring countries rather fairly, where Turkey and Afghanistan have the most and least species diversity, respectively.
Keywords: *diatoms, Kordan River, Hazarband River, diversity, new reports*

Introduction

Cymbellales are a diverse group of diatoms mostly accommodated in the family Cymbellaceae and Gomphonemataceae characterized by asymmetry along the transapical axis, presence of stigmata in most genera, non-bisected apical pore fields and other intra-cellular features (Kociolek & Spaulding, 2003; Solak et al., 2016). *Reimeria* Kocioleck & Stoermer is a new genus derived from the *Cymbella* in this group, first introduced in 1987 by Kociolek & Stoermer. The included species are characterized by slight dorsiventral shape of valves with the margin varying from straight to a bit convex or even undulate ventral side. The central area is rather unilaterally expanded towards the ventral margin and the ventral margin could be characterized as tumid. No more than one stigma is observed throughout the various species, and raphe ends are deflected towards the ventral margin (Levkov & Ector, 2010). Currently, there are a total of ten species accommodated within the genus *Reimeria* including *R. asiatica* Kulikovskiy, Lange-Bertalot & Metzeltin, *R. baicalensis* Kulikovskiy, Lange-Bertalot & Metzeltin, *R. capitata* (Cleve-Euler) Levkov & Ector, *R. cuneatiformis* Kulikovskiy, Lange-Bertalot & Metzeltin, *R. fontinalis* Levkov & Ector, *R. lacus-idahoensis* Kociolek & Stoermer, *R. ovata* Levkov & Ector, *R. pseudoencyonema* Kulikovskiy, Lange-Bertalot & Metzeltin, *R. sinuata* (W.Gregory) Kociolek & Stoermer, and *R. uniseriata* S.E.Sala, J.M.Guerrero & M.E.Ferrario (Kociolek & Stoermer, 1987; Kulikovskiy et al., 2012; Levkov & Ector, 2010; Sala et al., 1993).

In Iran, which is a considerably large country with approximately 1.6 million km^2 of land and vastly different ecosystems (Akhani et al., 2013), there are diverse aquatic ecosystems including rivers, streams, springs, waterfalls, reservoirs and lakes. The study of Iranian

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Ghavam, A., & Atazadeh, E. (2024). Study of genus Reimeria (Bacillariophyta) in the Kordan and Hazarband Rivers in the Central Alborz Northern Iran. *Taxonomy and Biosystematics*, *16* (60), 35-44.

http://dx.doi.org/10.22108/tbj.2024.141551.1265

diatoms has a history of about half a century (Hirano, 1973; Moghadam, 1975; Compère, 1981), but the number of researches conducted and the published data are not very high compared to the time period. Most of the studies have focused on the shores of the Caspian Sea (Zarei-Darki, 2009), central Iran (Afsharzadeh et al., 2003), the Persian Gulf (Attaran-Fariman & Asefi, 2022), the Central Alborz (Kheiri et al., 2018a; Naseri et al., 2022), and the west and northwest of Iran (Atazadeh et al., 2007; Panahy Mirzahasanlou, 2018; Mehrjuyan & Atazadeh, 2022; Goshtasbi et al., 2022; Parikhani et al.,2023; Yadollahi & Atazadeh, 2023).

The genus *Reimeria* has been reported in just a handful of studies so far, all of which focus on either *R. sinuata* (W.Gregory) Kociolek & Stoermer or *R. uniseriata* Sala, Guerrero & Ferrario. In the Tizab River which is also located in the Central Alborz Region and was studied shortly before this study (Kheiri, 2019) no taxa from *Reimeria* were found either. There is no research dating back to before 1987, when included species were referred to using their old taxonomically accepted name, *Cymbella* Agardh. Aside from other parts of the country, in the Central Alborz Region, *Reimeria sinuata* (W.Gregory) Kociolek & Stoermer has been reported in four different areas to date. These include Karaj River (Kheiri et al., 2018a), Jajrood River (Jamaloo et al., 2006), Ramsar streams (Soltanpour-Gargari et al., 2011) and Taleghan River (Naseri et al., 2022); although with lower relative abundance compared to other genera.

Central Alborz Region is actually the middle part of the Alborz Mountains located in southern Caspian Sea. This region holds immense geological and ecological significance, hosting a wide range of both endemic and non-endemic plant and animal species, alongside highly diverse populations of microscopic organisms. On the northern slope, which is much closer to the Caspian shoreline, humid-to-warm temperate climate and the Hyrcanian forests are predominant, but in the southern slope dry steppes account for the main vegetation; as the mountain itself, with its high peaks and deep canyons acts as a natural barrier in the way of humidity heading southward.

Hazarband River is a permanent river located within the Kordan rural area northwestern Tehran, Iran. This river is known for its rocky bed and originates from numerous small streams in the Bonrood heights at (2500-3000 m asl). It is nearly 22 kilometers long and flows all the way down to where it joins the Kordan River at an altitude of 1500 (m.a.s.l.) where the Baraghan and Varadeh roads intersect. The Kordan River is also a rocky-bed river and a part of it between Baraghan and Chalengdar villages is sometimes called the Baraghan River. Overall, the Hazarband and Kordan rivers are vastly affected by human exploitation in midstream and downstream areas, whereas upstream areas look much more intact and pristine. This study discusses the biodiversity of *Reimeria* species within a number of important locations along the Kordan and Hazarband rivers. In addition, it includes the first report of *Reimeria capitata* (A.Cleve) Levkov & Ector, *R. fontinalis* Levkov & Ector , and *R. ovata* (Hustedt) Levkov & Ector species in Iran, which is supported by morphological investigations using a light microscope. The aforementioned rivers, especially the Hazarband River, were poorly studied in terms of diatom taxonomy at the time of this research, and the data available on their diatom flora were scarce. As a result, the main aim of this study was to expand our scientific knowledge of these two ecologically invaluable waterbodies and introduce potential new records to the diatom world.

Material and methods

Sampling locations

A total of five sampling stations along the Kordan River and the Hazarband River were chosen for collecting epilithic diatom samples; including two sites in the Kordan village, two sites in the Varadeh village, and one site within the Baraghan rural area. The schematic map of all sampling stations is shown in Figure 1. The elevation ranges from 1419 to 1662 meters. Station 1 (*1) is the most downstream site and Station 5 (*5) is the most upstream site; albeit due to the topographic situation, the elevation decreases from Station 3 to Station 4. Table 1 shows the information of each sampling site in detail.

Table 1. Sampling stations along the Kordan and Hazarband rivers.

Station number	Latitude and Longitude	Altitude (m)	Description
1	35°57'17" N 50°50'34" E	1471	Kordan River, Kordan-Koohsar road, underneath first bridge
2	35°57'11" N 50°56'23" E	1628	Kordan River, before Jelengedar, Kordan road
3	35°58'17" N 50°53'24" E	1567	Kordan (Baraghan) River, Baraghan village
4	35°59'38" N 50°55'5" E	1662	Hazarband River, 1 km to Varadeh village, before Varadeh two-way, Varadeh road
5	35°56'45" N 50°49'21" E	1419	Hazarband River, Varadeh-Sibandarreh road

Sampling method

The primary objective across all five sites during the sampling process was to obtain the maximum epilithic diatom populations available. At each site, ten differently sized and shaped rocks were chosen for sample collection on average, within an area of ten to twenty meters long and a few centimeters to one meter deep. The surface of each rock was scrubbed in order to transfer the diatom populations to the final samples. The diatom biofilm was stored and divided into two 50 ml bottles: one intended for further procedures and analysis, and the other kept as a backup. Collected samples were fixed with 10X diluted Lugol’s solution instead of the more common 4% Formaldehyde because of the carcinogenic vapor and other potential hazards of the latter. Every single bottle was labeled with the information of the related site and finally transferred to the laboratory in a cool box.

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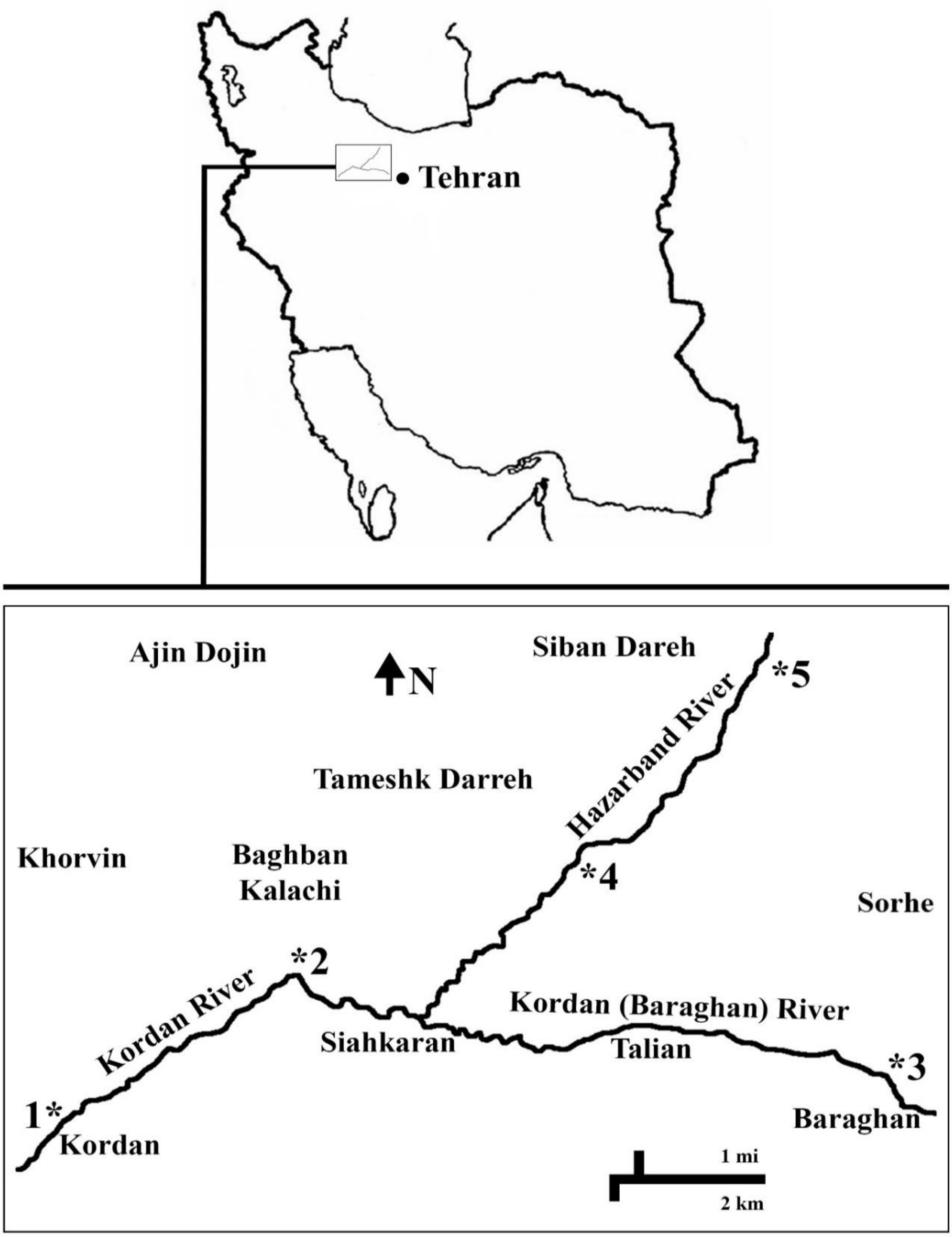


Figure 1. Schematic map of the studied locations along the Kordan and Hazarband rivers; downstream site (*1) in Kordan village and upstream site (*5) on Varadeh-Siban Dareh road.

Treatment and examination of the samples

A personalized version of the commonly known Hydrogen Peroxide method was used for the treatment of the collected samples (Renberg, 1990). This method was optimized specifically for the samples during a preliminary test phase. To remove the organic matter and carbonates, 20 ml of hot H_2O_2 with 35% concentration was mixed with the same volume of the raw sample and kept for 1.5 h at 100˚C (Battarbee, 1986). Five milliliters (ml) of 32% Hydrogen Chloride (HCl) was added to the solution right afterwards and put at 80˚C for another 30 minutes. Digested samples were left to cool for about 2-5 hours and rinsed daily using distilled water for 3 days to make sure that the siliceous frustules are neat (Atazadeh, 2023). The resultant treated samples were dried on coverslips for 24 hours and then mounted onto slides using Entellan mounting medium. Examination and taking light micrographs of final prepared slides carried out by 'Zeiss Axioskop 40' microscope with a Canon camera and a 'Zeiss Axioplan 2 imaging' microscope with integrated DP 450 camera under a 100× objective. Lastly, observed specimens were identified according to (Levkov & Ector, 2010).

Results and Discussion

Unfortunately, during sampling period of this study, due to rapidly expanding residential and commercial constructions, and massive and uncontrolled water exploitation, mostly nothing but a shallow current of water was left in this river below the Karaj-Qazvin Expressway. Examination of a couple of slides from each sampling site led to the identification of 5 various taxa belonging to the genus *Reimeria*. Two species were previously recognized for the diatom flora of Iran, including *R. sinuata* (W.Greg.) Kociolek & Stoermer (Figs. 3-5) and *R. uniseriata* Sala, Guerrero & Ferrario (Figs. 11-20) (Jamaloo et al., 2006; Kheiri et al., 2018a; Naseri et al., 2022; Soltanpour-Gargari et al., 2011). Three species are marked by an asterisk (*) as new reports for the diatom flora of Iran. The abundance of different taxa varied and not all of them were present in every sampling location. In other words, species diversity and abundance were different for each site (Figs. 2-20). Table 2 includes an alphabetical list of all identified taxa and their official authority, main identification reference, figure number and dimension(s); where in the latter, 'L' stands for valve length, 'W' for valve width (both with one/tenth decimal accuracy), 'S' for striae number in 10 µm, and 'St' for Stigma.

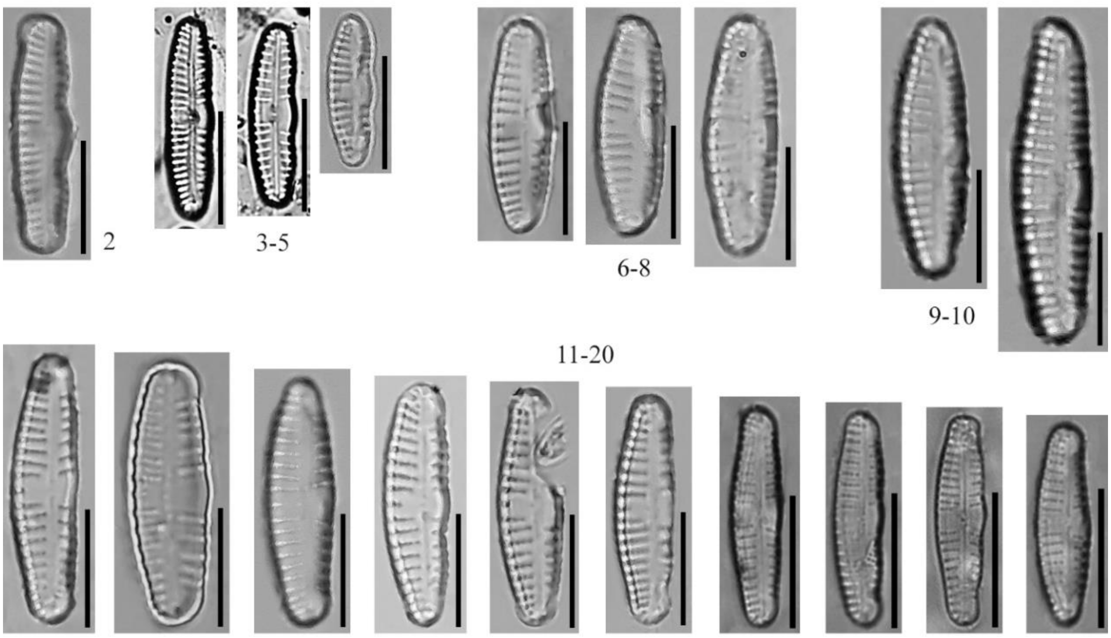
Table 2. List of identified species of genus *Reimeria*, with their authority, figure number, identification reference and dimension(s).

Taxon	Figure(s)	Reference(s)	Dimensions (µm)
*Reimeria capitata (Cleve Euler) Levkov & Ector	2	(Levkov & Ector, 2010, p. 481-Figs. 21-24)	L:22, W:6, S:11
*Reimeria fontinalis Levkov & Ector	9-10	(Levkov & Ector, 2010, p. 473-Figs. 1-13)	L:24-29.9, W:7, S:9
*Reimeria ovata **(Hustedt)** Levkov & Ector	6-8	(Levkov & Ector, 2010, p. 479-Figs. 14-20)	L:19-22.1, W:5.5-7, S:10
Reimeria sinuata (W.Gregory) Kociolek & Stoermer	3-5	(Levkov & Ector, 2010, p. 482-Figs. 34-40-32)	L:13.3-15.1, W:3.8-4.2, S:12-13
Reimeria uniseriata S.E.Sala, Guerrero &Ferrario	11-20	(Levkov & Ector, 2010, p. 485-Figs. 25-32)	L:15-23.4, W:4-7.3, S:9-14

A glance into the recorded taxa

The discussion includes the general morphological characteristics of the documented species, drawing from various references and emphasizing notable observations from specimens observed within this study.

Reimeria sinuata **(W.Gregory) Kociolek & Stoermer**:



Figures 2-20. Light micrographs of observed species of the genus Reimeria. 2: Reimeria capitata, 3-5: R. sinuata, 6-8: R. ovata, 9-10: R. fontinalis, 11-20: R. uniseriata. A 10 µm scale bar is provided individually for every specimen. Previously Reimeria sinuata and R. uniseriata were

http://dx.doi.org/10.22108/tbj.2024.141551.1265

reported from Iran. However, in this study three species are added to the diatom flora of Iran as new records.

Table 3. Localities of observed *Reimeria* species in the Kordan and Hazarband rivers and their "pp." values*.

Taxon / Sampling site	**1**	**2**	**3**	**4**	**5**	**pp. (%)**
Reimeria capitata (Cleve Euler) Levkov & Ector					●	20
Reimeria fontinalis Levkov & Ector		●			●	40
Reimeria ovata **(Hustedt)** Levkov & Ector	●	●		●		60
Reimeria sinuata (W.Gregory) Kociolek & Stoermer		●	●	●	●	80
Reimeria uniseriata S.E.Sala, J.M.Guerrero &M.E.Ferrario	●	●	●	●	●	100

***Percentage of presence in sites (pp.) with 20% = one site, 40% = two sites, 60% = three sites, 80% = four sites, 100% = all sites.

Table 4. Distributional evenness values for each sampling site.

Sampling site	**1**	**2**	**3**	**4**	**5**
Distributional evenness	8%	36%	11%	7%	22%

This is one of only two previously-known *Reimeria* species in the diatom flora of Iran, characterized by its linear, lanceolate, and slightly dorsiventral valves. A single stigma was visible within the central area of the observed specimens, which is an important characteristic of the type species. The length (13.3-15.1 µm) and width (3.8-4.2 µm) of all the observed specimens fall within the 8-22 µm and 3.1-5.5 µm range of the type species (respectively). Striae density was 12-13 in 10 µm, similar to the type species, and apparently the virgae (the solid siliceous rod between striae) in *R. sinuata* (W.Gregory) Kociolek & Stoermer are smaller than those in the other four species. The central part of the dorsal margin in some observed specimens is seemingly somewhat straight rather than curved (convex) and this has helped a little with the identification as it is rarely seen in other species. In some specimens, striae on the ventral side of the valve are more radiate. Just like the type species, the central area is wider on the ventral side and joins the visibly inflated ventral margin. Last but not least, the raphe distal ends curve towards the ventral side and the proximal ends are rather straight and hard to see with a light microscope (Kociolek & Stoermer, 1987; Levkov & Ector, 2010; Potapova, 2009).

Reimeria capitata **(Cleve Euler) Levkov & Ector**: This one has capitate or subcapitate and round apices, asymmetry in longitudinal axis, slightly- to fully-curved dorsal margin and triundulate ventral margin with more obvious central undulation. Central area is much broader in ventral side and unlike the dorsal side, which by the way possesses one stigma, extends to the ventral margin. Raphe is visible and located within the narrow axial area with rather undiscernible ventrally curved distal ends. It is stated in the original description of the *Cymbella sinuata* var. *capitata* Cleve-Euler (Cleve-Euler, 1955) that the species is found in numerous freshwater bodies with low abundances. Similarly, in the present work, *R. capitata* (Cleve Euler) Levkov & Ector was found in just one sampling cite (station 5), and was the least abundant species there. The shown specimen (Fig. 2) is 22 µm long and 6 µm wide, that is well within the 18-26 µm length and 6-7 µm width range of the type species, with 11 striae in 10 µm, which is the high end for the type species (Cleve-Euler, 1955; Levkov & Ector, 2010). Striae are biseriate, parallel to slightly radiate, not distinctly punctate and the breadth of the virgae is more than that of *R. sinuata* (W.Gregory) Kociolek & Stoermer (Cleve-Euler, 1955; Levkov & Ector, 2010). The closer we get to either ends, the striae get more radiate towards the center. Seemingly, the valves have spun slightly around the longitudinal axis and made the capitate apices less apparent.

Reimeria fontinalis Levkov & Ector: This species is one of the recent additions to the genus *Reimeria*. Two specimens of *R. fontinalis* Levkov & Ector are shown in Figs 9-10. Valves are 24-29.9 µm long and 7 µm wide with blunt round apices, which compared to the type species (14-40 µm long and of 6-9 µm wide) fall in the middle of the range. Ventral margin not triundulate and less curved than dorsal margin in some specimens. Dorsal margin could be tumid in the middle which causes the apices appear narrower than they really are. Longitudinal asymmetry in observed specimens was quite moderate, just like the type species. Striae biseriate, seemingly thick and strait to slightly radiate with wide virgae. Striae density in all observed specimen was 9, which according to type species (6-9) is the maximum number for *R. fontinalis* Levkov & Ector. Ventrally-bent proximal ends of the raphe are visible in the central area. Valve apices have a typical round shape and some have slightly triundulate ventral margin. Similar to the type species, extended to ventral margin in ventral side, containing a stigma in the center or dorsal side. Lastly, axial area is visibly wide (Kulikovskiy et al., 2012, 2016; Levkov & Ector, 2010).

Reimeria ovata **(Hustedt)** Levkov & Ector**:** Initially known as the *Cymbella sinuata* var. *ovata* Hustedt (Hustedt, 1922), this species is recognizable by its oval shape that is mainly apparent in smaller specimens, and longitudinal asymmetry that could be indistinct in smaller valves. Both of these characteristics could be recognized in our specimens as well. Like the type species, central area is limited to a shortened stria in dorsal side and extended to ventral margin on the other. (Hustedt, 1922; Levkov & Ector, 2010). Sometimes the last stria in upper dorsal row in the middle of the valve is elongated and curved or bent towards the central area, as in Fig. 8. All observed taxa have integrated round valve apices and broadly convex distal margin. Slight asymmetry along longitudinal axis is discernible. No distinct undulation observed in the middle of the ventral margin. Valve length (19-22.1) and striae density (10) fall exactly within the range for the type species (14-30 µm and 9-10 respectively), however, valve breadth in one specimen (Fig. 6) is 5.5 µm, thus 0.5 µm below the type species 6-8 µm range. Dorsal margin is more convex than ventral margin, with an inflation in the middle part. Raphe proximal ends bent ventrally and distal ends hardly visible, similarly to the type species. The striae radiation varies in different specimen. A single stigma is observed in center-dorsal area, or sometimes right between the proximal ends of the raphe.

Reimeria uniseriata Sala, Guerrero & Ferrario: *R. uniseriata* Sala, Guerrero & Ferrario was the most morphologically diverse species observed in this study, and even more abundant than *R. sinuata* **(W.Gregory**) Kociolek & Stoermer. Valves obviously asymmetrical to the longitudinal axis and mostly also to the transversal axis. Valve apices variously shaped, from blunt round to narrow and nearly subcapitate. The length fluctuated between 15-23.4 µm and the width was 4-7.3 µm, which places our specimens at the lower half of the range for the type species (length: 15-50 µm, width: 4-9 µm). A few specimens had slightly undulate ventral margin (Figs. 14, 16, 18-19). Striae punctate, radiate to rarely parallel, 9-14 in 10 µm, covering almost the entire range of the type species (7-14). The last striae in both dorsal rows in valve middle are occasionally shorter than the one before and more often equal or longer (Figs. 12-13). Typical for this species, porefields are quite easily recognizable on the ventral side of the valve ends. Raphe distal ends indistinct, whereas proximal ends visible and all bent towards the ventral side just like the type species. No species other than *R. uniseriata* Sala, Guerrero & Ferrario was captured in all sampling locations and it was the only taxon present in all of the sampling sites. Lastly, the stigma sits next to raphe proximal ends (Levkov & Ector, 2010; Potapova, 2010; Reichardt, 2018; Sala et al., 1993).

General diatom diversity in studied locations

Over 100 other species belonging to more than 30 different genera were captured in the 5 studied locations all together. Station 4 accommodated more than 40 species and accounted for the most diverse site. On the other hand, station 2 had only 11 species and showed the least diversity. In terms of species number, *Navicula* had the most representatives across 5 sites with just under 15 species. In stations 1-4, a great wealth of 2 *Cocconeis* Ehrenberg species, *C. pediculus* Ehrenberg and *C. placentula* Ehrenberg, was observed in every single slide prepared. However, they nearly disappeared in site 5 and just a handful were present. Additionally, in the latter the species of *Cymbella* Agardh, especially *C. excisa* Kützing and *C. affinis* Kützing, suddenly became extremely abundant and almost replaced *Cocconeis* species. Other species that accompanied *Reimeria* representatives in studied localities include *Achnanthes* Bory, *Cyclotella (*Kützing) Brébissonii, *Cymatopleura* W.Smith, *Denticula* Kützing, *Geissleria* Lange-Bertalot & Metzeltin, *Grunowia* Rabenhorst, *Hannaea* Patrick in Patrick Reimer, *Hantzschia* Grunow, *Pinnularia* Ehrenberg, *Tryblionella W.Sm* and *Ulnaria (*Kützing) Compère. Based on our data, the relative abundance of Reimeria fluctuates noticeably across the investigated sites. According to Table 4, the size of Reimeria population is the greatest in site 2 in relation to the total number of species present, with 36%. On the other hand, in site 4 they account for only 7% of the diatoms available.

Compared to other parts of Iran

In Iran, aside from Karaj River (Kheiri et al., 2018a), *Reimeria sinuata* (W.Greg.) Kociolek and Stoermer was already recorded in Jajrood River in northeastern Tehran (Jamaloo et al., 2006), Ramsar streams and Masouleh Roudkhan River in the south coast of Caspian Sea (Sharifinia et al., 2012; Soltanpour-Gargari et al., 2011), Gharasou and Marbare rivers in West (Atazadeh et al., 2007; Kheiri et al., 2018b), Lut Desert and Zayandeh River in center (Compère, 1981; Moghadam, 1975) and Balikhli River in northwest (Panahy Mirzahasanlou et al., 2018). *R. uniseriata* Sala, Guerrero & Ferrario was also observed in Taleghan River located in southern slope of the Central Alborz (Naseri et al., 2022). On the other hand, no *Reimeria* species was found in two closely related studies: one in Kordan River (Mehrani Adl et al., 2020), another in Damavand River basin (Kheiri & Spaulding, 2023). This is very surprising considering the identical location of the former and the little geographical distance of the latter to this research. Most of these sites are located in alpine or subalpine areas, which is also the case for the two rivers investigated in the present study. Notably, in the Jajrood River, it was found in epiphytic samples as well as epilithic populations. In the Karaj River, *R. sinuata* (W.Greg.) Kociolek and Stoermer was observed in 71% of the samples but not among the most abundant species. In other words, it was observed in low abundance in the majority of collected samples. Likewise, it was present in 4 of the 5 sampling stations in this study, equivalent to 80% of the samples, but not within large populations. Moreover, it was found in small numbers in five out of six investigated sites in the streams of Ramsar, and rarely observed in 3 out of 6 sites (5 out of a total of 72 samples) in the Balikhli River , and a small population appeared in no more than one location in the Lut Desert. Hence, we can conclude that not only has the genus *Reimeria* never had diverse species in the diatom flora of Iran, but also *R. sinuata* (W.Greg.) Kociolek and Stoermer, as its only representative so far, has not been found in large quantities in a given location and commonly falls among the least abundant taxa. Actually, in this research, it is the first time that more than one species of the genus *Reimeria*, and more importantly, five different species have been captured in a single study in Iran. Taking the ecological aspect into consideration sheds light on another noteworthy fact as well. According to the aforementioned research, the majority of mostly aquatic habitats where *R. sinuata* (W.Greg.) Kociolek and Stoermer was observed , for example in the Gharasou River in the Zagros Range (Atazadeh et al., 2007) and the Balikhli River which emanates from the Bozgoosh and Sabalan mountains (Panahy Mirzahasanlou et al., 2018), are located within alpine or subalpine ecoregions in the northern half of the country and the only desert ecosystem in which it was found in Lut Desert.

Considering similar records in neighboring countries

The rarity of the *Reimeria* species continues in the neighboring countries of Iran as well. In Afghanistan, which is a primarily mountainous country and shares a terrestrial border with the mid-eastern part of Iran, we could not find any evidence of the other taxa included in the genus *Reimeria* and only *R. sinuata* (W.Greg.) Kociolek and Stoermer was reported by Niels Foged (1959) from different streams. In Foged’s research, out of 40 sampling sites, *R. sinuata* (W.Greg.) Kociolek and Stoermer was found in 16 various locations, which equals to two-fifths of the samples and is less than four-fifth ratio (pp. 80%) in this study. In all of the collected samples, the relative abundance of the captured population did not exceed 1%, with a mean relative percentage abundance of 0.5%. Moreover, the average altitude of the sampling sites was nearly 2400 meters, much higher than the sampled locations in this study.

This implies that they belong to alpine and subalpine ecosystems, and their habitat resembles that of this study.

In Iraq, the western neighbor of Iran, there is no significant difference. Although plenty of researches have been conducted on various water bodies, the number of *Reimeria* records is at most a handful and the lack of species diversity is evident. Of the species encountered in the present study, just *R. sinuata* (W.Greg.) Kociolek and Stoermer was reported from only three different locations in Iraq; two of which are streams of Amadiya and Erbil in northern part (Hirano, 1973) and one is freshwater, epiphytic and epilithic samples collected from Shat Al-Arab (Alsaedy et al., 2020) which emanates from north of Basrah, terminates in northwestern part of Persian Gulf (southeastern Iraq). A part of it is considered to be the water border with Iran. In the former, the two sites hosting *R. sinuata* (W.Greg.) Kociolek and Stoermer were among 21 overall locations, and it was one of the rare taxa. Overall, the *Reimeria* diversity and *R. sinuata* (W.Greg.) Kociolek and Stoermer distribution in Iraq is less than Iran, supposedly due to the geographical difference and predominance of lowlands and non-alpine ecoregions in this country and the flow of the variously-sized streams in lower altitudes.

Based on the references, among all the neighboring countries, the genus *Reimeria* has its most species diversity in northern and northwestern Turkey, and three species, including *R. ovata* (Hustedt) Levkov & Ector, *R. uniseriata* Sala, Guerrero & Ferrario and *R. uniseriata* Sala, Guerrero & Ferrario, have been reported from a few waterbodies so far, of course with different abundance (Aysel, 2005; Baykal et al., 2011; Dere et al., 2002; Gonulul, 2016; Solak et al., 2012, 2016, 2020). Two species present in this study, *R. capitata* (A.Cleve) Levkov & Ector, and *R. fontinalis* Levkov & Ector, still need to be added in Turkey. Similar to this study, *R. sinuata* (W.Greg.) Kociolek and Stoermer is a common taxon in Turkish inland waters diatom assemblages regarding the number of localities (Gonulul, 2016). *R. uniseriata* Sala, Guerrero & Ferrario, on the other hand, is among the least abundant species, contrary to the present study in which it was found as a predominant species within larger populations (Solak et al., 2016). *R. ovata* (Hustedt) Levkov & Ector is a relatively new taxon compared to the other two, firstly captured in the Korundere stream, and like the present research, it is also a rare (Solak et al., 2016). Overall, besides *R. sinuata* (W.Greg.) Kociolek and Stoermer, none of the *Reimeria* species found in this research are commonly found in various streams of Turkey, and the genus shows scarce diversity. Having the data from Iran and the three above-mentioned neighboring countries in mind, it could be inferred that, at least in this region probably, habitats located in higher latitudes and elevations are more likely to host *Reimeria* populations, and they rarely appear in lower latitudes. In Iran, most of the current records belong to the upper half of the country, which mostly consists of mountainous ecoregions. Afghanistan and Iraq are located in lower latitudes than Turkey and have smaller and less-diversified populations of *Reimeria*. Moreover, the diversity of species observed in this study surpasses any other research conducted in Iran and neighboring countries. Furthermore, the rarity of *Reimeria* in this region significantly enhances the value of this finding.

Worldwide investigations of the genus *Reimeria*

In the big picture, *Reimeria* has been found in different ecosystems across the seven continents and is considered a cosmopolitan genus (Kociolek, 2018). Of course, species diversity and population size vary among different locations; but the noteworthy point is that the genus investigated in this study is not restricted to a given region and happens to appears in various parts of the world. Despite currently being a rather small genus, different species of *Reimeria* was reported from various countries including the Korean Peninsula (Kim et al., 2015), Russia (Nikulina & Kociolek, 2011), Poland (Stanek-tarkowska et al., 2017), Macedonia (Levkov & Ector, 2010), France (Fayolle et al., 2016), Italy (Lai et al., 2016, 2019), the Czech Republic (Fránková et al., 2009), Uganda (Stoyneva-Gartner & Descy, 2018), Colombia (Heinrich et al., 2019), Mexico (Mora et al., 2017), the United States (Bishop et al., 2017; Potapova & Charles, 2002; Stoermer et al., 1999) and even Arctic Ocean (Zgrundo et al., 2017). *R. sinuata* (pp. 80%) and *R. uniseriata* Sala, Guerrero & Ferrario (pp. 100%) account for the mostly captured and discussed taxa around the world and other taxa was rarely encountered. Considerably, except for the research conducted by Levkov & Ector in Lake Ohrid in southern Macedonia (Levkov & Ector, 2010) which contains the original diagnosis and description of *R. fontinalis* Levkov & Ector as a new species and a restatement of *R. capitata* (A.Cleve) Levkov & Ector and *R. ovata* (Hustedt) Levkov & Ector, we could not find any other publication worldwide that includes all five species found in the present study. This highlights the importance of the Kordan and Hazarband rivers as habitats for such species that rarely occur all together in a given waterbody. Although current records mostly belong to upper latitudes of the northern hemisphere (Asia, Europe, and North America), a few locations appear more noticeable: Lake Edward on the Uganda and Congo border, and Colombia (Africa and South America) that are close to the equator, and northern Spitsbergen in the Arctic Ocean, nearly the most northern part of the earth. These regions are totally different from the Central Alborz Region in terms of climate, ecological, and geographic characteristics, yet interestingly share a few species of *Reimeria*. *R. capitata* (A.Cleve) Levkov & Ector, as the rarest taxon in this study (pp. 20%) and also a less-encountered one in other countries, was reported from northern Spitsbergen (North Pole), along with *R. sinuata* (W.Greg.) Kociolek and Stoermer (both with small populations). This generates speculation about the factors that have made the area suitable for the occurrence of such a rare species despite the predominant Arctic extreme conditions. *R. sinuata* (W.Greg.) Kociolek and Stoermer has been found in almost every river investigated in the Czech Republic, but is scarce in Colombia and Uganda. Presumably, similar to different locations in Iran, *Reimeria* species, and even the most commonly found ones, generally do not form large populations in other countries' ecosystems. In other words, the frequency is limited to their presence in a greater number of study locations, and the quantity of specimens in each of them plays a less effective role.

Table 4 briefly compares the dimensions of our species with respect to the ranges provided by Levkov & Ector (2010). Except for *Reimeria ovata* (Hustedt) Levkov & Ector, none of our specimens exceed the aforementioned size range and each one falls within the same spectrum. Taking a closer look at the numbers for each species, one can conclude that all of the *Reimeria* species present in the Kordan and Hazarband rivers have average frustule dimensions and are neither very small nor very large.

Table 5. Size comparison of the specimens studied in this work with length and width ranges provided by Levkov & Ector (2010).

Species	This Study		Levkov & Ector (2010)
R. capitata	Length	22	18 – 26
(A.Cleve) Levkov & Ector	Width	6	6-7
R. fontinalis	Length	24-29.9	14-40
Levkov & Ector	Width	7	6-9
R. ovata	Length	19-22.1	14-30
(Hustedt) Levkov & Ector	Width	5.5	6-8
R. sinuata	Length	13.3 – 15.1	8-22
(W.Greg.) Kociolek and Stoermer	Width	3.8 – 4.2	3.1-5.5
R. uniseriata	Length	15-23.4	15–50
Sala, Guerrero & Ferrario	Width	4-7.3	4-9

This study adds four additional species to the diatom flora of Iran. Among neighboring countries, the diversity of *Reimeria* species is the highest in Turkey, but still lacks some of the taxa presented here. In other parts of the world, *R. sinuata* (W.Greg.) Kociolek and Stoermer and *R. uniseriata* Sala, Guerrero & Ferrario are the most encountered species, and others are very rare. The diversity observed in this research is unique, and except for one study on Lake Ohrid in Macedonia, none have documented all these species together. It is also important that different species were recorded in completely different ecoregions, which indicates that the genus is cosmopolitan.

Acknowledgements

The authors would like to kindly appreciate Professor Shahin Zarre (Department of Plant Science, School of Biology, University of Tehran, Tehran, Iran) for providing laboratory and microscopy facilities and great advisory during the project, and deeply thank Mr. Masood Mirmasoomi, the Plant Physiology Laboratory instructor (Department of Plant Science, School of Biology, University of Tehran, Tehran, Iran), who generously helped with laboratory equipment.

Author Contributions: All authors conceived and planned the project.
Funding: This project is supported by University of Tehran and University of Tabriz.
Data Availability: The data for the assessment included in the study is given as supplementary material.
Compliance with Ethical Standards
Conflicts of Interest/Competing Interests: The authors declare no conflicts of interest.
Ethics Approval: Not applicable.
Consent to Participate: Not applicable.
Consent for Publication: Not applicable.

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