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The epilithic and epipelic diatom flora of the Balikhli River, Northwest Iran

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Abstract: The taxonomic composition of diatom flora of the Balikhli River (Balikhli Chay), Northwest Iran, was studied from October 2013 through September 2014. In total 109 taxa belonging to 50 genera were identified. *Nitzschia* (18 spp.), *Navicula* (9 spp.), and *Gomphonema* (7 spp.) were the most abundant genera. Twenty-five diatom species were found in more than half of the samples; among them, *Nitzschia inconspicua*, *Planothidium lanceolatum*, *Amphora pediculus*, *Navicula trivialis*, *Gomphonema olivaceum*, *Nitzschia palea*, and *Rhoicosphenia abbreviata* were the most abundant taxa, which are characteristic for alkaline and eutrophic waters. The centric diatoms constituted only 4.54% of all identified taxa. In this study 20 taxa were recorded for the first time for the aquatic ecosystems of Iran.

Key words: Ardabil Province, diatoms, epilithic, epipelic, taxonomic composition

1. Introduction

Taxonomic diversity is one of the most important characteristics of biological communities: it reflects evolutionary processes and maintains ecological functions and stability of ecosystems. Diatoms are a specialized, systematic group of algae occurring in almost all water ecosystems and other damp habitats. They are a systematic group used in assessment of water quality (Noga et al., 2014). These organisms are one of the main dominant groups of periphytic algae in lotic systems and efficient indicators of environmental changes, since they respond sensitively to physical and chemical changes of water quality (Winter and Duthie, 2000; Lobo et al., 2002). However, thorough understanding of the taxonomy of diatoms has been identified as one of the major problems for using this group of algae in biological monitoring programs (Sabater et al., 1991).

Although extensive floristic studies have been carried out, the algal flora of many geographical areas is still poorly known, and in Iran studies on algal flora in general and particularly diatoms have received little attention and there are few publications on algal floras (Hirano, 1973; Wasylik, 1975; Compere, 1981; Zarei Darki, 2009). Moghadam (1976) reported diatoms from a small portion of the Zayandeh Rood River. Zarei Darki (2011) reported 704 diatom taxa from the aquatic ecosystems of Iran. In recent years several lakes, wetlands, and rivers in different areas were studied for diatom distribution, e.g., the diatom flora of Neure Lake (Nejadsattari, 2005) and the epilithic diatoms of streams in the Ramsar region (Soltanpour-Gargari et al., 2011). In the present study the diatom flora of the Balikhli River is reported for the first time to expand the knowledge of diatoms in the region for future monitoring programs. The objective of the present study was to understand the diversity and distribution of diatoms in the Balikhli River.

2. Materials and methods

The Balikhli Chay is a permanent river in Ardabil Province, Iran. It originates from the Bozgoosh and Sabalan elevations in Northwest Iran. The water catchment area of the Balikhli River (Balikhli Chay) is over 1600 km^2. Twenty-five kilometers to the southwest of the city of Ardabil, the Yamchi dam has been constructed on the river. The Yamchi reservoir serves as the main source for drinking and irrigation purposes. Several important

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tributaries including the Borjlou Chay, Saghghezchi Chay, Aghlaghan Chay, and Jurab Chay on their way downhill join the Balikhli Chay and increase its water volume. On the other hand, it also receives a huge amount of various waste materials of domestic, industrial, and agricultural origin.

The present study was carried out on the Balikhli River; six sampling stations were selected. Three sites were upstream and the other 3 were downstream of the Yamchi dam (Figure 1).

Diatom samples were taken at 6 sampling stations in monthly intervals from October 2013 through September 2014. Due to the extremely hard weather conditions, sampling was not possible in winter months. Epilithic diatoms were collected from stone surfaces using a toothbrush and distilled water and epipelic diatoms were collected from sediment surfaces by gently scooping up the top layer of sediment into a container (Bellinger and Sigee, 2010). In total 96 samples were collected. Samples were preserved in 4% formaldehyde solution. Diatom samples were cleaned using hot HNO_3. The acid-cleaned samples were then washed and rinsed with distilled water and mounted on slides with Naphrax (Taylor, 2007). Three slides were prepared for each sampling stations. They were examined under a light microscope at 1000× magnification using immersion oil, and at least 300 valves were counted from each slide. Taxonomic identification was performed according to Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Patrick and Reimer (1975), and Spaulding et al. (2010). To understand the diatom ecology, preferences of each individual taxon with respect to trophic status and pH values of water were determined according to Van Dam et al. (1994), Kelly et al. (2005), and Lysakova et al. (2007).

Samples for water quality analysis were collected at the same time as the diatom samples. Environmental factors including water temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), and salinity were measured in situ using a portable Hach G500 multimeter. The concentrations of silicate (SiO_2, mg L^{-1}), nitrate (NO_3^-, mg L^{-1}), orthophosphate ($PO4^{3-}$, mg L^{-1}), ammonium (NH_4^+, mg L^{-1}), and sulfate (SO_4^{-2}, mg L^{-1}) were measured in the laboratory following the American Public Health Association guidelines (APHA, 1999).

3. Results

The results of water analysis are presented in Table 1. The concentrations of nitrate ranged from 1.39 to 9.04 mg L^{-1},

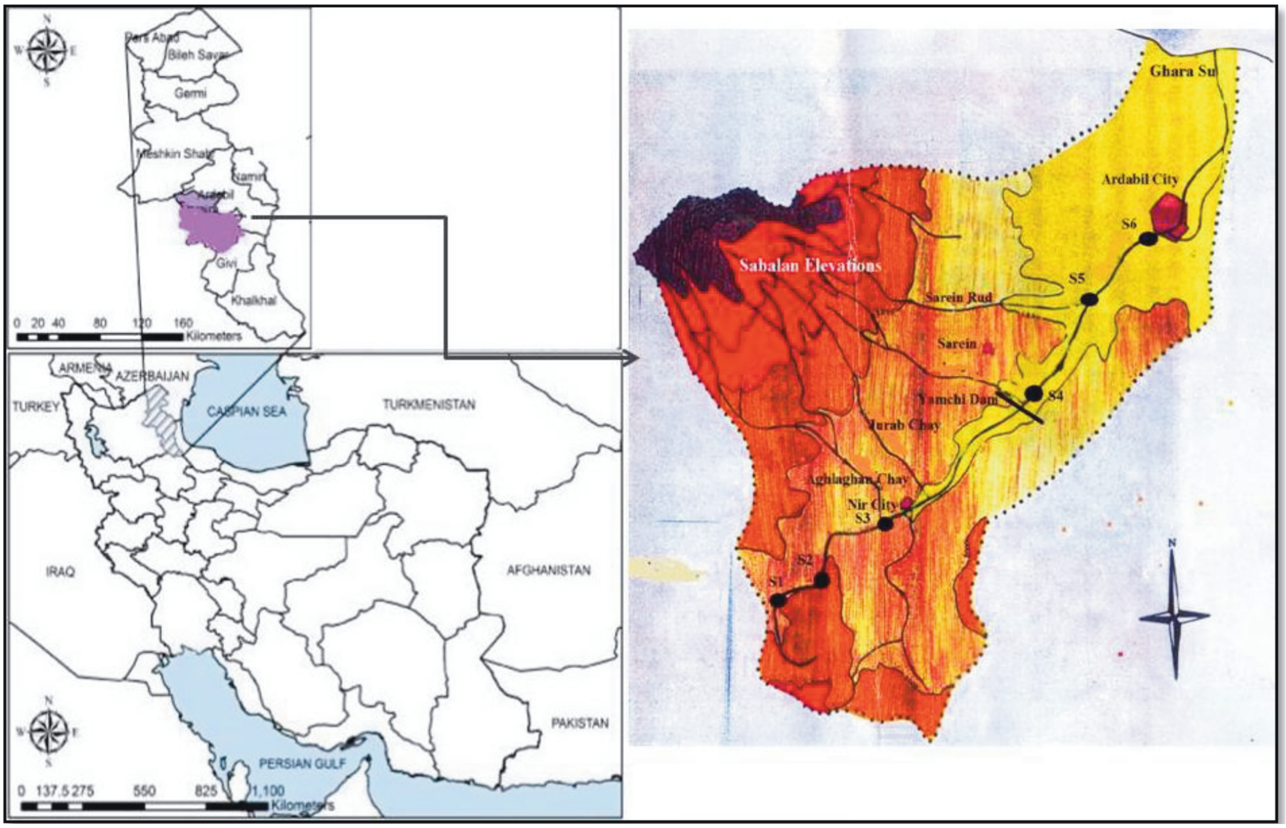

Figure 1. Location of sampling stations on the Balikhli River.

Table 1. Results of the water analysis during the study period. The first row represents mean ± SD and the second row represents the lowest and highest observed values.

	S1	S2	S3	S4	S5	S6
NO_3^-	4.48 ± 1.51 1.92–6.94	2.96 ± 1.04 1.81–4.9	7.85 ± 0.86 6.78–8.88	3.97 ± 2.9 1.39–9.04	3.36 ± 1.11 1.71–5.02	2.41 ± 0.36 1.83–2.82
NH_4^+	0.12 ± 0.2 0–0.61	0.18 ± 0.22 0–0.69	0.18 ± 0.29 0–0.89	0.06 ± 0.1 0–0.3	0.09 ± 0.11 0–0.25	0.13 ± 0.2 0–0.53
PO_4^{3-}	0.44 ± 0.05 0.39–0.58	0.74 ± 0.25 0.4–1.19	0.39 ± 0.07 0.32–0.49	0.36 ± 0.22 0.14–0.77	0.31 ± 0.09 0.2–0.47	0.2 ± 0.08 0.13–0.35
SO_4^{2-}	34.66 ± 27.07 13.41–96.96	99.33 ± 55.24 18.72–191.52	38.13 ± 8.89 22.34–49.92	62.05 ± 17.3 34.56–78.32	225.2 ± 100.37 112.32–404.64	289 ± 30.7 227.04–335.52
SiO_2	25.61 ± 7.32 16.53–34.54	30.30 ± .9.61 11.84–38.67	40.38 ± 9.26 27.39–54.14	23.81 ± 11.49 5.63–41.35	27.73 ± 10.41 11.89–43.93	25.41 ± 7.49 14.48–34.59
BOD	6.25 ± 3.7 2.5–14	11.69 ± 6.7 3.55–23	5.6 ± 3.7 1.5–14	6.22 ± 3.38 2–11	7.98 ± 4.4 3.85–14	8.02 ± 3.34 3.2–13
COD	12.62 ± 5.39 6–21	29.5 ± 22.04 8–76	11.75 ± 4.02 5–19	12 ± 4.37 7–19	17.9 ± 5.79 8.2–25	15.01 ± 5.21 7.1–22
T °C	14.7 ± 5.45 4.9–21	16.52 ± 5.92 5.4–25.7	14.73 ± 3.65 7.9–20.5	14.35 ± 4.24 9–20	15.41 ± 3.5 11.2–21.4	19.03 ± 5 10.8–24.3
pH	7.37 ± 0.79 6.2–8.8	8.11 ± 0.46 7.2–8.8	7.55 ± 0.73 6.2–8.5	7.85 ± 0.65 6.3–8.4	8.03 ± 0.26 7.6–8.5	7.8 ± 0.5 6.8–8.4
EC	883 ± 428.03 494–1624	3311.37 ± 1827.11 615–5820	960.87 ± 160.37 711–1126	902 ± 151.55 694–1182	1729.87 ± 600.97 966–2700	2216.87 ± 243.08 1914–2600
TDS	618 ± 299.63 346–1137	2370.87 ± 1316.62 430–4007	667.5 ± 112.32 554–788	592.37 ± 137.68 368–827	1269.12 ± 436.34 676–1887	1363.62 ± 346.68 554–1719
Salinity	0.45 ± 0.2 0.3–0.8	1.75 ± 0.98 0.3–2.9	0.45 ± 0.05 0.4–0.5	0.43 ± 0.09 0.3–0.6	0.88 ± 0.31 0.5–1.4	1.08 ± 0.08 1–1.2

ammonium from 0 to 0.89 mg L^{-1}, orthophosphate from 0.13 to 0.77 mg L^{-1}, silicate from 5.63 to 54.17 mg L^{-1}, and sulfate from 13.41 to 404.64 mg L^{-1} (probably due to the mineral sulfated hot waters in the region). TDS was 346–4007 mg L^{-1} and EC was 494–5820 µS cm^{-1} with the highest value being recorded at S2. pH ranged between 6.2 and 8.8 and temperature between 4.9 and 25.7 °C.

A total of 109 taxa (108 at species level, 1 at genus level) belonging to 50 genera, 26 families, and 3 classes were identified in this study (Table 2). Diatom taxa were arranged according to Guiry and Guiry (2014). Bacillariophyceae with 103 species, Bacillariaceae with 25 species, and *Nitzschia* with 18 species were the most dominant class, family, and genus (Figure 2) in the Balikhli River, respectively. Symmetrical biraphids with 14 genera and 29 species were the most diverse group and epithemioids with 2 genera and 4 species the least diverse group. The centric diatoms constituted only 4.54% (4 genera and 5 species) of all identified taxa (Table 3).

Trophic preferences (Van Dam et al., 1994; Lysakova et al., 2007) were available for 79.09% of the taxa (Table 3). Of these, 65.11% were eutraphentic, 16.27% meso-eutraphentic, 6.97% oligo- to eutraphentic, 4.65% mesotraphentic, and 3.48% oligotraphentic; oligo-mesotraphentic, hypereutraphentic, and eu-hypereutraphentic preferences were also seen, each with 1.16% (Figure 3).

With respect to pH preferences, unsurprisingly most were categorized in categories 4 (“alkaliphilous”, 67.44%), 3 (“circumneutral”, 22.09%), and 5 (“alkalibiontic”, 9.3%) (Table 3). The only exception was *Oxyneis binalis*, which belongs to category 1 (“acidobiontic”), but this species was sporadically found in only one sample (Figure 4).

Twenty-five diatoms were found in more than half of the samples. Some of the most frequently observed diatoms in the samples were *Rhoicosphenia abbreviata* (in 95% of all samples), *Planothidium lanceolatum* (90%), *Surirella brebissonii* (88%), *Nitzschia inconspicua* (86%), *Nitzschia*

Table 2. List of identified taxa in present study. Percentage of relative abundance of each taxa: (R) rare: <1.5%; (F) frequent: 1.5%–5%; (A) abundant: >5%; -: not noted. Taxa in bold letters have relative abundance above 5% in at least one site. The first row represents epilithic and the second row epipelic samples. *: New record. NO: Number of samples of the species found.

Scientific name	Trophic preferences	pH	NO	S1	S2	S3	S4	S5	S6
Bacillariophyceae									
Achnanthaceae									
Achnanthes brevipes C. Agardh.			1	- -	R -	- -	- -	- -	- -
Achnanthidiaceae									
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	Eutroph	4	**56**	F -	R R	R R	- -	- -	- -
***Planothidium lanceolatum* (Brebisson ex Kützing) Lange-Bertalot**	Eutroph	4	**87**	A A	F A	A A	F F	R R	R R
Psammothidium subatomoides* (Hustedt) Bukhtiyarova & Round	-	-	16	R -	R -	F -	- -	- -	- -
Anomoeoneidaceae									
Staurophora tackei (Hustedt) L.Bahls	-	-	4	- -	- R	- R	- -	- R	- -
Staurophora wislouchii (Poretzsky & Anisimova) D.G.Mann*	-	-	1	- -	- R	- -	- -	- -	- -
Bacillariaceae									
Bacillaria paxillifera (O.F.Müller) T.Marsson	Eutroph	5	3	- -	- -	- -	- -	R -	R -
Denticula elegans Kützing	-	-	3	- R	- -	- -	- R	- -	- R
Denticula subtilis Grunow*	-	-	4	- -	- R	- R	- -	- -	- -
Hantzschia amphioxys (Ehrenberg) Grunow	Oligo-Eu	3	5	- -	- R	- -	- R	- -	- R
Nitzschia clausii Hantzsch.	Eutroph	4		- -	- R	- -	- -	- -	- -
Nitzschia commutatoides Lange- Bertalot*	-	-	1	- -	- -	- -	- R	- -	- -
Nitzschia dippelii Grunow*	-	-	1	- -	- -	- R	- -	- -	- -
***Nitzschia dissipata* (Kützing) Rabenhorst**	Meso-Eu	4	**80**	R R	R R	F R	F R	F R	F R
Nitzschia flexa Schumann	-	3	18	R R	- -	R R	R R	R R	R R
***Nitzschia fonticola* (Grunow) Grunow**	Meso-Eu	4	**32**	R -	R -	A R	R -	R -	R -
Nitzschia fonticoloides Sovereign*	-	-	1	R -	- -	- -	- -	- -	- -
***Nitzschia frustulum* (Kützing) Grunow**	Eutroph	4	**26**	R R	- R	- F	R R	- R	- R
Nitzschia heufleriana Grunow	Eutroph	4	1	- -	- -	- -	- -	R -	- -
***Nitzschia inconspicua* Grunow**	Eutroph	4	**83**	A R	A A	A R	A F	A A	A R
Nitzschia lacunarum Hustedt	-	-	1	- R	- -	- -	- -	- -	- -
***Nitzschia liebetruthii* Rebenhorst**	-	-	**61**	A R	F R	F A	F F	R R	F F

Table 2. (Continued).

Nitzschia linearis W.Smith	Meso-Eu	4	1	- -	- -	- -	- -	- -	- R
***Nitzschia palea* (Kützing) W.Smith**	HyperEu	3	**82**	F A	R F	R A	A F	A F	F R
Nitzschia sigmoidea (Nitzsch) W. Smith	Eutroph	4	**41**	R F	R R	R R	R R	- R	R R
Nitzschia tryblionella Hantzsch	Eutroph	4	1	- -	- -	- -	- -	- R	- -
Nitzschia tubicola Grunow	Eutroph	-	1	R -	- -	- -	- -	- -	- -
Nitzschia vermicularis (Kützing) Hantzsch	Oligo-Eu	3	10	R R	- -	- R	- R	- R	- R
***Tryblionella apiculata* W. Gregory**	Eutroph	4	**52**	R R	R R	R R	R R	R R	R R
Tryblionella calida (Grunow) D.G.Mann*	Eutroph	-	5	- -	- R	- -	- R	- R	- R
Tryblionella hungarica (Grunow) Frenguelli	Eutroph	4	21	R R	- R	- R	- R	- R	- R
Catenulaceae									
Amphora copulata (Kützing) Schoeman & R.E.M.Archibald*	Eutroph	-	7	- R	- R	- R	- R	- R	- R
Amphora ovalis (Kützing) Kützing	Eutroph	4	18	- -	R R	R R	R R	R R	R R
***Amphora pediculus* (Kützing) Grunow**	Eutroph	4	**79**	A R	A F	A A	A F	A R	F R
Cocconeidaceae									
***Cocconeis pediculus* Ehrenberg**	Eutroph	4	**54**	R A	R R	A F	R R	R R	R R
***Cocconeis placentula* Ehrenberg**	Eutroph	4	**65**	R F	R R	F F	R A	R R	R F
Cocconeis pseudothumensis Reichardt*	-	-	1	R -	- -	- -	- -	- -	- -
Cymbellaceae									
***Cymbella cistula* (Ehrenberg) O.Kirchner**	Eutroph	4	21	R R	- -	- F	R F	R R	R F
Cymbella tumida (Brébisson) Van Heurck	Meso-Eu	4	**26**	R R	- R	R R	R R	R R	r -
Diadesmidaceae									
Luticola goeppertiana (Bleisch) D.G.Mann ex J.Rarick, S.Wu, S.S.Lee & Edlund	Eutroph	4	10	- R	- R	- R	- -	R R	- -
Luticola nivalis (Ehrenberg) D.G.Mann	Eutroph	3	2	- -	- R	- -	- R	- -	- -
Luticola mutica (Kützing) D.G.Mann	Eutroph	3	1	- -	- -	- -	- -	- R	- -
Diploneidaceae									
Diploneis subovalis Cleve	-	-	6	- R	R -	- R	- R	- -	R R
Entomoneidaceae									
Entomoneis paludosa (W.Smith) Reimer	-	3	1	R -	- -	- -	- -	- -	- -
Fragilariaceae									
***Fragilaria capucina* Desmazières**	Meso	3	**59**	R F	R F	R A	R F	F R	R R

Table 2. (Continued).

***Odontidium mesodon* (Kützing) Kützing**	Meso	3	**25**	R R	F F	F R	R R	R R	R R
Gomphonemataceae									
Encyonema lange-bertalotii Krammer	-	-	5	- -	- -	- -	R -	R R	- -
Encyonema leibleinii (C.Agardh) W.J.Silva, R.Jahn, T.A.Veiga Ludwig & M.Menezes	Eutroph	-	1	- R	- -	- -	- -	- -	- -
***Encyonema silesiacum* (Bleisch) D.G.Mann**	Oligo-Eu	3	**28**	F F	R R	R R	- R	- -	- R
Gomphonema acuminatum Ehrenberg	Eutroph	4	1	- -	- -	- -	- -	- -	R -
Gomphonema augur Ehrenberg	Meso-Eu	4	1	- -	- -	- -	- -	- -	- R
Gomphonema gracile Ehrenberg	Meso	3	7	- -	R R	- R	- R	- R	R R
***Gomphonema olivaceum* (Hornemann) Brébisson**	Eutroph	5	**81**	F F	R F	A F	A A	A R	A A
***Gomphonema parvulum* (Kützing) Kützing**	Eutroph	3	**68**	R R	F F	F F	A F	R R	F F
Gomphonema pseudoaugur Lange-Bertalot*	Eutroph	3	1	- -	- -	- -	- -	- -	- R
Gomphonema truncatum Ehrenberg	Meso-Eu	3	2	- -	- -	- -	- -	R -	R -
Placoneis elginensis (W.Gregory) E.J.Cox*	Eutroph	4	1	- -	- -	- R	- -	- -	- -
Reimeria sinuata (W.Gregory) Kociolek & Stoermer	Meso-Eu	3	5	- R	- -	R -	- R	- -	- -
Mastogloiaceae									
Mastogloia smithii Thwaites ex W. Smith	-	4	3	- R	- -	- -	- -	- -	- R
Naviculaceae									
Caloneis amphisbaena (Bory) Cleve	Eutroph	4	8	- -	- -	- -	- -	- R	R R
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin	Meso-Eu	4	4	- R	- -	- -	- R	- -	- -
Gyrosigma acuminatum (Kützing) Rabenhorst	Eutroph	5	13	- R	- R	- R	- R	- -	R R
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski	Meso-Eu	4	3	- -	- -	- -	R R	- R	- -
***Navicula capitatoradiata* H.Germain**	Eutroph	4	**52**	F F	R R	R R	R F	R A	R A
Navicula cincta (Ehrenberg) Ralfs	Eutroph	4	9	R -	- R	R -	- -	- -	- -
***Navicula erifuga* Lange- Bertalot**	Eutroph	4	21	R R	R F	- R	R -	- F	R R
***Navicula gregaria* Donkin**	Eutroph	4	**40**	R R	R R	R R	R F	A F	F R
***Navicula menisculus* Schumann**	Eutroph	4	9	R -	- F	- R	- R	R R	- R
Navicula recens* (Lange-Bertalot) Lange-Bertalot	Eutroph	4	**53**	F R	A F	F R	A R	R R	F R
***Navicula reichardtiana* Lange-Bertalot**	Eutroph	4	**38**	R R	R R	R R	R R	R R	R R

Table 2. (Continued).

***Navicula tripunctata* (O.F.Müller) Bory**	Eutroph	4	**74**	F F	R F	R R	F F	R R	A R
***Navicula trivialis* Lange-Bertalot**	Eutroph	4	**79**	R F	F F	R F	F R	A A	A A
Pinnulariaceae									
Pinnularia acutobrebissonii Kulikovskiy, Lange-Bertalot & Metzeltin*	-	-	**29**	- R	R R	R R	R R	R R	- R
Pinnularia borealis Ehrenberg	Oligo-Meso	3	1	- -	- -	- -	- R	- -	- -
Pinnularia ignobilis Cleve- Euler*	-		1	- -	- -	- -	- R	- -	- -
Pinnularia rupestris Hantzsch*	Oligo	3	1	- R	- -	- -	- -	- -	- -
Rhoicospheniaceae									
***Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot**	Eutroph	4	**92**	F F	F F	A A	A A	F F	A A
Rhopalodiaceae									
Epithemia argus (Ehrenberg) Kützing	Meso	4	4	- -	- -	- R	- R	- -	- R
Epithemia operculata (C.Agardh) Ruch & Nakov*	-	-	21	R R	R R	- R	- R	- R	R R
Epithemia sorex Kützing	Meso-Eu	5	6	- -	- -	- R	- R	R R	R -
Epithemia turgida (Ehrenberg) Kützing	Eu	5	2	- -	- -	- R	- -	- -	- R
Sellaphoraceae									
Fallacia pygmaea (Kützing) Stickle & D.G.Mann	Eutroph	5	8	R -	- R	- -	- R	- -	- R
Sellaphora pupula (Kützing) Mereschkovsky	Meso-Eu	3	2	- R	- -	- R	- -	- -	- -
Stauroneidaceae									
Craticula citrus (Krasske) E.Reichardt*	-	-	1	R -	- -	- -	- -	- -	- -
Craticula cuspidata (Kützing) D.J.Mann	Eutroph	4	2	R -	- -	- -	- R	- -	- -
Staurosiraceae									
***Pseudostaurosira parasitica* (W.Smith) E.Morales**	Meso-Eu	4	1	- -	- R	- -	- -	- -	- -
Staurosira binodis (Ehrenberg) Lange-Bertalot*	Meso-Eu	4	1	- -	- -	- R	- -	- -	- -
Staurosirella dubia (Grunow) E.A.Morales & K.M. Manoylov	-	4	1	- -	- -	- -	- -	R -	- -
Surirellaceae									
Cymatopleura elliptica (Brébisson) W. Smith	Eutroph	4	3	R -	- -	- -	- R	- -	- R
Stenopterobia sp.	-	-	2	- -	- R	- -	- -	- -	- R
Surirella angusta Kützing	Eutroph	4	14	R R	R -	R R	- R	- R	- R
***Surirella brebissonii* Krammer & Lange- Bertalot**	Eu- Hyper	4	**85**	F F	F F	F F	A F	F F	F A
Surirella librile (Ehrenberg) Ehrenberg	Eutroph	4	4	- -	- -	- -	- R	- -	- R

Table 2. (Continued).

Surirella minuta Brébisson ex Kützing	Eutroph	4	2	R -	- -	- -	- R	- -	- -
Surirella ovalis Brébissons	Eutroph	4	6	R -	R -	- -	R R	- -	- R
Tabellariaceae									
***Diatoma moniliformis* (Kützing) D.M.Williams**	Eutroph	4	**70**	F F	F F	R R	R A	A A	F A
***Diatoma tenuis* C.Agardh**	Etroph	4	7	R -	- -	- -	R R	R R	- R
***Diatoma vulgaris* Bory**	Meso- Eutroph	5	**52**	R F	R R	R F	R F	R R	R R
Meridion circulare (Grevile) C.Agardh	Oligo-Eu	4	3	- -	- R	- R	- -	- -	- R
Oxyneis binalis (Ehrenberg) Round*	Oligo	1	1	- -	- -	- -	- -	R -	- -
Ulnariaceae									
Ctenophora pulchella* (Ralfs ex Kützing) D.M.Williams & Round	Eutroph	4	**24**	R R	R R	R -	R R	R R	F R
Hannaea arcus (Ehrenberg) R.M.Patrick	Oligo	4	1	- -	- -	- -	- -	- -	- R
Tabularia fasciculata* (C.Agardh) D.M.Williams & Round	Eutroph	4	**14**	- R	R R	- R	R -	R R	R R
***Ulnaria ulna* (Nitzsch) Compère**	Oligo-Eu	4	**79**	R F	F F	R F	R F	F F	F A
Cosinodiscophyceae									
Aulacoseiraceae									
Aulacoseira granulata (Ehrenberg) Simonsen	Eutroph	4	1	- -	- -	- R	- -	- -	- -
Melosiraceae									
Melosira varians C. Agardh	Eutroph	4	**40**	R R	R R	- R	R R	R R	F F
Mediophyceae									
Stephanodiscaceae									
***Cyclotella meneghiniana* Kützing**	Oligo Eutroph	4	**64**	R A	A A	R F	R R	F A	R R
Stephanodiscus alpinus Hustedt	-	-	1	-	-	-	-	-	-
***Stephanodiscus neoastraea* Håkansson & Hickel**	Eutroph	**5**	**59**	R A	R R	R R	R A	R A	R F

palea (85%), *Gomphonema olivaceum* (84%), *Nitzschia dissipata* (83%), *Amphora pediculus* (82%), *Navicula trivialis* (82%), *Ulnaria ulna* (82%), *Navicula tripunctata* (77%), *Diatoma moniliformis* (72%), *Gomphonema parvulum* (70%), *Cocconeis placentula* (67%), and *Cyclotella meneghiniana* (66%); among them the most abundant taxa were *Nitzschia inconspicua* (maximum relative abundance 59.58% in epilithic and 32.72% in epipelic samples) and *Planothidium lanceolatum* (maximum relative abundance 36.47% in epilithic and 55.12% in epipelic diatoms) in both epilithic and epipelic assemblages, accompanied by *Amphora pediculus* in epilithic (33.8%) and *Navicula trivialis* (40.8%) in epipelic diatoms. Other abundant taxa were *Gomphonema olivaceum*, *Nitzschia palea*, *Rhoicosphenia abbreviata*, *Diatoma moniliformis*, and *Cyclotella meneghiniana*. Thirty-seven species represented more than 5% in at least one sample (Table 2, in bold). Some identified diatoms are presented in Figures 5–7.

4. Discussion

This study is the first attempt to uncover the taxonomic composition and distribution of diatoms in the Balikhli River. The recorded composition of the benthic diatom community is typical of running water and is somewhat

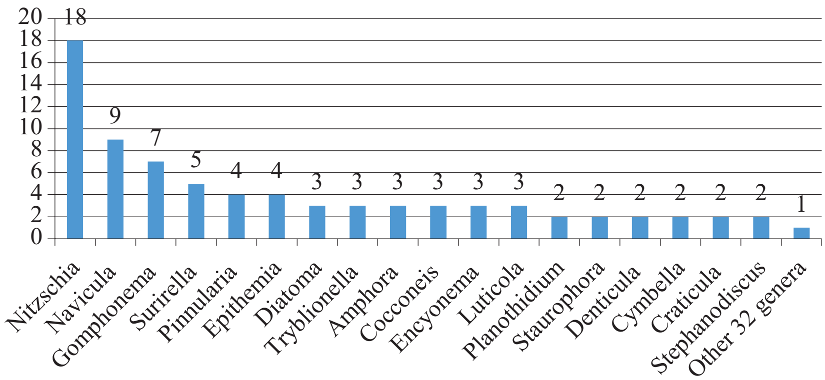

Figure 2. Number of species in various diatom genera collected from the Balikhli River - Ardabil - Iran.

Table 3. Morphological categorization of diatom taxa found in the Balikhli River according to Spaulding et al. (2010).

Group	Number of genera	Number of species
Symmetrical biraphids	14	29
Araphids	10	14
Asymmetrical biraphids	7	19
Nitzschioids	5	25
Centric	4	5
Monoraphids	4	7
Surirelloids	3	7
Epithemioids	2	4

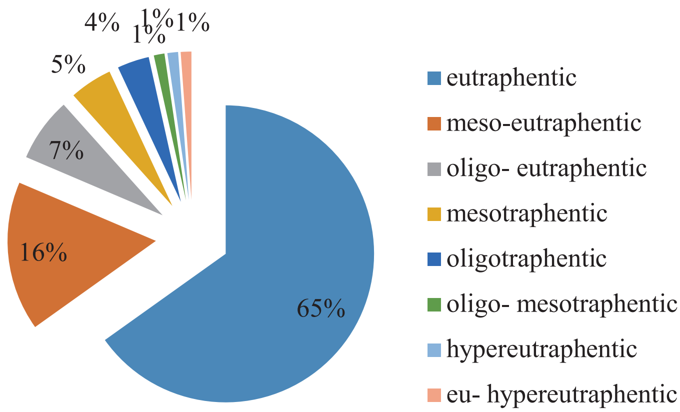

Figure 3. Trophic preferences of diatom taxa found in the Balikhli River.

similar (41 similar taxa) to the diatom communities reported from rivers in Ramsar, Iran (Soltanpour-Gargari et al., 2011) and the Nishava River (61 similar taxa) in southern Serbia (Andrejic et al., 2012). This may be due to the similar conditions of the rivers. When comparing species composition with the Karaj River (Kheiri et al., 2012) and Jajrud River (Jamalou et al., 2005) in northern parts of Iran, there are some similarities, but these

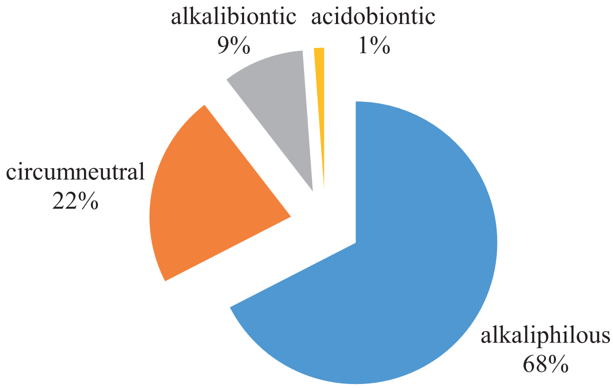

Figure 4. pH preferences of diatom taxa found in the Balikhli River.

taxa are known to be cosmopolitan species, including *Amphora pediculus*, *Cocconeis placentula*, *Surirella librile*, *Odontidium rnesodon*, *Diatoma vulgaris*, *Fragilaria capucina*, *Gomphonema olivaceum*, *Gomphonema parvulum*, *Melosira varians*, *Meridion circulare*, *Nitzschia palea*, *Planothidium lanceolatum*, *Rhoicosphenia abbreviata*, and *Ulnaria ulna*, which are found in various habitats throughout the world (Cantonati, 1998; Rott et al., 2006; Komulaynen, 2009; Gesierich and Kofler, 2011; Andrejic et al., 2012; Noga et al., 2014).

High species richness was recorded within the genera *Nitzschia* (18), *Navicula* (9), and *Gomphonema* (7), as found in studies of Andrejic et al. (2012), Delgado et al. (2013), and Suphan et al. (2012). These are very common genera with large numbers of species (Fourtanier and Kociolek, 2009; Spaulding et al., 2010). In comparison to other studied rivers in Iran, similar to our study *Nitzschia* with 24 species was the most species-rich genus in the Ramsar streams (Soltanpour-Gargari, 2011), the Gharasou River (25 spp.) (Atazadeh et al., 2007), and the Karaj River (10 spp.) (Kheiri et al., 2012). *Navicula* was the second most abundant genus in Ramsar (20 spp.) and the Gharasou River (25 spp.), although some species of *Navicula* sensu lato were represented by basionyms in our study. Differently, the third most species-rich genus in the above mentioned studies was *Cymbella*, which had no specific role in the diatom composition of the Balikhli River, but some species of this genus were represented by basionyms in the present study, including *Encyonema*.

The epilithic and epipelic diatom assemblages of the Balikhli River were dominated by taxa characteristic for alkaline and eutrophic waters. According to Richardson et al. (1996), *Cocconeis placentula*, *Diatoma vulgaris*, *Gomphonema parvulum*, *Melosira varians*, *Nitzschia palea*, *Planothidium lanceolatum*, and *Rhoicosphenia abbreviata* are some members of the "agricultural guild" that is dominant in diatom communities of streams enriched by runoff from agricultural land or input from industry. The appearance of these diatom species in water samples is an indication of the deterioration of water quality (Lee, 2008). Other studies from different rivers indicated that benthic diatoms in slightly or highly polluted rivers have similar dominant species, from which the most frequent are *Planothidium lanceolatum*, *Cocconeis placentula*, *Navicula lanceolata*, *N. gregaria*, *N. tripunctata*, and *Nitzschia palea* (Wasylik, 1985; Kawecka, 1986; Rakowska, 2001; Noga et al., 2014). The Eunotioid group had no representatives in the river. The genus *Eunotia* as a whole is a robust indicator for acid, fresh, oligotrophic water, which is rich in oxygen and poor in organic nitrogen compounds (Van Dem et al., 1994). Some dominant taxa were characterized by their small size, too, like *Nitzschia inconspicua*, *Planothidium lanceolatum*, and *Amphora pediculus.*

Thirty taxa were very rare in the river and were only observed in one sample: *Achnanthes brevipes*, *Aulacoseira granulata*, *Cocconeis pseudothumensis*, *Craticula citrus*, *Encyonema leibleinii*, *Entomoneis paludosa*, *Epithemia turgida*, *Gomphonema acuminatum*, *Gomphonema augur*, *Gomphonema pseudoaugur*, *Hannaea arcus*, *Luticola mutica*, *Nitzschia clausii*, *Nitzschia commutatoides*, *Nitzschia dippelii*, *Nitzschia fonticoloides*, *Nitzschia heufleriana*, *Nitzschia lacunarum*, *Nitzschia linearis*, *Nitzschia tryblionella*, *Nitzschia tubicola*, *Oxyneis binalis*, *Pinnularia borealis*, *Pinnularia ignobilis*, *Pinnularia rupestris*, *Placoneis elginensis*, *Pseudostaurosira parasitica*, *Staurophora wislouchii*, *Staurosira binodis*, and *Staurosirella dubia*. Among them, *Epithemia turgida* and *Hannaea arcus* were determined as boreal and arctic-alpine species, respectively (Komulaynen, 2009), and *Oxyneis binalis* is an acidobiontic species (Van Dam et al., 1994).

Among the centric diatoms identified, the genera *Stephanodiscus* and *Aulacoseira* are diverse and widespread planktonic genera of freshwaters (Hutchinson, 1967; Spaulding et al., 2010). The species *Aulacoseira granulata* is very rare in diatom assemblages of the river. The abundance of *Stephanodiscus neoastraea* (a diatom that is abundant in algal assemblages of the Yamchi dam), especially at sites 4 and 5, which are located downstream of the dams on the river, was probably a result of drift from dam. *Melosira varians* is one of the most common species of the genus and grows in benthic habitats of eutrophic streams and lakes (Spaulding et al., 2010). *Cyclotella meneghiniana* has a wide ecological distribution and is often found in waters with high conductivity (Kelly et al., 2005).

Cantonati et al. (2012) mentioned that the substrate present at a single site might influence the structure of diatom assemblages. Diatom species often show marked preferences for particular substrate and microniches or microhabitats (epilithic, epipelic, epipsammic, epiphytic)

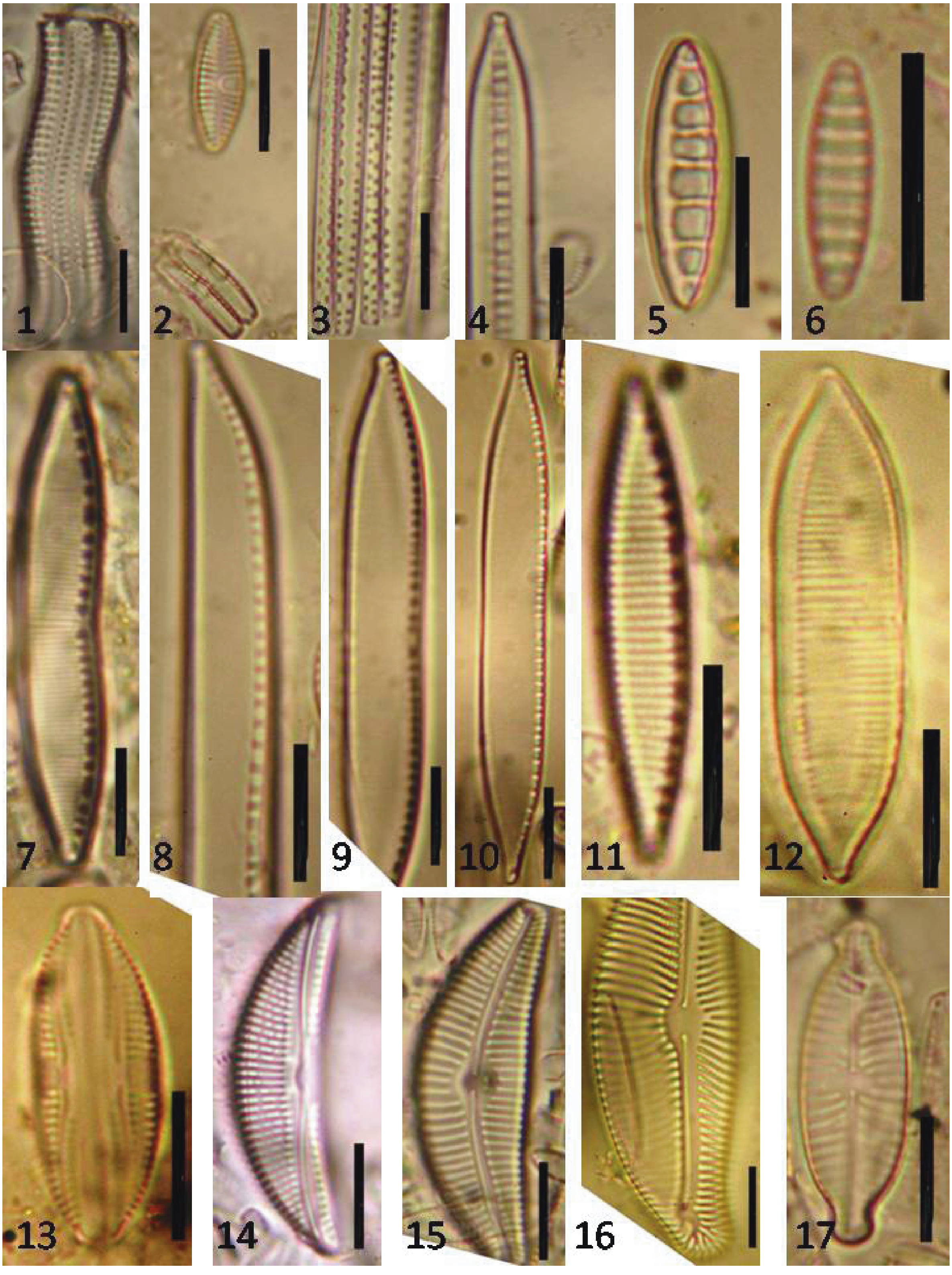

Figure 5. 1- *Achnanthes brevipes*. 2- *Planothidium frequentissimum*. 3, 4- *Bacillaria paxillifera*. 5- *Denticula elegans*. 6- *Denticula subtilis*. 7- *Hantzschia amphioxys*. 8- *Nitzschia clausii*. 9- *Nitzschia lacunarum*. 10- *Nitzschia tubicola*. 11- *Nitzschia liebetruthii*. 12- *Tryblionella calida*. 13- *Amphora copulata*. 14- *Amphora ovalis*. 15- *Cymbella cistula*. 16- *Encyonema leibleinii*. 17- *Placoneis elginensis*. Bar = 10 µm (photos: J Panahy Mirzahasanlou).

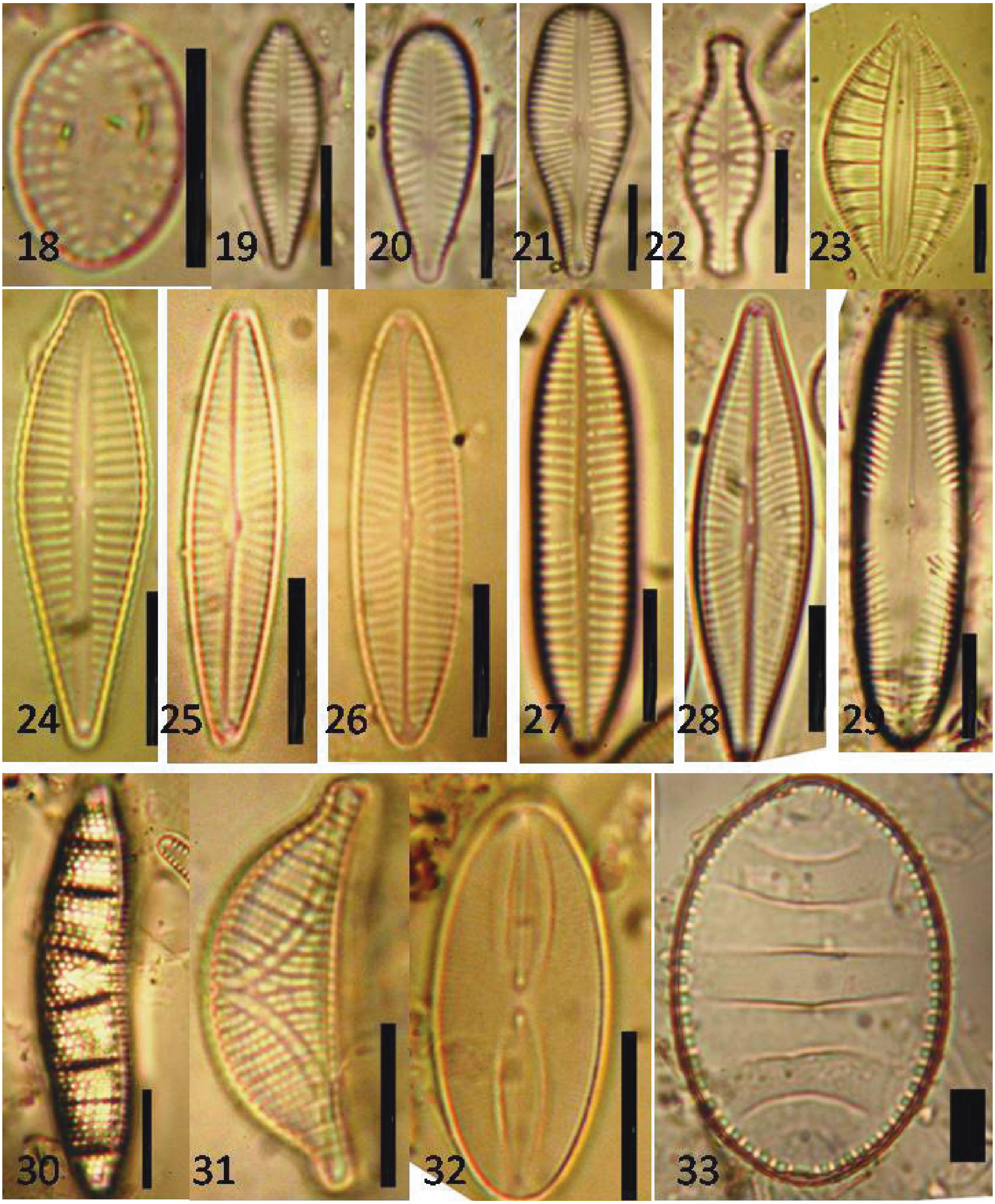

Figure 6. 18- *Cocconeis pseudothumensis*. 19- *Gomphonema augur*. 20- *Gomphonema olivaceum*. 21- *Gomphonema truncatum*. 22- *Hippodonta capitata*. 23- *Epithemia operculata*. 24- *Gomphonema pseudoaugur*. 25- *Navicula erifuga*. 26- *Navicula recens*. 27- *Navicula tripunctata*. 28- *Navicula trivialis*. 29- *Pinnularia acutobrebissonii*. 30- *Epithemia argus*. 31- *Epithemia sorex*. 32- *Fallacia pygmaea*. 33- *Cymatopleura elliptica*. Bar = 10 µm (photos: J Panahy Mirzahasanlou).

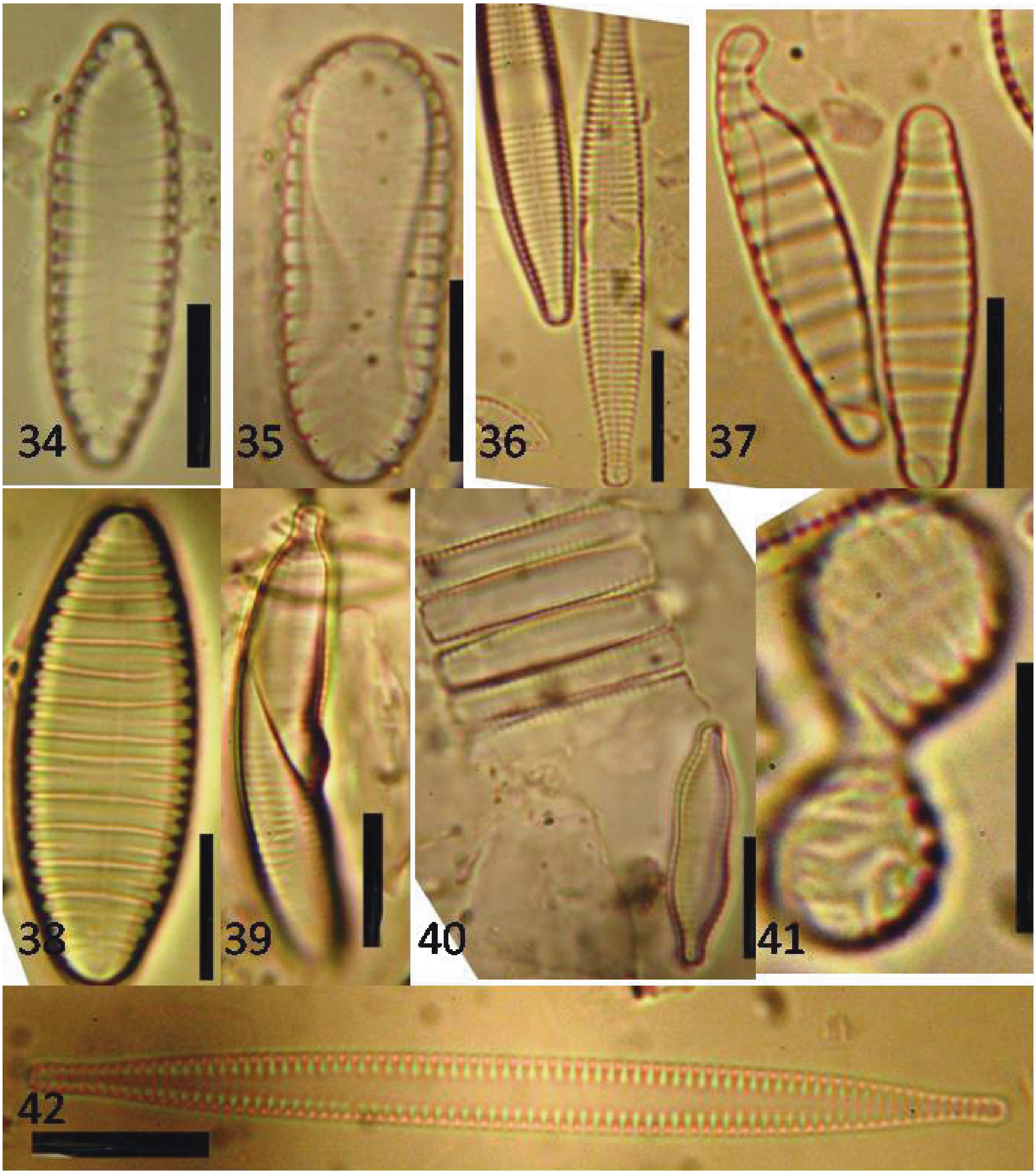

Figure 7. 34- *Surirella angusta*. 35- *Surirella minuta*. 36- *Ctenophora pulchella*. 37- *Diatoma moniliformis*. 38- *Diatoma vulgaris*. 39- *Hannaea arcus*. 40- *Staurosira binodis*. 41- *Oxyneis binalis*. 42- *Tabularia fasciculata*. Bar = 10 µm (photos: J Panahy Mirzahasanlou).

(Cox, 1988, 1990; Rothfritz et al., 1997). In this study, 37 taxa (33.63% of identified taxa) from 21 genera were encountered only in epipelic samples in this river, including *Amphora copulata*, *Aulacoseira granulata*, *Denticula elegans*, *Denticula subtilis*, *Epithemia argus*, *Epithemia turgida*, *Geissleria decussis*, *Gomphonema augur*, *Gomphonema pseudoaugur*, *Hannaea arcus*, *Hantzschia amphioxys*, *Luticola mutica*, *Luticola nivalis*, *Mastogloia smithii*, *Meridion circulare*, *Nitzschia clausii*, *Nitzschia commutatoides*, *Nitzschia dippelii*, *Nitzschia lacunarum*, *Nitzschia linearis*, *Nitzschia tryblionella*, *Pinnularia borealis*, *Pinnularia ignobilis*, *Pinnularia rupestris*, *Placoneis elginensis*, *Pseudostaurosira parasitica*, *Sellaphora pupula*, *Staurophora tackei*, *Staurophora wislouchii*, *Staurosira binodis*, *Staurosirella dubia*, *Stenopterobia* sp., *Surirella librile*, *Tryblionella calida*, and *Tryblionella hungarica*; on the other hand, 11 taxa (10%) from 8 genera exclusive to epilithic samples were *Achnanthes brevipes*, *Bacillaria paxillifera*, *Cocconeis pseudothumensis*, *Craticula citrus*, *Gomphonema acuminatum*, *Gomphonema truncatum*, *Nitzschia fonticoloides*, *Nitzschia heufleriana*, *Nitzschia tubicola*, *Oxyneis binalis*, and *Psammothidium subatomoides*. Most of the above mentioned taxa were rare species in the studied river.

Twenty taxa have not yet been recorded from the aquatic ecosystems of Iran and are new records for the diatom flora of Iran (Table 1; Figures 5–7). The taxa *Achnanthidium lanceolata*, *Achnanthes lanceolata* subsp. *frequentissima*, *Cymatopleura solea*, *Diatoma mesodon*, *Navicula capitata*, *Navicula cuspidata*, *Navicula goeppertiana*, *Navicula mutica*, *Navicula pupula*, *Navicula pygmaea*, *Nitzschia hungarica*, and *Synedrella parasitica*, which were recorded in previous works in different ecosystems of Iran (Hirano, 1973; Wasylik, 1975; Nejadsattari, 2005; Shams and Afsharzadeh, 2009; Soltanpour-Gargari, 2011; Ramazannejad Ghadi and Kianianmomeni, 2013) are considered with their current accepted names in this contribution: *Planothidium lanceolatum*, *Planothidium frequentissimum*, *Surirella librile*, *Odontidium mesodon*, *Hippodonta capitata*, *Craticula cuspidata*, *Luticola goeppertiana*, *Luticola mutica*, *Sellaphora pupula*, *Fallacia pygmaea*, *Tryblionella hungarica*, and *Pseudostaurosira parasitica*, respectively.

It has been shown that diatom communities are dominated by a few species that occur frequently and a large number of rare species that occur occasionally or sometimes only once (Round, 1993; Kelly and Whitton, 1995). The structure of the diatom assemblages from the Balikhli River agrees with this finding.

This paper presents the first study of the taxonomic composition and distribution of diatoms in the Balikhli River. A further step will be to evaluate the ecological status of this river based on the qualitative and quantitative diatom data from the present study.

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