

Epilithic diatoms (Bacillariophyceae) from streams in Ramsar, Iran

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Abstract – Epilithic diatoms were identified from five small streams and one canal in Ramsar, northwest Iran. A total of 155 diatom taxa belonging to 37 genera were found and only two species remained unidentified (*Fragilaria* sp. and *Nitzschia* sp.). *Achnanthes*, *Nitzschia*, *Navicula*, *Cocconeis*, *Melosira*, *Amphora*, *Craticula*, *Diatoma*, *Surirella*, *Cymbella*, *Diploneis* and *Entomoneis* were among the most abundant genera. Eighty seven taxa were recorded for the first time in Iran. Thirty two of the genera belong to the *Pennales* and 5 to the *Centrales*. Species richness was rather high ranging from 66 to 95 taxa at the six sites studied. The epilithic diatom species found in Ramsar were dominated by cosmopolitan taxa found in meso- to fairly eutrophic waters with high conductivity and high nutrient concentrations. The abundances found at all six sites were compiled in order to estimate the overall abundance of each taxon in Ramsar. This study includes EM pictures of diatoms observed in Ramsar, Iran.

Keywords: diatom, stream, Ramsar, Iran

Introduction

The diversity of freshwater diatoms is enormous (PATRICK and REIMER 1966, LANGE-BERTALOT 2001, KRAMMER 2002). Although algae constitute a fundamental part of the aquatic food chains, only few research papers deal with the freshwater or marine diatoms of Iranian environment. Some authors have studied the seasonal distribution of phytoplankton (SOLTANPOUR-GARGARI 1973, KIMBALL and KIMBALL 1977). HIRANO (1973) has studied the freshwater algae of Mesopotamia including nine sampling sites in Iran. WASYLIK (1975) and COMPÈRE (1981) have studied algae in general while ALFINITO and FUMANTI (1980) reported brief systematic results from a single sampling. Diatoms were used as an indicator of pollution in a small section of the Zayandeh River in Isfahan, Iran by MOGHADAM

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(1976). In recent years NEJADSATTARI (2005) has studied the diatom flora of Neure Lake in East Azerbaijan, Iran. NEJADSATTARI et al. (2005) studied the composition and seasonal distribution of epiphytic algae in Anzali lagoon. ATAZADEH et al. (2007) have calculated the trophic diatom index for assessing water quality in the Gharasou River, western Iran. WASYLIKOWA and WITKOWSKI (2008) have studied fossil diatoms of Lake Zaribar in western Iran. The diatoms of the coastal area of the Caspian Sea with hundreds of large and small tributaries have received little attention although diatoms, especially the freshwater species, are the major group of algae. The aim of this study is to assess the diatom flora of some Iranian freshwater ecosystems and evaluate the relation to water quality.

Material and methods

Study areas

Epilithic diatoms were collected from one river, four streams and one canal in Ramsar in spring 2007. The location of the sampling sites was determined in such a way as to avoid direct human influence: as far away as possible from roads but still accessible. Ramsar is located in the state of Mazandaran on the coast of Caspian Sea. The city of Ramsar borders the Caspian Sea to the north, Gilan Province to the west, Qazvin Province to the south and Tonekabon city to the east (Fig. 1). We found no published or unpublished reports on water quality in this area. Due to lack of facilities and authority we were unfortunately not able to analyze the water quality in situ.

The climate is semitropical with very high temperatures and high humidity especially in summer. Geologically, this area is relatively young containing uraniumiferous igneous rocks from the Precambrian to the Quaternary (BOZORGNIA 1970). Ramsar is predominately a rural area and over 50% of the local population is directly or indirectly involved in farming and agricultural activities e.g. in rice fields and citrus fruit and kiwi orchards. Dumping of organic and domestic garbage along road sides is very common. In addition, Ramsar attracts a lot of tourists every year which aggravates the environmental pollution.

The city is located between the Alborz Mountains and to the west of the Caspian coastal plain. The coastal plain in Ramsar is very narrow and the city extends on the hilly terrain to the south. The bedrock of this terrain is sandstone, covered with dense forests and the annual precipitation is 1500 mm. The weak lithology, high rainfall, high degree of weathering and also human activities such as deforestation, road construction, housing and agriculture, have increased in potential of slope instability in this area (HAFEZI MOGHADDAS and GAFOORI 2007).

Description of the sampling sites (sampling date 24 March 2007):

Site 1: Sample collected from the concrete wall of a canal. Width of the canal is approximately 80 cm. Depth is not more than 50 cm. Fast flowing, clear water.

Site 2: Small stream near the old road to the Hotel Ramsar. Width of the stream is about 3 m and the depth is not more than 30 cm. River bed is composed of pebbles and different size rocks. Water is clear.

Site 3: The same stream but about 300 meters down the road. Width is not more than 3 m. Depth is not more than 30 cm. At this location the water is mixed with a cooled hot spring stream. Water is clear.

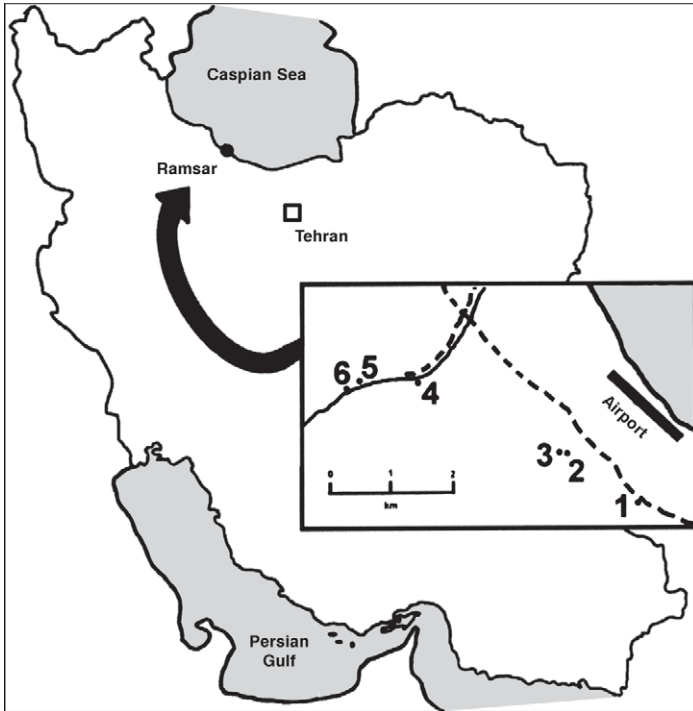


Fig. 1. The study area in Ramsar, North-West Iran.

Site 4: This site is located near the road of Javaherdeh. Due to the flood of the main river, the diatom sample was collected from the stream Gavramak 50 meters from where it joins the main river. Width is not more than 2 m. River bed is composed of fine pebbles, small stones and large boulders. Depth is not more than 20 cm. Water clear.

Site 5: This site is also in the Javaherdeh road. The water runs down a hill. Stones are covered with moss and green algae. Width is about 2 meters at sampling site. Depth is not more than 10 cm. Water is clear.

Site 6: Sample was taken from a small stream, which runs through the road. Width is not more than 2 m. Depth at sampling site is about 20 cm. River bed is composed of medium size pebbles and small stones. Water is clear.

Diatom sampling and identification

At each sampling location diatoms were collected by removing submerged stones and by scraping their surface using a plastic spatula and a plastic bottle. The samples were diluted with stream water and later preserved with 5% formaldehyde.

In the laboratory of the Department of Environmental Sciences of Helsinki University sub samples of diatoms were digested with sulphuric / nitric acid (4/1) in order to eliminate organic matter. Samples were then washed by decanting using distilled water.

For permanent diatom slides the cleaned and rinsed diatom samples were mounted on glass slides using NAPHRAX® ($i=1.74$). A Zeiss microscope with full immersion objec-

tives was used for diatom identification at 1000 x magnification. OMIT (no light microscope pictures are used). The electron microscope photos were obtained in Alfred Wegener Institute (Germany) with a Scanning Electron Microscope FEI Quanta 200 FEG. In order to determine the relative frequency of commonly occurring taxa, 3 slides were prepared for each sampling site, and in each slide 300 valves were counted along randomly selected transects. To achieve maximum taxa diversity, two slides from each sampling sites have been examined in detail.

The following references were used for diatom identification: KRAMMER (1992; 1997a, b, 2002); KRAMMER and LANGE-BERTALOT (1986; 1988; 1991a, b); LANGE-BERTALOT (1993, 2001); LANGE-BERTALOT and METZELIN (1996) and REICHARDT (1999).

Diatoms were scored on a semi quantitative scale according to VESELÁ and JOHANSEN (2009): rare (one or two frustules per sample), uncommon (less than 5% of cells), common (5-25%), frequent (25-50%), and dominant more than 50% of cells.

Results

A total of 153 diatom taxa were identified from the Ramsar samples. This study originally covered a total of 153 identified species from the Ramsar samples with some presented in Plates 1–4, Figs. 2–33. Eighty seven of the taxa observed in the present study have not been previously reported in Iran. Two species (*Fragilaria sp.* and *Nitzschia sp.*) remained unidentified.

Taxonomic diversity

Thirty two of the genera belong to the *Pennales* and 5 to the *Centrales*. Three of the *Centrals* were not reported in Iran before: *Ellerbeckia arenaria* f. *arenaria*, *Orthoseira rooseana* and *Pleurosira laevis* f. *polymorpha*. *Melosira varians* was present almost at all sites with 7% of the overall population (Tab. 1). Two species of *Cyclotella* (*C. comensis* and *C. meneghiniana*) were also observed. *Nitzschia* with 24 species showed the highest species diversity in the *Pennales*, followed by *Navicula* with 20 species. The list of all taxa (Tab. 2) including a semi-quantitative scale of abundance is in alphabetical order and shows diatom species found in Ramsar. *Bacillaria*, *Craticula*, *Entomoneis*, *Eunotia*, *Frustulia*, *Hantzschia*, *Haslea*, *Mastogloia*, *Meridion*, *Pleurosigma*, *Rhoicosphenia*, *Stenopterobia* and *Synedra* were represented by only one species each.

The abundances found at all six sites were compiled in order to estimate the overall abundance of each taxon in Ramsar. *Achnanthes*, *Nitzschia*, *Navicula*, *Cocconeis*, *Melosira*, *Amphora*, *Craticula*, *Diatoma*, *Surirella*, *Cymbella*, *Diploneis* and *Entomoneis* were among the most abundant genera (Tab. 3). Twelve species were particularly abundant: *Achnanthes minutissima* var. *jackii*, *Navicula phylleptosoma*, *Melosira varians*, *Cocconeis placentula* var. *euglypta*, *Nitzschia palea*, *Nitzschia constricta*, *Cocconeis pediculus*, *Amphora pediculus*, *Navicula salinarum* var. *salinarum*, *Craticula buderi*, *Nitzschia inconspicua* and *Navicula cryptocephala*. All sites contained diatom species characteristic of more alkaline and nutrient rich waters, with the exception of *Frustulia rhomboides* var. *crassinervia* (acidobiontic) which was rare, *Fragilaria tenera* (acidophilous) as a rare taxon only at site 3 and *Stenopterobia curvula* (acidophilous) as a rare taxon at sites 2 and 3.

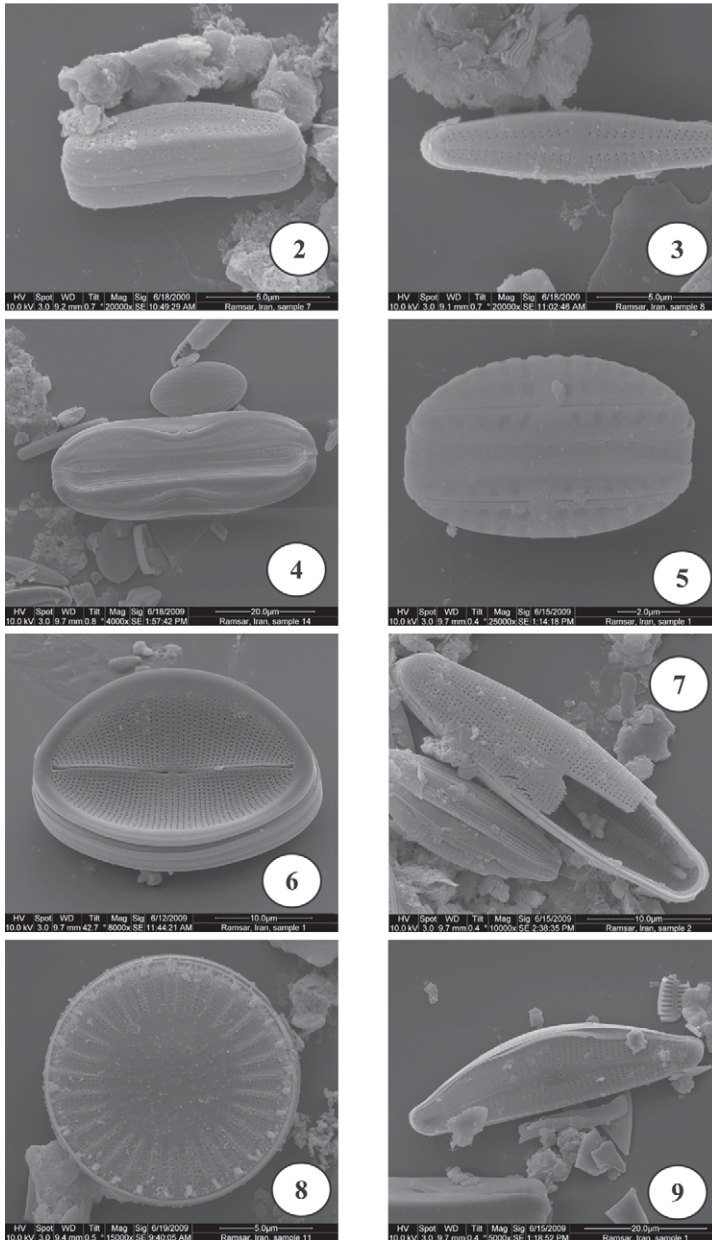


Plate 1. Figs. 2–3. *Achnanthes minutissima* var. *jackii* (Rabenhorst) Lange-Bertalot 1980. Length 15 µm, breadth 3.5 µm, striae 26/ 10 µm; Fig. 4. *Amphora commutata* Grunow 1880. Length 52 µm, breadth 12 µm, striae 13/ 10 µm. Fig. 5. *Amphora pediculus* (Kützing) Grunow 1880. Length 10 µm, breadth 5 µm, striae 18/ 10 µm; Fig. 6. *Cocconeis pediculus* Ehrenberg 1838. Length 27 µm, breadth 23 µm, striae 22/10 µm; Fig. 7. *Craticula buderi* (Hustedt) Lange-Bertalot 2000. Length 31 µm, breadth 8 µm, striae 21/10 µm; Fig. 8. *Cyclotella meneghiniana* Kützing 1844. Diameter 12 µm; Fig. 9. *Cymbella turgiduliformis* Krammer 2002. Length 47 µm, breadth 14 µm, striae 13/10 µm

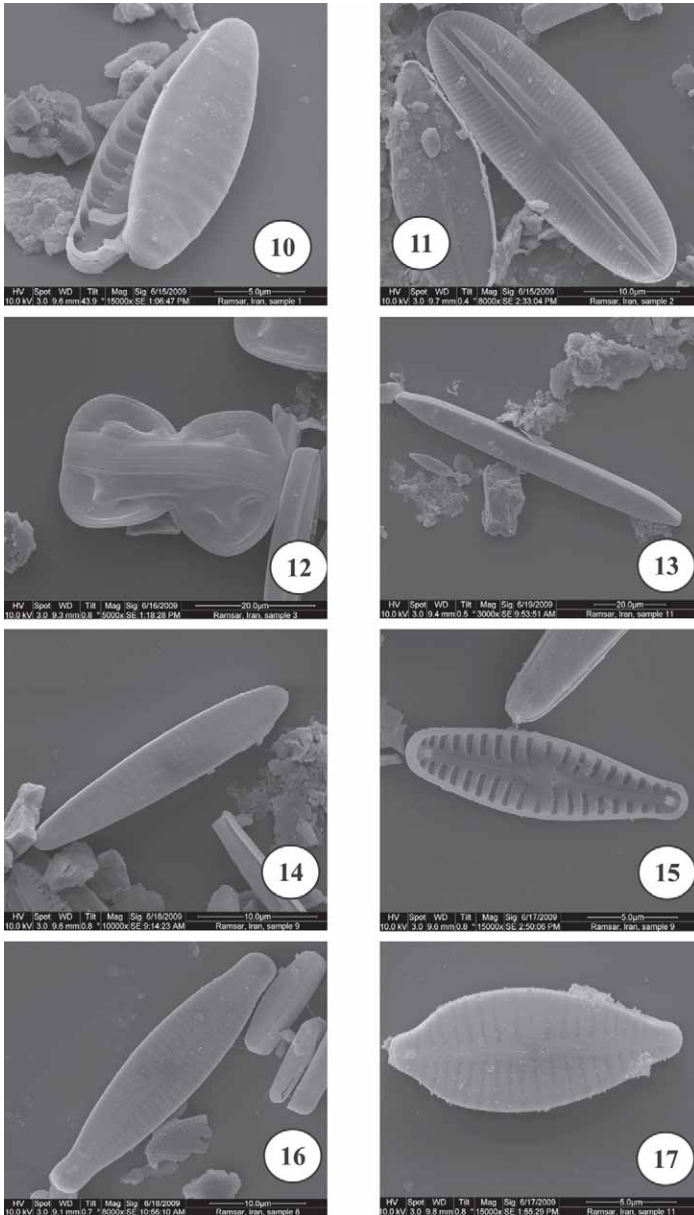


Plate 2 Fig. 10. *Diatoma vulgaris* Morphotype *vulgaris* Bory 1824. Length 15 μm , breadth 7 μm ; Fig. 11. *Diploneis oblongella* (Naegeli) Cleve-Euler 1922. Length 36 μm , breadth 9 μm , striae 19/10 μm ; Fig. 12. *Entomoneis paludosa* var. *subsalina* (Cleve) Krammer 1986. Length 60 μm , breadth 27 μm , striae 20/10 μm ; Fig. 13. *Fragilaria ulna* var. *ulna* (Nitzsch) Lange-Bertalot 1980. Length 83 μm , breadth 7 μm , striae 9/10 μm ; Fig. 14. *Gomphonema angustatum* (Kützing) Rabenhorst 1864. Length 25 μm , breadth 5 μm , striae 11/10 μm ; Fig. 15. *Gomphonema olivaceum* var. *olivaceum* (Hornemann) Brebisson 1838. Length 30 μm , breadth 7 μm , striae 12/10 μm ; Figs. 16-17. *Gomphonema parvulum* Kützing 1849. Length 35 μm , breadth 9 μm , striae 13/10 μm .

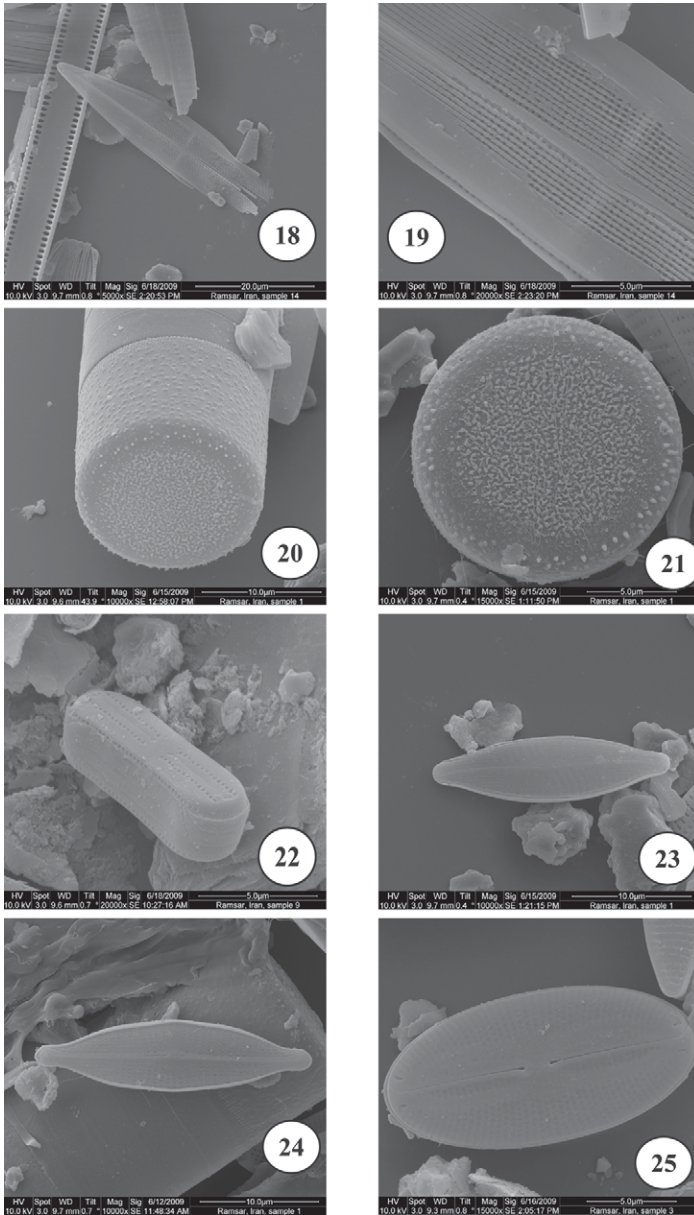


Plate 3 Figs. 18-19. *Haslea spicula* (Hickie) Lange-Bertalot 1997. Length 52 μm , breadth 10 μm , striae 32/10 μm ; Figs. 20-21. *Melosira varians* Agardh 1827. Diameter/15 μm Mantelhohe 11/10 μm ; Fig. 22. *Navicula contenta* Grunow in Van Heurck 1884-1887. Length 9 μm , breadth 2.5 μm , striae -/10 μm ; Fig. 23. *Navicula cryptocephala* Kützing 1844. Length 20 μm , breadth 6 μm , striae 15/10 μm ; Fig. 24. *Navicula phylleptosoma* Lange-Bertalot 1999. Length 24 μm , breadth 6 μm , striae 17/10 μm ; Fig. 25. *Navicula pygmaea* Kützing 1849. Length 20 μm , breadth 9 μm , striae -/10 μm .

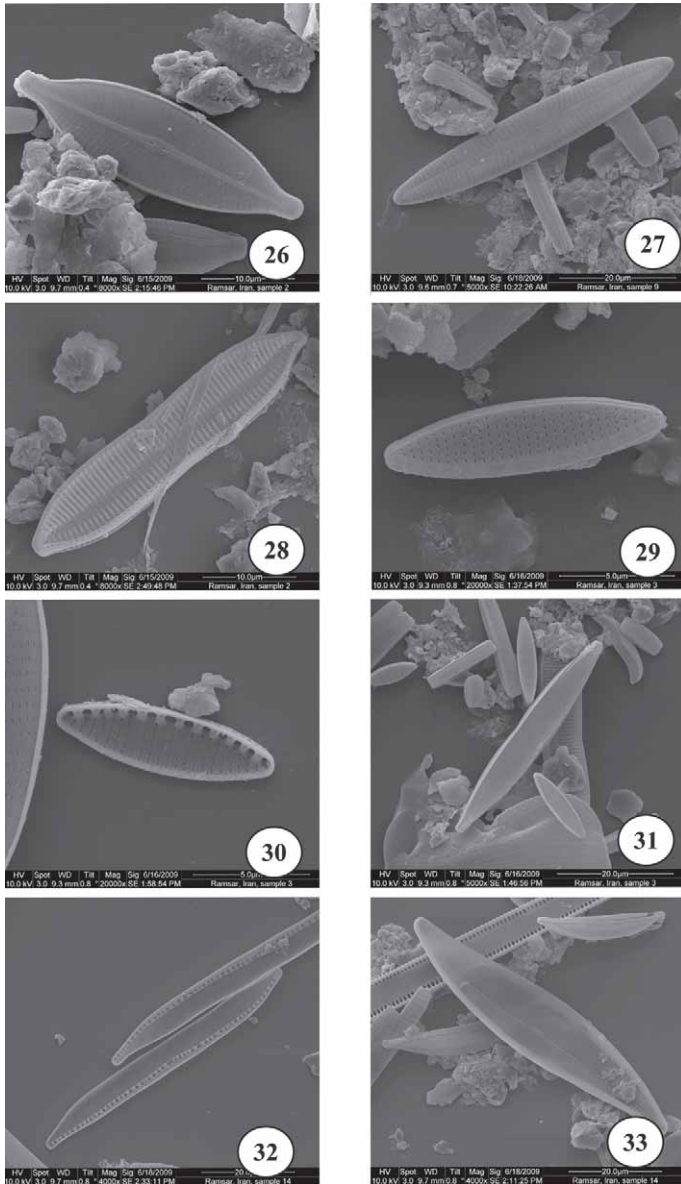


Plate 4 Fig. 26. *Navicula salinarum* var. *salinarum* Grunow 1880. Length 33 μm, breadth 11 μm, striae 17/10 μm; Fig. 27. *Navicula tripunctata* (O.F.Müller) Bory 1822. Length 67 μm, breadth 9 μm, striae 11/10 μm; Fig. 28. *Nitzschia constricta* (Kützing) Ralf in Pritchard 1861. Length 30 μm, breadth 6 μm, striae 18/10 μm; Fig. 29. *Nitzschia frustulum* var. *frustulum* (Kützing) Gronow 1880. Length 13 μm, breadth 3.2 μm, striae 18/10 μm, fibulae 11/10 μm; Fig. 30. *Nitzschia inconspicua* Grunow 1862. Length 10 μm, breadth 2.5 μm, striae 28/10 μm, fibulae 12/10 μm; Fig. 31. *Nitzschia palea* (Kützing) W. Smith 1856. Length 43 μm, breadth 4.5 μm, Fibulae 15/10 μm; Fig. 32. *Nitzschia scalpelliformis* (Grunow) Grunow 1880. Length 60 μm, breadth 5 μm, striae 36/10 μm, fibulae 12/10 μm; Fig. 33. *Pleurosigma salinarum* Grunow 1880. Length 70 μm, breadth 16 μm, striae -/10 μm.

Tab. 1: Mean percentages of more commonly occurring diatom taxa at each sampling site.

Species	sampling sites (mean %)					
	1	2	3	4	5	6
<i>Achnanthes minutissima</i> var. <i>jackii</i>	<1	–	–	39	51	32
<i>Amphora pediculus</i>	2.4	1	<1	7.6	<1	11
<i>Cocconeis pediculus</i>	10.4	<1	<1	16.1	–	1.2
<i>C. placentula</i> var. <i>euglypta</i>	4.7	<1	1.7	12	5.7	11
<i>Craticula buderi</i>	<1	–	–	–	19.3	–
<i>Melosira varians</i>	32.3	2	4.5	1	<1	1.7
<i>Navicula cryptocephala</i>	2	1	6.2	3	<1	6.2
<i>N. phylleptosoma</i>	–	40	1	–	–	–
<i>N. salinarum</i> var. <i>salinarum</i>	<1	20.3	<1	–	–	<1
<i>Nitzschia constricta</i>	–	1.6	27.3	–	–	–
<i>N. inconspicua</i>	<1	1.4	16.7	<1	<1	<1
<i>N. palea</i>	<1	–	<1	<1	14	17

Discussion and conclusions

As the present study carried out in Ramsar area is the first to observe the taxonomy of epilithic diatoms, it is hard to formulate any comparison with the diversity found in other regions. However, the general species composition of the diatoms recorded in Ramsar is mainly in agreement with that reported for the northern hemisphere. The majority of identified taxa are classified as alpine species (KRAMMER and LANGE-BERTALOT 1986, 1996). The epilithic diatom species found in Ramsar were dominated by cosmopolitan taxa found in waters with meso- to fairly eutrophic water with high conductivity and high nutrient concentrations. All the abundant species from table 3 have been characterized by VAN DAM et al. (1994) with exception of *Craticula buderi* and *Navicula phylleptosoma*, which were characterized by LANGE-BERTALOT (2001). Based on the taxa observed, the sampled canal and streams were established as being meso- to eutrophic waters with circumneutral to alkaline pH, elevated or periodically elevated with a concentration of organically bound nitrogen and oxygen level from moderate (above 50% saturation) to fairly high (above 75% saturation). According to FORE and GRAFE (2002), increase of alcaliphilic diatoms is due to the increasing intensity of agriculture and livestock grazing. Evaporation of the irrigation water in the agricultural fields can leave salt or alkaline residue that is washed into the rivers. In addition, fertilization and erosion can increase nutrient contents and alkalinity (KHAN and ALI 2003). Most frequent taxa occurring in all sites were *Achnanthes minutissima* var. *minutissima*, *Amphora pediculus*, *Cocconeis pediculus*, *Navicula cryptocephala*, *Navicula tripunctata* and *Rhoicosphenia abbreviate* (Tab. 2). These taxa are common species of the benthic diatom community and have been reported from other parts of Iran (NEJADSATTARI 2005, COMPÈRE 1981, MOGHADAM 1976, WASYLK 1975).

There were clear differences between different sites. Species diversity was rather high ranging from 66 to 95 taxa. The highest number of species was recorded at site 3 (95 taxa)

Tab. 2. List of diatom species from Ramsar and their semi-quantitative scale of abundance: r = rare, u = uncommon, c = common, f = frequent, d = dominant; pH iv = Van Dam's pH indication values: 1 = acidobiontic, 2 = acidophilous, 3 = circumneutral, 4 = alkaliphilous, 5 = alkalibiontic, 6 = indifferent; * = reported, ** = reported for the first time in Iran

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>Achnantes brevipes</i> var. <i>intermedia</i> (Kützing) Cleve	r	r	r	r	r	r	—	**					
<i>A. coaretata</i> (Brébisson) Grunow	—	—	r	r	r	r	3	**					
<i>A. inflata</i> (Kützing) Grunow	—	—	—	r	—	r	—	**					
<i>A. lanceolata</i> ssp. <i>biporoma</i> (Hohn et Hellermann) Lange-Bertalot	r	r	—	—	r	r	3	**					
<i>A. lanceolata</i> ssp. <i>frequentissima</i> var. <i>frequentissima</i> Lange-Bertalot	—	r	—	r	r	r	4	**					
<i>A. lanceolata</i> ssp. <i>lanceolata</i> var. <i>boyei</i> (Oestrup) Lange-Bertalot	r	r	r	r	r	r	—	**					
<i>A. lanceolata</i> ssp. <i>lanceolata</i> var. <i>haynaldii</i> (Schaarschmidt) Cleve	—	—	r	r	—	r	4	**					
<i>A. lanceolata</i> ssp. <i>lanceolata</i> var. <i>lanceolata</i> (Brébisson) Grunow	—	r	r	r	r	r	4	**					
<i>A. minutissima</i> var. <i>Jackii</i> (Rabenhorst) Lange-Bertalot	r	r	r	f	d	f	3	**					
<i>A. parvula</i> Kützing	—	—	r	—	—	—	4	**					
<i>A. ploenensis</i> var. <i>gessneri</i> (Hustedt) Lange-Bertalot	—	—	r	—	—	r	—	**					
<i>Amphora coffeaeformis</i> var. <i>coffeaeformis</i> (Agardh) Kützing	r	c	r	r	r	r	4	*		*			
<i>A. commutata</i> Grunow	r	r	r	—	—	—	—	*				*	

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>A. libyca</i> Ehrenberg	–	–	r	–	r	–	–	*		*			
<i>A. ovalis</i> (Kützing) Kützing	r	r	r	–	–	r	4	*	*	*	*		*
<i>A. pediculus</i> (Kützing) Grunow	u	u	r	c	r	c	4	*			*		
<i>Bacillaria paradoxa</i> Gmelin	r	r	r	–	–	–	5	*			*		
<i>Caloneis bacillum</i> (Grunow) Cleve	–	–	r	–	–	–	4	*		*			*
<i>C. budensis</i> (Grunow) Krammer	–	r	–	–	–	–	–	**					
<i>C. molaris</i> (Grunow) Krammer	–	–	r	r	–	r	3	**					
<i>Cocconeis neothumensis</i> Krammer	–	–	r	r	r	r	5	**					
<i>C. pediculus</i> Ehrenberg	c	r	r	c	r	u	4	*		*	*		
<i>C. placentula</i> var. <i>euglypta</i> (Ehrenberg) Grunow	u	r	u	c	c	c	4	*		*	*		
<i>C. placentula</i> var. <i>lineata</i> (Ehrenberg) Van Heurck	–	–	r	–	r	–	4	*			*		
<i>Craticula buderi</i> (Hustedt) Lange-Bertalot	r	–	–	–	c	–	–	**					
<i>Cyclotella comensis</i> Grunow	–	–	r	–	–	–	3	*		*			
<i>C. meneghiniana</i> Kützing	–	–	r	r	–	–	4	*	*	*	*		*
<i>Cymatopleura elliptica</i> var. <i>elliptica</i> (Brébisson) W. Smith	r	–	r	r	r	r	4	*	*	*			*
<i>C. solea</i> var. <i>apiculata</i> (W. Smith) Ralfs	–	–	r	–	–	–	–	**					
<i>C. solea</i> var. <i>solea</i> (Brébisson) W. Smith	r	r	r	–	–	r	4	*			*		*
<i>Cymbella aspera</i> (Ehrenberg) Peragallo	r	–	–	–	–	–	4	**					

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>C. helvetica</i> Kützing	–	–	–	r	–	r	4	*		*			*
<i>C. minuta</i> Hilse	r	r	r	r	u	u	3	**					
<i>C. naviculiformis</i> (Auerswald) Cleve	–	r	r	r	–	r	–	*			*		
<i>C. prostrata</i> (Berkeley) Cleve	r	r	–	r	–	r	4	*			*		
<i>C. simonsenii</i> Krammer	r	–	r	–	–	–	–	**					
<i>C. sinuata</i> Gregory	r	r	r	r	r	–	3	*		*	*		
<i>C. tumida</i> (Brébisson) Van Heurck	r	–	r	r	r	–	4	*			*		
<i>C. turgiduliformis</i> Krammer	r	r	r	c	c	r	4	**					
<i>Denticula kuetzingii</i> var. <i>kuetzingii</i> Grunow	–	–	–	–	r	–	4	**					
<i>D. tenuis</i> Kützing	–	r	–	–	r	r	4	**					
<i>Diatoma mesodon</i> (Ehrenberg) Kützing	–	–	–	r	–	r	3	**					
<i>D. moniliformis</i> Kützing	u	r	–	u	r	r	–	**					
<i>D. vulgaris</i> morphotype <i>constricta</i> Grunow	r	r	–	–	–	r	5	**					
<i>D. vulgaris</i> morphotype <i>vulgaris</i> Bory	c	r	r	r	–	r	–	*	*	*	*		
<i>Diploneis marginestriata</i> Hustedt	r	r	r	–	r	–	–	**					
<i>D. oblongella</i> (Naegeli) Cleve-Euler	r	c	r	r	r	r	4	*		*			
<i>D. parma</i> Cleve	–	r	–	–	–	–	–	**					
<i>D. smithii</i> var. <i>dilatata</i> (Peragallo) Terry	–	r	r	–	–	–	5	**					

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>D. smithii</i> var. <i>pumila</i> (Grunow) Hustedt	–	–	r	–	–	–	5	**					
<i>D. subovalis</i> Cleve	r	r	r	r	r	r	–	**					
<i>Ellerbeckia arenaria</i> f. <i>arenaria</i> (Moore) Crawford	–	–	r	–	–	–	4	**					
<i>Entomoneis paludosa</i> var. <i>subsalina</i> (Cleve) Krammer	–	–	u	–	–	–	–	**					
<i>Eunotia praerupta</i> var. <i>praerupta</i> Ehrenbreg	–	–	–	–	r	–	2	**					
<i>Fragilaria capucina</i> var. <i>capitellata</i> (Grunow) Lange-Bertalot	r	r	r	r	r	r	3	**					
<i>F. capucina</i> var. <i>vaucheriae</i> (Kützing) Lange-Bertalot	–	–	–	–	r	–	4	*		*	*		
<i>F. construens</i> f. <i>venter</i> (Ehrnberg) Hustedt	r	r	r	r	r	r	4	*		*			
<i>F. elliptica</i> Schumann	–	–	–	–	r	r	4	**					
<i>F. fasciculata</i> (Agardh) Lange-Bertalot	–	–	r	–	r	r	4	*		*			
<i>F. lata</i> (Cleve-Euler) Renberg	r	–	–	–	r	r	–	**					
<i>F. nanana</i> Lange-Bertalot	–	–	r	–	–	–	3	**					
<i>F. parasitica</i> var. <i>parasitica</i> (W. Smith) Grunow	r	r	–	–	r	r	4	**					
<i>F. tenera</i> (W. Smith) Lange-Bertalot	–	–	r	–	–	–	2	**					
<i>F. ulna</i> var. <i>acus</i> (Kützing) Lange-Bertalot	r	r	–	–	–	–	4	*	*	*	*		

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>F. ulna</i> var. <i>ulna</i> (Nitzsch) Lange-Bertalot	r	r	r	r	r	–	4	*	*	*	*		*
<i>F. ungeriana</i> Grunow	–	–	–	–	–	r	–	*		*			
<i>Frustulia rhomboides</i> var. <i>crassinervia</i> (Brébisson) Ross	r	–	r	r	r	r	1	**					
<i>Geissleria ignota</i> (Krasske) Lange-Bertalot et Metzeltin	–	–	–	–	r	–	–	**					
<i>G. moseri</i> Metzeltin, Witkowski et Lange-Bertalot	–	u	–	–	–	–	–	**					
<i>G. schoenfeldii</i> (Hustedt) Lange-Bertalot et Metzeltin	–	r	–	–	–	–	–	**					
<i>Gomphonema affine</i> var. <i>affine</i> Kützing	–	–	r	–	–	–	4	**					
<i>G. angustatum</i> (Kützing) Rabenhorst	–	–	–	r	–	r	–	*		*			*
<i>G. clavatum</i> Ehrnberg	–	r	r	r	r	r	3	**					
<i>G. olivaceum</i> var. <i>olivaceum</i> (Hornemann) Brébisson	r	r	r	r	r	r	5	*			*		*
<i>G. parvulum</i> (Kützing) Kützing	r	r	r	u	u	r	3	*	*	*	*		*
<i>G. truncatum</i> Ehrenberg	–	–	–	r	r	–	4	**					
<i>Gyrosigma attenuatum</i> (Kützing) Rabenhorst	r	r	r	–	r	–	5	**					
<i>G. peisonis</i> (Grunow) Hustedt	r	–	r	r	r	r	4	*		*			
<i>G. scalproides</i> (Rabenhorst) Cleve	–	r	r	r	–	–	–	*	*				
<i>Hantzschia virgata</i> var. <i>virgata</i> (Roper) Grunow	–	–	–	–	r	r	–	**					

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>Haslea spicula</i> (Hickie) Lange-Bertalot	–	r	–	–	–	–	–	*				*	
<i>Mastogloia elliptica</i> var. <i>elliptica</i> (Agardh) Cleve	–	r	–	–	–	–	4	*		*			
<i>Melosira varians</i> Agardh	f	u	u	r	r	u	4	*			*		
<i>Meridion circulare</i> (Greville) Agardh	r	r	r	r	r	u	4	*		*			
<i>Navicula accomoda</i> Hustedt	r	–	–	–	r	r	4	*			*		
<i>N. bacillum</i> Ehrenberg	r	–	–	–	r	r	4	*	*				
<i>N. capitatoradiata</i> Germain	–	r	r	–	–	–	4	**					
<i>N. contenta</i> Grunow	r	r	r	r	r	u	4	**					
<i>N. cryptocephala</i> Kützing	u	u	c	u	r	c	3	*	*	*			*
<i>N. cryptotenella</i> Lange-Bertalot	–	r	–	u	r	r	4	**					
<i>N. cryptotenelloides</i> Lange-Bertalot	u	–	r	–	r	–	–	**					
<i>N. elginensis</i> var. <i>elginensis</i> (Gregory) Ralfs	–	r	–	r	r	r	4	**					
<i>N. goeppertiana</i> var. <i>goeppertiana</i> (Bleisch) H.L. Smith	r	–	–	–	r	r	4	**					
<i>N. mutica</i> var. <i>mutica</i> Kützing	–	r	r	r	r	r	3	*		*	*		*
<i>N. mutica</i> var. <i>ventricosa</i> (Kützing) Cleve et Grunow	–	–	–	–	–	r	3	**					
<i>N. paramutica</i> Bock	–	–	–	–	–	r	–	*				*	
<i>N. phyllepta</i> Kützing	–	r	–	–	–	–	–	**					
<i>N. phylleptosoma</i> Lange-Bertalot	–	f	u	–	–	–	–	**					
<i>N. pygmaea</i> Kützing	–	u	u	–	–	–	5	*		*	*	*	

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>N. radiosa</i> Kützing	r	r	r	r	r	r	3	*	*		*		
<i>N. salinarum</i> var. <i>salinarum</i> Grunow in Cleve et Grunow	r	c	r	–	–	r	3	*					*
<i>N. subhamulata</i> Hustedt	–	r	–	–	–	–	3	**					
<i>N. tripunctata</i> (O.F. Müller) Bory	c	r	u	u	r	u	4	*		*	*		
<i>N. viridula</i> var. <i>viridula</i> (Kützing) Ehrenberg	–	–	–	–	r	–	4	*	*				
<i>Nitzschia agnita</i> Hustedt	r	–	–	–	–	–	–	**					
<i>N. amphibia</i> f. <i>amphibia</i> Grunow	–	–	–	r	–	–	4	*		*	*		
<i>N. bicapitata</i> Cleve	–	–	–	–	–	r	–	**					
<i>N. closterium</i> (Ehrenberg) W. Smith	–	r	–	–	–	–	–	*			*		
<i>N. constricta</i> (Kützing) Ralfs	r	u	f	r	r	r	4	**					
<i>N. dissipata</i> var. <i>dissipata</i> (Kützing) Grunow	u	r	r	u	r	u	4	*		*	*		
<i>N. dissipata</i> var. <i>media</i> (Hantzsch) Grunow	–	–	–	–	–	r	4	**					
<i>N. dubia</i> W. Smith	r	–	r	–	–	–	3	*			*		
<i>N. frustulum</i> var. <i>frustulum</i> (Kützing) Grunow	r	r	–	–	r	–	4	*		*	*		
<i>N. heufleriana</i> Grunow	–	r	–	–	–	–	4	**					
<i>N. hamburgensis</i> Lang-Bertalot	–	–	–	–	–	r	3	**					
<i>N. inconspicua</i> Grunow	r	u	c	r	r	r	4	**					
<i>N. linearis</i> var. <i>tenuis</i> (W. Smith) Grunow	r	–	c	–	–	–	3	**					
<i>N. modesta</i> Hustedt in Brendemühl	r	r	r	–	r	r	–	**					

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Com-père 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>N. palea</i> (Kützing) W. Smith	r	–	r	r	c	c	3	*	*	*	*		
<i>N. perminuta</i> (Grunow) Peragallo	–	–	r	–	r	–	4	*		*			
<i>N. recta</i> Hantzsch	r	r	r	r	r	r	4	*			*		
<i>N. scalpelliformis</i> Grunow	–	r	r	r	–	r	–	*		*		*	
<i>N. sigma</i> (Kützing) W. Smith	r	r	r	r	r	r	4	*		*	*		
<i>N. sigmoidea</i> (Nitzsch) W. Smith	–	–	r	r	r	r	4	*	*	*	*		*
<i>N. sinuata</i> var. <i>tabellaria</i> (Grunow) Grunow	–	–	–	r	r	–	3	**					
<i>N. umbonata</i> (Ehrenberg) Lange-Bertalot	–	–	–	–	r	–	3	**					
<i>N. vermicularis</i> (Kützing) Hantzsch	r	r	r	–	r	r	4	*	*				
<i>Orthoseira roeseana</i> (Rabenhorst) O'Meara	–	r	r	–	r	r	–	**					
<i>Pinnularia borealis</i> var. <i>borealis</i> Ehrenberg	–	–	–	–	r	–	3	**					
<i>P. divergence</i> var. <i>divergence</i> W. Smith	–	–	–	–	r	–	3	**					
<i>P. divergence</i> var. <i>elliptica</i> (Grunow) Cleve	–	–	r	–	–	–	–	**					
<i>P. lagerstedtii</i> Cleve (Cleve-Euler)	–	–	–	–	–	r	3	**					
<i>P. microstauron</i> var. <i>brebissonii</i> (Kützing) Mayer	r	–	r	–	–	–	3	**					
<i>P. obscura</i> Krasske	–	–	–	–	–	r	3	**					
<i>P. schroederii</i> (Hustedt) Krammer	r	–	–	–	–	–	–	**					
<i>P. viridis</i> (Nitzsch) Ehrenberg	–	–	r	r	–	r	3	*		*			

Taxon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	pH iv	this study	Nejad-sattari 2005	Compère 1981	Mogah-dam 1976	Wasylik 1975	Hirano 1973
<i>Pleurosigma salinarum</i> Grunow	r	r	–	–	–	–	4	*		*			
<i>Pleurosira laevis f. polymorpha</i> (Kützing) Compère	r	r	–	–	–	–	5	**					
<i>Rhoicosphenia abbreviata</i> (Agardh) Lange-Bertalot	c	r	r	r	r	u	4	*	*	*	*		
<i>Rhopalodia acuminata</i> Krammer	r	r	–	–	–	–	–	**					
<i>R. gibba var. gibba</i> (Ehrenberg) O. Müller	–	–	–	r	–	–	5	*		*			
<i>R. rupestris</i> (W. Smith) Krammer	–	r	r	–	–	–	–	**					
<i>Stauroneis acuta var. acuta</i> W. Smith	–	–	r	–	–	r	4	**					
<i>S. anceps var. anceps</i> Ehrenberg	r	r	–	–	–	r	3	*	*	*		*	
<i>Stenopterobia curvula</i> (W. Smith) Krammer	–	r	r	–	–	–	2	**					
<i>Surirella amphioxys</i> W. Smith	–	–	r	r	–	–	4	**					
<i>S. angusta</i> Kützing	r	r	r	r	r	r	4	*		*	*		
<i>S. brebissonii var. brebissonii</i> Krammer et Lange-Bertalot	r	r	r	–	r	–	4	**					
<i>S. brebissonii var. kuetzingii</i> Krammer et Lange-Bertalot	–	–	r	–	–	–	4	*			*		
<i>S. brebissonii var. punctata</i> Krammer	r	–	–	–	–	–	–	**					
<i>S. minuta</i> Brébisson	r	r	r	r	r	r	4	**					
<i>S. ovalis</i> Brébisson	u	r	c	r	r	u	4	*		*	*		*
<i>Synedra gaillonii</i> (Bory) Ehrenberg	–	–	r	r	–	–	–	**					

Table 3. Relative abundance of diatom species present in this study calculated and summed up for the six sites in Ramsar (300 valves were calculated at each site).

Most abundant genera	Median (min, max) abundance	Most abundant species	Median (min, max) abundance
<i>Achnanthes</i>	17 (0.2–52)	<i>Achnanthes minutissima</i> var. <i>Jackii</i>	16 (0.0–51)
<i>Nitzschia</i>	11 (3.6–64)	<i>Navicula phylleptosoma</i>	0.0 (0.0–40)
<i>Navicula</i>	9.6 (1.1–65)	<i>Melosira varians</i>	1.9 (0.4–32)
<i>Cocconeis</i>	9.1 (0.3–28)	<i>Cocconeis placentula</i> var. <i>euglypta</i>	5.2 (0.2–12)
<i>Melosira</i>	1.9 (0.4–32)	<i>Nitzschia palea</i>	0.6 (0.0–17)
<i>Amphora</i>	5.1 (0.6–18)	<i>Nitzschia constricta</i>	0.0 (0.0–27)
<i>Craticula</i>	0.0 (0.0–19)	<i>Cocconeis pediculus</i>	0.8 (0.0–16)
<i>Diatoma</i>	0.9 (0.0–1.9)	<i>Amphora pediculus</i>	1.7 (0.4–11)
<i>Rhoicosphenia</i>	0.9 (0.2–11)	<i>Navicula salinarum</i> var. <i>salinarum</i>	0.3 (0.0–20)
<i>Surirella</i>	0.9 (0.1–11)	<i>Craticula buderi</i>	0.0 (0.0–19)
<i>Cymbella</i>	1.1 (0.0–10)	<i>Nitzschia inconspicua</i>	0.7 (0.2–17)
<i>Diploneis</i>	0.2 (0.0–5.4)	<i>Navicula cryptocephala</i>	2.5 (0.7–6.2)

which was followed by site 6 (83 taxa). The lowest diversities were found at sites 4 and 1 (66 and 73 taxa respectively). Thirty species were present at all sites, and among them *Nitzschia* and *Navicula* were the most diverse genera (five and four taxa respectively). *Achnanthes* and *Surirella* (three taxa) and *Amphora*, *Cocconeis*, *Cymbella*, *Diploneis*, *Fragilaria* and *Gomphonema* (two taxa) and *Melosira*, *Meridion* and *Rhoicosphenia* were present with only one taxon each (Tab. 2).

Distribution and occurrence of species

Of the 153 identified taxa in this study, seventeen taxa, *Amphora ovalis*, *Caloneis bacillum*, *Cocconeis placentula* var. *euglypta*, *Cyclotella meneghiniana*, *Cymatopleura elliptica* var. *elliptica*, *Cymatopleura solea* var. *solea*, *Cymbella helvetica*, *Fragilaria ulna* var. *ulna*, *Gomphonema angustatum*, *Gomphonema olivaceum* var. *olivaceum*, *Gomphonema parvulum*, *Navicula cryptocephala*, *Navicula mutica* var. *mutica*, *Navicula salinarum* var. *salinarum*, and *Nitzschia sigmoidea* were recorded at nine sampling sites in Iran by HIRANO (1973). Seven diatom species *Amphora commutata*, *Cymbella affinis*, *Haslea spicula*, *Navicula paramutica*, *Navicula pygmaea*, *Nitzschia scalpelliformis* and *Stauro-neis anceps* var. *anceps* were reported by WASYLIK (1975) from different areas of Iran.

MOGHADAM (1976) observed a total of 38 species from the Zayandeh Rud in central Iran. Certain of these taxa were also observed in the present study (*Amphora ovalis*, *Bacillaria paradoxa*, *Cocconeis placentula* var. *euglypta*, *Cyclotella meneghiniana*, *Diatoma vulgare* morphotype *vulgare*, *Fragilaria ulna* var. *acus*, *Fragilaria ulna* var. *ulna*, *Gomphonema olivaceum* var. *olivaceum*, *Gomphonema parvulum*, *Melosira varians*, *Navicula pygmaea*, *Nitzschia frustulum* var. *frustulum*, *Nitzschia palea*, *Nitzschia sigmoidea*, *Surirella angusta*).

COMPÈRE (1981) reported 43 taxa from 21 localities in the central and southeastern parts of Iran. The following taxa were also found in the present study: *Amphora ovalis*, *Cocconeis pediculus*, *Cyclotella meneghiniana*, *Cymbella helvetica*, *Diatoma vulgare morphotype vulgare*, *Fragilaria ulna* var. *acus*, *Fragilaria ulna* var. *ulna*, *Gomphonema angustatum*, *Gomphonema parvulum*, *Navicula pygmaea*, *Nitzschia frustulum* var. *frustulum*, *Nitzschia palea*, *Nitzschia sigmaidea*, *Stauroneis anceps* var. *anceps* and *Surirella angusta*.

Among diatom species presented in this study, 16 taxa (*Amphora ovalis*, *Cyclotella meneghiniana*, *Cymatopleura elliptica* var. *elliptica*, *Diatoma vulgare morphotype vulgare*, *Fragilaria ulna* var. *acus*, *Fragilaria ulna* var. *ulna*, *Gomphonema parvulum*, *Gyrosigma scalproides*, *Navicula bacillum*, *Navicula cryptocephala*, *Navicula viridula* var. *viridula*, *Nitzschia palea*, *Nitzschia sigmaidea*, *Nitzschia vermicularis*, *Rhoicosphenia abbreviate*, *Stauroneis anceps* var. *anceps*) were previously reported by NEJADSATTARI (2005) from Lake Neure in the Ardebil province of Eastern Azarbijan, Iran.

Ecology of the more commonly occurring taxa

The following ecological requirements are based on VAN DAM et al. (1994).

Achnanthes minutissima var. *jackii* (Rabenhorst) Lange-Bertalot 1980

Distribution: This taxon was the most abundant species at site 4 with 38.3%, site 5 with more than 50% and site 6 with 32% of population (Tab. 1).

Ecology: Circumneutral mainly occurring at pH values about 7, fresh – brackish, sometimes in oligosaprobic waters, with mid- to weak light electrolytic conditions.

Amphora pediculus (Kützing) Grunow 1880

Distribution: Highest percentage (11%) occurred at site 6, and was present with low numbers at other sites.

Ecology: Alcaliphilic, mainly occurring at pH >7, fresh – brackish, oxygen, fairly high (above 75% saturation), β -mesosaprobic, nitrogen – autotrophic taxon, tolerating elevated concentrations of organically bound nitrogen. Mainly occurring in water bodies, also rather regularly on wet and moist places.

Cocconeis pediculus Ehrenberg 1838

Distribution: Constitutes 10.4% of diatom population at site 1, but was second most abundant with 16.3 % at site 4, occurring at other sites with low numbers.

Ecology: Alcaliphilic, mainly occurring at pH >7, fresh – brackish, oxygen, moderate (above 50% saturation), β -mesosaprobic, nitrogen – autotrophic taxon, tolerating concentrations of organically bound nitrogen, hyper-eutrophic. Never, or only very rarely, occurring outside water bodies.

Cocconeis placentula var. *euglypta* (Ehrenberg 1854) Grunow 1884

Distribution: Occurring at all sites, highest numbers were found at sites 4 and 6, with 12% and 11% respectively.

Ecology: Alcaliphilic, mainly occurring at pH >7, fresh – brackish, salt intolerant to indifferent. Oxygen, moderate (above 50% saturation), β -mesosaprobous, nitrogen – autotrophic taxon, tolerating concentrations of organically bound nitrogen, hyper-eutraphentic. Occurring mainly in water bodies and sometimes on wet places.

Craticula buderi (Hustedt) Lange-Bertalot 2000

Distribution: With 19.3% of the population at site 5, this was the second dominant species, but was absent at other sites with the exception of site 1 with 1%.

Ecology: It is common in freshwaters with average to higher electrolyte content, e.g. chalk rich springs. Its tolerance to trophic and saprobity is very broad, ranging from weakly meso – to hypereutrophic, and from oligo- to α -mesosaprobic. It is also found in periodically wet habitats, e.g. moist meadows and in industrial effluent.

Melosira varians Agardh 1827

Distribution: Dominant species with 32.3% at site 1, occurring with small numbers at other sites.

Ecology: Alcaliphilic, mainly occurring at pH >7, optimum about 8.5. Fresh – brackish, oxygen, moderate (above 50% saturation), α -meso/ polysaprobous, facultatively nitrogen – heterotrophic taxon, needing periodically elevated concentrations of organically bound nitrogen, eutraphentic. Mainly occurring in water bodies, also rather regularly on wet and moist places.

Navicula cryptocephala Kützing 1844

Distribution: Occurring in low numbers at all sampling sites with highest numbers at site 6 (7%) and lowest at site 5 (less than 1%).

Ecology: Circumneutral mainly occurring at pH values about 7, fresh-brackish, oxygen, moderate (above 50% saturation), β -mesosaprobous, nitrogen – autotrophic taxon, tolerating elevated concentrations of organically bound nitrogen, oligo- to meso- to rarely and weakly eutraphentic, Mainly occurring in water bodies, sometimes on wet places.

Navicula phylleptosoma Lange-Bertalot in Lange-Bertalot et Genkal 1999

Distribution: Dominant species with 40% of total population at site 2, but was absent at other sites with the exception of site 3 (1%).

Ecology: Occurs at pH values of about 7, fresh-brackish, presumably cosmopolitan. Occurrence is not precisely known, scattered throughout Europe (LANGE-BERTALOT 2001); occurs in electrolyte rich freshwaters.

Navicula salinarum* var. *salinarum Grunow in Cleve et Grunow 1880

Distribution: This taxon was the second most abundant at site 2, but almost absent at other sites.

Ecology: Circumneutral mainly occurring at pH values about 7, found in fresh and brackish waters, prefers water of high mineral content, oxygen, fairly high (above 75% sat-

uration), β -mesosaprobous, nitrogen – autotrophic taxon, tolerating elevated concentrations of organically bound nitrogen, eutrathentic. Never, or only very rarely, occurring outside water bodies.

Nitzschia constricta (Kützing) Ralf in Pritchard 1861

Distribution: Dominant taxon at site 3 with 27.3%, but almost absent at other sites with the exception of site 2 which consist 2% of population.

Ecology: Alcaliphilic, mainly occurring at pH >7, cosmopolitan, found in brackish and freshwaters, oxygen, moderate (above 50% saturation), α -mesosaprobous, nitrogen – autotrophic taxon, tolerating elevated concentrations of organically bound nitrogen, hyper-eutrathentic. Occurring mainly in water bodies, sometimes on wet places.

Nitzschia inconspicua Grunow 1862

Distribution: Highest number was found at site 3 with 16.3 %, but occurred in very low numbers (less than 1%) at other sites.

Ecology: Alcaliphilic, mainly occurring at pH >7, cosmopolitan, found in brackish and freshwaters, oxygen, moderate (above 50% saturation), α - β -mesosaprobous, nitrogen – autotrophic taxon, tolerating elevated concentrations of organically bound nitrogen. Oligo – to eutrathentic (hyper-eutrathentic). In waters of mid- to high electrolytic conditions, can withstand osmotic fluctuations typical of sapro-littoral zones, tolerant of high organic loading. Mainly occurring in water bodies, also rather regularly on wet and moist places.

Nitzschia palea (Kützing) W.Smith 1856

Distribution: Occurring with 16.6% was second most dominant taxon at site 6 and with relatively high numbers at site 5 with 14%, but very low numbers at other sites (Tab. 1).

Ecology: Circumneutral mainly occurring at pH values about 7, fresh-brackish, oxygen, low (above 30% saturation), polysaprobous. Obligately nitrogen heterotrophic taxa, constantly needing elevated concentrations of organically bound nitrogen, hyper-eutrathentic. Mainly occurring in water bodies, also rather regularly on wet and moist places. *N. palea* typically has its greatest development in polluted waters. Tolerant of high level of organic waste and is sometimes found in association with industrial waste. Tolerant of a wide range of trophic and electrolytic conditions.

The epilithic diatoms of the Ramsar streams were diverse and dominated by taxa found in meso – to fairly eutrophic waters. The species abundance observed in this study was high. The result from this study suggests that as more studies are performed in the region along the coast of Caspian Sea, many more diatom taxa will be added to the list of Persian diatoms. It should be noted that the current study was based on a single day's sampling in a single year. This limited information does not allow any in-depth conclusion on the epilithic diatom community in Ramsar. In order to obtain a better estimation of diatom diversity, further studies need to be carried out in the region and promise to greatly increase this diversity.

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