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Research Article

Diatom community structure along physico-chemical gradients in Southern Caspian Sea (Noor shore)

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Abstract

Diatom species diversity and cell abundance are influenced by environmental factors. The effect of physico-chemical factors on interseasonal dynamics of planktonic diatom community structure was examined along Noor shore of Caspian Sea to determine which of the variables impact more on the diatom diversity, distribution and cell number. Overall, 144 samples were collected during four sampling campaigns along four transects of 2 km long each with three sampling sites in 2014 (February, May, July and November). In total, 62 diatom species were identified, of which 27 species were typical marine or brackish-water and the rest were marine-freshwater or freshwater. In the present study, diatom species diversity was highest in winter. As a result, Shannon-Wiener Index was 3.5 in winter, while in spring it was reduced to 0.8. Among the revealed species, the centric *Thalassiosira caspica* was the most abundant (up to 2.75×10^6 cells L^{-1}). Comparison of species and their abundances between coastal, middle and offshore stations, as well as all stations as a whole, showed that they differed (Test χ 2, p<0.05) except for *Navicula* sp. (in summer) and *Ulnaria ulna* (in autumn and winter). Canonical correspondence analysis results showed that in particular temperature and salinity, in the second place transparency, phosphates and to a lesser extent dissolved oxygen and pH can affect diatom species diversity and abundance. Diatoms *Thalassiosira fasciculata, T. caspica* and *Melosira caspica* may be recommended as biological indicators along the shore of Caspian Sea.

Keywords: Abundance, Bacillariophyceae, Caspian Sea, CCA analysis, Diatom diversity, Phytoplankton

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Introduction

The Caspian Sea has particular natural conditions, rich natural resources and an important geopolitical role in the surrounding regions (Kostianoy and Kosarev, 2005). More than 700 species and infraspecific taxa of algae have been recorded in the Caspian Sea (Guseynov *et al.*, 2015). Among them diatoms are the most diverse (Yablonskaya, 2007). They play a significant role world-wide, being responsible for primary production in the pelagic zone (Charles, 1985). Furthermore, diatoms are siliceous algae that are sensitive to chemical conditions (Mann, 1999); therefore they are frequently used as biological indicators to evaluate the water quality (Hall and Smol, 1992; De la Rey *et al.*, 2004; Ponmanickam *et al.*, 2007).

Same as other algae, diatom species diversity, cell abundance and biomass are influenced by environmental factors (Habib *et al.*, 1997; Naz and Türkmen, 2005; da Silva *et al.*, 2005). Temperature, light intensity, concentration of nutrients, phytoplankton population density, antagonistic relations with aquatic plants, climate and hydrological changes and site depth are variables that can affect diversity and distribution of phytoplankton communities, especially diatoms (Onyema, 2008).

Presently salt composition of Caspian Sea is a result of changes in the originally oceanic water influenced by continental flows that occurred up after separating the Caspian Sea from the World Ocean (Kostianoy and Kosarev, 2005). The effect of seasonal changes and small rivers that enter it are considered the main factors in determining pH in Southern Caspian Sea (Tuzhilkin and Kosarev, 2005). Furthermore, the river flow results in increasing phytoplankton diversity and decreasing water transparency (Bagheri *et al.*, 2012). Phytoplankton distribution, especially diatoms, is not uniform, primarily due to the water temperature. For example, in northern Caspian Sea, in winter when it is ice covered, the growth of most algae is halted. However, in middle and Southern parts of the sea, algal growth continues at different growth rates (Tuzhilkin and Kosarev, 2005). During winter, inorganic phosphorus is accumulated mainly within surface of the Caspian Sea due to increasing freshwater inflow and reduction in consumption. The temperature and photosynthesis increase, especially in summer, resulting in consumption of inorganic phosphorus (Nausch *et al.*, 2008).

Taking into account all these conditions presently occurring in the Caspian Sea, it is important to determine variables that cause diatom distribution. The aim of this study was to follow the annual dynamics of the planktonic diatom structure under the influence of physico-chemical factors on the Noor coast in Southern Caspian Sea.

Materials and methods

Four transects and 12 sampling sites were selected along Noor shore in Southern Caspian Sea (Fig. 1, Table 1).

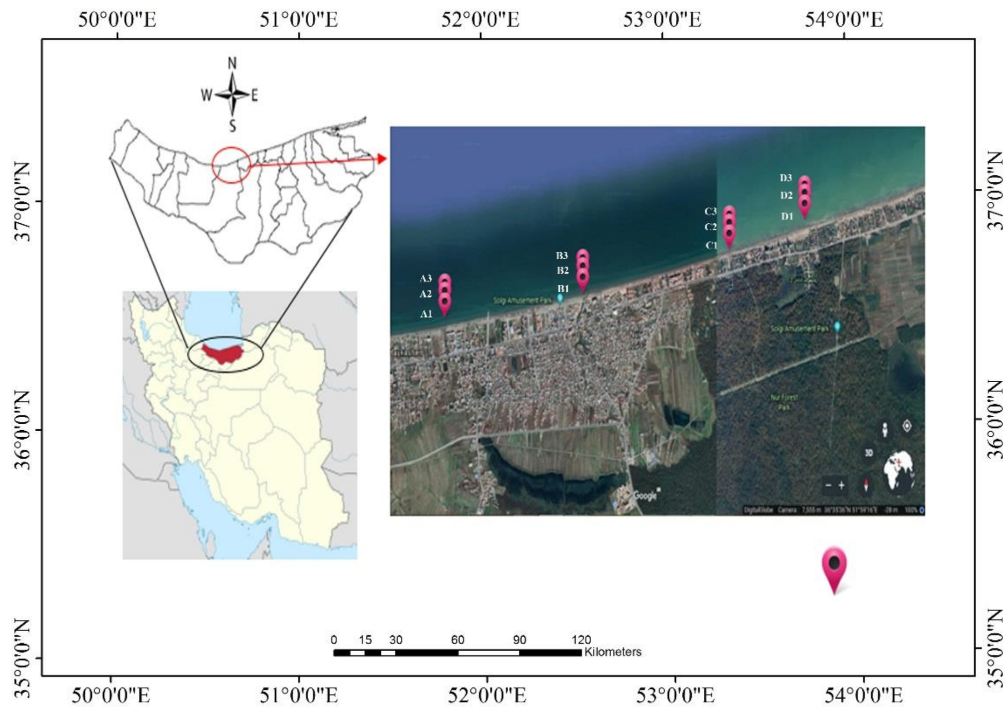

Figure 1: Phytoplankton sampling transects (A, B, C, D) each bearing three sites (1, 2, 3) at Noor, Southern Caspian Sea.

Table 1: Geographic coordinates and depths at the investigated sites in February, May, July and November 2014.

Transect		Site	Depth	Northern latitude	Eastern longitude
		A1	0.5	36°34’55	52°59’24
1	Sabze-rud River	A2	5.0	36°34’40	52°59’82
		A3	12.0	36°35’99	52°59’38
		B1	0.5	36°35’18	52°01’07
2	Noor River	B2	5.0	36°35’82	52°01’98
		B3	12.0	36°35’37	52°01’02
		C1	0.5	36°35’22	52°02’05
3	Tarbiat Modares University	C2	5.0	36°35’62	52°02’11
		C3	12.0	36°35’90	52°02’12
		D1	0.5	36°35’74	52°05’89
4	Lavij River	D2	5.0	36°35’95	52°05’72
		D3	12.0	36°36’21	52°05’08

The transects, which were nearly two kilometer in length, were placed at right angles to the coast and parallel to the Sabzehrood River (A), Noor River (B), Lavidjrood River (D), and Tarbiat Modares University (C). Sampling was carried out by a boat, seasonally from 2014 (May, July and November) to February 2015. Both qualitative and quantitative phytoplankton samples were taken with a plankton net (55 µm mesh size) and a Ruttner’s bathometer (2 liter in volume), respectively. Overall, 144 algal samples were collected. In order to study the affecting factors on diatom dynamics, some physico-chemical factors such as pH, temperature, transparency, oxygen saturation (O %), dissolved oxygen (DO), salinity, electrical conductivity (EC), phosphates were measured. Water transparency was estimated by a Secchi disk.

Phytoplankton samples were transported to the laboratory in dark cold containers as quickly as possible (Fathi and Flower, 2005). They were condensed by a settling method (Wasser *et al.*, 1989) and quantitatively analyzed with a Nikon-Eclipse E200 microscope in laboratory of the Marine Biology Department, Tarbiat Modares University, Iran. To identify diatom species, before microscopic analysis, the diatoms were processed for the purpose of deleting organic contents of the cell by cold methods using 30% sulfuric acid with potassium permanganate (Proshkina-Lavrenko 1974, Lange-Bertalot 2001). Furthermore, specialized taxonomic references were used (Proshkina-Lavrenko and Makarova 1968; Proshkina-Lavrenko, 1974; Krammer and Lange-Bertalot, 1991; Lange-Bertalot, 2001).

After sampling, chlorophyll-a was immediately measured. For extraction, acetone and citric acid were used and results were interpreted using a BioTek ELISA microplate reader (model 264852) at wavelengths of 630, 647, 664 nm (Lorenzen, 1967).

To analyze the diatom species diversity, Shannon-Wiener Index (SWI) was estimated using PRIMER 5.0 program. To determine differences among seasons and stations, SWI was applied with SPSS 20 program. Chi-square test ($\chi 2$) was used to compare species and cell abundances among stations and seasons. To determine the relationship between diatoms and environmental variables, canonical correspondence analysis (CCA) was applied using CANOCO 4.5 software (including ANOVA).

Results

Average values of physico-chemical factors during the study period are presented in Table 2. Moreover, chlorophyll-a concentrations were measured along transects during the investigated time (Fig. 2).

In total 62 species of diatoms belonging to 30 genera were recorded (Table 3). Among them, 27 species were typically marine or brackish-water and the rest (>50%) were brought by river runoff. Diatom species diversity varied with the seasons and sampling sites fluctuations. The maximum species diversity (41 species) was observed in winter, and the pennate *Nitzschia* sp. had the highest abundance (2.25×10^6 cells L^{-1}). The lowest diatom species diversity was recorded in spring (14 species); the centric *Thalassiosira caspica* was the most abundant at transect A (2.75×10^6 cells L^{-1}). In summer, among 20 recorded species, the centric *Chaetoceros muelleri* reached the maximum abundance (2.00×10^6 cells L^{-1}) at station A2. In autumn, 34 diatom species were found

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in all stations. *Thalassionema nitzschioides* (11×10^6 cells L^{-1}), *Nitzschia* sp. (5.25×10^6 cells L^{-1}), *Pseudosolenia calcar-avis* (6.75×10^6 cells L^{-1}) were the most numerous, especially at stations B1, C1 and D1.

Table 2: Mean values and ranges of physico-chemical factors in coastal water along Noor shore in Southern Caspian Sea over the studied period.

Season	S	Physical and chemical factor, Mean ± SD						
		pH	DO, mg L^{-1}	O%	Salinity, ‰	T, °C	EC	Ph
Winter	A	8.16±0.02	11.76±0.16	106.76 ±0.11	10.96±0.63	10.40±0.41	18.51±0.67	0.10±0.09
	B	8.19±0.03	10.56±0.78	97.66±4.87	10.97±0.99	10.90±0.17	14.43±1.84	0.12±0.01
	C	8.22±0.03	9.73±0.47	91.53±7.72	11.60±0.12	10.96±0.11	18.81±0.24	0.09±0.06
	D	8.30±0.02	9.15±0.22	83.93±1.40	11.00±1.07	11.10±0.49	17.46±1.50	0.10±0.02
Spring	A	8.46±0.22	7.50±0.26	91.90±4.06	11.23±0.80	24.60±0.25	18.37±0.2.	0.11±0.04
	B	8.65±0.04	7.53±0.20	91.06±1.92	11.10±0.18	25.40±0.10	18.51±0.51	0.10±0.01
	C	8.68±0.05	7.50±0.17	94.03±1.92	11.43±0.09	26.16±0.58	18.64±0.17	0.09±0.03
	D	8.66±0.03	7.56±0.15	92.60±1.35	11.20±0.09	25.40±0.25	18.35±0.25	0.09±0.02
Summer	A	8.38±0.09	4.56±0.87	57.50±11.4	11.60±0.01	27.90±0.63	18.94±0.03	0.46±0.24
	B	8.57±0.01	6.60±2.02	75.50±1.67	11.60±0.01	27.60±0.60	19.34±0.49	0.20±0.03
	C	8.67±0.03	5.50±0.30	71.90±3.58	11.84±0.33	28.30±0.17	2.64±1.48	0.19±0.12
	D	8.68±0.03	6.03±0.05	77.26±0.40	11.70±0.03	28.00±0.37	19.09±0.04	0.24±0.14
Autumn	A	8.60±0.24	13.04±0.80	107.93±1.18	11.27±0.05	14.70±0.55	18.36±0.13	0.20±0.14
	B	8.48±0.16	7.96±0.58	75.50±1.67	11.10±0.16	11.70±0.41	18.19±0.32	0.08±0.06
	C	8.66±0.06	12.44±2.14	107.16 ±2.01	11.14±0.16	14.70±0.15	18.05±0.37	0.09±0.03
	D	8.58±0.13	10.25±0.32	101.53 ±0.40	10.67±0.67	15.00±0.15	17.42±1.51	0.09±0.02

Notes: S, site; SD, standard deviation; DO, dissolved oxygen; O%, oxygen saturation; T, temperature; EC, electrical conductivity; Ph, phosphates.

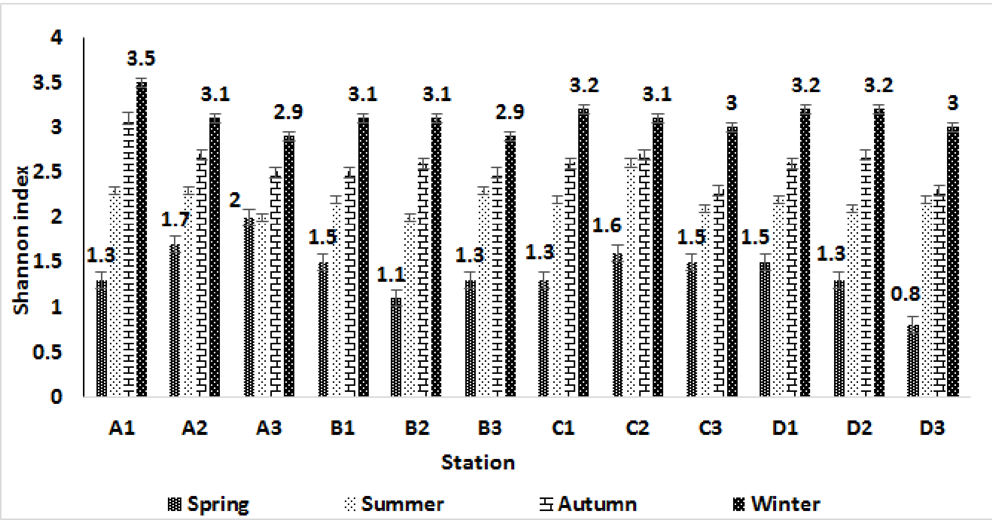

Figure 3: Variation of Shannon-Wiener Index applied to planktonic diatomic species diversity at different sampling stations (1 to 3) along transects (A to D) in different seasons.

Table 3: Planktonic diatom species composition in coastal waters along Noor shore in Southern Caspian over the studied period.

N	Taxa	Season			
		Sp	S	A	W
1	*Amphora ovalis* (Kützing) Kützing 1844	-	-	+	+
2	*Amphora* sp.	+	+	-	+
3	*Aulacoseira granulate* (Ehrenberg) Simonsen 1979	-	-	+	+
4	*Chaetoceros muelleri* Lemmermann 1898*	-	+	+	+
5	*Chaetoceros peruvianus* Brightwell 1856*	-	-	+	-
6	*Chaetoceros subtilis* Cleve 1896*	-	+	-	-
7	*Chaetoceros throndsenii* Marino, Montresor & Zingone 1991*	-	-	+	+
8	*Chaetoceros* sp	-	-	+	-
9	*Cocconeis placentula* Ehrenberg 1838	-	-	+	+
10	*Coscinodiscopsis jonesiana* (Greville) E. A. Sar & I. Sunesen in Sar, Sunesen & Hinz 2008 *	+	-	-	-
11	*Coscinodiscus gigas* Ehrenberg 1843*	-	-	-	+
12	*Coscinodiscus* sp. Gran & Angst 1931	-	-	+	-
13	*Cyclotella meneghiniana* Kützing 1844	-	+	+	+
14	*Cyclotella* sp.	-	-	+	-
15	*Cymbella* sp.	+	-	-	+
16	*Diatoma vulgaris* Bory de Saint-Vincent 1824	-	-	+	+
17	*Diploneis interrupta* (Kützing) Cleve 1894*	+	-	-	-
18	*Diploneis papula* (A. W. F. Schmidt) Cleve 1894*	-	+	-	-
19	*Diploneis smithii* (Brébisson) Cleve 1894*	-	-	+	+
20	*Epithemia turgida* (Ehrenberg) Kützing 1844	-	+	-	-
21	*Fragilaria capucina* Desmazières 1830	+	+	+	+
22	*Gyrosigma attenuatum* (Kützing) Rabenhorst 1853	-	+	+	+
23	*Gyrosigma* sp.	-	-	-	-
24	*Halamphora coffaeiformis* (C. Agardh) Mereschkowsky 1903	-	-	+	-
25	*Halamphora veneta* (Kützing) Levkov 2009	-	-	+	-
26	*Hantzschia* sp.	-	-	-	+
27	*Melosira juergensii* var. *caspica* A. Henckel*	-	-	-	+
28	*Melosira lineata* (Dillwyn) C. Agardh 1824*	-	+	-	-
29	*Melosira moniliformis* C. Agardh 1824*	-	-	+	-
30	*Melosira* sp.	-	-	-	+
31	*Melosira varians* C. Agardh 1827	-	-	+	+
32	*Navicula cincta* (Ehrenberg) Ralfs 1861*	-	-	+	+
33	*Navicula cryptocephal*a Kützing 1844*	+	+	+	-
34	*Navicula erifuga* Lange-Bertalot 1985*	-	-	-	+
35	*Navicula radiosa* Kützing 1844	-	-	-	+
36	*Navicula* sp.	+	-	+	-
37	*Nitzschia acicularis* (Kützing) W. Smith 1853*	-	-	-	+
38	*Nitzschia frustulum* (Kützing) Grunow 1880*	-	-	-	+
39	*Nitzschia longissima* (Brébisson) Ralfs 1861*	-	-	-	+
40	*Nitzschia palea* (Kützing) W. Smith 1856	-	-	-	+
41	*Nitzschia reversa* W. Smith 1853	-	-	+	+
42	*Pinnularia* sp.	-	-	+	-
43	*Planothidium vanheurckii* (Grunow in Van Heurck) E. W. Thomas, Van de Vijver & Kociolek 2015	-	-	-	+
44	*Pseudosolenia calcar-avis* (Schultze) B. G. Sundström 1986*	-	+	+	-
45	*Pseudo-nitzschia seriata* (Cleve) H. Peragallo 1899*	+	+	+	+
46	*Pseudo-nitzschia* sp.	+	+	+	+
47	*Rhizosolenia* sp.	-	+	+	+

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Table 3 (Continued):

N	Taxa	Season			
		Sp	S	A	W
48	*Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 1980	-	-	+	+
49	*Rhoicosphenia sp.*	-	-	+	+
50	*Skeletonema costatum* (Greville) Cleve 1873*	-	+	-	-
51	*Skeletonema subsalsum* (A. Cleve) Bethge 1928*	-	-	+	+
52	*Skeletonema* sp.	-	-	+	-
53	*Surirella ovalis* Brébisson 1838	-	-	-	+
54	*Synedra* sp.	+	+	-	+
55	*Tabularia fasciculata* (C. Agardh) D. M. Williams & Round 1985*	+	-	-	-
56	*Tabularia* sp.	-	+	-	+
57	*Thalassionema nitzschioides* (Grunow) Mereschkowsky 1902*	+	+	+	+
58	*Thalassionema* sp.	-	-	-	+
59	*Thalassiosira caspica* I. V. Makarova 1957*	+	+	+	+
60	*Thalassiosira coronifera* Proshkina-Lavrenko*	-	-	-	+
61	*Thalassiosira* sp. Cleve P. T. 1873	-	-	-	+
62	*Ulnaria ulna* (Nitzsch) Compère 2001*	+	+	+	+

* Marine species including not only typical marine species, but also species of brackish water ecotypes
Notes: Sp, spring; S, summer; A, autumn; W, winter

Shannon-Wiener Index (SWI) for different seasons reached a maximum value of 3.5 at station A1 in winter, whereas the minimum value was 0.8 at station D3 in spring (Fig. 3). Analysis of variance showed significant differences in SWI among seasons (p<0.05 ***, ANOVA, F=26.805). Mean SWI values for transects ranged between 1.2 and 3.2.

A comparison of species and their abundances among coastal, middle and offshore stations, as well as all stations as a whole, showed that they significantly differed (Test χ 2, p<0.05) except for *Navicula* sp. (in summer) and *Ulnaria ulna* (in autumn and winter).

Based on CCA results, the eigenvalue of axis 1 (0.23-0.44) explained from 21.6 to 30.3% and the eigenvalue of axis 2 (0.23-0.32) interpreted 41.4-51.4%, indicating a relationship between diatom abundance and water temperature, transparency, salinity, EC, oxygen saturation, DO, pH as well as phosphates in different seasons (Fig. 4). Interestingly, the indices of species-environment correlations of both axes were 100%. In spring *Tabularia fasciculata*, *Amphora* sp, and *Th. caspica* were positively correlation with DO at offshore stations. The abundance of *Pseudo-nitzschia seriata*, *Ulnaria ulna*, *Synedra* sp, *Diploneis interrupta*, and *Coscinodiscopsis jonesiana* were correlated with the water temperatures, which had a significant impact on their presence in the water column. The pH did not have a strong impact on the species abundance. Chlorophyll-a was correlated with *Navicula* sp., *N. cryptocephala* and *Thalassionema nitzschioides*.

In summer, *Rhizosolenia* sp. and *Tabularia* sp. were associated with salinity at middle stations. *Pseudo-nitzschia seriata* and *Melosira caspica* were correlated positively with oxygen

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saturation and DO. *Flagilaria capucina*, *Melosira lineata* and *Epithemia turgida* were principally responsible for chlorophyll-a at stations nearest to the coast. *Diploneis papula*, *Cyclotella meneghiniana*, *Skeletonema costatum*, *Thalassionema nitzschioides*, *Synedra* sp. and *Amphora* sp. were associated with phosphates at these coastal stations. *Gyrosigma attenuatum* was positively correlated with transparency. Temperature directly influenced *Chaetoceros muelleri* and *C. subtilis* at offshore stations.

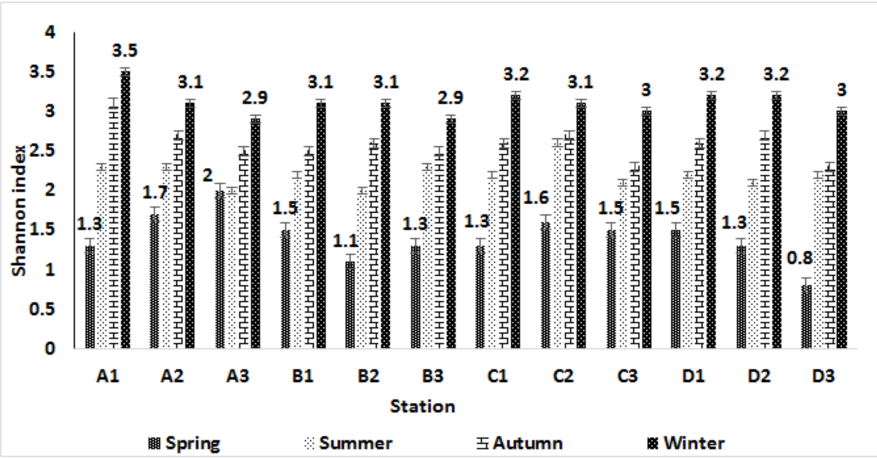

Figure 3: Variation of Shannon-Wiener Index applied to planktonic diatomic species diversity at different sampling stations (1 to 3) along transects (A to D) in different seasons.

In autumn, the correlation between diatom abundance and physico-chemical factors were not ascertained for many species. However, *Diatoma vulgaris* was positively related to phosphates; *Nitzschia reversa* was positively correlated with temperature; *Chaetoceros muelleri* was moderately associated with pH; and *Th. caspica* and *Gyrosigma attenuatum* were correlated with transparency. *Thalassionema nitzschioides*, *Pseudo-nitzschia* sp, *Coscinodiscus* sp., *Melosira moniliformis*, *Chaetoceros throndsenii*, *Chaetoceros* sp. were positively correlated with salinity. *Cyclotella* sp. and *Ulnaria ulna* were positively correlated with chlorophyll-a at coastal stations.

In winter, *Diatoma vulgaris* was positively correlated with oxygen. When temperature increased, the abundance of some species, for instance, *Aulacoseira granulata*, *Melosira caspica*, *M. varians*, *Chaetoceros throndsenii*, *Pseudo-nitzschia* sp., increased. Moreover, the abundance of *Coscinodiscus gigas*, *Cyclotella meneghiniana*, *Nitzschia reversa*, *Rhizosolenia* sp., *Rhoicosphenia abbreviata*, *Thalassionema* sp. and *Thalassiosira* sp. decreased when the salinity decreased. *Thalassiosira coronifera* and *Th. caspica* were positively correlated with transparency.

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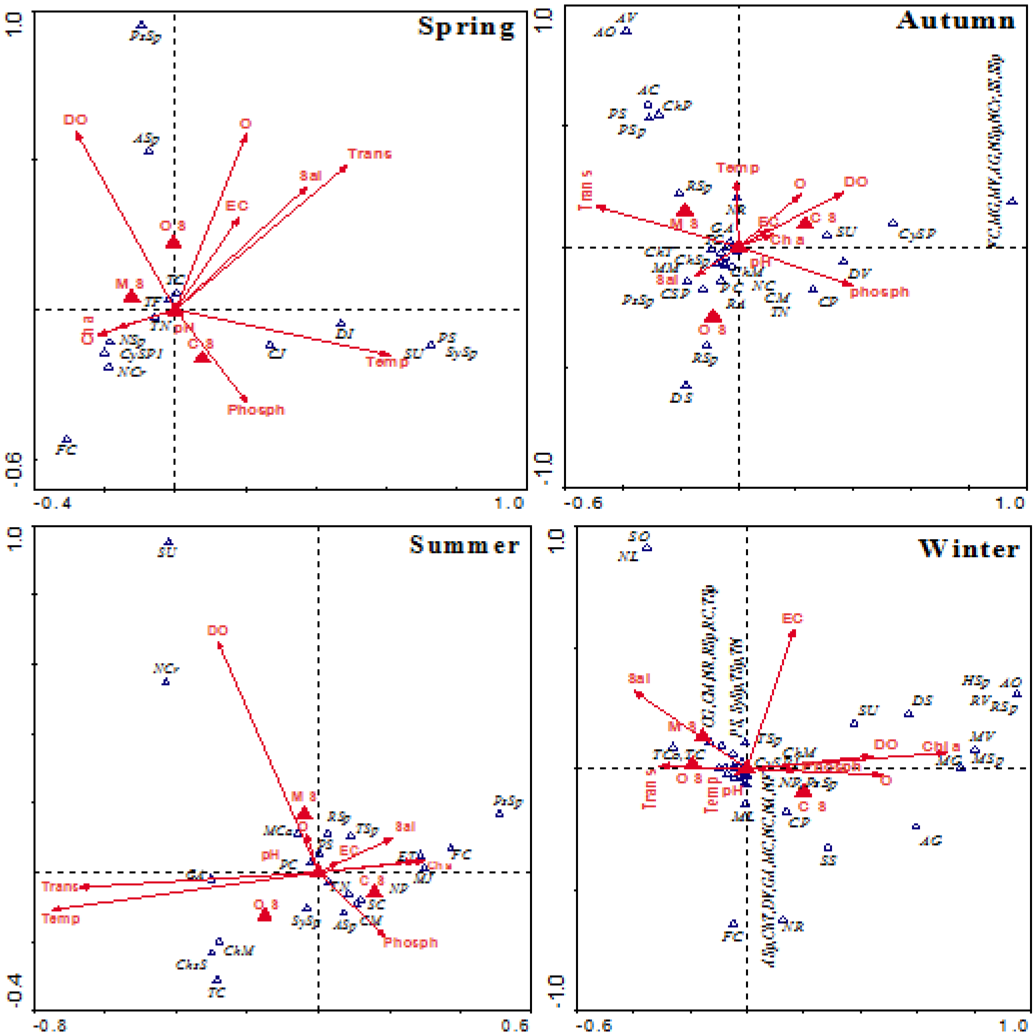

Figure 4: CCA biplot between planktonic diatom abundance and physico-chemical variables in four seasons at Noor in Southern Caspian Sea.

Notes: CS, coastal station; MS, middle station; OS, off-shore station; DO, dissolved oxygen; EC, electrical conductivity; O, oxygen saturation; Phosph, phosphates; Sal, salinity; Trans, transparency; Temp, temperature; *AO, Amphora ovalis; ASp, Amphora* sp.; *MG, Aulacoseira granulate*; *ChM, Chaetoceros muelleri*; *ChP, Ch. peruvianus*; *ChsS, Ch. subtilis*; *ChT, Ch. throndsenii*; *ChSp, Chaetoceros* sp.; *CP, Cocconeis placentula*; *CJ, Coscinodiscus jonesiana*; *CG, C. gigas*; *CSP, Coscinodiscus* sp.; *CM, Cyclotella meneghiniana*; *CySP, Cyclotella* sp.; *CySP1, Cymbella* sp.; *DV, Diatoma vulgaris*; *DI, Diploneis interrupta*; *DP, D. papula*; *DS, D. smithii*; *ET, Epithemia turgida*; *FC, Fragilaria capucina*; *GA, G. attenuatum*; *GSp, Gyrosigma* sp.; *AC, Halamphora coffeiformis*; *AV, H. veneta*; *HSp, Hantzschia* sp.; *MC, Melorira caspica; ML, M. lineata*; *MM, M. moniliformis*; *MSp, Melosira* sp.; *MV, M. varians*; *NC, Navicula cincta*; *NCr, N. cryptocephal*a; *NL, N. erifuga*; *NR, N. radiosa*; *NSp, Navicula* sp.; *NA, Nitzschia acicularis*; *NF, N. frustulum*; *NL, N. longissima*; *NP, N. palea*; *NR, N. reversa*; *PSp, Pinnularia* sp.; *PV, P. vanheurckii*; *PS, Pseudo-nitzschia seriata; PsSp, Pseudo-nitzschia* sp.; *RC, Rhizosolenia calcar-avis*; *RSp, Rhizosolenia* sp.; *RSp, Rhoicosphenia* sp.; *RA, R. abbreviata*; *SC, Skeletonema costatum*; *SS, S. subsalsum*; *SSp, Skeletonema* sp.; *SO, Surirella ovalis*; *SySp, Synedra* sp.; *TF, T. fasciculata*; *TSp, Tabularia* sp.; *TN, Th. nitzschioides*; *TSp, Thalassionema* sp. *TC, Th. caspica*; *TCo, Th. coronifera*; *TSp, Thalassiosira* sp.; *SU, Ulnaria ulna.*

Discussion

Study of the structure and function of phytoplankton communities in a marine ecosystem is important for understanding biogeochemical and ecological processes and for identifying common distributional patterns that might suggest underlying mechanisms controlling them (Goericke, 2011; McFarland, 2014). In total 306 planktonic diatom species belonging to 78 genera, 41 families and 22 orders have been recorded in the Caspian Sea (Karayeva and Jafarova, 2007; Karayeva and Bukhliyarova, 2010). During the present study, 62 diatom species were identified. Among them, *Th. caspica* had the highest abundance (2.75×10^6 cell L^{-1}) in spring, and the lowest diatom species diversity was observed at this time of the year. The decrease in diatom diversity and mass proliferation of a single species in the study area in spring may be related to river discharge, including human domestic, industrial and agricultural wastewater (Jamshidi and Bin Abu Bakar, 2011). In winter, diatom species diversity was highest. SWI varied between 0.8 and 3.5, suggesting an unstable diatom community structure during the year (Tahami *et al.*, 2012).

Interseasonal changes in water physico-chemical variables may affect the structure of phytoplankton communities (Liu *et al.*, 2010). The most important factor among them is temperature (Kideys *et al.*, 2005; Abrantes *et al.*, 2006). Salmanov (1987) and Resende *et al.* (2007) reported that seasonal changes in temperature are considered the main factor controlling phytoplankton species composition and structure. Algal distribution in the Caspian Sea is also dependent on temperature. Eurythermal algae such as *Fragilaria capucina*, *Pseudo-nitzschia seriata*, *Thalassionema nitzschioides*, *Thalassiosira caspica* and *Ulnaria ulna* live in Southern Caspian, and most diatoms living in Southern part of the sea are often found in the Middle Caspian (Karayeva and Makarova, 1973). When water temperature decreases to 8°C throughout Southern Caspian Sea, diatom diversity and cell abundance increase and vice versa (Salmanov, 1987). Their species diversity decreases when water temperature increases to 30°C (Bagheri *et al.*, 2012). The present results also showed that changes in temperature affected the species appearance and proliferation, especially those of *Chaetoceros muelleri*, *C. subtilis*, *C. throndsenii*, *Coscinodiscopsis jonesiana*, *Diatoma vulgaris*, *Diploneis interrupta*, *Gyrosigma attenuatum*, *Aulacoseira granulata*, *Melosira caspica*, *M. varians*, *Nitzschia cincta*, *N. acicularis*, *N. frustulum*, *N. palea*, *N. reversa*, *Pseudo-nitzschia seriata*, *Ulnaria ulna*, *Th. caspica*, and *T. coronifera.*

Salinity is also important. During the study period it ranged from 9.8 to 19.1. Salinity varied greatly between winter and summer (Khosropanah *et al.*, 2011) and with distance from the coast and also with depth (Guliyev *et al.*, 2014). In general aquatic organisms inhabiting Caspian Sea grow within four basic and

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three intermediate salinity zones, having specific salt composition at all barrier salinities (Plotnikov and Aladin, 2011). In the study zone, freshwater occupied areas were around the Sabzehrood River, Noor River and Lavidjrood River estuaries. Freshwater and brackish-water diatom species contributed more than half the total diatom species richness, being especially numerous in spring and summer. The number of brackish and marine species increased with distance from the shore and with increasing EC, and the freshwater ones, in contrast decreased. Overall, based on CCA marine species (*Thalassionema nitzschioides*, *Melosira moniliformis*, *Chaetoceros throndsenii* and *Coscinodiscus gigas*) were positively correlated with salinity and EC, while freshwater species (*Cyclotella meneghiniana*, *Nitzschia reversa*, *Rhoicosphenia abbreviata*) were negatively correlated with these variables. In particular, the salinity influence was found to be higher at middle stations of each transect where the river algae invaded brackish-marine waters and a significant decrease in phytoplankton growth can be observed (Lionard *et al.*, 2005).

Presence of oxygen in water allows aquatic organisms to live. Measurements of DO helps to estimate the health of water ecosystems and the amount of organic pollutants in water bodies (Xie *et al.*, 2003). Anthropogenic stress in Caspian Sea has resulted in decrease of Dissolved Oxygen (Kostianoy and Kosarev, 2005; Hadjizadeh Zaker, 2007). Furthermore, the lagoons and coastal areas in Southern Caspian Sea are constantly polluted by human activities (Kideys and Moghim, 2003; CEP, 2006; Kopelevich *et al.*, 2008). Therefore, reliable indicators are needed for rapid determination of water quality. The diatoms *Thalassiosira fasciculata, Th. caspica* and *Melosira caspica* may be recommended as biological indicators because they were positively correlated with DO in our study.

Among other species, it is notable that *G. attenuatum*, *Th. caspica*, and *Th. coronifera* are sensitive to transparency. In the Caspian Sea, transparency can decrease because of fluctuations in the water level and as a result of destruction of coastal soil, the inflow river drifts as well as significant growth of hydrobionts (Nasrollahzadeh Saravi and Hosseini, 2004**;** Plotnikov and Aladin, 2011; Salmanov *et al.*, 2015). Therefore, chlorophyll-a represents an unmeasured potential for influencing DO and also allows indirect assessment of ecological conditions in a water body (Miltner, 2010; Jamshidi and Bin Abu Bakar, 2011). In Caspian Sea mean chlorophyll-a content in the surface layer increased since 2003 (Jamalomidi, 2013). High chlorophyll-a values were observed in our study, especially at the coastal stations in autumn. In spring, chlorophyll-a was negatively correlated with water transparency. Study of chlorophyll-a distribution in some lakes showed a significant hyperbolic

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relationship between transparency and algal biomass (Canfield and Hodgson, 1983; Hosseini and Ordog, 1995).

To a greater extent this is due to increasing concentrations of nitrates and phosphates caused by discharge of untreated domestic sewage and pesticides from agricultural activities into rivers (Khosropanah *et al.*, 2011). It is known that some diatoms are not able to dominate when phosphorus is deficient, even if silicate and nitrate are in excess (Katiyar *et al.*, 2010). However, some of them can apply physiological and molecular strategies such as phosphorus scavenging or recycling as well as adjusting cell growth to adapt to limiting phosphorus concentrations (Brembu *et al.*, 2017). According to the conducted research, phosphates were responsible for growth of *Diatoma vulgaris*, *Diploneis papula*, *Cyclotella meneghiniana*, *Skeletonema costatum*, *Thalassionema nitzschioides*, *Synedra* sp. and *Amphora* sp. at coastal stations.

Thus the present study showed that temperature, salinity, transparency, phosphates, and to a lesser extent DO and pH, can affect planktonic diatom species diversity in the Southern Caspian. In some cases it was not possible to determine the relationships between species and physico-chemical factors. However, one thing is absolutely certain: ecological conditions of Caspian Sea along the Noor shore are unfavorable because of anthropogenic activities and need to be improved to preserve its unique aquatic species diversity.

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