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Seasonal and regional distribution of phytoplankton in the southern part of the Caspian Sea

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Abstract

In the present study, seasonal distribution of species composition, cell abundance and biomass of phytoplankton in the southern part of the Caspian Sea were investigated. This survey were fulfilled in 6 transects and 26 stations. A total of 260 samples were collected during winter to autumn in 2005. Totally, 163 species of phytoplankton were identified, including phyla Bacillariophyta (71 species), Chlorophyta (31 species), Cyanophyta (27 species), Pyrrophyta (21 species), and Euglenophyta (13 species). The overall total average of cell abundance and biomass of phytoplankton were 56.30± 30.97 ×10⁶cells/m³ and 221.70±75.87 mg/m³, respectively. Bacillariophyta accounted for 47% in cell abundance and Pyrrophyta consisted of 53% of the phytoplankton biomass. Maximum phytoplankton population was recorded in winter due to Bacillariophyta and the maximum biomass was recorded in spring due to Pyrrophyta. The maximum density of Bacillariophyta was in winter and autumn while maximum biomass was observed in spring due to larger size of Bacillariophyta such as Rhizosolenia calcar avis and Nitzschia sigmoidea followed by Pyrrophyta (Exuviaella cordata) with high cell abundance throughout the year.

Keywords: Phytoplankton, Seasonal distribution, Biomass, Cell abundance, Caspian Sea

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Introduction

Different groups of phytoplankton such as Bacillariophyta, Pyrrophyta, Chlorophyta, Cyanophyta and Euglenophyta determine the quality and quantity of the primary production in the aquatic systems. Caspian Sea has more brackish and freshwater phytoplankton species than marine (Exxon, 2001; Ganjian, 2007; Ganjian et al., 2008). For example, fresh and brackish water species dominate in north while euryhaline, marine brackish in the middle and southern Caspian (Exxon, 2001). Dinoflagellates (Pyrrophyta) typically prosper in stratified conditions as their motility enables them to exploit both the overlying euphotic zone and the underlying nutrient-rich waters (Carter et al., 2005). Diatoms inhabit cool waters. whereas other (e.g., phytoplankton dinoflagellates) inhabits tropical waters. The total number of the Caspian Sea phytoplankton species was recorded 449 consisting of 163 139 Chlorophytes, 102 diatoms. Cyanophytes, 39 Dinofagellates, Euglenophytes and 1 Chrysophyta during 1962-1974. The species diversity decreases from the north (414 species) to the middle (225 species) and south (71 species) mainly due to the disappearance of fresh water forms towards the south (Proshkina- Lavrenko, et al., 1968; Kosarev, et al., 1994). Diatoms and pyrrophyta have the important role in primary production in the Sea (Ghasemov and Bagharrov, 1983; Salmanov, 1987; Ganjian, et al.; 1998, 2003, 2004b, 2009a; Ganjian, 2007). Comparing diatoms to other phyla has shown that this group has the highest growth in the whole seasons and also has the most density and biomass

throughout the year. They spread out all of surface layer in the Caspian Sea as well as reach to maximum in autumn (Ghasemov and Bagharrov, 1983; Salmanof, 1987; Ganjian, et al., 1998, 2003, 2004a,b; Ganjian, 2007). According Salmanof, 1987; Bagherof Ghasemof, 1983 (for north and middel) and Ganjian et al., 2004b and 2009b (for south) the highest biomass Phytoplankton in the Caspian Sea included in diatoms and pyrophyta and the maximum abundance of Phytoplankton included in blue-green algae (Cyanophyta) in the each late of summer. There are a few studies available on phytoplankton in the Caspian Sea 1994). (Kosarev Yablonskaya, and with Recently, the invasion Mnemiopsis leidyi, phytoplankton species composition were flactuated (Roohi et al., 2008). Voracious feeding on zooplankton, (mainly copepods, cladocerans and meroplankton which are the major consumer of primary producers) by this ctenophore could lead to an abnormal increase in total phytoplankton quantity (Kideys and Moghim, 2003). However, at present, the Caspian Sea suffers from both natural, e.g., sea level changes and anthropogenic disturbances e.g. pollution, eutrophication and invasive species (Dumont, 1998). The impact of the accidentally introduced ctenophore Mnemiopsis leidyi (Ivanov et al., 2000) has been tremendous on the Caspian ecosystem causing sharp decreases in zooplankton levels, pelagic fish stocks and other higher components of the ecosystem (Shiganova et al., Kideys, 2002; Kideys et al., 2004). This study is therefore important for presenting data on phytoplankton of the Caspian Sea from recent years. Main objectives of this study were to identify phytoplankton taxa, and to determine the abundance, biomass and species composition of the main phytoplankton groups in the southern aprt of the Caspian Sea.

Materials and methods

Samples were collected at the west (Lisar-Anzaly), center (Sefidrod-Nooshar) and east (Babolsar-Amirabad) of the southern part of Caspian Sea (Fig. 1, Table 1). The sampling stations were established near shore. Sampling was performed seasonally, during winter 2005 to autumn 2006. This study was conducted along 6 transects with 4 stations at the depths of 5, 10, 20 and 50m (and 2 extra stations at 100 m in selected seasons). Two hundred and sixty Phytoplankton samples were collected from the depths of 5, 10, 20, 50 and 100m column waters (at 26 stations) from winter (January-February, N=60), spring (May, N=70), summer (July, N=70) and autumn (October-November, N=60) along the southern coast of the Caspian Sea with Van Dorn water bottle (Ruttner) (Vollenweider, 1974). Phytoplankton samples held in 0.5L bottles and preserved using buffered formaldehyde obtain final concentration of 4% (Sourina, 1978). Keeping the samples stagnant for at least 10 days then were concentrated to 30 ml by the sedimentation and centrifuge method (5 minute 3000 rpm), (HettichD7200, Tuttlingen: Germany). For micro and nanophytoplankton analyses, 0.1-ml subsamples were taken from the 30 ml sample and counted using a scanned slide (in two steps of quality and one step in quantity) under a phase contrast binocular microscope (covering slip 24×24 with magnification of 100x, 200x and 400x) (Kiselev, 1956; Vollenweider, 1974; Newell, 1977; Clesceri, et al., 1998). The volume of each cell was calculated by measuring morphometric characteristics (i.e., diameter, length and width) and geometric shape (Senichkina, 1986; Hillebrand et al., 1999; Robert 2000). Then, the volume values were converted to 1 m³ biomass. Phytoplankton were identified according to previous studies al., 1951; Morosova-(Zabelina, et Vodanidskaya, 1954: Kiselev. 1956: Prescott, 1962; Piroshkina et al., 1968; Habit and Pankow, 1976; Eker et al., 1999; Kasimov, 2000). Depth water was measured temperature with reversing thermometer and periodically checked with Multiparameter (Idornaut Ocean Seven 320) probe device (Clesceri, et al., 1998). Salinity as a main effective parameter in the Caspian Sea waters were measured with electrosolemer GM-65 M and also checked with Multiparameter **CTD** (Idornaut Ocean Seven 320) probe device at different depths. The existence of significant differences (P < 0.05) between sampling stations, transects and seasons was tested using a one-way analysis of variance (ANOVA).

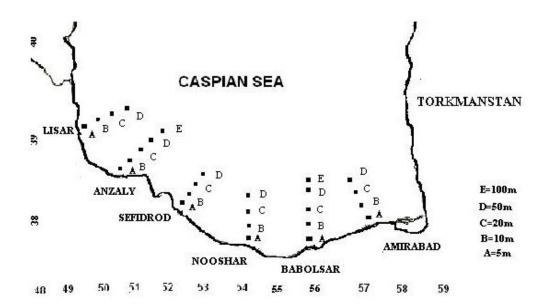


Figure 1: Map of the southern part of the Caspian Sea, showing the sampling sites

Table 1: Sampling transects and the location of stations in the southern part of the Caspian Sea

				Bottom		
Transect	Stations	N	Depths (m)	Depths	Longitude	Latitude
				(m)		
Lisar	Lis1	1	5	5	48.57.00	37.57.50
	lis2	2	5,10	10	48.58.00	37.57.5
	Lis3	3	5,10,20	20	49.05.00	37.57.5
	Lis4	4	5,10,20,50	50	49.12.30	37.57.20
Anzaly	Anz1	1	5	5	49.27.590	37.29.100
	Anz2	2	5,10	10	49.27.910	37.29.350
	Anz3	3	5,10,20	20	49.30.064	37.30.882
	Anz4	4	5,10,20,50	50	49.30.414	37.34.961
	Anz5	5	5,10,20,50.100	100	50.26.977	38.16.002
Sefidrod	Sef1	1	5	5	49.54.783	37.28920
	Sef2	2	5,10	10	48.54.956	37.29.379
	Sef3	3	5,10,20	20	49.55.20	37.30.45
	Sef4	4	5,10,20,50	50	49.54.800	37.31.370
Nooshar	N1	1	5	5	51.30.704	36.40.042
	N2	2	5,10	10	51.31.177	36.40.261
	N3	3	5,10,20	20	51.32.075	36.40.976
	N4	4	5,10,20,50	50	51.33.429	36.42.968
Babolsar	B1	1	5	5	52.38.787	36.43.298
	B2	2	5,10	10	52.38.646	36.43.641
	В3	3	5,10,20	20	52.38.638	36.45.172
	B4	4	5,10,20,50	50	52.36.882	36.48.127
	B5	5	5,10,20,50.100	100	52.35.987	37.25.110
Amirabad	Am1	1	5	5	53.22.699	36.52.357
	Am2	2	5,10	10	53.23.306	36.53.661
	Am3	3	5,10,20	20	53.20.129	36.57.176
	Am4	4	5,10,20,50	50	53.16.350	37.00.750

Prior testing, normality homoscedasticity of data were checked to comply with the assumptions of ANOVA (Zar, 1996). Subsequent significance between averages was delineated by Duncan's test. The relationship between abundance and biomass phytoplankton at different transects in the southern part of the Caspian Sea was investigated by means of Canonical Discriminate Functions Analysis (CDFA), using the SPSS version 10 package (Garcia-Berthou and Moreno-Amich 1993; Dytham, 1999).

Results

seasonal fluctuations of water temperature varied from 9.9°C (20m) to 29.0°C (5m). The highest and lowest temperatures were in summer and winter, respectively. The salinity values fluctuated between 9.1 and 12.6 (Table 2). A total of 163 phytoplankton species comprised which of 71 diatoms (Bacillariophyta; 43% of the total taxa), 31 Chlorophytes (19% of the total taxa), 27 Cyanophytes (17% of the total taxa), 21 Dinoflagellates (Pyrrophytes) (13% of the total taxa) and 13 Euglenophytes (8% of the total taxa) species were identified and quantified throughout the sampling period (Tables 3 to 5). A total of 77 phytoplankton's were recorded in winter (January-February), 91 in spring (May), 101 in summer (July) and 86 in autumn (October-November) (Table 3). In 2005, the predominant phytoplankton group was Bacillariophyta (diatoms) which observed in high number in summer (42 species) and autumn (41 species) while the lowest number of diatoms was observed in spring (32 species). The number of Pyrrophyta was observed more in spring (18 species) and summer (17 species). Also Cyanophyta were observed 17 species in summer, while Chlorophyta were more in spring (21 species). Euglenophyta were recorded more in spring and summer (9 species) (Table 3).

The overall average cell abundance and biomass total of phytoplankton were $(56.30 \pm$ 30.97) $\times 10^6$ cells/m³ and 221.70±75.87 mg/m³, respectively. The overall mean of cell abundance was belonging to 47% Bacillariophyta and overall mean biomass pertaining to 53% Pyrrophyta. The maximum cell abundance and biomass of the other groups were between 2 to 16% and 2 to 4%, respectively (Figs. 2a, b, 3). The maximum average abundance of phytoplankton in winter was due to Bacillariophyta, while the maximum average biomass in the spring was due to Pyrrophyta. The maximum average of biomass and cell abundance belonged to Bacillariophyta (26×10⁶ cells/ m³, 84.60 mg/m³) and Pyrrophyta (12×10⁶cells/m³, 116.89mg/m³) in 2005. The same situation (average of biomass and cell abundance) exhibited for other phyla of phytoplankton in four seasons (Tables 4 and 5).

The minimum biomass of Bacillariophyta was observed in autumn (51.84 mg/m³), but the maximum biomass was observed in spring (129.05 mg/m³). The biomass of Bacillariophyta showed no significant difference in different seasons. The minimum cell abundance of Bacillariophyta (9×10⁶ cell/m³) was in summer. The maximum cell abundance was observed (53×10⁶cells/m³) in winter. The cell abundance of Bacillariophyta in different seasons showed significant

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difference (p<0.007); N=108; (Tables 4, 5). The maximum and minimum average biomass and cell abundance Bacillariophyta was observed in middle and eastern parts, respectively (Figs. 4a, b).

The maximum biomass and cell abundance of Pyrrophyta were observed in spring $(238.30 \text{ mg/m}^3 \text{ and } 31 \times 10^6)$ cells/m³), while the minimum biomass and cell abundance observe in summer (62.07mg/m^3) and autumn $(4\times10^6 \text{cells/m}^3)$. The biomass and cell abundance of Pyrrophyta showed significant difference in spring (P<0.003, P<0.042, N=108, respectively (Tables 4, 5). The minimum and maximum average biomass of this phylum was observed in the eastern and middle area, while the minimum and maximum average of cell abundance were observed in the east and west, respectively (Figs. 4a, b).

Table 2: Seasonal fluctuation of temperature (°C) and salinity (‰) in the southern part of the Caspian

Transect	Stations	Depth	Water temperature °C				Salinity ⁰ / ₀₀			
		(m)	WI	SP	SU	AU	WI	SP	SU	AU
Lisar	Lis1	5	10.0	23.4	28.0	13.8	12.5	9.7	12.0	12.0
	lis2	10	10.0	20.3	26.0	13.7	10.7	11.6	12.1	12.1
	Lis3	20	9.9	18.7	25.1	13.7	12.3	10.1	12.4	12.4
	Lis4	50	10.9	15.8	21.3	14.2	12.6	11.4	12.4	12.4
Anzaly	Anz1	5	11.0	22.4	27.6	17.5	11.0	11.3	11.9	11.9
	Anz2	10	10.8	20.0	27.4	15.6	11.5	10.3	11.5	11,5
	Anz3	20	10.7	18.2	25.5	16.3	9.1	11.6	12.2	12.2
	Anz4	50	10.6	16.0	21.2	15.7	12.2	11.0	12.3	12.3
	Anz5	100	-	15.8	20.1	-	-	12.5	12.5	-
Sefidrod	Sef1	5	12.9	22.0	27.5	20.5	10.7	12.3	12.0	12.0
	Sef2	10	12.8	20.5	24.6	17.9	11.7	11.8	12.4	12.4
	Sef3	20	11.9	18.2	23.4	18.4	12.1	11.2	12.5	12.5
	Sef4	50	11.2	16.4	20.0	16.0	12.5	11.7	12.6	12.6
Nooshar	N1	5	11.8	23.0	27.8	24.2	11.9	11.1	10.8	10.8
	N2	10	11.8	20.4	27.6	23.9	12.5	11.6	11.6	11.6
	N3	20	11.6	17.5	27.6	19.8	11.5	12.4	12.1	12.1
	N4	50	11.7	15.8	24.1	20.6	12.4	12.1	11.8	11.8
Babolsar	B1	5	11.4	23.2	28.0	24.0	12.1	10.9	10.8	10.8
	B2	10	12.3	22.1	28.3	23.0	11.6	11.8	11.6	11.6
	В3	20	12.4	19.5	27.9	19.8	11.9	11.5	12.1	12.1
	B4	50	12.0	17.5	23.7	20.1	12.4	11.6	11.8	11.8
	B5	100	-	17.0	22.3	-	-	11.0	11.0	
Amirabad	Am1	5	13.0	25.7	29.0	20.8	11.6	10.5	10.8	10.8
	Am2	10	12.5	23.8	28.2	20.8	12.0	10.8	11.4	11.4
	Am3	20	11.7	18.8	27.8	20.9	12.4	11.2	12.6	12.6
	Am4	50	13.1	17.2	24.0	20.2	11.6	10.4	12.4	12.4

Note: Wi: Winter, Sp: Spring, Su: Summer, Au: Autumn

Table 3: List of seasonal distribution of phytoplankton species identified in the present study

Bacillariophyt	a	Wi	Sp	Su	Au	Bacillariophyta	Wi	Sp	Su	Au
Rhizosolenia Schultze	calcaravis	+	+	+	+	Fragilaria capucina Desmazière	-	-	+	-
Rhizosolenia f Bergon	ragilissima	+	+	+	+	Nitzschia acicularis	+	+	+	+
Thalassionema nitz	rsahiadas	+	+	+	+	Nitzschia tenirustris .	+	+	+	
Mereschkowsky	schioues	т	т-	-	т-	muzsema tentrustris .	т.		-	-
Thalassiosira	namia		+	+	+	Nitzschia tryblionella			+	
Ehrenberg	parva	-	+	+	+	Rakhmatulina.	-	-	+	-
Thalassiosira	hustdti	+	+	+	+	Nitzschia closterium			+	
Anissimova	пизии	т	т.		т.	Tritzsenia ciosierium	_	_	т	_
Thalassiosira	variabilis	_	+	+	+	Nitzchia thermalis				+
Makapoba	variabilis		т		т	witzenta inermatis				
Thalassiosira acule	eate	_	+	_	_	Nitzschia seriata H.	+	+	_	+
Proshkina-Lavrenk		_	т	_	_	Peragallo	-		_	т
Thalassiosira	caspica	+	_	_	_	Nitzschia reversa	+	_	+	_
Makapoba	cuspicu	'				Tritzsenia Teversa			'	
Thalassiosira sp		_	+	+	+	Nitzschia sigma	_	+	_	+
Tribonema vulgar		+	+	+	+	Nitzschia sigmoidea W. Smith	_	+	+	
Tribonema vaigar		т	т	т	т	iviizsenia sigmoiaea w. smiin	-		т	-
Cyclotella men Kützing	enghiniana	+	+	+	+	Nitzschia sp	+	+	+	+
Chaetoceros Brightwell	wighamii	-	-	-	+	Nitzschia sp1	-	-	+	-
Chaetoceros Lemmermann.	muelleri	+	+	+	+	Nitzschia sp2	+	+	+	-
Chaetoceros rigidu	is Ostenfeld	-	-	-	+	Nitzschia sp3	+	-	+	-
Chaetoceros subtil	is Cleve	-	+	+	+	Navicula cryptocephala Kützing.	-	-	-	+
Chaetoceros Ostenfeld	simplex	-	-	-	+	Navicula bombus Greg	+	-	-	+
Chaetoceros delic	atulus Van	-	-	-	+	Navicula sp	+	+	+	+
Chaetoceros sp		+	-	+	+	Navicula sp1	+	+	+	+
Cymbella tumidae	Cleve	+	-	+	+	Melosira moniliformis O.F. Müller.	-	-	+	-
Cymbella sp		+	+	+	+	Melosira varians C.A. Agardh	-	-	-	+
Cocconeis Ehrenberg	placentula	+	-	+	-	Melosira granulate Ralf.	-	-	+	-
Coconeis husteli I	Krasske.	-	-	+	-	Melosira juergensii C.A. Agardh.	-	-	+	-
Cocconeis	scutellum	-	-	+	-	Melosira sp	-	-	+	-
Ehrenberg										
Coconeis sp		+	-	+	-	Gyrosigma strigile Rakhmatulina.	+	-	-	-
Coscinodiscus Ehrenberg	perforatus	-	+	+	+	Gyrosigma attenuatum akhmatulina	+	+	-	+
Coscinodiscus	proximus	-	-	-	+	Gomphonema sp	+	-	-	-
Makar										
Coscinodiscus gra	nii Gough	-	-	-	+	stephonodiscus sp	-	-	-	+
Coscinodiscus Ehrenberg	gigas	+	+	+	+	Surirella aracta	+	-	-	-

Table 3: Continued

Bacillariophyta	Wi	Sp	Su	Au	Bacillariophyta	Wi	Sp	Su	Au
Actinocyclus parduxus	_	_	_	+	Synedra ulna	+	+	_	+
Makapoba.					Syncura una	•			
Amphora sp	+	+	_	_	Skletonema subsalsum	_	+	+	+
Imphora sp	•				Bethge		•	•	•
Diatoma ochki sp	+	_	_	_	Skeletonema costatum	+	+	+	+
Dianoma ochur sp	•				Greville	•	•	•	•
Diatoma bombus Cleve	+	_	_	_	Skeletonema costata Greville	_	_	_	+
Diatoma sp	+		_	_	Pleurosigma elongatum W.	_	+	+	+
Diatoma sp					Smith			•	
Diploneis interupta Kutz	+	+	+	+	Pleurosigma delicatulum W.	_	_	+	_
Dipioneis interupia Ruiz			·	•	Smith			•	
Dinobryon sp	_	+	_	_	Total	36	32	42	41

Pyrrophyta Enwigella condata Ostonfold	Wi	Sp	Su	Au	Pyrrophyta lantiquia	Wi	Sp	Su	Au
Exuviaella cordata Ostenfeld.	+	+	+	+	Glenodinium lenticula Schiller	+	+	+	-
Prorocentrum scutellum	,	_	+	.1	Schiller Glenodinium danticulum	_	,		
Prorocentrum scutettum Schröder	+	+	+	+	Paulsen	-	+	-	-
Prorocentrum praximum	+	+	+	+	Gymnodinium variabile	+	+	+	+
Makapoba.	1	1		T	Herdman	r		Γ	T
Prorocentrum obtusum	+	+	+	+	Goniaulax polyedra Stein	+	+	+	+
Ostenfeld	1	1		T	Somunian poryeura siem	r		Γ	-
Prorocentrum micans	+	+	+	+	Goniaulax digitale Kofoid.	+	+	+	+
Ehrenberg micans	•	•	•			•			•
Peridinium achromaticum	+	+	+	+	Goniaulax minima	_	+	+	+
Levander					Matzenauer				
Peridinium trochoideum	_	+	-	*	Goniaulax spinifera Diesing.	+	+	+	+
Lemmermann					1 0				
Peridinium subsalum	-	+	-	-	Gonyastomum depressum	+	+	+	-
Ostenfeld					Herdman				
Peridinium latum Paulsen.	+	+	+	+	Total	16	18	17	15
Peridinium sp	+	-	-	+					
Peridinium sp1	-	-	+	-					
Glenodinium behningii Kissel.	+	+	+	+					
Glenodinium penardii	+		+	-					
Lemmermann									
Chlorophyta	Wi	Sp	Su	Au	Chlorophyta	Wi	Sp	Su	Au
4 1 1 1									
Ankistrodesmus convolutes	+	+	-	+	Crucigenia quadrata Morren	-	+	+	-
Corda		,			C 1 + 11				
Ankistrodesmus falcatus Ralfs Ankistrodesmus arcuatus	-	+	-	-	Codotella sp	-	-	-	+
Ankistrodesmus arcuatus Korschikov	-	+	+	-	Scheroderia setigea Schröder	-	-	-	+
		,							
Ankistrodesmus sp	+	+	-	-	Selenstrum bibrajanum Reinsch	-	-	+	+
Binuclearia lauterbornii	_نـ	_د	+		Keinscn Scenedesmus quadricauda		+	+	+
Schmidle	+	+	+	+	Brebisson	-	+	+	+
schmale					DIEUISSON				

Table 3: Continued

Chlorophyta	Wi	Sp	Su	Au	Chlorophyta	Wi	Sp	Su	Au
Binuculeria sp	+	-	-	+	Scenedesmus denticulatus Lagerheim	-	-	-	-
Chlorella sp	+	+	+	+	Scendesmus abundans Kirchner	-	+	-	-
Clamydomonas monasovalis Shen	-	-	+	-	Scenedesmus acuminatus R. Chodat	-	+	+	+
Clamydomonas ovalis Shen	+	+	+	-	Selenstrum bibrajanum Reinsch	-	+	-	-
Clamydomonas olifanii Korsch	-	+	+	-	Oocystis nodulosa West	-	+	-	-
Clamydomonas globosa Snow	-	+	+	-	Oocystis solitaria Wittrock	+	-	+	+
Clamydomonas floscularia Korsch	-	-	+	-	Oocystis borgi Snow	+	+	-	-
Clamydomonas sp	+	+	+	+	Oocystis pulvevea G.S.West	-	+	-	-
Closterium spharicum Nägeli	-	-	+	-	Mougeotia sp	+	-	-	-
Closterium moniliferum Ehrenberg	+	+	-	-	Pediasreum tetras Ralfs	-	-	+	-
Crucigenia sp	-	+	-	-	Total	11	21	16	11
Cyanophyta	Wi	Sp	Su	Au	Cyanophyta	Wi	Sp	Su	Au
Anabaena spirodes Pankow	+	-	-	+	Spirulina laxissma West	+	+	+	+
Anabaena aphanizomenoides Ostenfeld	-	-	-	+	Spirulina subtilisima Kutzing	-	-	+	+
Anabaena bergii Ostenfeld	-	+	-	-	Spirulina sp	-	+	-	-
Anabaena reniformis Lemmermann	-	-	+	-	Merismopedia punctata Meyen	+	-	-	-
Anabaena kisselerii Proshki	-	-	+	-	Merismopedia mimima G.Beck	-	-	-	+

Table 3: Continued

Cyanophyta	Wi	Sp	Su	Au	Cyanophyta	Wi	Sp	Su	Au
Anabaenopsis arnoldii	-	-	+	+	Microcystis pulverea Wood	-	+	+	-
Miller									
Anabeanopsis rasiborskii	-	-	+	-	Microcystis aeruginosa	+	+	+	-
Woloszinska					Kuetzing				
Anabeanopsis nodsonii	-	-	+	-	Microcystis sp	-	-	+	-
Woronichim									
Aphenizominon ussaczevii	-	-	-	+	Nodularia harveyana		+	-	-
Proshkina-Lavrenko					Thuret				
Aphanotece sp	-	-	-	+	Lyngbya limneticula	+	+	+	+
					Lemmermann				
Aphanothece elabens Berb	-	-	+	+	Lyngbya birgei Agardh	-	+	-	-
Oscillatoria limosa Agardh	+	+	+	+	<i>Lyngbya</i> sp	+	+	+	+
Oscillatoria tennuis Agardh	-	-	+	-	Gloeocapsa minor Kutzin	-	-	+	-
Oscillatoria sp	+	+	+	+	Total	8	11	17	13
Euglenophyta	Wi	Sp	Su	Au	Euglenophyta	Wi	Sp	Su	Au
Euglena acus Ehrenberg	-	+	+	+	Tracholemonas similes	-	+	+	+
					Stokes				
Euglena viridis Ehrenberg	+	+	+	-	Trachelomonas planctoniea	-	+	-	-
					Swirenko				
Euglena tuba Philipose	-	-	+	-	Trachelomonas tambavica	-	+	+	+
					Stokes				
Euglena wangi Chu	-	+	+	-	Trachelomonas sp	+	+	+	+
Euglena sp	+	-	+	+	Trachelomonas sp1	+	-	-	-
Euglena sp1	+	-	-	-	Phacus sp	-	+	+	+
Trachelomonas spiculifera	+	+	-	-	Total	6	9	9	6
Schkorbatov									

Note: Wi: Winter, Sp: Spring, Su: Summer, Au: Autumn

Table 4: The cell abundance (cells×10⁶/m³) of phytoplankton groups in different seasons in the present study (means± SD)

Division	Winter	Spring	Summer	Autumn	Average
Bacillariophyta	53.84 ± 36.27 b	12.53 ± 8.83 ^a	9 .35± 5.86 ^a	29.99 ± 20.55^{ab}	26.43 ± 10.78
Pyrrophyta	9.56 ± 7.72^{a}	31.57 ± 33.31 b	5.39 ± 1.35 a	4.50 ± 3.91^{a}	12.75 ± 7.59
Cyanophyta	4.82 ± 4.08 a	3.88 ± 1.41^{a}	19.60 ± 18.18 a	8.70 ± 11.30^{a}	9.25 ± 7.47
Cholorophyta	10.59 ± 5.47^{b}	2.35 ± 1.22^{a}	11.17 ± 7.83^{b}	2.56 ± 2.41^{a}	6.67 ± 2.81
Euglenophyta	1.21 ± 1.47	0.24 ± 0.16^{a}	3.03 ± 6.80^{a}	0.38 ± 0.69^{a}	1.17 ± 2.05

Note= Values with different superscript letters within each row are significantly different (P < 0.05)

Table 5: The biomass (mg/m³) of phytoplankton groups in different seasons in the present (means± SD)

Division	Winter	Spring	Summer	Autumn	Average
Bacillariophyta	83.32 ± 54.06 a	129.05 ± 81.47^{a}	74.20 ± 60.55 a	51.84 ± 33.61^{a}	84.60 ± 25.34
Pyrrophyta	84.62 ± 34.79^{a}	238.30 ± 117.34^{b}	62.07 ± 28.37^{a}	83.58 ± 90.99 a	116.89 ± 33.34
Cyanophyta	8.21 ± 11.32^{a}	4.58 ± 6.25^{a}	5.53 ± 2.98 a	10.33 ± 11.99^{a}	7.16 ± 3.96
Cholorophyta	16.57 ± 32.17^{a}	1.72 ± 0.96^{a}	11.88 ± 6.25^{a}	1.04 ± 1.83^{a}	7.80 ± 8.44
Euglenophyta	9.33 ± 8.17^{a}	1.81 ± 2.17^{a}	6.44 ± 10.52^{a}	1.76 ± 0.50^{a}	5.25 ± 4.79

Note: Values with different superscript letters within each row are significantly different (P < 0.05)

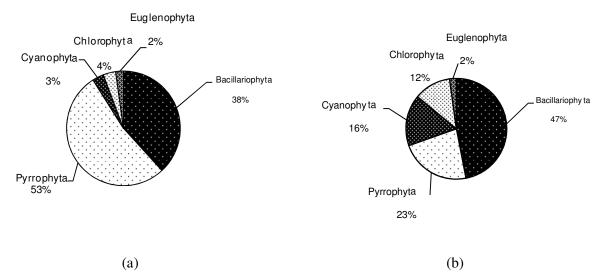


Figure 2: The mean percent of biomass (a) and cell abundance (b) of different phytoplankton groups in the present study

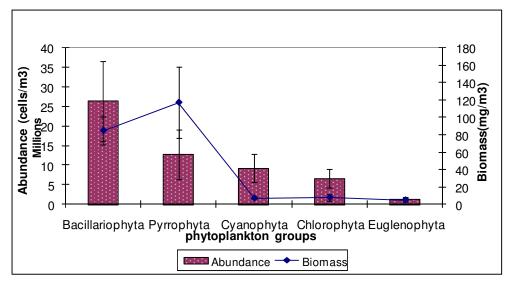


Figure 3: The annual distribution changes in the mean biomass (mg/m³) and cell abundance (cells/m³) of phytoplankton groups in the present study

As a comparison, the biomass of Cyanophyta phylum was less than two previous phyla. The minimum amount was in spring (4.58 mg/m³) but the maximum amount was in autumn (10.33 mg/m³). The minimum and maximum of cell abundance were observed in spring and summer (3×10⁶cells/m³ and 19 ×10⁶ cells/m³, respectively). The biomass and

cell abundance of Cyanophyta in different seasons did not show significant difference (Tables 4, 5). The minimum and maximum average biomass of this phylum was observed in the west and middle area, while the minimum and maximum averages of cell abundance were observed in the west and east, respectively (Figs. 4a, b).

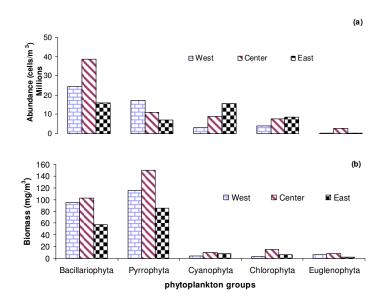


Figure 4: The regional distribution of different phytoplankton groups to the mean cell abundance (a) and biomass (b) in the southern part of Caspian Sea (in the present study)

The minimum and maximum biomass estimated in autumn and in winter were mg/m³ and 16.57 1.04 mg/m^3 , respectively. The cell abundance and biomass of this phylum were as low as those for the phylum Chlorophyta. The minimum maximum cell abundance were in autumn and summer that were $2 \times 10^6 \text{cells/m}^3$ and 11×10^6 cells/m³ respectively. The biomass in different seasons has no significant difference, while the cell abundance in different seasons showed a significant different (p<0.005) N=108 (Tables 4, 5). The minimum and maximum average biomass of Chlorophyta was observed in the west and middle area, while the minimum and maximum average of cell abundance observed in the west and east, respectively (Fig. 4a, b). As a comparison, this phylum of biomass was less than other phyla, the minimum and maximum

biomass were observed in autumn (1.76 mg/m^3) and in Winter (9.33 mg/m^3), respectively. The minimum and maximum cell abundance was in autumn and in summer, being 0.3×10^6 cells/m³, and 3×10^6 cells/m³, respectively. The biomass and cell abundance in Euglenophyta had no signification difference (Tables 4, 5). The minimum and maximum average biomass of Euglenophyta were observed in the east and middle area, while the minimum and maximum average of cell abundance were observed in the west and middle, respectively (Figs. 4a. Canonical discriminate function analysis based on the biomass of phytoplankton groups at different transects shown similarity of the scatter plots overlapping 2, 5, 6 transects were thick cluster due to Pyrrophyta include more than 50 %, while in 1 (Lisar) transect which was separated on the impacts of diatoms species.

Euglenophyta caused separation at transect 3 (Sefidrod) in addition of diatoms and Pyrrophyta species.

Chlorophyta had also the main phytoplankton role in transect 4 (Nooshar) in addition to the other groups (Fig. 6).

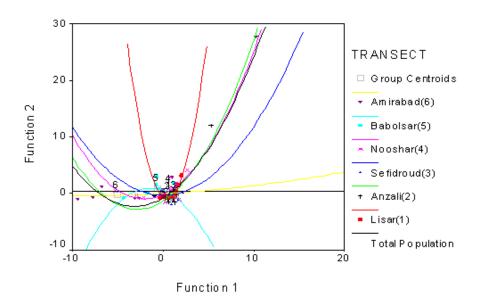


Figure 5: Canonical discriminate function analysis based on cell abundance of Phytoplankton groups at different transects in the southern part of the Caspian Sea

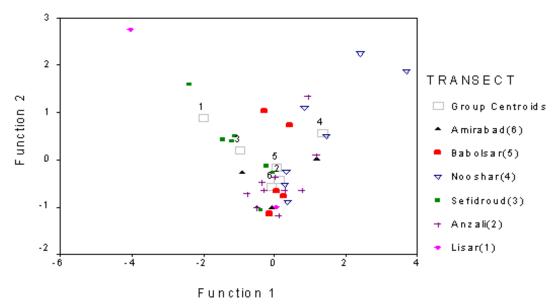


Figure 6: Canonical discriminate function analysis based on biomass of phytoplankton groups at different transects in the southern part of Caspian Sea, in the present study

Discussion

Seasonal distribution, cell abundance, biomass and species composition of Phytoplankton in northern part of the Caspian Sea are well known (Ghasemof and Bagherof, 1983; Salmanof, 1987). The main phytoplankton groups in the Caspian Sea are diatoms, Pyrrophyta and Cyanophyta (Ghasemof and Bagherov, 1983; Salmanof, 1987; Ganjian, et al., 1998; 2003; 2004a,b; 2009a, b; Ganjian, 2007). During this study, the main phytoplankton group was Bacillariophyta (diatoms) with more than 71 species and 43% of the total taxa. This group was more diversified in summer and autumn with 42 and 41 species, respectively. It seems that temperature has more effect on the growth of this phylum. The occurrence of phytoplankton in summer was more varied and diatoms, Pyrrophyta and Cyanophyta were more abundant in this season (Ghasemof and Bagherof, 1983; Salmanof, 1987; Ganjian, et al., 1998, 2003, 2004a,b, 2009a, b; Ganjian, 2007). Previously diatoms species were reported to be the most abundant and widespread group throughout the Caspian Sea (Kosarev and Yablonskaya, 1994). After diatoms, Chlorophytes and Cyanophytes are the most abundant groups in the north (since they are chiefly fresh and brackish water forms), while dinoflagellates are dominant in the middle (included eastern) and southern part of the Caspian Sea all year round terms of cell abundance (Kosarev and Yablonskaya, 1994; Ganjian et al., 2004b; 2009b Ganjian, 2007). In this study, the highest number of phytoplankton species was recorded in summer with 101 species in the southern part of the Caspian Sea. Bacillariophyta (diatoms), Pyrrophytes (dinoflagellates) and Cyanophytes were more abundant in summer. Chlorophytes and Pyrrophytes were more abundant in spring and may be the environmental conditions, during spring, are conducive for their growth. Only a small number of Euglenophytes recorded in this study and contributed less to the phytoplankton community structure in the Southern part of Caspian Sea. Ghasemof and Bagherof (1983) and Salmanof (1987) carried out some investigations in the middle and the southern part of the Caspian Sea. Based on these studies, diatoms and Pyrrophyta constitute two main phyla in the Caspian Sea, and also the survey of southern part of the Caspian Sea (Iranian coasts) were performed in 1994-1996 (Ganjian et al., 1998; 2003; 2004 a, b; 2009b; Ganjian, 2007), which revealed two phyla constitute the dominant groups phytoplankton. These surveys revealed that the highest cell abundance and biomass in the first rank belong to diatoms and the second rank is regarded to Pyrrophyta. Salmanof (1987) mentioned that the summer phytoplankton include in diatoms, Pyrrophyta and Cyanophyta. The main group of phytoplankton in the Caspian Sea contains diatoms dinoflagellates. The Blue-green algae (Cyanophyta) were increased in the late of summer. Carter et al. (2005) reported that maximum diatoms and Pyrrophyta biomass in Beatrix Bay appeared between 1994 and 2002. Diatoms dominated the phytoplankton biomass, with the exceptions being occasional Pyrrophyta blooms during summer months. In 2001 – 2003, the phytoplankton community in the Western Australian Ocean was characterized by a relatively low diversity taxonomical structures and predomination of heterotrophic Dinophyceae species during most part of the year (Floreat et al., 2005). Of the total 146 phytoplankton species, varieties and forms and the species composition were dominated bv diatoms and dinophlagellates (Floreat et al., 2005). The high increase in cyanobacteria abundance, from 35% of the population in June to values close to 100% as the summer progressed, suggests existence of strong relationship between cyanobacteria abundance and water temperature, as observed in the Blanes Bay (Agawin et al. 1998; Agawin et al., 2000; Hense and Beckmann, 2006). In the present study, canonical discriminate function analysis (CDFA) on abundance of members of the phylum Cyanophyta showed that cell abundance was higher in summer and in the Amirabad transect than to other phyla. It seems that the temperature has the most important role in this transect. The surface layer community structure at the fixed station changed from Cyanophyta typical summer bloom community to dominated by Euglenophyta, Bacillariophyta and Pyrrophyta were also abundant (Richadson et al., 2000; Izaguirre et al., 2001; Vahtera et al., 2005). The five years survey from 1960 to 1965, conducted by Salmanof (1987) and Kosarev and Yablonskaya (1994) showed that cell abundance of phytoplankton was higher in the middle and the southern parts of the Caspian Sea with the diatoms being the most predominant in the autumn. In comparison to the spring blooms, the autumn phytoplankton was rich of biomass and cell abundance. Ghasemove and Bagherov, (1983) showed that the diatoms reach to maximum in autumn season and can be observed throughout the year. In the survey carried out in the Iranian coast (1994-1996), Ganjian et al. (1998,2004b), the maximum cell abundance of Bacillariophyta was observed in autumn. In another survey (Ganjian, et al., 2003) in the southern part of the Caspian, the maximum cell abundance Bacillariophyta was observed in winter and autumn while, maximum biomass observed in summer. As a result of this study, the maximum cell abundance of Bacillariophyta was in winter and autumn and maximum biomass observed in the spring due to bigger size of diatoms Rhizosolenia spp and Nitzschia sigmoides followed by Pyrrophyta with cell abundance throughout year due to Exuviaella cordata and maximum biomass in spring due to Prorocentrum The cell abundance of spp. Bacillariophyta (Table 4) in different seasons showed significant difference After Bacillariophyta, (p<0.007). Pyrrophyta has maximum cell abundance throughout year and biomass was higher Bacillariophyta, it reaches maximum in spring season. The growth and blooms of this phylum observed in spring season. The biomass and cell abundance of Pyrrophyta (Tables 4, 5) showed significant difference in spring (P<0.05).

In a survey in 1994-1996 (Iranian coast), Ganjian et al. (1998, 2003, 2004a, b) indicated that the maximum density of Pyrrophyta were in spring, and Bacillariophyta, Pyrrophyta has highest

density throughout year. The abundance and biomass of Chlorophyta and Euglenophyta were decrease. The maximum cell abundance and biomass of Chlorophyta and Euglenophyta were in summer and winter, respectively. The cell abundance of Chlorophyta is higher than that for Euglenophyta but the biomass of Euglenophyta is higher than that in Chlorophyta due to their large-sized and high weight (Adame et al., 2008). In the Bacillariophyta regional survey of indicated that the maximum density and biomass were in central regions. Phyrrophyta phylum has the maximum biomass and density in west and center region, respectively. The maximum cell abundance and biomass of Cyanophyta and Chlorophyta were in east and center regions, respectively and Euglenophyta was in central region. It seems that the distribution of the phyla in different regions and also the increase of primary production in each phylum are related to vital factors and vital elements in any phylum in each region. The salinity usually does not vary much between the surface waters of the east and west of the southern part of the Caspian Sea ranging around 12.5–13.4 ppt during the course of the year (Kosarev and Yablonskaya, 1994). Kideys et al., (2005) also reported that salinity was similar between several regions being around at 12.5 Shiganova et al., (2003) studied the hydrochemical and biological characteristic of the north and central parts of the Southern Caspian Sea. They also reported that there was a small change of salinity between surface and lower column of the water (almost 2.6%). Vertical changes in salinity are also minimal (0.1–0.2 ppt). In the present study, the salinity between the surface waters of the four seasons was from 9.1 to 12.6 ppt.

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