The fluctuations of physicochemical factors and phytoplankton populations of Urmia Lake, Iran

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Abstract

Urmia Lake is one of the two large hypersaline lakes in the world which have *Artemia*. It is located in northwest of Iran. Due to a decrease in water inflow and volume, the salinity of Urmia Lake has reached to more than 300 $g.l^{-1}$ since 2001. The increased salinity has greatly influenced biological aspects of the lake, and caused the lake undergoes at critical conduction. The aim of the present study was to investigate the distribution fluctuations of phytoplanktons and selected physicochemical factors in relation to *Artemia* distribution in Urmia Lake during 8 months. Statistical analysis of mean values of ion concentrations and phytoplankton abundance indicated significant differences among sampling months. The minimum and maximum values for the selected factors were, as Cl^- 176.2-201.3 $g.l^{-1}$, CO_2 95-175$mg.l^{-1}$, dissolved oxygen (DO) 0.1-2.8 $mg.l^{-1}$, HCO_3^- 144-496 $mg.l^{-1}$, PO_4^{2+} 104-875 $mg.l^{-1}$, NO_3^- 330-4104 $mg.l^{-1}$, NO_2^- 4-21.5 $mg.l^{-1}$, SO_4^{2-} 10490-29840 $mg.l^{-1}$, Ca^{2+} 561-1606 $mg.l^{-1}$, Mg^{2+} 3649-14587 $mg.l^{-1}$ while water hardness was 21000- 62000 $mg.l^{-1}$. Fourteen phytoplankton genera included Bacillariophyceae (10 genera), Chlorophyceae (2 genera) and Cyanophyceae (2 genera) were identified during sampling period. The smallest average density of phytoplankton 97249 L^{-1} was observed in December 2005 and the greatest average density 481983 L^{-1} in August 2005. *Dunaliella* sp. composed 92.1% of the lake's phytoplankton. Statistical analysis of phytoplanktons fluctuations showed a significant difference among different months ($p< 0.05$).

Keywords: Urmia Lake, Physicochemical, Phytoplankton, Iran.

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Introduction

To understand water ecosystems, study of biological reactions are essential. This type of research can help to confront with crisis and to remedy the imposed impacts in order to have an effective management approach to water resources (Taghvaeipour, 2001). Urmia Lake is a thalasohaline lake and one of the most hypersaline one in the world (Abbaspour and Nazaridoust, 2007). This lake can be considered as one of the largest permanent hypersaline lakes in the world and resembles the Great Salt Lake in the western USA in many respects of morphology, chemistry and sediments (Kelts and Shahrabi, 1986). Urmia Lake is located at 37º, 30´ northern altitude and 45º, 30´ eastern longitude with a surface area of 4750 to 6100 Km² (Eimanifar and Mohebbi, 2007). This lake with 130- 150 Km length and 20- 50 Km width is located in 1280m above the sea level (Bagherzadeh Karimi and Ruhani Rankuhi, 2007). Urmia Lake uniqe creature named Artemia urmiana has a crucial dual role both in aquaculture and ecology. E.g. Hafezieh et al. (2010) suggested the positive effect of Artemia DHA ratio on growth and survival of Persian sturgeon. On other hand Urmia Lake′s Artemia cysts has a relatively thick shell which ensures its survival in unfavorable conditions such as high salinity and the cold season (Mehdizade Fanid, 2007). The salinity of the lake has risen from 175 to 340 ppt during last decade (Negarestan, 2001). The main water sources of the lake are precipitation and water inflows from 15 permanent and 7 seasonal rivers (Hafezieh, 2003). Geologically, Urmia Lake is a relatively large tectonical and super saturated lake Urmia formation age has been determined between 30-40 thousand years ego (Jabbarlooye Shabestari, 1995). Annual average precipitation in Urmia Lake basin is about 398mm and its average volume is about 20.7 billion cubic meters (Ahmadi, 2005). The lake's level fluctuated and created salinity changes which consequently influenced its living organisms in a simple food chain (like other hypersaline lakes).

Urmia Lake with its 101 islands has been introduced as a national park, as an international wetland in Ramsar Convention and as a conserved region of biosphere by UNESCO in 1977(Esmaeili, 2007). Salt extraction, remedy of some skin diseases, navigation, ecotourism and recently *Artemia* harvesting are the main benefits obtained from the lake (Bagerzadeh Karimi and Ruhani Rankuhi, 2007). One of the characteristics of an ecosystem is the number and nature of the species that occupy its various trophic levels (Mackenzie et al., 2001). Living organisms (especially *Artemia*) of the lake which are affected by abiotic factors are crucial from fisheries point of view. Therefore, these abiotic parameters and their interactions with living organisms had been investigated in the study. Since there are few data on chemical composition of Urmia Lake in the literature, some of these chemical parameters had been studied more extensively. The aim of the research was to investigate phytoplankton composition, abundance and fluctuation of some dissolved materials in different months of Urmia Lake.

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Materials and methods

Urmia Lake has been divided into north and south arms by a causeway project whichwas built on the lake (Eimanifar and Mohebbi, 2007). To facilitate water flow between the north and south part of the lake, there is a 1400m opening gap that is going to be covered by a bridge (Van Stappen et al., 2001). Four sampling sites (A, D, G and M) with geographical coordinates were selected for this study (Table 1). Sampling was performed monthly for 8 months (July 2005-February, 2006). A portion of the filtered water samples were used to measure phosphorous as orthophosphate (PO_4^{2+}, ascorbic acid method, detection limit 0.01mg.l-1) and nitrogen as nitrate (NO_3^--N, brosin sulfate method, detection limit 0.1 mgl-1), nitrite (NO_2^- - N, diazotization method, detection limit 0.001 mgl-1) (Clescert et al., 1989). Hardness, CO_2 and alkalinity were measured by titration (Grasshoff et al., 1983). Salinity was detected by Mohr (chloride detection) method and O_2 by Winkler method (Rand et al., 1976). Phytoplankton counts were made using 5-ml settling chambers with a Nikon TS100 inverted microscope by the Utermöhl method (Utermohl, 1958). All Phytoplankton and Physicochemical data were analyzed by one-way analysis of variance (ANOVA) followed by LSD test after performing homogeneity test by using SPSS software.

Table 1: Geographical locations of the sampling sites in the present study locations in Urmia Lake

Southern sites		Northern sites	
G	M	A	D
N: 37°, 36', 580"	N: 37°, 25', 903"	N: 38○, 03', 637"	N: 37°, 53', 850"
E: 45°, 15', 764	E: 45°, 37', 145"	E: 45°, 17', 758"	E: 45°, 09', 136"

Results

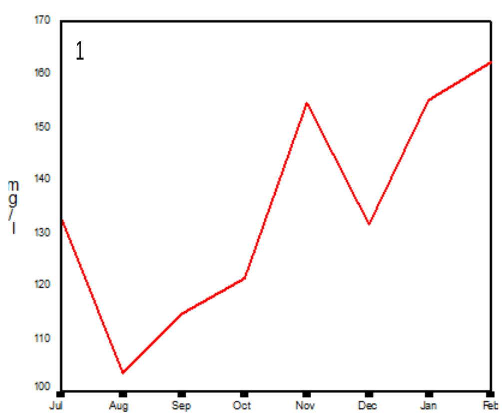
For abiotic parameters physical and chemicals were: water temperature, salinity, hardness, TDS, dissolved oxygen (DO), carbon dioxide, nitrite, nitrate, chloride, sulfate, phosphate, calcium and magnesium. As indicated in Table 2, the lowest water temperature was 0ºC which was, the recorded measured in February 2006 (site D) and the warmest water was 30.5 ºC in August 2005 (site G). The lake's salinity fluctuations during the study periods were indicated in Table 3. According to the Table 3 the lowest salinity (291 $g.l^{-1}$) was recorded in July 2005 and the highest (326 $g.l^{-1}$) was in October 2005 and February 2006. Statistical analysis showed that the salinity fluctuations among different months were significantly different ($p < 0.05$). Physical and chemical parameters were indicated for sampling sites (Tables 4 to 7). Also the figures showed that the maximum average dissolved oxygen (DO) and carbon dioxide concentrations of water were 2.8 $mg.l^{-1}$, 210 $mg.l^{-1}$ and minimum 0.1 $mg.l^{-1}$, 65 $mg.l^{-1}$, respectively (Figs. 1 , 2). The maximum and minimum average Ca^{2+} concentrations at site D were 1606 $mg.l^{-1}$ and 561 $mg.l^{-1}$ on December 2005 and September 2005, respectively (Fig. 3). Other parameter values were shown in Figs. 4 to 8.

Table 2: Urmia Lake water temperature (ºC) changes in sampling sites during the study period

Month	Sites			
	A	D	G	M
Jul.	25.7	26.7	27.9	28.2
Aug.	27.5	28.0	30.5	28.0
Sep.	25.0	22.5	26.5	25.5
Oct.	21.5	18.0	23.0	19.5
Nov.	13.5	14.0	14.5	13.0
Dec.	10.0	10.5	11.5	10.0
Jan.	3.5	3.5	5.0	4.0
Feb.	4.5	0.0	3.0	3.0

Table 3: Urmia Lake water salinity (gl-1) fluctuation in sampling sites during the study period

Month	**Sites**			
	A	**D**	**G**	**M**
Jul.	299	303	297	291
Aug.	301	303	306	306
Sep.	311	308	309	310
Oct.	318	326	313	315
Nov.	318	311	310	313
Dec.	323	315	314	316
Jan.	319	309	324	325
Feb.	306	292	326	319



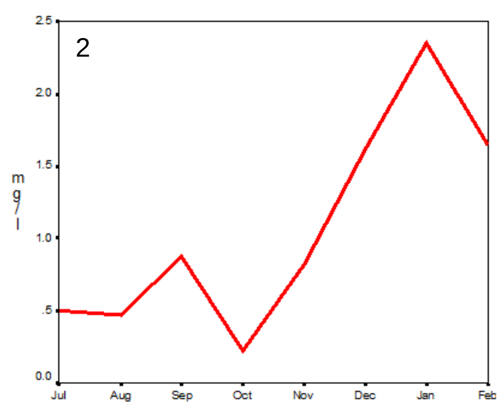


Figure 1: DO changes in Urmia Lake during the study period
Figure 2: CO_2 changes in Urmia Lake during the study period

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Table 4: Urmia Lake water chemical composition in sampling site (A) during the study period

Ion	Date							
	Jul. 2005	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 2006	Feb.
Cl^- (g/l)	193.6	199.4	200.2	190.9	179.7	181.9	180.5	---
CO_2 (mg/l)	125	120	110	135	152	128	165	---
HCO_3^- (mg/l)	158	230	280	320	320	370	460	---
DO (mg/l)	0.6	0.4	0.9	0.1	0.8	2.4	2.6	1.7
PO_4^{2+} (mg/l)	185	340	476	390	104	371	201	612.4
NO_3^- (mg/l)	512	330	1014	3121	723	5104	2310	750
NO_2^- (mg/l)	7.8	7.6	21.5	17.3	10	15.5	14.2	15.5
SO_4^{2-} (mq/l)	20120	29150	18680	18040	15890	11430	18370	---
Ca^{2+} (mg/l)	952	1002	1202	1202	801	1603	762	---
Mg^{2+} (mg/l)	5705	4862	4376	9482	11913	11184	12642	---
Hardness (mg/l)	24000	22500	21000	42000	44200	50000	53000	---

Table5: Urmia Lake water chemical composition in sampling site (D) during the study period

Ion	Date							
	Jul. 2005	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 2006	Feb.
Cl^- (g/l)	195.1	201.3	196.6	193	179.7	184.1	182	---
CO_2 (mg/l)	150	130	95	135	152	105	135	---
HCO_3^- (mg/l)	150	241	240	321	320	380	444	---
DO (mg/l)	0.7	0.6	0.8	0.2	0.8	0.9	2.8	1.2
PO_4^{2+} (mg/l)	184	679	544	173	104	205	221	129.2
NO_3^- (mg/l)	422	891	842	3125	723	3611	1105	376
NO_2^- (mg/l)	8.8	10.1	14.5	18.2	10	14.9	13	4
SO_4^{2-} (mq/l)	14010	24900	18190	22500	15890	18795	18300	---
Ca^{2+} (mg/l)	1202	801	561	1603	801	1606	801	---.
Mg^{2+} (mg/l)	6078	4376	5105	9481	11913	12642	13128	---.
Hardness (mg/l)	26000	20000	21000	41000	44200	59000	56000	---.

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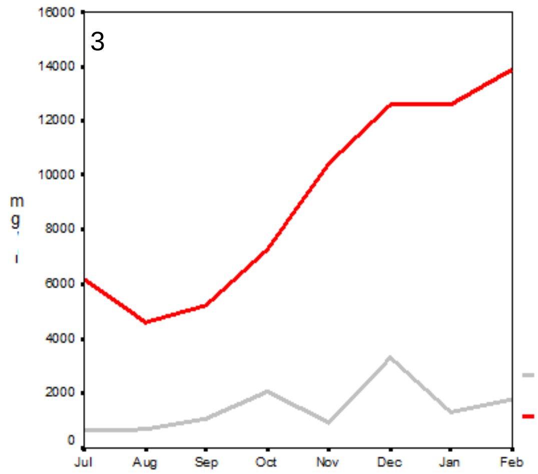
Table 6: Urmia Lake water chemical composition in sampling site (G) during the study period

Ion	Date							
	Jul. 2005	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 2006	Feb.
Cl^- (g/l)	185.1	197.7	198	198.4	183.3	183.3	179.8	176.2
CO_2 (mg/l)	152	125	130	110	175	173	160	170
HCO_3^- (mg/l)	144	180	220	330	340	370	430	490
DO (mg/l)	0.6	0.2	0.9	0.3	1.4	0.4	2.5	1.9
PO_4^{2+} (mg/l)	131	774	330	611	562.7	196	875	363
NO_3^- (mg/l)	871	481	1142	1005	1205	1454	660	1815
NO_2^- (mg/l)	11.5	6.1	14.8	13.4	10.5	14.5	6	19.5
SO_4^{2-} (mq/l)	18050	22320	29840	15530	10490	23030	15050	17910
Ca^{2+} (mg/l)	801	1202	902	1402	1683	1202	962	721
Mg^{2+} (mg/l)	5634.9	5592	6321	5228	13031	13858	12156	13177
Hardness (mg/l)	26000	26000	28000	35000	44200	60000	55000	56000

Table 7: Urmia Lake water chemical composition in sampling site (M) during the study period

İon	Date							
	Jul. 2005	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 2006	Feb.
Cl^- (g/l)	190.1	194.1	199.2	195.6	195.6	183.3	179.8	180.5
CO_2 (mg/l)	105	100	125	105	105	120	160	155
HCO_3^- (mg/l)	160	210	240	320	320	365	400	496
DO (mg/l)	0.1	0.7	0.9	0.3	0.3	2.8	1.5	1.8
PO_4^{2+} (mg/l)	191	408	408	272	272	354	354	375
NO_3^- (mg/l)	752	921	1252	1003	1003	4012	1105	1720
NO_2^- (mg/l)	10.1	19.5	14.1	18.2	18.2	9.5	9.1	15.5
SO_4^{2-} (mq/l)	13200	27900	12620	18440	18440	18430	18750	18260
Ca^{2+} (mg/l)	801	1202	801	1202	1202	1603	962	801
Mg^{2+} (mg/l)	7293.6	3649	5106	4984	4984	12642	12545	14587
Hardness (mg/l)	25000	28100	23000	32000	32000	5600	54000	62000



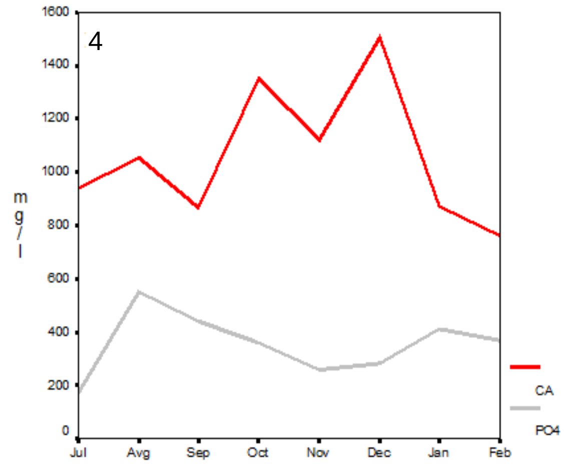
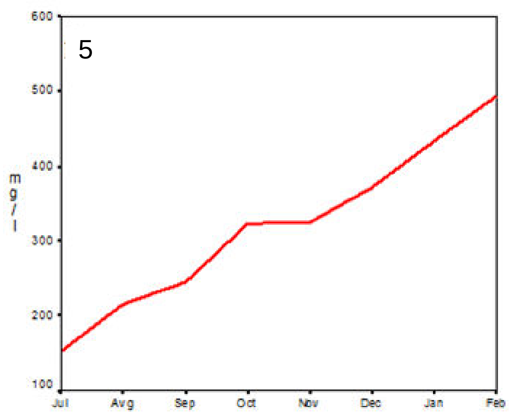


Figure 3: PO_4 and Ca^{2+} changes inUrmia Lake during the study period

Figure 4: NO_2^- and Mg^{2+} changes in Urmia Lake during the study period



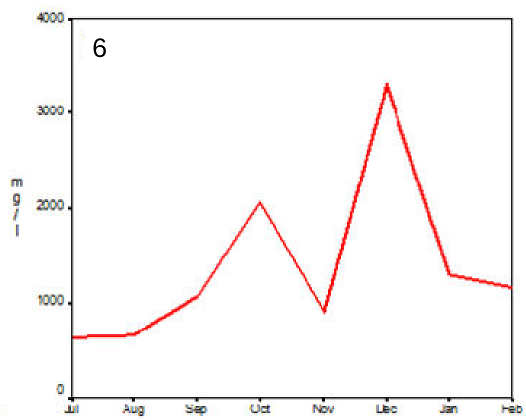
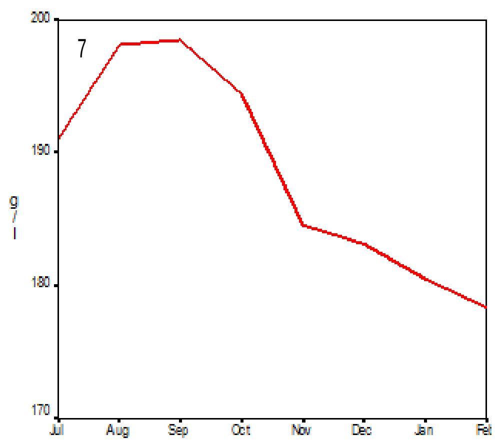


Figure 5: NO_3^{2-} changes in Urmia Lake during the study period

Figure 6: HCO_3^- changes in Urmia Lake during the study period



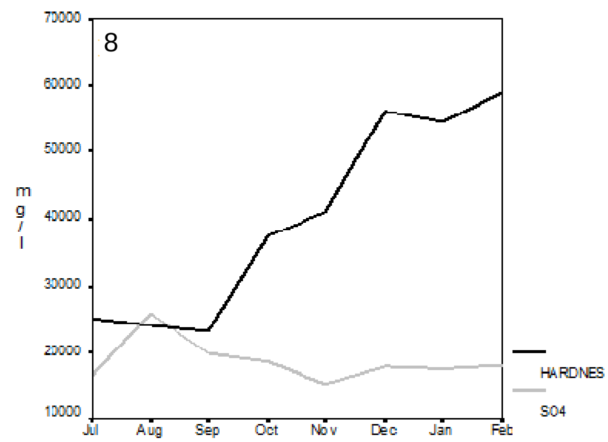


Figure 7: SO_4^{2-} and hardness changes in Urmia Lake during the study period

Figure 8: Cl^- changes in Urmia Lake during the study period

The most abundant microalgae identified in the lake were genera *Dunaliella* (92.1%), *Navicula* (2.4%), *Synedra* (1.9%) and *Nitzschia* (1.1%). The most commonly observed species of microalgae in the samples are depicted in Table 8. *Dunaliella sp.* was found throughout the lake. In general, 14 phytoplankton genera were identified among which 10 genera were belonged to Bascillariophytae (diatoms), 2 genera Chlorophyceae (green algae) and 2 genera Cyanophyceae (blue-green algae). During the study period, the percentage of *Dunaliella* sp. reached to 92.1 % of the planktonic microalgae populaton at the investigated sites (Fig. 9) which maximum and minimum densities of *Dunaliella* sp. were observed in December $0.08*10^6$ cell/l and August, 0.48×10^6 cell/l respectively (Fig. 10). After *Dunaliella*, the maximum and minimum density of diatoms like *Navicula* were 23963 cell/l on Feb. and 0 cell/l on Aug. and *Synedra* were 12283 cell/l on Feb. and 0 cell/l on Aug. composed an important fraction of the lake's phytoplankton populations. The highest phytoplankton densities surpassed 0.48×10^6 cell/l on August 2005 and lowest was 0.1×10^6 cell/l on December 2005. Analysis of phytoplankton data fluctuations by one-way analysis of variance (ANOVA) indicated significant differences ($p< 0.05$) among different months.

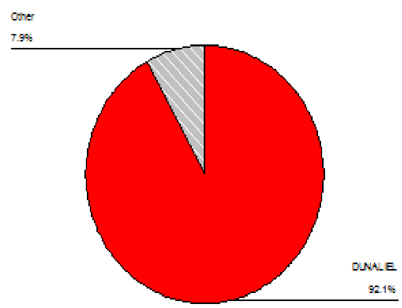


Figure 9: The percentage of *Dunaliella* sp. and other phytoplankton

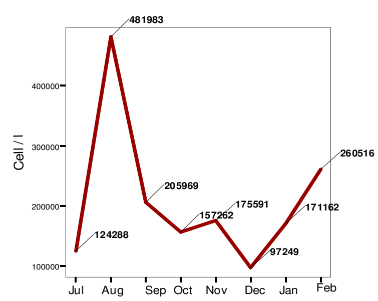


Figure 10: The phytoplankton population fluctuation during the study period

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Discussion

Urmia Lake has a relatively simple food chain which has made the lake's ecosystem so sensitive (Abbaspour & Nazaridoust, 2007). Most abiotic parameters impact directly and indirectly the living organisms particularly phytoplankton and *Artemia* populations. Analysis of the lake's water temperature fluctuations indicated four distinct seasons in this ecosystem. The water temperature was measured from 21ºC to 30ºC in the summer, 10ºC to 20ºC in the autumn and 0ºC to 10.5ºC in the winter season (Table 2). The average temperature of surface layers of Urmia Lake water was reported 27.2º C, 9.1º C and 5.2º C in the summer, autumn and winter 2001, respectively (Pourasghar, 2004). These factors in our study (2005- 2006) were 26ºC, 14.6ºC and 5.6 ºC, respectively (Table 2). Urmia Lake is a hypersaline lake with highly salty water. The high salinity of the lake water may originate in early stages of its formation or the chemical weathering and erosion of the lake's watershed rocks (Ghazban et al., 1998). The salinity of Urmia Lake was increased from July to February due to increased evaporation in the summer and autumn seasons. Then with increased precipitation in the late autumn and early winter, the salinity was decreased. However the lake's water salinity was at the saturated level (> 300 gl^{-1}) during the entire study period. This is due to decreased water inflow into the lake and consequently lower water levels in Urmia Lake in the last decade. The salinity of Urmia Lake was measured previously, about 240 ppt in the year of 2000, 260 ppt in 2001 and 300 ppt in 2005 (Personal observations). The salinity was adversely related to the phytoplankton and *Artemia* densities. Although it has been reported in the literature that *Artemia* thrives in salinities between 60 to 220 $g.l^{-1}$ (Camargo et al., 2005). Artemia can live up to a water salinity of 260 $g.l^{-1}$ but tolerance of *A. urmiana* salinities can extends more than 300 $g.l^{-1}$(Negarestan et al., 2004). However, in these salinities *Artemia* population in Urmia Lake indicated a significant shortage and its breeding were weakened dramatically. Ionic compositions of Urmia Lake water have been reported by several authors (e.g., Azari Takami, 1987; Sorgeloos, 1997; Jabbarlooye Shabestari, 1995; Alipour, 2006). Some of them depicted in Table 9. Phytoplankton need about 20 elements for growth, but only C, N and P are likely to limit growth rates on any general basis (Moss, 1998). Analysis of Urmia Lake CO_2 concentration indicated that it was reached to a minimum level in the summer while algal population goes up (Figs. 2 , 10). Oxygen has been found to be a critical factor for the resumption of development while temperature is the second critical factor for hatching (Vallejo et al., 1980). Furthermore, dissolved oxygen (DO) level in the summer was less than winter which was related to increasing *Artemia* biomass in summer (Ahmadi, 2005). The hardness of natural water depends mainly on the presence of dissolved calcium and magnesium salts, therefore hardness may vary widely (Ramachandra et al., 2005). In the streams the percentages of SO_4^{2-} and Cl^- were almost equal to that in the precipitation. Ca^{2+}, Mg^{2+} were often 2 to 3 times higher

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in the stream than in the precipitation, showing how the watershed can modify the ionic concentration and proportions of rain before it enters the lake or river (Bacca and_Threlkeld, 2000). The average concentrations of Ca^{2+}, SO_4^{2-}, Mg^{2+}, Cl^- and TDS in the northern part of the Great Salt Lake for a 30-year period were 0.2-0.5, 6-20, 3-10, 45-100 and 90-270 $g.l^{-1}$, respectively (Gwynn, 2002). The maximum concentration of these ions in the Great Salt Lake was 25- 30% less than Urmia Lake which obtained in the present study. The difference in Ca^{2+} concentration between the two lakes was up to 4 times and in TDS more than 1.5 times (Table 9). The table showed that in our study these ions concentrations increased in Urmia Lake in 2005- 2006 compared to 1993 (Azari Takami, 1987). This may be related to the doubling of the lake's salinity in 2005-2006. On the other hand, in a relatively recent study average concentrations of Mg^{2+} and Ca^{2+} in Urmia Lake was reported to be 4.8 $g.l^{-1}$and 4.5 $g.l^{-1}$, respectively (Alipour, 2006), which varied from these two ions concentrations obtained in the present study (8.8 $g.l^{-1}$ and 1.1 $g.l^{-1}$), respectively. Samadi Idenloo (1995) reported a value of 432000µm EC for Urmia Lake which was higher than the value reported by Azari Takami (1987) and lower than the present study (433000-588000) (Table 6). The lake's EC changes may be influenced by the water salinity fluctuations. Hypersaline environments can be classified into three categories according to their anionic composition which are chlorated, sulphated and carbonated water (Cole and Brown, 1967). They studied the anions in Artemia habitats and classified the lakes based on the chloride (the majority), sulfate and carbonate. Most lakes have one dominant anion (greater than 80%), however, a few lakes have two dominant anions. Due to its high chloride concentration, Urmia Lake has been classified based on chloreide. The brine shrimp *Artemia*, is a typical inhabitant of hypersaline lakes and ponds, which are characterized by communities with low species diversity and simple trophic structures, leading to an under estimation of the diversity in physical and chemical characteristics of *Artemia* habitats. High chloride lakes are very suitable for *Artemia* thriving (Cole and Brown, 1967) and it is probably the reason that Urmia Lake's *Artemia* has been able to survive in such saturated water. Most studies on chemical parameters of Urmia Lake are based on a few randomly selected samples; therefore, these results can not be used to provide an integrated scheme for seasonal and annual fluctuations of parameters in the lake (Eimanifar and Mohebbi, 2007). However,in the present study we tried to influence the composition and density of algal and brine shrimp communities. The macroscopic green alga *Enteromorpha intestinalis* which was quite common throughout Urmia Lake in the past decades (Saberi, 1978) has disappeared completely during the late 1980's. Diatoms, common marine algae are also nearly ubiquitous inhabitants of hypersaline environments, but they never appear to dominate (Javor, 1989). Some species of diatoms were strongly euryhaline: *Amphora*, *Navicula* and *Nitzschia* (Melack, et al., 1999). The best known halotolerant or halophilic eukaryotic algae are species of genus

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Dunaliella (Javor, 1989). *Dunaliella* was found in the highest salinity range, i.e., 99 to 145 ppt (Melack, et al., 1999). On the other hand, various authors have reported relatively different phytoplankton populations from disparate sampling sites of the lake. For example, Ryahi, et al. (1994) observed 12 algal genera belong to Cyanophytae, Chlorophytae and Bascillariophytae. Shoa Hasani (1996) reported 6 algal genera, while Mohebbi et al. (2006) reported 16 phytoplankton genera belong to Cyanophytae,

Table 8: Urmia Lake phytoplankton identified in different years

Genus	Family	1992	1995	2005
Dunaiella	Chlorophyceae	+	+	+
Navicula	Bacillariophyceae	+	+	+
Nitzschia	Bacillariophyceae	+	+	+
Synedra	Bacillariophyceae	-	-	+
Closterium	Chlorophyceae	-	-	+
Diatoma	Bacillariophyceae	-	-	+
Oscilatoria	Cyanophyceae	+	+	+
Symbella	Bacillariophyceae	-	+	+
Cymatopluera	Bacillariophyceae	-	-	+
Gyrosygma	Bacillariophyceae	-	-	+
Cyclotella	Cyanophyceae	-	+	+
Anabaena	Bacillariophyceae	+	-	+
Surirella	Bacillariophyceae	-	-	-
Anacystis	Bacillariophyceae	+	-	+
Amphora	Bacillariophyceae	+	-	-
Synechococus	Bacillariophyceae	+	-	-
Lyngbya	Bacillariophyceae	+	-	-
Chroococcus	Bacillariophyceae	+	-	-
Monostroma	Bacillariophyceae	+	-	-
Ankistrodesmus	Chlorophyceae	+	-	-
Pandorina	Bacillariophyceae	+	-	-

Table 9: Some chemical parameters of Urmia Lake recorded by other authors

Ion	Unit	Azari Takami (1987)	Sorgeloos (1997)	Sorgeloos (1997) Sea water	present study (2005-2006)
Ca^{2+}	mg/l	200-640	553	400	561-1606
Mg^{2+}	mg/l	2496-2668	3580	1350	3649-14587
Cl^{-}	mg/l	93820-125315	77578	19000	176200-201300
SO_4^{2-}	mg/l	588-884	6964	--	10490-29840
HCO_3^{-}	mg/l	244-451	317	--	144-496
EC	mikromus	234000-300000	-	--	433000-588000
Hardness	mg/l	23000-28400	-	--	21000-62000
Salinity	ppt	152-168	130	32	300>

Chlorophytae and Bascillariophytae during monthly sampling over an entire year. These variations may be related to limited and irregular sampling or increased salinity of the lake during recent years that has eliminated some non-

[DOR: 20.1001.1.15622916.2010.9.3.1.7]

tolerant species. More studies are clearly Quantitative analysis of algal density indicated that algal production in Urmia Lake is lower than its sister Great Salt Lake (Gliwicz et al*.,* 1995). *Dunaliella* is the dominant phytoplankton of Urmia Lake. The chlorophyceae include about 560 genera and 8600 species. About 90% of these are freshwater and the remaining are marine (Bilgram and Saha Hasani, 2002). In most habitats they function as the primary producers in the food chain. Besides, forming the basic food, source for these food chains, they also form the oxygen necessary for the metabolism of the consumed organisms (Sambamurty, 2005). The growth and multiplication of phytoplankton is primarily dependent on temperature, solar illumination and the availability of certain essential nutrients such as nitrates, phosphates (Pillai, 1986).

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