The Algae of Urmia Lake (Northwest Iran): a Brief Review

Fereidun Mohebbi[1]*, Masoud Seidgar[1]

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Abstract

This study tries to review the algal assemblage of Urmia Lake in different environmental circumstances. There was an inconsistency about the phytoplankton of Urmia Lake in references. For example, *Enteromorpha intestinalis* a macroscopic green alga was already reported from the lake and permanently vanished in the 1990s. On the other hand, various researchers have reported different algae from different sampling sites. These variations are related to limited and irregular samplings or increased salinity during recent years, which has eliminated some intolerant species. *Dunaliella* salt-tolerant green alga is responsible for more than 90% of primary production in hypersaline environments. This two-flagellate unicellular alga, in Urmia Lake, composed 92.1% and 99.6% of algal population density in high-stand and low-stand periods, respectively. In drought conditions, eight species of algae were observed in Urmia Lake. Chlorophyll as an indicator of primary production was lower in Urmia Lake than in the sister Great Salt Lake. So, it can be categorized as an oligotroph lake from this point of view. This study showed the significance of an algal herbarium on the national or regional scale to record and preserve algae species that may be vanished someday from the ecosystems.

Keywords: *Dunaliella*, Urmia Lake, Phytoplankton, Chlorophyll a, Hypersaline

Background

Urmia Lake hosts diverse bacterial communities, hyperhalophilous phytoplanktons, the macrozooplankton crustacean, and the brine shrimp *Artemia urmiana.* Thus, about its ecological significance, unique biodiversity, and indigenous communities, Urmia Lake has been recognized as a Protected area since 1967 and was designated as a National Park in 1976 as one of 59 biosphere reserves by UNESCO (Eimanifar and Mohebbi, 2007). In 1975, it was also registered in the Ramsar Convention on Wetlands as a wetland of international importance (Djoined, 1970).

The world has been witnessing the violent withdrawal of Urmia Lake, the second-largest hypersaline lake in the world during the last two decades. Despite this rapid shrinking, recording the Urmia Lake organisms, as an extreme environment,

1- National Artemia Research Center, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization, Urmia, Iran
*Corresponding author email: mohebbi44@gmail.com

either extant or extinct, particularly algae as crucial primary producers is significant. There is not an integrated study on the algae of Urmia Lake as an important extreme habitat in the eastern hemisphere. Therefore, this study tries to review the algal communities of the lake in various environmental circumstances.

Introduction

Early investigations on hypersaline lakes' phytoplankton structure were mostly related to that of the Great Salt Lake. Even an algal herbarium was established in the nineteen century (Harvard University, 2018). Perhaps the first systematic study of algae in the Great Salt Lake was conducted in the 1890s by an algae expert and a famous woman, Josephine Tilden, the first female professor at the University of Minnesota (Horsfield, 2016). She started a scientific study in the western United States that involved sampling and isolating algae from extreme environments such as Yellowstone Park and the Great Salt Lake (Tilden, 1898). In addition, she stored samples in the herbariums that are still available.

In Urmia Lake, there was a limited systematic study of algae. However, with algae as the main primary producers and food source for the brine shrimp, *Artemia* has participated in most of the investigations performed on ecology, monitoring, or stock assessment programs on the lake.

Algal flora of Urmia Lake

The food web of hypersaline environments is very simple. In a seemingly simple food web, birds who visit the lake eat brine shrimp and brine flies, and the fly larva and shrimp eat the algae and other microorganisms in the brine. As a hypersaline environment, Urmia Lake complies from this rule. So, algal species is expected to contain lower richness than that of freshwater.

It seems that there is a seasonal fluctuation in phytoplankton population structure in hypersaline lakes of temperate regions of the world. For example, the results of studies in Urmia Lake indicated that the highest algal species richness was observed in spring and early summer and the lowest in the late summer, autumn and winter (Mohebbi et al., 2020; Esmaeili Dahesht et al., 2010). Besides, the same results was reported from Mighan Lake and the Great Salt Lake (Hafezieh et al., 2020; Barret and Belovsky, 2020).

There is an inconsistency about phytoplankton of Urmia Lake in references (Eimanifar and Mohebbi, 2007). For example, *Enteromorpha intestinalis* macroscopic green alga which was reported from the lake by Plattner (1960) and Saberi (1977) has completely disappeared from the lake in late 1990s. During the years when the salinity was lower, this alga was so abundant that the whole lake looked like a plant soup. On the other hands, various researchers have reported different algae from different sampling sites. Riahi et al. (1994) have reported six species of Cyanophyta; *Anacystis* sp., *Chroococcus* sp., *Lyngbya* sp., *Oscillatoria* sp., *Synechococcus* sp., *Anabaena* sp. Four species of green algae; *Dunaliella* sp., *Monostroma* sp., *Ankistrodesmus* sp., *Pandorina* sp., two species of Bacillariophyta; *Amphora* sp., *Navicula* sp. from the lake. Mohebbi et al., (2006) have reported three species of Cyanophyta; *Anabaena* sp., *Oscillatoria* sp., *Synechococcus* sp., two species of green alga; *Dunaliella* sp., *Ankistrodesmus* sp., eleven species of Bacillariophyta; *Navicula* sp., *Nitzschia* sp., *Cyclotella* sp., *Symbella* sp., *Synedra ulna*., *Pinnullaria* sp., *Diatoma* sp., *Amphiprora* sp., *Surirella* sp., *Cymatopleura* sp., *Gyrosigma* sp. during whole year (June 2005- May 2006). Samplings was done from the eight stations. These variations can be related to limited and irregular samplings or increased salinity during the recent years which has eliminated some intolerant species (Table 1).

The main difference between two studies was laid in the presence of *Monostroma* sp. a macroalga belonging to Chlorophyta in study performed by Riahi et al., (1994) and absence of the macroalga in the later study (Mohebbi et al. 2006). *Monostroma* sp. is green macroalga that has many similarities to *U. intestinalis,* both have nutritional values and belonging to Ulvophyceae class. Therefore, it may be the same species. This was confirmed when we considered the sampling time of the *Monostroma* sp. by Riahi et al. (1994), in which either the Urmia Lake salinity was about 165 g/l and met the time when this alga was present in the lake, *U. intestinalis* was disappeared from the lake in the late 1990s. The salinity of Urmia Lake in the second study was about 310 g/l and its level was decreased compared to the first study period. When comparing two above mentioned studies from Bacillariophyta species number point of view, we see that there is few species in the first than the second study (2 vs. 11 species). This high number difference has two reasons; the first study was based on one sampling performance probably in warm season and the second study had monthly samplings during one year round, and Bacillariophyta species mostly were observed in cold season, the first study samplings was probably performed in warm season.

Ulva intestinalis

It was the only macroscopic alga in Urmia Lake that completely vanished from the lake in the late 1990s. Although there are no studies on this macroalgae's history, morphology, taxonomy, and ecology and could not determine it initially, there are few resources on its pigments and applications in food industries and medicine. Gunther (1899) first described a macroscopic lichen from Urmia lake that was probably *U. intestinalis*. Plattner (1960) a lecturer at Tabriz University, described *E. intestinalis* of Urmia Lake as dark green strips several meters long. *E. intestinalis (U. intestinalis)* originally described by Linnaeus (1753), is a cosmopolitan species and considered a euryhaline species (Reed and Russell, 1979; Edwards et al., 1987; Kamer and Fong, 2000).

Table 1. Phytoplankton species taxonomy of Urmia Lake

phylum	class	order	familly	genus	species	Reference
		Bacillariales	Bacillariaceae	*Nitzschia*	sp.	(5) ،(3) ،(1)
		Symbellales	Symbellaceae	*Symbella*	*Prostrata*	(5) ،(3) ،(2)
			Naviculaceae	*Amphiprora*	sp.	(3) ،(1)
				Navicula	sp.	(5) ،(3) ،(1)
Gyrista		Naviculales	Plurosigmaceae	*Gyrosigma*	sp.	(3)
			Pinnulariaceae	*Pinnularia*	sp.	(3)
	Bacillariophyceae	Surirellales	Surirellaceae	*Cymatopleura*	sp.	(3)
				Surirella	sp.	(3)
		Thalassiophysales	Catenulaceae	*Amphora*	sp.	(1)
		Thalassiosirales	Stephanodiscaceae	*Cyclotella*	sp.	(5) ،(2) ،(1)
		Achnanthales	Cocconeidaceae	*Cocconeis*	*pediculus*	(5)
		Frgilariales	Fragilariaceae	*Diatoma*	sp.	(3)
				Synedra	*ulna*	(5) ،(3)
		Sphaeropleales	Selenastrceae	*Ankistrodesmus*	sp.	(3) ،(1)
	Chlorophyceae	Volvocales	Dunaliallaceae	*Dunaliella*	sp.	(5) ،(3) ،(2) ،(1)
Chlorophyta			Volvocaceae	*Pandorina*	sp.	(1)
	Ulvophyceae	Ulotricales	Monostromaceae	*Monostroma*	sp.	(1)
		Ulvales	Ulvaceae	*Enteromorpha*	intestinalis	(4)
		Oscillatoriales	Oscillatoriaceae	*Lyngbya*	sp.	(1)
				Oscillatoria	sp.	(5) ،(3) ،(1)
Cyanobacteria	Cyanophyceae	Notocales	Nostocaceae	*Anabaena*	sp.	(3) ،(1)
		Chroococcales	Chroococcaceae	*Synechococcus*	sp.	(3) ،(1)
				Chroococcus	sp.	(1)
				Anacystis	sp.	(1)

(1) Riahi et al., 1994; (2) Shoa hasani et al., 1996; (3) Mohebbi et al., 2006; (4) Plattner (1960); (5) Mohebbi (2020)

Therefore, its occurrence in the hypersaline Urmia Lake was not so surprising.

There is solid evidence that *Ulva* and *Enteromorpha* are not distinct evolutionary entities and should not be recognized as separate genera (Hayden et al. 2003). As *Ulva* is the oldest name, *Enteromorpha* is here reduced to synonym.

Salinity may be one of the parameters that impacted the disappearance of this alga from Urmia Lake in the 1990s. We do not know if natural or anthropogenic influences might have vanished this alga from Urmia Lake. *E. intestinalis* produces considerable amounts of β-carotene, a red-colored carotenoid with antioxidant properties (Djoined, 1970).

Even though *Dunaliella* is responsible for more than 90% of primary production in hypersaline lakes so, the whole ecosystem depended on its carbon fixation a few studies have focused on this alga's ecology. However, as *Dunaliella* capability in beta-caroten production, its physiological and biochemical characteristics have been studied extensively. A few studies have been performed on the seasonal fluctuations of *Dunaliella* in the Great Salt Lake (Stephens and Gillespie, 1976; Post, 1977).

In 1838, *Dunaliella* was observed in salt evaporation ponds on the Mediterranean coast of Montpellier (southern France) by Michel Felix Donal for the first time (Dunal, 1838). In the 116 years since *Dunaliella* was formally identified, it has emerged as a traditional model microorganism for studying the algal adaptation to salinity. The observed organism was called *Hematococcus salinus* and *Protococcus* by Donal. The discovery of this alga was carried out following research regarding the cause of the red color of salt ponds by the French Academy of Sciences in Paris.

Dunaliella population structure in salt production pools has been poorly studied. So, a detailed investigation goes back to the 1920s in salt ponds on the Atlantic coasts of France (Labbé, 1921). In high salinities or during dilution asexual cells with a thick wall called an aplanospore may be formed. These cells may be contributed to facilitating severe conditions as they were observed in the cold season at the bottom of the lakes.

Labbé mistakenly proposed that large red and small green cells of *Dunaliella* were two stages of development of the same creature. However, we know that these cells may be present simultaneously red cells are produced in the warm and dry seasons.

When the Romanian botanist Emanoil C. Teodoresco (1949-1866) described the characteristics of the new halophile unicellular algal genus *Dunaliella*, the alga had been identified from salt lakes and ponds around the Mediterranean and Black Seas (1, 3). He named the alga *Dunaliella* in honor of Felix Donal, who had described these red unicellular algae from salt ponds in 1838 (Dunal, 1838; Teodoresco, 1905). The first definition of *Dunaliella* by Hamburger (1905) refers to aplanospores (dormant cysts) and palmeloid cell formation in the alga life cycle.

The green alga *Dunaliella* was first reported from the Great Salt Lake by Daines in 1910 (Daines, 1910). *Dunaliella salina* in high salinities (332 g/l) of the northern part of The Great Salt Lake was reported in the range of 1000-10000 cells/ml in the 1970s (Post, 1977).

High concentrations of Mg and Ca and the reduced water level have turned the dead lake into an unsuitable environment for *Dunaliella*, which was present in the past.

However, *Dunaliella* is an aquatic alga, and a few species were observed in terrestrial ecosystems. Buchheim et al. (2010) reported a *Dunaliella* population from saline soils of Oklahoma deserts based on the 18S rRNA findings. More surprisingly, a new strain of *Dunaliella* was observed in the spider's web of a cave in Chile. Molecular analysis based on the 18S rRNA and chloroplastic genes, this alga was related to *D. atacamensis* (Azúa-Bustos et al., 2010).

Dunaliella is a key primary producer in hypersaline ecosystems which consumer components depend on it. Glycerol is an important compound that is produced inside the *Dunaliella* cells and accumulated to regulate osmotic pressure in high salinities.

Molecular analyses of an algal bloom in Urmia Lake were provided by the study of the 18srDNA gene and sequencing of the ITS region (Manaffar et al., 2015). The results of this study revealed the main reason for bloom-forming was the dominant species of the *Dunaliella tertiolecta* alga in the concentration of 1.2×106 cells/ml.

Hejazi et al., (2016) applied the intron-sizing method to compare the 18S rDNA fingerprint between *Dunaliella* isolates of Urmia Lake. According to the results, the genetic variation in the *Dunaliella* genus depends on different areas of Urmia Lake. PCR with species-specific primers in the population confirmed the existence of at least four species of *D. tertiolecta*, *D. parva*, *D. salina*, and *D. bardawil*, and some types of isolates which were similar to *Dunaliella* sp. ABRIINW-M1/2. In summary, this study indicated that this method was appropriate to differentiate between some species of *Dunaliella* and rapidly identify them.

Dunaliella spp. was observed in the whole body of Urmia Lake. In a study performed in 2005-2006, 14 phytoplankton species were reported from the lake among which ten species of Diatoms, two species of Chlorophyta (green algae), and two species of Cyanophyta (blue-green algae) (Esmaili Dahesht et al., 2010; Mohebbi et al., 2006). During 2005-2006 the *Dunaliella* density reached 92.1% of the total phytoplankton density of the lake. In this study, *Navicula* sp. and *Synedra ulna* contained the highest density with 23963 and 12283 cells/l, respectively.

Phytoplankton communities of Urmia Lake in shrinkage

Urmia Lake is the largest natural habitat of a unique brine shrimp species, *A. urmiana* which is the main food source for migratory birds (Ahmadi et al., 2011; Asem et al., 2014, 2016; Aghakouchak et al., 2015). The lake water level has dropped dramatically which can be compared to the fate of the Aral Sea in Eurasia, where its size was decreased to 10% of its original size due to diverting the two main rivers for agricultural irrigation (Aghakuchak et al., 2015). The main morphology characteristics of Urmia Lake in the Low-stand and high-stand periods were indicated in Table 2.

According to the latest study (Mohebbi, 2020), eight species of algae were observed in Urmia Lake: one species of Chlorophyta ; *Dunaliella*

Table 2. Morphometric characteristics of Urmia Lake before and after shrinkage

Characteristics	High-stand period	Low-stand period	References
Watershed area (km^2)	51876	51876	Marden et al., 2014; Delju et al., 2012
Surface area (km^2)	4800-6100	1730-2200	http://agrw.ir
Mean depth (m)	4.5	0.5	Sima and Tajrishi, 2013
Volume (m^3)	26×10^9	1.5×10^9	http://agrw.ir
Stream flow (m^3/yr)	972×10^6	250×10^6	Nourani et al., 2018
Mean evaporation (mm/yr)	1156	1629	Heidari et al., 2010
Salinity (ppt)	150-180	>300	Eimanifar and Mohebbi, 2007
pH	6-8	6-8	Alipour, 2006

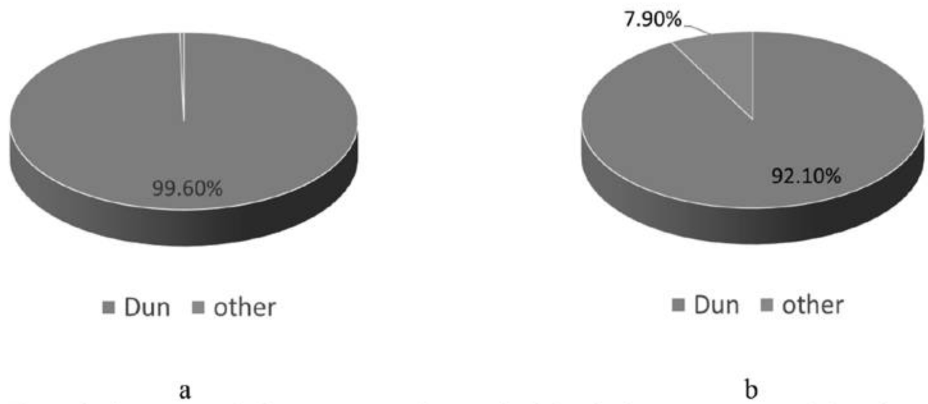

Fig. 1. Phytoplankton population structure in Urmia lake during 2018-2020 (a) and 2005-2006 (b)

sp., one species of Cyanophyta; *Oscillatoria* sp., and six species of Bacillariophyta; *Cocconeis pediculus*, *Nitzschia* sp., *Synedra ulna*, *Symbella prostrate*, *Cyclotella* sp.; N*avicula* sp. (Table 3).

The phytoplankton population density of Urmia Lake during the shrinkage period is indicated in Table 3.

A crucial aspect of the shrinkage that should be pointed out is that *Dunaliella* sp. shared higher density of total algae (99.6% vs. 0.4%), while in periods the water level was higher, *Dunaliella* had about 92.1% of total algal density in Urmia Lake (Esmaeili et al., 2010) (Fig. 1). Actually, this is because *Dunaliella* is tolerant against harsh environmental conditions so can replace with low tolerant species.

Algal flora of Urmia Lake vs. Mighan Lake

When the relationship between water salinity and algal composition in Urmia Lake and Mighan Lake (Arak province, center of Iran) was compared, we got fascinating results (Mohebbi, 2020; Hafezieh et al., 2020),

Table 3. phytoplankton population structure and density of Urmia Lake in water withdrawal condition (2018-2020)

Density (%)	Density (No/l)	species	Spr 2018	Sum 2018	Fall 2018	Win 2018	Spr 2019	Sum 2019	Fall 2019	Win 2019	Spr 2020
99.6	1923025	*D. salina* (Dunal) Teodoresco	+	+	+	+	+	+	+	+	+
	2172	*Oscillatoria* sp.	+	+	-	-	+	-	-	-	-
	2573	*Navicula* sp.	+	+	+	+	+	-	-	+	+
	271	*Cocconies pediculus* Her.	-	+	-	+	-	-	-	-	-
	1801	*Nitzschia* sp.	-	-	+	+	+	-	-	-	+
0.4	219	*Synedra ulna* (Nitzsch) Ehrenberg	-	+	+	-	-	-	-	-	-
	62	*Symbella prostrate* (Berkeley) Cleve	-	-	+	-	-	-	-	-	-
	287	*Cyclotella* sp.	-	-	+	-	-	-	-	-	+

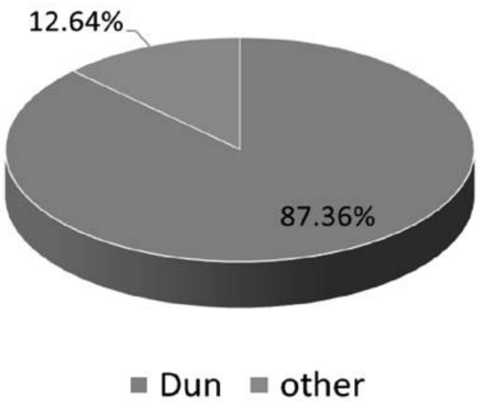

Fig. 2. Phytoplankton population of Mighan lake (Mar-Dec 2019)

which are indicated in Table 4.

Comparing the two lakes, salinity as a key factor plays a crucial role in phytoplankton population structure in both ecosystems comes true. However, it should be noted that above a definite salinity level, the species diversity (the number of species) declined sharply in hypersaline waters.

As shown in Table 4 as salinity rises *Dunaliella* density and dominance increase, and other algae density decreases accordingly and vice versa. However, salinity is not the sole factor influencing the algal composition in hypersaline lakes and researchers believe that integrated conditions and factors are involved in shaping the algal composition in these environments.

In Mighan Lake, the highest and the lowest *D. salina* density was observed in June and October 2018, respectively (Hafezieh et al., 2020). Dunaliella density, water level, and nutritional ions were simultaneously increased in the spring, which was agreed with observations made in other hypersaline lakes such as Urmia Lake (Mohebbi et al., 2020). However, the role of brine shrimp as a filter-feeding organism in phytoplankton population fluctuations should not be

Table 4. Comparison of phytoplankton structure in Urmia lake (2018-2019) and Mighan lake (Mar-Dec 2019)

parameter	Urmia Lake	Mighan Lake (Arak)
Salinity (g/l)	220-350	30-120
Phytoplankton species number	8	10
Dunaliella abundance (%)	99.6	87.36
Other microalgae (%)	0.4	12.64

ignored. In this regard, Brine shrimp plays a crucial role in the definite season of the year.

Primary production in Urmia Lake

In 1995-96 chlorophyll concentration in Urmia Lake was measured as 0.5-0.8 µg/l and seldom exceeded 1 µg/l (Van Stappen et al., 2001). This was lower than that of the Great Salt Lake (0.5-3.5 µg/l) reported by Gliwicz et al. (1995). Therefore, Urmia Lake may be categorized as an oligotroph from a phytoplankton production point of view. Quantitative analysis of chlorophyll and phytoplankton has indicated that primary production in Urmia Lake is lower than that of the Great Salt Lake (Van Stappen et al., 2001), and *Dunaliella* was the dominant species in both lakes.

All types of chlorophylls showed similar fluctuations, indicating that continuous blooms of different species did not occur. Therefore, there were uniform phytoplankton species in the whole lake. Chlorophyll concentrations in December-January rose to a maximum which then during late winter a gradual decline occurred during the spring and early summer. Minimum chlorophyll values were observed in June 1996 (Van Stappen et al., 2001).

Minimum chlorophyll values were observed in June 1996. This indicates that phytoplankton density reached an approximate bloom. Phytoplankton was eliminated by Artemia with a steady process that occupy the lake from late winter onward. Algal bloom did not occur like in other hypersaline lakes such as Mono Lake and the Great Salt Lake.

There was an evident variation in the primary production of various stations. Generally, chlorophyll values were higher near shore and river deltas than offshore sampling sites, which can be related to nutrients loading into the lake in these regions. However, recorded values for delta regions of Urmia Lake were well below the values (60 µg/l) reported for similar regions of the Great Salt Lake (Van Stappen et al., 2002).

Seasonal fluctuations of the lake phytoplankton were matched with chlorophyll variations: maximum Dunaliella density was observed in winter and minimum in May - September. A similar pattern was observed for *Cyclotella* sp. and *Nitzschia* sp. but with a lower density. According to this study, we can declare that the Urmia Lake microalgae composition is similar to that of the GSL, which mainly included *Dunaliella* with a fraction of Diatoms.

In 1995-96 *Dunaliella* was the dominant microalga of the lake, with a density more than 10 times higher than the sum of other microalgae. In August and December 2005, *Dunaliella* density in Urmia Lake reached 480×103 and 80×103 cells/L, respectively.

Red coloration of Urmia Lake

During warm and dry seasons, as the water level drops below 1372 m (Fig. 1), the density of halophilic bacteria in the family of Halobacteriaceae rises to more than 108 cells/ ml in the lake. These are prokaryotic organisms and have pigments distributed evenly on the cell membranes. So, absorb light more efficiently than carotenoids of eukaryotic *Dunaliella* as a dominant alga (Mohebbi et al. 2011). Although β-carotene derived from *Dunaliella* is the most abundant carotenoid pigment in hypersaline water, its dense packaging within granules inside the cell's chloroplast greatly decreases its participation in the overall light absorbance in the water. As for Urmia Lake (e.g. Arash Rad, 2000; Asgarani et al., 2006; Bahari et al., 2009), the presence of Halobacteriaceae family has been reported by Post (1977) and Baxter et al. (2005) in the North Arm of Great Salt Lake, Utah, which shows similar color changes in high salinities. Urmia Lake's color changes seasonally, and as drought and agricultural water overuse persist in the region, a ruddy hue may become a more common sight.

The Urmia Lake vegetation

The Urmia Lake ecosystem includes two particular plant communities; the vegetation of salt marshes around the lake and the island's vegetation which may be observed in Kaboodan, Spir, Ashk, and Arezoo islands. The island's vegetation is composed mostly of steppe and sub-shrub, and shrubs and is estimated around 4810 ha (Baghaee, 2009). Salt marshes around the lake and islands included 177 and 174 plant species, respectively. The largest plant families were Asteraceae and Poaceae with 33 and 21 species, respectively. The largest plant genus was *Euphorbia* and *Trigonella foenum-graecum*. Among the Urmia lake national park plant families, 12 were endemic to Iran. However, about 50% of plant species belonged to the Irano-Touranian phytogeographic region (Alipour, 2009).

According to the latest study (Ghorbanalizadeh, 2022), 24 plant communities were distinguished regarding floristic and ecological characteristics in Kaboodan Island, the largest island of

Urmia Lake. They were categorized into three groups: First of all, Plant communities formed on the dried bed of Urmia Lake *Salicornietum iranicae*, *Halimocnemis rarifolia* comm. Frankenia hirsuta comm., *Halocnemetum strobilacei*. Secondly, Plant communities developed on the island's former shorelines: *Atraphaxis spinosa*, *Ephedra major* subsp. *procera* comm., *Alhagi maurorum* comm. Lastly, Plant communities found on hills adjacent to shorelines, steppe areas, and valleys of the island: *Caroxylon dendroides* comm., *Halothamnus glaucus* comm., *Artemisia spicigera, Ephedra major* subsp. *procera* comm., *Rhamnus pallasii*, *Artemisia spicigera* comm., *Pistacia atlantica* subsp. *mutica-Rhamnus pallasii* comm., *Peganum harmala* comm. For example, Kaboodan Island has an unspoiled ecosystem and no anthropogenic activities over decades which is home to various plant species and vegetation types.

It was found that Urmia Lake shrinkage had influenced the vegetation of salt lands around it. During 21 years, from 1995 to 2015 about 67.3% of plant communities dried up, other communities have replaced, and only 32.7% could retain their life power (Ahmadi et al., 2018). On the other hand, the crown cover has decreased by a minimum of 10.4% and a maximum of 73.3% for Halantietum rarifolii and Iridetum musulmanicae communities, respectively.

Discussion

Twenty-four algal species were reported from Urmia Lake by various authors. However, there is an inconsistency about the phytoplankton of Urmia Lake in references. These variations can be related to limited and irregular samplings or increased salinity during the last two decades which has eliminated some intolerant species. *Ulva intestinalis* macroscopic alga was reported from the lake in the 1960s, and 1970s even until the early 1990s completely disappeared from the lake in the late 1990s.

Urmia Lake phytoplankton is comprised mainly of *Dunaliella* spp. as a dominant genus. So, in high stand periods, it included more than 90% of phytoplankton abundance. In low stand periods of the Urmia Lake water level, *Dunaliella* spp. composed even higher components of phytoplankton assemblages (98-99%). *Dunaliella* species are euryhaline and can tolerate high salinities and are so the dominant species in hypersaline environments worldwide.

Primary production in Urmia Lake is lower than its sister The Great Salt Lake located in Utah in the United State of America (0.5-0.8 µg/l vs. 0.5-3.5 µg/l). Therefore, Urmia Lake was considered oligotrophic from Chlorophyll a values point of view. Urmia Lake water withdrawal has influenced the vegetation of saline marshes and areas around the lake. According to studies, During 21 years, from 1995 to 2015 about 67.3% of plant communities have dried up and other communities have replaced, and only 32.7% could retain their life power.

Despite the rapid shrinkage of Urmia Lake during the last two decades, its island vegetation has not been impacted by this disaster and could maintain its plant species diversity. This was improved by the fact that human accessibility was limited to the lake's islands due following reasons. The Environment Agency protected the Urmia Lake and its islands as a protected region and had difficulty accessing the islands human for cattle grazing.

Regarding the anthropogenic and climate changes that rapidly impact the natural ecosystems, particularly crucial ecosystems such as Urmia Lake, this study showed the significance of an algal herbarium on the national or regional scale to record and preserve specimens of algae that may be vanished someday from the ecosystems.

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