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Review

Biodiversity of the Hypersaline Urmia Lake National Park (NW Iran)

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Abstract: Urmia Lake, with a surface area between 4000 to 6000 km^2, is a hypersaline lake located in northwest Iran. It is the saltiest large lake in the world that supports life. Urmia Lake National Park is the home of an almost endemic crustacean species known as the brine shrimp, *Artemia urmiana*. Other forms of life include several species of algae, bacteria, microfungi, plants, birds, reptiles, amphibians and mammals. As a consequence of this unique biodiversity, this lake has been selected as one of the 59 biosphere reserves by UNESCO. This paper provides a comprehensive species checklist that needs to be updated by additional research in the future.

Keywords: biodiversity; hypersalinity; Urmia Lake; National Park

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1. Introduction

Urmia Lake is the 20th largest lake in the world. The surface area of this salt lake varies between 2300 to 6000 km^2 (Figure 1) for two main reasons. First, its hydrology largely depends on precipitation in the catchment area. Secondly, extremely gentle slopes of its marginal plains lead to inundation of large areas even by small water level rises. The average altitude is 1274 m above sea level and the salinity ranges between 120 g/L and more than 300 g/L. 102 islands have been recorded in this lake. Today, only the Islami (Shahi) Peninsula is inhabited by humans, but the "*Limit of the World from the East to the West*"—the oldest Persian geography book—written by anonymous author(s) in 982 A.D., described Kaboudan Island as suitable for human settlement [1].

Figure 1. Geographical localisation of Urmia Lake in the northwestern of Iran.

Contrary to widespread opinion, Urmia Lake is a second hypersaline lake with an active food web compared to the Dead Sea (with a salinity of >340 g/L), which includes bacteria, archaea, algae, protozoa and ciliates [2–4]. Urmia Lake is saltier than the Aral Sea (>100 g/L) [5] and Karabogaz Gol (40−100 g/L in the deep zone, 170−250 g/L in the northwest and southwest parts of the bay) [6]. The lake hosts diverse bacterial communities, hyperhalophilous phytoplanktons, and notably the macrozooplankton crustacean, the brine shrimp *Artemia urmiana*. Thus, with regard to its ecological significance, unique biodiversity and the presence of indigenous communities, Urmia Lake has been recognized as a Protected Field since 1967 and was designated as a National Park in 1976 as one of 59 biosphere reserves by UNESCO [7]. In 1975, it was also registered in the Ramsar Convention on Wetlands as a wetland of international importance [7]. Although the lake is a UNESCO biosphere reserve, several development projects have had detrimental consequences for biodiversity.

The lake is divided into north and south parts, separated by a dike-type causeway, which has a small gap (1400 m) that allows a limited exchange of water between the two sides [7] (Figure 1). About 35 dams have been built on 21 permanent rivers flowing to the lake [8], which restrict the influx of fresh water. In the last decade, Urmia Lake has been affected by a transformation in the hydrological regime, due to climate instability and the construction of dams [9]. Water resource development projects are diverting enormous quantities of fresh water and preventing a replenishment of lake water, which is lost to evaporation [10]. The intensive development of agriculture during the last decades and the resultant over-exploitation of groundwater have also deprived the lake of one of its main water input resources.

A progressive drought has caused fundamental changes in the physio-chemical composition of the lake–the salinity exceeds >300 g/L, the surface area has decreased to less than 2366 km^2, the lake level has decreased to 1271 m, the volume of water has decreased from 42 to 22 billion m^3 between 1995 and 2010, and the water depth has decreased to 6 m, whereas reservoirs of dams have increased from 1.624 billion m^3 to 3.568 billion m^3 [9,11,12].

Climate and anthropogenic alterations are recognized as crucial factors in population declines and even the risk of extinctions in most ecosystems [13,14]. A decrease of population density would ultimately limit dispersal, as well as gene flow, among populations. This will eventually lead to the loss of genetic diversity [15]. On the other hand, an increased rate of dispersal can also disturb local genetic adaptation [16]. At present, the severe drought which happened in 2003–2004 is jeopardizing the biodiversity of the lake [17].

In this review, we have summarized the available information on the biodiversity of the lake ranging from bacteria and fungi to plants and animals. Apparently, the existing information is incomplete and more detailed future studies are required for a complete inventory of the biodiversity of Urmia Lake.

2. Archaebacteria and Bacteria

Urmia Lake harbours a diverse group of bacterial species (Table 1). Two pathogenic bacteria *Clostridium perfringens* and *Enterococcus faecalis* have been identified in the lake water and particularly in the estuary sediments. As these bacteria constitute the natural flora of the human digestive tract, their presence in the lake water and sediments suggests that they have originated from the inflow of urban waste water into Urmia Lake [18,19].

In Urmia Lake, the muds contain green sulphur-bacteria, purple sulphur-bacteria and ferro-bacteria [19,20]. Halophilic archaebacteria can usually synthesize red and pink pigments in response to environmental stress [21–23]. During the summer of 2008, the water of Urmia Lake around Kaboudan Island changed from blue, its normal colour, to red [24]. This was the first report of this event that may be attributed to the bloom of Archaebacteria or of *Dunaliella* or both (see [25]).

Table 1. List of Archaebacteria and Bacteria from Urmia Lake.

Domain	Phylum	Class	Order	Family	Genus	Species	Reference
Archaea	Euryarchaeota	Halobacteria	Halobacteriales	Halobacteriaceae	*Haloarcula*	sp.	[23,26]
					Halobacterium	sp.	[23]
					Haloferax	sp.	[22]
					Halorubrum	sp.	[23]
Bacteria	Actinobacteria	Actinobacteria	Actinomycetales	Microbacteriaceae	*Microbacterium*	sp.	[27]
				Micrococcaceae	*Kocuria*	sp.	[27]
					Micrococcus	sp.	[27]
				Sanguibacteraceae	*Sanguibacter*	sp.	[27]
	Bacteroidetes	Cytophagia	Cytophagales	Cytophagaceae	*Adhaeribacter*	sp.	[27]
					Pontibacter	sp.	[27]
				Flammeovirgaceae	*Cesiribacter*	sp.	[27]
		Incertae sedis	Incertae sedis	Rhodothermaceae	*Salinibacter*	sp.	[27]
	Cyanobacteria	Cyanophyceae	Chroococcales	Chroococcaceae	*Chroococcus*	sp.	[28]
				Microcystaceae	*Anacystis*	sp.	[28]
					Gloeocapsa	sp.	[29,30]
				Spirulinaceae	*Spirulina*	*S. maxima*	[30]
			Nostocales	Nostocaceae	*Anabaena*	sp.	[28,31]
					Nostoc	sp.	[29,30]
			Oscillatoriales	Oscillatoriaceae	*Lyngbya*	sp.	[28]
					Oscillatoria	sp.	[28–32]
			Synechococcales	Synechococcaceae	*Synechococcus*	sp.	[28]

Table 1. *Cont*.

Domain	Phylum	Class	Order	Family	Genus	Species	Reference
Bacteria	Firmicutes	Bacilli	Bacillales	Bacillaceae	*Bacillus*	*B. licheniformis*	[33]
						sp.	[27,34–36]
					Gracilibacillus	sp.	[27]
					Halobacillus	sp.	[27,34,36,37]
					Oceanobacillus	sp.	[27]
					Piscibacillus	sp.	[27]
					Pontibacillus	sp.	[27]
					Thalassobacillus	sp.	[27,34]
					Virgibacillus	*V. halodenitrificans*	[38]
						sp.	[37]
				Planococcaceae	*Planococcus*	sp.	[27]
				Staphylococcaceae	*Staphylococcus*	sp.	[27]
			Lactobacillales	Carnobacteriaceae	*Alkalibacterium*	sp.	[27]
				Enterococcaceae	*Enterococcus*	*E. faecalis* *	[18]
		Clostridia	Clostridiales	Clostridiaceae	*Clostridium*	*C. perfringens*	[18]
	Proteobacteria	Alphaproteobacteria	Caulobacterales	Caulobacteraceae	*Brevundimonas*	sp.	[27]
			Rhodobacterales	Rhodobacteraceae	*Paracoccus*	sp.	[27]
		Gammaproteobacteria	Alteromonadales	Alteromonadaceae	*Marinobacter*	sp. H57B71	[36]
					Marinobacter	sp.	[27,34,36,37]
				Idiomarinaceae	*Idiomarina*	sp. Y24	[36]
			Enterobacteriales	Enterobacteriaceae	*Plesiomonas*	*P. shigelloides*	[39]
					Providencia	sp.	[27]

Table 1. *Cont*.

Domain	Phylum	Class	Order	Family	Genus	Species	Reference
Bacteria	Proteobacteria	Gammaproteobacteria	Oceanospirillales	Hahellaceae	*Halospina*	*H. denitrificans*	[36]
				Halomonadaceae	*Chromohalobacter*	*C. salexigens*	[40]
					Halomonas	*H. ventosae*	[36,41]
						H. sediminis YIM C248	[36]
						sp.	[37]
					Halovibrio	*H. denitrificans*	[36]
					Salicola	sp.	[27,36]
			Pseudomonadales	Pseudomonadaceae	*Pseudomonas*	sp.	[36]
			Vibrionales	Vibrionaceae	*Vibrio*	*V. mimicus*	[39,42]
						V. alginolyticus	[39,42]
						V. fluvialis	[39,42]
			Xanthomonadales	Xanthomonadaceae	*Lysobacter*	sp.	[27]

Reference: [18] Saberi (1987): lake water and particularly in the estuary sediments; [22] Asgarani *et al.* (2006): lake water; [23] Bahari *et al.* (2009): salt crystals; [33] Rezazadeh-Bari (1992): coastal sediments; [28] Ryahi *et al.* (1994): lake water; [32] Shoa-Hasani *et al.* (1996): lake water; [39] Arash-Rad (2000): in fresh biomass of *Artemia urmiana* samples from Urmia Lake; [42] Yousefbeygi and Rahimlou (2001): in fresh biomass of *Artemia urmiana* samples from Urmia Lake; [31] Mohebbi *et al.* (2006): lake water; [37] Rohban *et al*, (2007): lake water; [34] Amoozegar and Zahraei, (2007): lake water; [41] Yousefi *et al*, (2007): coastal salty soils; [40] Yousefi *et al*, (2007): lake water; [38] Rafiee *et al*, (2007): soil specimens of lake; [35] Sadramehr *et al*, (2008): lake water; [26] Taran (2011): lake water; [29] Asadi (2011): lake water; [30] Asadi *et al.* (2011): lake water; [36] Zununi-Vahe *et al.* (2011): water and soil specimens of lake; [27] Mehrshad *et al.* (2012): water, sediments, salt crystals and residue of plants in in the western coastal line of lake; * Synonymous with *Streptococcus faecalis*.

3. Microfungi

Fungi are a large group of eukaryotic organisms with worldwide distribution, inhabiting a diverse range of extreme habitats from deserts to hypersaline environments [43]. Investigations of the distribution of fungi in extremely hypersaline environments are rare. Numerous fungi have been identified from *Artemia* cysts and hypersaline water. Fungal contamination of *Artemia* cysts is possibly one of the important reasons for their reduced hatchability, and therefore one of the main problems in cyst processing and culture [44]. Twelve fungi have been reported in some halophytes and glycophytes of islands and also from the western shores of Urmia Lake [45]. A list of fungi species from Urmia Lake is presented in Table 2.

Table 2. List of Microfungi from Urmia Lake.

Division	Class	Order	Family	Genus	Species	Reference
Ascomycota	Ascomycetes	Incertae sedis	Incertae sedis	*Epicoccum*	sp.	[44]
	Dothideomycetes	Pleosporales	Pleosporaceae	*Alternaria*	sp.	[44]
	Eurotiomycetes	Eurotiales	Trichocomaceae	*Aspergillus*	*A. flavus*	[44]
					A. fumigatus	[44]
					A. niger	[44]
				Penicillium	*P. chrysogenum*	[46]
					P. polonicum	[46]
					sp.	[44]
	Sordariomycetes	Hypocreales	Nectriaceae	*Fusarium*	*F. incarnatum*	[44]
					sp.	[44]
		Microascales	Microascaceae	*Scopulariopsis*	sp.	[44]
Glomeromycota	Glomeromycetes	Diversisporales	Acaulosporaceae	*Acaulospora*	sp.	[45]
		Glomerales	Glomeraceae	*Glomus*	*G. aggregatum*	[45]
					G. clarum	[45]
					G. clavisporum	[45]
					G. constrictum	[45]
					G. coremioides	[45]
					G. etunicatum	[45]
					G. fasciculatum	[45]
					G. fecundisporum	[45]
					G. geosporum	[45]
					G. microaggregatum	[45]
					G. mosseae	[45]
					G. verruculosum	[45]
Zygomycota	Zygomycetes	Mucorales	Mucoraceae	*Absidia*	sp.	[44]
				Rhizopus	sp.	[44]

Reference: [44] Ownagh *et al.* (2008): freshly harvested cysts of *Artemia urmiana*; [45] Khara (2004): arbuscular mycorrhiza in some halophytes and glycophytes of islands and the western coasts of the Urmia Lake; [46] Niknejad *et al*. (2013): water of Urmia Lake.

4. Phytoplankton

The algal flora of Urmia Lake was studied by Plattner in 1960 [47], who reported *Enteromorpha intestinalis* as a macroscopic alga [18,20]. *E. intestinalis* produces considerable amounts of β-carotene, a red-coloured carotenoid with antioxidant properties [20]. Urmia Lake contains a diverse assemblage of phytoplankton species, with *Dunaliella* as the major species (more than 95% of the total phytoplankton in number) and an important fraction of diatoms such as *Navicula* and *Nitzschia* [31]. *Dunaliella* is a green halophilic alga which bears two flagellates and produces high amounts of β-carotene. This phytoplankton is the major food source for *Artemia* in the Urmia Lake. It seems that phytoplankton populations in the lake benefit from the increased salinity that has reduced the number of other species and favoured the dominance of *Dunaliella*. Usually, in the early spring, especially in Golmankhane Port, a bloom of *Dunaliella* occurs near the shore line which changes the water colour to yellow (see [48]). A current list of phytoplankton composition in Urmia Lake is given in Table 3.

Table 3. List of phytoplankton species from Urmia Lake.

Phylum	Class	Order	Family	Genus	Species	Reference
Heterokontophyta	Bacillariophyceae	Bacillariales	Bacillariaceae	*Nitzschia*	sp.	[28,31]
		Cymbellales	Cymbellaceae	*Cymbella*	sp.	[31,32]
		Naviculales	Naviculaceae	*Amphiprora*	sp.	[28,31]
				Navicula	sp.	[28,29,31]
			Pleurosigmataceae	*Gyrosigma*	sp.	[31]
			Pinnulariaceae	*Pinnularia*	sp.	[31]
		Surirellales	Surirellaceae	*Cymatopleura*	sp.	[31]
				Surirella	sp.	[31]
		Thalassiophysales	Catenulaceae	*Amphora*	sp.	[28]
	Coscinodiscophyceae	Thalassiosirales	Stephanodiscaceae	*Cyclotella*	sp.	[31,32]
	Fragilariophyceae	Fragilariales	Fragilariaceae	*Diatoma*	sp.	[31]
				Synedra	sp.	[31]
Chlorophyta	Chlorophyceae	Sphaeropleales	Selenastraceae	*Ankistrodesmus*	sp.	[28,31]
		Volvocales	Dunaliellaceae	*Dunaliella*	sp.	[28,31,32]
			Volvocaceae	*Pandorina*	sp.	[28]
	Ulvophyceae	Ulotrichales	Monostromataceae	*Monostroma*	sp.	[28]
		Ulvales	Ulvaceae	*Enteromorpha*	*E. intestinalis*	[47]

Reference: [28] Ryahi *et al.* (1994); [32] Shoa-Hasani *et al.* (1996); [31] Mohebbi *et al.* (2006); [47] Plattner (1960).

5. Land Plants

Because of the diversity of soils and topography, Urmia Lake islands possess a diverse flora. Table 4 shows the checklist of plants in the Urmia Lake National Park. The halophilous vegetation around Urmia Lake displays an interesting gradient of salinity-tolerance, ranging from annual obligatory hygro-halophytic communities on lake marshes dominated by *Salicornia* spp. up to hydrophytic communities dominated by *Alisma plantago-aquatica*. The latter species grows on the margins of salty and brackish water marshes where the fresh groundwater dilutes the salt contents of the soil [49,50]. The constant occurrence of plant communities in this habitat may suggest that

salt-water inundation plays the main role in plant distribution. Inundation seems to act mainly through increasing soil moisture and affecting soluble salt contents to levels suitable for life.

Several cryptic species in the area still need to be identified. This is the case for a rare liverwort *Riella* aff. *cossoniana*, whose spores have only recently been discovered in ancient and recent sediments of the lake [50].

Table 4. List of plants on islands and in salt marshes of Urmia Lake.

Order	Family	Genus	Species	Reference
Alismatales	Alismataceae	*Alisma*	*A. plantago-aquatica*	[49]
	Araceae	*Arum*	sp.	[51]
	Butomaceae	*Butomus*	*B. umbellatus*	[49]
Apiales	Apiaceae	*Alococarpum*	*A. erianthum*	[51,52]
		Bupleurum	*B. falcatum*	[51,52]
			B. gerardii	[51,52]
		Eryngium	*E. billardieri*	[51,52]
		Malabaila	*M. secacul*	[51,52]
		Pimpinella	*P. tragium*	[51,52]
		Scandix	*S. stellata*	[51,52]
		Torilis	*T. leptophylla*	[51,52]
		Zosima	*Z. absinthifolia*	[51,52]
Asparagales	Amaryllidaceae	*Allium*	*A. akaka*	[51,52]
			sp.	[51]
	Asparagaceae	*Bellevalia*	sp.	[51,52]
		Leopoldia	*L. caucasica* [1]	[51,52]
	Iridaceae	*Crocus*	sp.	[51,52]
		Iris	*I. barnumae*	[51,52]
			I. spuria	[49]
			sp.	[51]
	Ixioliriaceae	*Ixiolirion*	*I. tataricum*	[52]
	Orchidaceae	*Dactylorhiza*	*D. umbrosa*	[49]
	Xanthorrhoeaceae	*Eremurus*	*E. spectabilis*	[51,52]
Asterales	Asteraceae	*Amberboa*	*A. nana*	[51,52]
		Artemisia	*A. fragrans*	[45,49,53]
			A. haussknechtii	[51,52]
			sp.	[51]
		Aster	*A. tripolium*	[49]
		Centaurea	*C. aucheri*	[51,52]
			C. ustulata	[51,52]
			C. virgata	[51,52]
		Cirsium	*C. alatum*	[49]
		Cousinia	sp.	[51,52]
		Crepis	sp.	[51,52]
		Crupina	*C. vulgaris*	[51,52]
		Echinops	*E. orientalis*	[45]
			sp.	[51,52]
		Garhadiolus	*G. angulosus*	[52]
		Helichrysum	*H. rubicundum*	[51,52]
		Inula	*I. aucheriana*	[49]
		Koelpinia	*K. linearis*	[49]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Asterales	Asteraceae	*Lactuca*	*L. serriola*	[53]
			L. undulata	[51,52]
		Picris	*P. kotschyi*	[51,52]
		Saussurea	*S. salsa*	[49]
		Scorzonera	*S. laciniata*	[49]
		Senecio	*S. vernalis*	[45]
			sp.	[51,52]
		Steptorhamphus	*S. tuberosus*	[52]
		Taraxacum	sp.	[49]
		Tragopogon	*T. graminifolius*	[49]
			T. marginatus	[51,52]
		Xeranthemum	*X. squarrosum*	[51,52]
Boraginales	Boraginaceae	*Anchusa*	*A. arvensis*	[51,52]
		Buglossoides	*B. arvensis*	[52]
		Heliotropium	*H. samoliflorum*	[49,51,52]
		Heterocaryum	*H. laevigatum*	[52]
		Moltkia	*M. longiflora*	[51,52]
		Nonnea	*N. caspica*	[51,52]
Brassicales	Brassicaceae	*Aethionema*	*A. carneum*	[51,52]
		Alyssum	*A. linifolium*	[45]
			A. murale	[51,52]
			A. szovitsianum	[51,52]
			sp.	[51,52]
		Descurainia	*D. sophia*	[45]
		Erysimum	*E. sisymbrioides*	[49]
		Hutchinsia	*H. procumbens*	[53]
		Isatis	*I. buschiana*	[51,52]
		Lepidium	*L. aucheri*	[49]
			L. cartilagineum	[49,53]
		Malcolmia	sp.	[51,52]
		Neslia	*N. apiculata*	[51,52]
	Capparaceae	*Capparis*	*C. spinosa*	[51,52]
	Cleomaceae	*Cleome*	*C. iberica*	[51,52]
Caryophyllales	Amaranthaceae	*Atriplex*	*A. aucheri*	[51,52]
			A. hastata	[49]
			A. patula	[51,52]
			A. tatarica	[49]
			A.verrucifera	[45,49,53]
			sp.	[51,52]
		Camphorosma	*C. monspeliaca*	[49,53]
		Chenopodium	*C. murale*	[51,52]
			sp.	[51]
		Climacoptera	*C. crassa*	[49]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Caryophyllales	Amaranthaceae	*Halanthium*	*H. rarifolium*	[49,52,53]
		Halocnemum	*H. strobilaceum*	[49,52,53]
		Halopeplis	*H. pygmaea*	[49]
		Halostachys	*H. caspica*	[49,51,52]
		Kalidium	*K. caspicum*	[49]
		Noaea	*N. mucronata*	[51,52]
		Petrosimonia	*P. brachiata*	[49,53]
			P. glauca	[49]
		Salicornia	*S. maritime* [2]	[45,49,51–53]
		Salsola	*S. crassa*	[51–53]
			S. dendroides	[51,52]
			S. kali	[45]
			S. laricina	[51,52]
			S. soda	[49,53]
			S. verrucosa	[51,52]
		Suaeda	*S. acuminata*	[52]
			S. altissima	[45,49,53]
			S. crassifolia	[53]
			S. maritima	[49,53]
			S. microphylla	[49,51,52]
			sp.	[51]
	Caryophyllaceae	*Acanthophyllum*	*A. mucronatum*	[51,52]
		Cerastium	*C. inflatum*	[51,52]
		Dianthus	*D. orientalis*	[51,52]
			sp.	[51,52]
		Gypsophila	sp.	[51]
		Minuartia	*M. hamata*	[51,52]
		Paronychia	*P. kurdica*	[51,52]
		Saponaria	*S. viscosa*	[51,52]
		Silene	*S. conoidea*	[45,51,52]
			S. marshallii	[51,52]
			S. spergulifolia	[51,52]
			sp.	[51,52]
		Spergularia	*S. marina*	[49,53]
			S. salina [3]	[49,53]
		Velezia	*V. rigida*	[51,52]
	Frankeniaceae	*Frankenia*	*F. hirsuta*	[49,51–53]
			F. pulverulenta	[49,51–53]
	Plumbaginaceae	*Acantholimon*	sp.	[51,52]
		Limonium	*L. bellidifolium*	[49]
			L. carnosum	[49]
			L. caspium	[51,52]
			L. gmelinii	[49]
			L. meyeri	[49,52,53]
		Psylliostachys	*P. leptostachya*	[49,53]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Caryophyllales	Plumbaginaceae	*Psylliostachys*	*P. spicata*	[49]
	Polygonaceae	*Atraphaxis*	*A. spinosa*	[51,52]
		Polygonum	*P. aviculare*	[51,52]
		Rumex	*R. conglomeratus*	[45,49]
			R. crispus	[49,51,52]
			R. tuberosus	[51,52]
	Tamaricaceae	*Reaumuria*	*R. cistoides*	[52]
		Tamarix	*T. kotschyi*	[49]
			T. octandra	[49]
			T. octandra	[49]
			T. ramosissima	[49,51,52]
Dipsacales	Dipsacaceae	*Dipsacus*	sp.	[45]
		Pterocephalus	*P. canus*	[52]
		Scabiosa	*S. rotata*	[52]
			sp.	[52]
	Valerianaceae	*Valerianella*	*V. amblyotis*	[52]
			V. coronata	[52]
			V. oxyrrhyncha	[52]
			V. vesicaria	[52]
Ephedrales	Ephedraceae	*Ephedra*	*E. procera*	[51,52]
Ericales	Primulaceae	*Androsace*	*A. maxima*	[52]
Fabales	Fabaceae	*Alhagi*	*A. pseudalhagi*	[49,53]
			sp.	[51]
		Astragalus	*A. eriocarpus*	[51,52]
			A. oxyglottis	[51,52]
			sp.	[45,51,52]
		Glycyrrhiza	sp.	[51]
		Lotus	*L. tenuis*	[49]
		Medicago	*M. radiata*	[51,52]
			M. rigidula	[51,52]
			M. sativa	[51,52]
		Trifolium	*T. arvense*	[51,52]
			T. fragiferum	[49]
		Trigonella	*T. asteroides*	[51,52]
			T. filipes	[51,52]
			T. monantha	[51,52]
			T. spruneriana	[51,52]
		Vicia	*V. michauxii*	[51,52]
Gentianales	Rubiaceae	*Callipeltis*	*C. cucullaris*	[51,52]
		Crucianella	*C. gilanica*	[51,52]
			C. latifolia	[51,52]
		Galium	*G. aparine*	[51,52]
			G. verticillatum	[51,52]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Gentianales	Rubiaceae	*Rubia*	sp.	[51,52]
Geraniales	Geraniaceae	*Erodium*	*E. ciconium*	[52]
			E. cicutarium	[51,52]
			E. oxyrrhynchum	[51,52]
		Geranium	*G. rotundifolium*	[51,52]
Lamiales	Lamiaceae	*Eremostachys*	*E. moluccelloides*	[52]
		Hymenocrater	*H. bituminosus*	[52]
		Lamium	*L. amplexicaule*	[52]
		Mentha	*M. longifolia*	[49]
		Salvia	*S. ceratophylla*	[51,52]
			S. hydrangea	[51,52]
			S. multicaulis	[51,52]
			S. reuteriana	[51,52]
			sp.	[51,52]
		Scutellaria	*S. theobromina*	[51,52]
		Sideritis	*S. montana*	[51,52]
		Teucrium	*T. polium*	[51,52]
		Thymus	*T. fedtschenkoi*	[51,52]
		Ziziphora	*Z. capitata*	[51,52]
			Z. tenuior	[51,52]
	Orobanchaceae	*Orobanche*	sp.	[52]
	Plantaginaceae	*Linaria*	*L. micrantha*	[51,52]
			L. simplex	[51,52]
		Plantago	*P. major*	[49]
			P. maritima	[49,53]
		Veronica	*V. anagallis-aquatica*	[49]
			V. beccabunga	[49]
	Scrophulariaceae	*Scrophularia*	*S. variegata*	[51,52]
		Verbascum	*V. nudicaule*	[52]
			V. songaricum	[51,52]
			V. thapsus	[51,52]
Liliales	Liliaceae	*Gagea*	*G. reticulata*	[52]
		Tulipa	*T. montana*	[51,52]
Malpighiales	Euphorbiaceae	*Euphorbia*	*E. heteradenia*	[51,52]
			E. myrsinites	[51,52]
			E. phymatosperma	[51,52]
			E. szovitsii	[52]
	Hypericaceae	*Hypericum*	*H. hyssopifolium*	[52]
			H. scabrum	[52]
	Phyllanthaceae	*Andrachne*	*A. aspera*	[52]
	Violaceae	*Viola*	*V. rupestris*	[51,52]
Malvales	Cistaceae	*Helianthemum*	*H. ledifolium*	[51,52]
	Thymelaeaceae	*Daphne*	*D. mucronata*	[52]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Malvales	Thymelaeaceae	*Diarthron*	*D. vesiculosum*	[52]
Myrtales	Onagraceae	*Chamerion*	*C. angustifolium*	[49]
Pinales	Cupressaceae	*Juniperus*	*J. excelsa*	[51,52]
Poales	Cyperaceae	*Bolboschoenus*	*B. maritimus*	[49]
		Carex	*C. distans*	[49]
			C. divisa	[49]
			sp.	[51,52]
		Cyperus	*C. fuscus*	[49]
			C. laevigatus	[49]
		Eleocharis	*E. palustris*	[49]
	Juncaceae	*Juncus*	*J. acutus*	[49]
			J. gerardii	[49]
			J. heldreichianus	[49]
			J. inflexus	[49]
			J. maritimus	[49]
	Poaceae	*Aegilops*	*A. columnaris*	[51]
			A. triuncialis	[51,52]
		Aeluropus	*A. littoralis*	[45,49,52,53]
		Agropyrum	*A. elongatum*	[49]
		Agrostis	*A. stolonifera*	[49]
		Alopecurus	*A. arundinaceus*	[49]
		Arrhenatherum	*A. kotschyi*	[52]
		Avena	*A. fatua*	[51,52]
			sp.	[51]
		Beckmannia	*B. eruciformis*	[49]
		Bromus	*B. danthoniae*	[51,52]
			B. scoparius	[45]
			B. tectorum	[52]
		Catabrosa	*C. aquatica*	[49]
		Crypsis	*C. schoenoides*	[49]
			C. vaginiflora	[49]
		Cynodon	*C. dactylon*	[49]
		Eremopyrum	*E. triticeum*	[49]
			F. arundinacea	[49]
		Festuca	sp.	[51]
		Gaudinopsis	*G. macra*	[52]
		Hordeum	*H. geniculatum*	[49]
			H. leporinum	[52]
			H. spontaneum	[52]
			sp.	[51]
		Melica	*M. jacquemontii*	[52]
		Nardurus	*N. subulatus*	[52]
		Parapholis	*P. incurva*	[49]
		Phleum	sp.	[51]
		Phragmites	*P. australis*	[45,49,51,52]
		Poa	*P. bulbosa*	[51,52]
			P. persica [4]	[52]

Table 4. *Cont.*

Order	Family	Genus	Species	Reference
Poales	Poaceae	*Polypogon*	*P. trivialis*	[49]
			P. monspeliensis	[49]
			P. semiverticillata	[49]
		Puccinellia	*P. bulbosa*	[49,53]
			P. distans	[49]
		Sclerochloa	*S. dura*	[49]
		Stipa	*S. barbata*	[45,51,52]
		Taeniatherum	*T. crinitum*	[52]
		Zingeria	*Z. trichopoda*	[49]
Ranunculales	Berberidaceae	*Berberis*	*B. integerrima*	[51,52]
		Leontice	*L. leontopetalum*	[52]
	Papaveraceae	*Fumaria*	*F. parviflora*	[51]
			F. vaillantii	[51,52]
		Glaucium [5]	sp.	[51]
		Papaver	*P. argemone*	[51,52]
			P. glaucium	[52]
			sp.	[51,52]
	Ranunculaceae	*Adonis*	*A. aestivalis*	[51,52]
		Batrachium	*B. trichophyllum*	[49]
		Consolida	sp.	[51]
		Delphinium	*D. quercetorum*	[51,52]
		Ranunculus	sp.	[51,52]
		Thalictrum	*T. isopyroides*	[51,52]
			T. sultanabadense	[51,52]
Rosales	Cannabaceae	*Celtis*	*C. glabrata*	[51,52]
	Moraceae	*Ficus*	*F. carica*	[51]
	Rhamnaceae	*Rhamnus*	*R. pallasii*	[51]
	Rosaceae	*Amygdalus*	*A. trichamygdalus*	[51,52]
		Cerasus	*C. microcarpa*	[51,52]
		Cotoneaster	sp.	[51,52]
		Potentilla	*P. recta*	[49]
		Prunus	sp.	[51]
	Urticaceae	*Parietaria*	*P. judaica*	[51,52]
Sapindales	Anacardiaceae	*Pistacia*	*P. atlantica*	[51,52]
	Nitrariaceae	*Nitraria*	*N. sibirica*	[51,52]
		Peganum	*P. harmala*	[51,52]
		Tetradiclis	*T. tenella*	[52]
	Rutaceae	*Haplophyllum*	*H. perforatum*	[52]
	Sapindaceae	*Acer*	*A. monspessulanum*	[51,52]
Saxifragales	Crassulaceae	*Rosularia*	*R. persica*	[52]
		Sedum	*S. hispanicum*	[52]
Sphaerocarpales	Riellaceae	*Riella*	aff. *Cossoniana* [6]	[50]
Solanales	Convolvulaceae	*Convolvulus*	*C. lineatus*	[51,53]
		Cressa	*C. cretica*	[49]

Table 4. *Cont*.

Order	Family	Genus	Species	Reference
Solanales	Convolvulaceae	*Cuscuta*	sp.	[51]
	Solanaceae	*Hyoscyamus*	*H. pusillus*	[51,52]
		Lycium	*L. ruthenicum*	[49,51,52]
		Solanum	sp.	[51]
Zygophyllales	Zygophyllaceae	*Zygophyllum*	*Z. fabago*	[51,52]

Reference: [45] Khara (2004); [49] Asri and Ghorbanli (1997); [50] Djamali *et al.* (2008); [52] Zehzad (1989); [53] Asri (1993); [51] Nasiri *et al.* (1996); [1] synonym with *Muscari caucasicum*; [2] synonym with *Salicornia herbacea* and *Salicornia herbacea*; [3] synonym with *Spergularia media*; [4] synonym with *Eremopoa persica*; [5] synonym with *Glacium*; [6] see text.

6. Brine Shrimp *Artemia*

The brine shrimp *Artemia* (Crustacea: Anostraca) is a small crustacean adapted to hypersaline habitats, of Urmia Lake. It was first reported from the lake in 982, more than one thousand years ago [54]. In Curzon's published work "Persia and the Persian Question" (1892, Volume i, p. 533), he described *Artemia* as a species of small "Jelly-Fish" [55,56]. In the first reports of A. Günther and R.T Günther, it was interpreted as a "Medusa", "a species of *Branchipus*" [57] and "the *Artemia* group of varieties of the *Branchipus* type" [58]. Finally, Günther pointed out that this bisexual species belongs to the genus *Artemia* [59] (p. 509), and the species was nomenclatured as *Artemia urmiana* [60] (p. 395).

Barigozzi *et al*. (1987) [61] reported the existence of only parthenogenetic populations of *Artemia* based on a single sample from Urmia Lake. However, another study of *Artemia* cysts (which are encysted gastrula embryos) collected from the western shore-line of Urmia Lake in 1987 revealed that Urmia Lake has both bisexual and parthenogenetic populations in the surrounding lagoons, especially on the western shore of the lake [62]. Sediment cores suggest that parthenogenetic populations of *Artemia* have lived in Urmia Lake for at least 5000 years [11]; however, the oldest remains of *Artemia* that have been recovered from a sediment core from this lake are 200,000 years old [63]. The two parthenogenetic *Artemia* populations from the Urmia Lake basin (those in the coastal lagoons and interior of the lake) have been tentatively attributed to two morphotypes that are not yet completely separated [64]. Several studies have shown that biometrical, morphometrical and genetic variations exist in *A*. *urmiana* [65–67]. The results indicate that ecological speciation is an ongoing process in Urmia Lake [67].

7. Brine Fly *Ephydra*

The brine fly *Ephydra urmiana* (Diptera: Ephydridae) has been described by R.T. Günther near the margin of the Urmia Lake (the mouth of the Nazlu Chai (Nazlu River) at Superghan [Suporqun]) [68] (p. 415). Breeding and feeding of *E*. *urmiana* totally depends on the lake. Eggs of the genus *Ephydra* are attached to an algae mat [69]. The main food sources of adults and larvae are algae, some bacteria, and protozoa [70–72]. Nemenz [73] had observed adults of *Ephydra cinerea* feeding on masses of algae washed ashore at the Great Salt Lake in Utah, USA.

8. Land and Freshwater Molluscs

The biodiversity of molluscs is documented in Table 5.

Table 5. List of land and freshwater molluscs from the Island of Koyun Daghi (Kaboudan).

Phylum	Class	Order	Family	Genus	Species	Reference
Mollusca	Gastropoda	Stylommatophora	Chondrinidae	*Chondrina*	*P. granum* [1]	[74]
			Enidae	*Geminula*	*G. isseliana* [2]	[74]
					G. continens [3]	[74]
			Hygromiidae	*Helicella*	*H. acutistria*	[74]
			Pupillidae	*Gibbulinopsis*	*G. signata* [4]	[74]

[1] synonymous with Pupa granum; [2] synonymous with Buliminus (Chondrulus) didymodus; [3] synonymous with Buliminus (Amphiscopus) continens; [4] synonymous with Pupa signata.

9. Birds

The islands, beaches, and lagoons of Urmia Lake are excellent habitats for resident breeding species and winter visitors. Several species which love saline lakes with a rich food source, such as flamingos, terns, gulls and waders, are typical residents or migrants to Urmia Lake. Table 6 lists the birds of Urmia Lake National Park basin and surrounding regions, a list which is apparently incomplete, especially for migrant species.

Table 6. List of birds from Urmia Lake National Park basin and surrounding regions. (B = breeder, SM = summer migrant, WM = winter migrant, PM = passage migrant).

Order	Family	Genus	Species	Status	Reference
Accipitriformes	Accipitridae	*Accipiter*	*A. nisus*	WM	[75]
		Aegypius	*A. monachus*	B	[75]
		Aquila	*A. chrysaetos*	B	[51,75]
			A. clanga	PM	[76]
		Buteo	*B. buteo*	PM	[76]
			B. rufinus	B	[75]
		Circaetus	*C. gallicus*	B	[76]
		Circus	*C. aeruginosus*	B, PM	[69]
			C. cyaneus	PM, WM	[76]
			C. macrourus	PM	[76]
			C. pygargus	B	[76]
		Gypaetus	*G. barbatus*	B	[76]
		Gyps	*G. fulvus*	B	[51,75]
		Haliaetus	*H. albicilla*	WM	[75]
		Neophron	*N. percnopterus*	B, PM	[51,75,76]
		Milvus	*M. migrans*	B, PM	[76]
Anseriformes	Anatidae	*Anas*	*A. acuta*	WM, SM	[51,75,76]
			A. clypeata	WM, B, PM	[51,75,76]
			A. crecca	B, PM	[76]
			A. platyrhynchos	B, WM	[51,75]

Table 6. *Cont.*

Order	Family	Genus	Species	Status	Reference
Anseriformes	Anatidae	*Anas*	*A. penelope*	WM, PM	[76]
			A. querquedula	B, PM	[76]
			A. strepera	WM, PM	[76]
		Anser	*A. erythropus*	WM	[76]
			A. albifrons	WM	[76]
			A. anser	B, WM	[51,75,76]
		Aythya	*A. ferina*	PM	[76]
			A. nyroca	B	[76]
			A. fuligula	PM,WM	[76]
		Bucephala	*B. clangula*	PM	[76]
		Cygnus	*C. bewickii*	WM	[76]
			C. cygnus	WM	[51,75]
			C. olor	WM	[76]
		Marmaronetta	*M. angustirostris*	B, WM	[76]
		Mergus	*M. albellus*	WM	[76]
			M. merganser	WM	[76]
		Oxyura	*O. leucocephala*	B	[51,75]
		Tadorna	*T. ferruginea*	B, PM	[51,75,76]
			T. tadorna	B, PM	[51,75,76]
Apodiformes	Apodidae	*Apus*	*A. apus*	B, PM	[76]
			A. melba	B, PM	[76]
Bucerotiformes	Upupidae	*Upupa*	*U. epops*	B, PM	[76]
Caprimulgiformes	Caprimulgidae	*Caprimulgus*	*C.europaeus*	B	[76]
Charadriiformes	Burhinidae	*Burhinus*	*B. oedicnemus*	B	[51,75]
	Charadriidae	*Charadrius*	*C. asiaticus*	PM	[76]
			C. alexandrinus	B, PM	[76]
			C. dubius	B, PM	[76]
			C. hiaticula	PM	[76]
			C. leschenaultii	B	[76]
			C. morinellus	PM	[76]
		Pluvialis	*P. squatarola*	PM	[76]
		Vanellus	*V. indicus*	PM	[76]
			V. spinosus	B	[76]
			V. vanellus	B, WM	[51,75,76]
	Glareolidae	*Glareola*	*G. pratincola*	B	[75]
	Haematopodidae	*Haematopus*	*H. ostralegus*	B	[76]
	Laridae	*Chroicocephalus*	*C. genei*	B, PM	[76]
			C. ridibundus	B, PM	[75,76]
		Hydrocoloeus	*H. minutus*	WM	[76]
		Larus	*L. cachinnans*	WM	[76]
			L. ichthyaetus	WM	[76]
			L. armenicus	B	[75]
			L. canus	WM	[75]
	Recurvirostridae	*Himantopus*	*H. himantopus*	B, PM	[51,75,76]

Table 6. *Cont.*

Order	Family	Genus	Species	Status	Reference
Charadriiformes	Recurvirostridae	*Recurvirostra*	*R. avosetta*	B, PM	[76]
	Scolopacidae	*Arenaria*	*A. interpres*	PM	[76]
		Calidris	*C. alpina*	PM, WM	[76]
			C. minuta	PM	[76]
			C. temminckii	PM	[76]
			C. ferruginea	PM	[76]
		Actitis	*A. hypoleucos*	B, PM	[75,76]
		Gallinago	*G. gallinago*	WM, PM	[75,76]
		Limosa	*L. limosa*	WM, PM	[76]
		Lymnocryptes	*L. minimus*	PM	[76]
		Numenius	*N. arquata*	PM, WM	[76]
			N. phaeopus	PM	[76]
		Phalaropus	*P. lobatus*	PM	[76]
		Philomachus	*P. pugnax*	PM	[76]
		Tringa	*T. erythropus*	WM, PM	[76]
			T. glareola	PM	[76]
			T. ochropus	PM	[76]
			T. nebularia	PM	[76]
			T. stagnatilis	PM	[76]
			T. totanus	B, PM	[76]
		Xenus	*X. cinereus*	PM	[76]
	Stercorariidae	*Stercorarius*	*S. pomarinus*	PM	[76]
	Sternidae	*Chlidonias*	*C. niger*	PM	[76]
			C. hybridus	B, PM	[76]
			C. leucopterus	PM	[51,75]
		Gelochelidon	*G. nilotica*	B, PM	[76]
		Sternula	*S. albifrons*	B	[76]
		Sterna	*S. hirundo*	B, PM	[76]
		Hydroprogne	*H. caspia*	B, PM	[76]
Ciconiiformes	Ciconiidae	*Ciconia*	*C. ciconia*	B, SM	[51,75]
			C. nigra	PM	[76]
Columbiformes	Columbidae	*Columba*	*C. livia*	B	[51,75]
			C. oenas	B	[75]
			C. palumbus	B, WM	[51,76]
		Streptopelia	*S. decaocto*	PM	[76]
			S. turtur	B, PM	[76]
Coraciiformes	Cerylidae	*Ceryle*	*C. rudis*	PM	[76]
	Coraciidae	*Coracias*	*C. garrulus*	B, PM	[76]
	Meropidae	*Merops*	*M. apiaster*	B, PM	[76]
			M. persicus	B	[76]
Falconiformes	Falconidae	*Falco*	*F. biarmicus*	B	[75]
			F. cherrug	B, WM	[75,76]
			F. columbarius	PM	[75,76]
			F. peregrinus	B, PM	[76]

Table 6. *Cont.*

Order	Family	Genus	Species	Status	Reference
Falconiformes	Falconidae	*Falco*	*F. naumanni*	B	[77]
			F. subbuteo	B, PM	[75,76]
			F. tinnunculus	B,WM	[51,75,76]
Galliformes	Phasianidae	*Alectoris*	*A. chukar*	B	[51,75]
		Coturnix	*C. coturnix*	B, PM	[51,75]
		Perdix	*P. perdix*	B	[76]
		Tetraogallus	*T. caspius*	B	[76]
Gruiformes	Gruidae	*Grus*	*G. grus*	PM	[75]
	Rallidae	*Fulica*	*F. atra*	B	[51,75]
		Gallinula	*G. chloropus*	B, WM	[51,75,76]
		Rallus	*R. aquaticus*	PM	[76]
Otidiformes	Otididae	*Otis*	*O. tarda*	B, WM, PM	[76]
Passeriformes	Acrocephalidae	*Acrocephalus*	*A. arundinaceus*	B	[76]
			A. dumetorum	PM	[76]
			A. schoenobaenus	PM	[76]
			A. scirpaceus	B, PM	[76]
			A. melanopogon	B	[76]
	Alaudidae	*Calandrella*	*C. brachydactyla*	B	[76]
			C. rufescens	B, WM,PM	[76]
		Eremophila	*E. alpestris*	WM	[76]
		Galerida	*G. cristata*	B	[75]
		Melanocorypha	*M. calandra*	B, PM	[76]
			M. bimaculata	B, PM	[75,76]
	Cettiidae	*Cettia*	*C. cetti*	B	[76]
	Cinclidae	*Cinclus*	*C. cinclus*	B	[76]
	Corvidae	*Corvus*	*C. corax*	B	[51,75]
			C. frugilegus	B, WM	[76]
			C. cornix	B	[76]
			C. monedula	B, WM	[76]
		Garrulus	*G. glandarius*	B	[75]
		Pica	*P. pica*	B	[51,75]
		Pyrrhocorax	*P. graculus*	B	[75]
			P. pyrrhocorax	B	[51,75,76]
	Emberizidae	*Emberiza*	*E. cineracea*	PM	[76]
			E. citrinella	WM	[76]
			E. calandra	B, WM	[75,76]
			E. melanocephala	B	[76]
			E. schoeniclus	B, PM, WM	[76]
	Fringillidae	*Carduelis*	*C. cannabina*	PM, WM	[76]
			C. carduelis	B, WM	[76]
			C. flavirostris	WM	[76]
			C. spinus	WM	[76]
		Fringilla	*F. coelebs*	B, PM	[76]

Table 6. *Cont.*

Order	Family	Genus	Species	Status	Reference
Passeriformes	Fringillidae	*Rhodopechys*	*R. sanguinea*	B, WP	[75,76]
	Hirundinidae	*Delichon*	*D. urbicum*	B	[76]
		Hirundo	*H. rustica*	B	[76]
		Riparia	*R. riparia*	B, PM	[76]
	Laniidae	*Lanius*	*L. collurio*	B, PM	[76]
			L. minor	B	[76]
			L. senator	PM, WM	[76]
	Motacillidae	*Anthus*	*A. campestris*	B, PM	[76]
			A. cervinus	PM	[76]
			A. pratensis	WM	[76]
			A. spinoletta	B, PM, WM	[76]
			A. trivialis	PM	[76]
		Motacilla	*M. alba*	B, WM	[75]
			M. citreola	PM	[51]
			M. flava	B, PM	[51,75,76]
	Muscicapidae	*Cercotrichas*	*C. galactotes*	B, PM	[76]
		Luscinia	*L. svecica*	PM	[76]
		Oenanthe	*O. deserti*	B, PM	[76]
			O. hispanica	B	[76]
			O. finschii	B, PM	[76]
			O. isabellina	B, PM	[76]
			O. oenanthe	B, PM	[76]
		Erithacus	*E. rubecula*	WM	[75]
		Luscinia	*L. megarhynchos*	B	[76]
		Phoenicurus	*P. ochruros*	B	[76]
		Saxicola	*S. rubicola*	B, PM	[76]
		Monticola	*M. saxatilis*	B	[77]
		Turdus	*T. pilaris*	WM	[76]
			T. viscivorus	WM	[76]
	Oriolidae	*Oriolus*	*O. oriolus*	B, PM	[76]
	Paridae	*Cyanistes*	*C. caeruleus*	B, WM	[76]
		Parus	*P. major*	B	[76]
	Passeridae	*Carpospiza*	*C. brachydactyla*	B	[76]
		Passer	*P. montanus*	B	[76]
			P. domesticus	B	[51,75]
		Petronia	*P. petronia*	B	[76]
	Phylloscopidae	*Phylloscopus*	*P. collybita*	PM	[76]
			P. trochiloides	PM	[76]
	Remizidae	*Remiz*	*R. pendulinus*	B	[76]
	Sittidae	*Sitta*	*S. tephronota*	B	[76]
	Sturnidae	*Pastor*	*P. roseus*	B, PM	[76]
		Sturnus	*S. vulgaris*	B	[51,75]
		Sylvia	*S. communis*	B, PM	[76]

Table 6. *Cont.*

Order	Family	Genus	Species	Status	Reference
Passeriformes	Sturnidae	*Sylvia*	*S. mystacea*	B, PM	[76]
			S. nisoria	PM	[76]
			S. curruca	PM	[77]
	Tichodromadidae	*Tichodroma*	*T. muraria*	B	[76]
	Troglodytidae	*Troglodytes*	*T. troglodytes*	WM	[76]
Pelecaniformes	Ardeidae	*Ardea*	*A. alba*	WM	[76]
			A. cinerea	B, WM, PM	[51,75,76]
			A. purpurea	B, PM	[76]
		Ardeola	*A. ralloides*	B, PM	[76]
		Botaurus	*B. stellaris*	PM	[51,75]
		Egretta	*E. garzetta*	B, WM,PM	[51,75,76]
		Ixobrychus	*I. minutus*	B	[76]
		Nycticorax	*N. nycticorax*	B	[76]
	Pelecanidae	*Pelecanus*	*P. onocrotalus*	B	[76]
	Threskiornithidae	*Platalea*	*P. leucorodia*	PM	[76]
		Plegadis	*P. falcinellus*	B, PM	[76]
Phoenicopteriformes	Phoenicopteridae	*Phoenicopterus*	*P. ruber*	B, WM	[51,75,76]
Piciformes	Picidae	*Dendrocopos*	*D. syriacus*	B	[51,75]
Podicipediformes	Podicipedidae	*Podiceps*	*P. nigricollis*	B, WM, PM	[76]
			P. cristatus	B, WP,WM	[75,76]
		Tachybaptus	*T. ruficollis*	B, WP	[51,75]
Pteroclidiformes	Pteroclidae	*Pterocles*	*P. orientalis*	B	[76]
Strigiformes	Strigidae	*Athene*	*A. noctua*	B	[51,75]
		Bubo	*B. bubo*	B	[51,75]
		Strix	*S. aluco*	B	[51,75]
Suliformes	Phalacrocoracidae	*Phalacrocorax*	*P. carbo*	WM	[76]
			P. pygmeus	WM	[76]

Reference: [51] Nasiri *et al.* (1996); [75] Alipour (2009); [76] Aliabadian (2013) (personal communication); Taxonomical status has been checked with Wink (2013) [77].

10. Amphibians and Reptiles

The Urmia Lake area harbours several amphibian and reptile species (Table 7). Amphibian and reptile communities might be faced with a possible threat of extinction due to unsuitable ecological conditions in Urmia Lake. Special care should be taken to maintain these species in the lake.

Table 7. List of amphibia and reptiles from Urmia Lake.

Class	Order	Family	Genus	Species	Locality	Ref.
Amphibia	Anura	Bufonidae	*Pseudepidalea*	*P. viridis* [1]	some islands of Urmia Lake and the shores of Urmia Lake	[51,75]
		Hylidae	*Hyla*	*H. savignyi*	the shores of Urmia Lake	[75]
		Ranidae	*Rana*	*R. ridibunda*	the shores of Urmia Lake	[75]
	Caudata	Salamandridae	*Neurergus*	*N. crocatus* [2]	west mountains of Urmia Lake	[78–80]
Reptilia	Squamata	Agamidae	*Paralaudakia*	*P. Caucasia* [3]	some islands of Urmia Lake	[75]
			Trapelus	*T. lessonae*	has been collected around the lake in 2012	[81]
		Colubridae	*Coluber*	*C. Schmidti* [4]	some islands of Urmia Lake and the shores of Urmia Lake	[51,75]
			platyceps	*P. najadum* [5]	the shores of Urmia Lake	[75]
			Eirenis	*E. punctatolineatus*	the shores of Urmia Lake	[75]
			Hemorrhois	*H. ravergieri* [6]	the shores of Urmia Lake	[75]
			Telescopus	*T. fallax*	the shores of Urmia Lake	[75]
		Geckonidae	*Cyrtopodion*	*C. scabrum*	has been collected around the lake in 2012	[81]
		Lacertidae	*Apathya*	*A. cappadocica* [7]	some islands of Urmia Lake	[75]
		Lacertidae	*Eremias*	*E. arguta*	the shores of Urmia Lake	[75]
			Ophisops	*O. elegans*	Islands of Aruz and Shazalan (shah-saran)	[82]
		Scincidae	*Ablepharus*	*A. bivittatus*	the shores of Urmia Lake	[75]
			Eumeces	*E. schneideri*	Island of Koyun Daghi (Kaboudan) and Shazalan (shah-saran)	[82]
			Trachylepis	*T. aurata* [8]	Island of Koyun Daghi (Kaboudan)	[82]
		Viperidae	*Macrovipera*	*M. lebetina* [9]	some islands of Urmia Lake and the shores of Urmia Lake	[51,75]
	Testudines	Testudinidae	*Testudo*	*T. ibera* [10]	Island of Koyun Daghi (Kaboudan)	[83]

Reference: [51] Nasiri *et al.* (1996); [75] Alipour (2009); [78] Cope (1862); [79] Stöhr *et al.* (2013); [80] Najafi-Majd and Kaya (2013); [81] Boulenger (1899); [82] Günther (1899); [83] Rastegar-Pouyani (2013) (personal communication); [1] synonymous with *Bufo viridis*; [2] Urmia Lake newt; [3] synonymous with *Laudakia caucasia*; [4] synonymous with *Coluber jugularis*; [5] synonymous with *Coluber najadum*; [6] synonymous with *Coluber ravergieri*; [7] subspecies: *Apathya Cappadocica urmiana*; synonym with *Lacerta cappadocica urmiana*; [8] subspecies: *Treachylepis aurata transcaucasica***;** synonym with *Trachylepis septemtaeniata*; [9] subspecies: *Macrovipera lebetina optusa*; synonym with *Vipera xanthina* and *Vipera lebetina*; [10] synonymous with *T. graeca*, this species has been reported only from fragments of a carapace reported from islands of Urmia Lake [83].

11. Mammals

Some Armenian sheep, *Ovis orientalis gmilini*, were transferred to Kaboudan Island in 1895 and 1906 by one of the governors of Azerbaijan [84]. In 1970 and 1971, in order to control the population of Armenian sheep, two leopards, *Panthera pardus*, were introduced on Kaboudan Island; however, their corpses were found in 1982. During 1993, 49, and in 1995, 98 Armenian Sheep were transferred from Kaboudan Island to the Islami Peninsula [51,75,85].

Fifty-two Persian fallow deer, *Dama dama mesopotamica*, were transferred to Ashk Island between 1977 and 1989. Also in 1989, six of these deer (three males and three females) were introduced to Kaboudan Island in order to study their ecology [51,75,85]. Table 8 lists the Mammals of Urmia Lake National Park.

Table 8. List of mammals from Urmia Lake.

Order	Family	Genus	Species	Locality	Reference
Artiodactyla	Bovidae	*Ovis*	*O. orientalis* [1]	Kaboudan Island and Islami Peninsula	[51,75,84,85]
	Cervidae	*Dama*	*D. dama* [2]	Kaboudan Island and Ashk Island	[51,85]
Carnivora	Canidae	*Canis*	*C. aureus*	the shores of Urmia Lake	[75]
			C. lupus	the shores of Urmia Lake	[75]
		Vulpes	*V. vulpes*	the shores of Urmia Lake	[75]
	Felidae	*Panthera*	*P. pardus* [3]	Kaboudan Island	[51,75,85]
	Mustelidae	*Martes*	*M. foina*	the shores of Urmia Lake	[75]
		Mustela	*M. nivalis*	the shores of Urmia Lake	[75]
Chiroptera	Emballonuridae	*Taphozous*	*T. nudiventris*	some islands of Urmia Lake and the shores of Urmia Lake	[75]
	Rhinolophidae	*Rhinolophus*	*R. ferrumequinum*	some islands of Urmia Lake and the shores of Urmia Lake	[75]
	Vespertilionidae	*Myotis*	*M. blythii*	some islands of Urmia Lake and the shores of Urmia Lake	[75]
			M. mystacinus	some islands of Urmia Lake and the shores of Urmia Lake	[75]
		Pipistrellus	*P. kuhlii*	some islands of Urmia Lake and the shores of Urmia Lake	[75]
			P. pipistrellus	some islands of Urmia Lake and the shores of Urmia Lake	[75]
			P. savii	some islands of Urmia Lake and the shores of Urmia Lake	[75]
Insectivora	Erinaceidae	*Erinaceus*	*E. europaeus*	the shores of Urmia Lake	[75]
	Soricidae	*Crocidura*	*C. russula*	the shores of Urmia Lake	[75]
Lagomorpha	Leporidae	*Lepus*	*L. capensis*	the shores of Urmia Lake	[75]
Rodentia	Cricetidae	*Arvicola*	*A. amphibious* [4]	the shores of Urmia Lake	[75]
		Cricetulus	*C. migratorius*	the shores of Urmia Lake	[75]
	Dipodidae	*Allactaga*	*A. elater*	the shores of Urmia Lake	[75]
	Muridae	*Apodemus*	*A. sylvaticus*	the shores of Urmia Lake	[51,75]
		Meriones	*M. persicus*	the shores of Urmia Lake	[75]
		Mus	*M. musculus*	some islands of Urmia Lake and the shores of Urmia Lake	[51,75]

Reference: [51] Nasiri *et al.* (1996); [75] Alipour (2009); [84] Günther (1899); [85] Ziaie (1996); [1] subspecies: *Ovis orientalis gmelini*; [2] subspecies: *Dama dama mesopotamica*; [3] They do not presently exist on Kaboudan Island (see text); [4] synonymous with *Arvicola terrestris*.

12. Hidden Biodiversity

Our knowledge of the biodiversity of a given area or ecosystem is based on the species already discovered and described by biologists. However, the list of plants and animals is subject to change in that new species are discovered in the field, taxonomic revisions based on the application of molecular techniques are carried out, or both.

The case of *Riella* aff. *cossoniana*, whose spores have only recently been discovered in ancient and recent sediments of the lake, is worth mentioning [50]. *Riella* is a liverwort extremely rarely encountered in the field, owing to the very particular ecological conditions needed for the germination of its spores. In Urmia Lake, the spores of this liverwort have been documented in the sediment

archives since about 200,000 years ago, and they are also found in recent sediments, showing that the plant is still thriving in brackish water ponds and springs around the lake. However, despite its presence in sediments of salt lakes in many salt and brackish water wetlands, this plant has never been documented in Iran by botanists [50]. Today, *Riella* is considered an endangered plant in many places in semi-arid regions of the world (e.g., [86]). The above example indicates that the conservation of aquatic ecosystems around the lake is of primordial importance for the conservation of such hidden components of the biodiversity.

13. Urmia Lake Hydrological Variations and their Impact on the Biodiversity

Palaeoecological and geochemical investigations of long sediment cores from Urmia Lake have revealed that lake levels underwent dramatic changes during the glacial-interglacial cycles of the Quaternary period [17,50,87]. Based on the total thickness of the fluvio-lacustrine infill of the Urmia Lake basin, as revealed by geophysical explorations and the dated 100-m long core samples taken from the central basin, the age of the lake can be grossly estimated at >600,000 years. Pollen evidence shows that the aquatic vegetation composition and density has greatly fluctuated in response to these hydrological changes during the last 200,000 years. The most important development of aquatic vegetation took place during glacial, rather than interglacial periods (see Figure 8 in [88] for details). During the Last Glacial (70 ka to 17 ka) and Penultimate Glacial (190 ka to 130 ka), numerous time intervals with extensive development of fresh- to brackish water macrophytic vegetation may be observed. These periods have been interpreted as high lake levels during which the lake chemistry became considerably less saline [50]. Although the glacial periods are known as periods with a significant loss of biodiversity, they were times of a more diversified plant and most probably animal life within the lake and in its associated ecosystems. The presence of several peaks of brackish to fresh water dinoflagellates and *Pediastrum* (green alga) indicate that the algal life also increased in response to the dilution of lake water [17,50,87,88].

14. Conclusions

The biodiversity of Urmia Lake is impressive, even if the species inventory is far from being complete. More and detailed studies, probably including the use of DNA barcoding, are needed to document the composition of this hypersaline lake, which faces the threat of vanishing. Saline lakes provide a fragile environment which needs careful protection to avoid the extinction of highly adapted species. Palaeoecological evidence clearly shows that dramatic lake level fluctuations have always been part of the lake's history and have modulated the diversity and dynamics of microbial plant and animal life in the lake. The recent environmental crisis of Urmia Lake is not an excuse to intervene in such a fragile ecosystem. Wiser restoration strategies should be selected in such a way as to minimize the artificial interventions in the lake and associated ecosystems.

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Conflicts of Interest

The authors declare no conflict of interest. MW is Editor-in-Chief of DIVERSITY.

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