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On the red coloration of Urmia Lake (Northwest Iran)

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In summer 2010, the Urmia Lake water was changed to a pinkish-purple color in several areas such as two sides of the causeway (Fig 1). To investigate on the reasons of this color change, we collected water samples for phytoplankton and some physicochemical parameters analyses from six sampling sites on the both sides of the lake causeway on August 18th 2010 (Table 1). Phytoplankton samples were immediately fixed by 4% formaldehyde and preserved in cold, dark conditions for laboratory analysis. Phytoplankton counting and identification were made using 5-ml settling chambers with a Nikon TS100 inverted microscope at ×400 magnification by Utermöhl (1958) method.

Figure 1- Urmia Lake in the sampling site (north of causeway) on August 18th 2010

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Table 1- The location of sampling sites

Sampling site	Number
north of Causeway-Urmia city entrance	1
north of Causeway-5 km	2
North of the causeway: bridge	3
South of Causeway-5 km	4
South of Causeway- under the bridge	5
Causeway- under the bridge	6

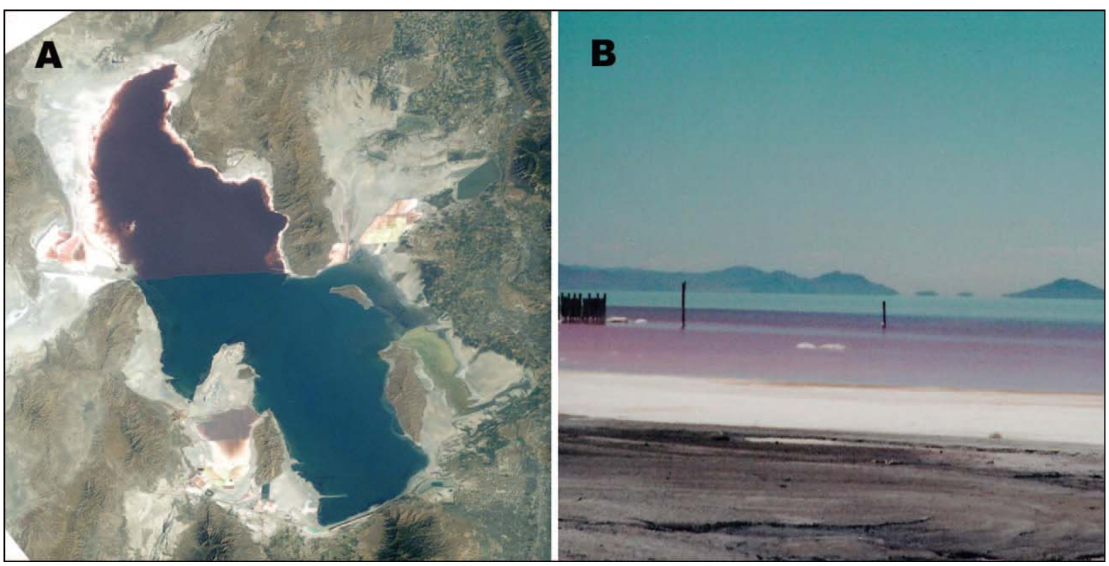
The phytoplankton population of Urmia lake has mainly composed of a unicellular green alga namely *Dunaliella* which included about more than 90% of the whole phytoplankton density of the lake. Other phytoplanktons such as a few species of diatoms like *Nitzschia* and *Navicula* play only a minor role in phytoplankton composition of the lake (Mohebbi et al., 2009).

In the present study, *Dunaliella* yet contained even more abundance than previous studies in Urmia Lake (e.g. Mohebbi et al., 2009; Shoa hasani 1996) (Table 2). On the other hand, we observed *Dunaliella* as two different morphological varieties differed from each other by their colors: a green and a red colored *Dunaliella* which apparently the latter had higher concentrations of carotenoid pigment than the first. As shown in table 2, however, there were no significant differences among sampling sites regarding these two morphological forms density. Therefore, though the increased red colored (morphological form) *Dunaliella* density may be attributed to the saturation of the lake water and other extreme conditions, but it cannot have a basic role in color shift of the lake. As a matter of fact, although β-carotene derived from *Dunaliella* may be the most abundant carotenoid pigment in the hypersaline water, its dense packaging within granules inside the cell's chloroplast greatly decreases its contribution to the overall light absorbance in the water. As a result, most of the pink-red color of the hypersaline environments is caused by α-bacterioruberin and other bacterioruberin derivatives present in the family of Halobacteriaceae (Fernandez-Castillo et al., 1986).

The North Arm of Great Salt Lake, Utah, with salt concentrations above 300 g l^{-1} shows similar color changes (Post 1977; Baxter et al. 2005). A railroad causeway built in 1959 divided Great Salt Lake into northern and southern sections, leading to dilution of the southern section, and concentration of the northern section to nearly saturating salinity. The red color is the result of a bloom of extreme halophiles, which can reach 10^8 cells.ml^{-1} or greater concentration in the north arm (DasSarma, 2006) (Fig.2).

Table 2- Phytoplankton density (cells.ml^{-1}) at sampling sites of Urmia Lake on August 18th 2010

	Sampling Site					
Alga	1	2	3	4	5	6
Dunaliella (green)	576	419	447	467	765	519
Dunaliella (red)	19	315	253	19	18	287
Symbella	-	-	5	-	-	-
Total	595	735	705	486	783	806



Figurer 2- Great Salt Lake from space (A) and the north section from ground level (B)

Solar salt ponds are established all over the world in many tropical and subtropical regions to produce salts from seawater. The seawater is evaporated by a step by step process through shallow ponds which have relatively constant salinity, so that each set of ponds contains particular microbial population which adapted to same salt concentration. At the last step of evaporation process, the salt concentration rises to more than 300 gl^{-1} in crystallization ponds. In this situation, the main microbial communities are as planktonic populations which give a pink-reddish color to water (Javor, 1989).

In fact, α-bacterioroberin and its other 50-carbon derivatives present in Archaea from Halobacteriaceae play the major role in establishing such a pink-reddish color in crystallization ponds. It can be concluded that a similar mechanism contributed in color change of brine water both at natural hypersaline waters and at man-made solar salt ponds. This is a biological process in which Halobacteriaceae with its vast number of genera and a few recently identified bacteria involved in water color shift in NaCl saturated water.

Conclusion

Briefly, when water salinity exceeds saturation levels, the density of halophilic bacteria increases to more than 10^8 $cells.ml^{-1}$. Since the bacterioroberin are distributed evenly on the cell membranes in these prokaryotic cells, so can absorbe light more efficiently than pigments of eukaryotic *Dunaliella*.

Water saturation, as well as high temperatures induces a large growth in the number of halophilic bacteria in Urmia Lake. The presence of these bacteria in Urmia Lake has recently been investigated by several authors (e.g. Amoozegar and Zahraei, 2007; Arash Rad, 2000; Asgarani et al., 2006; Bahari et al., 2009 and Rafiee et al., 2007). In conclusion, the role of prokaryotic halophilic bacteria is more than *Dunaliella* in red coloration of saturated water including Urmia Lake.

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