Drought in Urmia Lake, the largest natural habitat of brine shrimp *Artemia*

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Urmia Lake is an oligotrophic and extremely hypersaline lake that is the largest natural habitat of brine shrimp *Artemia* (Ahmadi 2005, Eimanifar and Mohebbi 2007). It has a surface area between 4000 and 6000 km^2 and a maximum depth of 16 m, located in northwestern Iran at an elevation of 1274 m. Salinity of lake water ranges between 120 and 280 g/L. Urmia Lake is the saltiest lake on earth with an active food web. It is a UNESCO biosphere reserve and a Ramsar wetland (Asem *et al*. 2010).

Urmia Lake has been experiencing a serious ecological crisis over the past decade. Lake water is saturated with salts to the point where salt crystals form on the lake surface year round. The salinity of Urmia Lake has increased from 169 g/L in 1995 to more than 300 g/L in 2003-2004 (Fig. 1) (Sorgeloos 1997, Ahmadi 2005, 2007). Many hectares of surrounding land have been converted to salt marshes and, in the southern and southeastern areas, the coastline has retreated several kilometers (Fig. 2). The salt-saturated water of the lake has disrupted the development of waterbirds (Fig. 3).

In 1995, *Artemia urmiana* cyst production (dry weight) in the surface half-meter of Urmia Lake was calculated by integration and summation to range from 4243 to 4536 t/yr. The lake area was estimated to be 5500 km^2 that year.

The concentration of cysts can be estimated as follows:

1) lake area in 1995: 5500 km^2 = 5,500,000,000 m^2
2) volume in 0.5 m of lake surface = 5,500,000,000 × 0.5 = 275 × 10^7 m^3 = 275 × 10^{10} L
3) 1 g of cysts = 250,000 cysts (Sorgeloos 2007) mean biomass of dry cysts in 0.5 m of lake surface (t) = (a_i + a_s)/2 = (4243 + 4536)/2 = 4389 t/yr = 438,914 × 10^4 g/yr, where
   a_i = amount of dry cysts calculated by integration
   a_s = amount of dry cysts calculated by summation
5) number of cysts in 0.5 m of lake surface = (438,914 × 10^4) × 250,000 = 10,972,925 × 10^8 cysts
6) concentration of cysts = (10,972,925 × 10^8) / 275 × 10^{10} = 399 cysts/L

Since 2000, with the drought in Urmia Lake, the harvest of *Artemia* cysts has collapsed (Ahmadi 2005). A resource assessment of *A. urmiana* measured cyst concentrations in the surface 20 cm of 27 cysts/L (2003) and 25 cysts/L (2004) (Ahmadi 2005). Cyst concentrations declined further to 11 (2005), 8 (2006), and 3 (2007) cysts/L (Ahmadi

Fig. 1. Clear evidence of the retreating coastline of Urmia Lake.

Fig.2. The difficult and disrupted life of waterbirds.

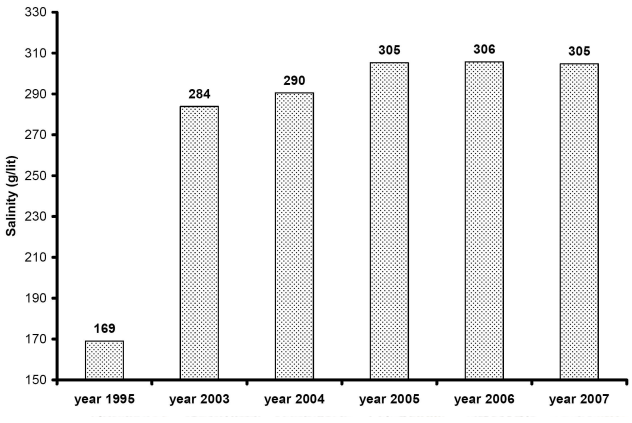

Fig 3. Annual salinity of Urmia Lake in different years

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2007). Although there was no resource assessment of *A. urmiana* after 2007, unofficial reports indicate that there is less than1cyst/L of *Artemia urmiana* in Urmia Lake.

According to an evaluation in West Azerbaijan Province in 2002 (Mohebbi 2002), the establishment of a 100-ha *Artemia* farm, construction of an *Artemia* cyst processing facility with 210 tons capacity, and the establishment of a facility for *Artemia* culture in tanks with a 9000-m^3 capacity, may create 76, 21, and 82 jobs, respectively. With regard to recent drought years and the environmental crisis in Urmia Lake, employment opportunities arising from the harvest, production, and processing of *Artemia* have been lost.

Experts believe the current situation of Urmia Lake is a result of global climate change, dam projects in the watershed, and the development of non-mechanized farming in the lake basin. However, historical documents indicate that Urmia Lake experienced a severe drought more than 200 years ago. In 1800, the maximum depth was only 75 cm. The lake was so shallow that an east-west road was created through the lake bed and oral histories from elders confirm the presence of this road (Tamaddon 1971). This history indicates that Urmia Lake has undergone more extreme droughts than present but the lake subsequently recovered.

Figure 4 shows the water level fluctuations of Urmia Lake from 1965 to 2009 (Ahadnejad Reveshty and Maruyama 2010, Asem *et al.* 2010). Figure 4 indicates that Urmia Lake experienced a drought from 1965 to 1968. The water level in that period matches that of 2003-2004 and the average salinity at that time was conceivably greater than 280 g/L (Asem *et al.* 2010).

Although drought in Urmia Lake has been described as a crisis, this lake ecosystem has also experienced rising water and landward shifts of the shoreline. In 1993-1998, the lake reached its highest historical level (Fig. 4). During that period, hypersaline lake water and the advancing shoreline affected farms and coastal buildings, causing large financial losses. In those years, the average salinity was 180 g/L (Asem *et al.* 2010). Figure 5 shows Osman Yumrugu, the smallest island of Urmia Lake in two different ecological conditions, illustrating the wide range in historical lake elevation. This variability is also indicated in Figure 6, which displays the shoreline of Urmia Lake from 1976 to 2009 (Ahadnejad Reveshty and Maruyama 2010).

Urmia Lake is one of the principle global ecosystems for *Artemia* production. The current drought has negatively affected *Artemia* production and consequently threatens the biodiversity of Urmia Lake National Park.

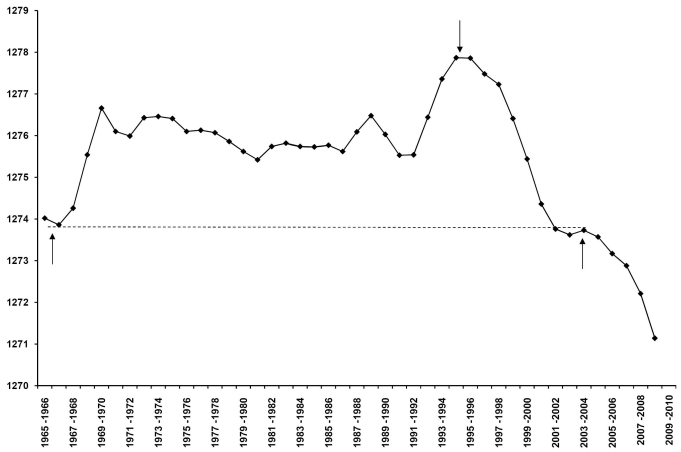

Fig 4. Water level fluctuation of Urmia Lake (1965-2007)

Fig. 5. Osman Yumrugu, the smallest island of Urmia Lake in two different ecological conditions.

Notes

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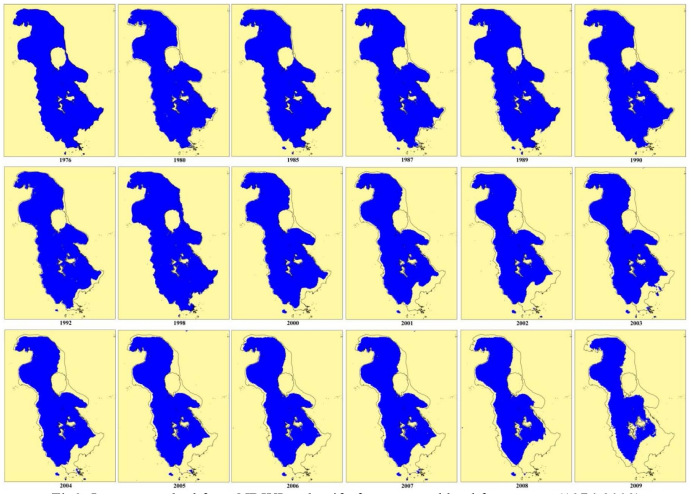

Fig. 6. Changes in extent of Lake Urmia from 1976-2009 (Ahadnejad Reveshty and Maruyama 2010). Note decline in lake area during the last decade.

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