The effects of drought on reproduction mode of *Artemia urmiana*

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Abstract

Urmia lake is located at the northwest of Iran with 5 m average depth .Variations of water discharge and evaporation causes the lake itself to rise and fall, fluctuating by 0.6 to 0.9m. In addition to seasonal variations, there are also longer periods of fluctuations, lasting from 2 to 100 years, with water level fluctuations of 1.8 to 4.0 m.

Drought year began from 1999 because of low precipitation and preventing of freshwater input to lake Urmia with Dyke and Dam constructed on rivers. Therefore the average depth was decreased and the salinity was increased from 140 g/l in 1993 to 310 g/L in 2002. A comprehensive monitoring and analytical program began in 1993, employs frequent surveys of *Artemia* populations, measurment of environmental data, and mathematical modeling to understand the dynamics of the *Artemia* population in Urmia lake. This information is then used to establish the timing and harvest limits for the commercial fishery in the lake. Since 1993, there have been six years with large populations of *Artemia* and record cyst harvests, and three years with relatively poor cyst harvests. In this study, watery years (1993- 1998) and drought years (1999-2003) were compared and following conclusions were obtained:

Artemia is stressed by high salinity but even in high salinity more than 300 ppt, active *Artemia* were observed in Urmia lake. The tendency of *A.urmiana* is towards to oviparous. According to analysis variance (one way) data concluded of sampling *Artemia* and water salinity of urmia lake during 1993-2000 , there are significant differences <95% ($p<0.05$) between salinities group (less than 172 ppt and more than 172 ppt) and changes reproduction mode from ovoviviparous to oviparous were obtained. In salinities <172 ppt some populations of *Artemia* produced nauplii but in salinities >172 ppt only cysts production were observed.

Keywords:*Artemia urmiana*, dryness, reproduction model

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Introduction

Urmia lake in northwest of Iran is the largest lake in the Middle – East. It covers an area that varies 5,200 to 6,000 km^2 and its shoreline is 460 km. Since 1967 it has enjoyed the status of a wetland protected region, and efforts have been made by the Iranian government to increase its wildlife.

It is rich in number of natural resources, most notably its abundant minerals, a unique brine shrimp population, and a diverse and abundant migratory bird population. The lake has also been heavily utilized for the recreation, open space, and tourism opportunities it offers.

The lake is about 87 miles (140 km) long and 25 to 35 miles (40 to 55 km) width, with a maximum depth of 53 feet (16 m) and the average depth is 5 m.
.The salinity of the lake's water changes during the different seasons and ranges from 140 to 310 g/l. During the winter months the lake is sometime frozen.

Islands in the lake, numbering 102 and ranging in size, are a very important stop in the migratory route of many species of birds throughout Asia and are the year round home of many other species.

The governing factor of Lake Urmia's hydrograph is its lack of an outlet. It forms the dead end of a large drainage system that covers an area of about 52,000 km^2 and is subject to great seasonal variation. The main affluent is the Talkheh river in the northeast, which gathers the melted snows from the Sabalan and Sahand massifs, and the twin rivers of Zarineh and Simineh in the south. The volume of water discharged into the lake by these rivers varies considerably during the year. During the spring the Talkheh River and Simineh river may each discharge about 57 m^3 /sec, while the rate drops to only 3.7 or 1.7 m^3 /s in the dry summer. The salinity in this lake is so high (8 to 11 percent in the spring to 26 or 28 percent in the late autumn). The main salts are chlorine, sodium, and sulfates.

Organic life in the lake's waters is limited to a few salt – tolerant species. Copious algae provide food for brine shrimp and cause a bad smell along the lake's shores. There are breeding populations of Sheldrake, Flamingo, and pelican, as well as migratory birds

The brine shrimp of *Artemia* exhibits two modes of reproduction: ovoviviparity, the production of live nauplii within the uterus, and oviparity, the production of dormant cysts (encysted gastrulae), which after releasing must undergo desication and rehydration before hatching.

With few exceptions, these modes of reproduction are mutually exclusive, for any particular brood. Because dormant eggs are easily collected, canned and shipped, later rehydrated in seawater, and the resulting larva and adults fed to a wide variety of aquatic species, *Artemia* cysts have become an important commodity in aquaculture. Traditionally, cysts have been collected from natural habitat or commercial saltworks, but increasing demands for cysts in the 1970s prompted the introduction of *Artemia franciscana* into coastal salterns in Brazil (Camara and

De Medeiros Rocha, 1987). These populations initially produced cysts but in recent years, cyst production has fallen. Possible reasons for this, are changes in environmental conditions that shifted the reproductive mode toward ovoviviparity and unwitting selection for oviparity as cyst harvesting removed genotypes predisposed towards oviparity. In order to revive cysts production in salterns, a highly oviparous strain should be restored and environmental factors that affect cyst production should be identified and appropriately manipulated. An understanding of the physiological basis underlying oviparity determination in the female brine shrimp might be of even greater help in controlling cyst production

Material and methods

Urmia lake is located at the northwest of Iran at 30° 20’ E/ 45° 54’ N and an altitude of 1250 m above sea level.The total surface area fluctuates between 4750 and 6100 km^2. A maximum length and width of 128-149 km and 50 km are reported, respectively (Loffler, 1961; Azari Takami, 1987). The average depth is close to 6 m, and the maximum depth is 16 m (Azari Takami, 1993). The total water reserve can be estimated at 12 billion m^3.

The study used data from stock assessment of *Artemia urmiana* project 1993-2003. In this periods, sampling of *Artemia* and note of physiochemical parameters were continued.

Brine shrimp, like all zooplanktons, are notoriously patchy in their distribution within a lake. This partially due to the presence of life stages such as cysts that float and are totally dependent on currents to move them throughout the water. Other life stages, such as adults, are actively motile and able to move toward food sources and sexual partners with a limited dependency on currents. The patchy distribution makes it difficult to estimate accurately the numbers of various life stages present at any one time in the lake. Sampling sites were selected using a random stratified design. Map of this lake at a scale of 1:1000000 were assembled to create a Geographic mosaic patterns and 12 stations were selected on this patterns randomly.

Artemia were sampled monthly at each site using a 0.5 m plankton net with a length of 2 m and a 150 µm mesh size for surface sampling and using pump system and filter net for deeper waters. Three replicate haules were made at each site to provide an estimate of the within site variability. In each replicate, 5 metric tons of water were filtered .Experience in assessing production figures in ponds (Baert *et al*., 1996) reveal that this combination of sampling methods has the best guarantee of providing a global insight in population evolution and standing crop.

Artemia preserved with buffered formalin were counted and determined the percent of females reproducing oviparously and ovoviviparously in the laboratory by using a dissecting microscope. Those were separated by development stages and size into nauplii (length less than 1.5 mm), juvenile(

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length>1.5 mm and filtering appendages present) , and adults (presence of ovisac on females and claspers on males).

Environmental measurements conducted at each site consisted of a vertical profile of water temperature and dissolved oxygen, transparency, pH, and salinty.

Salinity, temperature, transparency, pH and D.O of urmia lake water were measured with referectometer, Hg thermometer, Secchi disc, digital and portable pH meter and Oxygen meter respectively.

Processing of results

All data were compiled and statistically processed with statgraph programme (Table 1).

Table1: Analysis of variance.

Source	Sum of Squares	Df	Mean Square	F-ratio	*p*-value
Between groups	47996.1	1	47996.1	325.66	0.0000
Within groups	155635.0	1056	147.382		
Total (Corr.)	20631.0	1057			

The ANOVA table decomposes the variance of oviparous into two components: a between- group component and within group component. The F-ratio, which in this case equals 325.66, is a ratio of the between – group estimate to the within group estimate. Since the P-value of the F-test is less than 0.05, there is a statistically significant difference between the mean oviparous from one level of area to another at 95 % confidence level.

Results

Artemia is the major zooplankton living in Urmiah lake because of the high salinity and there isn’t any predator for it except birds. Cysts can be seen laying the shoreline from the summer to late autumn when they are more abundant (Fig. 1A) but in several years ago because of drought, salt were covered all over the shoreline (Fig. 1B).

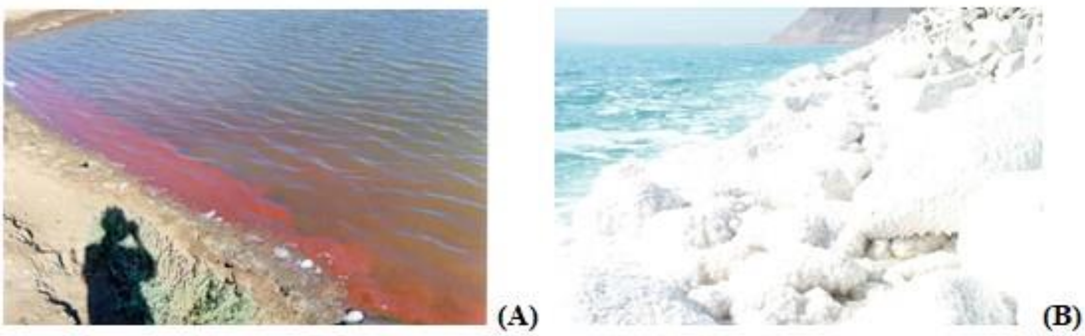

Figure1: Urmia Lake shorline (A) before the drought 1995, (B) after the drought 2000.

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In natural environments, it is difficult to detect possible synergistic or antagonistic interactions between factors affecting life history traits, such as salinity, temperature or food levels (Browne, 1982; Wear *et al*., 1986; Mura, 1995). But in this project, effect of salinity on reproduction mode of *Artemia urmiana* was obtained naturally. During the years between 1993 to 2003 there were some fluctuations on some physicochemical parameters (Table 2; Figs. 2 and 3).

Table 2: Physicochemical characteristics ranges of Lake Urmiah in 1993 and 2000.

Parametrs	Range 1993	Range 2000
Water Temperature(°C)		
November	5.0-9.5	
August	6.0-10	
	23-25	26-28
Air temperature (°C)	9.5-15	8-30
E. Conductivity(µm/Cm)	234000-300000	310000-420000
Total alkalinity (mg CaCO3/l)	206-312	350-440
Salinity(ppt)	160 (Min=130, Max=190)	285 (Min=260, Max=315)
D.O(mg/l)	2.3-2.6	1.5-2.2

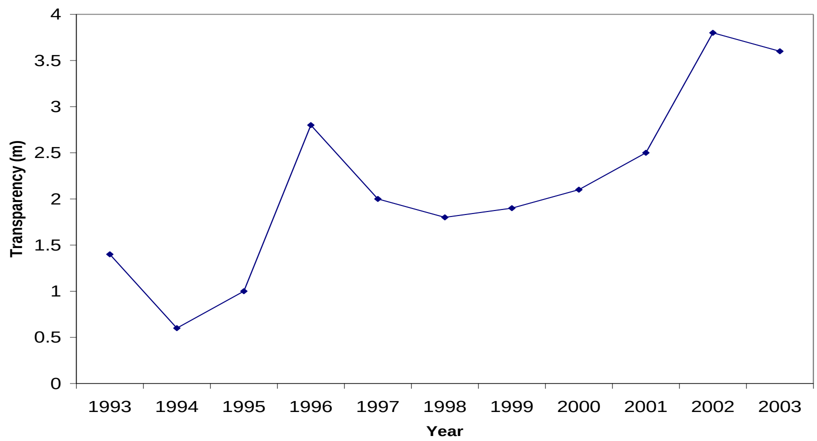

Figure2: Changes of Urmia lake water Transparency during 1993-2003.

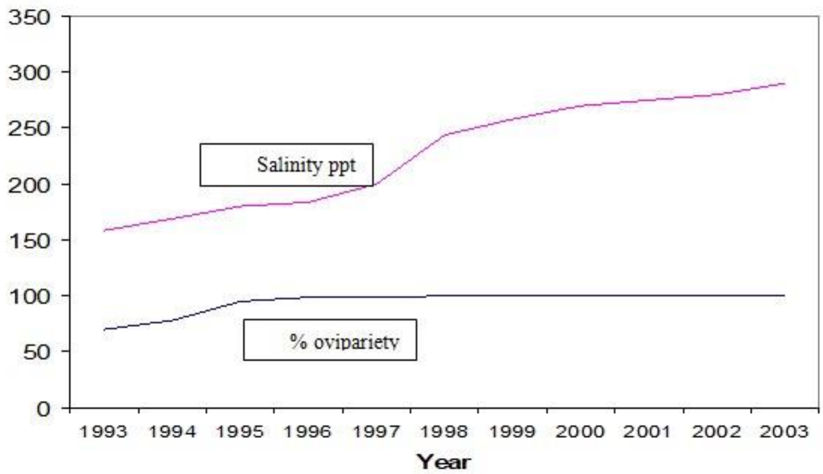

Figure 3: Correlation of Salinity and Ovipariety percentage during 1993-2003.

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Because of low percipitations and high evaporations after 1999 , the condition changed and consequently the reproduction mode of *A. urmiana* totally shifted to ovipariety (Figs.3 and 4).

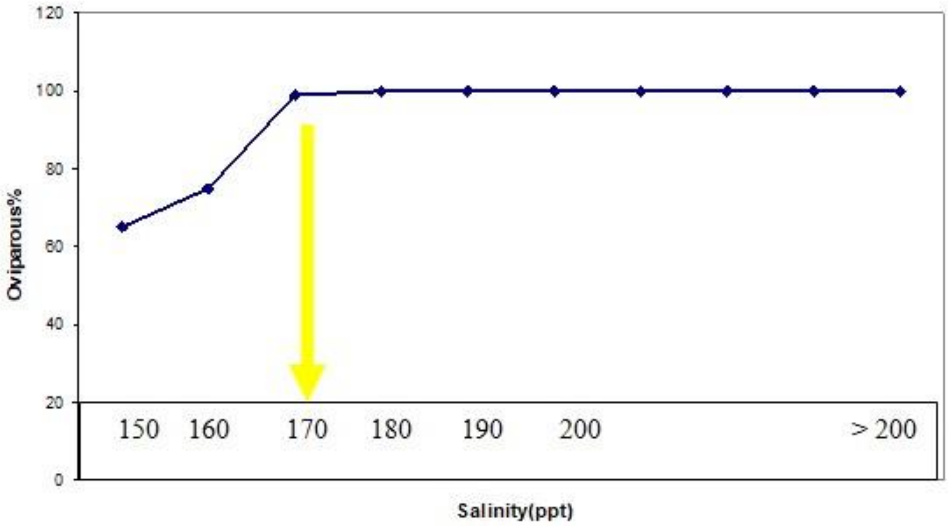

Figure4: Cysts production percentages in different salinities.

According to analysis variance (one way) data concluded of sampling *Artemia* and water salinity of urmia lake during 1993-2000 , there are significant differences <95% ($p<0.05$) between salinities group (less than 172 ppt and more than 172 ppt) and changes reproduction mode from ovoviviparous to oviparous were obtained.

In salinities <172 ppt some populations of *Artemia* produced nauplii but in salinities >172 ppt only cysts production were observed.

Discussion

Variation of water discharge and evaporation causes the lake itself to rise and fall, fluctuating by 0.6 to 0.9m. In addition to seasonal variations, there are also longer periods of fluctuations, lasting from 2 to 100 years, with water level fluctuations of 1.8 to 4.0 m. (Fig. 5).

Figure 2 showed fluctuations of water transparency dyring 1993-2003. In 1994 density of phytoplankton population was so high and water transparency came down to the minimum level in the 10 last years (0.6 m) and the maximun range was occurred in 2002 when the salinity was so high and rainfall was so low. Presence of *Artemia* biomass and consequently cysts and nauplii acutely depend on to presence of phytoplankton as food , hence with decreasing of food available during 2000-2003, the production of cysts were decreased to the minimum amount. It seems increasing in water transparency that means decreasing in phytoplankton density via indirectly way effected on reproduction mode of *Artemia urmiana* and they appetenced to oviparety.

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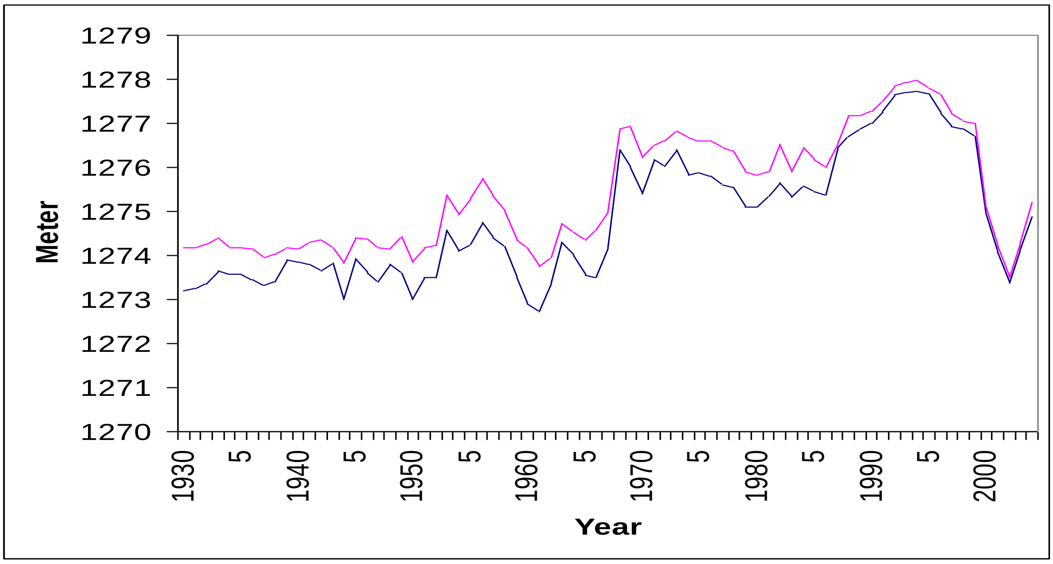

Figure 5: Fluctuations of water surface in Urmia lake (1930-2003).

Salinity and temperature significantly affect survival and development of all stages of *Artemia*, but effects on reproduction are of greatest significance Laboratory studies by Wear *et al.* (1986) showed that maturation and reproduction for A. *franciscana* (NewZealand population) occurred at temperature between 20°C and 28°C and salinities between 120-200 parts per thousands (ppt).

The optimum salinity for growth and reproduction of *Artemia* in GSL is not known because it is a function of an interaction with temperature, food supply, and competitors. The maximum salinity for adult *Artemia* determined by laboratory studies of cultures from the lake is about 300 g/L (Croghan, 1958): nauplii cannot tolerate salinities in excess of 146 to 175 g/L (Conte *et al*., 1972, 1973). In Urmia lake, adult Artemia were observed in salinity more than 310 g/L But in Urmia lake they were observed in salinity even up to 250 g/L.

Barigozzi (1939) found a slight preponderance of oviparity at salinities less than 80% but Ballardin and Metalli (1963) later found no correlation between oviparity and high salinity, temperature, photoperiod, food type, or densities in an Italian strain. They attributed oviparity to stress in general.

Figure 3, showed correlation between salinity and ovipariety percentage during 1993 to 2003 in Urmia lake. This is an average data from first and second six months including:

In the 1st ، six months of the years (1993-2002) there were correlation between salinity and reproduction mode of *A.urmiana*.

In 1st ، six months of 1993 , the average salinity was 158 ppt and the oviparous percentage was 64% (36% ovoviviparous were reported):

In 1st ، six months of 1994, , the average salinity was 165 ppt and the oviparous percentage was 70% (30% ovoviviparous were reported):

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In 1st , six months of 1995, , the average salinity was 170 ppt and the oviparous percentage was 78% (22% ovoviviparous were reported):

In 1st , six months of 1996, , the average salinity was 183 ppt and the oviparous percentage was 98.2% (1.8% ovoviviparous were reported):

In 1st , six months of 1997-2002, , the averages salinities were more than 220 ppt and the oviparous percentages were almost 100% (no ovoviviparous reproduction were reported) .

Since in the 2nd, six months of the years (1993-2002), the averages of salinities were more than 172 ppt , the oviparous percentages were almost 100% (no ovoviviparous reproduction were reported)

Figure 4 showed the break in ovipariety percentage in point of 172 ppt salinity and Tab 1 cocluded that there are significant differences <95% (p<0.05) between salinities group (less than 172 ppt and more than 172 ppt) and changes reproduction mode from ovoviviparous to oviparous were obtained.

In salinities <172 ppt some populations of *Artemia* produced nauplii but in salinities>172 ppt only cysts production were observed.

Nicole *et al*. (1987) have examined the effects of several physical and biological factors on the mode of reproduction in *Artemia* from San Francisco Bay. Maternal age, photoperiod, temperature and salinity were found to be major factors controlling the mode of reproduction. At low (16°C) or medium (20-22°C) temperature, females were 68-99 % oviparous under photoperiods with 12 h or less of light, but were only 10% oviparous under long days or constant light. At higher temperature (25°C), photoperiod has alittle or no effect with 50% cyst broods produced under short and long days. Few females were oviparous for the first brood(10%) but nearly 100% produce cysts by the third brood. But in Urmia lake and according to compare the water temperature between 1993 to 2000 (Table 1) however, the average of ovipariety percentages differe from 68% to 100 % but average of water temperature were same ranges between these two years. Unfortunately data of photoperiod and it's effcet on reproduction mode of *Artemia urmiana* were not done. Under laboratory conditions, salinities above 120% inhibited cyst formation at least for the first three broods (Browne, 1982) but in this project , the results showed differences because in high salinity more than 170 ppt almost 100% of *Artemia* reproducable female produced cyst. However it seems no one environmental factors was clearly responsible for controlling reproductive mode and interactions among several factors appear to be significant but one of the most important factor that effect on reproduction mode shift fron ovoviviparity to ovipariety is salinity. Of course a more promising approach to understanding the control of reproductive mode in *Artemia* may obtain via investigations into the common physiological pathway whereby diverse environmental factors

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induce a switch for oviparity. A new working hypothesis focusing on stress induced metabolism is offered.

Conclussion

This study was done between 1993-2003. There were significant differences <95% (*p*<0.01) between salinities groups (less than 172 ppt and more than 172 ppt) and changes reproduction mode from ovoviviparous to oviparous. However the tendency of *Artemia urmiana* is towards to oviparity, but in salinities less than172 ppt some populations of *Artemia* were produced nauplii. In salinities >172 ppt only cysts production were observed.

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