Annual and Seasonal Variation in Artemia Population in Relation to Water Quality Parameters in Lake Galgas in Crimea, Russia

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Authors’ contributions

This work was carried out in collaboration among all authors. Author RII designed the study. Authors SVG and ZAV participated in the field studies and collection of the data. Author SAV performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

ABSTRACT

Aim: To study seasonal changes of hydrological parameters of the water and Artemia population status in the hypersaline Galgas Lake in the period of 2017-2019.

Study Area and Duration: The study was carried out in the Crimea, a peninsula on the northern coast of the Black Sea in Eastern Europe in 2017-2019.

Methodology: Water (brine) and Artemia samples were collected monthly from the lake located at the coastal line of the Black Sea. The parameters namely temperature, pH, salinity, Eh, and oxygen concentration of were determined in the water. Artemia population including the developmental stages and the cysts hatching rate of the cysts were measured in different seasons in the study period. The differences in hydrochemical characteristics of the study area in different years and seasons were observed.

Results: The results showed that the hydrochemical characteristics of the study area varied with the...
1. INTRODUCTION

Hypersaline water bodies are widespread all over the world. They display high concentration of salt in the water (brine), very simple trophic structure and very low diversity of fauna, including invertebrates [1,2]. Salt lakes are important for salt and minerals industry, spa-production, tourism, Artemia production for aquaculture purposes, and so on [3]. Understanding the factors that control the ecological status in such ecosystems is very important for sustainable use of the mineral and biological resources. However, these inland water bodies are highly fragile and vulnerable to both natural processes (e.g. climate changes, insolation, desalination) and anthropogenic activities. Urbanization, agriculture and recreation mostly have significant impacts on the water quality, hydrodynamics, geomorphology and the biodiversity in the lakes [4,5,6].

In the Crimean peninsula (Black Sea, Russia) it is estimated that 45 hypersaline lakes had been formed approximately 6,500-7,000 years ago [7]. The Crimean salt lakes provide valuable resources because salt water containing various minerals such as salt, bromides, Mg, K, mirabilite, covellite. They are extracted by chemical, agricultural and pharmaceutical industries. Sediments are successfully applied for medical and cosmetic purposes. Artemia cysts, an important biological property of salt lakes are commonly used by local aquaculture industries. However, in the last 70 years Crimean salt lakes were stressed upon the different kinds of natural and anthropogenic hazards, causing alterations in chemical properties and microbial pollution of the water, desalination, evaporation, eutrophication, etc. Even several lakes were either degraded, or they transformed to the other type of water bodies.

Several salt lakes were turned into freshwater ecosystems freshwater lakes, and some lakes were dried out.

The brine shrimp, Artemia (Crustacea: Branchiopoda) is a highly distributed and dominant crustacean species present in many hypersaline environments [8,9,10], including Crimean salt lakes. It is filter-feeding organism, which is vital in order to understand ecosystem functioning and the impact of natural and anthropogenic stressors, because the adult brine shrimp accumulated chemicals from the water [11]. Various life stages of Artemia are sensitive to the changes of various environmental and anthropogenic factors. Therefore the brine shrimp is recommended as test-organism for the evaluation of the ecological status of the natural water and for the marine and hypersaline water. Hence, the present investigation was aimed to know the impacts of study seasonal changes of hydrological parameters of the water on Artemia population in the hypersaline Galgas Lake (Crimea, Russia).

2. MATERIALS AND METHODS

2.1 Study Area

Coordinates of the geographical location of Galgas Lake (Fig. 1) were detected with the smartphone GSM A510F/DS (Samsung Electronics. CoLtd, South Korea) and the position was detected as 45°11′30″N 33°10′38″E. It covers an area of 0.16 km² where the estimated length and width are 420 m and 130 m, respectively; and the depth is estimated as 0.55 m. It is separated from the sea by sand barrier, however in autumn and winter marine water can enter into the lake. Anthropogenic activity includes sand production, transport traffic, recreation and tourism.
2.2 Field Sampling and Laboratory Analysis

Water samples were collected in the bottles placed under water with the cap in 3-4 sites in the lake monthly during the period of 2017-2019, used the special constructed equipment. All brine samples were collected monthly in polythene bags followed by transportation to the laboratory Ecotoxicology of the Kovalevsky Institute of the Biology of the Southern Seas RAS for further determination of the pH, Eh, salinity and oxygen concentration. Water temperature was measured directly in the lake using electronic Temperature analysator HANNA Instruments Check Temp – 1 (Volta CoLtd, Sant-Petersburg, Russia). The surface water samples were kept in refrigerator at 4°C before the chemical analysis.

Artemia cysts were collected at the coastal line of the lake for the determination of hatch rate. Cysts were washed by salt water and then by fresh water for viable cysts separation. The viable cysts were collected and dried at 28°C during 10 days for further studies. The analysis of different Artemia developmental stages was provided in the water samples also.

2.3 Water Samples Analysis

Water pH, Eh, dissolved oxygen concentration was measured in situ with a multiparameter analysator Expert-001 (Econix-Expert Moexa CoLtd, Moscow, Russia) and selective electrodes (VOLTA, Co Ltd, Saint-Petersburg, Russia). Salinity was determined by the Salinity Refractometer PAL-06S LTA GO (Japan), immediately after samples collection and expressed in ‰ units.

2.4 Determination of Artemia Cysts Hatching Percentage

Hatching performance of the cysts were examined in standard conditions (salinity 35‰, T = 25°C during 48 h). Hatching percentage of the examined samples was measured according to the method previously described by Van Stappen [12] and El-Magsodi et al. [13]. Hatching percentage was analyzed as a per cent of the number of nauplii, which were hatched from 100 cysts during 48 h incubation according the equation

Hatching percentage = number of hatching nauplia / 100 cysts X 100%

The number of the different Artemia developmental stages namely cysts, nauplia and adults were estimated in the 1 liter of the brine collected from three different sites of the lake.

2.5 Statistical Analysis

The determinations were recorded of triplicate measurements. The results were processed using ANOVA. Statistical differences were calculated using Student's t-test. All numerical data are given as means ± SE [14]. The significance level was p<0.05. The correlation analysis was provided used the computer program CURFVIT.

Fig. 1. Geographical location of study area
3. RESULTS

3.1 Changes of Water Parameters

In the examined period the chemical parameters of the lake varied widely. The temperature of the water is present in Fig. 3. Air and water temperature increased to the spring-summer period and the highest values were indicated in June - October (>+30°C). We could note that in 2017 during the period from July to October the lake was dried out and the water parameters we could not measure.

Salinity is present in Fig. 4. The parameter increased in the warm period of the year and the highest values was observed in June-July (more than 300‰). In 2017 the evaporation was very high and the lake was dried out during the period July-October. In November the rainy season was began, the water in the lake appeared again and its salinity was decreased.

The dynamics of water pH is present in Fig. 5. pH varied insignificantly from 6.78 to 7.78. We noted the lowest pH in summer months, in September 2019 pH was the lowest. In cold season the pH were elevated insignificantly.

The annual and seasonal changes of the Eh characteristics are present in Fig. 6. The parameters ranged between -4.77 to -73.76. The highest value was observed in August, 2019 and the lowest one was shown in July, 2019.

Therefore, the main seasonal trends of water parameters are the similar in the examined period.

3.2 Fluctuations of Artemia Population in Galgas Lake during the Period 2017-2019

The seasonal dynamics of the population composition of Artemia in Galgas Lake is present in Table 1.

In 2017 we found the cysts in the water from April to July and in November, and adults were observed at the period of April-June. In 2018 Artemia cysts were present in the water during the total year, nauplii were shown in April and from August to November, and adults were present from August to November. In 2019 we found cysts in February and March and from June to September, nauplii were shown from March to June and adults were indicated from March to July.

The hatching percentage of the cysts collected in Galgas Lake was ranged also. In December 2017 it was 33.3±7.9%, in September, 2018 this parameter was estimated as 8.7±1.4%, in December, 2018 it was 46.4±3.9% and in March, 2019 it was 12.7±1.5%.

Therefore, the general seasonal trend of Artemia population in Galgas Lake was the following: the cysts were found throughout the year, nauplii predominated in spring-summer months and the adults were shown in summer-autumn months.

Fig. 2. Air and water temperature of the Galgas Lake
Fig. 3. Salinity and pH of the water in Galgas Lake during the period 2017-2019

Fig. 4. Eh of the water in Galgas Lake during the period of 2017-2019

Table 1. Seasonal fluctuations of life stages of *Artemia* (specimen in I) in Galgas Lake during the period of 2017-2019

<table>
<thead>
<tr>
<th>Month</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cysts</td>
<td>Nauplii</td>
<td>Adults</td>
</tr>
<tr>
<td>January</td>
<td>4-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>1-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>1-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>1-4</td>
<td>1</td>
<td>1-2</td>
</tr>
<tr>
<td>May</td>
<td>1-4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>1</td>
<td>0,5</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>0-4,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>Dried</td>
<td>2-10</td>
<td>9</td>
</tr>
<tr>
<td>September</td>
<td>Dried</td>
<td>1-11</td>
<td>1</td>
</tr>
<tr>
<td>October</td>
<td>Dried</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>November</td>
<td>3</td>
<td>1-4</td>
<td>1-7</td>
</tr>
<tr>
<td>December</td>
<td>1-9</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The hatching characteristics of the cysts were ranged and depended on the period of collection.

4. DISCUSSION

In most saline ecosystems hypersalinity is connected with hot period of the year, and in different seasons the salinity can change depended on climate conditions and, especially, temperature [5]. However, in inland Crimean salt lakes, including Galgas Lake, hypersalinity persists throughout the year, and the values of the salinity varied widely. For instance, at the period of August-October the lake was dried out and in January, 2019 it was covered by the snow. In summer period the air and water temperature was the highest (+30°C and higher), the evaporation was increased, the salinity elevated progressively and the lake dried out. As we described previously, examined water body is closed off the sea and separated from it by sand barrier. However, it may be open to the sea during rainy season (in autumn, winter and at the beginning of spring), when storm surges erode sand barriers and open up closed lake to the sea. Therefore, the salinity and temperature in the lake may range widely not only monthly, but daily also.

Salinity and pH are two water chemical characteristics, that vary drastically (seasonally or daily) in a variety of aquatic environments. The pH of examined lake varied insignificantly from 6.6 to 7.8. This parameter in aquatic ecosystems is determined by the dominant buffer systems of the water [15]. We found the changes of pH trends in the water of the lake. In June pH decreased as compared to spring and winter seasons. At the other hand, there are some differences among the annual trends: In 2019 this parameter continued to decrease in July and August, while in 2017 and 2019 it was elevated. pH fluctuations in the water may depend on freshwater inflows supplied continuously in the lakes in inflow from precipitation, tributaries, rain, snow and groundwater, and from losses through evaporation which change the pH and salinity also. During dilution with freshwater the pH of the brine in saline water bodies rises [16] and it decreases during evaporation [17]. Similar decrease in pH with increasing ionic strength was observed at the case of Dead Sea [15,16] and Great Salt Lake [18]. Salinity in the Galgas Lake ranged from 60‰ in February, 2017 to 350‰ in June, 2017 and July, 2018. The changes of salinity depended on evaporation and freshwater inflows, as we described above.

Dissolved oxygen concentration is very important characteristic in water quality assessment. Oxygen concentration in examined samples ranged significantly from 1.91 mg/l in July, 2019 to 16.2 mg/l in January, 2018. The oxygen concentration was decreased in summer period as compared with the cold season. The similar trend we found at the case of Eh, that characterizes the ratio of oxidation and reduction processes in the water. The dynamics of these processes were the similar during the examined periods and the values increased in summer months and decreased in cold months. Additionally, in warm season the lake is contaminated by organic pollution. The main sources of biogens entering this environment are domestic and agricultural effluents, which have deleterious effects on the ecosystem, and especially on biota. Another negative consequences of nutrients entering aquatic systems are attributed with eutrophication [6]. In summer period we observed intensive algae bloom in Galgas Lake.

Hypersaline ecosystems are unstable environments, and living organisms inhabiting these locations require adaptations to varying environmental conditions [19,18,31]. The brine shrimp *Artemia* is widely distributed in hypersaline biotops, including salt lakes and lagoons in the coastal part of the Black Sea and in the Crimean Peninsula, where it is found in the coastal and inland salt lakes, man-made or managed solar saltworks. Crimean climate promotes for *Artemia* development: The life cycle of brine shrimp is estimated as 220-240 days per year [20,21]. Thus through the year it is possible to collect *Artemia* biomass, nauplii and cysts, and to use them in aquaculture. Hatching characteristics, physiological lifespan, reproductive trait and population dynamics of *Artemia* in various biotops are differed each from other, and is depended on specificity of climate, geographical position of water bodies, salinity, mineral and microalgae composition, season, year, and etc. [8,2,22]. Previously we described the *Artemia* status in several Crimean salt lakes [23]. The purpose of the present study was to determine the fluctuations of *Artemia* life stages in checked Galgas Lake due the period of 2017-2019.

*Artemia* distribution in tested water body changed in different seasons. Cysts were found
in all seasons, however their number fluctuated monthly. Nauplii and adults were observed in spring and autumn periods, and very rare in summer months, when the temperature is very high and the conditions in water body are not ambient for Artemia adults. In addition, Artemia distribution is not only determined by natural factors, but also on human activities. Galgas Lake is located in the region of high human activity namely recreation and agriculture, which influence on the water quality and food composition of Artemia. Pollution negatively impacts water quality and microalgae communities, stimulates eutrophication and damages relationships in the ecosystem. Therefore, the Artemia density in Galgas was very low, and in some period of the year we did not find the cysts in the water and on the coast line.

The hatching percentage of Artemia cysts in tested Galgas Lakes varied depending on the period of the collection. It depended on specificity of water body characteristics, season, food composition (microalgae) and year. As we described previously [23], low hatching percentage could be explained by the specificity of diapause behavior of the cysts from Crimean hypersaline lakes. However, the hatching percentage of the cysts in tested Galgas Lake was lower than the commercial Artemia strains [24,25]. We could propose that the main reason of this is long diapause, that agrees with the opinion of several investigators [12]. According their opinion, Artemia females inhabiting the locations characterized very extreme environmental conditions, produce dormant embryos in cysts formation. This mechanism protects the embryos against environmental stress and supports the survival of the brine shrimp in unstable and extreme environments. It suggested the fact, that in the summer period, 2017, the lake was dried out and the cysts could kept in the bottom sediments for further development in favorable conditions. At the other hand, the hatchering percentage of Artemia cysts was higher in winter period as compared with spring or autumn seasons. Therefore, we could propose that in spring and autumn periods they hydrated and damaged caused high insolation and the viability of them was decreased.

5. CONCLUSION

The progressive development of aquaculture the new sources of Artemia are needed. The local salt lakes in different geographical regions could be the potential natural sources of brine shrimp production. However, the success of Artemia production depends on the conditions in biotope and climate, and anthropogenic activity. The monitoring of the Crimean hypersaline Galgas Lake in Crimea illustrates the effects of natural and anthropogenic impact on this water body. This knowledge is important for the risk assessment and for the understanding of the management of salt lakes resources, for development the strategy of protection water quality against possible negative impacts and biota conservation. However, the further studies are required for the understanding annual cycle of salt lakes processes that attributed with seasonality and anthropogenic activity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

24. Vanchaecke P, Sorgrloos P. International study on Artemia XLVII. Effect of temperature on cyst hatching, larval survival and biomass production for different geographical strains of brain


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