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Influence of hydrometeorological factors on the ecological state of the hypersaline lake Saki (Crimea) in 2017–2018

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In order to identify the influence of hydrometeorological conditions on the seasonal changes in the ecological state of the salt Lake Saki (Crimea), the dynamics of hydrochemical parameters of water (salinity, oxygen content, temperature, pH, Eh) and changes in the population of the brine shrimp *Artemia salina* L., as well as the proportion of hatching nauplii from cysts were studied in 2017 and 2018. A decrease in oxygen content and an increase in brine salinity in the summer were accompanied by an increase in air temperature and water temperature; the interannual differences of these parameters were preconditioned by the hydrometeorological peculiarities. *Artemia* cysts were found in the water column throughout the year; the nauplii appeared in February – March; the maximum abundance of all life stages of brine shrimp was noted in May. The proportion of hatching nauplii from cysts collected in the cold season was significantly higher than that in the warm season. The observed patterns are discussed as a possible source for analyzing the transformation of hyperhaline ecosystems within the ongoing climate change and for developing the guidelines for the optimal commercial use of the mineral and biological resources of such ecosystems.

Keywords: seasonal changes, hydrochemical indicators, *Artemia*, salinity, oxygen content, temperature, pH, Eh.

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Introduction

Global biosphere processes and economic activity modify aquatic ecosystems, violate the hydrodynamic and hydrochemical conditions developed through a long evolution; this ultimately can lead to the resource depletion, to deterioration of the quality of resources, or to the inability for using by humans. Changes in climatic conditions entail a change in other natural factors, which, combined with increasing anthropogenic impact, negatively affects the hydrodynamics and stratification of waters, their mineralization, and thereby violates the vital activity of aquatic organusms (Bradley et al., 2015; Gulov, 2007; Huang et al., 2017 ; Liu et al., 2018).

Hypersaline lakes are widespread globally, many of them are located in the areas characterized by high air temperature and intense evaporation (Wooldridge et al., 2016). These water bodies are characterized by different salinity, pH, mineral composition, as well as by low biodiversity. Their ecosystems are very vulnerable to the changes in abiotic factors, which may lead to irreversible changes in the conditions historically prevailing in these reservoirs. Biota itself is an important factor in the stable functioning of the lacustrine-mud ecosystem, since the interactions of its key components determine the most important processes for the production and destruction of organic matter, the pharmacological properties of hydromineral resources, the toxicity of soils and brine at the events of eutrophication and accumulation of pollutants, including those of anthropogenic origin (Bamba et al., 2017; Berman and Chava, 1999). The resources of hypersaline lakes are intensively used in human economic activity, since the brine minerals serve as raw materials for chemical industry enterprises, the sediments are used for medicinal purposes in balneology, in the cosmetic and pharmaceutical industries, and the dominant species of brine shrimp (*Artemia* sp.) is one of the most valuable starting feed for aquaculture facilities (Lavens et al., 1986; Rudneva, 1991). Brine shrimp is a filter-feeder, consuming microalgae and suspended organic particles, this contributing to the clarification of water in the reservoir, the formation of sediments with medicinal properties, and the normal functioning of the water body (Shadkam et al., 2016).

The Lake Saki is one of the largest saline lakes of the Crimean Peninsula (Fig. 1). Evolutionary, it is a bed of ancient draws flooded by the sea waters. For thousands of years, the bottom sediments have formed under the influence of specific hydrometeorological, hydrogeological, hydrochemical, and biological conditions; these sediments are nowadays serve as a natural healing resources (Kurnakov et al., 1936). The economic development of this salt lake and surrounding areas has a long history. At present, the Lake Saki is divided into seven pools isolated from each other, two of which are used for therapeutic purposes, and the other five pools perform a protective function against flood and wastewater. A complex flood protection hydrotechnical system (FPHTS) is organized for the stable functioning of the lake's ecosystem under intensive economical activities. The diversion dams, bypass channels, pumping stations, and division gates help to block the income of the excess fresh water to the treatment pools from the protective reservoirs and nearby flooded areas. In order to compensate the intense evaporation of water from brine in the hot season, the sea water is supplied from the Kalamitsky Bay of the Black Sea by means of hydraulic structures; this seawater is close to the brine of medicinal reservoirs by the hydrochemical parameters. Thus, the artificial regulation of the water-salt balance is performed successfully, which, in turn, provides favorable conditions for the development of aquatic organisms.

Over the past fifty years, the Eastern basin of the Lake Saki, which is a site for the extraction of peloids (medicinal sulfide-silt mud) and lake brine, has been almost completely excluded from the natural supply system for surface and ground waters and income of the soil erosion products. Under these conditions,

Fig. 1. Map of the Eastern basin of the Lake Saki and the location of the sampling site.

this water body has been almost transformed into a mud basin, where the geochemical function of the lithosphere has little effect on the formation of bottom sediments. As a result, the natural mud formation has slowed down significantly in recent years (Chaban, 2013; Tyutyunnik and Khokhlov, 2007). Currently, the lake is undergoing an intense anthropogenic load; therefore, there is a need to evaluate the changes taking place there in order to develop the protection measures and the objectives for the rational use of its resources. The study aims to search for the interaction of the totality of hydrometeorological and hydrochemical factors, as well as to assess their influence on the *Artemia* population inhabiting the Eastern basin of the Lake Saki, in the period of 2017–2018.

Materials and Methods

The coordinates of the location of the lake and sampling sites were determined using a Samsung Galaxy A5 smartphone (Samsung Electronics, CoLtd, South Korea). Water samples were taken at a 10-cm depth using a special device. All observations were made at the control station in the reservoir (N 45°07'24.91", E 33°35'25.63"; WGS 84 system). The analysis of the meteorological situation in the area of the Lake Saki was performed using the dataset of regular meteorological observations at the stationary hydrometeorological site of the Crimean Hydrogeological Regime and Operation Station, Saki. The minimum and maximum air temperatures were determined by the minimum and maximum thermometers, respectively; the total precipitation during the studied periods, by the Tretyakov non-recording precipitation gauge.

Water temperature was measured directly in the lake using a HANNA Instruments Check Temp-1 electronic thermometer (Russia). The pH, redox potential (Eh), and oxygen content were measured in laboratory using an Expert-001 analyzer (Econix-Expert Moexa CoLtd, Russia) using the corresponding Volta selective electrodes (Russia). Water salinity was measured using a PAL-06S LTA GO refractometer (Japan) and expressed as ppm (‰). Before determining all the parameters, the water samples were kept in the refrigerator at +4 °C for 4–6 hours after sampling. All measurements were performed in the Laboratory of Ecotoxicology of the A.O. Kovalevsky Institute of Biology of the Southern Seas.

Hydrobiological studies were carried out at the control station (CS) of the Eastern basin. The brine sampling was performed monthly to assess the size-age groups of brine shrimp by filtering 100 L of water through a plankton net with a 42-μm mesh size. The identification of the various ontogenetic stages of brine shrimp and the determination of their number were carried out under the MBS-10 binocular (Russia) and a Carl Zeiss Axio Scope A1 microscope (Germany). All hydrobiological studies and processing of the results of monitoring observations were carried out at the Laboratory of Biological Research, Crimean Hydrogeological Regime and Operation Station, Saki (Khokhlov et al., 2018, 2019).

In order to determine the quality of *Artemia* cysts, they were collected along the lake coast monthly during 2017 and 2018, washed and dried according to generally accepted recommendations (Van Stappen, 1996), then the samples were reared under standard conditions (incubation salinity of 35‰, temperature +25 °C, for 48 hours) with periodic stirring for assessing the proportion of hatching nauplii from cysts. The cyst quality was calculated as the ratio of the number of larvae hatched after 48 hours to the total number of cysts used for the incubation.

All determinations were performed in triplicates. Statistical differences between the studied parameters were assessed using the Student *t*-test at a significance level of $p < 0.05$ (Khalafyan, 2008). The proportion of nauplii hatched from cysts is presented as arithmetic mean (M) and the error of mean (m).

Results

Meteorological characteristics of the Lake Saki area

The meteorological situation in the area of the Lake Saki was stable during the study period of 2017–2018, no extremes of climatic factors were observed.

The average monthly air temperature corresponded to long-term seasonal cycles, increasing gradually in the spring-summer period and decreasing in the autumn. In 2018, winter and spring (except March) were warmer than those in 2017 (Fig. 2). The lowest temperature was recorded in January 2017 (−13.0 °C), the highest, in August 2017 (+39.0 °C).

The annual precipitation in 2018 was 169.6 mm less than in 2017 (Fig. 3). In addition, the precipitation was completely absent only in October 2017, but the dry months in 2018 were May, July, and September.

Hydrochemical characteristics of brine in the Eastern basin of the Lake Saki

The brine temperature in the lake gradually increased, reaching the highest values in August (+34.6 °C in 2017 and +32.1 °C in 2018), then it decreased in the autumn-winter period down to +1.5–2.4 °C (Fig. 4).

The salinity fluctuations of the brine had similar dynamics in the studied years (Fig. 5). In March – April, mineralization ranged 140–170‰, increasing in the summer period, and reached a maximum in November (220–249‰), then it decreased. It should be noted that the brine salinity was higher in the spring of 2017 than for the same period in 2018; it was nearly similar in the summer of 2017 and 2018; in autumn 2018, the water salinity was higher than that in 2017.

The oxygen content in the brine of the Eastern basin of the Lake Saki varied as 8.2–14.9 mg/L in 2017 and 5.0–12.5 mg/L in 2018 (Fig. 6). In 2017, the minimum values were observed in July (8.2 mg/L), the maximum, in August (14.9 mg/L), but in 2018, the lowest values were observed in May and June (5.0 mg/L) , and the highest, in August as well (12.5 mg/L). Further on, there was the same trend observed: a decrease in oxygen content in September and a slight increase in the autumn-winter period.

The redox potential (Eh) of brine varied slightly in 2017, from −40.8 mV to −46.0 mV (Fig. 7). In 2018, the differences were more pronounced: in winter, the indicators were lower (−48.8 mV), in May – June, they increased up to −35.5 mV, and then decreased down to −44.2 mV.

The changes in brine pH in the studied years were also insignificant, from 7.2 to 7.4 in 2017 and from 7.1 to 7.4 in 2018 (Fig. 8). A slight decrease in pH was observed from May through September 2018 compared with this period in 2017 and the values recorded in winter period.

Artemia population dynamics in the Eastern basin of the Lake Saki

The abundance dynamics of different life stages of brine shrimp in 2017–2018 are presented on Fig. 9. During the study periods, four life stages of this crustacean were noted: cysts, nauplii, juveniles, and mature females. At the same time, cysts were found throughout the year both in 2017 and in 2018, but their abundance depended both on the month and the year. In 2017, the number of cysts increased in February compared to January, but then decreased in March – April, and increased sharply again, reaching the maximum values (16000 and 46600 ind./m^3) in May and June, followed by a gradual decline till November. In November, the number of cysts has increased significantly (up to 12680 ind./m^3), but in December their abundance has decreased again.

Generally, the abundance dynamics of the brine shrimp eggs in the Eastern basin of the Lake Saki in 2018 was similar to that observed in 2017, but some differences were observed. High abundance was observed in May, June, and July (47760; 24050; and 26920 ind./m^3, respectively), in August, the abundance has decreased by more than an order of magnitude; in September, it reached 21680 ind./m^3 again; in October, decreased, but increased slightly again in November; finally, it gradually decreased to the minimum values during the winter months. Therefore, the maximum concentration of cysts in the water was observed in May – July 2017 and in May – June 2018; however, significant differences were noted in other months during the study period.

In 2017, the first nauplii have appeared in February, their abundance increased in March, but in April it has decreased by almost 3 times. In May – December 2017, *Artemia* larvae were not registered. In 2018, the first nauplii were found in March; a small number were also present in June and July.

In 2017, first juveniles (immature specimens) of the brine shrimp appeared in April (about 2000 ind./m^3), in May, their number increased almost tenfold, reaching 21000 ind./m^2; but then their abundance dropped sharply in June. In 2018, immature brine shrimps were found only in June in small numbers.

In 2017, the highest abundance of mature females was observed in May (over 1000 ind./m^3), then it decreased sharply in the summer-autumn period; in December, this age group was not found. The same trend was noted in 2018, but the abundance of mature females was significantly higher (about 6000 ind./m^3), and then it sharply decreased, and this age group has disappeared in late November – December.

Therefore, the dynamics of the abundance of different life stages of brine shrimp in the Eastern basin of the Lake Saki in 2017 and in 2018 had both similar trends and differences. There were also differences in the *Artemia* nauplii hatching from cysts collected in different months along the shores of the Lake Saki (Fig. 10). The proportion of hatched larvae was higher for the eggs collected in the cold season both in 2017 and in 2018, except for the cysts collected in August 2018. In 2017, the highest hatching rate was recorded in February (21.5%), in 2018, in March (43%). In the summer, the share of hatched nauplii decreased significantly, but it increased in the autumn-winter period. In addition, from January to April 2018, the share of nauplii hatched from cysts exceeded significantly ($p < 0.05$) the corresponding indicators of cysts collected in the same period of 2017.

Discussion

In order to understand the mechanisms that govern the functioning of the aquatic ecosystem, a comprehensive study is indispensable to assess the totality of natural and anthropogenic factors affecting the dynamics of processes occurring in a water body both directly and indirectly for a certain time. Our study allowed us to report on the main trends in seasonal dynamics of hydrometeorological factors in the area of the Lake Saki, as well as to trace their influence on the seasonal variability in the hydrochemical parameters of water and the state of the brine shrimp population.

Since the Eastern basin of the hypersaline Lake Saki is used for medicinal purposes and is located in the zone of active recreational activity, the results obtained may be important for the developing the recommendations for the optimal use of its resources, both hydromineral and biological. The formation of peloids (medicinal sulfide-silt mud) in the Lake Saki occurs as a result of the deposition of organic matter with subsequent transformation by its hydrobionts,

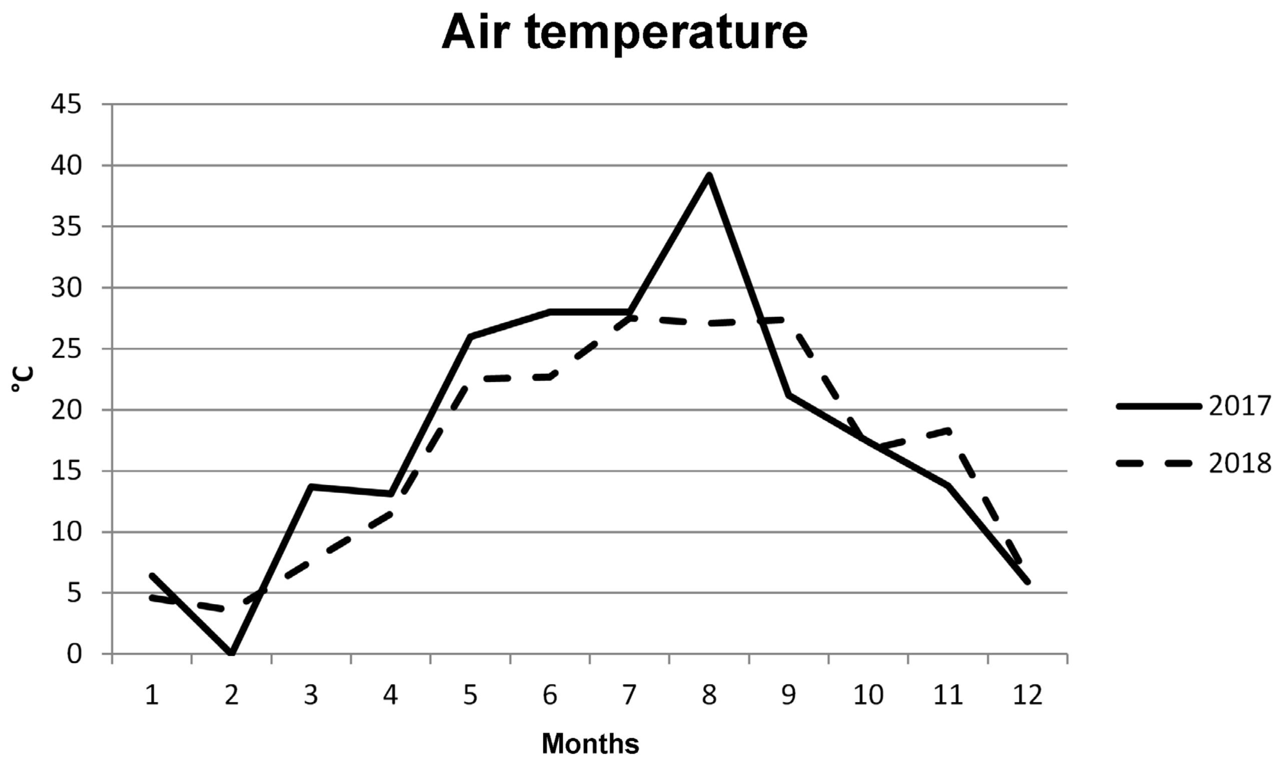


Fig. 2. Seasonal monthly average air temperatures in the area of the Lake Saki.

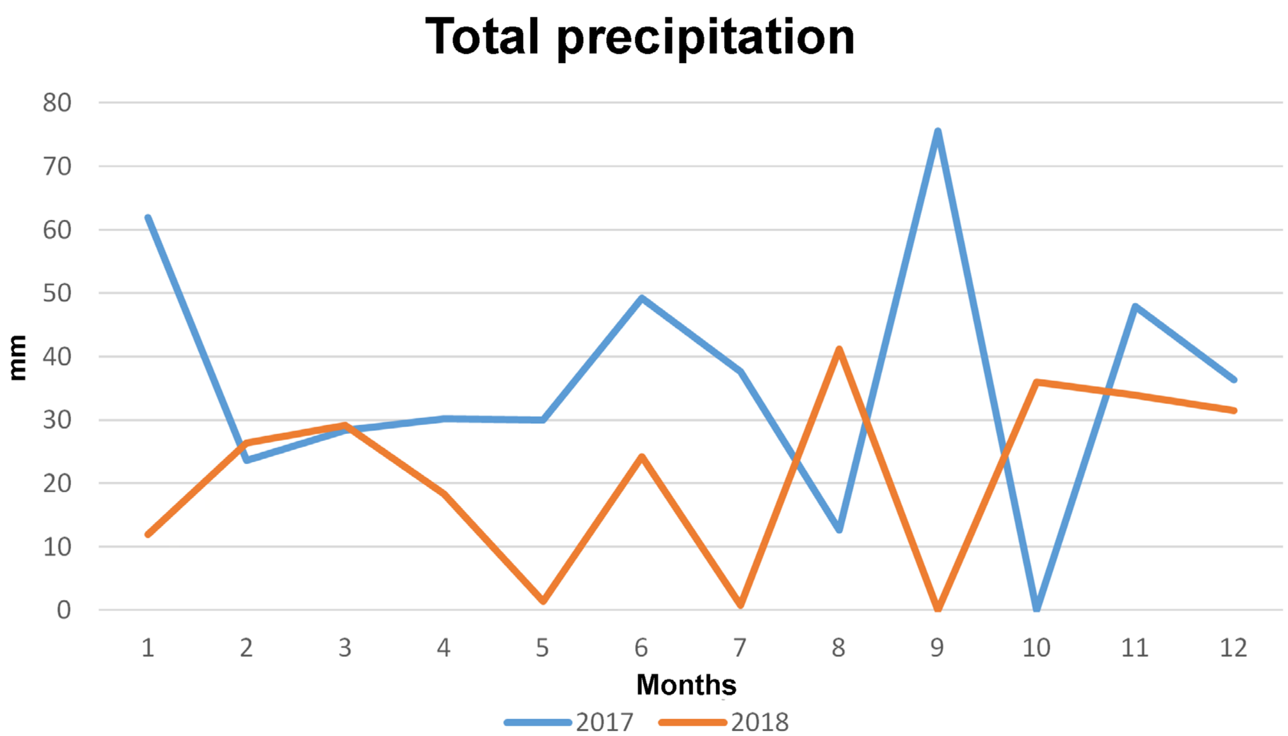


Fig. 3. Seasonal dynamics of precipitation in the area of the Lake Saki.

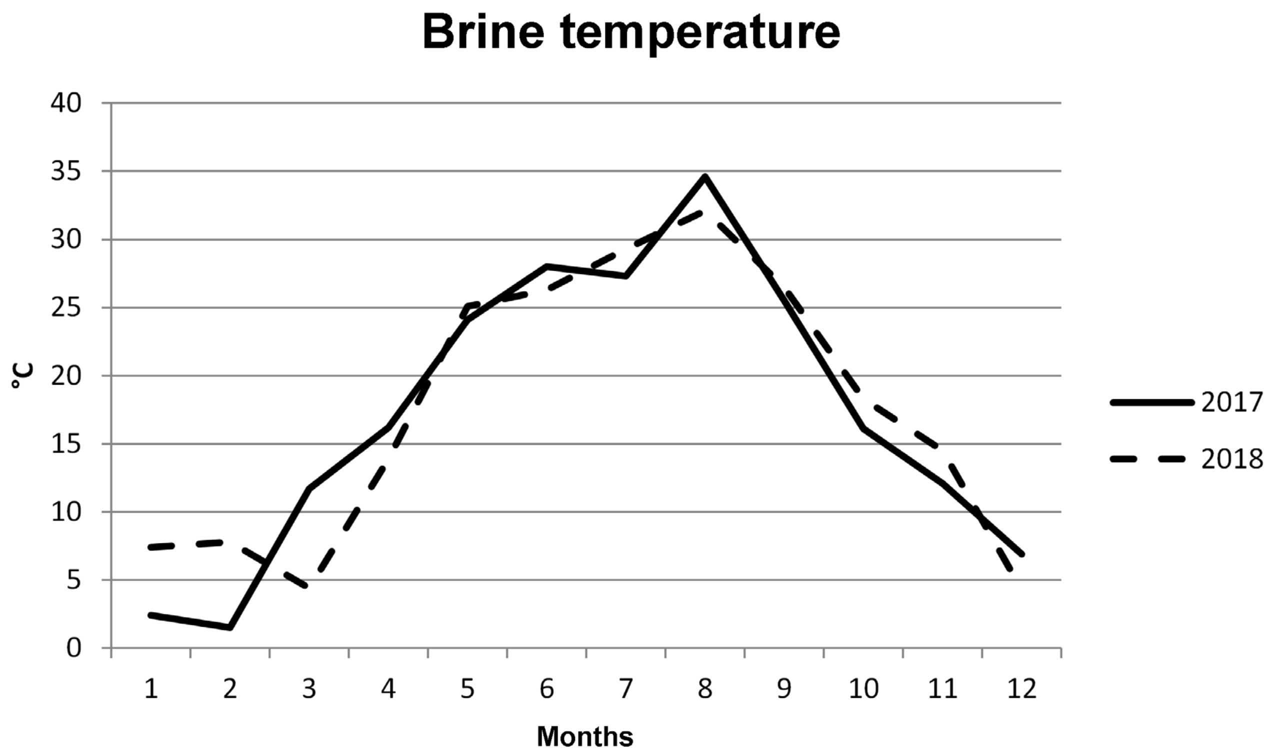


Fig. 4. Seasonal dynamics of brine temperature in the Eastern basin of the Lake Saki.

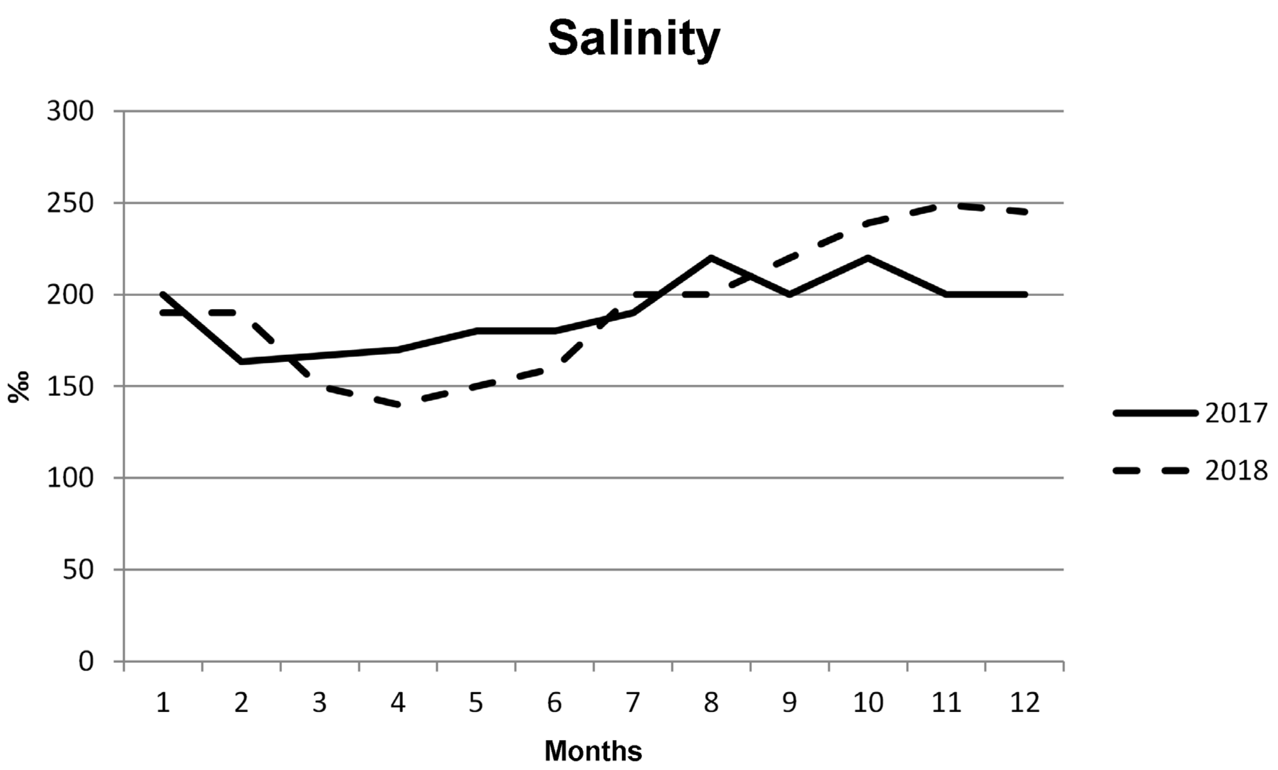


Fig. 5. Seasonal dynamics of brine salinity in the Eastern basin of the Lake Saki.

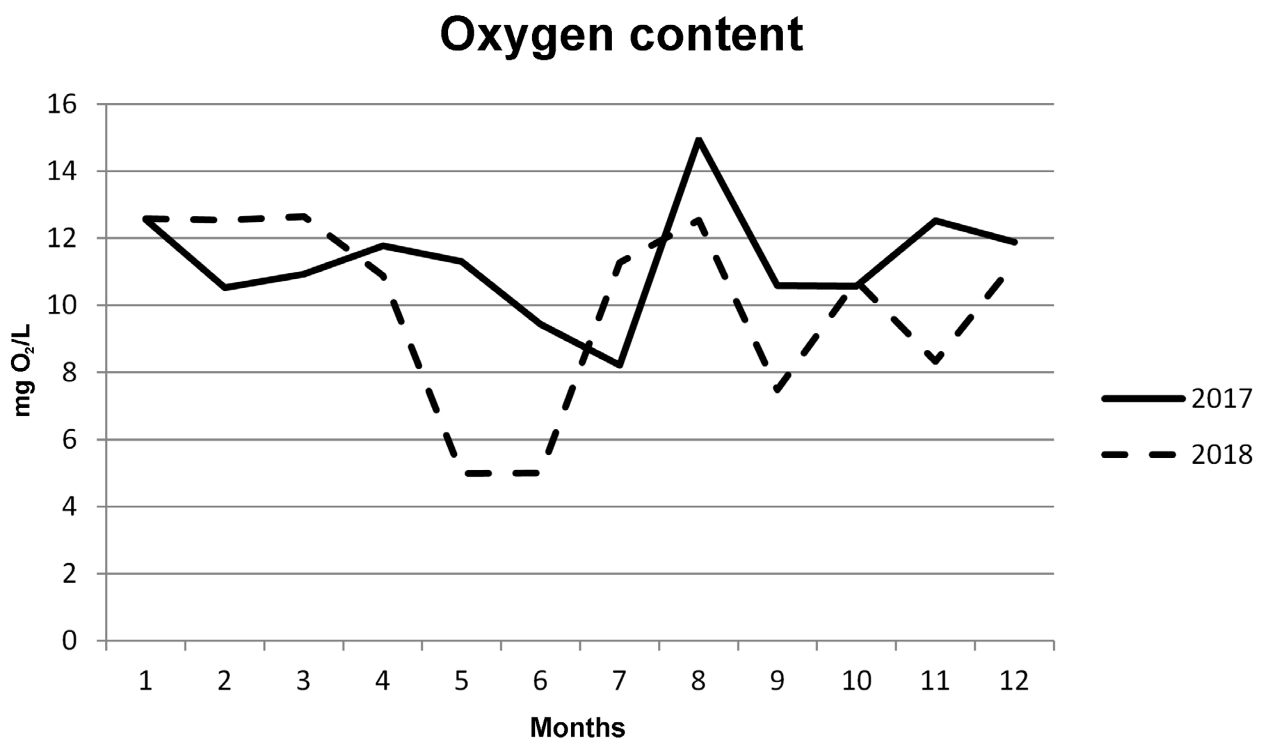


Fig. 6. Seasonal dynamics of the oxygen content in the brine of the Eastern basin of the Lake Saki.

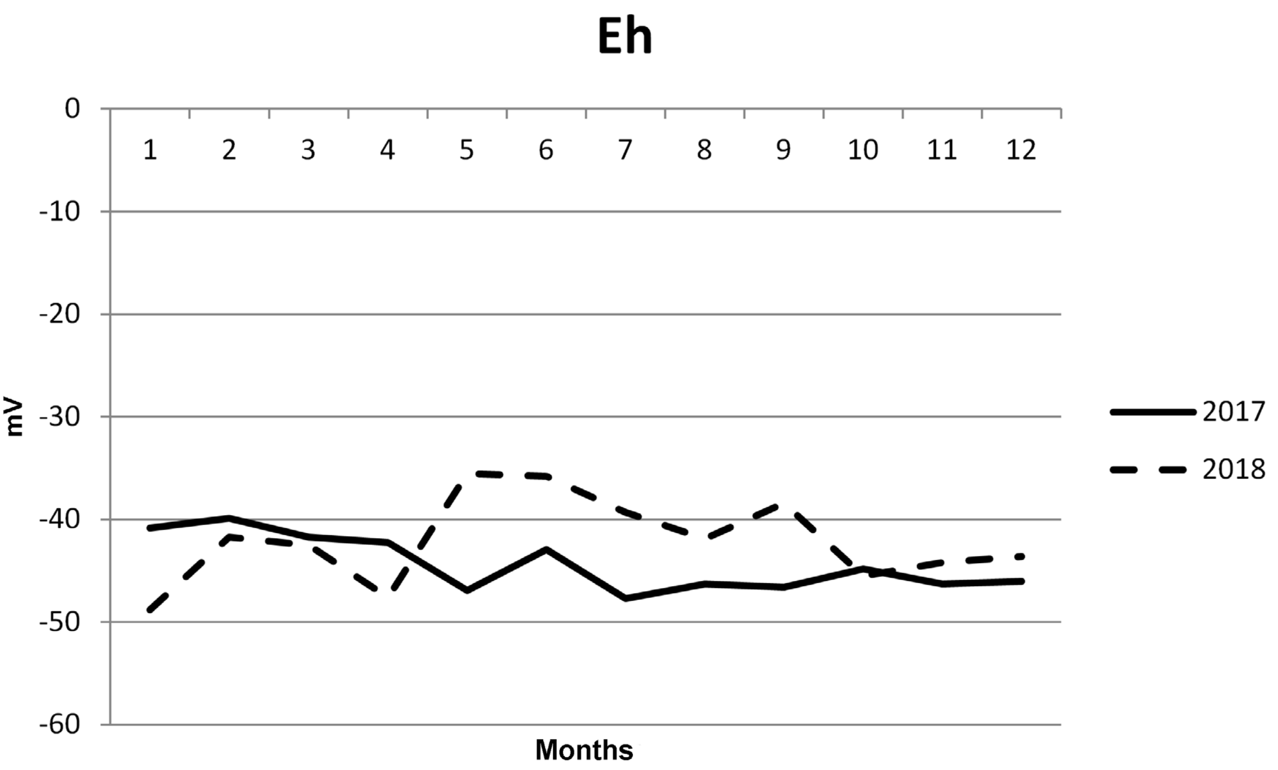


Fig. 7. Seasonal dynamics of Eh in the brine of the Eastern basin of the Lake Saki.

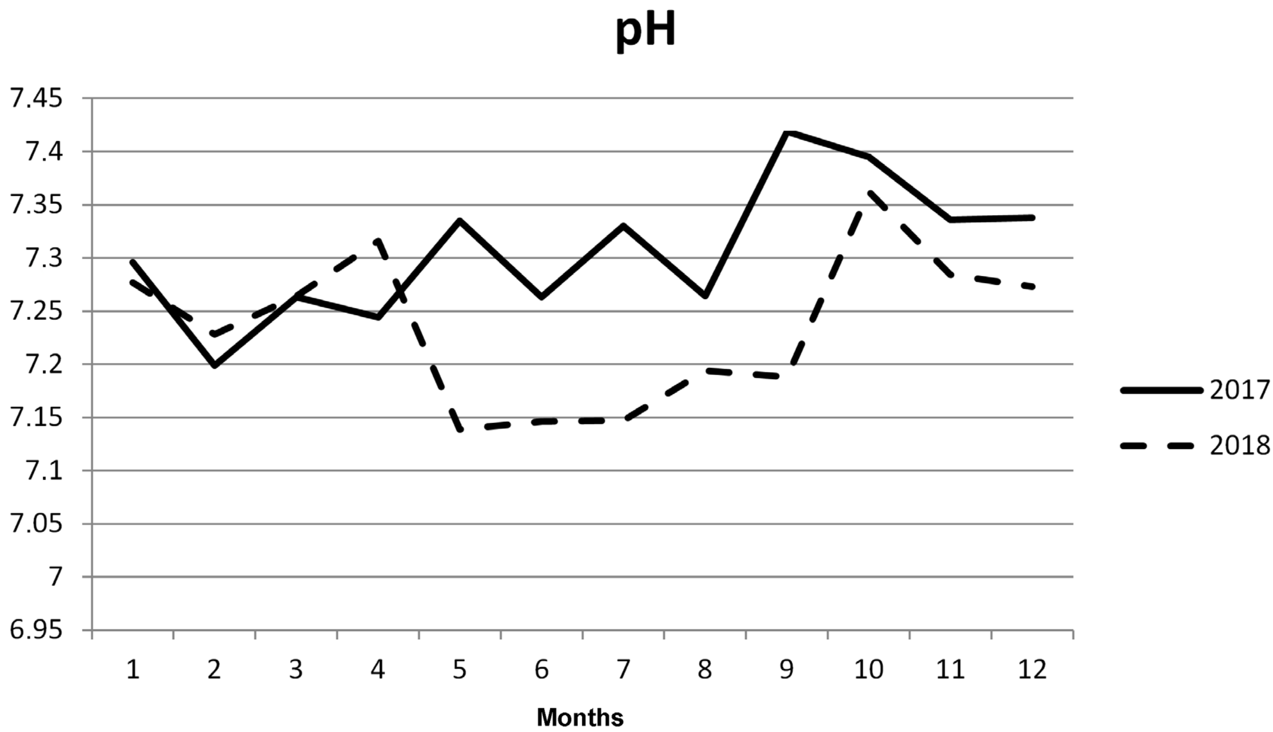


Fig. 8. Seasonal dynamics of the pH of brines in the Eastern basin of the Lake Saki.

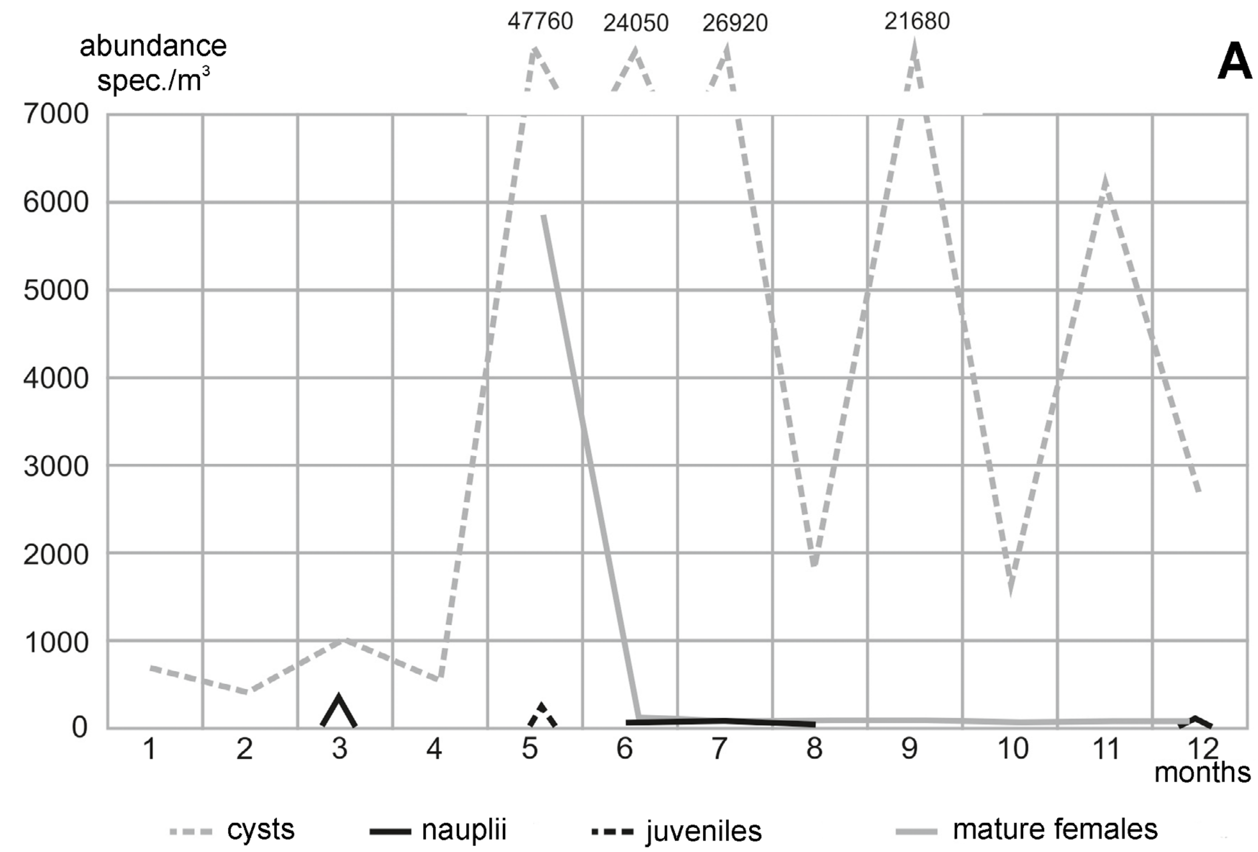
so this process must be taken into account. The autochthonous biota is a main supplier of these organic components, which includes a number of planktonic and benthic invertebrates (small crustaceans, some insects and their larvae), as well as micro- and macroalgae. In addition, these processes may alter greatly due to the significant recent climatic changes (IPCC, 2013), which may lead to the disruption of trophic links evolved evolutionary in the salt lake ecosystem.

Our data evidenced that winter and spring in 2018 were warmer than those of 2017. The average monthly temperature was also higher in 2018, especially in the summer months. At the same time, the annual precipitation in 2018 was less than in 2017 by 169.6 mm; in 2018, three months were dry, in 2017, it was only one. During dry periods, the arid zones formed in the area of the Lake Saki. Generally, there are a lot of estuaries and inland waters in the arid climatic zones around the world, the salinity of these water bodies is significantly higher than in the oceans and seas. These water bodies are located very close to the sea, they may dry out in the warm season and be filled again with the sea water or precipitation up to significant desalination. Therefore, hypersalinity is a seasonal phenomenon for such water bodies, which occurs due to intense evaporation in the warm season. Meantime, hypersaline lakes, especially continental ones, are characterized by the constantly high level of mineralization. The Lake Saki also belongs to the latter category, therefore, the changes in the meteorological situation have a significant impact on its hydrochemical characteristics.

We found that the temperature of brine in the lake in 2017–2018 gradually increased in the spring, reaching maximum values (exceeding +30 °C) in July – August, and then decreased again. The water temperature in the winter season of 2018 was higher than that in 2017, which also affected the life conditions of *Artemia* in the lake.

The movement of air masses that form stable pressure zones on the shores of the lake during the year is another important hydrometeorological factor affecting the ecological state of the reservoir as a whole and the functioning of particular organisms. The wind determines the degree of mixing of the waters and their vertical stratification, as well as the overflow of sea water through the sand barrier into the lake (Hetzel et al., 2015; Kompaniets and Iakubailik, 2015).

The hydrometeorological situation in the lake area has also significantly affected the hydrochemical parameters of its waters. Over the course of two years, similar tendency of the salinity decrease in the winter-spring period subsequent increase in the summer-autumn period was observed. In spring, salinity ranged as 140–170‰, increasing up to 200–240‰ in August – September. The spring decrease in the water salinity in the Eastern basin of the Lake Saki may be due to both atmospheric precipitation and flood; in this area, the precipitation usually increases in the spring months. Similar seasonal phenomena in salinity fluctuations were also observed in other hy-



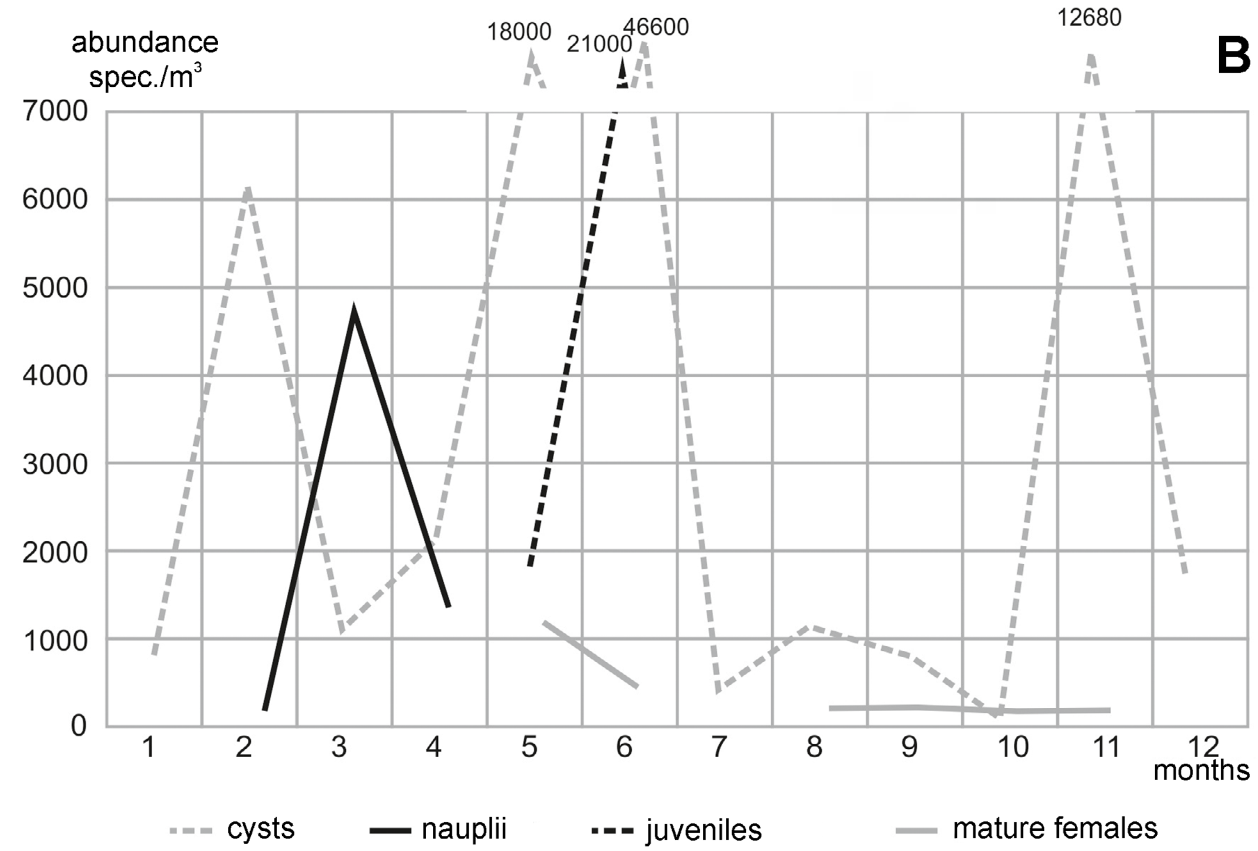


Fig. 9. Seasonal distribution and abundance of different life stages of the brine shrimp in the waters of the Eastern basin of the Lake Saki in 2017 (**A**) and in 2018 (**B**).

persaline lakes (Geldenhuys et al., 2016; Mitchell et al., 2017). At the same time, there were interannual variability of the water salinity of the lake. In 2017, the precipitation in February and March significantly exceeded the corresponding values in 2018, which led to a decrease in salinity in the lake, persisting until June 2017 (Figs. 4, 5). However, from May through July, the opposite trend was observed. In particular, the precipitation was higher in 2018 than in 2017, and by September 2018, the salinity in the Eastern basin exceeded that observed in 2017. This evidences on a seasonal dependence of the hydrochemical parameters of brine on the hydrometeorological situation.

The oxygen content in the brine also had a pronounced seasonal pattern, when it decreased in May – June due to eutrophication processes that were also the characteristic of other lakes (Bamba et al., 2017). By August, the oxygen content increased up to the maximum values; however, the range of variability was much pronounced in 2018 comparing to that in 2017. A sharp decrease in the oxygen content in May – June 2018 may be associated with a decrease in the precipitation and a decrease in the degree of water mixing, as well as with the formation of stagnant water areas, where the processes of decomposition of organic matter (dead crustaceans, microalgae, etc.) are actively occurring, which requires a large amount of oxygen.

The environmental pH and Eh are among the most important indicators of the ecological state of a reservoir, determining the living conditions for aquatic organisms (Hargrave et al., 2008). The Eh and pH varied slightly in the Eastern basin of the Lake Saki in 2017 and 2018. At the same time, a stable decrease in pH in May – July 2018 was noted, which was consistent with a decrease in the oxygen content and an increase in the redox potential during the same period. This was probably due to increased destruction of organic substances, which accumulated during this season due to dead crustaceans, microalgae, etc.

The branchiopod *Artemia* sp., benthic larvae of mosquitoes of the Chironomidae family, halophilic microorganisms, including a complex of diatoms, forming a powerful layer on the bottom, and algae, presented mainly by the macrophyte *Cladochora siwaschensis*, were the most common species of the salt lake biota. The community structure and the abundance and biomass of these aquatic organisms determine the vector of production/destruction processes in the formation of bottom sediments. Since *Artemia* is the dominant species in hypersaline lakes, the changes in its population reflect the dynamics of processes in the ecosystem, occurring under the influence of external factors, including hydrometeorological ones (Sánchez et al., 2016; Xin, 2004).

The current ecological state of the Lake Saki is significantly different from that observed in the past (Golub et al., 2007; Tyutyunik and Khokhlov, 2007). Prior to dividing the lake by the dams, the activity of hydrobionts in the lake depended on seasonal fluctuations in the brine level and salinity. The

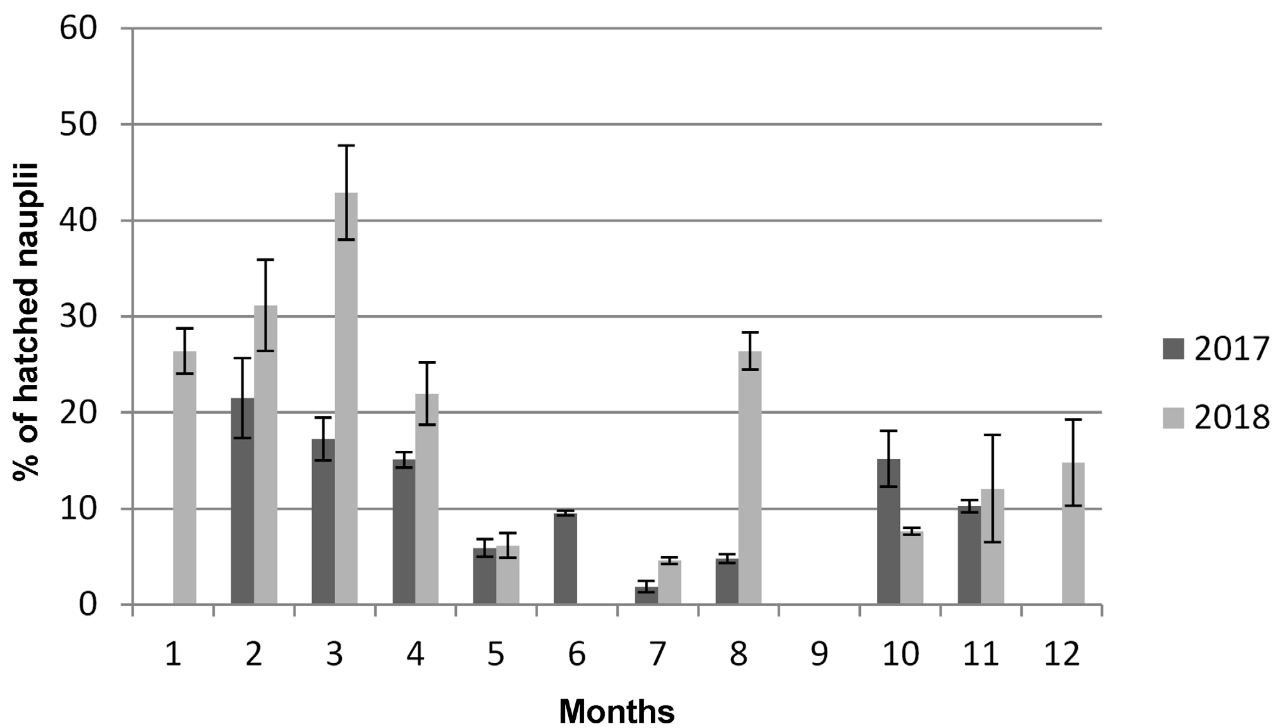


Fig. 10. The share of hatched nauplii from *Artemia* cysts (%) collected in the Eastern basin of the Lake Saki (*M* ± *m*, where *M* is the average value, *m*, the error of mean).

altering of the periods of complete or partial drying out with the periods of filling the lake water area during the rainy season or as a result of erosion of the sea embankment with a subsequent decrease in mineralization level was a necessary condition for the reproduction and active life of *Artemia* sp. and anaerobic destruction of organic residues. The extensive drained zones, appeared during the drought and necessary for anhydrobiosis of cysts and their spring activation by oxygenated desalinated waters, were the main conditions for the further development of the brine shrimp population. Alongside with the beginning of the artificial regulation of the hydrological regime of the Eastern basin and the maintenance of a stable brine level throughout the year in the range from −0.8 to −1.2 m operating altitude, the initial conditions in the ecosystem have changed and hydrometeorological factors have become limiting (Tyutyunik and Khokhlov, 2007; Shklovsky, 2016).

Our studies evidenced that the abundance dynamics of different life stages of brine shrimp was directly affected by brine temperature, depending on the season. The first nauplii appeared in February – March, when the brine temperature was approaching +10 °C; the most intensive development of the brine shrimp population, expressed as increase in the abundance of all life stages, was observed in May – June, when the water in the lake warmed up to +18…+28 °C. During the same period, favorable feeding conditions were formed for *Artemia* in the ecosystem as a result of the intensive development of phytoplankton and the income of suspended and dissolved organic matter.

The number of crustacean generations depends on the length of the warm period, when the brine is warm enough. As a rule, *Artemia* sp. produces from 2 to 4 generations per year. Other hydrochemical conditions in the reservoir may also be limiting factors for this crustacean. In particular, changes in the ionic composition of brine, accompanied by an increase in mineralization up to 190 g/dm^3 and even more, lead to the population inhibition. Reduced oxygen concentration, eutrophication, and the formation of the dead zones contribute to the death of brine shrimp; as a result, one can observe a large number of dead specimens at different life stages in the surf zone. As a rule, such conditions develop in the hottest summer months, July and August. However, before the death, the crustaceans form cysts, which number increases significantly during this period both in the water column and along the shores of the lake.

The cyst deposits along the coast depend on the movement of air masses forming stable pressure zones on the lake shores during the year. Since the north-east and south-west directions of the wind dominate in the area of the lake location, the vast surge zones necessary for the subsequent drainage and anhydrobiosis of brine shrimp eggs are formed taking into account the bottom morphology along its eastern shore (Khokhlov et al., 2018, 2019). At the same time, the proportion of nauplii hatched from cysts and then concentrated along the shores may vary significantly both in different seasons and years. The nauplii hatching ratio was higher for cysts collected in the winter – spring period (January – April), but it decreased gradually in late spring and summer until July. In autumn, the hatching ratio increased again. This increase in hatching ratio in the cooler months compared to warmer ones was due to low water temperature and the absence of precipitation.

A decrease in the water salinity in spring as a result of snow melting and precipitation leads to irreversible hydration of cysts, stimulates embryogenesis, but subsequent development of larvae is impossible at low temperatures and lack of sufficient food supply (Sugumar, 2012; Sura and Belovsky, 2016). This explains the sharp decrease in the ratio of hatching nauplii from cysts collected in March and subsequent months. Regard must be paid to the relatively high hatching ratio in August 2018. Probably, the conditions in the lake were favorable for forming by *Artemia* of so-called "summer cysts", which differed by a thinner shell (cuticle). Further development of nauplii hatched from such cysts occurred when a sufficient fodder base and the favorable hydrochemical conditions (oxygen content, pH, temperature, and salinity) were formed (van Stappen, 1996; Rudneva et al., 2005, 2008), which was typical for the ecosystem of the Eastern basin of the Lake Saki in the autumn of 2018. These data may be useful for optimizing the period of commercial collection of *Artemia* cysts in the Lake Saki.

Based on our data, we argue that the ecological state of the Eastern basin of the hypersaline Lake Saki had a pronounced seasonal variability due to the influence of hydrometeorological factors. The increase in air temperature in summer, up to extreme values, the absence of precipitation and strong evaporation, as well as prevailing wind direction are the most important factors for the dynamics of the hydrochemical characteristics of the lake. These changes lead to an increase in water temperature, salinity, a decrease in its oxygen content, and a change in water pH and Eh. The combination of these parameters preconditions the life cycle realization of aquatic organisms, which should be taken into account when artificially regulating the water-salt regime of the lake ecosystem. This will make it possible to avoid the developing of the drained zones along the shores in the summer-autumn period and to fill the lake with the water volume sufficient for spring activation of *Artemia* sp eggs and subsequent development of the population of this crustacean species. During the period of a natural decrease in the water level, it is necessary to maintain its mineralization of about 150 g/dm^3 in order to prevent inhibition of the populations of aquatic organisms. In addition, the reported dynamics of *Artemia* nauplii hatching from cysts, which is higher in the cold months, may contribute to the development of measures for their collection and further use for aquaculture purposes.

Conclusions

Therefore, a comprehensive study of seasonal fluctuations of the meteorological, hydrochemical and hydrobiological characteristics of hypersaline water bodies can provide significant information for understanding their transformations in specific geographical conditions during ongoing climate change and under increasing anthropogenic load. Our data evidence that the artificial regulation of the water-salt regime of the Eastern basin of the Lake Saki, bearing in mind the effect of hydrometeorological factors, provides favorable conditions for the development of zooplankton in the ecosystem, which is especially significant when analyzing the dynamics of the *Artemia* sp. population. This must include the data on the appearance of the first nauplii, their further development, distribution and correlation of different life stages, the formation and abundance of cysts, as well as their quality, estimated by the ratio of hatched nauplii. In order to sustain the optimal development of the *Artemia* population and its population success, the water-salt regime should be artificially regulated. In particular, it is necessary to maintain the average annual brine mineralization at the level of 150 g/dm^3. In addition, it is also indispensable to take into account the prevailing directions of air mass movement, which affect greatly the formation of stable surge zones, necessary for the successful completion of the full life cycle of brine shrimp and the formation of cysts on the coast, which can be collected for commercial purposes. In this case, the anthropogenic impact on the ecosystem of the Lake Saki may have a positive effect, which will preserve the ecosystem and help to maintain the normal functioning of its inhabitants, as well as use optimally its hydro-mineralogical and biological resources.

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