Invertebrates of hyperhaline reservoirs of the Orenburg Region (Russia)

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ABSTRACT. A study of the composition and structure of macrozoobenthos communities of 4 hyperhaline reservoirs of resort areas and places of mass recreation in the Orenburg Region: artificial reservoirs on the Tuzlukkol river, a reservoir near the spring of the Gora Boevaya Nature Monument, lakes Maloe Gorodskoe and Tuzluchnoe (Sol-Iletsky lakes) was fulfilled. The taxonomic composition of macrozoobenthos includes 10 species of Branchiopoda and Insecta. It is shown that an increase in the level of mineralization to 159‰ leads to a decrease in species diversity of biota and halobiont Artemia salina and halophilic Cricotopus salinophile, Calicoides (Monoculicoides) riethi and Ephydra pseudomurina become dominant species in hyperhaline reservoirs. The development of the shore fly Ephydra attica was confirmed in hyperhaline water bodies at a mineralization level of 51–67‰; this species, previously known from the territory of Crimea and the Astrakhan region, is recorded on the territory of the Orenburg region for the first time.

Abstract: По результатам статистического анализа сообществ макрозообентоса четырех гипергалинных водоемов рекреационных зон Оренбургской области, расположенных в разных зонах минерализации уровня воды (от 51 до 67‰), было обнаружено доминирование видов Artemia salina, Cricotopus salinophile, Calicoides (Monoculicoides) riethi и Ephydra pseudomurina. Отмечено развитие берегового мухи Ephydra attica, ранее неизвестной для Оренбургской области, на территории Оренбургской области. Определен новый вид и редкое для России вида Ephydra pseudomurina, который зарегистрирован на территории Оренбургской области впервые.

Introduction

High salinity inland waters are essential for maintaining natural processes in arid zones. Salt water bodies are an important source of halophilic fauna formation, which differs sharply from that of freshwater communities and often contains rare highly specialized forms. Of particular interest to researchers is the study of changes in species diversity in the salinity gradient in water bodies with different salt concentrations [Vare-

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The health of people in resort areas is associated with a close occurrence of Permian salts is a cascade of bowl-shaped natural cavities with a depth of 0.2 m and a width of 0.7 m. Bottom sediments are represented by a mixture of gray silt and clay. This place is a little less popular since the spring can dry out in summer.

There is a unique Ilets rock salt deposit, which is a salt dome in a salt core brought to the surface on the territory of the city of Sol-Ilets, Orenburg Region. A complex of lakes was formed as a result of open-pit mining of salt, when large karst funnels, excavations of used open pits and cavities of old mine workings formed in saline sediment were filled with water. There are very popular among tourists and more than 1.5 million people attend them. We have investigated 2 of them — Maloe Gorodskoe and Tuzluchnoe.

Lake Maloe Gorodskoe has a karst origin, the maximum depth reaches 15 m. The area of the lake is 21 030 m². The total salt content in this reservoir is from 31.4‰ in the spring to 86.5‰ in the autumn. The bottom lies a layer of therapeutic mud, the total reserve of which is about 3 thousand m³. Bottom sediments of the lake are sandy-silty.

Lake Tuzluchnoye also has karst origin. Its area is 23 750 m² and a depth of approximately 3–4 m. Mineralization fluctuates throughout the year and amounts to 30.3‰ in spring and 159‰ in autumn. The bottom sediments of Lake Tuzluchnoye are represented by a thick layer (2 m or more) of black silt — a homogeneous fine silt with the remains of decomposed vegetation with the smell of hydrogen sulfide.

**Methods**

To determine the species diversity of macrozoobenthos of the studied water bodies, samples were taken from silty soils using a DAK-100 automatic box-type scoop on a steel cable with a grip area of 1/100 m², and from a sand and gravel substrate using a hydrobiological scraper (knife length 16 cm, scraper pulling 1 m). Samples were taken at depth 0.7–0.8 m at Tuzlukkol reservoirs, at depth 0.2 at Gora Boevaya station, at depth of 0.7–1 m at Maloe Gorodskoe and Tuzluchnoe lakes with 3 replicates each season. The soil was washed through a sieve cloth with a mesh size of 300 µm. Bottom invertebrates were fixed with 4% formaldehyde solution. Sampling and processing of macrozoobenthos samples was carried out according
Invertebrates of hyperhaline reservoirs of the Orenburg Region (Russia)

339

to the methods generally accepted in hydrobiology [Abakumov, 1983]. To determine the constant weight of the larvae, they were kept in a 4% formaldehyde solution for three months, dried on filter paper until the wet spot disappeared, measured and weighed on an HR-100AZG analytical balance. The species composition, abundance and biomass of bottom invertebrates were determined, followed by a conversion to 1 m². The classification of V.Ya. Levanidov [1977] was applied to determine the species structure of benthocenoses. The dominance of macrozoobenthos groups in the community was estimated by the percentage of the total number and biomass. Water sampling for chemical analysis, storage, transportation and preparation for research were carried out in accordance with GOST 31861-2012. Hydrochemical analysis of water samples was carried out according to standard methods on the basis of an accredited laboratory in Orenburg Federal State Budgetary Institution State Center for Agrochemical Service “Orenburgsky”.

The species composition was determined by fixed larvae using keys and species descriptions [Tsaiolikhin 2000, 2001; Kri vosheina, 2003; Zinchenko et al., 2009; Zorina et al., 2014], using light microscopes of the MBS-2 and Standard-25 brands (Carl Zeiss). We did not collect adults specifically except for the case of mass reproduction of E. pseudomurina on Lake Tuzluchnoye to confirm the species affiliation of the object. A total of 56 samples were collected and processed.

Results and discussion

The waters of the investigated water bodies are of the sodium chloride type with a varying level of mineralization.

As part of the macrozoobenthos of the artificial microreservoirs on the Tuzlukkol river, 4 taxa were registered within the place. Insects are represented by larvae of 2 species of dipterans (Cricotopus salinophilus Zinchenko, Makarchenko et Makarchenko, 2009, Ephydra pseudomurina Kri vosheina, 1983), 1 species of beetles (Berosus (Enoplorus) spinosus (Steven, 1878)). Of the other invertebrate groups, 1 species of crustaceans (Artemia salina (Linnaeus, 1758)) was noted (Table 1). Among the species, there are species that live in salt bodies of water.

In artificial reservoirs 1 and 3 on the Tuzlukkol river, the mineralization level reaches 159‰, which provides a stable habitat for certain species: Ephryda pseudomurina, Cricotopus salinophilus, Artemia salina. The number of representatives of the bottom communities of individual sections of the river varies from 51 to 6362 ind./m², and the biomass — from 0.40 to 7.35 g/m². Benthos stations 1 and 3 are characterized by the dominance of larvae of shore-flies. The rest of the fauna 1 is represented mainly by eurybiont species. At station 2, larvae of Ephydra pseudomurina flies massively develop in spring as well as in autumn (abundance 75 ind./m² and 775 ind./m², biomass 0.34 g/m² and 6.17 g/m², respectively).

As a part of macrozoobenthos, 5 taxa were registered in the mineral spring on the territory of the Gora Boevaya Nature Monument: Branchiopoda — Artemia salina; Insecta: Diptera — Culicoides (Monoculicoides) riethi Kieffer, 1914, Ephydra glauca Meigen, 1830, E. attica Becker, 1896, E. pseudomurina (Table 1). In spring, the most common species in the Gora Boevaya spring are the larvae of Ephydra pseudomurina, numbering 1075 ind./m². These flies are known to form layers of larvae and pupae up to 2–3 cm thick [Krivosheina, 1983, 1986]. Our samples showed a large number of puparia and flies in the spring. In the autumn period, the communities of ceratopogonids Culicoides (Monoculicoides) riethi are formed in the natural environment of the spring with a dominance of 99.6%.

As a part of macrozoobenthos in Salt-Iletsky lakes, 8 taxa were registered: Branchiopoda — Artemia salina; Insecta: Heteroptera — Sigara assimilis (Fieber, 1848); Coleoptera — Hygrota (Coelambus) enneagrammus (Ahrens, 1833); Diptera — Culex sp., Culicoides (Monoculicoides) riethi, Cricotopus salinophilus, Ephydra glauca, E. pseudomurina (Table 1).

In the pelagic zone of Lake Maloe Gorodskoye, the gill-footed crustacean Artemia salina, along with the larvae of beetles (Hygrota (Coelambus) enneagrammus), mosquitoes (Culex sp.), ceratopogonids (Culicoides (Monoculicoides) riethi), chironomids (Cricotopus salinophilus) and shore-flies E. pseudomurina lived in large numbers.

In Lake Tuzluchnoe, the larvae of Ephydra pseudomurina developed in spring in such quantities that the surface of the water seemed to be covered with a continuous layer of imago. The entire water line of the anthropogenic reservoir was dotted with their empty pupae. The number of larvae of E. pseudomurina reached 910 ind./m², and the biomass was 4.75 g/m². Cricotopus salinophilus, Artemia salina, Sigara assimilis, Ephydra glauca were also found in large numbers there. Among the species, there are species that live only in salt bodies of water (Cricotopus salinophilus, Ephydra spp., Artemia salina), and species with wide ecological plasticity. For example, Sigara assimilis is able to colonize nearly all aquatic habitats: rivers, streams, lakes, ponds, temporary waters, pools and brackish coastal waters [Boda, Csabai, 2009; Polhemus, Polhemus, 2008]. They occur in waters with salinity up to 100‰ [Strauss, Niederinghaus, 2014].

In general, it should be noted that, compared to mixohaline reservoirs [Shayhu dina, 2019 a, b], an increase in salinity leads to a decrease in species diversity, and species such as Artemia salina, Ephydra pseudomurina and Cricotopus salinophilus dominate in hyperhaline reservoirs. The main structural indicators of macrozoobenthos communities are presented in Table 2. The benthos abundance during the study period ranged from 923 ind./m² (microreservoirs on the Tuzlukkol river) to 8487 ind./m² (Maloe Gorodskoe
Table 1. Distribution of species composition and ecological groups (ER — euryhaline, GF — halophilic, GB — halobiont) of macrozoobenthos in the hyperhaline reservoirs of the Orenburg Region.

Таблица 1. Распределение видового состава и экологические группы (ER — эвригалинные, GF — галофильные, GB — галобионтные) макрозообентоса в гипергалинных водоемах Оренбургской области.

| Species and taxa                                      | Name of water body | Environmental group |
|-------------------------------------------------------|--------------------|---------------------|
|                                                      | artificial microreservoirs on the Tuzlukkol river |                     |
|                                                      | Gora Boevaya spring |                     |
|                                                      | Sol-Hetsky lakes   |                     |
|                                                      | Maloe Gorodskoe    |                     |
|                                                      | Tuzluchnoe         |                     |
|                                                      | **BRANCHIOPODA**    |                     |
| Artemiidae                                            |                    |                     |
| *Artemia salina* (Linnaeus, 1758)                     | +                  | +                   | +                   | +                   | GB       |
|                                                      | **INSECTA**         |                     |
| Heteroptera                                           |                    |                     |
| Corixidae                                             |                    |                     |
| *Sigara assimilis* (Fieber, 1848)                     |                    |                     |
|                                                      |                    | +                   | ER, GF              |
| Coleoptera                                            |                    |                     |
| Dytiscidae                                            |                    |                     |
| *Hygrotus (Coelambus) enneagrammus* (Ahrens, 1833)    |                    | +                   | ER, GF              |
|                                                      | **Hydrophilidae**   |                     |
| *Berosus (Enoplurus) spinosus* (Steven, 1878)          | +                  | +                   | ER, GF              |
|                                                      | **Diptera**         |                     |
| Culicidae                                             |                    |                     |
| *Culex sp.*                                           |                    | +                   | ER, GF              |
|                                                      | Ceratopogonidae     |                     |
| *Culicoides (Monoculicoides) riehti* Kieffer, 1914     |                    | +                   | +                   | ER, GF              |
|                                                      | **Chironomidae**    |                     |
| *Cricotopus salinophilus* Zinehenko, Makarchenko et Makarchenko, 2009 | +                  | +                   | +                   | +                   | ER, GF |
|                                                      | **Ephydridae**      |                     |
| *Ephydra glauca* Meigen, 1830                         |                    | +                   | +                   | ER, GF              |
| *Ephydra pseudomurina* Krivosheina, 1983               | +                  | +                   | +                   | +                   | ER, GF |
| *Ephydra attica* Becker, 1896                         |                    | +                   | +                   | ER, GF              |
Table 2. Structural indicators of bottom communities of hyperhaline reservoirs of the Orenburg region.

| Index                        | Sampling point                              | Maloe Gorodskoe Lake | Tuzluchnoe Lake |
|------------------------------|---------------------------------------------|-----------------------|-----------------|
| Abundance, ind./m^2          | artificial microreservoirs on the Tuzlukkol river | 923                   | 2613            |
|                              | Gora Boevaya spring                         | 2613                  | 8487            |
| Biomass, g/m^2               |                                             | 4.85                  | 7.20            |
|                              |                                             | 7.20                  | 4.31            |
| Species:                     |                                             |                       |                 |
|                             | d — dominants,                              |                       |                 |
|                             | ds — subdominants calculated by abundance   |                       |                 |
| Ephydra pseudomurina         | (d = 54.2)                                  |                       |                 |
| Cricotopus salinophilus      | (d = 36.6)                                  |                       |                 |
| Artemia salina              | (ds = 9.2)                                  |                       |                 |
| Ephydra pseudomurina         | (d = 41.1)                                  |                       |                 |
| Artemia salina              | (d = 30.3)                                  |                       |                 |
| Culicoides                   | (Monoculicoides) rieithi (d = 23.5)          |                       |                 |
| Artemia salina              | (d = 83.5)                                  |                       |                 |
| Cricotopus salinophilus      | (d = 14.7)                                  |                       |                 |
| Ephydra pseudomurina         | (d = 63.7)                                  |                       |                 |
| Artemia salina              | (d = 69.6)                                  |                       |                 |
| Cricotopus salinophilus      | (d = 17.7)                                  |                       |                 |
| Ephydra pseudomurina         | (d = 27.7)                                  |                       |                 |
| Artemia salina              | (d = 91.1)                                  |                       |                 |

Lake), biomass from 4.31 g/m^2 (Maloe Gorodskoe Lake) to 7.59 g/m^2 (Tuzluchnoe Lake).

Conclusions

As part of the macrozoobenthos of the studied hyperhaline reservoirs, 10 taxa were identified. Under the conditions of the mineralization gradient, the benthic fauna variability has pronounced structural and functional features. An increase in mineralization to 159‰ leads to a decrease in species diversity of biota, reflecting the high concentration of dominance of halobiont species Artemia salina and halophilic species Cricotopus salinophilus, Culicoides (Monoculicoides) rieithi and Ephydra pseudomurina. The development of the shore fly Ephydra attica was confirmed in hyperhaline water bodies at a mineralization level of 51–67‰; this species, previously known from the territory of Crimea and the Astrakhan region, is recorded on the territory of the Orenburg region for the first time. The mass reproduction of halophilic species can lead to clogging of therapeutic mud. In addition, some objects, for example, larvae of Ephydra pseudomurina are known to be reserves for the preservation of opportunistic bacteria of the Escherichia coli group in water bodies with high salinity [Gogoleva et al., 2019]. Chironomidae larvae may have connections with other dangerous bacterial agents [Meir et al., 2008; Halpern, Senderovich, 2015; Laviad, Halpern, 2016]. Two bloodsuckers were identified among dipterans: Culicoides (Monoculicoides) rieithi and Culex sp., capable of attacking people. In addition, the mass emergence of some Diptera species, such as chironomids Cricotopus salinophilus, shore-flies Ephydra pseudomurina, E. glauca as well as Corixidae bugs Sigara assimilis in the daytime and in the evening (attracted by light sources) may be nuisant for people.

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