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SYSTEMATIC STUDY OF ARID TERRITORIES

Salinity Tolerance of Macroinvertebrates in Stream Waters (Review)

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Abstract—The review of the salinity tolerance of various macrozoobenthos taxa is based on the published data and the results of our studies. Significant differences in the tolerance of hydrobionts to water salinity in rivers of different arid regions are shown. Leeches, bivalved mollusks, larvae of stoneflies, caddis flies, and mayflies are the most stenohaline species. The taxonomical structure of macrozoobenthos in saline rivers of Lake Elton basin in the arid zone of Russian South is presented.

Keywords: saline streams, macrozoobenthos, salinity tolerance

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INTRODCUTION

The mineralization of water in rivers or its saturation with inorganic substances in the form of ions or colloids is determined by the composition and total amount of dissolved mineral compounds, the concentration of which in Russian publications is usually presented in mg L^{-1} or g L^{-1} (Alekin, 1970; Dedyu, 1990). The main source of water mineralization is the input of mineral matters with ground waters and surface waters from the watershed. Zonation of ion composition of river water can be explained not only by the effect of modern climate conditions but by climate conditions of the past. The degree of leaching of soils and rocks, the presence of easily soluble salts, and the salinization of soils are the result of the centuries-long impact of climate conditions.

The range of mineralization of river waters in different regions of the world is rather wide and is conditioned by a specific character of hydrochemical processes in lotic systems and by the lithologic composition of the aquifers (Alekin, 1970). The feeding of streams by underground waters results in an increase in the degree of mineralization, whereas the surface runoff decreases the mineralization. Thus, the water properties of river water can vary significantly throughout the year.

Most rivers of the world have low and high mineralization of water, but river waters with increased and high mineralization are widespread geographically and are associated with arid and semi-arid regions (figure). In the territory of Russia, water mineralization in rivers reaches 150–200 mg L^{-1} to the north, 600–1000 mg L^{-1} in the forest–steppe zone, and 2000–41000 mg L^{-1} in the south of the steppe zone, e.g., in rivers that flow into the hyperhaline Lake Elton.

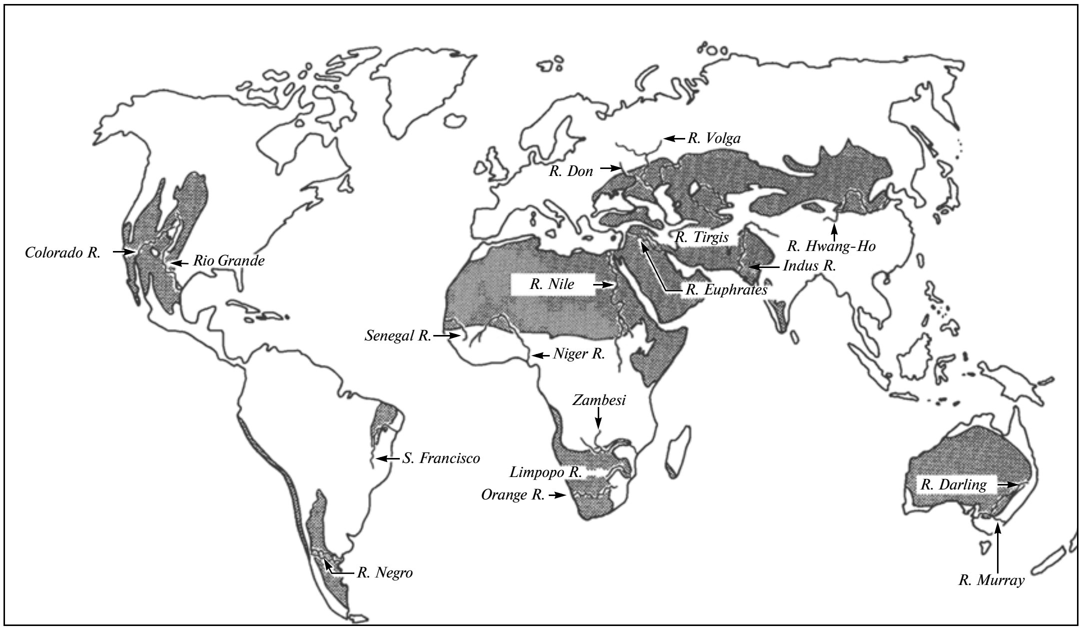
At present, in many regions of the world, the salinity of inland waters has been increasing (Williams, 1987; Stoner, 1988; Velasco et al., 2006). Under the conditions of global climate changes, the process of salinization leads to changes in biotic components in water bodies and watercourses. The studies of the salt sensitivity of aquatic animals, which is one of the key abiotic factors that affect hydrobionts, are of primary importance (Aladin, 1996).

Macrozoobenthos is one of the main components of biota in highly mineralized lotic systems in which the impact of salinity on bottom communities depends mainly on the salt sensitivity of some species (Schmidt-Nielsen, 1982; Williams and Williams, 1998). The threshold of salt sensitivity of taxa can be estimated by the maximum salinity at which species occur in natural waters, as well as in the course of the experiment during which the animals are exposed to the effect of different salt concentrations (Filenko and Mikheeva, 2007; Berezina, 2003; Echols et al., 2009).

RESULTS AND DISCUSSION

In the analysis of publications of Russian and foreign investigators, the main attention is paid to some taxa of bottom organisms that are typical of river systems. Information about their salt sensitivity is presented below.

Mollusca. Some species of mollusks common to fresh waters are tolerant to increased salinity. Gastropods are more tolerant to an increase in salinity than bivalved mollusks. According to the results of monitoring conducted in rivers of Australia, the salt sensitivity of the gastropods of the families Hydrobiidae, Lymnaeidae, Ancylidae. Planorbidae, Physidae, and Pomatiopsidae ranged from 2.7 to 32.1 g L^{-1}; *Potamopyrgus antipodarum* of the family Hydrobiidae had



Scheme of location of arid and semiarid regions (in black) in the world and major rivers associated with them (according to Williams, 1987).

the maximum threshold of salinity (Rutherford and Kefford, 2005). In the rivers of Western Europe, different species of gastropods and bivalves were detected at salinities of no higher than 2.6–6.8 g L^{-1}. Thus, in the Meurthe River (France), mollusks *Radix* sp., *Physa* sp., *Corbicula fluminalis*, *Gyraulus* sp., *Dreissena polymorpha*, and *Planorbarius corneus* are common at a mineralization of 2.6 ± 0.46 g L^{-1} and, in the Rambla Salada River (Spain), the gastropod *Melanopsis praemorsa* reaches its mass development at salinity of 3.5–6.8 g L^{-1} (Piscart et al., 2005; Velasco et al., 2006).

The study of the osmoregulation of some species of bivalves has demonstrated that an increase in water salinity causes osmotic stress in *Velesunio ambiguus* and *Alathyria jacksoni* (Vickery, 1978). Freshwater mollusks that inhabit rivers of Australia with a salinity range of 0.4–2.24 g L^{-1} have the highest density at salinities less than 1 g L^{-1} (Metzeling, 1986). An analysis of distribution of the mollusk *Dreissena polymorpha* makes it possible to determine the upper threshold of salinity tolerance, which approximates 14–15 g L^{-1} (Orlova et al., 1998). The experimental study has demonstrated that the partial mortality of the mollusk *Pisidium amnicum* begins at salinity of 4.2 g L^{-1}, and gastropods *Bithynia tentaculata* and *Lymnaea ovata* sustain salt concentrations in water up to 4.2–6.3 g L^{-1} (Berezina, 2003). The dependence of quantitative and qualitative parameters of the development of mollusks on concentrations of calcium and sodium in water and the relative content of potassium has been found. The unbalanced content of some cations, especially potassium, restricts development in mollusks (Berezina, 2000).

Oligochaeta. The upper threshold of the salt sensitivity of oligochaetes in saline rivers reaches 82 g L^{-1} (Rutherford and Kefford, 2005). Representatives of Tubificidae, Naididae, and Megascolecidae, which inhabit waters of Australia exhibit greater tolerance to salinity in the range of 2.1–39.6 g L^{-1} (Kay et al., 2001). The results of the studies of saline rivers in the Lake Elton basin have showed that oligochaetes of the families Tubificidae, Naididae, and Enchytraeidae are abundant at salinities of 3.8–25.6 g L^{-1} (see the table, which presents the taxonomical structure of macrozoobenthos and maximal water salinity in habitats of hydrobionts in seven saline rivers in the arid region of southern Russia).

Despite that most oligochaete species inhabit continental waters with mineralization from 0.28 to 1 g L^{-1} (Popchenko, 1988; Hart et al., 1991) we recorded high abundance of *Enchytraeus issykkulensis* in the saline Khara and Chernavka Rivers at mineralizations of 12.6–25.7 g L^{-1}. In addition, upon an increase in water salinity in river estuaries, during the ebb and tide period, oligochaetes respond to rapid changes of salinity, not by osmoregulation, but by their behavior; they borrow into the substrate of black mud where the salinity is more stable.

Hirudinea. Leeches that dwell in river waters exhibit low tolerance to water salinity. In natural conditions, solitary specimens of the family Glossiphoniidae are found in rivers with 4 g L^{-1} salinity, which is the upper threshold of findings of leeches in highly mineralized rivers (Bunn and Davies, 1992; Rutherford and Kefford, 2005). It was confirmed by the experiments that demonstrated the high mortality of

Taxonomic composition of macrozoobenthos and maximum salinity in habitats of hydrobionts in Khara, Lantsug, Chernavka, Solyanka, Bolshaya Samoroda, Malaya Samoroda, and Karantinka Rivers in Lake Elton basin (April 2007, May 2011, July 2011, August 2006–2011, September 2008)

Taxon	Salinity, g L^{-1}	Taxon	Salinity, g L^{-1}
Oligochaeta		*Peltodytes caesus*	9.6
Enchytraeus issykkulensis	25.6	Diptera	
Limnodriloides dnieprobugensis	15.8	Psychodidae	
Limnodrilus grandisetosus	11.6	*Ulomyia* sp.	11.5
Limnodrilus hoffmeisteri	13.3	Culicidae	
Limnodrilus profundicola	14.0	*Aedes* sp.	13.2
Limnodrilus sp.	16.4	*Culex* sp.	13.2
Limnodrilus udekemianus	7.5	Ceratopogonidae	
Potamothrix bedoti	14.0	*Culicoides* sp.	
Homochaeta naidina	15.1	*Palpomyia* sp.	
Nais communis	16.8	Chironomidae	
Nais elinguis	13.7	*Corynoneura* sp.	7.5
Paranais simplex	25.0	*Cricotopus ornatus*	15.8
Uncinais uncinata	16.7	*Cricotopus salinophilus*	31.6
Crustacea		*Cricotopus* gr. *sylvestris*	28.6
Gammarus lacustris	15.8	*Cricotopus* sp.	14.0
Odonata		*Glyptotendipes paripes*	14.4
Aeschna sp.	21.1	*Glyptotendipes salinus*	28.6
Sympetrum sanquineum	7.5	*Chironomus aprilinus*	16.9
Heteroptera		*Chironomus* gr. *plumosus*	9.6
Callicorixa gebleri	6.8	*Chironomus salinarius*	41.1
Paracorixa concinna	10.3	*Cladopelma* gr. *lateralis*	14.0
Sigara nigrolineata	31.6	*Cladotanytarsus* gr. *mancus*	21.1
Sigara assimilis	31.6	*Dicrotendipes notatus*	21.1
Sigara lateralis	10.3	*Microchironomus tener*	28.6
Sigara sp.	30.8	*Polypedilum nubeculosum*	7.5
Coleoptera		*Paratanytarsus inopertus*	13.1
Anacaena sp.	16.4	*Paratanytarsus* sp.	7.5
Berosus bispina	31.6	*Psectrocladius* sp.	21.1
Berosus fulvus	31.6	*Tanypus punctipennis*	6.8
Berosus frontifoveatus	31.2	*Tanytarsus kharaensis*	16.7
Berosus sp.	31.6	*Tanytarsus* sp.	7.5
Cymbiodyta sp.	9.8	Stratiomyidae	
Enochrus quadripunctatus	31.2	*Nemotelus* sp.	25.6
Helochares obscurus	30.9	*Odontomyia* sp.	30.9
Hydrobius fuscipes	15.8	*Stratiomys chamaeleon*	11.5
Hygrotus enneagrammus	28.6	Tabanidae	
Hygrotus flaviventris	10.3	*Tabanus* sp.	21.1
Ochthebius marinus	30.9	Ephydridae	
Paracymus aeneus	27.6	*Ephydra* sp.	41.1

leeches of the genera *Erpobdella* and *Helobdella* (family Erpobdellidae) at salinities higher than 6.3 g L^{-1}. The mineralization range of 0.1–0.5 g L^{-1} is the most favorable for the development and reproduction of leeches (Berezina, 2003). Toxic tests with species of the family Glossiphoniidae demonstrated that 50% of the mortality (LC_{50}) was at a salinity 10.5 g L^{-1} (Kefford et al., 2003), which significantly exceeded the data obtained for leeches of the family Erpobdellidae. Leeches were not detected in bottom communities of mesohaline and polyhaline rivers in Lake Elton basin (table).

Crustacea. With regard to salinity, freshwater crustacean maintain the osmoregulation of a distinctly expressed hypotonic type and are the most tolerant group of invertebrates within the normal range of species response acquired over the course of natural selection (Bunn and Davies, 1992).

Toxic tests demonstrated the greatest salinity tolerance of crustacean *Amarinus lacustris* and *Cymodetta* sp. among benthos groups from the Barwon River (Australia), which included mollusks, stoneflies, mayflies, caddis flies, hemipterans, beetles, dragonflies, and mites. Crustaceans were tolerant to water salinity up to 38 g L^{-1} (Kefford et al., 2003). This value is close to the maximum salinity (37.8 g L^{-1}) at which the species *Austrochiltonia australis* of the order Amphipoda inhabits rivers of Australia (Rutherford and Kefford, 2005). The species *Austrochiltonia subtenuis* of this genus dominated in the Mile Brook and Hotham rivers with a salinity of 2.2–19 g L^{-1} (Bunn and Davies, 1992). Euryhaline gammarids *Gammarus lacustris* reach a high abundance in macrophyte overgrowths in Khara, Lantsug and Bolshaya Samoroda at a salinity of 7.3–15.8 g L^{-1} (table).

At the same time, in the experiment, freshwater stenobiontic amphipods *Gammarus pulex* common to the rivers die after 15 min in water with salt concentrations up to 35 g L^{-1} (Gurkov et al., 2012; Williams and Williams, 1998).

During experiments conducted to study invasive processes, the salinity tolerance was found for some freshwater crustaceans, such as *Asellus aquaticus* and *Gmelinoides fasciatus*, which are characterized by low mortality (5–10%) in waters with a range of salinity of 0.02–8.1 g L^{-1}. The osmoregulation of crustaceans was maintained according to the filtration–reabsorption principle (Martemiyanov and Borisovskaya, 2012; Berezine, 2003).

Odonata. Most of species of dragonflies (Hart et al., 1991) are typical inhabitants of fresh waters, though some taxa can survive in waters of increased and high salinity. For example, *Hemicordulia tau* and some species of the genus *Ischnura* were collected in rivers with salt concentrations up to 2.24 g L^{-1} (Metzeling, 1986), and larvae of dragonflies *Anax* sp. colonize biotopes in the hyperhaline Rambla Salada River which inflow the Mediterranean Sea upon its desalination to 3.5–6.8 g L^{-1} (Velasco et al., 2006). Dragonflies of the families Coenagrionidae, Aeschnidae, Gomphidae, Libellulidae, Hemicorduliidae, and Lestidae) inhabit river waters in Australia and Spain with salinity of 5.9–40 g L^{-1} (Gallardo-Mayenco, 1994; Rutherford and Kefford, 2005). The maximum salinity tolerance of species (25.8 g L^{-1}) was recorded for *Austrolestes annulosus* of the family Lestidae. Larvae of dragonflies *Sympetrum sanguineum, Ischnura elegans*, and *Aeschna* sp. inhabit mesohaline Khara and Lantsug rivers (Lake Elton basin) at a salinity of 7.5–21.1 g L^{-1} (table). Experimental studies demonstrated a high tolerance of the larvae of dragonflies *Libellula depressa* and *Epitheca bimaculata* in water salinity of up to 6.3–8.1 g L^{-1} (Berezina, 2003).

Ephemeroptera. It is commonly thought that mayflies do not occur in saline water bodies because they do not possess physiological tolerance and are halophobes (Short et al., 1991; Gallardo-Mayenco, 1994). Thus, in small rivers of the Lake Elton basin with degrees of salinity of 3.8–41.1 g L^{-1}, the larvae of mayflies were not recorded and, in Red River, Middle Fork, South Fork, and Stump Cave Branch Rivers in the United States, mayflies were not detected at mineralization of more than 2 g L^{-1} (Short et al., 1991). The studies conducted in the rivers of Australia (Kay et al., 2001; Rutherford and Kefford, 2005) showed the tolerance of mayflies of the families Leptophlebiidae, Baetidae, and Caenidae to salt concentrations in water to 3.8–9.2 g L^{-1}. Mayflies *Tasmanocoenis* sp. of the family Caenidae are the most tolerant to water salinity. Findings of mayflies of the family Caenidae (genus (*Caenis*) were recorded in rivers with a high content of chlorides (Harrel and Dorris, 1968). The data of Berner and Sloan (1954) evince the habitation of mayflies in Florida (the United States) at salinity of up to 2–10 g L^{-1}. An example of the upper threshold of salinity tolerance of mayflies is the presence of *Cloeon schoenemundi* larvae in waters of the Segura and Rambla rivers basin at mineralization to 75 g L^{-1} (Ubero-Pascal et al., Velasco et al., 2006).

Different results were obtained under the experimental conditions. Acute chronic tests with mayflies of the genera *Cloeon* and *Centroptilum* (family Baetidae) showed that the mortality of 50% of larvae started in 72 h at a salinity of 5.5 g L^{-1}. Similar results were obtained for larvae of *Isonychia bicolor* in experiments with the concentration of NaCl in water to 5.95 g L^{-1} (Kefford et al., 2003; Echols et al., 2009). The concentration of biological fluids in freshwater hydrobionts is hypertonic in relation to aquatic environment. Thus, the maintenance of osmotic pressure in the internal medium is a multifunctional process that includes a certain isolation of the organism from the penetration of fresh water through the integument, the active excretion of water entering the organism, and the absorption of ions from water through gills in the direction opposite to the concentration gradient. This is manifested as a certain species-specificity. Thus, the studies of the species *Hexagenia limbata*, which is common in the saline rivers of Canada, Argentina, and the United States, demonstrate its tolerance to the increase in salinity up to 8 g L^{-1} (Giberson and Rosenberg, 1994).

Plecoptera. It is known that most species of stoneflies live at water mineralization of up to 1 g L^{-1} (Zhiltsova, 2003; Golovatyuk, 2011; Hart et al., 1991). Stoneflies were not detected in the hyperhaline Rambla Salada River (Velasco et al., 2006) or in small mesohaline and polyhaline rivers in Lake Elton basin (Zinchenko and Golovatyuk, 2010). Studies in streams of Australia, the United States, and Spain have broadened the view of the salinity tolerance of stoneflies inhabiting waters with a range of mineralization of 2–9 g L^{-1}. The species recorded in this range of salinity belong to the families Capniidae, Gripopterygidae, Leuctridae, Nemouridae, Perlidae, and Perlodidae (Rutherford and Kefford, 2005). Among representatives of the family Gripopterygidae dominant in saline streams of Australia, larvae of the species *Illiesoperla mayi* were found at salinity of up to 4.4 g L^{-1}, *Riekoperla naso* were found at salinity of up to 4.5 g L^{-1}, *Leptoperla tasmanica* were found at salinity of up to 4.8 g L^{-1}, and *Dinotoperla evansi* were found at salinity of up to 8.8 g L^{-1} (Rutherford and Kefford, 2005). In highly mineralized streams of the United States located in the east part of Kentucky, mayflies *Isoperla* sp. of the family Perlodidae and *Acroneuria* sp. of the family Perlidae are the most salt tolerant and live at a water salinity of 2.0–5.7 g L^{-1} (Short et al., 1991).

Heteroptera. Many species of water mites colonize successfully inland saline bodies of water and streams in different parts of the world (Kanyukova, 2006; Hart et al., 1991). Salinity tolerance and osmoregulatory properties of Corixidae were studied in detail by Knowles and Williams (1973). Species of the families Corixidae, Veliidae, and Notonectidae are highly tolerant to water salinity (to 2.6-42 g L^{-1}) (Gallardo-Mayenco, 1994; Kay et al., 2001; Piscart et al., 2005; Rutherford and Kefford, 2005). Among Corixidae the species *Sigara assimilis* colonizes mesohaline and polyhaline rivers (Bening, 1926), and the species *Sigara selecta* develops in mass in waters with salinity from 3.5 to 100 g L^{-1} and ends its life cycle at salinity to 55 g L^{-1} (Gallardo-Mayenco, 1994; Barahona et al., 2005; Velasco et al., 2006). Mites of the genera *Sigara, Callicorixa*, and *Paracorixa* are constant dwellers in mesohaline and polyhaline small rivers in Lake Elton basin and are tolerant to salinity of up to 6.6–30.8 g L^{-1} (table). At a salinity of 30.8 g L^{-1}, the most widespread species is *Sigara assimilis*. The increase in water salinity in rivers can result in the elimination of less tolerant species of mites and their replacement by more tolerant species. Along with taxa that are highly tolerant to salinity, a significant number of the species of mites dwell in waters where mineralization does not exceed 0.5 g L^{-1} (Hart et al., 1991).

Coleoptera. Despite that many species of beetles live in fresh bodies of waters with a range of mineralization of 0.1–1 g L^{-1}, representatives of some families form diverse bottom communities in some saline rivers of Australia and Spain (Hart et al., 1991; Gallardo-Mayenco, 1994; Velasco et al., 2006). Small rivers in arid regions of the world are refuges for some species of beetles of different ecological groups (Dyadichko, 2004). For example, in small rivers of the Lake Elton basin (table), species of the genera Berosus, Ochthebius, Enochrus, and Hygrotus dwell at a salinity of 6.6–31.6 g L^{-1} (Zinchenko and Golovatyuk, 2010). The highest abundance was recorded for the larvae of beetles *Enochrus quadripunctatus*.

A wide range of salinity tolerance is typical of representatives of the families Hydraenidae, Dytiscidae, and Hydrophilidae, including the genus *Ochthebius*, contains the highest number of halophilous species. Representatives of the genus *Ochthebius* inhabit river waters with salinity of 100 g L^{-1}, and their sensitivity decreases in the series *Ochthebius glaber* → *O. notabilis* → *O. corrugatus* → *O. cuprescens* → *O. delgadoi* → *O. tudmirensis*. Hydrophilids *Enochrus falcarius* and *Berosus hispanicus* are characterized by a high abundance in rivers with salinities of 20–50 g L^{-1} and are tolerant to salinity at up to 81 g L^{-1} (Velasco et al., 2006). The taxonomic diversity of beetles of the families Dytiscidae, Hydraenidae, and Hydrophilidae is also typical of mesohaline and polyhaline rivers in southwestern Australia, where they live in waters with salt concentrations to 125–135 g L^{-1} (Bunn and Davies, 1992; Kay et al., 2001; Rutherford and Kefford, 2005).

Trichoptera. It is known that caddis flies, as well as mayflies and stoneflies, are inhabitants of streams with high current velocity and a high concentration of dissolved oxygen, and are mainly associated with fresh waters. The data of some authors indicate that an increase in water salinity and in concentrations of chlorides in bottom sediments has a negative impact on the fauna of caddis flies and causes a decrease in their species richness, abundance, and biomass of larvae (Hart et al., 1991; Bunn and Davies, 1992; Kholmogorova, 2009). The increase in the drift of larvae of caddis flies at high concentrations of chlorides in water over 1 g L^{-1} is described (Crowther and Hynes, 1977). In addition, the low abundance of caddis flies of the genus *Cheumatopsyche* (total of 120 ind. m^{-2}) was recorded in streams of Kentucky (United States) at a salinity of 5.7 g L^{-1} (Short et al., 1991). The studies conducted in rivers of Spain, France, Australia, and the United States have demonstrated that some species of caddis flies can live in waters with salt concentrations of 2.0–30 g L^{-1} (Short et al., 1991; Gallardo-Mayenco, 1994; Kay et al., 2001; Piscart et al., 2005). For example, the caddis fly *Cheumatopsyche* sp. was found at a salinity of 25.9 g L^{-1} (Rutherford and Kefford, 2005).

Diptera. Representatives of the order have high faunistic diversity in highly mineralized rivers (Zinchenko and Golovatyuk, 2010; Hart et al., 1991;

Velasco et al., 2006). At present, the tolerance of the species of the family Tipulidae to salinity to 1.99 g L^{-1} has been documented (Short et al., 1991, and some species of the family Simuliidae live in rivers with salinity to 27 g L^{-1} (Rutherford and Kefford, 2005; Velasco et al., 2006). The monitoring studies conducted in rivers in Kentucky with the salinity range from 0.02 to 31.3 g L^{-1} has shown that larvae of *Ephydra* sp. and *Culicoides* sp. dominate at salinity more than 10 g L^{-1} (Short et al., 1991). The highest salinity tolerance of different species of dipterans of the families Ceratopogonidae (to 108 g L^{-1}), Ephydridae (to 100 g L^{-1}), and Chironomidae (to 115 g L^{-1}) was documented in saline rivers in other arid regions of the world by some authors (Kay et al., 2001; Rutherford and Kefford, 2005; Velasco et al., 2006; Zinchenko and Golovatyuk, 2011) (table). The studies conducted in saline rivers of Australia have demonstrated that, among different subfamilies of chironomids, representatives of Chironominae and Tanypodinae that inhabit waters with salinities of 115 g L^{-1} and 75 g L^{-1}, respectively, are the most tolerant of salinity, whereas the salinity in sites of Orthocladiinae findings does not exceed 30 g L^{-1}. Some species of the genera *Procladius, Cricotopus, Halocladius, Nanocladius, Semiocladius, Chironomus, Tanytarsus, Cladotanytarsus, Dicrotendipes, Parachironomus*, etc., which live under the conditions of mesohaline saline gradients have high salinity tolerance (Cranston and Dimitriadis, 2005; Dimitriadis and Cranston, 2007). According to our data, in saline rivers, in deserts steppes of the Lake Elton basin, the species of chironomids of the subfamilies Chironominae (to 41.1 g L^{-1}) and Orthocladiinae (to 31.6 g L^{-1}) were the most tolerant to salinity, whereas Tanypodinae were recorded at a salinity of no more than 6.8 g L^{-1}. The first studies of macro- and meiozoobenthos in highly mineralized rivers of the Lake Elton basin made it possible to document the species of chironomids *Cricotopus salinophilus* (31.6 g L^{-1}), *Tanytarsus kharaensis* (to 16.7 g L^{-1}), and nematodes *Calodorylaimus salinus* (6.8 g L^{-1}), which were new for science (Zorina and Zinchenko, 2009; Zinchenko et al., 2009; Gagarin and Gusakov, 2012).

Salinity tolerance of larvae of *Chironomus salinarius*, which inhabit saline rivers, coastal lagoons, seas, and lakes in the salinity range of 6–80 g L^{-1} is well known (Khlebovich, 1962; Istomina et al., 2012; Koskinen, 1968; Biever, 1971; Ceretti et al., 1987; Drake and Arias, 1995; Kawai et al., 2000; Suemoto et al., 2004; Ree and Yum, 2006; Gascon et al., 2007; Ponti et al., 2007; Marchini et al., 2008; Fuentes et al., 2005). In experimental studies, the life span of eurihaline larvae of the species *Chironomus salinarius* as so-called advanced osmoregulators increases from 24 to 37 days in the salinity gradient of 0–5 g L^{-1} up to 20–50 g L^{-1}. The prolongation of the life cycle of *Chironomus salinarius* occurs due to the development of the first and second larvae stages (Cartier et al., 2011), which is a typical example of the stable functioning of the population under a changing environment (Hart et al., 1991; Nielson et al., 2003). High fecundity, capability to migration, nonspecific trophic relations, high mobility of larvae, short life cycle, and the use of nutrition sources in the trophic link that are not used by other organisms make a decisive contribution to the survival of dipterans under extreme environmental conditions (Krivosheina, 2004). Under the conditions of unstable salinity in rivers of the Lake Elton basin, the so-called "salt anabiosis," which is typical of some chironomid larvae and their eggs, is observed. It is considered that "excess water and salts of insect larvae at their water stage are excreted through Malpighian vessels and the rectum" (Romanenko, 2004 p. 246).

CONCLUSIONS

Despite the wide range of salinity tolerance of bottom invertebrates, the critical level of salinity for the development of hydrobionts in rivers in different arid regions ranges from 10 to 15 g L^{-1}, above which significant structural changes occur in bottom communities (Rutherford and Kefford, 2005; Williams et al., 1990). However, when analyzing salinity tolerance, we should consider other abiotic and biotic factors that can affect hydrobionts in detail (Ward, 1992; Velasco et al., 2006).

Adaptations as responses of the biological system to environmental conditions can be observed at different levels of organization ranging from individuals to whole ecosystems. In other words, the problem of the adaptation of mollusks, oligochaetes, leeches, crustaceans, and larvae of insects and other taxa is the regulation of not only quantitative, but also qualitative differences in the ion composition of cells and environment. The adaptation of hydrobionts to salinity, which is not considered in the paper, can be considered to be a response of the organism, species, or biocenosis aimed at maintaining their functional stability in a changing environment. In numerous publications devoted to analyzing the problem of the adaptation of poikilo- and homoiosmotic hydrobionts to salinity (Romanenko, 2004; Schmidt-Nielson, 1982; Khlebovich, 2012; Forbes and Allabson, 1970; Kefford et al., 2004; Kefford et al., 2005), it is stated that different mechanisms of salt adaptations were formed in the course of the evolution and adaptive responses of hydrobionts at different levels of phylogenetic development and are aimed at maintaining ionic and osmotic homeostasis.

Taking into consideration that the information about the cause-and-effect relationships of adaptive responses of one organism and the absence of adaptive regulations in other hydrobionts (Attrill et al., 1996), it should be stated that studies of the salinity tolerance of different macrozoobenthos species requires field and experimental studies (Gallardo-Mayenco, 1994; Giberson and Rosenberg, 1994), which will make it possible to study the growth, development, life cycles, and survival of species depending on water salinity under the effect of other abiotic factors.

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