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Composition, Structure, and Formation Factors of Bottom Invertebrate Communities in Lakes of the Southern Ob–Irtysh Interfluve

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Abstract—The composition and structure of bottom invertebrate communities have been studied in 37 lakes of the southern Ob–Irtysh interfluve in 2008–2011. The aquatic fauna of these communities includes 146 species of eight classes. The influence of the main abiotic ecological factors (hydrophysical and hydrochemical parameters of water, bottom substrate type) on the composition and fauna of bottom communities have been estimated. It is shown that hydrochemical factors determining the total salt content of the water, substrate type, and water transparency have the strongest effect on the level of bottom invertebrate community development.

Keywords: zoobenthos, lakes, salinity, ecological factors, Ob–Irtysh interfluve.

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Bottom invertebrate communities constitute an important structural component of lake ecosystems. Their composition and abundance depend on many ecological factors. Among the diversity of environmental factors influencing these communities in lakes of the southern Ob–Irtysh interfluve, only the effects of salinity, distribution of aquatic vegetation, and type of winter oxygen regime have been studied previously. These parameters in most lakes of the region are unstable and change depending on the water regime of each particular year (Blagovidova, 1973; *Opyt*..., 1982; Bezmaternykh, 2007).

The hydrobiological characteristics of lakes and lake systems of the southern Ob–Irtysh interfluve have been studied very unevenly. Relevant information on small lakes are usually absent; for some lakes, only fragmentary reconnaissance data from the first half of the 20th century are available (Berezovskii, 1927; Zvereva, 1930). Large brackish water bodies and lake systems of commercial significance have been better studied (Pirozhnikov, 1929; *Pul'siruyushchee ozero Chany,* 1982; *Opyt*..., 1982; *Ekologiya ozera Chany*, 1986; *Ozero Obinskoe*..., 1994; *Vodoemy Altaiskogo kraya*, 1999), but special synoptic studies on the zoobenthos of these lakes are lacking. Moreover, the composition and structure of the communities of lakes of this region could have changed considerably under the effect of changing climatic conditions and anthropogenic factors.

The purpose of this study was to analyze the composition, structure, and formation factors of bottom invertebrate communities in lakes of different types in the southern Ob–Irtysh interfluve.

MATERIAL AND METHODS

The communities of bottom invertebrates were studied in 2008 to 2011 in the course of complex limnological expeditions to four lake systems of the southern Ob–Irtysh interfluve: Kasmala, Kulunda, Karasuk, and Burla (Fig. 1); a total of 37 lakes were examined.

The lake systems of the Karasuk, Burla, and Kulunda rivers are located in an internal drainage area of the Ob–Irtysh interfluve. In the Karasuk River basin, 14 lakes were studied. These are brackish water bodies with a salinity of 1 to 3 g/L. According to chemical composition, the waters of these lakes are mostly of sulfate–chloride type.

In the Burla lake and river system, 12 lakes were studied. The waters of the lakes located in the upper reaches of the Burla River are of carbonate type, sodium group type, or calcium type I. In the middle and lower reaches of the river, the waters are of sulfate sodium type I or II. The salinity type of waters in this system varies within a wide range, from α-hypohaline fresh to polyhaline brackish.

Six lakes were studied in the Kulunda basin. The waters of the hyperhaline Kulundinskoe Lake are of

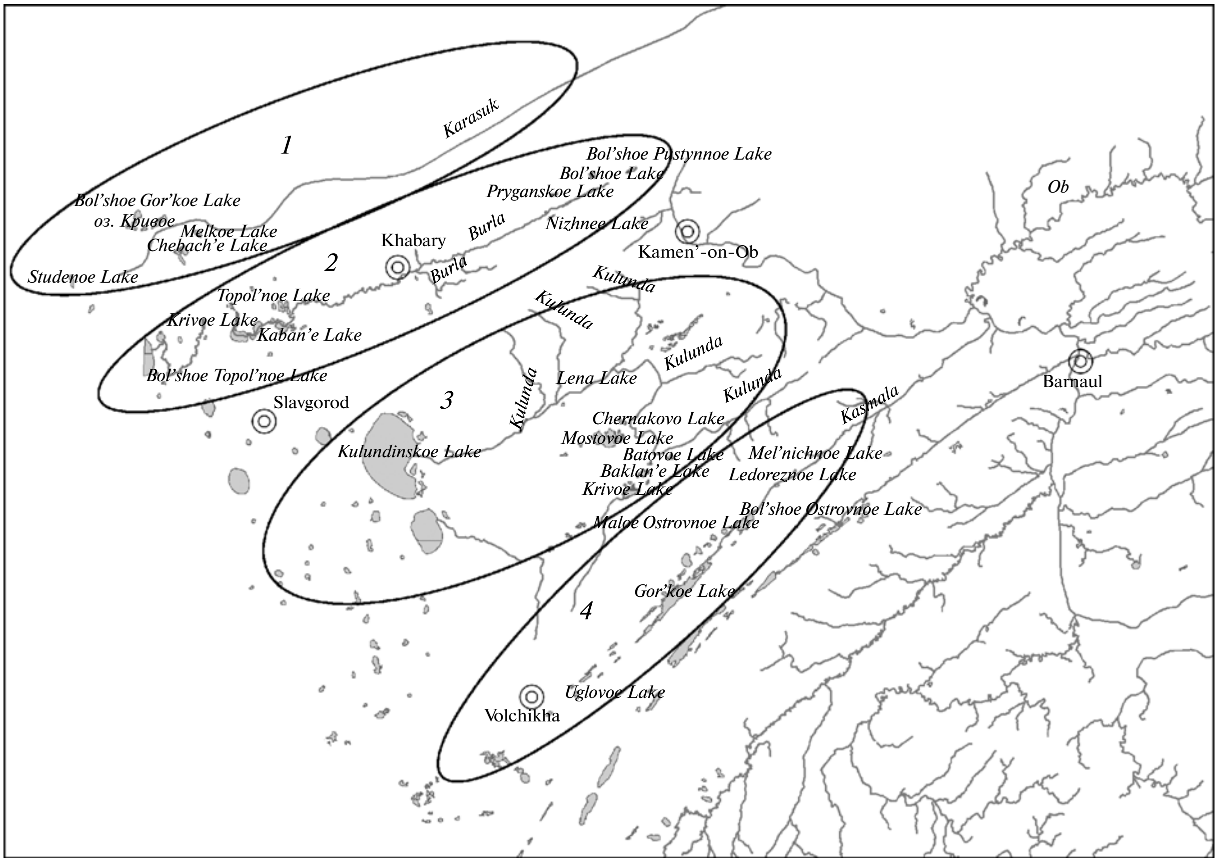

Fig. 1. Lake systems studied in the southern Ob–Irtysh interfluve: (*1*) Karasuk; (*2*) Burla; (*3*) Kulunda; (*4*) Kasmala.

the chloride class of sodium type II group; waters of other lakes in this system are brackish, of the hydrocarbonate class of sodium type I group.

Seven lakes were studied n the Kasmala basin. Two of them (Mel'nichnoe and Ledoreznoe) are open, constantly connected to the river; five lakes (Uglovoe, Bol'shoe Ostrovnoe, Gor'koe, Presnoe, and one nameless lake) are not connected directly to the Kasmala River but lie in the bed of an ancient flow. According to the classification by Alekin (1953), the waters of most lakes of this system (except Gor'koe Lake) belong to the hydrocarbonate class of type I sodium group, i.e., they are soda lakes. Most of the lakes of this system are fresh or brackish, except for one nameless polyhaline lake and the ultrahaline Presnoe Lake. Detailed hydrochemical descriptions of the lakes were made by Kirillov et al. (2008, 2009, 2010).

The material was collected and processed by standard methods (*Rukovodstvo...*, 1992): qualitative samples were taken with a water net or scraper, and quantitative samples were taken with a Peterson dredge with a mouth area of 0.025 m^2 or with a GR 91-000 TO bar dredge with a mouth area of 0.007 m^2. A total of 202 quantitative and 60 qualitative samples were collected and analyzed. The trophic levels of the lakes were determined according to the scale by Kitaev (1986). Dominant species were identified by their occurrence frequency (Bakanov, 1987). Similarity in taxonomic composition was evaluated using inclusion measures (Andreev, 1980). The data were statistically processed with the MS Excel-2003 and Statistica 6.0 program packages.

RESULTS AND DISCUSSION

In lakes of the Karasuk system, a total of 65 bottom invertebrate species of five classes were recorded: oligochaetes, two species; leeches, two species; gastropods, seven species; crustaceans, one species; and insects, 53 species. Among insects, dipterans had the highest species diversity (29 species, including 23 chironomids); dragonflies, mayflies, true bugs, caddis flies, and beetles were also present. The bottom community of the lakes had a chironomid aspect (chironomids were recorded in 95% samples). The greatest number of macroinvertebrate species was found in lakes Astrodym (28 species), Krivoe (22), and Titovo (21). The faunistic similarity of the benthic invertebrate communities from the lakes studied was generally high, reaching about 60% for six pairs of lakes. The highest similarity was revealed between Chebachenok Lake and lakes Krotovo and Astrodym, probably due to the small number of species recorded in the former

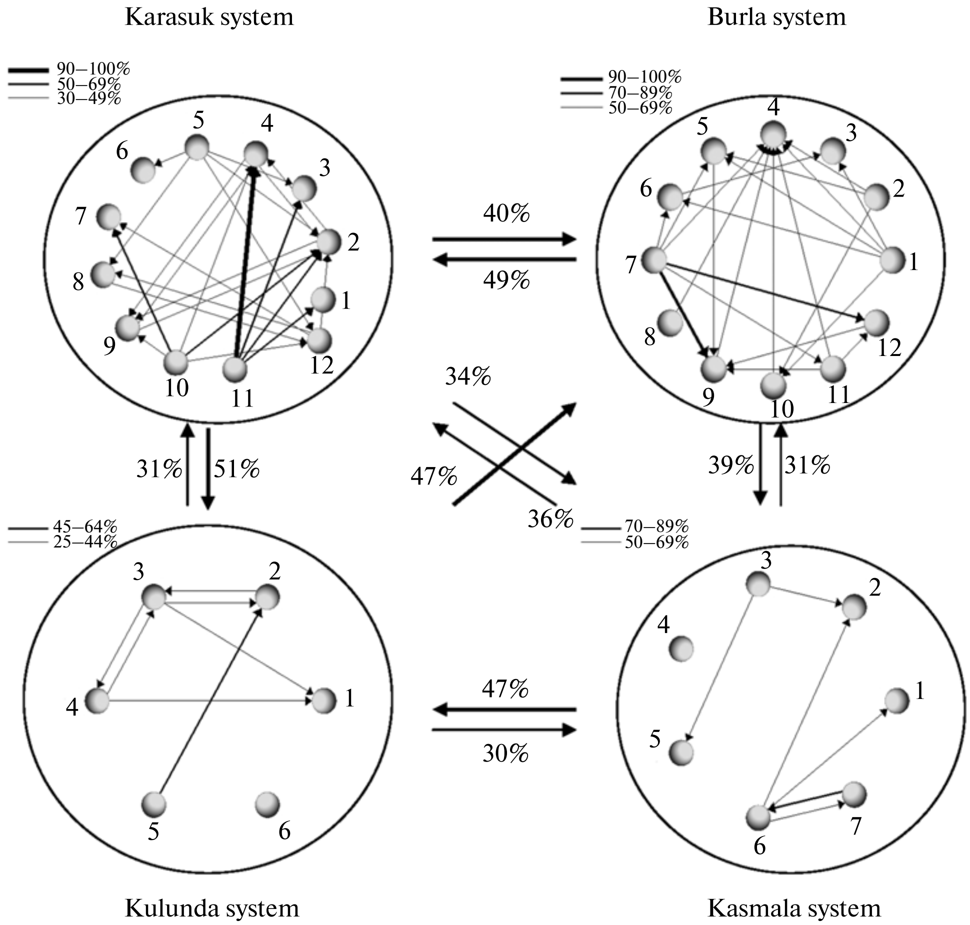

Fig. 2. Directed multigraphs of binary relationships based on a set of inclusion measures for describing the bottom communities of the lakes by the presence of species (numbers of lakes as in Table 2).

lake (Fig. 2). The density and biomass of bottom invertebrates in the lakes varied within a broad range: from 30 to 15 900 ind./m^2 and from 0.09 to 29.8 g/m^2, respectively. The lowest density and biomass values were recorded in lakes Studenoe (35 ind./m^2 and 0.35 g/m^2) and Bol'shoe Gor'koe (139 ind./m^2 and 0.09 g/m^2); the highest biomass, in Titovo Lake (29.8 g/m^2).

In the benthos of lakes studied in the Burla system, 76 bottom invertebrate species of eight classes have been recorded: nematodes, oligochaetes, leeches, bryozoans, bivalves, gastropods, crustaceans, and insects. Amphibiotic insects accounted for 82.9% of the total number of species recorded (68). Many of them (32 species) belonged to the order Diptera; the other 36 species represented dragonflies, mayflies, true bugs, beetles, lepidopterans, and caddis flies. Most of the dipterans were chironomid larvae (23 species), representing mainly the subfamily Chironominae. Other bottom invertebrates recorded in the lakes included three species of oligochaetes, seven species of mollusks, two species of crustaceans, one bryozoan species, and one nematode species. The greatest numbers of bottom invertebrate species were recorded in lakes Verkhnee (28) and Peschanoe (26). Calculations of inclusion measures for the species compositions of bottom invertebrates from lakes of the Burla system revealed a high degree of similarity between these communities (50–69%); the highest similarity was found in the pairs Maloe Topol'noe–Khoroshee and Maloe Topol'noe–Peschanoe lakes; the most specific composition of the benthos was that of Verkhnee Lake (Fig. 2). Lakes of the Burla system were characterized by high density and biomass of bottom invertebrates, with their communities in most of the lakes showing a moderate or medium level of development. The biomass varied between the lakes from 0.7 to 60.98 g/m^2. The lowest values of density and biomass were recorded in Bol'shoe Topol'noe Lake; the highest, in Khomutinskoe Lake.

The bottom invertebrate communities in water bodies of the Kulunda system had fairly low values of species diversity: a total of 37 species of four classes were recorded, most of them insects. The insects with

Table 1. Major characteristics of bottom invertebrate communities in lake systems of the southern Ob–Irtysh interfluve (2008–2011)

Lake system	Number of species	Species dominating in occurrence frequency	Shannon's diversity index	Average density $\overline{X} \pm S\overline{X}$, 1000 ind./m^2		Average biomass $\overline{X} \pm S\overline{X}$, g/m^2	
				littoral	open-water area	littoral	open-water area
Karasuk	65	*Chironomus* sp., *Procladius ferrugineus* Kiffer, *Polypedilum* gr. *nubeculosum*	1.4 ± 0.2	1.6 ± 0.8	1.38 ± 0.3	5.5 ± 1.9	0.71 ± 0.2
Burla	76	*Chironomus* sp., *Fleuria lacustris* Kiffer	1.2 ± 0.1	7.5 ± 4.2	15.8 ± 10	7.6 ± 3.5	10.4 ± 4.4
Kulunda	37	*Chironomus* sp., *Polypedilum* gr. *nubiculosum*	1.2 ± 0.3	8.7 ± 7.9	0.6 ± 0.3	6.7 ± 2.3	1.2 ± 0.2
Kasmala	67	*Chironomus* sp., *Spheromias pictus* Meig.	1.0 ± 0.2	2.9 ± 1.0	1.3 ± 0.5	4.1 ± 1.0	1.5 ± 0.7

the highest species diversity were dipterans (25 species, including 18 chironomids); others included dragonflies, mayflies, beetles, and caddis flies. The greatest number of species was recorded in Batovoe Lake (28, compared to a maximum of 11 in other lakes). On the whole, the bottom communities in lakes of the Kulunda system had a chironomid aspect (chironomids were recorded in 83% of samples). The faunistic similarity between the lakes was, on the whole, fairly low. Calculations of inclusion measures for the species composition of bottom invertebrate communities revealed a generally low degree of similarity between the lakes, which however was higher in the pair Chernakovo–Krivoe lakes (Fig. 2). The biomass of bottom invertebrates varied between the lakes from 0.28 to 14.36 g/m^2. The biomass of bottom invertebrates was higher in the littoral zone (3.3–14.36 g/m^2) than in the open-water parts of the lakes (0.28–0.9 g/m^2).

In lakes of the Kasmala system, 67 bottom invertebrate species of four classes were recorded. Insects accounted for the greatest number of species; among them, dipterans had the highest species diversity (36 species, including 26 chironomids); others included beetles, mayflies, caddis flies, dragonflies, true bugs, springtails, and lepidopterans. The highest density and biomass among bottom invertebrates were recorded for larvae of the family Chironomidae (found in 89% samples), with the genus *Chironomus* being dominant among them (51.7%); biting midges of the family Ceratopogonidae were subdominant (48.2%). The occurrence frequency of other taxa was at most 14%. The greatest number of bottom invertebrate species was recorded in lakes Mel'nichnoe (28) and Uglovoe (23). Smaller numbers of species were recorded in soda lakes, Presnoe (5) and the nameless lake included in the study (3). The faunistic similarity between lakes of this system, as between those of the Kulunda system, was rather low. Calculations of inclusion measures for the species compositions of macroinvertebrates revealed low degrees of similarity; for most pairs of lakes, this parameter reached at most 50–69% (Fig. 2). Soda lakes (Presnoe and the nameless one) were especially similar in their species composition: the degree of faunistic similarity between them reached 70–89%, probably reflecting the similarity between their hydrological and hydrochemical characteristics.

A total of 146 bottom invertebrate species of eight classes were recorded in the lakes studied. The benthos of the lakes was mostly of the chironomid aspect, which is common to mesotrophic and eutrophic shallow flatland lakes. The dominants of the bottom invertebrate communities were species and forms widespread in the Holarctic and Palearctic and also typical of many water bodies of European Russia.

The levels of bottom community development in the deep-water parts of the lakes varied from ultraoligotrophic to oligotrophic; in the littoral zones it varied in most cases from oligotrophic to beta-mesotrophic (Table 1).

The great number of recorded species is indicative of a high diversity of taxa and ecological groups of the benthos. In the bottom communities of the lakes studied, oligochaetes are represented by a few species, namely, the widespread eurybionts *Chaetogaster* sp. and *Stylaria lacustris* L., which is probably explained by the adverse effect of brackish waters on this group. A decrease in the species diversity of oligochaetes with increasing salinity has also been observed in the Chany lake system and in lakes of Austria (*Ekologiya*..., 1986; Wolfram et al., 1999).

Mollusks are largely represented by phytophilous species, which are common to relatively small permanent water bodies with stagnant or slowly flowing water. Most mollusk species are gastropods, mainly members of the families Planorbidae and Lymnaeidae.

Mayflies and crustaceans are represented by widespread species living mostly in stagnant water bodies,

Table 2. Levels of bottom invertebrate community development in lakes of the southern Ob–Irtysh interfluve according to the scale by Kitaev (1986)

Development level	Lake system			
	Karasuk	Burla	Kulunda	Kasmala
Lowest	Bol'shoe Gor'koe (2*), Gusinoe (3), Krotovo (5), Peschanoe (8), Studenoe (9), Khoroshonok (11), Chebachenok (13), Shkalovo (14)	Bol'shoe Topol'noe (3), Krivoe (6), Maloe Topol'noe (7)	Lena (3)	Bol'shoe Ostrovnoe (3)
Low	–	Bol'shoe Pustynnoe (2)	Krivoe (2), Kulundinskoe (6)	Gor'koe (2), Ledoreznoe (4), Presnoe (6)
Moderate	Chagan (12)	Kaban'e (5), Nizhnee (8), Khoroshee (12)	Chernakovo (5)	nameless (7), Mel'nichnoe (5), Uglovoe (1)
Medium	Astrodym (1), Krivoe (4), Kusgan (6), Melkoe (7)	Bol'shoe (1)	–	–
Increased	–	Verkhnee (4), Peschanoe (9)	Batovoe (1), Mostovoe (4)	–
High	Titovo (10)	Pryganskoe (10)	–	–
Very high	–	Khomutinoe (11)	–	–

* Numbers in brackets from Fig. 2.

such as *Caenis miliaria* Tshernova and *Gammarus lacustris* Sars.

Caddis flies are represented by limnophilous and potamophilous species: phytophiles of the genus *Neureclipsis* gr. *bimaculata*, *Ecnomus tenellus* Rambur, *Pryganea bipunctata* Retzius, *Triaenodes* sp., *Limnephilus rhombicus* L., *Agripnia obsoleta* Hagen, *Agraylea multipunctata* Curtis, *Orthotrichia* sp., *Leptocerus* sp., *Mystacides longicornis* L., *Oecetis* sp., and the facultative psammophile *Molanna albicans* Zetterstedt.

The faunistic similarity between the lake systems proved to be fairly low: each of the systems has its own distinctive features in the composition of bottom invertebrates. As shown by the analysis of inclusion measures, the smallest number of species is characteristic of the Kulunda system. As a result, its fauna is largely represented in the faunas of the Karasuk and Burla systems.

The amounts of bottom invertebrate biomass in most lakes ranged on Kitaev's (1986) scale from "very low" to "medium," corresponding to water bodies of oligotrophic and beta-mesotrophic types. "Increased," "high," and "very high" amounts of biomass recorded in some lakes lying in drainless areas of the Kulunda, Karasuk, and Burla systems (Table 2).

Similar distribution patterns of bottom communities are also characteristic of other lake and river systems in the southern Ob–Irtysh interfluve (the Chany and Barnaul systems), being conditioned by the type and distribution of bottom substrates and specific features of hydrological and hydrochemical regimes in individual water bodies (Bezmaternykh, 2005, 2008; Miseiko, 1982).

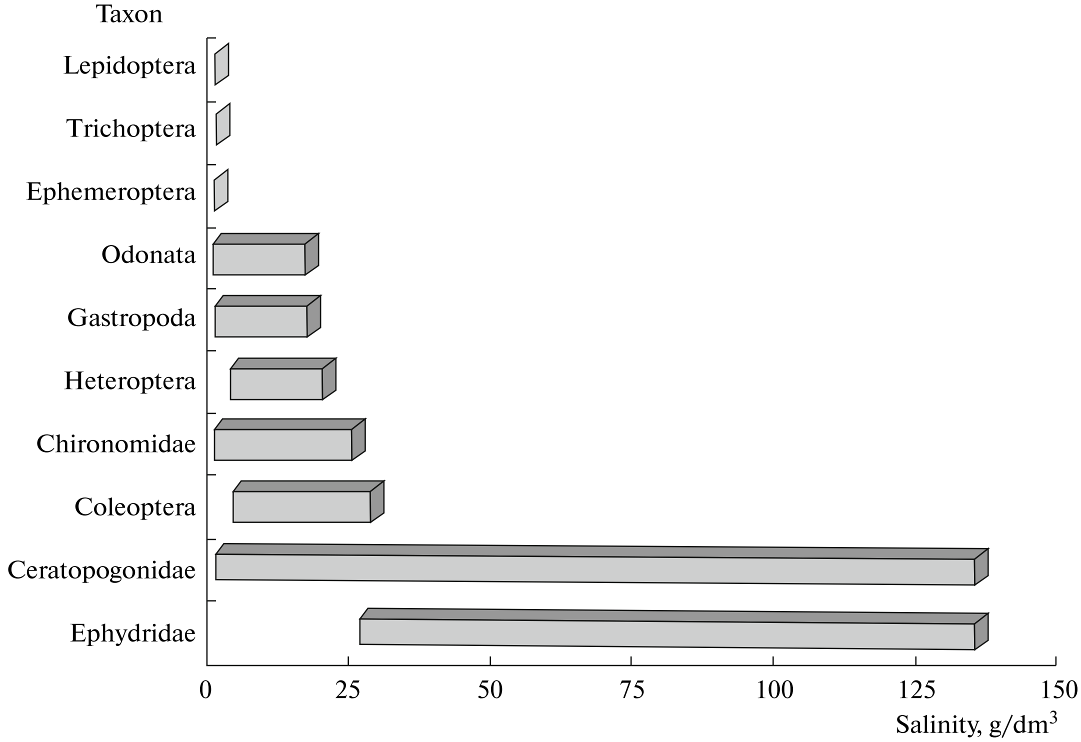

Fig. 3. Halotolerance of basic taxonomic groups of bottom invertebrates in lakes of the southern Ob–Irtysh interfluve.

The composition and abundance of benthos depend on many factors. According to Blagovidova (1973), the main factors of benthos formation in lakes of southern Western Siberia are the total salt content of the water and the winter oxygen regime. Salinity strongly affects the taxonomic composition of hydrobionts: when it increases, the number of species in lakes usually decreases (Williams, 1998). We have found that the highest tolerance to high salinity is characteristic of dipteran larvae of the families Ephydridae and Ceratopogonidae (Fig. 3), especially when salinity varies within a range of 0.56 to 134 g/L. High ecological plasticity has also been revealed in chironomid and beetle larvae, which have proved to occur in waters with salinity ranging from 0.38 to 25.4 g/L. Members of these taxa are known to form bottom communities also in other lakes with increased salinity (Alcocer et al., 1997; Hammer, Sheard, and Kranabetter, 1990; Williams, Boulton, and Taaffe, 1990). In addition, it has been found that increasing salinity in the studied lakes leads to a decrease in the proportion of homotopic species in favor of heterotopic species.

The type of bottom sediments also has a strong influence on bottom communities of the studied lakes. These communities usually develop most actively on silts, where their biomass reaches 6.1 ± 1.6 g/m^2, whereas the biomass of communities on silted sands and sands is only 2.6 ± 1.2 and 2.2 ± 0.7 g/m^2, respectively.

Williams (1998) pointed out that water salinity is a complex factor whose effect depends not only on its level but also on the ratio of main ions. To determine the relative roles of various ecological factors in the formation of bottom invertebrate communities in the lakes, we analyzed 20 such factors: four physical (depth, substrate type, transparency, and temperature) and 16 hydrochemical (pH, O_2, biological oxygen consumption, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, water hardness, Ca^{2+}, Mg^{2+}, sum of Na^+ and K^+, sum of all ions, permanganate oxygen demand, $NH_4{}^+$, NO^{2-}, and NO^{3-}). Analysis of these factors revealed a significant negative correlation between the total biomass of bottom invertebrates and the concentration of NH_4^+ ($r = -0.56$; $p = 0.04$), which probably reflected the response of the animals to increased concentrations of organic matter decomposition products in the water bodies. In addition, correlations were revealed between the biomass of homotopic species and water transparency ($r = 0.58$, $p = 0.02$), total salt content ($r = -0.63$; $p = 0.01$), and several other hydrochemical parameters, major determinants of water CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{+2}, $\Sigma Na^+ + K^+$.

Factor analysis revealed significant effects of parameters such as substrate type ($F = 5.7$, $p = 0.02$), water transparency ($F = 6.1$, $p = 0.007$), and salinity ($F = 8.8$, $p = 0.007$) on the biomass of bottom invertebrates. Principal component analysis was also used to

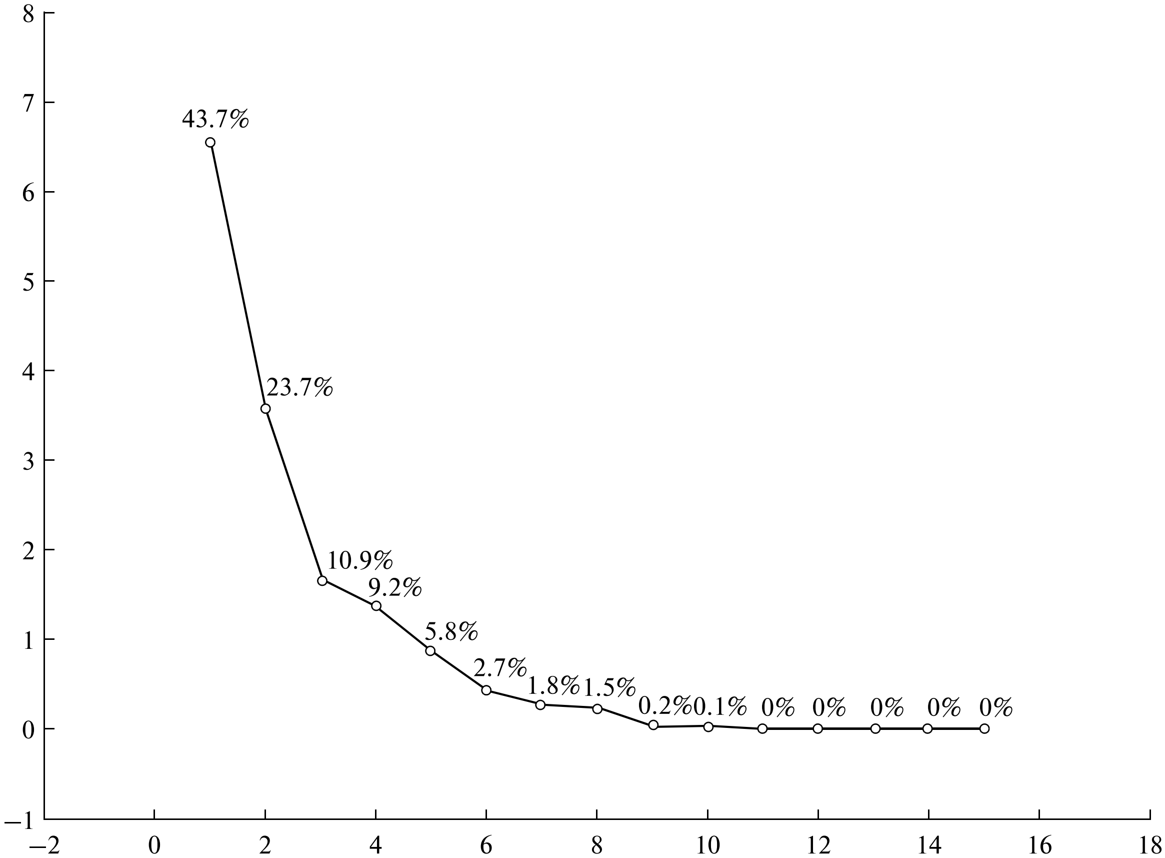

Fig. 4. Results of principal component and classification analysis for the effect of ecological factors on the biomass of bottom invertebrate communities in lakes of the southern Ob–Irtysh interfluve: axes show own numbers of values (factors) of the correlation matrix.

determine major factors having an effect on their biomass. This method allowed all test factors to be combined into several groups, with the first three groups having a significant effect on the biomass of bottom invertebrates (Fig. 4). The first group consisted mainly of hydrochemical parameters determining water salinity (Cl^-, SO_4^{2-}, water hardness, Ca^{+2}, Mg^{+2}, sum of Na^+ and K^+, and sum of all ions); the second group included the concentration of carbonates (CO_3^{2-}); and the third group consisted of physical factors such as water transparency and temperature.

Therefore, water salinity is one of several leading ecological factors that determine the composition and structure of bottom invertebrate communities in lakes of the southern Ob-Irtysh interfluve. Increasing salinity leads not only to reduction of the species diversity and biomass of these communities but also to reorganization of their taxonomic and ecological structure.

CONCLUSIONS

(1) A total of 146 bottom invertebrate species of eight classes have been recorded in lakes of the southern Ob-Irtysh interfluve: Nematoda (1 species), Oligochaeta (3), Hirudinea (4), Phylactolemata (1), Bivalvia (1), Gastropoda (10), Crustacea (2), and Insecta (124). Insects are represented by dipterans, beetles, mayflies, caddis flies, dragonflies, true bugs, springtails, and lepidopterans. The highest species diversity among them is characteristic of dipterans (66 species, including 45 chironomids). Larval chironomids are the dominant taxonomic group, and larval ceratopogonids are subdominant.

(2) The highest level of similarity in the taxonomic composition of bottom invertebrate communities is found in the lake systems of the Karasuk and Kulunda rivers located in an internal drainage area. More distinctive faunas are characteristic of the Burla and Karasuk lake systems.

(3) The density and biomass of bottom invertebrate communities strongly vary between the lakes. These parameters decrease to a minimum in some lakes of oligotrophic to beta-mesotrophic type in the Kasmala system and reach a maximum in lakes of the Burla system.

(4) Analysis of the effects of different ecological factors on bottom invertebrate communities has

shown that their development depends primarily on hydrochemical factors determining the total salt content of water and on physical factors such as substrate type and water transparency.

(5) Higher salinity impedes the development of bottom invertebrate communities and leads to a decrease in the proportion of homotopic species in favor of heterotopic species. The strongest tolerance to high salinity is characteristic of dipteran larvae of the families Ceratopogonidae and Ephydridae.

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