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Distribution of Fish in the Complex of Floodplain–Riverbed Biotopes of the Irtysh

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Abstract—Distribution, composition, and movements of fish within the floodplain–riverbed complex of the Lower Irtysh are investigated. The principal working tools were hydroacoustic computerized complexes for the detection of fish aggregations and of their movements in the floodplain water course. Twenty-four-hour hydroacoustic observations revealed the predominantly crepuscular-nocturnal type of activity of most fish and the mass downstream migration of juveniles at the onset of the night. Seasonal traits of formation of fish aggregations on key biotopes of the Irtysh are revealed, and their biological harmony is shown. The necessity that fish distribution should be analyzed as a dynamic phenomenon is shown.

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Key words: fish distribution, floodlands, riverbed depression, habitats, hydroacoustic researches, aggregations, juveniles, fish movements.

INTRODUCTION

The environment of hydrobionts in the river systems is characterized by multilevel lability. Changes of environmental parameters occur in stochastic and periodic patterns. Abiotic parameters of the river—hydrodynamic, optical, thermal, and hydrochemical—change continuously. Biotic factors also undergo regular changes: conditions of feeding, reproduction, and defense of hydrobionts, as well as size, structure, and mosaic of biotopes (Stanford et al., 2005) and abundance and biomass of particular organisms and communities. The complex of adaptations of fish to environmental lability manifests itself in their distribution which, in turn, is a function of behavior of separate individuals, groups, and schools.

Normally the occupation of shelters and food resources by fish, support of the equilibrium of the system of "triotroph" (Manteifel', 1987), or "biotope capacity" (Nikolsky, 1980) depend on the character of fish distribution—migrations and movements (Mochek, 1987). In other words, fish distribution is a dynamic category, a permanent process of their movement on various spatial–temporal scales. From such a viewpoint, traits of fish distribution within particular habitats and complexes of conjugate biotopes, up to whole river systems, should be considered.

Synchronization of the environmental lability and of manifestations of nomadity of fish has a first-rate significance in the annual large-scale process of fish redistribution in the rivebed–floodplain system. At increasing water level, the fish swim for spawning and feeding to vast floodplain areas. Here, in floodplain water bodies, the fish find necessary vital resources at different stages of the life cycle: mature spawners find spawning substrata, adults find rich food resources, and developing juveniles find necessary and relatively safe conditions for growth. Later, at decreasing water level, the fish of various species and ecological groups distribute over the riverbed. Highly important sites of permanent concentrations of fish of all age in the riverbed are bottom depressions (Ioganzen, 1972; Poddubnyi and Malinin, 1988; Pavlov et al., 2008; etc.).

Seasonal circulation of the fish population within floodplain–riverbed components of the river system occurs irrespectively of their latitudinally zonal and geographic position (Welcomme, 1985). Exploitation by fish of the biological resources of the floodplain has a special meaning in river systems with a wide floodplain and prolonged period of flood. In particular, the size of flooded areas known as "sors" and the duration of the flood control the success of reproduction of valuable fish in the Lower Ob (Bogdanov and Agafonov, 2001) and in other areas of the Ob-Irtysh basin, including water bodies of the Lower Irtysh (Pavlov and Mochek, 2006).

The present study is undertaken to analyze the regularities of distribution of fish in the floodplain–riverbed complex of biotopes as a harmonic and dynamic phenomenon. The tasks of this study comprise elucidation of the species and size composition of fish, their quantity, their diurnal and movements within flood-

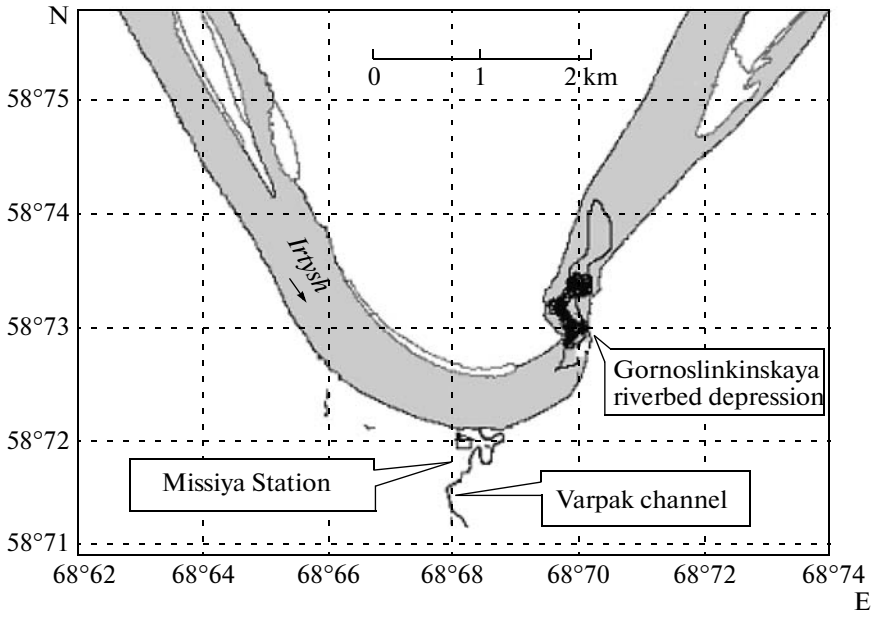

Fig. 1. Schematic map of the area of work.

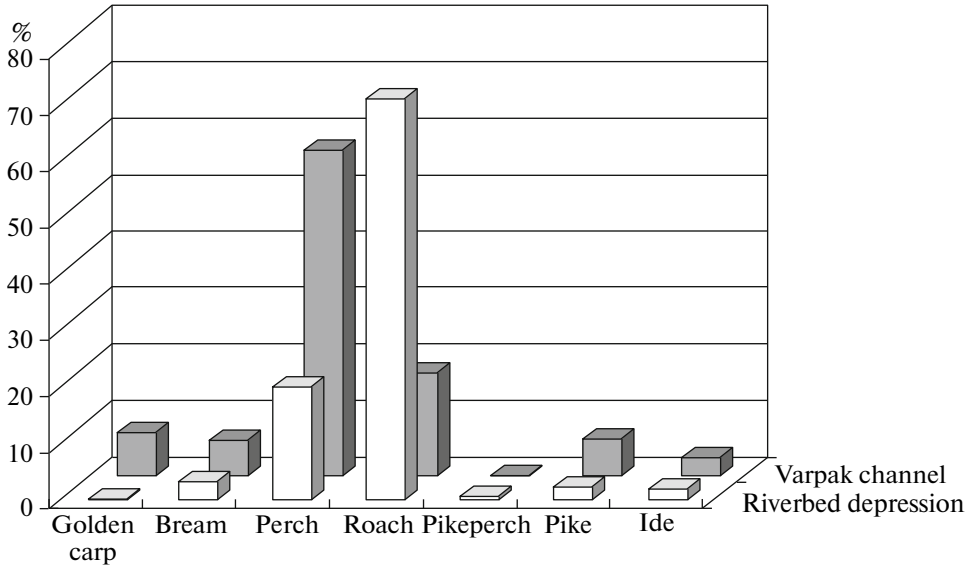

Fig. 2. The species composition of fish in the Gornoslinkinskaya riverbed depression and the Varpak floodplain channel.

plain and riverbed habitats, and special traits of redistribution between conjugated components of the river system of the Lower Irtysh.

MATERIAL AND METHODS

The study was made in the Lower Irtysh basin on the water area of the floodplain–riverbed complex of biotopes: the Irtysh bed (Gornoslikinskaya riverbed depression) and the floodplain channel (Varpak) (Fig. 1). In the place of investigations, the Irtysh is a large water artery with the riverbed width of approximately 500 m, with an average depth along the fairway of 7–9 m. In the Irtysh bed, below the inflow of the Varpak channel, the Gornoslinkinskaya riverbed depression is formed, the largest in the Irtysh. The Varpak channel connects, during the flood, the floodplain of the right bank and the Irtysh mainstream. The depth of this channel in its lower reaches attains 8 m at the maximum water level, while, in the low water period, the water course dries up almost completely. At "high water" the motor boat may go upstream the Varpak up to 2 km.

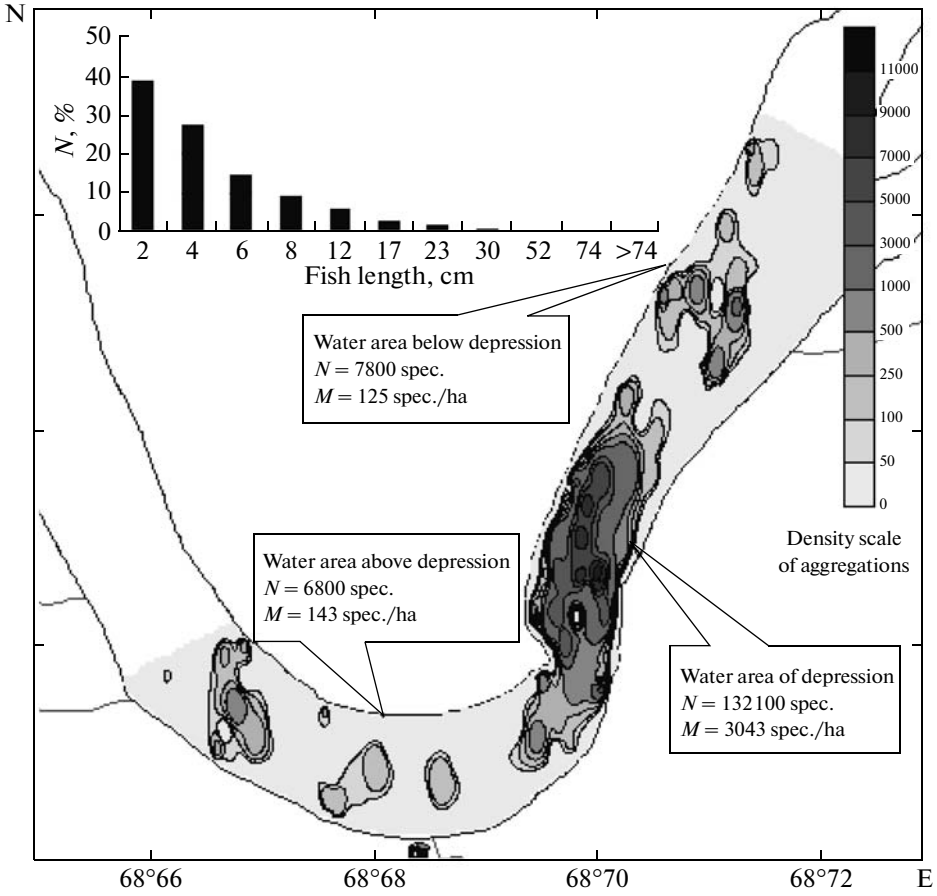

Fig. 3. The plot of fish distribution in the Gornoslinkinskaya riverbed depression on July 1, 2008. Light period of the day.

The field material was collected from June to October 2008; i.e., the work comprised all period of life activities of mass fish of the Lower Irtysh: their reproduction and feeding in early summer and activity prior to winter in late autumn. The study is made on the basis of various modifications of computerized acoustic complexes produced in Russia (OOO Fisheries Hydroacoustic): AsCor for hydroacostic surveys of water bodies over 2 m deep, PanCor for hydroacoustic surveys of shallow water bodies (up to 30 cm deep), and NetCor for observation of fish routes in water courses.

Distribution of fish in the Irtysh bed. The distribution of fish, determination of their abundance, and sizes at depths from 3 to 45 m were investigated by hydroacoustic surveys by means of the AsCor complex. The surveys were made from the board of a KS water jet cutter or a boat with an outboard motor by the grid of tacks. The distance between tacks was calculated with regard to the optimum coverage of the water area. The surveys were made in the daytime and at oncoming of night in July and October 2008. Altogether, six surveys were made.

Distribution of fish in the Varpak channel. Similarly, using a PanCor complex, hydroacoustic surveys were made in the shallow Varpak channel at depths from 0.5 to 4 m. The surveys were made in the daytime and at oncoming of twilight, in the period of decreasing flood, in July 2008. Altogether, two surveys were made.

Fish run in the Varpak channel. Hydroacoustic observation of the fish run in the Varpak channel, including determination of abundance, size of passing fish, and direction of their movement (upstream or downstream in relation to the current), was made by means of the NetCor complex. Transceiving elements of the complex were installed on a floating platform and situated in the lower reaches of the cannel at the left bank. Receiving, recording, and analytic elements of the complex were placed in the laboratory rooms of the Missiya field station of the Tobolsk Biological Station, Russian Academy of Sciences, on the bank. Communication within the complex was by radio. Hydroacoustic monitoring was made round the clock from June 29, 2008 to July 7, 2008.

In all cases, both at mobile surveys and at the stationary pattern, hydroacoustic materials were recorded on a hard disk of a notebook computer for their further treatment. The obtained hydroacoustic materials allowed for the possibility of estimating the quantity and size composition of the fish population of

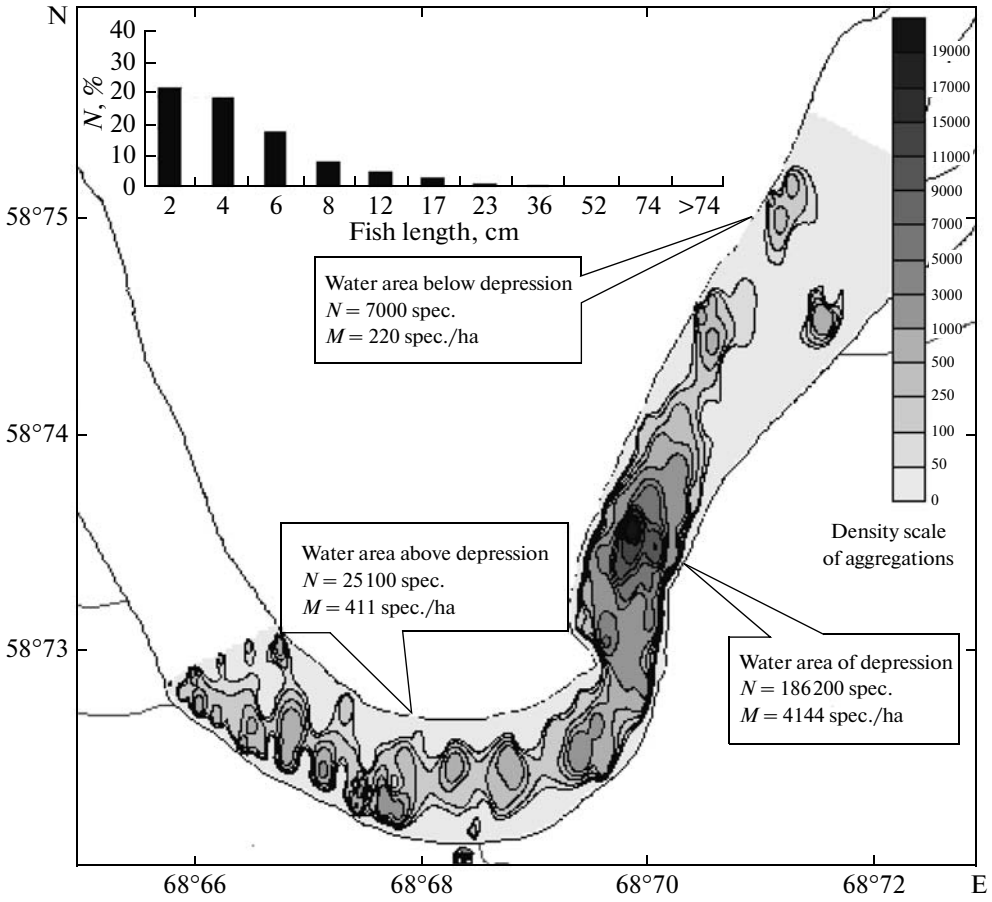

Fig. 4. The plot of fish distribution in the Gornoslinkinskaya riverbed depression on July 2, 2008. Dark period of the day.

the explored water area, to reveal the position of fish in the water area with determination of geographic coordinates, and to study the kind and rhythms of their movements.

Determination of the species composition of fish on the explored water areas was made by means of seining with stake nets (mesh size 14, 25, 35, 45, 55, and 65 mm, length of nets 35–75 m), by fry trawl, and manual dipnet. Further, biological analysis of the caught fish was made using traditional ichthyological methods (Pravdin, 1939). Altogether, 526 specimens were caught, including 333 specimens in the water area of Gornoslinkinskaya riverbed depression and 193 in the Varpak floodplain channel.

RESULTS

The water area of the riverbed depression in summer is populated by representatives of six species: roach *Rytilus rutilus* (L.), bream *Abramis brama* (L.), ide *Leuciscus idus* (L.), pikeperch *Stizostedion lucioperca* (L.), perch *Perca fluviatilis* (L.), and pike *Esox lucius* (L.); roach and perch are the most abundant. In this period, the Varpak channel is populated by siberian dace *Leuciscus baikalensis* (Dybowski), ide, golden carp *Carassius auratus gibelio* (Bloch), bream, roach, perch, and pike. The most abundant is perch while roach is not numerous (Fig. 2).

Fish juveniles (body length <8 cm) in Gornoslinkinskaya riverbed depression are represented by roach, dace, and perch; in the Varpak floodplain channel, they are represented by dace and id. In the depression, juveniles of roach were dominant, and, in the channel, the dominant fish were dace.

The fish are distributed over the Irtysh bed extremely irregularly. On pads composed by the results of the summer hydroacoustic survey of the water area (July 1–2), in different time of the day, the boundaries of maximum fish concentrations are clearly seen—this is a water area of Gornoslinkinskaya riverbed depression (Figs. 3, 4). Besides, in the daytime, the concentrations above and below Gornoslinkinskaya riverbed depression are seen (Fig. 3). With oncoming night, the distribution of fish on the water area noticeably changes: riverbed fish aggregations, outside of the depression, occupy increasing areas. Their abundance and average density significantly increase (Fig. 4). The size composition of summer fish aggregations over the

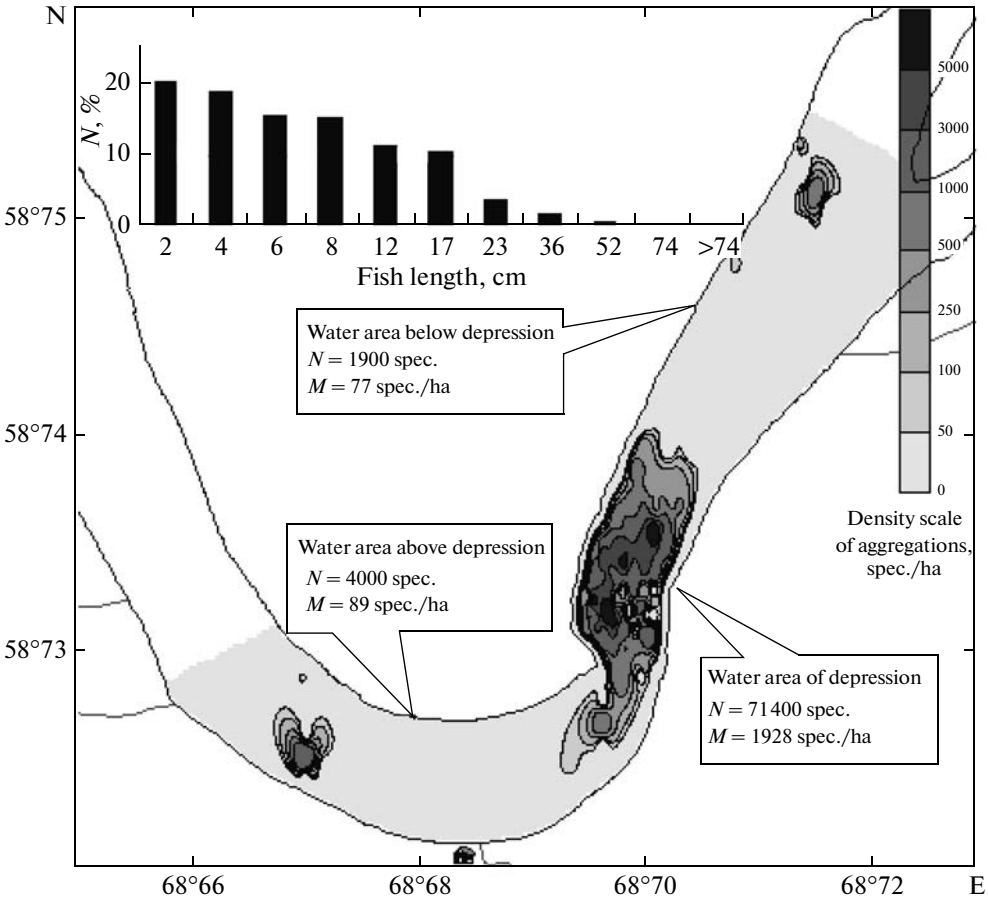

Fig. 5. The plot of fish distribution in the Gornoslinkinskaya riverbed depression on October 11, 2008. Light period of the day.

whole riverbed is characterized by clear prevalence by the abundance of juveniles with a body length from 2 to 8 cm.

The results of hydroacoustic surveys of the investigated water area made in the late autumn demonstrate significant changes in comparison with the early summer in the character of fish distribution, their size composition, abundance, and density of aggregations (Figs. 5, 6). First, large aggregations were concentrated exclusively in the water area of the depression. Only isolated specimens or small fish groups were noted in the mainstream of the river. Secondly, the total abundance of fish radically decreased, as well as, accordingly, the density of their aggregations. In addition, the diurnal dynamics of distribution of the fish on the water area in autumn was less expressed than in summer. In the late autumn, size composition of the fish population changes. Along with conservation of domination of abundance of small-sized fish, average-sized specimens with the body length from 12 to 25 cm appear, as well as large fish whose body size exceeds 35 cm.

Distribution of fish in the Varpak channel, similarly to the Irtysh, is aggregated irrespective of the day time (Figs. 7, 8). At the investigated part of the channel up to 2 km long, the fish in the Varpak channel form several centers with increased concentration—six sites in the daytime and 15 sites at night. In a comparison of the results of hydroacoustic surveys in different times of the day, the increase of the total abundance of fish in open water areas is well seen, as well as of density of their aggregations at night in comparison with the daytime. The size composition of ten fish populations of the Varpak channel is characterized by the quantitative predominance of juveniles with the body length from 5 to 10 cm (Fig. 9).

Regularities of the fish run in the Varpak channel, upstream and downstream, are shown in the summary plot (Fig. 10). The downstream run—downstream migration of juveniles from the Varpak—was the most intensive in the crepuscular-nocturnal period. At night, for the whole period of observations in total, over 2000 fish migrated to the Irtysh, while upstream, in the darkness, less than 300 specimens passed to the floodplain. Abundance of downstream migrants increased at night, from 11:00 to 12:00 p.m., local time, and an abrupt decrease in abundance of downstream migrants was observed in the early morning,

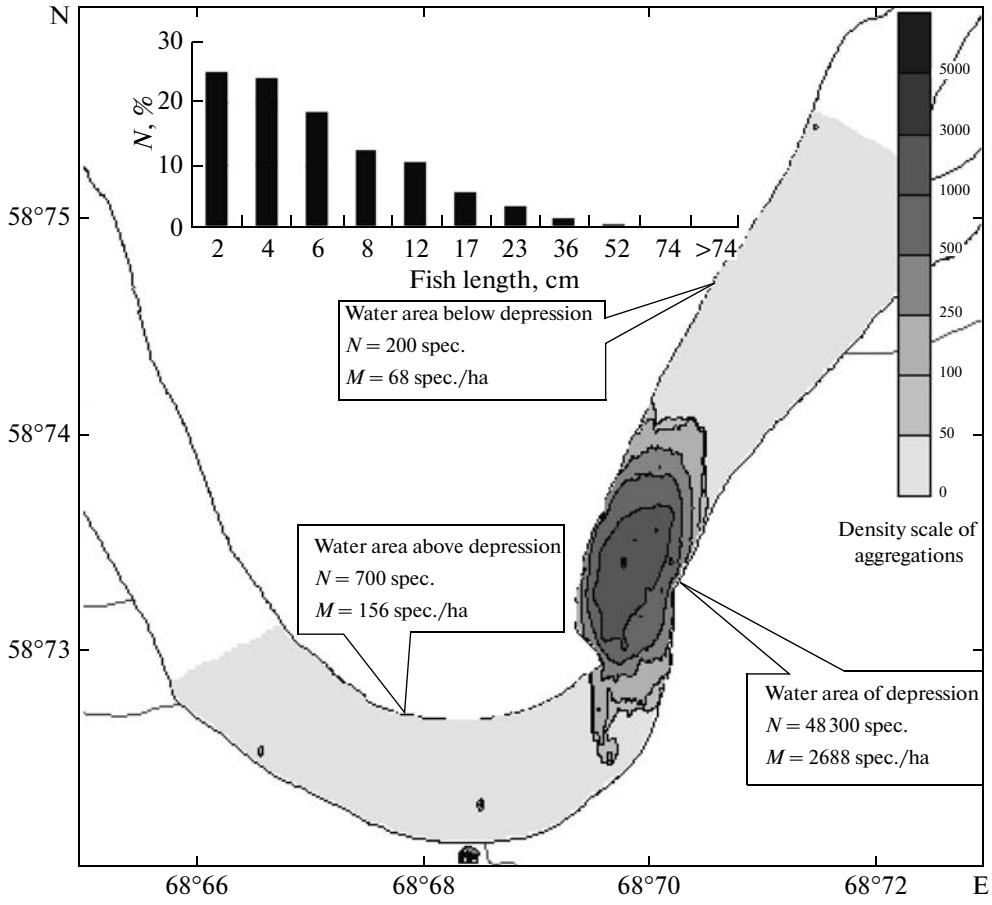

Fig. 6. The plot of fish distribution in the Gornoslinkinskaya riverbed depression on October 11, 2008. Dark period of the day.

from 4:00 to 5:00 a.m. In the daytime, a relatively homogeneous low quantity of juveniles made migration from the Varpak channel to the Irtysh. It may be noted that the peak of downstream migration of juveniles—from 8:00 to 10:00 a.m., local time—shown in the plot depended, according to our observations, on storm rains that occurred in these hours on June 30 and July 6. The reverse fish run, against the flow, from the Irtysh to the Varpak, i.e., to the water area of the floodplain, was uniform during 24 hours. The absolute majority of fish moving along the Varpak were early juveniles with linear size from 2 to 8 cm (Fig. 11). Altogether, during our observations, 3838 fish made downstream migration for the Varpak to the Irtysh and 2445 fish ascended from the Irtysh via the floodplain channel Varpak.

The present study did not envisage special investigation of fish diet. However, in the process of biological analysis of the captured fish the part of the feeding of fish was revealed, both in the Gornoslinkinskaya riverbed depression and the Varpak channel (Fig. 12). It was found that, in most fish, the gastrointestinal tract was empty. The quantity of feeding specimens in the investigated water areas did not exceed a third of all fish. The exception was only ides in the Varpak channel; in these fish, the part of feeding specimens was 80%.

On the whole, the feeding status of adults of various fish species in the depression and in the channel somewhat differs. Thus, among adults in the depression, the following fish feed actively: nonpredatory fish bream and roach, and predators perch and pike. In the channel, numerous feeding adults were predatory perch and non-predatory ide, bream, and roach. Among juveniles (body length up to 8 cm), the part of feeding specimens was low everywhere—maximum of 48% in ide. The highest number of feeding juveniles of fish of all species was recorded in the riverbed depression.

DISCUSSION

The obtained materials reflect multi-level biological harmony of the fish population of the floodplain channel and of the riverbed depression, manifested in the species and size similarity of their inhabitants, special traits of distribution and redistribution on the water area, food consumption, and diurnal rhythms of activity.

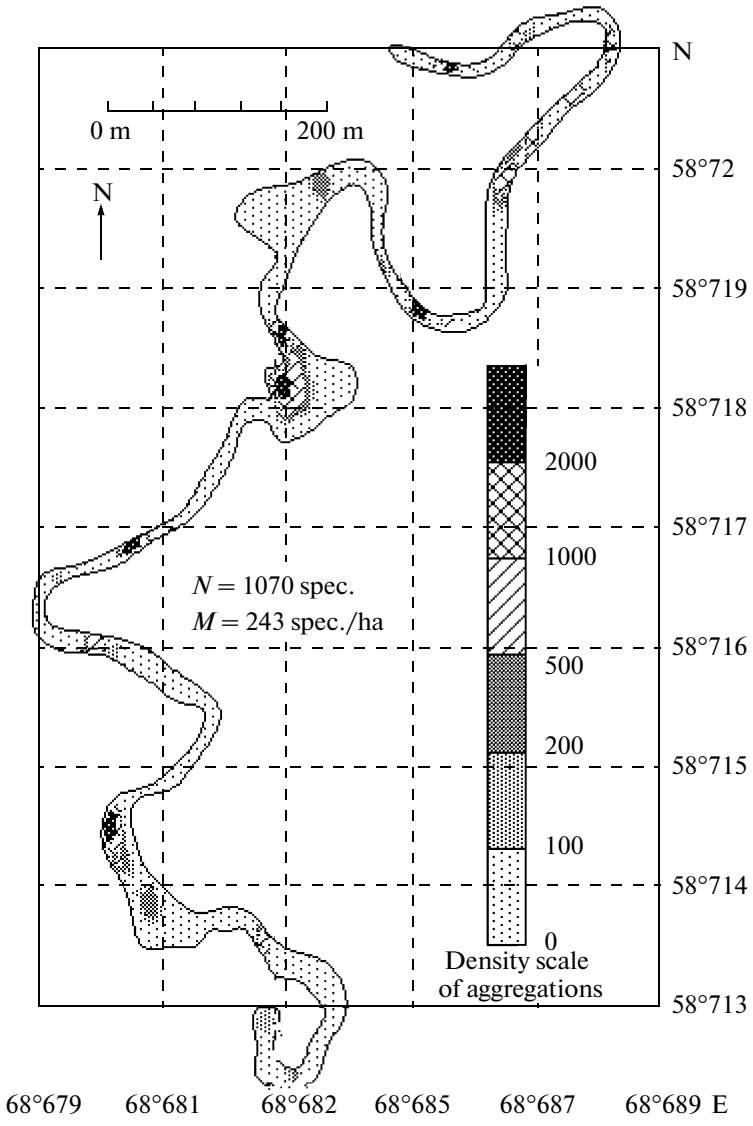

Fig. 7. The plot of fish distribution in the Varpak channel on July 1, 2008. Light period of the day.

On the whole, the species composition of adults from these water bodies little differs. The size series of fish recorded in the investigated water areas was similar: juveniles with the body length less than 8 cm dominated everywhere.

Most fish populating both the riverbed depression and the floodplain channel are crepuscular-nocturnal. With oncoming twilight, the fish left the protected shallow water and moved to open water. At dawn, the reverse process was unveiled: the fish left the open pelagial and hid in habitats protected by macrophytes, bottom irregularities, and snags. In most cases, the densest fish aggregations were formed in the dark part of the day. The phenomenon of morning and evening biotopic wanderings depends on defensive-trophic relationships of hydrobionts, is universal, and characteristic of most freshwater and marine fish (Girsa, 1981; Manteifel', 1987).

Everywhere, both in the floodplain channel and in the riverbed depression, the fish were characterized by aggregated distribution in space, with the obvious preference of heterogeneous habitats: snags, macrophytes, and abrupt changes of depth and flow structure. The physical heterogeneity of the environment is a major factor attracting fish. It causes the formation of natural and artificial fish concentrations in widely diverse water bodies (Mochek, 1987; Mikheev, 2006). By the results of our observations, the spatial pulses of fish aggregations is seen both diurnal and seasonal, indicating to the fact that fish distribution has a dynamic background.

The biological harmony of the fish population of the floodplain channel and the riverbed depression, in

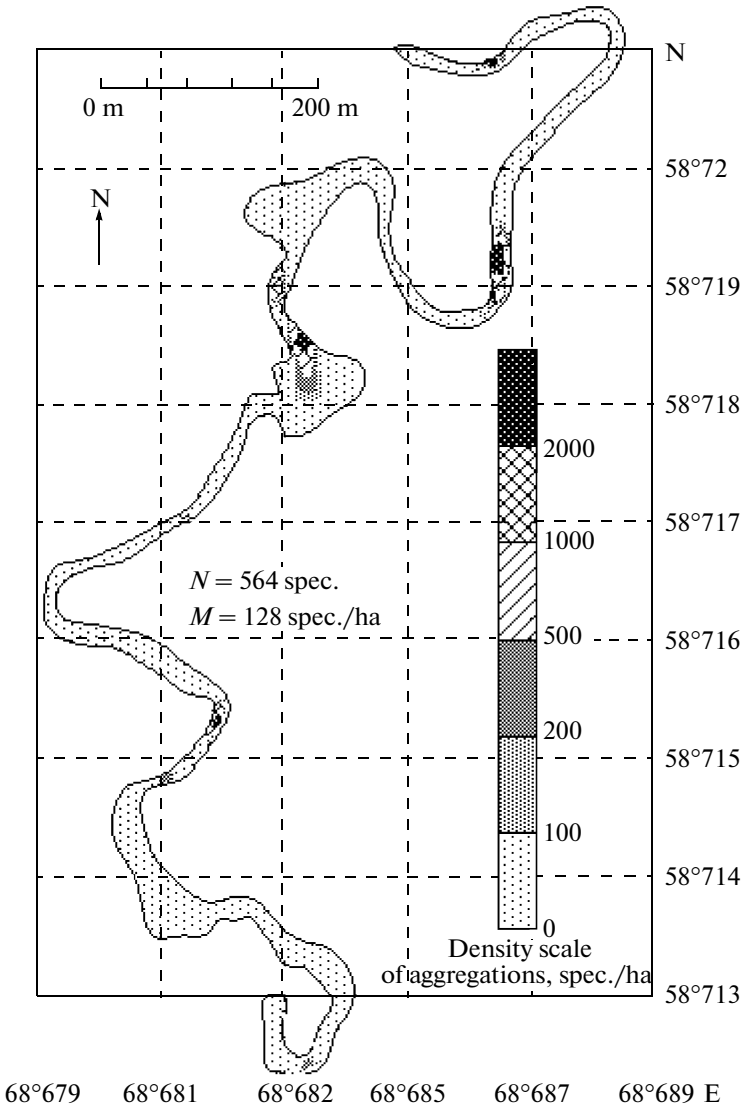

Fig. 8. The plot of fish distribution in the Varpak channel on July 2, 2008. Dark period of the day.

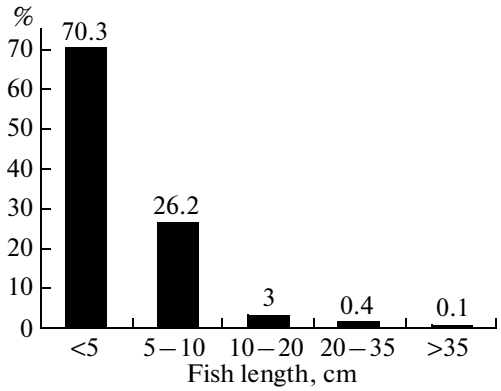

Fig. 9. Size composition of fish in the Varpak channel.

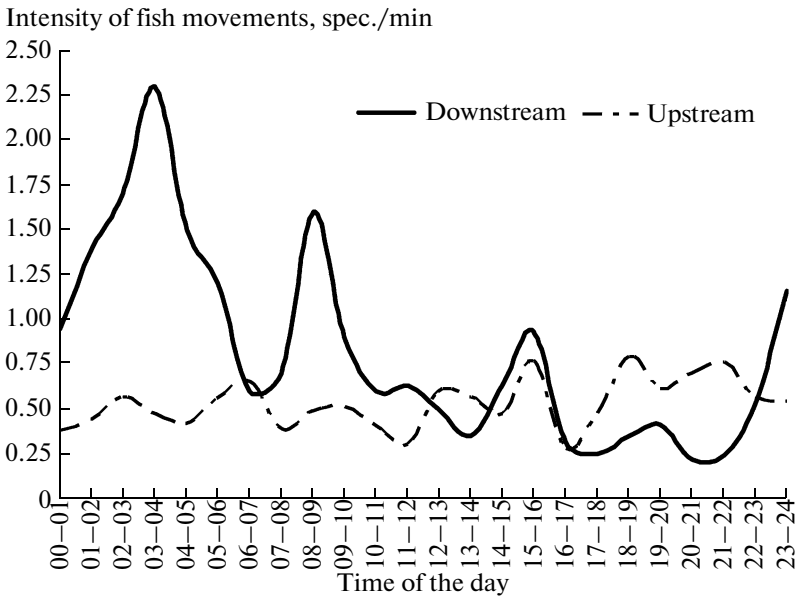

Fig. 10. Diurnal intensity of fish movements in the Varpak channel.

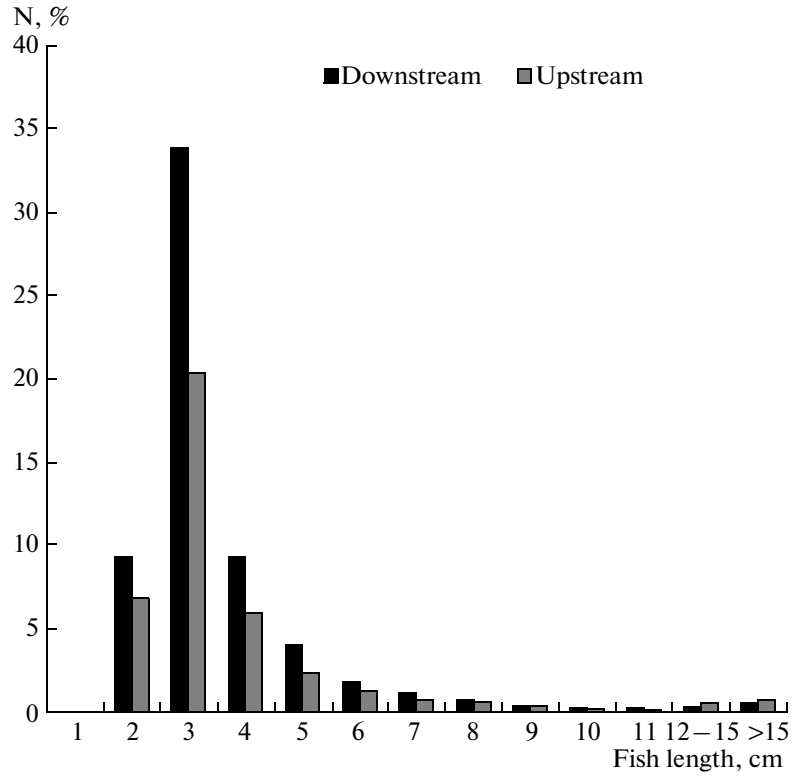

Fig. 11. Size composition of fish that passed through the Varpak channel mouth.

spite of contrasting differences of these water areas, depends on free two-way fish movements in the direction: riverbed–floodplain–riverbed via the floodplain channel. From the floodplain to the Irtysh mainstream, great amounts of juveniles make downstream migrations and their maximum occurs in the crepuscular-nocturnal period. Thus, there is a universal phenomenon for river systems of downstream migration of juveniles from the floodplain water bodies to the mainstream, occurring mainly at night (Pavlov, 1970;

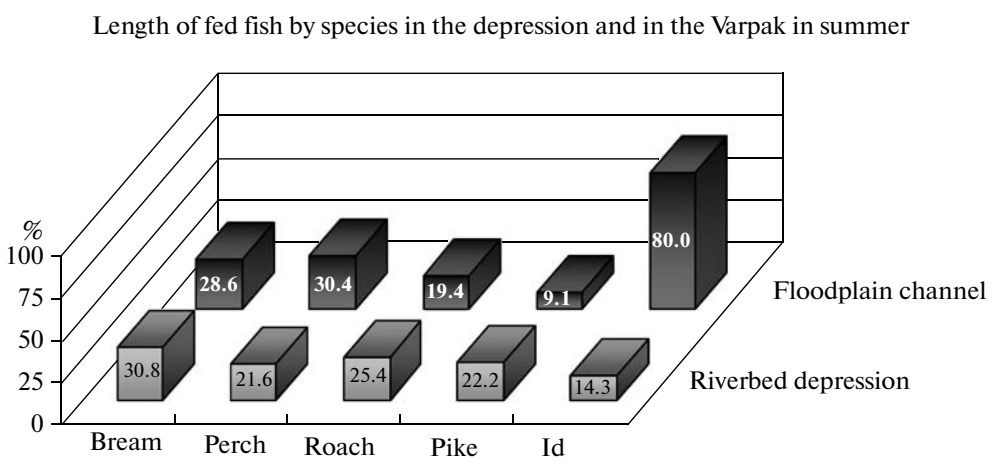

Fig. 12. The part of feeding fish (by species) in the Varpak channel and the Gornoslinkinskaya riverbed depression.

Pavlov et al., 2007). During 24 h, fish of various size swim from the river to the floodplain, with uniform intensity.

It is a regular phenomenon that with decreasing water level during floods and, accordingly, decreasing size of floodplain water bodies (sors), the formerly abundant fish population of these water areas moves to the water area of the mainstream and is also concentrated in riverbed depressions, known for a long time as wintering depressions (Nikolsky, 1963). Our investigations demonstrated (Pavlov and Mochek, 2005) that, in these deep-water sites, not only the spawners winter but also fish juveniles permanently concentrate. In the riverbed depression and in the known feeding grounds—in the floodplain and in shallow stretches of the mainstream—the fish feed at all age.

Among fish left the floodplain, absolute majority are grown underyearlings, but large specimens also penetrate to the river mainstream in rather high numbers, as sors dry up. In a riverbed depression, the underyearlings and adults (resident and potamodromous) form wintering aggregations. Abundance and composition of these aggregations undergo regular changes during the ice period: underyearlings partly perish or move to other parts of the river and the juveniles remaining in the depression noticeably increase in size. During winter, the composition of spawners noticeably changes according to seasonal changes of the physiological state of fish and of abiotic environmental factors. With the oncoming spring flood and formation of floodplain water bodies, the ripened spawners and fish of various trophic levels—from planktophages to ichthyophages set off again to these highly productive water areas (Pavlov, 1979).

Thus, the fish cyclically exploit the spatial, food, and protecting resources of the floodplain-riverbed complex of the river system of the Lower Irtysh—the Gornoslinkinskaya riverbed depression and the Varpak floodplain channel.

CONCLUSIONS

The Gornoslinkinskaya riverbed depression and the Varpak floodplain channel constitute an entire ecological complex where a dynamic fish community is formed and their regular diurnal and seasonal migrations occur. The species and size composition of the fish population of the riverbed depression are very similar. The fish living in these water bodies manifest general traits of diurnal activity and spatial distribution. Formation of fish concentrations in the investigated water areas is not random but is biologically predetermined by such phenomena universal for river systems as downstream migration of juveniles, diurnal wanderings, and seasonal migrations. Thus, a total system is formed of exploitation by fish of the space, food resources, and shelters of the floodplain–riverbed complex. An important biological phenomenon determining the ecological harmony and capacity of floodplain–riverbed biotopes is the dynamics of fish distribution, as an integral function of their behavior.

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