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Irregularities of the Bottom and Fish Aggregations on a Stretch of the Irtysh

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Abstract—An original method for estimation of the effect of bottom irregularities on density of fish aggregations is elaborated. Calculation of the investigated relationship is based on material of surveys collected by an AsCor hydroacoustic complex and is made by means of special software. With reference to a deep-water stretch of the Irtysh channel, the quantitative parameters of the relationship between densities of fish aggregations and the index of bottom irregularity are revealed. The diagram of the relationship between bottom irregularities and density of fish aggregations, the three-dimensional model of bottom relief of the investigated water area, and echograms of fish aggregations on various stretches of the river are presented.

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Key words: distribution of fish, the Ob–Irtysh basin, hydroacoustic surveys.

INTRODUCTION

Communities of organisms living under conditions of inhomogeneous environment are characterized by high values of abundance, biomass, diversity, and productivity. The nature of the gradient or of inhomogeneity of the environment may be physical, chemical, biological, etc. but in most cases it is caused by the complex, systemic interaction of heterogeneous factors. This fundamental pattern is true of ecological systems of all types and levels but manifests itself most clearly at boundaries of ecosystems, in ecotones (Odum, 1971). It is here, at the division boundary of physical media, that concentration of organic matter transported by aquatic and air currents takes place. As an example of such ecological systems, we have to point out forest margins, piedmont hills, coral reefs, and mangroves.

The largest ecotone of the globe is the boundary between aquatic and terrestrial ecosystems: coasts on the side of land and coasts on the side of a water body. The coastal zone is everywhere a concentration of hydrobionts, a highly productive zone of the World Ocean. These water areas among all water bodies of the globe are highly rich in fish, invertebrates, and macrophytes irrespective of their size, origin, natural–climatic situation, salinity, and chemical composition of water.

Occupation by fish of the coastal zone of water bodies is extremely irregular. It is widely known in fisheries that the greatest number of fish is attributed to environmental gradients, fish live on water areas with abrupt change of depth, among reefs and cliffs. For example, productivity of reef and cliff habitats exceeds the value of this parameter known for the open ocean by 200 times (Odum, 1971).

Underwater observations revealed that abundance and diversity of fish populations of shallow water areas mostly depend on irregularity of the bottom relief. In the river, most resident fish exist permanently in the inhomogeneous inshore zone—among macrophytes and in snagged sites (Mochek et al., 1981; Poddubnyi and Malinin, 1988). In the coastal zone of seas, the maximum number of permanent inhabitants of the shelf live in areas with rugged bottom relief, while the fish population of monotonous bottom plateau is scarce and comparatively poor taxonomically (Mochek, 1979). Particularities of fish distribution in the coastal zone with complicated underwater relief depends on the kind of their defensive–trophic interrelations (Mochek, 1987; Mikheev, 2006) and should be taken into consideration in measures on rational use of fishery in the coastal zone (Mochek and Val'des, 1982).

In spite of evident influence of bottom irregularities on formation of fish aggregations, the quantitative characteristic of this relationship has not been elaborated until now. In the present study, the analysis of bottom irregularities is made on a mesoscale; i.e., local bottom slopes in the fairway during movement to banks are taken into consideration, as well those in channel depressions.

The aim of the present study is to quantitatively estimate the relationship between the density of fish aggregations and bottom irregularities at a local stretch of the river channel. The following tasks were planned: to elaborate methods of treatment of echograms for

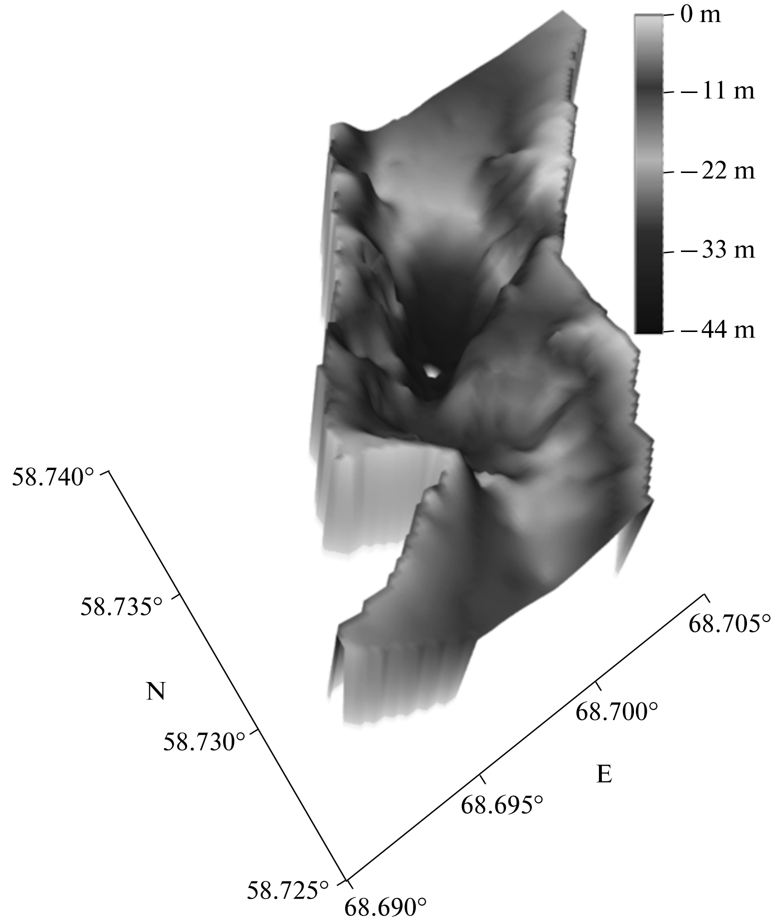

Fig. 1. Graphic model of the bottom relief of the investigated water area.

elucidation of the quantitative relationship of density of fish aggregations and bottom irregularities; to determine the relationship between the density of fish aggregations and mesoscale bottom irregularities with reference to the Gornoslikinskaya riverbed depression of the Irtysh.

MATERIAL AND METHODS

Investigation was made on the basis of analysis of the daytime echometric survey of June 18, 2007, made by means of the AsCor hydroacoustic research complex. The echometric survey was made by the network of tacks onboard a small vessel whose coordinates were determined by the GPS satellite navigation system. Density of fish aggregations was calculated by means of a standard software AsCor complex (Degtev and Ivanter, 2002).

As a result of treatment of echograms a sample of mean values was obtained (for 100 acoustic pulses) for densities of fish aggregations at different stretches of the river: above the riverbed depression, on the water area of the depression, and downstream of the depression. Simultaneously, in the course of surveying, the data file was formed by depth for each acoustic pulse and separately for 100 pulses. The period measured by 100 acoustic pulses of an echo sounder approximately corresponded to 40 s of real time or approximately 100 m of the passed distance. The corresponding points on the chart board were obtained, with known coordinates, values of densities of fish aggregations, and depths. Using the obtained data, by the method of linear interpolation, by means of Surfer®-8 standard software and MapInfo-6 software, boards were constructed with isolines of densities of fish aggregations on the investigated water area.

For characterization of the relief of the investigate water area the three-dimensional graphic model was constructed (Fig. 1). In construction of the model, GRID-files of a three-dimensional network were used with a cell size 4 × 4 m. The model of mesorelief of the bottom allows, using the Surfer® software for isolation of particular bottom sites corresponding to the distance passed in 100 acoustic pulses of the echo sounder, to calculate the area of this bottom site "sound-detected" by the hydroacoustic equipment and its horizontal projection to the water surface. Calculation of the bottom area was made with consider-

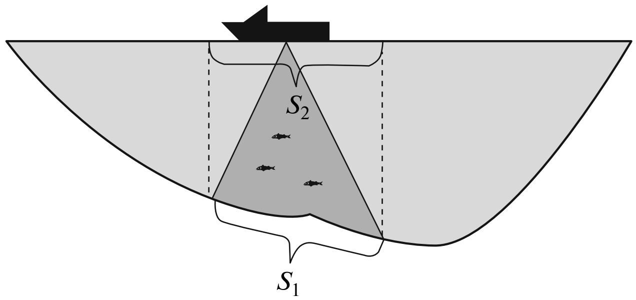

Fig. 2. Scheme of ratio of the area of "sound-detected" site (S_1) and of its projection (S_2).

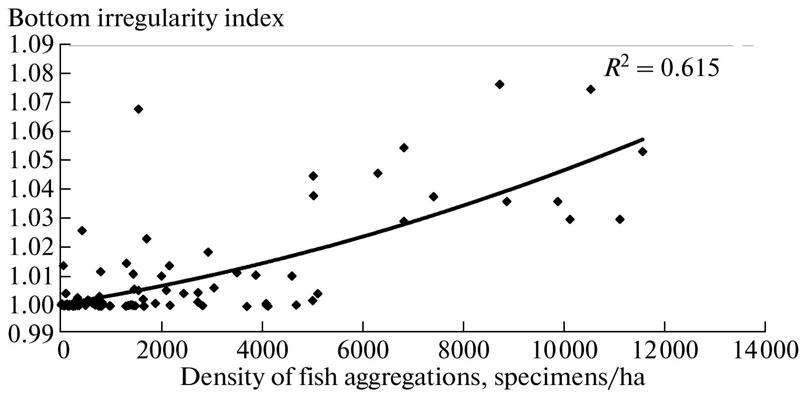

Fig. 3. Diagram of relationship between the density of fish aggregations and the bottom irregularity.

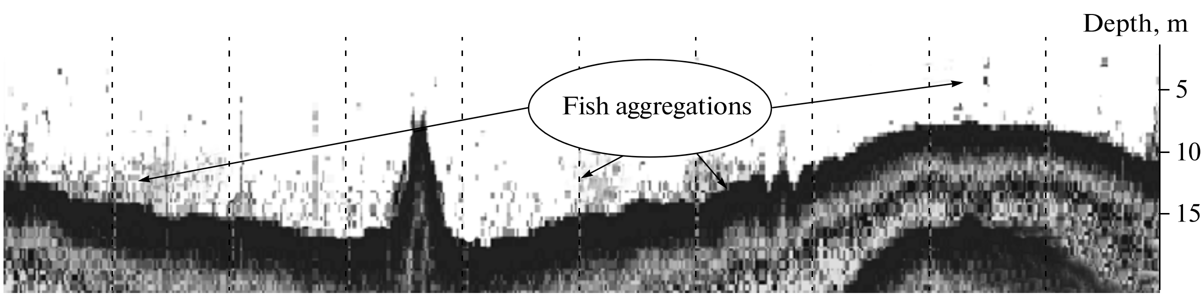

Fig. 4. Echogram of rarefied fish aggregations on a site of bottom plateau (BII 1.00–1.02).

ation of the diagram of direction of the antenna of the research echo sounder by the factual site depth for each acoustic pulse. A series of values of the bottom areas was obtained which then were summed up for each 100 pulses. The value of bottom irregularity index (BII) is determined by the ratio of the area of bottom plot S_1 (with consideration of its irregularities) to the area of its horizontal projection S_2 (Fig. 2). By the results of calculation, approximately 100 points were obtained on the investigated water area with the known coordinates, mean values of density of fish aggregations, the value of BII.

RESULTS

By treatment of echometric data, the final echogram was created for the relationship between density of fish aggregations and bottom irregularities on the Gornoslinkinsklaya riverbed depression and adjacent water areas (Fig. 3). The plot is a dotted diagram with polynomial trend of relationship. Approximation of the trend (square of mixed correlation) yields the value 0.615.

According to the above material, the rarefied fish aggregations with density up to 5000/ha were recorded predominantly on sites with an even bottom surface; the BII value was 1.00–1.02. An example of visualization of fish aggregations on such stretch is shown in the echogram (Fig. 4). On sites with increasing depth, within BII range 1.02–1.04, the density of fish aggregations gradually increases up to 6000–10000 specimens/ha. An echogram of such aggregation is shown in Fig. 5. On depth drop-offs with extremely irregular bottom

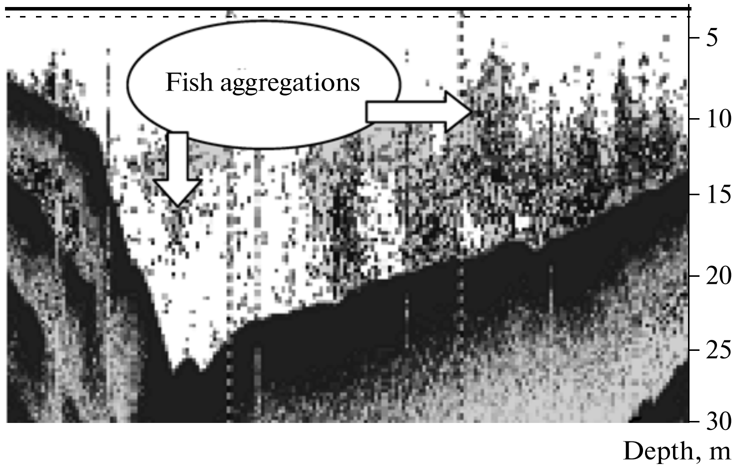

Fig. 5. Echogram of fish aggregations of mean density on a site of gradual decrease of the bottom relief (BII 1.02–1.04).

relief in the central part of the depression the density of fish aggregations significantly increases up to 12000 specimens/ha; in this case, BII attains the maximum values—1.05–1.08. Such value of BII is characteristic of the water area of the riverbed depression maximally populated by fish. Probably, it is the optimum for formation of fish aggregations. The density of fish aggregations on such sites surpassed the value typical of bottom plateau of this parameter by several times. A typical echogram of such water area is shown in Fig. 6.

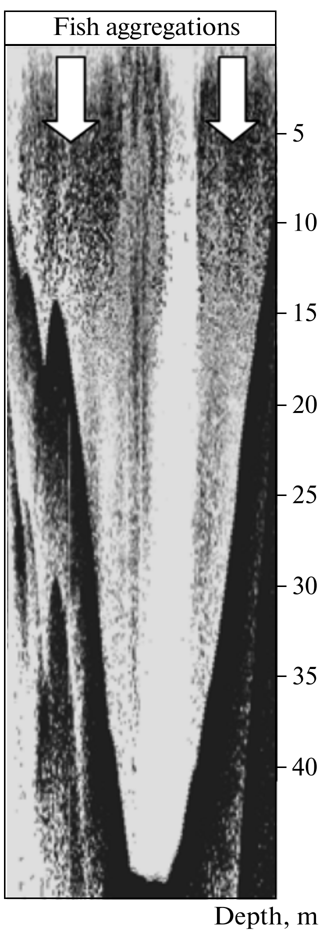

Fig. 6. Echogram of fish aggregations of maximum density at the depth drop-off (BII 1.05–1.08).

DISCUSSION

The performed investigations allowed to approach the quantitative estimation of the influence on distribution of fish in the river of one of the major factors in the heterogeneity of the environment—bottom irregularity. The fish population of the riverbed part of the Lower Irtysh is represented principally by six species: roach *Rutilus rutilus*, bream *Abramis brama*, id *Leuciscus idus*, pikeperch *Stizostedion lucioperca*, perch *Perca fluviatilis*, and pike *Esox lucius* (Pavlov et al., 2008). At different stages of the life cycle, these species are connected to a certain extent to shallow water. There is a trend that bottom irregularities significantly control distribution of fish, including density of their aggregations. However, our investigations demonstrated that, in nature, this trend has a complicated character due to direct and indirect influence on the density of fish aggregations not of one but a complex of environmental factors. The controlling physical parameters are: rate and structure of transit water currents of the river, depth of water column, and riverbed width (Pavlov and Mochek, 2009). Major biotic factors comprise the defensive–trophic situation in the water body and the success of spawning of spawners of background species and of early development of their juveniles.

The diagram composed on the basis of our calculations (Fig. 3) indicated that the approximated trend of the relationship between density of fish aggregations and BII is polynomial. According to our data, the mean value of BII of the water area of a depression maximally populated by fish is 1.04. Density of fish aggregations steadily increases with increase of BII from 1.02 to 1.07. Three zones may be differentiated in the diagram: I—BII has an insignificant value and the density of fish aggregations is characterized by minimum values; II—increasing value of BII within optimum limits favors formation of fish aggregations of medium and high density; and III—fish aggregations of maximum density are formed on river stretches with high BII, in the zone of high turbulence.

A general trend of relationship between distribution of fish and irregularity of bottom relief is revealed for large waterflows. The obtained results indicate that under natural conditions BII substantially influences the density of fish aggregations and correlation of these values attains a significant level. It is evident that this relationship would change under the influence of a complex of environmental factors, biological, hydraulic, and geomorphological in water bodies of a different type.

The present study is first step in the quantitative description of the fundamental and many-sided relation of fish distribution to irregularity of bottom relief. Further development of methods of calculation and special investigations of such kind are necessary on rivers, coastal limnic, and marine water areas under conditions of modification of a biotic component of ecological systems.

CONCLUSIONS

The density of fish aggregations depends, to a certain extent, on bottom irregularity. On a relatively even bottom, at bottom irregularity index 1.00–1.01, the density of fish aggregations is minimal. With increase of bottom irregularity index to 1.04 the value of the density of fish aggregations significantly increases. The values of bottom irregularity index within 1.02–1.07 may be considered as optimum for formation of fish aggregations. A high bottom irregularity index (over 1.07) at depth drop-off does not favor increase in the density of fish aggregations, and the density of fish aggregations on such sites decreases. This trend is complex and in the riverbed part of the Irtysh is determined by the complex effect of conjugated environmental factors—hydrodynamics of the flow, morphology of the riverbed, and biotic background.

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REFERENCES

1. A. I. Degtev and D. E. Ivanter, "Automatic System of Quantitative Assessment of Fish Resources by the Hydroacoustic Method Askor-2," Rybn. Khoz., No. 4, 58–60 (2002).
2. V. N. Mikheev, *Environmental Inhomogeneity and Trophic Relations of Fish* (Nauka, Moscow, 2006) [in Russian].
3. A. D. Mochek, *Ethological Organization of Coastal Communities of Marine Fish* (Nauka, Moscow, 1979) [in Russian].
4. A. D. Mochek, "Shelters and Food Accessibility for Coastal Fish," Vopr. Ikhtiol. **27** (5), 870–872 (1987).
5. A. D. Mochek and E. Val'des, "Artificial Reefs in Seas of Different Latitudes," in *Behavior and Migrations of Fish* (IEMEZh, Moscow, 1982), pp. 26–32.
6. A. D. Mochek, D. S. Pavlov, and S. N. Kapustin, "Specific Features of Fish Distribution in River (Underwater Observations)," Vopr. Ikhtiol. **21** (1), 177–178 (1981).
7. E. Odum, *Fundamentals of Ecology* (Saunders, Philadelphia, 1971)
8. D. S. Pavlov and A. D. Mochek, "Fish Distribution in River Systems as a Dynamic Phenomenon," Usp. Sovrem. Biol. **129** (6), 528–537 (2009).
9. D. S. Pavlov, A. D. Mochek, E. S. Borisenko, et al., "Comparative Analysis of Fish Aggregation in Channel Depression of the Irtish," J. Ichthyol. **48** (11), 919–936 (2008).
10. A. G. Poddubnyi and L. K. Malinin, *Fish Migrations in Inland Water Bodies* (Agropromizdat, Moscow, 1988) [in Russian].