Floodplain-channel complex of the lower Irtysh: dynamics of flood and fish number

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Abstract. The dynamics of fish aggregation density in the riverbed was studied using the hydroacoustic method during the intensive phase of the hydrological regime of the Irtysh River – the spring-summer flood. The dynamics of fish density with increasing water levels was recorded taking into account the analysis of average values of the indicator for decades periods of May in 2020 and 2021. During the flood period under study, the size of the share of taxonomic fish groups (cyprinids, percids, coregonids-esociids, unidentified) at the family level varied insignificantly, intensive dynamics were noted for the fish density indicator: Fish density decreased with increasing water level. The decrease in the number of fish in the riverbed is associated with their transition to the flooded floodplain of the river of the studied floodplain-channel complex. With a more powerful flood in 2020, the decrease in fish density in the riverbed occurs more intensively than with a less intensive rise in water level in 2021. The significance differences between decades were noted both for the indicator of the total fish density and for the density of taxonomic groups of fish.

1 Introduction

Understanding the ecology of large river systems is most correct in considering a single complex of the riverbed and floodplain; important ecological factors determining the ecology of the complex are temperature and phases of the hydrological regime (floods, high and low water) [1-3].

Natural river floodplains are complex systems consisting of a network of aquatic and terrestrial ecosystems [4]. The floodplain is connected to the riverbed complex by both permanent and intermittent watercourses [5], which ensure the migration and dispersal of aquatic organisms into the floodplains during high water and rapid rise in the water level, as well as from the floodplain to the main riverbed during low water. Floodplain areas are of fundamental importance; when they are flooded, they provide fish populations with both breeding grounds and feeding grounds. At the same time, floodplains are considered highly dynamic and the most vulnerable, but at the same time they contain a high biological diversity of aquatic ecosystems [1;2;6]. The dynamics of the river's hydrological regime influences the intensity and duration of flooding and creates temporary connections between floodplain and riverbeds ecosystems, which facilitates the migration and movement of organisms [2;7]. In turn, the hydrological connection between the riverbed and the floodplain, created by high

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water levels, forms migration routes for living organisms in the floodplain-channel complex [4]. When floodplain areas are flooded, the number of fish in the main riverbed decreases as a result of its transition to the floodplain and redistribution in the main riverbed. However, there are very few studies on fish migration from main riverbeds to floodplains in natural large river systems of the temperate climate zone [8], this type of migration is studied in most detail in the floodplains of tropical rivers [7;9;10].

In this regard, the aim of the work is to assess the dynamics of fish density and the insights of its change in the riverbed of the floodplain-channel complex of the Irtysh during the intensive phase of the spring-summer flood.

2 Material and methods

The studied section of the Irtysh River is located on the territory of the West Siberian geographical country, located on the territory of the accumulative West Siberian Plain [11], 6.2 km upstream from the village of Gornoslinkino within the boundaries of the municipal formation Uvatsky district, Tyumen region, in coordinates 58.731267° N.L., 68.698504° E.L.

The studies were carried out during the period May 1-29 in 2020 and 2021 using the hydroacoustic method using the computerized acoustic complex «AsCor» (Promgidroakustika LLC, Petrozavodsk).

At the studied water area are moved along a grid of tacks in the according to the generally accepted method of conducting hydroacoustic surveys [12]. The operation of the computerized hydroacoustic complex used is based on the use of a serial vertical dual-beam echo sounder Furuno LS 4100 (Furuno Inc, Japan) with operating frequencies of 50 and 200 kHz.

The data from hydroacoustic surveys are processed in laboratory conditions using specialized software «AsCor», which also determines the body length of registered fish individuals and their average density (ind. /ha).

Taxonomic identification of fish populations based on echometric probing results is performed based on the swim bladder shape [13] in laboratory conditions using the Taxonomy program. Registered fish are classified into 4 groups: Cyprinidae, Percidae, Esociidae and Coregonidae, not identified (Acipenseridae and Lotidae).

Statistical analysis was performed using the Statistica 10.0 program (Statsoft Inc., USA).

To determine the presence of a significance effect of changes in fish density over decades of observations, a one-way statistical analysis Anova-one way was used; the significance of the difference between the average values of densities over decades was assessed using the Tukey test.

3 Results and discussion

During the intensive phase of the hydrological regime of the Irtysh River - the spring-summer flood, using hydroacoustic surveys, it was established that in the water area of the riverbed pit, along with an increase in the water level in the river, the dynamics of the fish density indicator is observed, and its general linear trend is aimed at reducing this indicator, that is, with an increase in the water level, the density of fish in the water area of the riverbed pit decreases.

Over the period of monthly observation, the average value of fish density decreased from 3.379 to 1.974 and from 2.720 to 2.163 thous. ind./ha in the I and III decades of observations in May of 2020 and 2021, respectively (Fig. 1.).

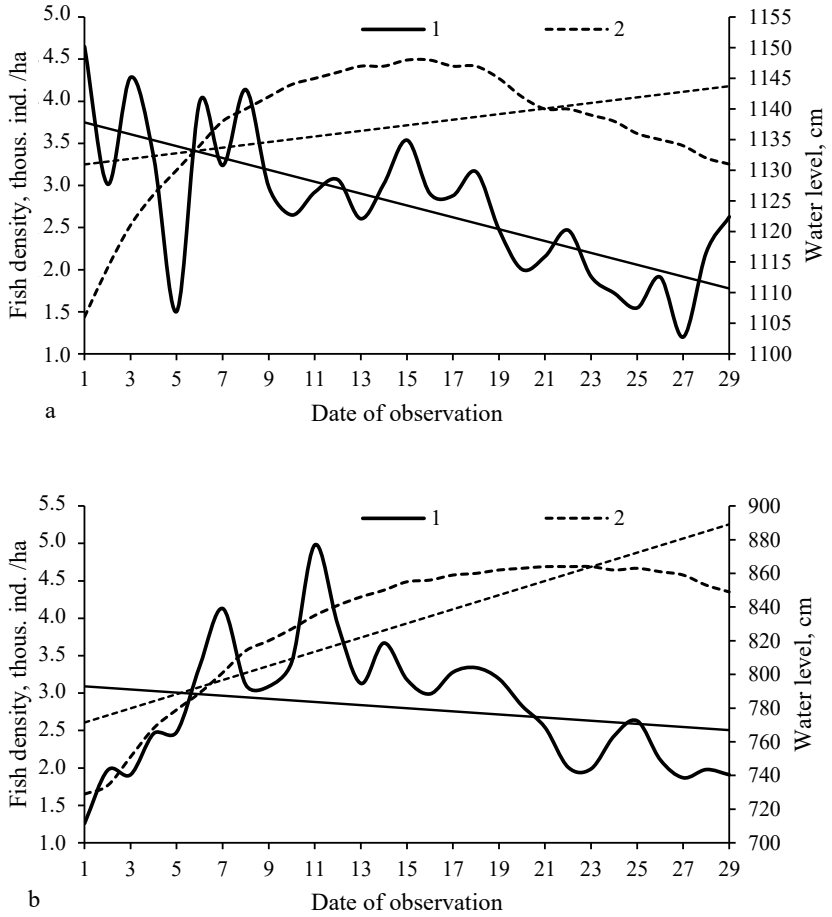

Fig. 1. Dynamics and trend of indicators of the total fish density in the water area of the riverbed pit and the water level in the Irtysh River: a.2020; b. 2021; 1 – Fish density; 2 – Water level.

It is worth noting that a more intense dynamics of the decrease in fish density in the water area of the pit is observed at a higher water level in the river, i.e. when the floodplain part of the river is more flooded. Thus, on 15.05.2020, the water level was 1148 cm according to the Uvat hydropost, and the fish density from 01.05. to 15.05.2020 decreased by almost 24% from 4.648 to 3.538 thous. ind./ha. The following year, on the same date, the water level in the river was 855 cm, and the change in fish density from 01.05. to 15.05.2020 had a trend towards an increase in the indicator from 1.261 to 3.18 thous. ind. /ha (Fig. 1.)..

Thus, the phase and intensity of the flood affects the density of fish in the water area of the riverbed pit.

Based on the results of the hydroacoustic surveys, it was established that the dominant taxonomic group of fish in the studied section of the river is the group - Cyprinidae. The average share of this fish group was 48.64% in 2020 and 49.06% in 2021. The share of Percidae was 35 and 34.36%, respectively, by study year. For the two remaining fish groups - Esociidae-Coregonidae and not identified, the shares were 9.32 and 7.26% in 2020, 9.12 and 7.24% in 2021, respectively (Fig. 2).

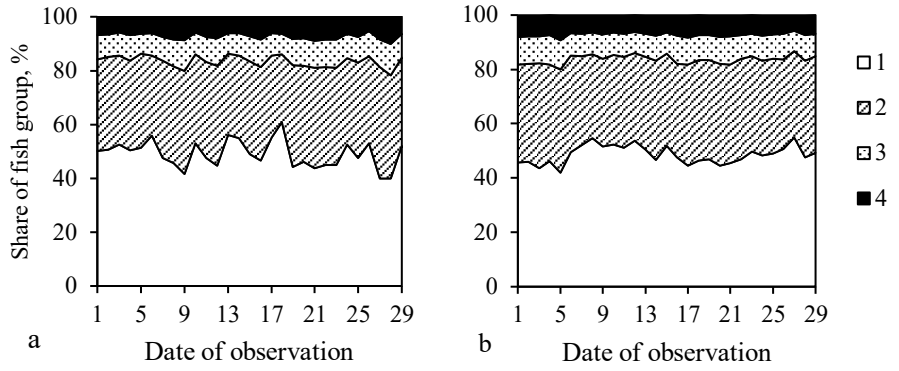

Fig. 2. Taxonomic structure of fish population in the water area of the Gornoslinkinskaya riverbed pit during the spring-summer flood on the Irtysh River (according to echometric sounding data): a.2020; b. 2021; 1 – Cyprinidae; 2 – Percidae; 3 – Esociidae-Coregonidae; 4 – Not identified.

Between the decades of observations, both in 2020 and 2021, the proportions of taxonomic groups of fish recorded by the hydroacoustic method varied slightly, with the range of values being greater in the fish density indicator.

Thus, the values of the share of carp fish in the I, II and III decades of observations in 2020 were for Cyprinidae - 1.687, 1.450 and 0.923 thous. ind./ha, for Percidae - 1.155, 0.942 and 0.701 thous. ind. /ha, for the Esociidae-Coregonidae group 0.308, 0.259 and 0.197 thous. ind./ha and for the group of not dentified fish 0.234, 0.205 and 0.152 thous. ind/ha, respectively. The total fish density indicator changed by decades of observations as follows: I - 3.379, II - 2.857 and III - 1.974 thous. ind. /ha, respectively (Fig. 2).

In 2021, between the I, II and III decades of observations, the dynamics of the average values of the density of various taxonomic groups of fish was also noted: Cyprinidae - 1.341, 1.679 and 1.060 thous. ind. /ha, Percidae - 0.934, 1.213 and 0.755 thous. ind. /ha, Esociidae-Coregonidae group - 0.247, 0.309 and 0.195 thous. ind. /ha, group of not dentified fish - 0.197, 0.249 and 0.153 thous. ind. /ha (Fig. 2).

For the indicator of the total fish density in the I, II and III decades of observations, high dynamics of values of 2.720, 3.450 and 2.163 thous. ind. /ha, respectively, were also noted (Fig. 3).

As a result of the statistical analysis performed to determine significance differences for the data for 2020, the presence of an effect was established both for the total fish density ($F = 11.29$, $p < 0.001$) and for the density of fish of individual taxonomic groups when considering their average indicators for the decades periods of May, during the most dynamic hydrological period of the spring-summer flood: Cyprinidae ($F = 10.52$, $p < 0.001$), Percidae ($F = 10.11$, $p < 0.001$), Esociidae-Coregonidae ($F = 6.48$, $p = 0.005$), not dentified (sturgeons and burbot) ($F = 5.42$, $p = 0.01$) (Table 1).

To determine the reliability of differences between decades for various indicators, a post hoc Tukey test was performed, which established the reliability of differences in the indicator of total fish density between the I and III ($p<0.001$), II and III ($p<0.05$) decades of observations (Table 2).

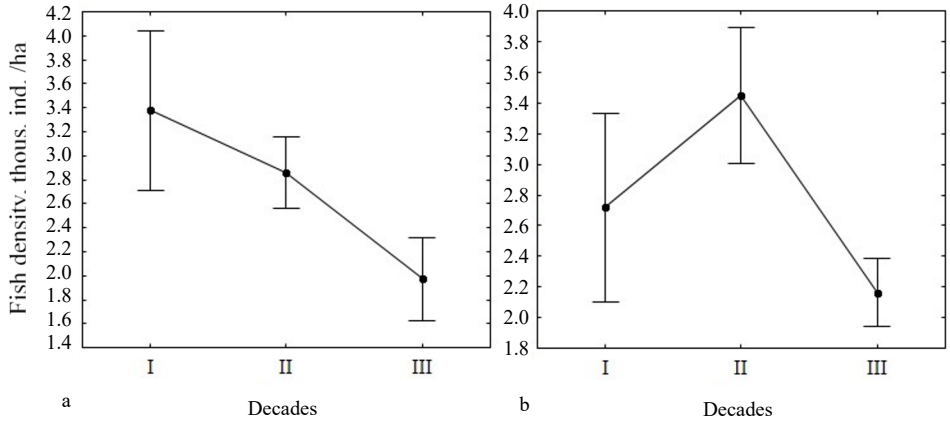

Fig. 3. Dynamics of average values of total fish density in the water area of the riverbed pit (dots - average values, whiskers - confidence interval): a.2020; b. 2021.

Table 1. Anova one-way analysis of the presence of a reliable difference in fish density in the water area of the pit with changes in the water level in the Irtysh River (I-III decades, May 2020 and 2021).

№	Indicators	SS	dF	MS	F	p*
2020						
1.	Total fish density	9.495	2	4.748	11.29	*p<0.001*
2.	Density of Cyprinidae	2.864	2	1.432	10.52	*p<0.001*
3.	Density of Percidae	0.976	2	0.488	10.11	*p<0.001*
4.	Density of Esociidae-Coregonidae	0.059	2	0.029	6.48	*0.005*
5.	Density of not dentified fish	0,032	2	0.016	5.42	*0.01*
2021						
6.	Total fish density	7.938	2	3.969	9.56	*p<0.001*
7.	Density of Cyprinidae	1.827	2	0.913	6.35	*p<0.001*
8.	Density of Percidae	1.020	2	0.510	12.88	*p<0.001*
9.	Density of Esociidae-Coregonidae	0.062	2	0.031	12.21	*p<0.001*
10.	Density of not dentified fish	0.043	2	0.021	12.56	*p<0.001*
*- the level of significance is indicated in italics, with a significance presence of the effect						

When studying the average values of this indicator for Cyprinidae, the difference was registered similarly to the indicator of the total density of fish for the I and III ($p<0.001$), II and III ($p<0.05$) decades of observations. When analyzing the group of Percidae, the presence of significance differences was established only for the I and III ($p<0.001$) decades of observations. For the Esociidae-Coregonidae group, as well as for the group of not identified fish, significance differences were also recorded between the I and III decades of observations ($p<0.05$) (Table 2).

When performing a statistical analysis of fish density data in the water area of the riverbed pit in 2021, significance effects were also found for the decadal change in the average values of the studied indicator, both for the entire fish population ($F = 9.56$, $p <0.001$) and for individual taxonomic groups.: Cyprinidae ($F=6.35$, $p=0.006$), Percidae ($F=12.88$, $p<0.001$), Esociidae-Coregonidae ($F=12.21$, $p<0.001$), not identified fish (sturgeons and burbot) ($F=12.57$, $p<0.001$) (Table 2).

Table 2. Statistical analysis of the reliability of differences in the average fish density in the riverbed pit water area with changes in the water level in the Irtysh River (I-III decades, May 2020 and 2021) (Post-hoc Tukey test).

№	Decades	Year of observations			
		2020		2021	
Total fish density					
1.		I	II	I	II
2.	II	0.190	-	*<0.05*	-
3.	III	*<0.001*	*<0.05*	0.179	*<0.001*
Density of Cyprinidae					
4.	II	0.338	-	0.134	-
5.	III	*<0.001*	*<0.05*	0.275	*<0.05*
Density of Percidae					
6.	II	0.096	-	*<0.05*	-
7.	III	*<0.001*	0.070	0.154	*<0.001*
Density of Esociidae-Coregonidae					
8.	II	0.253	-	*<0.05*	-
9.	III	*<0.05*	0.142	0.092	*<0.001*
Density of not dentified fish					
10.	II	0.471	-	*<0,05*	-
11.	III	*<0.05*	0.120	0.087	*<0.001*
*- the level of significance is indicated in italics, with a significance presence of the effect					

As a result of the Tukey test, it was established that, in terms of the total fish density, a reliable difference was established between the I and II ($p<0.05$), II and III ($p<0.001$) decades of observations. When studying the values of the Cyprinidae group, a significance difference was found between the II and III decades of observations ($p<0.05$). For the group of Percidae, Esociidae-Coregonidae, and also for the group of not identified fish, significance differences were recorded between the I and II ($p<0.05$), III and III ($p<0.001$) decades of observations ($p<0.05$) (Table 2).

The high dynamics of fish density in the water area of the riverbed, expressed in reliable changes in average values, reflects the transition of fish from the riverbed to the floodplain [14], as a rule, representatives of spring-spawning fish species in the floodplain – Cyprinidae, Percidae and Esociidae. For many representatives of these fish groups, water temperature is also important during spawning, along with flooding [2]. It was noted [15] that the greatest positive effect of high floods is recorded in the increase in the biomass of fish species reproducting in the floodplain, the juveniles fish of which also develop in floodplain areas [16].

The intensive migration of the fish population from the Irtysh riverbed to its floodplain during the flood period and the presence of a hydrological connection occurs due to the fact that floodplain areas have a larger range of water temperatures [1], ensuring the presence of a temperature optimum to which the fish population strives. [17]. Mass migration to the floodplain ensures not only reproduction, but also feeding of fish, since zoobenthos, zooperiphyton and zooplankton develop intensively in floodplain areas [18;19], their mass development contributes to the high availability of food objects, ensuring higher growth rates of fish [20].

The difference in the dynamics and time intervals of the flood in 2020 and 2021, during which a decrease in fish density in the main riverbed was recorded, is primarily due to the distinctive insights of the onset of the peak water level and the rate of flooding of the floodplain [2]. The higher the water level during the flood, the faster the floodplain areas are flooded. It has been established [21] that at a higher level of flooding of floodplain areas, fish migrating from the main riverbed are able to move over large distances within the floodplain. In addition, when studying fish migrations between the riverbed and its backwater, it has

been shown [2;22] that, along with other environmental factors, both water level and temperature impacts at fish movements.

Thus, a more intense dynamics of the decrease in fish density in the riverbed occurs with a more powerful flood in 2020 and with early onset of maximum water levels of 1147 cm (15.05-16.05.2020), ensuring the formation of a hydrological connection within the floodplain-channel complex. In 2021, significantly lower maximum water levels of 864 cm were recorded later, in the period 21.05. - 23.05.2021. Later dates of floodplain flooding contribute to later warming of water in its areas, respectively, and later migration of fish in the channel-floodplain system [21], as shown [20], that with an increase in water temperature, the metabolism of cyprinids fish intensifies, which in turn increases their ability to swim and migrate accordingly. It is worth noting that in the floodplain-channel complex of the Lower Irtysh, the proportion of cyprinids fish is on average ½ of the total number of fish recorded by the hydroacoustic method.

4 Conclusion

Thus, as a result of the studies of the floodplain-channel complex of the Lower Irtysh, it was shown that during the spring-summer flood period, there is a dynamic decrease in the density of fish in the riverbed of the main river; the decrease in the number of fish in the riverbed is due to their transition to the flooded floodplain for feeding and reproduction. At the same time, the characteristics of the flood dynamics affect the dynamics of the fish population in the riverbed; with a higher water level and an earlier onset of the flood peak, the density of fish in the riverbed decreases more intensively, and on the contrary.

References

1. K. Tockner, F. Malard, J. V. Ward, Hydrological Processes **14**, 16–17 (2000)
2. K. Górski, A.D. Buijse, H.V. et al, J. River Research and Applications **29(10)** (2012)
3. E. Abrial, L.A. Espínola, A.P. Rabuffetti, M.L. Amsler, K.M. Wantzen, Canadian Journal of Fisheries and Aquatic Sciences **76(3)** (2019)
4. T. Stoltefaut, P.J. Haubrock, E.A.R. Welti, N.J. Baker, P. Haase, Ecological Engineering **198** (2024)
5. J. Penha, V.L. Landeiro, J.C.G. Ortega, L. Mateus, Hydrobiologia **797(1)** (2017)
6. K. Tockner, J.A. Stanford, Environmental Conservation **29(3)** (2002)
7. L.R. Virgilio, W.P. Ramalho, M.S. Suçuarana, L.J.S. Vieira, Limnologica **93** (2022)
8. M.C. Lucas, E. Baras, T.J. Thom, A. Duncan, O. Slavík, *Migration of Freshwater Fishes* (Blackwell Science, Oxford, 2001)
9. H.M.V. Espírito-Santo, M.A. Rodríguez, J. Zuanon, Hydrobiologia **792(1)** (2016)
10. E.S.F. Medeiros, M.J. da Silva, T.P.A. Ramos, R.T.C. Ramos, Acta Limnologica Brasiliensia **36** (2024)
11. N.A. Gvozdetsky, *Physical-geographical zoning of the USSR characteristics of regional units* (MSU Publishing house, Moscow, 1968)
12. K.I. Yudanov, I.L. Kalikhman, V.D. Tesler, *Guidelines for hydroacoustic surveys* (VNIRO, Moscow, 1984)
13. E.S. Borisenko, A.I. Degtev, A.D. Mochek, D.S. Pavlov, Journal of Ichthyology **46(2)** (2006)

14. K. Górski, H.V. Winter, J.J. De Leeuw, A.E. Minin, L.A.J. Nagelkerke, *Proceedings of the Scientific and Practical Conference «Protected Natural Areas of the Lower Volga as the Most Important Mechanism for Preserving Biodiversity: Results, Problems and Perspectives»* (2010)
15. K. Górski, J.J. De Leeuw, H.V. Winter, D.A. Vekhov, A.E. Minin, A.D. Buijse, L.A.J. Nagelkerke, Freshwater Biology **56(11)** (2011)
16. K. Górski, J.J. De Leeuw, H.V. Winter, V.V. Khoruzhaya, V.S. Boldyrev, D.A. Vekhov, L.A.J. Nagelkerke, Inland Waters **6(1)** (2016)
17. F. Amat-Trigo, D. Andreou, P.K. Gillingham, J.R. Britton, Fish and Fisheries **24** (2023)
18. K. Górski, K.J. Collier, I.C. Duggan, C.M. Taylor, D.P. Hamilton, Freshwater Biology **58** (2013)
19. N.I. Yermolaeva, Yu.A. Noskov, I.V. Kritskov, Inland Water Biology **1** (2024)
20. Slavík, N. Pfauserová, M. Brabec, J. Kolářová, D. Červený, P. Horký, Ecology of Freshwater Fish **33** (2024)
21. J. Cucherousset, A. Carpentier, J. -M. Paillisson, Fisheries Management and Ecology **14(4)** (2007)
22. E. Hohausová, G.H. Copp, P. Jankovský, Ecology of Freshwater Fish **12(2)** (2003)