Dynamics of distribution of inconnu in the riverbeds depression of the Irtysh River

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Abstract. The studies were performed by the hydroacoustic method in the section of the lower reaches of the Irtysh River (Western Siberia, Tyumen Region). The density dynamics of a group of fish with a symmetrical swimming bladder (Coregonidae and Esocidae) in the water areas of the riverbeds depression was studied. Among coregonids, inconnu dominates. The share of this group of fish is in the range of 10-11% of the total density of the fish population, and the density is an average of 0.3 thousand individuals ha⁻¹. Fish density has an inverse statistically significant correlation with the water level factor and the inverse correlation with the water temperature. Lower Irtysh is a wintering and feeding section for inconnu individuals; here, inconnu are formed aggregations in river areas called riverbeds depression.

1. Introduction
Fish are important in the functioning of Arctic aquatic ecosystems [1], [2], including the Arctic coast of Western Siberia [3]. One of the species of the Arctic faunistic complex, the inconnu (nelma) Stenodus leucichthys nelma (Pallas, 1773) inhabits all rivers in the Arctic Ocean basin in Russia from the White Sea in the west to Anadyr in the east, and individuals of populations from different watercourses differ in size and weight characteristics [4], [5]. On the territory of the North American continent inhabits two large rivers – the Yukon and Mackenzie [6]. Feeding inconnu occurs in fresh areas of estuaries and lower sections of rivers, while it can withstand salinity up to 20 ‰ [7], [8]. On the territory of the Tyumen region, inconnu forms aggregations year-round on river sections of the Lower Irtysh, which are called riverbeds depression. Their list and location on the river are given in the Fishing Rules for the West Siberian Fisheries Basin [9]. These sites are important in the formation and conservation of aquatic biological resources of the Ob-Irtysh basin, including valuable fish species: sturgeons and coregonids. Among coregonids in riverbeds depression, inconnu is the dominant species, while peled Coregonus peled (Gmelin, 1788) and muksun Coregonus muksun (Pallas, 1814) are quite rare, but they still occur. The spatial organization of estuarine and mouth of river fish communities is determined by salinity, which in these ecosystems is the main abiotic factor [8], [10], [11], [12], [13], including for inconnu [14]. In freshwater ecosystems, the fundamental environmental factors that form a complex of fish species by limiting their physiological capabilities and therefore preferences are the water temperature [8], [15], pH [16], the concentration of dissolved oxygen [3], [17], [18], [19], as well as the water level [17], [20], turbidity [21], etc. Thus, abiotic environmental factors influence the distribution of fish.

In this regard, the aim of the research work is to study the influence of some abiotic factors (temperature and water level) on the distribution of inconnu in the water areas of riverbeds depression.
2. Material and methods

The studies were carried out by the hydroacoustic method in the lower reaches of the Irtysh River, in the waters of 2 riverbeds depression (Kondinskaya and Gornoslinkinskaya), which are located in the Khanty-Mansiysk and Uvat districts of the Tyumen region. The studied sections are located in the coordinates 60.707467° n.l., 69.669229° e.l. and 58.732605° n.l., 68.699211° e.l. (Figure 1).

Figure 1. The map-scheme of the study area: 1. Russian Federation 2. Tyumen region 3. Location of riverbeds depression on the Irtysh River 4. Kondinskaya 5. Gornoslinkinskaya

In the water area of the Gornoslinkinskaya riverbed depression, hydroacoustic surveys were performed in between the seasonal period (July-October, 2018), and in the water area of the Kondinskaya surveys were carried out during the month of intense spring flood after the ice break of river (May 2017). Simultaneously with the surveys, control fishing was carried out. To perform hydroacoustic surveys of the studied water areas of the riverbeds depression, used the mobile sonar software and hardware complex “AsCor” (LLC Fishhydroacoustics, Russia). In the water bodies moved in a motor boat along a zigzag grid, according to generally accepted methods [22]. The complex is based on the principle of analog-to-digital conversion of received echo signals from a serial two-beam echo sounder Furuno 4100 (Japan), frequencies 50 n 200 kHz. Computer post processing of sonar surveys in laboratory is processed using the special software application “Taxonomy”. This application allows to separating from the registered fish population the proportion of a group of fish with a symmetrical swimming bladder [23], in the studied sections of the river, these include representatives of the Coregonidae and Esocidae family. Water level was recorded using a measuring rail in the near bank zone; temperature was determined using a water quality rating system “Horiba” (Japan). For daily
monitoring of the water level, the initial water level was taken as the zero mark; for monthly monitoring were used data from the “Uvat” hydrometric station of the monitoring network of the Russian Federation. Statistical data processing was performed using the program Statistica 10.0 (Statsoft, USA). The value of the correlation was estimated on a scale: weak (0.1–0.3), moderate (0.3–0.5), noticeable (0.5–0.7), high (0.7–0.9) very high (0.9–1).

3. Results
According to control fishing, it was found that in the studied sections of the river a group of fish from families Coregonidae и Esocidae represented by 4 species: inconnu Stenodus leucichthys nelma (Pallas, 1773), peled Coregonus peled (Gmelin, 1788), muksun Coregonus muksun (Pallas, 1814) and northern pike Esox lucius (Linnaeus, 1758). Among coregonids are dominate individuals of inconnu of various sizes and ages. As a result of studies in the water areas of riverbeds depression, it was found that the dynamics of the temperature and water level are directly opposite to the density of the fish population and the density of the group of fish from the families of Coregonidae and Esocidae, as with a narrower measurement range for a month (Figure 2), and in determining indicators between 2 seasons: summer and autumn (Figure 3).

![Figure 2](image)

**Figure 2.** The dynamics of the density of the fish population, the group of fish of the families Coregonidae and Esocidae depending on the level (a) and water temperature (b) in the water area of the Kondinskaya riverbed depression, their trends (c, d): 1. Density of fish 2. Density of the group Coregonidae and Esocidae 3. Values of level (a) and temperature (b) of water

During the spring flood at the initial stage of research, the maximum density of the fish population and the studied fish group in the Kondinskaya riverbed depression amounted to 12.42 and 1.60 thousand individuals·ha⁻¹, respectively, the water temperature indicator was in the range of 3.2-3.5 °C.
Figure 3. The dynamics of the density of the fish population, the group of fish of the families Coregonidae and Esocidae depending on the level (a) and water temperature (b) in the water area of the Gornoslinkinskaya riverbed depression, their trends (c, d): 1. Density of fish 2. Density of the group Coregonidae and Esocidae 3. Values of level (a) and temperature (b) of water

During the one-month observation period, there was a tendency toward a decrease in the density of the fish population to 3.013, and the studied group of fish up to 0.346 thousand individuals·ha⁻¹, while the total rise in water level reached 3.318 m, and the temperature water was 11.7 °C. It should be noted that the density of fish of the Coregonidae and Esocidae families during the last 5 days of a month's observation came “to a plateau” and amounted to an average of 0.3 thousand individuals·ha⁻¹. The share of the studied group of fish among the fish population varied from 10 to 16%; at the end of the observation period, the value of this indicator was 11.12%.

An analysis of the dynamics of the density of the fish population, the studied fish group, and the temperature and water level indicators in the water area of the Gornoslinkinskaya riverbed depression in the summer-autumn period (July-October) also showed that are observed the opposite dynamics of fish density and water level and temperature indicators (Figure 3). During this period, the density of the fish population increases from 2.09 to 3.06 thousand individuals·ha⁻¹, in this case, the temperature decreases from 21.1 to 4.7 °C and the water level from 8.94 to 3.83 m.

Due to the fact that a sufficient number of measurements for statistical correlation analysis was performed only with daily observations in the Kondinskaya riverbed depression (May, 2017), the correlations between the density of the fish groups of the families Coregonidae and Esocidae and the temperature and water level were calculated for this period, respectively. The analysis showed that the density of fish from the whitefish and pike group has an inverse statistically significant noticeable correlation (R_p = -0.54, P <0.01) with a factor of the water level and an inverse moderate correlation with the water temperature (R_p = -0.43, P <0.05). Opposite patterns of dynamics of the fish density depending on the level and temperature of water are presented in the graphs with the change in indicators in the form of relevant trends (Figures 2, 3).

4. Discussion
The decrease in fish density during the spring flood in the water area of riverbed depression is explained by their migration to the flooded floodplain for feeding and spawning, as fluctuations in environmental factors over several days, including temperature and water level, especially in the main river, are appropriate stimuli initiating and controlling the intensity of migration, including spawning [24], [25]. In this regard, from the group coregonids and pikes most likely the northern pike passes into the floodplain, and the inconnu remains to feeding in the water area of riverbed depression, since this species, after spring ice break of river, prefers mouth of rivers and estuary for feeding [26-28]. A similar picture is observed annually on the mouth section of the Konda River, a tributary of the Irtysh River: during spring flood after ice break rivers in the water area of these sections, active feeding inconnu. For mouth of rivers and riverbeds depression are characterized the presence of flow turbulence [29], which is formed due to the structural features of the river bed on the meander of the river and the interaction of the streams of the watercourse. Thus, during the study period in the Kondinskaya riverbed depression, the density of this group of fish, mainly coregonids, and in particular inconnu, stabilizes at the level of 0.3 thousand individuals·ha\(^{-1}\). The spawning migration of inconnu is occurs from mid-July to mid-September, [26], [28], [30], after spawning, mature fish again downstream migration to wintering sections in the middle and lower reaches of the rivers [28], [30], [31], [32], where they are feeding for several years. The dynamics of increasing fish density in the water area of the Gornoslinkinskaya riverbed depression with a decrease in the level and temperature of the water in the summer-autumn period is due to a decrease in fish movements [33] [34], [35] and the formation of aggregations of fish in the deep section of the river for wintering [36], [37], including the aggregations of mature fish of inconnu after spawning, as well as juvenile individuals of inconnu for feeding [27], [28]. By the end of the study period (October), the density of the group of fish group coregonids and pikes also reaches 0.3 thousand individuals·ha\(^{-1}\). Among coregonids in the Gornoslinkinskaya riverbed depression, inconnu is also the dominant species.

It is worth noting [4] that in the Ob-Irtysh basin a 13-14 year cycle of inconnu abundance was revealed, while it was shown that the abundance of this species depends on the number of mature fish and on a number of factors related to the water level. With a high and prolonged level of flooded floodplain, formed are favorable conditions for the food supply and feeding of juveniles, and deteriorate conditions for fishing [4], which is considered to be the main factor affecting the abundance of inconnu [4], [38], because most of the individuals are removed from the population before fertility [4], occurs the rejuvenation of the mature fish [39], as a result of which the decreases of fecundity of the females [38].

Matkovsky A.K. [4] emphasizes that the population structure of the studied species is currently poorly studied, because there is insufficient data on morphometric, linear-weight indicators and maturity time of inconnu from different parts of the Ob-Irtysh basin (Severnaya Sosva river, Irtysh river, Ob river).

The comparable values of the density of the studied group of fish in different seasons of the year on geographically remove (> 440 km) connected sections of the river are most likely explained [28] by the mature fish of inconnu are adherents for many years to spawning, feeding and wintering sections of the rivers, as well as the fact that Gornoslinkinskaya and Kondinskaya riverbeds depression are located in the lower reaches of the Irtysh River, which for inconnu are feeding and wintering sections [31, 32].

To protect inconnu populations, in addition to reproduction [4], it is proposed [39], [40] to create fishery conservation zones in spawning and wintering areas of this species with the prohibition of any type of anthropogenic activity. This recommendation is valid for wintering sections [9], any kind of fishing is prohibited here except for fishing for scientific research purposes.

5. Conclusion

Thus, the density of inconnu in the water area of geographically remove riverbeds depression of the Lower Irtysh is determined by the seasonality and orientation of abiotic factors – temperature and water level, the trends of these factors and the density of fish are directed opposite. During the spring flood, the density of fish in the studied water areas decreases, in the summer-autumn period increases. The
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