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Articles

Changes in Middle Ob fish diversity: an analytical review

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The Ob River is the largest river in Eurasia, and its ichthyofauna in the Middle Ob consists of species that inhabit not only the entire river but also the upper and lower reaches. This region faces numerous anthropogenic activities that pose a significant threat to aquatic biodiversity. Therefore, changes in fish species diversity in the Middle Ob can serve as an indicator of the overall ecosystem health. This study aims to analyze these changes and their potential causes. Materials and methods: This study presents an analytical review of the Middle Ob River ichthyofauna over the past 120 years. It assesses changes in fish species diversity and discusses various natural and anthropogenic factors. Results: The ichthyofauna of the Middle Ob basin currently includes 38 fish species from 2 classes, 9 orders, 12 families, and 30 genera. Over the past century, the number of species has increased by 27%, with 9 naturalized alien species and 1 extinct species. Additionally, there has been a significant decrease in the abundance of some commercial fish species. The ichthyofauna of the Middle Ob is influenced by hydraulic construction, pollution, overexploitation of aquatic resources (especially commercially valuable fish species), the expansion of alien species, anthropogenic alteration of the river bed, and climate change. Conclusion: While most factors affect the abundance of individual fish species, they do not significantly impact fish species diversity, with the exception of alien species and pollution.

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Keywords

Alien species, climatic changes, fish, hydraulic construction, natural resource management, Ob, Siberia

Introduction

Freshwater bodies cover only about 0.8% of the Earth's surface (Gleick 1996), yet they support a wide range of habitats and harbor up to 12% of all known species (Wrona et al. 2005; Heino et al. 2009; Wrona and Reist 2013; Reid et al. 2019), contributing to high biodiversity. The key factors influencing changes in aquatic ecosystem biodiversity include water pollution, habitat destruction, alterations in the hydrological regime, overexploitation of aquatic resources, climate change, and the spread of alien species (Revenga et al. 2000; Poff and Schmidt 2016; Winemiller et al. 2016; Dudgeon 2019; Grill et al. 2019; Dudgeon 2020; Albert et al. 2021). The Ob River is the largest river in Eurasia, stretching 3,650 km in length with a catchment area of approximately 3,000 km^2 (http://textual.ru2023). Hydrologically, the Ob is traditionally divided into three main areas: the upper part, from the confluence of the Biya and Katun rivers to the mouth of the Tom River (Upper Ob); the middle part, from the mouth of the Tom river to the mouth of the Irtysh river (Middle Ob); and the lower part, from the mouth of the Irtysh river to the Gulf of Ob (Lower Ob) (Korotaev 2004; Savichev and Guseva 2020). Due to its intermediate position within this basin, the ichthyofauna of the Middle Ob includes species that inhabit the entire river, as well as those predominantly found in the upper or lower reaches. Occasionally, species such as taimen (*Hucho taimen*) and Tumen lenok (*Brachymystax tumensis*) from the upper reaches of the Middle Ob are sporadically recorded in this area.

The migration routes through this area serve as spawning grounds for fish species that primarily inhabit the Lower Ob, such as the Siberian sturgeon (*Acipenser baerii*), muksun (*Coregonus muksun*), and nelma (*Stenodus nelma*). Occasionally, the broad whitefish (*Coregonus nasus*) and the humpback whitefish (*C. pidschian*) also travel up the Ob, beyond the mouth of the Irtysh River. Moreover, the Middle Ob is heavily impacted by various human activities, posing a significant threat to aquatic biodiversity. Large industrial centers are situated in this basin, hydrocarbon resources are extracted, there is significant fishing pressure, and the area is particularly affected by changes in the hydrological regime due to hydraulic construction. Consequently, the ichthyofauna of the Middle Ob can serve as an indicator of ecosystem health. Long-term analysis of individual fish species abundance and catch data can provide insights into existing trends in fish diversity changes. In the latter half of the twentieth century, the production volume of several commercial species in the Middle Ob basin notably declined. This decline affects not only commercially valuable fish species, such as sturgeons and whitefish (Enshina 1998; Babkin et al. 2018; Interesova et al. 2018; Krokhalevsky et al. 2018; Matkovsky 2019b; Interesova et al., 2022c), but also noncommercial species, for example, the roach (*Rutilus rutilus*) (Interesova and Rostovtsev 2021). Therefore, the objective of this study was to analyze changes in the diversity of fish species in the Middle Ob.

Materials and methods

This study presents an analytical review of the ichthyofauna in the Middle Ob River basin, drawing on a comprehensive examination of research papers and reports published over the past 120 years. Our analysis assesses changes in fish species composition and delves into the diverse natural and anthropogenic factors impacting fish diversity in Siberia. Additionally, we conducted an in-depth analysis of official fisheries statistics for valuable commercial fish species in the Tomsk region, which serves as a representative administrative region in the Middle Ob River basin, spanning more than 80 years. The species names and taxonomy utilized in this study adhere to the conventions outlined in Romanov et al. (2017).

Result

The first scientifically verified data on the ichthyofauna of the Ob basin was reported by Pallas in the late 18th century (Pallas 1786). Over time, the list of species was gradually refined, and by the beginning of the 20th century, it included 42 species according to existing taxonomy (Varpakhovsky 1902). Presently, a total of 52 species of lamprey and fish are known from the entire Ob River basin (Popov 2009, see Table 1).

Initial systematization of data on the ichthyofauna species composition in the middle reaches of the Ob River was carried out by N.A. Varpakhovsky (1902). However, he inadvertently omitted several small noncommercial species, such as minnow *Phoxinus ujmonensis*, grayling *Rhynchocypris percnurus*, Tom river loach *Barbatula tomiana*, Siberian spiny loach *Cobitis sibirica*, sculpin *Cottus altaicus* and *C. sibiricus*, wrongly confining their distribution only to the upper or lower reaches of the Ob. This oversight may be attributed to Varpakhovsky's exploration of the main bed of the Ob and its large tributaries, while these fish species primarily inhabit the right bank tributaries of the second and third orders. Furthermore, Varpakhovsky did not include some species (tugun *Coregonus tugun*, lenok, and taimen) in the Middle Ob basin, although their presence in this area at the beginning of the twentieth century is undisputed. Subsequently, M.D. Ruzsky (1920) recorded these species, affirming their existence in this area during that period.

Based on current data on grayling taxonomy in this region (Romanov 2017), the ichthyofauna of the Middle Ob at the beginning of the 20^{th} century comprised 30 species. In the mid-20^{th} century, B.G. Ioganzen [Johansen] (1948; 1953) revised the ichthyofauna of the Ob, including the features of the composition of lamprey and fish species in different areas of the basin. For the Middle Ob, he identified only 23 species. Notably, Ioganzen proposed a zoning scheme for the ichthyofauna and determined the southern boundary of the Middle Ob near the town of Kolpashevo, which is downstream compared to the hydrographic division of the Ob basin (Fig. 1).

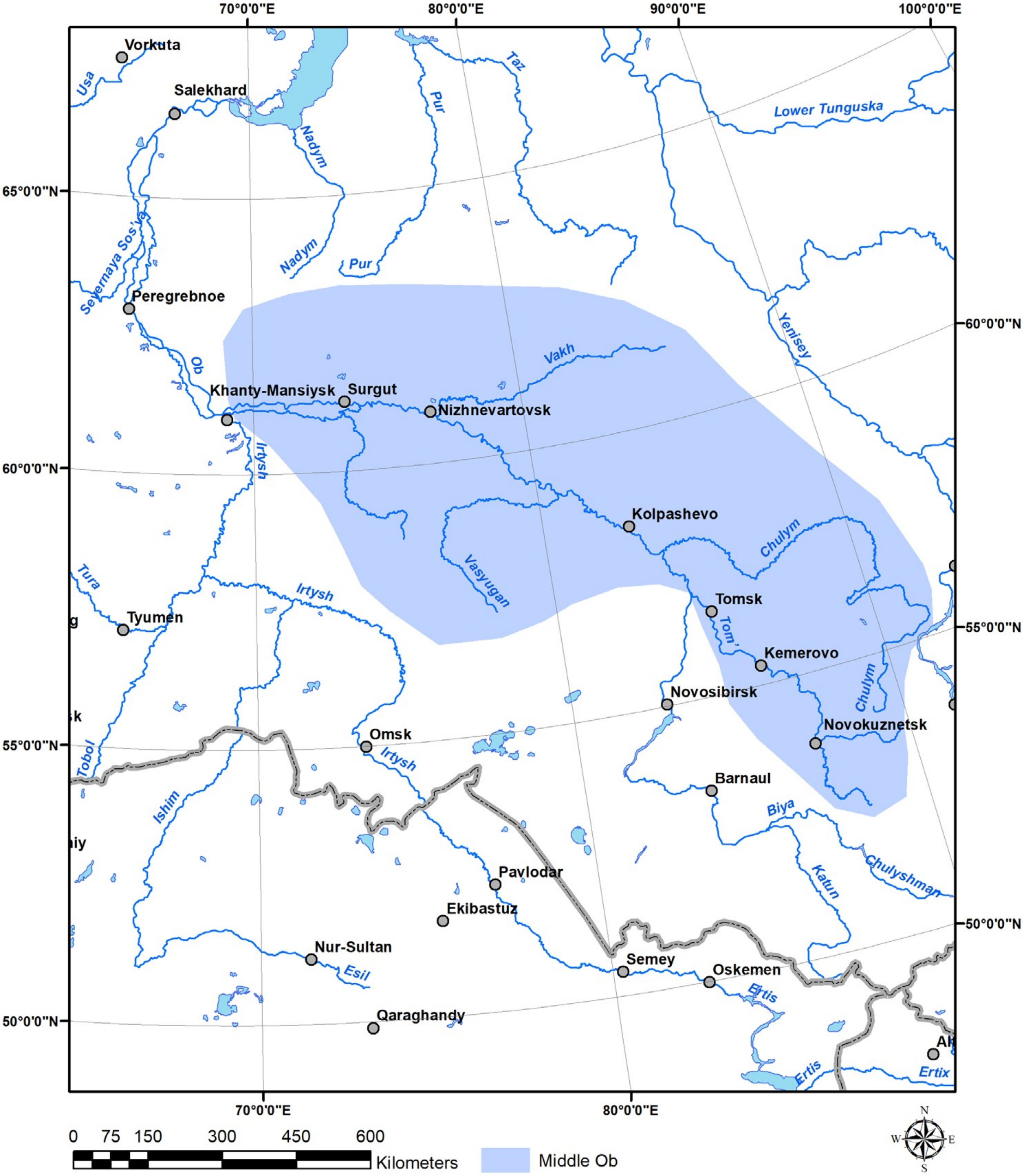

Figure 1. *Middle Ob basin.*

Consequently, the Middle Ob River ichthyofauna does not include species from the basins of the Tom and Chulym Rivers. By the mid-20th century, the ichthyofauna of the Middle Ob was represented by 30 species due to the disappearance of tugun (Bashmakova 1949) and the naturalization of vendace Coregonus albula (Popkov 1979) in the upper Chulym Lakes.

In the late 20th century, A.N. Gundrizer et al (2000) provided data on the species composition of the ichthyofauna in the Middle Ob, considering the area from the mouth of the Tom River to the mouth of the Irtysh River as part of the Middle Ob. According to Gundrizer, this area contained 30 species of lamprey and fish. Notably, alien species such as the nine-spine stickleback *Pungitius pungitius*, belica *Leucaspius delineatus*, bleak *Alburnus alburnus*, and Amur sleeper *Perccottus glenii* were found in the lower reaches of the Tom River, but were not included in the ichthyofauna composition of the Middle Ob in this study.

G.L. Karasev (2006) also provided information on the composition of the Middle Ob, defining its southern border below the mouth of the Chulym River, near the town of Kolpashevo. This delineation was in accordance with the Middle-Ob region allocated by him, similar to the zoning proposed by B.G. Ioganzen (1953). However, the composition of lamprey and fish species in the Middle Ob region described by Karasev did not include species from the Tom and Chulym River basins. Additionally, Karasev did not include alien fish species, including those naturalized in the Ob basin, such as the common bream and common pike perch.

Taking into account the introduced species and the modern taxonomy of grayling, as well as the species inhabiting the Tom and Chulym Rivers, the ichthyofauna of the Middle Ob included 37 species at the end of the 20^{th} century (see Table 1).

No	Species name		Beginning of the 20^{th} century		Middle of the 20^{th} century	End of the 20^{th} century		Beginning of the 21^{th} century
			1	2	3	4	5	6
1	Arctic lamprey	*Lethenteron camtschaticum* (Tilesius, 1811)	-	+	+	+	+	+
2	Siberian lamprey *	*Lethenteron kessleri* (Anikin, 1905)	-	+	-	+	-	+
3	Siberian sturgeon	*Acipenser baerii* (Brandt, 1869)	+	+	+	+	+	+
4	Sterlet	*Acipenser ruthenus* Linnaeus, 1758	+	+	+	+	+	+
5	**Common bream**	*Abramis brama* (Linnaeus, 1758)	-	-	-	+	-	+
6	**Bleak**	*Alburnus alburnus* (Linnaeus, 1758)	-	-	-	-	-	+
7	Crucian carp	*Carassius carassius* (Linnaeus, 1758)	+	+	+	+	+	+
8	Prussian carp	*Carassius gibelio* (Bloch, 1782)	-	+	+	+	+	+
9	**Common carp**	*Cyprinus carpio* (Linnaeus, 1758)	-	-	-	+	-	+
10	Siberian	*Gobio*	+	+	+	+	+	+

	gudgeon	*sibi ricus* Nikolsky, 1936						
11	**Belica**	*Leucaspius delineatus* (Heckel, 1843)	-	-	-	-	-	+
12	Ide	*Leuciscus idus* (Linnaeus, 1758)	+	+	+	+	+	+
13	Baikal dace	*Leuciscus b ai cale nsis* (Dybowski, 1874)	+	+	+	+	+	+
14	Altai minnow	*Phoxinus* Kashchenko, 1899	-	+	-	+	+	+
15	Czekanowski's minnow**	*Rhynchocypris czekanowskii* (Dybowski, 1869)	-	+	-	-	-	+
16	Lake minnow	*Rhynchocypris percnurus* (Pallas, 1814)	-	+	+	+	+	+
17	Roach	*Rutilus rutilus* (Linnaeus, 1758)	+	+	+	+	+	+
18	Tench	*Tinca tinca* (Linnaeus, 1758)	+	+	+	+	+	+
19	Siberian spiny loach	*Cobitis sibirica* Gladkov, 1935	-	+	+	+	+	+
20	**Nikolsky's loach**	*Misgurnus nikolskyi* Vasil'eva, 2001	-	-	-	-	-	+
21	Tom River loach	*Barbatula tomiana* (Ruzsky, 1920)	-	+	-	+	+	+
22	Northern pike	*Esox lucius* Linnaeus, 1758	+	+	+	+	+	+
23	**Vendace**	*Coregonus albula* (Linnaeus, 1758)	-	-	-	-	-	+
24	**Peipus whitefish*** **	*Coregonus maraenoides*	-	-	-	-	-	+

		Polyakov, 1874						
25	**Valaam w hitefish*** **	*Coregonus wi degr eni* Malmgren, 1863	-	-	-	-	-	+
26	Muksun	*Coregonus muk sun* (Pallas, 1814)	+	+	+	+	+	+
27	Broad whitefish	*Coregonus nasus* (Pallas, 1776)	+	-	+	-	-	+
28	Peled	*Coregonus peled* (Gmelin, 1789)	+	+	+	+	+	+
29	Humpback whitefish	*Coregonus pids chian* (Gmelin, 1789)	+	+	+	-	+	+
30	Tugun	*Coregonus tugun* (Pallas, 1814)	-	+	-	-	-	?
31	Nelma	*Stenodus nelma* (Pallas, 1773)	+	+	+	+	+	+
32	Arctic grayling	*Thymallus arct icus* (Pallas, 1776)	-	+	+	+	+	+
33	Upper Ob grayling	*Thymallus nik olskyi* Kashchenko, 1899	-	-	-	-	-	+
34	Tumen lenok	*Brachymysta x tumensis* Mori, 1930	-	+	-	+	-	+
35	Taimen	*Hucho taime n* (Pallas, 1773)	-	+	-	+	-	+
36	Burbot	*Lota lota* (Linnaeus, 1758)	+	+	+	+	+	+
37	**Nine-spine stickleback**	*Pungitius pungitius* (Linnaeus, 1758)	-	-	-	-	-	+
38	Altaic sculpin	*Cottus altai cus* Kashchenko, 1899	-	+	-	+	-	+
39	Siberian sculpin	*Cottus sibiricus*	-	+	+	+	+	+

		Kessler, 1889						
40	Ruffe	*Gymnocephalus cernua* (Linnaeus, 1758)	+	+	+	+	+	+
41	European perch	*Perca fluviatilis* Linnaeus, 1758	+	+	+	+	+	+
42	**Common pike perch**	*Sander lucioperca* (Linnaeus, 1758)	-	-	-	+	-	+
43	**Amur sleeper**	*Perccottus glenii* Dybowski, 1877	-	-	-	-	-	+
Number of species listed			17	30	23	30	24	43
Total number of species in a time period, according to modern taxonomic concepts			30		30	37		38

Table 1. *Changes in fish species composition in the Middle Ob basin*

Alien species are indicated in bold, * at present, no evidence for the species validity is available, ** the presence of the species in the basin is doubtful; it is not considered in the study, *** the taxonomic status is debatable; it is not considered in the study. 1– Varpakhovsky 1902; 2 – Ruzskiy 1920; 3 – Ioganzen 1948, 1953; 4 – Gundrizer et al. 2000; 5 – Karasev 2006; 6 – Romanov et al. 2017.

In the 21st century, V.I. Romanov et al. (2017) conducted a revision of the composition of the Middle Ob, which included 43 species of lamprey and fish, with tugun being presumed extinct in this part of the Ob basin. Furthermore, the lack of evidence for Siberian lamprey *Lethenteron kessleri* as a valid species (Interesova et al. 2022a), the modern taxonomy of grayling (Romanov 2017), and the debatable taxonomy of whitefish species (Reshetnikova 2002) suggest that the ichthyofauna of the Middle Ob included 38 lamprey and fish species at the beginning of the twentieth century (see Table 1).

As such, the twentieth century saw significant changes in the composition of the Middle Ob's ichthyofauna, with species diversity increasing by 27% (Fig. 2).

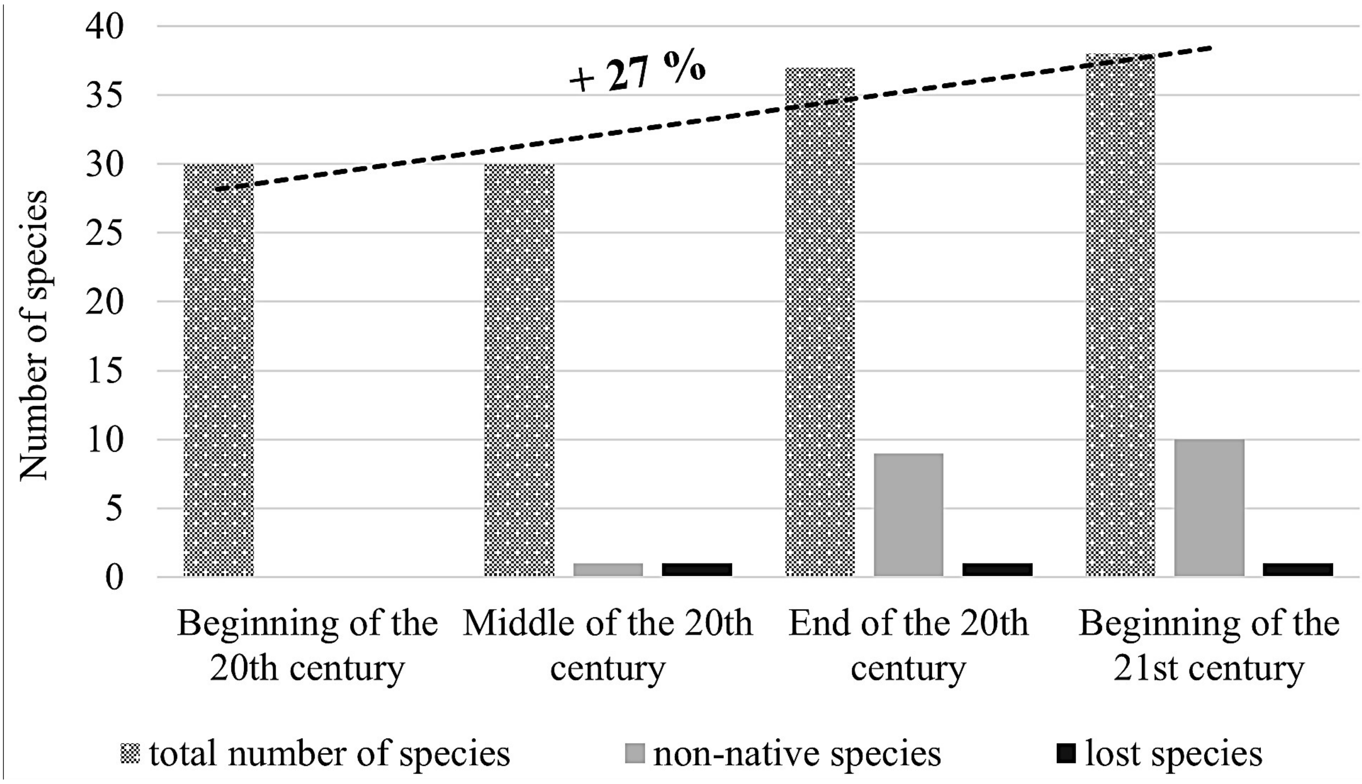

Figure 2. *Fish species composition dynamics in the Middle Ob.*

Discussion

The ichthyofauna in the Middle Ob basin is significantly affected by several factors caused significant changes in the biodiversity of aquatic ecosystems.

Aftereffects of hydraulic construction. In 1956, the construction of the Novosibirsk hydroelectric power station resulted in the blocking of the Ob River. In the Middle Ob basin, hydraulic construction mainly affects river runoff control and its decrease during spring, as water is stored in the reservoir at this time (Savkin 2000; Zemtsov et al. 2019). However, spring spawning fish reproduce during spring floods, with most of these species being phytophilic, meaning they spawn in the flooded vegetation of last year's floodplain. The water level rise and duration of floodplain flooding in spring play a crucial role in the reproduction, feeding, and ield of annual juvenile fish (Ioganzen 1953; Trifonova 1982; Rostovtsev and Interesova 2015). Only periods with increased water levels during the spring flood are favorable for the formation of stocks of spring-spawning phytophilic fish species. During years with average water levels, the areas of spawning and feeding grounds decrease by 50%.

The control of the Ob River led to significant interannual fluctuations in the duration of floodplain flooding. During low-water years, the floodplain is flooded for a period that is insufficient for the embryonic stage, resulting in the death of eggs when the spawning grounds dry up. In some years, the spring flood level is so low that the water does not reach the floodplain, greatly reducing the abundance of spring-spawning phytophilous fish species. As a result, hydraulic construction had an extremely negative effect on the abundance of the main commercial fish species in the Middle Ob, including ide, roach, perch, and pike.

To address the consequences of the decrease in water level and maintain the potential fishing resource in the Middle Ob basin, it is essential to implement measures for fishery amelioration of the floodplain. Amelioration aims to provide the required water level for early fish ontogenesis in spawning grounds and ensure the free migration of juveniles from these areas (Vovk 1951; Ioganzen et al. 1958; Rostovtsev et al. 2015; 2020). Additionally, the construction of the Novosibirsk hydroelectric dam disrupted migration routes and isolated a significant part of the spawning areas for semi-anadromous fish species, such as Siberian sturgeon and nelma.

Estimates suggest that the isolated spawning grounds for Siberian sturgeon were at least 40%, and for nelma, it was at least 70% (Perkevich 1952; Popov 2010). All these processes had a negative impact on the abundance of whitefish and sturgeon species (Koneva 1972; Enshina, 1999; Krokhalevsky et al. 2018; Popov 2022).

Pollution. The natural waters of the Middle Ob basin in the Tomsk region and Khanty-Mansiysk Autonomous Okrug are polluted with organic substances of anthropogenic origin, including alkanes with an even number of carbon atoms, polycyclic aromatic hydrocarbons (PAH), organochlorine compounds, and easily oxidizable organic substances. In addition, an increased content of inorganic nitrogen compounds (NH4+ and NO2–) and heavy metals has been detected in the water (Savichev 2010, Savichev, Guseva, 2020). Consequently, surface water in the Tomsk region and Khanty-Mansi Autonomous Okrug mainly falls under quality classes III and IV (Popkov and Vorobyov 2005; State report... 2021, 2022; Report on environmental ... 2021).

The source of pollution is large settlements located near the Ob and its tributaries, including Novosibirsk, Kemerovo, Novokuznetsk, Tomsk, Nizhnevartovsk, and Surgut (Nikanorov et al. 2011; Popov and Trifonova 2002; Stoyashcheva 2018). Coal mining, metallurgical and chemical companies, and petroleum enterprises significantly contribute to water pollution in the Kemerovo region (Svarovskaya et al. 2018). In the Khanty-Mansi Autonomous Okrug, oil pollution is a relevant problem, with over 2.5 thousand accidents occurring annually in this region, affecting the environment, including water bodies (Moiseenko et al. 2010; Soromotin 2011; Moskovchenko and Babushkin 2014). At the end of the twentieth century, the water bodies on the right bank of the Ob in the Nizhnevartovsky district, which drain the territory of the Samotlorskoye, Uryevskoye, Potochnoye, and Las-Eganskoye deposits, were subject to salt pollution (Moskovchenko et al. 2017). In recent years, there has been a reduction in salt and oil water pollution in the Ob and its tributaries (Moskovchenko and Babushkin 2014; Moskovchenko et al. 2017).

It is assumed that pollution caused the disappearance of tugun in the Middle Ob basin and reduced the natural reproduction of muksun and nelma in the spawning grounds of the Lower Tom (Vovk 1948; Ioganzen 1953; Gundrizer et al. 1984; Popov and Trifonova 2002).

Overexploitation of aquatic biological resources. Fishing has always been a vital source of nutrition for the human population of the Middle Ob basin. Historically, commercially valuable fish species such as Siberian sturgeon, sterlet, muksun, and nelma have been subjected to increased fishing pressure. However, at present, the catch of these fish species is negligible, particularly in the Tomsk region (Fig. 3). This is primarily due to excessive illegal, unreported, and unregulated (IUU) fishing (Koneva 1972; Chupretov and Zamyatin 1990; Enshina 1998; Gundrizer et al. 2000; Matkovsky 2010; Rostovtsev and Interesova 2015; Matkovsky et al. 2017; Krokhalevsky et al. 2018).

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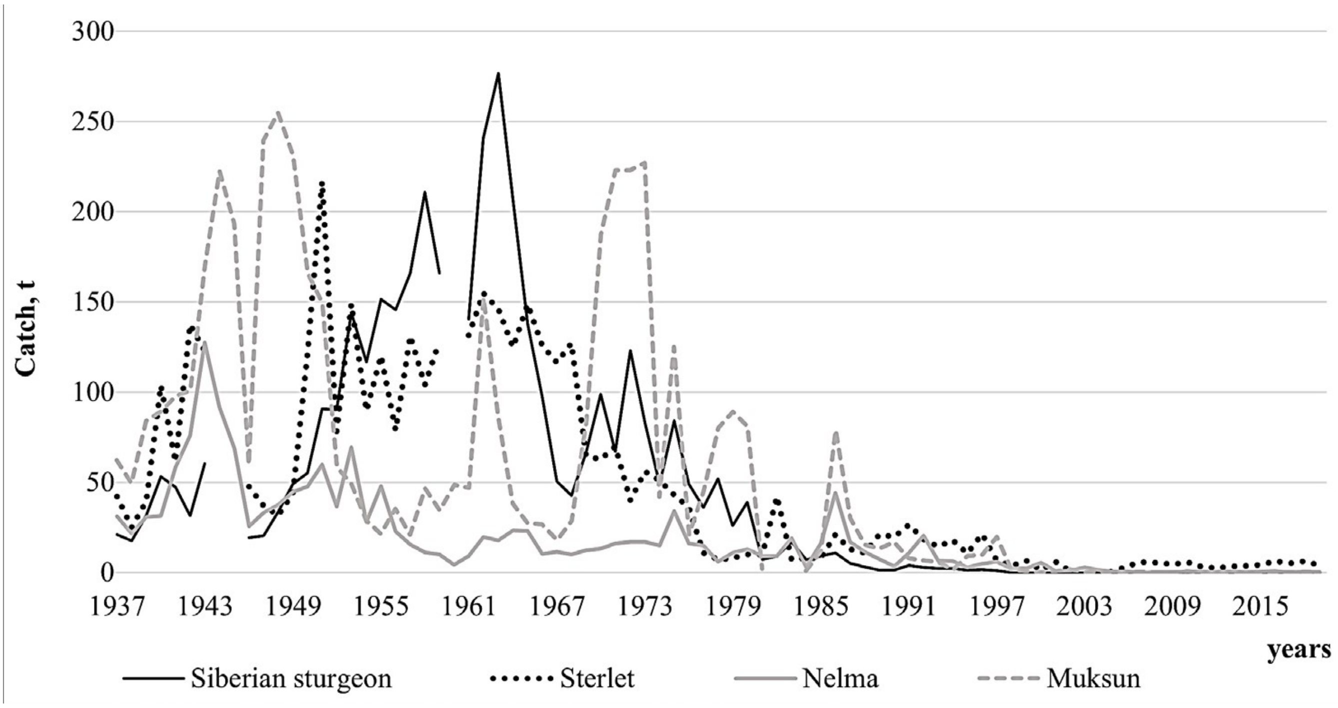

Figure 3. *Catch dynamics of valuable fish species in Tomsk region.*

Expansion of alien species. In the early 1930s, alien fish species were introduced into the Middle Ob basin. Fertilized eggs of Valaam whitefish from Lake Ladoga were brought into Lake Bolshoye in the upper reaches of the Chulym River in 1931 and 1932, totaling 9.25 million eggs (Ioganzen and Bashmakov 1952; Bashmakov 1953). Later in the late 1930s, eggs for introduction into Lake Ingol were mixed with Ladoga vendace and Peipus whitefish (Bashmakov 1953; Podlesny 1964, 1969). This resulted in the formation of self-sustaining populations of vendace in Ingol and Bolshoye Lakes, which still exist today (Zlotnik and Romanov 2011). Additionally, common bream was introduced to Lake Bolshoye in 1957 (Lobovikova 1968). However, it was only in 1980 that this species was found in the lower and middle reaches of the Chulym River, likely due to self-dispersal from the Novosibirsk reservoir, where these species were introduced as part of large-scale fish acclimatization in the twentieth century (Interesova 2016). The population of common pike perch in the Middle Ob basin is not abundant (Rostovtsev et al. 2016), while the number of common bream in the region is rapidly increasing (Zlotnik and Romanov 2015; Interesova et al. 2017), potentially impacting native benthic fish species due to possible food competition with the invader (Popkov et al. 2008). Common carp appeared in the Middle Ob basin as a result of self-dispersal from the Novosibirsk reservoir at the end of the 20th century. Belica, bleak, Amur sleeper, and nine-spine stickleback likely entered the Middle Ob through the upper part of the basin. Nikolsky’s loach was found in this area at the beginning of the twentieth century, having previously been known from the Upper Ob basin (Interesova et al. 2010).

Currently, the share of alien species in the Middle Ob basin's composition is 24%, which is critical, as some of the introduced species pose a high invasive risk (Interesova et al. 2020).

Climate change. The impact of climate change on the fish population in western Siberia is not thoroughly studied in current literature. However, it is believed that rising temperatures may lead to an increase in the growth rate of cyprinids and a decrease in the yield of whitefish species due to a shortened feeding period in the northern floodplain of the region (Matkovsky 2019a, 2019b). While such observations are available for the Middle Ob basin, the projected climate warming in Siberia (Groisman et al. 2012) is expected to significantly alter the fish habitat conditions across the entire region (Kirpotin et al. 2021; Savichev et al. 2022).

These changes could impact the spawning period of fish, potentially leading to earlier emergence of juveniles for spring-spawning species, thereby extending the growing season. However, the consequences for autumn-spawning species due to reduced feeding and incubation periods remain unclear. It is anticipated that climate warming will result in the northward expansion of heat-loving alien fish species, constrained by the spawning temperature threshold (Interesova 2022). This expansion seems to be already occurring, as the habitats of belica, bleak, Amur sleeper (Reshetnikov et al. 2017), and the Nikolsky loach (Interesova et al. 2022b) have recently expanded in the Middle Ob basin.

Furthermore, commercial breeding of the silver carp, Hypophthalmichthys molitrix, has led to its naturalization and subsequent distribution in the Ob River bed from fish farms. As a planktivorous species, it has the potential to significantly disrupt the primary link in the trophic chain. The adverse effects of its naturalization are well-documented in North America (Chick and Pegg 2001; Parker et al. 2016; Kočovskė et al. 2018).

Riverbed anthropogenic transformation. The implementation of various economic projects involving soil movement in watercourses, such as sand and gravel extraction, and the construction of dams and bridges, leads to a transformation of the riverbed. This transformation occurs due to the disturbance of bottom topography at the impact site and changes in the hydrological regime of the watercourse. Consequently, there is a reformation of the accumulation-erosion riverbed processes downstream.

This factor is often overlooked in Siberia (Matkovsky 2019b); however, it can be particularly relevant for the Middle Ob. The disturbance caused by these economic activities can lead to the disappearance of local wintering pits and spawning grounds of sand and pebbles, crucial for sturgeon and whitefish, which will inevitably reduce the abundance of these fish species.

Conclusion

Over the past century, the fish species diversity in the Middle Ob basin has undergone significant changes. One species has gone extinct and nine alien species have become naturalized, resulting in a 27% increase in the total number of species. Presently, the ichthyofauna of the Middle Ob basin comprises 38 species of lamprey and fishes from 2 classes, 9 orders, 12 families, and 30 genera. The ichthyofauna of the Middle Ob is impacted by hydraulic construction, anthropogenic alteration of the river bed, pollution, overexploitation of aquatic biological resources (particularly commercially valuable fish species), the spread of alien species, and climate warming. However, with the exception of expansion and pollution, most of these factors currently affect the abundance of specific fish species rather than the overall composition of the ichthyofauna.

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