Compensation for Damage to Aquatic Biological Resources and their Habitat in Magadan Region. Promising Objects of Aquaculture

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Abstract

In Magadan Region, damage to aquatic biological resources in waterbodies of the Kolyma basin is caused by activities of mining enterprises and creation of reservoirs (Kolyma and Ust-Srednekanskoye). For Kolyma, we analyzed the composition of net catches and its trends, as well as estimates of extents of damage caused to aquatic biological resources by mining enterprises during the period 2001-2019. Reservoirs negatively affect salmon-like fish and burbot, and activities of mining enterprises affect grayling, round whitefish, lenok, and common sucker fish. Promising objects of these measures in waterbodies of the Pacific Ocean basin are sockeye salmon (nerka), coho salmon, chum (keta) salmon, and rainbow smelt. For the Kolyma River and its tributaries, the promising species are sturgeon, nelma, broad whitefish, humpback whitefish, muksun, peled, omul, common sucker fish, grayling, and crucian.

Keywords: Kolyma; aquatic biological resources; reservoirs; artificial reproduction; compensation measures.

Introduction

In many regions of Russia, human economic activities affect and alter the habitat of aquatic biological resources (hereinafter referred to as ABR). Waterbodies are particularly sensitive to this sort of changes. Damage caused to ABR of the Magadan region in waterbodies of the basin of the Pacific Ocean is currently insignificant. It mainly occurs to waterbodies of the basin of the Kolyma River; there is no commercial fishing there, amateur ABR fishery rate is insignificant, and negative impact on waterbodies and ABR condition is mainly of anthropogenic origin. The impact is primarily caused by activities of mining enterprises and two water reservoirs which regulate the flow of the Kolyma River, Kolyma and Ust-Srednekanskoye. River flow regulation negatively affects fish habitat factors and fish reproduction by reducing the volume of river flow. This causes reduction, degradation, or extinction of spawning sites and worsens conditions for the development of eggs and young fish, as well as feeding conditions. It is known that construction of hydroelectric power stations and water reservoirs significantly alter factors of fish habitat and conditions of fish reproduction, while often reducing or completely destroying places of spawning and feeding (Koposov, 2015, Chekaldin, 2017).

Intense activity of mining enterprises also causes great damage to the entire aquatic ecosystem, exerting negative impact not only on the ichthyofauna of waterbodies, but also on the entire river biota.

Damage to the ABR and their habitat in the basin of the Pacific Ocean, caused by economic entities of the Magadan Region, is compensated by releasing young *Oncorhynchus* individuals from fish farms and by amelioration of waterbodies (creation of artificial spawning grounds for herring). In the case of waterbodies of the Arctic Ocean basin, juvenile whitefish and grayling are released.

Methods

This study is based on data obtained from net catches in the upper reaches of the Kolyma River and the Kolyma reservoir. The catches were collected by employees of the “Okhotskrybvod” branch and the first author of this communication. Results of calculation of the damage caused by mining enterprises to ABR and their habitat in the water ecosystem of the Kolyma River during the period 2001 – 2019 were also used in the study. Methods generally accepted in ichthyology were used in data collection and processing.

Results and Discussion

It is known (Kirillov, 1972) that representatives of 12 families and 24 species of fish and fish-like species live in the Magadan Region in the Kolyma River basin:

Within the Magadan Region, 12 species are important for amateur fishing: char, pike, humpback whitefish, burbot, common dace, common sucker fish, perch, grayling, broad whitefish, lenok, round whitefish, and crucian. Nelma and Siberian sturgeon are listed in the Red Book of the Magadan Region.

Let us briefly describe the most important species.

Siberian (Yakut) sturgeon, *Acipenser baeri hatys* (Drjagin, 1948)

In the Kolyma, sturgeon is common in the lower and middle reaches, from the delta to Verkhny Seymchan settlement, but there is information about a capture of sturgeon in 2005 at the mouth of the Bahapcha River. As far as tributaries are concerned, sturgeon was found only in the Buyunda, Omolon, and Korkodon Rivers. According to the mode of feeding, Kolyma sturgeon is a benthofage. However, small fishes, whitefish caviar and small rodents are often found in stomachs of adult individuals. Sturgeon winters in deep holes. Sexual maturity in the conditions of the Kolyma River is reached at the age of 11 years, mass maturation occurs at 12-14 with a body length of 87-92 cm and a weight of 2.6-3.6 kg. Fertility varies from 65.6 to 245 thousand eggs. Spawning is not annual, once every 3-5 years. Spawns in July and early August on stony-shingle and hard sandy soils. Rare. It is a promising and priority object of compensation measures and aquaculture (Kondratiev et al., 2019).

Nelma, *Stenodus leucichthys nelma* (Pallas, 1773)

Nelma inhabits all the main rivers of the Arctic Ocean basin. It is the largest and the most valuable representative of the whitefish family. In the Kolyma, nelma is mainly localized in its lower reaches, found in small numbers in the middle reaches, and sporadically in the upper reaches (Koposov, Smirnov, 2017). According to our observations, males of Kolyma nelma first enter the mating period at the age of 7-8 years, females – at 8-11 years. Mass maturation of males occurs at the age of 9-11 years, with a length of 68.5-85 cm and a weight of 3.1-6.1 kg; in females at 12-13 years, with a length of 85-101 cm and a weight of 6.3-11.2 kg. Before the closure of the Kolyma River by dams of Kolyma hydroelectric power stations, nelma rose to Ayan-Yuryakh. A priority and promising object of compensation measures and aquaculture.

Peled (northern whitefish), *Coregonus peled*

Peled is a lacustrine and fluvial fish. Common in lower and middle reaches of the Kolyma River. In waterbodies of the Kolyma basin, reaches 60 cm in size and 2.9 kg in weight. Mass maturation occurs at the age of 4-5 years. A promising object for compensation measures and aquaculture.

Arctic cisco (omul), *Coregonus autumnalis* (Pallas, 1776)

Typical semidiadromous fish. In the Kolyma, it is found mainly in the lower reaches. In the river section belonging to the Magadan region, it is now found in small numbers. The most euryhaline among the whitefish species. In waterbodies of the Kolyma basin, reaches 50 cm in size and 1.9 kg in weight. Mass maturation occurs at the age of 5-6 years. A promising object for compensation measures and aquaculture (Kondratiev et al., 2019).

Broad whitefish (chir), *Coregonus nasus* (Pallas, 1776)

Present in the lower and middle reaches of the Kolyma. Inhabits not only the main channel and floodplain lakes, but sometimes occurs in the brackish waters of the delta and avandelta. In waterbodies of the Kolyma basin, reaches 69 cm in size and 4.5 kg in weight. A promising object for compensation measures and aquaculture (Koposov, 2014).

Humpback whitefish (pidschian), *Coregonus lavaretus pidschian* (Pallas, 1776)

In the Kolyma, humpback whitefish is found in the lower and middle reaches. In the waterbodies of the Kolyma basin reaches 52 cm in size and 1.1 kg in weight. A promising object for compensation measures and aquaculture (Koposov, 2016).

East Siberian grayling *Thymallus arcticus pallasi* (Valenciennes, 1848)

Ubiquitous in the Kolyma basin. Found both in the main channel and in tributaries, where it spawns and feeds. In the Kolyma itself, tends to mouths of rivers and streams. In waterbodies of the Kolyma basin reaches 56 cm in size and 1.6 kg in weight. A promising object of compensation measures and aquaculture. A method of artificial incubation of eggs for further release of larvae into waterbodies has recently been developed (Koposov, 2013).

Yakut crucian, *Carassius carassius jacuticus* (Kirillov, 1972)

Lives in floodplain and oxbow lakes overgrown with aquatic vegetation. Undemanding to oxygen regime and unpretentious to the species composition of the forage base of waterbodies. Reaches up to 50 cm in size and 1.5 kg in weight. A promising object of compensation measures and aquaculture (Koposov, 2017).

Siberian sucker fish, *Catostomus catostomus rostratus* (Tilesius, 1814)

Found everywhere in the Kolyma basin (Novikov et al., 1972). Due to the regulation of the flow of the Kolyma and periodic discharges of water from hydroelectric power plants, the Siberian sucker fish population in the middle reaches of the river is currently in a depressed state. Becomes sexually mature at the age of 5-6 years and reaching up to 56 cm in size and 1.3 kg in weight. Siberian sucker fish is one of the ABR species which are promising objects of compensation measures and aquaculture. In addition, it can be a biological indicator of the state of the ABR habitat, since it is sensitive to water pollution due to its way of life.

The Okhotsk branch of the Federal state budgetary institution “Glavrybvod” (“Okhotskrybvod” branch) has been developing methods and conducted practical studies on artificial reproduction of the most important commercial fishery species in the Magadan Region since the 1970s. As for now, authors and specialists of the Okhotsk branch of “Glavrybvod” have developed methods of artificial rearing of peled, omul, chir and pidschian in pools up to a weight of 0.5 g, with subsequent release into natural reservoirs.

Anthropogenic factors associated with human economic activities reduce the reserves of ABR in waterbodies. This leads to certain changes in the composition of ichthyocenosis and primarily causes a decrease in the proportion of valuable fish species and an increase in the proportion of mainstream fish species. The greatest damage to the ABR and their habitat in the Magadan Region is caused by the activities of the Kolyma HPP cascade. As a result of these activities, the most affected by the changes of environmental conditions are salmon-like fish species (nelma, broad whitefish and other whitefishes), Siberian sucker fish and burbot that live in the main channel of the Kolyma. The estimated non-avoidable damage from the construction of the Ust-Srednekanskaya HPP alone is 42 t of ABR per year. At the stage of design of the HPP, compensation measures are proposed. Activities of mining enterprises for the extraction of minerals in small watercourses of the Kolyma river basin also cause great damage to water biocenoses. The main area of gold mining is the Upper Kolyma basin from its source to the mouth of the Buyunda River and basins of the Ayan-Yuryakh, Berelyokh, Tenke, Detrin, Bohapcha, Debin, Orotukan, Taskan and Srednekan Rivers. About 150 subsurface users of various forms of ownership are currently engaged in mining in the Magadan Region, and the estimated non-avoidable damage is 2-3 t of ABR per year. Activities of mining enterprises mainly negatively affect fish species such as grayling, round whitefish, lenok and Siberian sucker fish, which spend a significant part of their lives in small streams. The number of fish in all reservoirs affected by mining operations is decreasing due to changes in environmental conditions of spawning and reduction in food supply.

In Table 1, estimated extents of damage caused by gold mining (both by open-pit mining and by mining complexes), are given. The estimates take into account losses of forage organisms (river drift) as a result of water intake from natural water bodies, and losses of forage organisms (benthos) due to riverbed-forming works, which disturb bottoms of watercourses, and reduction of surface runoff.

Table 1. List of main watercourses and estimated extent of damage to ABR in the Magadan Region for 2018–2022

Years	Watercourses	Extent of damage, kg
2018-2022	Bratishka	22,38
2018-2022	Natalkin, Uvalchik, Razdolnyi, Omchak, 8 unnamed streams	127,64
2018-2022	Intrigan	2326,04
2018	Tumannyi	11,01
2018	Sosed, Berelekh, Tihyi, Kvartsevyi, Bolshoi Erdzotshakh	32,09
2018	Gherba, Miakit	13,19
	Pavlik, Vanin, Unnamed	371,17
2018	Zavetnyi, Goluboi, Korotkyi, Vopros, Tsennyi, Yevrashkalakh, Suslikovyi	10,42
2018	Berelekh, Belichan, Glukhoi, Kemindzha, Kontrandya, Maldyak, Proletarka, Sputnik	40,23
2018	Berelekh, Susuman, Uyunku	11,23
2018	Tengkelyakh, Burgali, Povorotny, Burgagy, Glukhoi, Topkyi, Solnechnyi, Levaya Taboga, Taboga, Peshekhon, Otkrytyi	24,86
2018	Nelgu, Pravaya Vizualnaya	43,9
2018	Glukharinyi, Malyi Tyi-Yuryuye, Temnyi, Khaya, Nadezhda, Los', Chebukulakh, Savelyevskiy	56,31
2018	Berelekh, Detrin	66,38
2018	Debin, Posledniy, Tsennyi, Lednikovyi, Sukzhar, Prozhachnyi, Vysokiy	58,76
2018	Bolshoi At Yuryakh, Anchar, Odinokiy, Obmanchivyi, Veselyi, Dorozhnyi, Zimniy, Vasilisa, Maristyi, Chikai, Ved'min, Ravninyi, Vetvisty	28,9
2018	Berelekh, Belichan, Maldyak, Burevestnik, Shar, Lukich, Khatakchan, Sarga-Yuryakh, Veselyi, Zabytyi, Raskidistyi, Bolshoi Talyi	97,88
2018	Khudzhakh, Sagyl, Dryakhlyi, Zabytyi	23,72
2018	Pravaya Dzhelgala	14,34

2018	Berelekh, Khevkandya, Tengkelyakh, Upryami, Sokhatyi, Golovnoi, Zabolochennyi, Kygyl, Lenkovyi, Povorotnyi, Stakhanovets	17,52
2018	At-Yuryakh, Malyi At-Yuryakh, Geroi, Moryak, Tumannyi, Minayevskiy, Pryamoi, Partizanskiy, Khatynnakh-Kolymskiy, Goltsovyi	61,72
2018	Kolyma, Orotukan, Osenniy (left tributary of the Kolyma), Pyatiletka, Topograficheskii, Osenniy (right tributary of the Kolyma)	22,61
2018-2020	Bolshoy Chalbykan	14,06
2018	Srednekan, Zolotistaya	30,48
2019	Tatyngychan, Ola, Tumannyi, Skif, Malysh	11,27
2018	Khatynnakh, Mokhovoi, Shakh, At-Yuryakh	34,15
2018	Susuman, Svetlaya, Vetrovyi, Lunnyi, Klyuchik, Gribnoi, Mayskiy, Vodnyi, Metkiy	32,71
2018	Arinkin, Gribnoi, Zolotoi	19,83
2018-2020	Veselyi, Unnamed, Unnamed	12,83
2019-2020	Nizhniy Neksikan	57,27
2019	Ola, Donyshko, Kudryavyi, Unnamed	10,12
2019-2021	Krivoi	14,44
2018	Tokichan, Arga-Yuryakh	15,08
2019	Ola	10,97
	Omchak, Geologicheskii, Tabornyi, Orotukan, Unnamed	97,87
2019	Chelbanya, Berelekh, Salgybystakh, Poludennyi	12,22
	Donyshko	14,08
	Donyshko	12,07
	Neorchan	33,99
2019	Tengkelyakh, Burgali, Povorotnyi, Burgagy, Glukhoi	35,97
2019	Pravaya Vizualnaya, Yunyi, Zolotistyi, Vilka	11,15
2019	Berelekh, Detrin	66,83
2019	Gherba, Myakit	10,68
2019	Dzhelgala, Yura, Trapper	10,4
2019	Komanda	10,86
2019	Bolshoi Talyi	11,98

2019	Berelekh	13,25
2019	Debin, Tsennyi, Lednikovyi, Vysokiy, Prozhachnyi	11,3
2019	Bolshoi At-Yuryakh, Odinkoy, Veselyi, Nervnyi, Obmanchivyi, Vetvisty, Anchar, Chikai, Ved'min, Ravninnyi, Maristyi, Zimniy, Dorozhnyi	12,94
2019	Lukich	17,56
2019	Berelekh, Khevkandya, Tengelyakh, Upryami, Kygyl, Povorotnyi, Yolka	18,72
2019	Susuman, Svetlaya, Vetrovyi, Lunnyi, Olenek	45,73
2019-2021	Kongo	12,97
2019-2021	Avekova	57,924
2019	Debin, Kolyma (Mayorch), Duskania, Pravaya Burkhala, Tavrovyy, Sannyi, Berezovyy, Pozdny, Melkiy, Sedoi	10,089
2019	Osenniy	10,65
2019	Glukharinyi, Nadezhda, Savelyevskiy, Chebukulakh, Malyi Tyi-Yuryuye	52,54
2019	Khudzhakh, Dryakhlyy, Sonnyi, Zabytyi	11,21

The number of young peled fish required to restore the disturbed state of aquatic bioresources through artificial reproduction was calculated according to the methodology for calculating the extent of damage caused to aquatic biological resources (Russian Federal Agency for Fishery, 2011, November 25).

In 2019, compensation for damage to the ABR and their habitat was made by releasing only young peled, 0.5 g in weight, into waterbodies of the Kolyma river basin in August and September. The total output was about 1.5 million pieces of juveniles, which was 98 % of the total calculated and planned release of juveniles for 2019.

Artificial cultivation of young fish (sturgeon, nelma, broad whitefish, peled, humpback whitefish, Siberian sucker fish) is planned in Magadan Region for 2020-2023, both to compensate for the damage to ABR caused by economic activities and for the purposes of commercial aquaculture.

We have found that the most promising objects of artificial (aquacultural) reproduction for compensation purposes are sockeye salmon (nerka), coho salmon, chum (keta) salmon, and rainbow smelt. This is true for waterbodies of the Pacific Ocean basin in Magadan Region.

For waterbodies of the Arctic ocean basin, in particular, the Kolyma River and its tributaries, Siberian (Kolyma) sturgeon, nelma, broad whitefish, humpback whitefish, muksun, peled, omul, Siberian sucker fish, grayling, and Yakut crucian are promising species.

Conclusion

In order to prevent and reduce negative impact of economic activities on waterbodies, various sets of measures, aimed at minimizing unavoidable damage to waterbodies and their habitat, are currently being developed. Above all, it is the introduction of modern working technologies. Artificial reproduction of ABR and amelioration of water bodies for fish culture can be recommended as compensation for damage.

We have found that the most promising objects of artificial (aquacultural) reproduction for compensation purposes are sockeye salmon (nerka), coho salmon, chum (keta) salmon, and rainbow smelt. This is true for waterbodies of the Pacific Ocean basin in Magadan Region.

For reservoirs of the Arctic Ocean basin, in particular, the Kolyma river and its tributaries, Siberian (Kolyma) sturgeon, nelma, broad whitefish, humpback whitefish, muksun, peled, omul, Siberian sucker fish, grayling, and Yakut crucian are promising species.

The majority of compensation measures in Magadan Region is carried out in the watercourses of the Kolyma River basin. In connection with the construction of the Kolyma HPPs and regulation of the Kolyma flow, works are needed to form the ichthyofauna of reservoirs by releasing the most valuable whitefish species as part of compensation measures.

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