The role played by the Umba fish hatchery in artificial reproduction and conservation of water biological resources in the Murmansk region

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Abstract. The article provides information on the need for artificial reproduction of water biological resources. It is shown that the conservation of biological diversity of fish, maintaining stocks of valuable fish species, preserving the natural habitat is impossible without effective measures in the field of artificial reproduction. A brief description of the activities of the Murmansk branch «Glavrybvod» is given. The greatest attention is paid to the oldest enterprise in the Murmansk region – the Umba fish hatchery. The historical information about the activity of this enterprise is given. An assessment of the current state of the Atlantic salmon stocks in the Umba River basin is given. The main problems of the fish-breeding enterprise are identified and analyzed: a high level of illegal fishing, the consequences of molten timber rafting and the influence of the activities of enterprises of the mining complex. Measures aimed at solving these problems are proposed. It has been proved that thanks to the fish breeders of the Umba fish hatchery, the stocks of the Atlantic salmon population of the Umba River are replenished. It is shown that a promising direction of the plant's activity is the cultivation of other valuable fish species (whitefish, pink salmon, brown trout), which will significantly contribute to the replenishment of valuable fish stocks in the water bodies of the Murmansk region. The role and importance of artificial reproduction and conservation of water biological resources will increase more and more as the anthropogenic impact on the environment intensifies. This type of activity will be the only way to preserve the commercial value of valuable species of fish and other biological resources, which makes artificial reproduction artificial reproduction one of the highest priorities in development of fishery system of the Russian Federation.

1 Introduction

Humanity's demand for fish food products in the contemporary world significantly exceeds potential capacity of natural fish reproduction. Further intensification of exploitation of natural populations of fish can cause a sharp decrease in their number, disruption of natural habitats, reduction of water bodies' productivity, and loss of biological diversity. Solution of these problems is being implemented through artificial reproduction of fish.

Artificial reproduction of fish includes work associated with obtaining offspring and rearing of young water biological resources at fish-farms which are subsequently released into natural water bodies and reservoirs.

Artificial reproduction of fish in the Russian Federation has the following goals:

- preservation of fish biological diversity;
- maintenance of valuable fish species' stocks taken away by fishing;
- improvement of species composition of fish-fauna that lives in fishery water bodies.

2 Materials and Methods

2.1 Description of the activity of the Murmansk branch "Glavrybvod"

The Murmansk branch of FGBU "Glavrybvod" (hereinafter referred to as the Branch) is the only entity on the Kola Peninsula involved in artificial reproduction and conservation of water biological resources business. The Branch has three fish hatcheries: Knyazhegubskiy fish hatchery, Kandalakshsky experimental salmon fish hatchery and Umbsky (Umba) fish hatchery. These fish hatcheries have been primarily dealing with reproduction of Atlantic salmon (Semga), in particular, rearing of young fish until they become yearlings (one year old) and then releasing them into natural water bodies of the Murmansk region. The work described above is performed by fish-farms under government contracts awarded every year [1].

Atlantic salmon (Semga) has been traditionally reproduced at fish hatcheries of Murmansk region as well as pink salmon and trout. Since 2017, the Murmansk region's fish farmers have been in business of rearing whitefish for reproduction purposes. The plan is to bring in coho salmon from Arkhangelsk region to the

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Umba fish hatchery for purposes of biological processes optimization.

The subject of research completed in this article is to review the role played by the Umba fish hatchery in artificial reproduction and conservation of water biological resources of the Murmansk region.

The Umba fish hatchery is involved in the following activities:

- artificial reproduction of water biological resources;
- implement measures to conserve water biological resources and their habitat;
- improve water bodies for fish-farming purposes;
- create, maintain, operate and account for brood stock, including spawners;
- produce (catch) water biological resources for aquaculture (fish farming) purposes;
- maintain and operate water works and structures;
- provide security for biological resources and property controlled by the hatchery.

2.2 Historical background

The Umba fish hatchery (UFH) was commissioned in 1932. It is located at the mouth of the Umba River that flows into the Kandalaksha bay of the White Sea (Figure 1).

Fig. 1. Umba fish hatchery. 1949 r. (courtesy of "Murmanrybvod").

Umba fish hatchery has been mostly involved in artificial reproduction of Atlantic salmon (Semga) of the Umba River of the White Sea basin.

The first phase of facility operations in 1932–1959 is characterized by a sharp decrease in the amount of salmon fished in specific years, increased quantities of timber rafted down spawning rivers of the White Sea basin, considerable immigration of new population, construction of river infrastructure [2].

During these years, the majority of eminent Russian fish-breeding researchers believed that natural reproduction of fish was inefficient, especially at the embryonic phase. This circumstance has determined specific organizational forms of fish breeding.

In 1932, fish hatcheries have been built on the Varzuga and Umba Rivers. I. L. Zhukovsky's field method of salmon eggs and larvae incubation has been practiced for fish breeding. The production process consisted of catching and holding of spawners, getting the eggs fertilized, incubation of eggs in the river, short-term holding of larvae and releasing them with yolk sac undissolved into water body. During ice formation and ice drift periods, the eggs were incubated in a humid environment inside specialized incubating iceboxes.

At the hatchery, egg production, incubation, and larvae holding areas were located at great distances from each other – 5 to 50 km. This added challenges to fish breeding which was by itself very labor-intensive.

The production capacity of the UFH, based on its ability to incubate eggs at the initial phase of development, was determined to be 3 million fish larvae.

In 1940s it was generally firmly believed that salmon-farming in the Polar region, the way it was practiced back then, was, for no sufficient reason, opposed to natural reproduction and was implemented, in a number of cases, not to supplement it, but to damage it. Efforts made by fish-farming science at that time were concentrated upon in-depth study of salmon biology and conditions that drove the state of its stock as well as construction of foundation for intensive fish breeding technology.

Within the period from March 7 to April 30, 1949, the fish hatchery management has built several natural nurseries by constructing three log dams in the tributary of Umba River between the «Upper intake» islands thus creating 800 m^2 of total water surface area. Out of this number, 300 m^2 of water surface was dedicated to natural nurseries for holding fry; and the main pool –500 m^2 – was used for salmon spawners.

Due to challenges faced throughout the renovation of national economics after the Great Patriotic War, it took around 10 years for the real opportunity to emerge to start doing fish farming in the Murmansk region.

Drastic changes in salmon hatchery reproduction methods and technology in the Murmansk region have been driven by the fact that a number of activities associated with acclimatization of far-eastern salmon (pink and chum salmon) in the White Sea and the Barents Sea that commenced in 1959, have required appropriate production facilities to be constructed.

Within the period from 1959 through 1961, the Umba fish hatchery was redesigned to match Sakhalin fish hatcheries. In 1958 an incubating hatchery was constructed having 290 m^2 of usable area as well as auxiliary premises. In 1961 another incubating hatchery, having 510 m^2 of usable area, was constructed as well as channel cage having 2000 m^2 of water surface area.

The design capacity of UFH in 1999 was 70 thousand pieces of downstream fry of salmon (three-year-old fish). Since 2005, pursuant to decision made by the Inter-industry ichthyologic commission, the Umba fish hatchery has been producing 140 thousand yearlings of

Atlantic salmon (Semga). Since 2006, after Taybolsky fish hatchery has been shut down, the number of fish to be provided under government contract went up to 187,0 thousand.

At present, the fish hatchery continues to artificially reproduce the Umba River population of Atlantic salmon (Semga). The Far East salmon (pink salmon) is being dealt with as well. Since 2019, the hatchery has been engaged in breeding the whitefish (freshwater live form). Whitefish eggs, at the "eyelet" phase, are delivered to the hatchery from Leningrad region.

3 Results and Discussion

3.1 The status of Atlantic salmon (semga) stock in the Umba River basin

The Umba River basin is located in the southwest of the Kola Peninsula and is characterized by high presence of lakes (12.9 %), marsh-lands and wood-lands. The river flows out of Umbozero and flows into the Kandalaksha bay of the White Sea. The river length is 125 km. The catchment area is 6.25 thousand km^2 (Figure 2).

Based on the nature of its hydrological regime, the Umba River is a lake-river type of water body. Half of the total length of the lake-river system are channel lakes, the total area of which is 807.3 km^2. Quite large lakes are located at sources and channels of major salmon-inhabited tributaries of Umba – the rivers of Vyala and Muna. The fact that the flow of rivers is controlled by lakes affects their temperature and water levels resulting in belated water warming-up in spring and prolonged cooling-down in autumn [3].

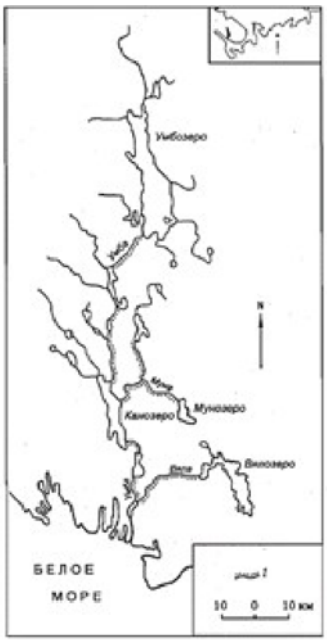

Fig. 2. Umba River basin map. 1 – Atlantic salmon spawning-and-rearing areas [3].

The total area of the Umba River spawning-and-earing areas (SRF) is 450 hectares, pestle fish density varies from 6 to 140 specimens/100 m^2.

Based on calculations that were made, production of smolts in the Umba River can be about 700 thousand specimens, and potential number of spawners, if the return rate is at 5%, is around 35 thousand spawners. The salmon spawning run lasts from May through October. Based upon many years' statistics, most of the spawners enter since middle of July through the end of September (Figure 3).

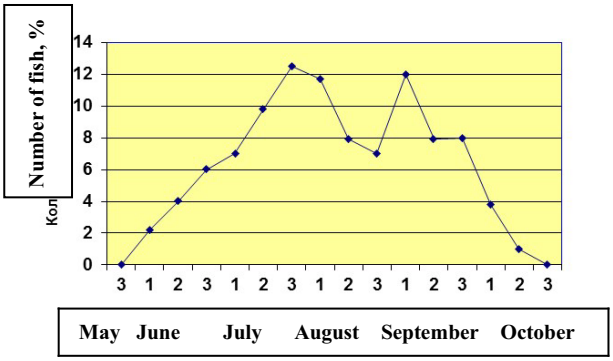

Fig. 3. Atlantic salmon run statistics in the Umba River based upon multiple year/average data [3].

The total spawning-and-rearing stock of the Umba River, including 1-st and 2-nd order tributaries – Vyala, Muna, Inga, Lyamuksa and channels Kitsa, Rodvinga, Nizma, Bolshoi Krivets is 4 477 800 m^2, out of which 1 909 700 m^2 are spawning areas and 2 568 100 m^2 are rearing areas [3].

The density of young salmon distribution is dependent upon water temperature, current, presence of predators and many other factors. The highest density – 45 fish/m^2 has been observed up in the mid- stream of the Umba River as well as in a tributary – the Vyala River – 40 fish /m2.

Based upon various assessments made, the potential number of salmon spawners in the Umba River can be anywhere from 34.6 to 40.5–80.9 thousand. However, the value of conservation limit, i.e., the minimum level of fish stock that provides the maximum sustainable catch during fishing, is estimated at 6 270 specimens [3, 4].

The salmon run dynamics in the Umba River in 2009–2020 as recorded by "Maly Krivets" fish accounting fence and "Rybovodny Zavod" fish accounting fence is presented in Figure 4. In 2018, as recorded by «Maly Krivets» fish accounting fence, the number of salmon that came in was 3208 fish which is much more than in the years before. This is probably due to increased protection of fish migration routes that was available that year.

Currently, the number of Atlantic salmon (Semga) in the Umba River is in depressive status, which is driven by anthropogenic factors: high level of illegal fishing, consequences of timber rafting as well as mining businesses' operations [5, 6].

The number of Atlantic salmon fished illegally in the Umba River in the second half of the 20th century has been at 25–26% of the annual number of spawning migrants. At the beginning of the new century it increased sharply, and now illegal fishing quantities are

at 67–73% of the fall biological group of salmon. As a matter of fact, the critical level fish perished through fishing and below which the fish population becomes extinct, varies between 82–85% [4].

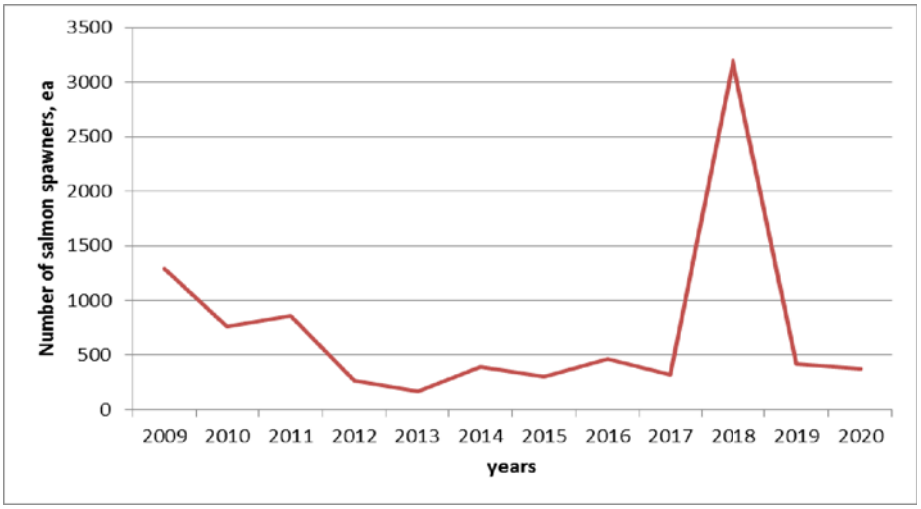

Figure. 4. Number of spawners entering the Umba River in 2009–2020.

For the Umba River, based upon high percentage of lakes present within its basin, pressure exerted by predatory fish upon other fish is believed to be widespread. At the same time, the quantities of biological reclamation have decreased noticeably over recent years.

Timber rafting downh the Umba River and its major 1-st and 2-nd order tributaries - the Muna, Inga, Vyala and Lyamuksa – has been on-going for a long time and was completely terminated in 1993. The timber rafting has changed hydrological conditions of the Umba River and worsened the condition of spawning-and-rearing areas. Consequences of timber rafting are felt to this day [5–7].

In recent years (2019–2020), the Umba River has been facing another problem - salmon spawners infected with Ulcerative Dermal Necrosis (UDN). This is a fish skin disease that causes skin ulcerations and is most commonly seen in Atlantic salmon (semga) and sea trout (kumja) every time they come back to fresh water for spawning. Salmon having this disease cannot be used for fish-farming and should be disposed of (cremated). For this particular reason, no work was done at the fish hatchery associated with selection of germplasm and placement of salmon eggs for incubation in 2019–2020.

3.2 The role played by the Umba fish hatchery in artificial reproduction and conservation of Atlantic salmon (Semga) stocks

Since the mid-1980s, there have been negative changes in the population characteristics of the Umba River salmon that were caused by aftermath of timber rafting and over-fishing. There are no smolts aged over 5 and over 6 anymore. The annual maximum and minimum numbers of spawning migrants now differs by 18 times [6].

The Umba fish hatchery is the only hatchery doing artificial reproduction of Atlantic salmon on the White Sea coast. The hatchery is located right on the Umba River where salmon spawners are penned for reproduction. Young salmon is released into this river basin without having to be transported over a long distance. It has a positive effect on fish survival rate and further adaptation in the natural environment.

There are many rivers where salmon has become extinct or salmon numbers are depressed. Construction of salmon hatcheries at such rivers is well justified, and ideally, it should be supported by restoration of natural spawning areas so that over time, due to contribution made by fish hatcheries, wild salmon herds recover their numbers.

Construction of salmon hatcheries for the purpose of re-acclimatization is also well justified. There are rivers where salmon used to live, but due to certain natural reasons it has disappeared. This also includes rivers within the habitat that have no conditions to support natural spawning. That is the reason why Umba is the river where artificial restoration of natural salmon population is necessary and well justified.

The UFH successfully complies with all requirements associated with holding of spawners, holding of eggs, holding and rearing of larvae, rearing and wintering of fish born the current year. The amounts of waste generated at each phase are minimal (Table 1). Based upon the available data (Table 1), the actual survival rate of salmon throughout all the phases of the process exceeds requirements.

To assess UFH operational efficiency, young fish to be released goes through tagging every year. The fat fin amputation method is used to tag young fish. Fish hatchery efficiency is assessed by the number of tagged fish entering “Maly Krivets” fish accounting fence. The number of salmon fish that have entered “Maly Krivets” fish accounting fence is presented in Table 2.

Table 1. Compliance with major biological requirements associated with Atlantic salmon (semga) farming throughout all the phases of fishing breeding process at the Umba fish hatchery (based upon inventory results).

Item	Parameter	UOM	Required value	Generation	
				2017	2018
1	Holding of spawners	%	**75**	100	96.4
2	Average fertility	thous. ea.	**5.6**	6.9	8,6
3	Holding of eggs	%	**90**	98	97
4	Holding of larvae	%	**93**	97	97
5	Rearing of larvae	%	**76**	86	90
6	Rearing of fish born the current year	%	**66.5**	72*	81*
7	Average mass of fish born the current year	g.	**0.8–1.0**	2.0	1.5
8	Wintering of fish born the current year	%	**80**	98	90
9	Rearing of two-year-olds	%	**80**	90*	57*
10	Average mass of two-year-olds	g	**6.0–9.0**	13.2	12.1
11	Wintering of two-year-olds	%	**94**	67	

Table 2. Number of salmon that entered “Maly Krivets” fish accounting fence in 2017–2020.

Date:	Total:	Fish hatchery	
		Each	% of total number
19 July, 17 – 31 July, 17	168	2	1.2
01 Aug, 17 – 10 Aug, 17	89	3	3.4
11 Aug, 17 – 26 Aug, 17	61	0	0
Total for 2017:	**318**	**5**	**1.6**
18 June, 18 – 30 June, 18	104	0	0
1 July, 18 – 10 July, 18	134	3	2.2
11 July, 18 – 20 July, 18	1467	10	0.7
21 July, 18 – 31 July, 18	1098	4	0.4
1 Aug, 18 – 10 Aug, 18	405	1	0.2
Total for 2018:	**3208**	**18**	**3.5**
16 June, 19 – 30 June, 19	65	0	0
1 July 19 – 10 July, 19	95	4	2.5
11 July, 19 – 20 July, 19	180	0	0
21 July, 19 – 1 August, 19	81	2	0.6
Total for 2019:	**421**	**6**	**3.1**
22 July, 20 – 31 July, 20	275	2	0.7

1 Aug, 20 – 7 Aug, 20	97	2	2.1
Total for 2020:	**372**	**4**	**1.1**

4 Conclusion

Thus, the number of fish that came back to fish hatchery over period under study ranged from 1.1% (2020) to 3.5% (2018). In recent years, fish return rates have decreased markedly. For comparison, within 2000-2010, the number of hatchery fish that came back was steadily at 7%. 5% of fish that came back is a good percentage (close to natural values). Therefore, it is necessary to take measures to increase percentage of hatchery fish coming back.

Due to significant level of unauthorized fishing (67-73%) and pollution caused by timber rafting, the number of salmon spawners in the Umba River has been decreasing. At present, most of the Atlantic salmon spawners in the lower and upper reaches of the river are being fished illegally. Therefore, urgent measures are required to protect the Umba River salmon population from complete extinction as well as measures to replenish its inventories.

Measures aimed at improving operational efficiency of the Umba fish hatchery:

- resume biological reclamation at locations where young fish is released and reach areas of Umba River and its tributaries (downstream migration of fish);
- propose to do experiments associated with changing biological methods of rearing juveniles in hatcheries, in particular, juveniles can be released via adaptation pond when they turn three years of age;
- continue cleaning the river of timber rafting debris;
- at the «Maly Krivets» fish accounting fence, put all the salmon (if fish comes in small quantities) into penns and release right before the spawning time. This will prevent poachers from fishing them at fish wintering locations (Middle Umba of Kanozero Lake);
- augment presence of fish water bailiffs at the Umba River;
- conduct joint operations involving local law enforcement agencies and executive authorities. This will expose poaching, corruption bonds with poachers and users of water biological resources.

The measures above should be supported by development and implementation of social-and-economic programs, development of recreational fishing and development of fishing tourism infrastructure.

Even though problems were found, it should be noted that due to efforts made by Umba fish hatchery fish-farmers, the Umba River Atlantic salmon population is growing. Additionally, now that fish hatchery has gone through renovation, other fish species (whitefish, humpback salmon, kumzhi) can be bred there. This would significantly contribute to replenishment of valuable fish species in water bodies of the Murmansk region [9].

Thus, the role and importance of artificial reproduction and conservation of water biological resources will increase as environment anthropogenic impact grows larger. This type of activity will be the only way to preserve the commercial value of valuable fish species and other biological resources. This, even at present time, makes artificial reproduction one of the highest priorities in development of fishery system of the Russian Federation.

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