Current state of Atlantic salmon populations in Karelia and updating its farm breeding technologies

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Abstract. Diadromous marine and freshwater Atlantic salmon occurs in Karelia’s water bodies. Freshwater salmon populations are listed in the Red Data Books of the Russian Federation and the Republic of Karelia. Marine salmon occurs in relatively small Karelia’s rivers flowing into the White Sea. In the past few decades, the deleterious influence of economic activities on North European Russia’s valuable fish stock tends to increase. As a result of hydraulic construction and other types of human activities, the White Sea salmon stock has rapidly decreased. An efficient way of restoring its abundance is “farm” reproduction. In the Republic of Karelia, artificial salmon reproduction is carried out at Vyg and Kem fish farms. One of the methods used to improve fish production quality is to apply laser radiation to salmon eggs and juveniles during “farm” reproduction. Application of low-intensity laser radiation to fish in a certain dose range has been shown to improve the compensatory adaptation of organisms. As a result, death rate declines and fish samples grow more rapidly. To reconstruct and maintain the original structure of Atlantic salmon populations in Karelia’s water bodies, purpose-oriented fish breeding, which comprises farm reproduction, fish protection and the recultivation of spawning and growing grounds, is needed.

1. Introduction
The natural Atlantic salmon distribution area covers a large part of North European Russia. The rivers, in which this species is reproduced, are part of the Barents, White and Baltic sea basins [1]. Diadromous marine and freshwater salmon occurs in Karelia’s water bodies. Freshwater salmon populations are listed in the Red Data Books of the Russian Federation and the Republic of Karelia. Marine salmon, also known as Atlantic salmon, occurs in relatively small Karelia’s rivers flowing into the White Sea [2].

In the past few decades, the harmful effect of economic activities on the valuable fish stock tends to increase in most countries. Hydraulic construction and other types of human activities are responsible for a disastrous decline in valuable fish abundance in Russia’s water bodies. In Northwest Russia, the salmon stock in such large rivers as Pechora, Mezen, Onega and Severnaya Dvina, as well as river populations in Karelia and the Kola Peninsula, have been depressed since the late 1980s. Many Atlantic salmon populations have been lost. The disappearance of natural populations and a rapid decrease in the abundance of preserved populations have led to the irretrievable loss of part of the Atlantic salmon gene pool [1], [3], [4], [5], [6].

The White Sea area, which adjoins Karelia, consists of the central basin, the Kandalaksha Bay, the Karelian shore and the Onega Bay. According to aquatic biologists, 18 rivers in Karelia are inhabited by Atlantic salmon. Karelia’s rivers are relatively short. However, lotic lakes make up as much as 50%
of the river system [1]. The Kem and Vyg rivers, where commercial fishing was maintained for centuries, were most productive in this area before the 1940s. However, the rivers were dammed by hydroelectric power plants, and natural salmon reproduction in them was terminated. According to official statistics, over 4 tons of Atlantic salmon were caught every year from the Keret River as early as the 1980s. In the past few years commercial fishing has been carried out mainly for fish farming.

Atlantic salmon remains one of the most attractive targets of licensed and sport fishing. North European Russia is now one of the most promising regions from the point of view of amateur fishing. To keep the region attractive for amateur fishers, measures to restore salmon abundance and to protect the salmon populations should be taken. The most rapid and efficient method of restoring salmon abundance is artificial reproduction [7]. Obviously, new approaches to fish-rearing problems and ways of updating the farm valuable fish breeding technology should be sought for.

2. Results and discussion
Commercial fish stock is known to depend on recruitment [8], [9]. Recruitment, in turn, is a variable value controlled by reproduction conditions. It is particularly important for Atlantic salmon, which has a long life cycle and a complex intraspecific structure. The abundance (“yielding capacity”) of a generation is commonly established in the first year of juvenile fish’s life and is closely related to its survival rate. Furthermore, the abundance of the Salmonidae now depends to a greater extent on the amount and quality of farm-reared immature fish. Commercial fish stock is known to depend on recruitment [8], [9]. Recruitment, in turn, is a variable value controlled by reproduction conditions. It is particularly important for Atlantic salmon, which has a long life cycle and a complex intraspecific structure. The abundance (“yielding capacity”) of a generation is commonly established in the first year of juvenile fish’s life and is closely related to its survival rate. Furthermore, the abundance of the Salmonidae now depends to a greater extent on the amount and quality of farm-reared immature fish.

The artificial reproduction of aquatic biological resources in the Republic of Karelia is conducted on Vyg and Kem fish farms. The Atlantic salmon planting stock production technology consists of several processes: 1) producers (sexually mature individuals) are caught and kept in a river; 2) eggs are collected and incubated; 3) free embryos are stored; 4) larvae are let grow and immature fish are reared and 5) released into a river. About 390 000 immature Atlantic salmon individuals of various ages are released every year into rivers on the Karelian shore of the White Sea (Figure 1). Data on the release of Atlantic salmon in 2018 are shown in Table 1 [10]. In spite of ongoing artificial reproduction, White Sea Atlantic salmon populations in Karelia are not abundant.

Intense biotechnologies in fish breeding are based on the use of genetic methods and the application of biologically active substances and physical factors controlling the vital activity of fish in the various periods of ontogenesis [11, 12, 13]. One way of improving the quality of farm-reared fish (eggs, larvae) is to use quantum biological methods. Assessment of the effect of low-intensity laser radiation on biological objects is of interest. The curable effect of low-intensity laser radiation (intensity of ~ mWt/cm²) with a radiation wave length in the red range (~ 600 – 800 nm) is considered as clinically proven. Helium-neon laser radiation is commonly used for these purposes (633 nm) [14].

A helium-neon laser can operate in a continuous mode in the visible and infra-red spectral regions at milliwatt-range output power. The laser is small and has a simple reliable design. It is most commonly used practically; intense, well-collimated radiation, provoked by laser transition in the visible region (red colour with a wavelength of 632.8 nm), is primarily used.

The stimulating effect of helium-neon laser radiation is assumed to be due to the fact that resonance power absorption by membrane structures is adequate to visible radiation (resonance frequency of 6.9·10⁴Hz) [15] and to the presence of the wavelength of this radiation in absorption region of a certain light-perceiving compound of a photo-regulating system [16]. The assumption that the biostimulating effect of helium-neon laser radiation is maintained via the photo-regulating system is supported by a
similarity between the pattern of biological laser radiation activity and the functioning pattern of the photo-regulating systems of microorganisms, plants and animals.

The effect of low-intensity laser radiation on various animals has been assessed. The results obtained show that some of physiological changes in the animal organism are triggered by low-intensity helium-neon laser radiation. In this case, blood supply is stimulated, the connecting tissue is regenerated, arterial pressure is shifted, nervous fibre conductivity is changed, energy-forming processes in the tissues are strengthened etc. [17], [18], [19], [20].

![Figure 1. Indicators of release of Atlantic salmon into the rivers by Vyg and Kem fish farms](image)

### Table 1. Data on the release of Atlantic salmon in 2018

| River     | Age of fish | Average mass, g | Number, ind. |
|-----------|-------------|-----------------|--------------|
| **Vyg fish farm** |              |                 |              |
| Keret     | 1+          | 23,6            | 42910        |
| Suma      | 1+          | 29,2            | 78420        |
| Vyg       | 2           | 23,5            | 18000        |
| Keret     | 2           | 29,6            | 97830        |
| Suma      | 2           | 29,8            | 44850        |
| Vyg       | 2+          | 82,5            | 535          |
| Keret     | 2+          | 61,9            | 3932         |
| Suma      | 2+          | 73,2            | 1540         |
| **Kem fish farm** |              |                 |              |
| Keret     | 1+          | 21,15           | 21800        |
| Suma      | 1+          | 28,0            | 700          |
| Kem       | 1+          | 25,9            | 33590        |
| Keret     | 2           | 23,9            | 82717        |
| Suma      | 2           | 32,2            | 28000        |
| **Total** |              |                 | 454824       |

Studies, based on the use of laser radiation in aquaculture, were launched in the 1980s [21], [22], [23], [24], [25], [26], [27], [28], [29]. The above authors note that the effect of low-intensity helium-neon laser (wavelength is 632.8 nm) on Atlantic salmon embryos increases their survival ratio in comparison with a control group [30], [31]. The study of the influence of radiation on the growth of Baltic salmon embryos has shown that the growth rate of the embryos is controlled by a laser radiation
dose interval. When salmon eggs are affected by radiation in an optimum dose interval (1.5×10⁻² J/cm²), the mass, length and height of the bodies of embryos of the same age are reliably greater than those in the control group. As energy radiation exposure increases or decreases, there are no valid differences in body mass between salmon embryos from experimental and control groups. A decline in the variability level of phenotypic characters is consistent with an increase in the resistance of Baltic salmon embryos.

It was found during an experiment, in which rainbow trout eggs were affected by laser radiation, that trout embryos from the experimental group are longer than those from the control group. The greatest absolute length values were shown by rainbow trout affected by laser radiation with an energy exposure of 2.0×10⁻² J/cm² (the difference is statistically valid). The body mass of trout larvae upon hatching in the experimental group showed slightly higher indices than those in the control group.

When rearing immature Atlantic salmon on fish farms, uncontrolled selection, triggered by the selective death of fish of certain genotypes under artificial conditions, may sometimes take place. As a result, genetic adaptations, required for the existence of population in nature, are destroyed [32, 33, 34]. The study of the effect of helium-neon laser radiation on the morphological, physiological and genetic variability of immature Atlantic salmon over a certain dose range shows that it contributes to the maintenance of the genetic diversity of artificially reared immature fish [31].

Byelorussian researchers have shown experimentally that low-intensity optical radiation can affect the growth and development of rainbow trout larvae and fry [29]. Unisexual eye-stage female rainbow trout embryos were used. The embryos were subjected to optical radiation (experimental groups) for 1–5 days (1–30 min/day) at a power density of 3.0 mWt/cm². Optical radiation was provided by the matrix of light-emitting diode sources (LED) of a Stronga optical instrument (red spectral region λ=630±10 nm) designed at the Department of Ichthyology and Fishery of the Byelorussian State Agricultural Academy together with the Institute of Physics, National Academy of Sciences of Byelorussia. The studies conducted in vivo have shown that the survival rate parameters and the size-weight indices of the rainbow trout larvae were dependent on optical radiation doses such as periodicity and time of exposure. From the third period (day of exposure) onwards, low-intensity optical radiation exerted a stimulating effect on the above indices of the rainbow trout larvae and fry. The greatest stimulating effect was exerted by 10–20 minute exposure during 5 days (depending on the parameter controlled). Analysis of the further results of the studies has shown that 31 days after hatching the main morphometric parameters of experimental larvae were statistically proven to be greater than those of control larvae.

The use of helium-neon laser in fish rearing also increases the resistance of fish eggs to saprolegniosis. Owing to its strong bactericidal and regenerating effect, microfractures on egg shells are rapidly healed, and, consequently, substrate for the development of fungus disease disappears [30].

It should be pointed out that in spite of a large number of publications in which the positive effect of exposure to red and infrared light is described, some authors report no positive results and even the development of indirect effects [35, 36]. It has been shown, for example, that the effect of low-intensity laser radiation depends on the evolution stage of fish embryos [25]. Helium-neon laser radiation increased productivity upon exposure of the eggs at the gastrulation and embryonal motorics stage and had a negative effect upon exposure at the organogenesis stage. Consequently, knowing the time intervals and intensities of laser radiation for evolution processes, one can slightly change the pattern of individual ontogenesis and control the evolution of particularly valuable fish species as required for fish rearing [26].

3. Conclusions

Thus, the study of the effect of low-intensity laser radiation on fish shows that red light (wavelength is 633 nm) in a certain dose interval strengthens the compensatory adaptation of organisms, reducing the influence of negative environmental factors and contributing to a decline in the loss of fish products upon artificial reproduction. Further studies on the effect of laser radiation on fish are needed to increase the resistance of immature fish released into a natural environment by decreasing death rate and
accelerating growth processes, thus contributing to the revival of natural populations of valuable commercial fish species.

To reconstruct and maintain the original structure of Atlantic salmon populations in Karelia’s water bodies, purpose-oriented fish rearing, which comprises farm reproduction, fish-protecting activities and the recultivation of spawning, feeding and growing grounds, is needed.

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