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# Sturgeon breeding as the basis for forming a food base in the Arctic zone of the Russian Federation

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**Abstract.** The article provides an analysis of sturgeon breeding, as well as materials for assessing the reproductive indicators of the Siberian sturgeon breeding stock in the conditions of the Arctic zone. The experience gained as a result of the multi-year research allows us to consider sturgeons, in particular the Siberian sturgeon, to have great potential for use in the Arctic zone of the Russian Federation. The cultivation of this species in the Northern regions may have great prospects for the formation of a food base, since it has high fish-biological, physiological and reproductive indicators when using various aquaculture technologies. The best productive indicators were obtained when sturgeon was reared in recirculating aquaculture systems (RAS), however, the experience of using the cage method showed a good physiological state of the fish. All the studied methods can be applied for the development of aquaculture in the Arctic zone of the Russian Federation. The cage method can be recommended for reproduction purposes, while using RAS can be recommended for fish rearing for sale.

## 1. Introduction

Geographical location and climatic features significantly hinder the development of the Arctic territories of Russia. However, the huge resource potential of these regions makes them very promising for use. The creation of their own food base is of great importance for the development of the Arctic territories, as well as for the population living there. Their own food facility is practically non-existent at this point and does not satisfy the needs of the population for food [1].

Providing the regions of the Far North and the Arctic with food of their own production will promote the development of these territories, formation of job opportunities, development of unused territories, improvement of the social sphere and creation of a food security system for the Arctic region [2].

One of the strategically important directions of food production is aquaculture, the development of which is quite fast in the conditions of the Northern regions. Thus, the North-West region of the Russian Federation is the leader in the cultivation of fish products and provides the production of about 70% of all Russian trout and salmon [3]. The method of cage rearing of trout in natural reservoirs has been developed and is effectively applied in the conditions of northern regions. However, further growth of fish production in cages is difficult, as it entails an increase in the negative impact on the environment. Therefore, along with the existing methods of rearing, alternative technologies should be developed and introduced into production. These technologies should be based on the sustainable use of modern resource-saving (RAS), non-waste industries, as well as new



promising objects, such as sturgeon. The use of some species of this family will expand the range of fish products manufactured by enterprises in the northern regions. The existing experience of sturgeon production in the European North can solve the problem of food security in the Arctic region.

The aim of this research was to study the experience of rearing the Siberian sturgeon using various methods and to assess the potential use of this species as a promising object for the formation of a food base in the Arctic region.

The objectives of the study were to assess the fish-breeding parameters and physiological state of the Siberian sturgeon using various technologies of rearing in the farms of the Arctic zone, as well as to analyze the reproductive and fish-biological indicators of matured female Siberian sturgeon when kept in the natural temperature regime of the northern regions.

## 2. Materials and methods

On the basis of the multi-year research we analyzed the results of work with sturgeon in the regions of the European North, including the regions of the Arctic zone of the Russian Federation. We analyzed the results of Siberian sturgeon rearing using various aquaculture technologies. In the Murmansk region, due to the peculiarities of the climate of the extreme north, we studied the features of sturgeon rearing in cages near the thermal discharge from the outlet canal of the nuclear power plant. In the Republic of Karelia, the main fish-biological indicators of the Siberian sturgeon were studied when reared in cages established in the Lizhenskaya Bay of Lake Onega. In the Leningrad region, the features of sturgeon growth in the basins of the RAS were assessed. To evaluate the materials obtained, the average live weight of fish was analyzed at the beginning and at the end of the experiment, and the survival ability and feed costs for the growth of fish were assessed during the entire period of rearing.

For the physiological assessment we used an express method of semi-quantitative analysis of the main indicators of mucus using the indicators of Multistix 10SG manufactured by Bayer/Siemens. Using this method, we determined pH, glucose, protein, bilirubin, nitrites, ketones, and hemoglobin in sturgeons as the main indicators of the physiological state of the organism. The application of this method made it possible to assess the main biochemical parameters of the organism in a vital and non-traumatic way for the fish.

Along with the commercial qualities, the reproductive characteristics of sturgeon are of great importance for the development of sturgeon breeding in the Arctic zone of the Russian Federation. Therefore, the reproductive characteristics of Siberian sturgeon brood fishes raised in cages in the Republic of Karelia were analyzed. To assess the quality of the sturgeon breeding stock according to the standard method [4-5], an ultrasound study was carried out, the sex of the fish and the stage of maturity of the reproductive products were identified. Based on this assessment, ripe spawners were selected and stimulated with the "Surfagon" medication. Reproductive products were obtained from the brood fishes that matured as a result of hormonal stimulation. To assess the reproductive indicators of sturgeon females, the working and relative fecundity, oocyte mass, and maturity coefficient were determined [5]. The materials obtained were evaluated using the methods of variation statistics.

## 3. Results and discussion

Most species of the family Acipenseridae are objects of warm water aquaculture, but there are also typical eurythermal species. The most popular object that can grow and mature in a wide temperature range is the Siberian sturgeon, whose production in the world accounts for more than 30% of the total sturgeon production [6]. This species is grown in more than 40 countries of the world [7]. Fish farms in the Northern regions use cooling ponds of state district power plants and nuclear power plants or recirculating aquaculture systems (RAS) for rearing of Siberian sturgeon [8].

Growing juveniles, commercial fish and keeping sturgeon brood fishes using these technologies is effectively used in almost all regions of the European North. However, the total volume of sturgeon rearing in Russia is still relatively small. For instance, according to official data, the output of products from sturgeon among other objects of breeding is only 4% [9].

The largest amount of sturgeon products in Russia is produced in the Vologda region in the full-system sturgeon farm "Diana". This enterprise maintains the largest sturgeon brood stock in the Russian Federation. The breeding of marketable products and the maintenance of brood stock is carried out by the cage method in the cooling pond of the hydroelectric power station. The annual production of commercial fish is about 600 tons, and the enterprise also receives about 16 tons of caviar from various species of sturgeon, and this is half of all black caviar produced in Russia. A similar technology for the production of sturgeon breeding products, as well as RAS technology, is used in the farms of the Leningrad Region. The production of commercial sturgeon in this region is about 90 tons of fish per year [9].

In the Murmansk region, Siberian sturgeon is raised in cages, but using warm water from the Kola nuclear power plant. Cage lines for rearing sturgeon are located in lake Imandra, the temperature regime of which largely depends on the warm water supplied here. In total, the cages in this region contain about 3,000 sturgeons, with a large proportion of brood fish.

As the results of the analysis of the operation of fish farms show, sturgeon cultivation in the Arctic regions can be carried out in various ways. The biological features of the Siberian sturgeon, high temperature adaptability, the ability to actively consume food and grow in a wide temperature range make it possible to grow this object both in cages in natural temperature regimes - under the conditions of the Republic of Karelia, and using warm water (cooling ponds of industrial facilities and RAS) in more northern areas. An assessment of the main results of Siberian sturgeon rearing using these methods is presented in Table 1.

**Table 1.** The results of rearing Siberian sturgeon in farms of various types.

Indicators	<i>Technology used</i>		
	RAS (tanks)	Cages in natural reservoirs	Cages in cooling ponds
Thermal constants for the entire period, degree-days	7500 - 6500	4200 - 4700	4300 - 5100
Live weight of underyearlings, g	15	100	150
Live weight of two-year-olds, g	1865	1290	580
Live weight of three-year-olds, g	3250±204.4	2053±122.3	1720±143.6
Survival rate, %	95	96	99.6
Feeding ratio	1.2	1.1	1.2

It is known that the most favorable conditions for growing sturgeon can be created in the RAS, since the optimal water temperature is maintained in the tanks constantly, regardless of the season [7]. The absence of an autumn-winter period with low water temperatures contributes to the year-round intensive growth of sturgeon, allows accumulating the maximum number of degree-days in a limited time and obtaining marketable products in 10-12 months. When using this method in areas with unfavorable climatic conditions, including in the Arctic zone, it is possible to use fish stocking material with a minimum initial live weight. Thus, despite the low weight of fish at the beginning of the experiment (15 g) at the end of the rearing period, the average live weight turned out to be the highest, and increased to 1865 g in two-year-olds and 3250 g in three-year-olds (Table 1).

Sufficiently good fish-breeding performance was noted when sturgeon was reared in cages in natural reservoirs of the Northern regions. The amount of heat that lakes and water reservoirs of the Republic of Karelia can accumulate over the summer period ranges from 1500 to 1700 degree-days, depending on their location and limnological features. It takes about 4000-5000 degree-days to reach the marketable mass, therefore, if this method is used, the production cycle is lengthened. Despite the increasing costs of time, the application of this method makes it possible to obtain marketable products in the conditions of the Arctic territories. So, when growing Siberian sturgeon in cages in Lake Onega, for 1 year of cultivation, the weight of two-year-olds increased more than 12 times and amounted to

about 1.29 kg, and of three-year-olds - 2.05 kg, which corresponds to the size required for the sale of commercial fish.

The regions located to the north from Karelia, including the Murmansk region, are characterized by a more severe climate. Growing sturgeon in such climatic conditions is complicated by the lack of heat, which natural reservoirs can accumulate during the summer period. Therefore, the most optimal method in the Far North is the use of recirculating water or the use of alternative heat sources for aquaculture, including warm water from cooling ponds. Table 1 shows that over the entire growing period, a cooling pond located outside the Arctic Circle can accumulate up to 5000 degree-days. Thanks to the warm water supplied to the cages through the outlet canal, a favorable temperature regime is formed in the fish growing area, the water temperature in winter does not drop below 15°C, and in summer it stays at the level of 20-24°C, which corresponds to the biological characteristics of the Siberian sturgeon [10]. As a result of growing sturgeon in such a temperature regime, sufficiently high fish-biological indicators are manifested - the survival rate of fish is about 99%, low feed costs for growth gain (feeding ratio is 1.2) and a good growth rate (3-4 times weight gain annually) [11]. This indicates that, despite the extremely harsh climatic characteristics of the northern regions, there are good opportunities for breeding Siberian sturgeon. But to obtain marketable products with a larger live weight in the Far North, it is necessary to use a 3-4 year growing period.

Along with the fish-breeding biological indicators, the favorable conditions for growing sturgeon in the Arctic zone can be judged by the physiological state of commercial fish (Table 2).

**Table 2.** The analysis of the biochemical composition of Siberian sturgeon mucus

Indicator	Rearing technology	
	Cages	RAS tanks
Glucose, mmol/l	0.2-0.3	-
Protein, g/l	0.1-0.3	-
Bilirubin, c.u.	-	+
Urobilinogen, mmol/l	-	3.5-0.2
Ketones, mmol/l	0.5	0.5
Hemoglobin, er/mcl	25-250	-
Nitrite, c.u.	-	-/+
pH	5.0-5.5	6-6.5

\* "-" not detected; "+" - identified traces in single individuals

The table shows that in the group of fish from the cages, the presence of protein, glucose and hemoglobin in the mucus was revealed. Similar data on the composition of mucus in the Siberian sturgeon are given by other researchers [12]. This is considered as a physiological regularity. In sturgeons raised in RAS, hemoglobin, as well as glucose and protein, were not detected using this technique. The appearance of decay products of proteins, fats and carbohydrates in mucus is an adaptive response of the body to intensive nutrition, which is typical for industrial rearing methods, and is associated with liver function. Some studies confirm that an increase in protein breakdown products in fish mucus, in particular, bilirubin, urobilinogen, etc., is the body's response to various stress factors [13]. In our case, no bilirubin and urobilinogen were detected in the mucus of caged fish, which indicates favorable growing conditions. The presence of urobilinogen, bilirubin, as well as traces of nitrites was noted in sturgeons raised in RAS. This is probably due to the intensive feeding, rapid growth and intensive metabolism in fish, which is typical for the technology of cultivation in RAS. The disadvantage of this method is the risk of an increase in the concentration of protein breakdown products in water, an increase in the effect of stress factors on fish, and physiological parameters in the studied sturgeons confirm this probability. Despite this, the condition of fish during rearing both in cages and in RAS can be assessed as good. By adjusting some parameters of keeping and feeding, it is possible to obtain products from sturgeon with high fish-breeding performance in the Arctic zone, using both the recirculation technology and the cage rearing method.

In addition to marketable fish products from sturgeon in the Arctic zone of the Russian Federation, it is possible to produce food caviar and fish stocking material. Sturgeon caviar is a delicacy food product and has a high nutritional value. Obtaining caviar from sturgeon for the production of both food and reproduction is a highly profitable and very popular area of aquaculture. Moreover, the technologies for the production of caviar for both reproductive and food purposes are the same. The most important and lengthy stage in this production is the process of creating a brood stock of caviar. The duration of this period can be from 5 to 10 years, depending on the species of sturgeon used, and optimal conditions for the formation of a brood stock of sturgeon can be created when grown in RAS, including in the regions of the Far North. The breeding stock of Siberian sturgeon can be kept not only in the basins of the RAS, but also in natural reservoirs under natural temperature conditions. Table 3 presents the material on the assessment of the linear-weight and reproductive parameters of female Siberian sturgeon from brood stock raised in cages in the Republic of Karelia.

The table shows that the average live weight for the herd was 21 kg, and the length was 1.4 m, which is sufficient for the transition of fish to the spawning state. Thus, despite being kept at fairly low water temperatures, brood fishes have good weight and length. The quality of fish in the brood stock is also affected by their fatness. An excess of the condition factor of more than 1 in sturgeon brood fishes often indicates an excess of nutrition and often contributes to obesity. This is accompanied by the accumulation of adipose tissue in the fish gonads and leads to a delay in the fish maturation. In our case, the condition factor has an optimal value, and this indicates the good quality of females in the brood stock. This is confirmed by the assessment of fertility indicators (Table 3).

**Table 3.** Reproductive and fish-biological indicators of the Siberian sturgeon.

Linear weight indicators (n = 15)			
Value	Weight, kg	Length, m	Fulton condition factor (FCF)
$X \pm m$	$21.01 \pm 2.12$	$1.41 \pm 0.03$	$0.73 \pm 0.03$
<i>Max-Min</i>	13.7-35.0	1.30-1.56	0.60-0.92
<i>Cv, %</i>	30.37	7.12	13.91
Reproductive indicators (n=11)			
Value	Working fecundity, thousand fish eggs	Oocyte mass, mg	Maturity coefficient (Gonadosomatic index - GSI), %
$X \pm m$	$149.3 \pm 28.91$	$24.9 \pm 1.56$	$14.27 \pm 0.98$
<i>Max-Min</i>	266.094-82.645	29.10-18.25	17.71-11.54
<i>Cv, %</i>	47.45	15.36	18.16

The fecundity of fish is one of the most important indicators of the quality of female fish in the brood stock, since the amount of the obtained fish stocking material depends on it. Even more important reproductive indicators of brood stock are considered to be the maturity coefficient and the mass of oocytes, since they affect the quality of the offspring, its fish-breeding characteristics, as well as the quality of food caviar. The table shows that, on average, for the studied group of Siberian sturgeon females, working fecundity was 149.3 thousand eggs, the maturity coefficient was 14.27%. The maximum egg yield was at the level of 17.7%, the minimum was 11.5%, which is a high value and corresponds to the results of other studies [7,14-15]. So, despite keeping the sturgeon brood stock in a low temperature regime, fecundity and maturity coefficient on average in the group were rather high.

In the studied group of Siberian sturgeon females, a rather high oocyte mass was also noted. On average, this figure was 24.9 mg, which significantly exceeds the weight of sturgeon eggs from wild populations of this species, and also exceeds the size of eggs in female sturgeon from fish farms in the central part of the country. A large mass of sturgeon oocytes has a positive effect on the cost of food caviar, and it is also important in artificial reproduction, as it contributes to a more complete formation of embryos. The high average weight of sturgeon eggs in the studied group is a consequence of the

large live weight of females (about 20 kg), this pattern is often manifested in sturgeon and is described in some studies [16]. The high values of the reproductive indicators of the Siberian sturgeon confirm that in the northern regions it is possible to create favorable conditions for the growth and maturation of these fish, to organize the work of enterprises for the reproduction and obtaining of fish stocking material, as well as for the production of food caviar from sturgeon.

#### 4. Conclusion

The experience of working with sturgeon in the conditions of the Northern regions of the Russian Federation allows us to consider them as promising objects of aquaculture. The currently available technologies make it possible to widely use these species for rearing in the Arctic zone of the Russian Federation in order to increase the production of high quality fish products and form their own food base.

The use of sturgeons in the aquaculture of the Northern Territories may have great prospects, since the biological capabilities of these objects allow obtaining high fish-biological, physiological and reproductive indicators when grown using various methods. The highest fish-breeding indicators can be achieved when sturgeons are reared in recirculating aquaculture systems and in cages using cooling ponds. Using the cage method in natural reservoirs can be recommended for the maintenance of breeding stock, the production of caviar and fish stocking material.

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