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Biological Characteristics Of Fish Breeding Facilities In The Water Bodies Of Yakutia

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Abstract The increasing anthropogenic impact on the natural complex puts the populations of commercial fish on the brink of physical destruction. The number of populations of some economically valuable fish is so low that it reaches a critical value, after which their restoration without active human participation is impossible. Organization of ichthyological monitoring is one of the measures for the conservation of biological diversity. The fishery has become unprofitable as a result of a decrease in the number of fish in the water bodies of Yakutia and a decrease in catches of the main commercial species to 67-75% over the past 10 years (Coregonus nasus (Pallas), Coregonus lavaretus pidschian (Gmelin), Coregonus muksun (Pallas), Coregonus tugun (Pallas), Stenodusleucichthysnelma (Guldenstadt), Hucho taimen (Pallas), Brachymystaxlenok(Pallas), Thymallus arcticus (Pallas), etc.). It was recommended to weaken the fishery for these species in Yakutia, shift the focus to lake fish farming and bring its catch level to the quota level in fisheries due to biological and economic overfishing.

Keywords: Coregonus peled,Carassius carassius , Oncorhynchus keta, temperature, feeding and hydrological conditions, intracavitary and muscle fat, yolk sac, soil, breeding technology, compensating agents, heavy metals.

1. Introduction

Currently, the lakes of Central Yakutia with a total area of about 80 thousand hectares are of the greatest interest for fish breeding purposes. The reservoirs are located in the middle and lower reaches of the Vilyuy River (over 30 thousand hectares), between the estuaries of the Aldan and Vilyuy rivers (about 10 thousand hectares), as well as in the Lena-Amga interfluve (over 40 thousand hectares), where, with proper fish farming sustained and increasing catches could be provided for a relatively long time. Furtherexpansion of the fishery should go through the development of remote reservoirs and activities for the development of aquaculture. It is necessary to conduct special commercial exploration in water bodies, without which it is impossible to expect the development of the most complete lake fund of the republic and an increase in the marketable output of fish products.

2. Discussion

Yakutia is one of those few regions of the country that abound in lake reservoirs and are inhabited by valuable commercial fish species (Acipenser baerii, Stenodus leucichthys nelma, Hucho taimen, Coregonus muksun, Coregonus nasus, Coregonus peled, etc.). In addition, the Lena, one of its greatest rivers, has undergone large-scale changes in the flow and hydrological regime of the river over the past 30-40 years (Macritsky, Aibulatov, 2018) and a comparison of multi-temporal images performed for morphologically different parts of the delta's sea edge showed the stability of most of the Lena delta (Kravtsova, Inyushchin, 2019)

At the same time, the distribution of lakes throughout the region is uneven. The bulk is located within the Yano-Indigirskaya, Kolymskaya, Central Yakutskaya lowlands, as well as in the Lena River valley. The remote water bodies of the Yano-Indigirsky and Kolyma-Indigirsky interfluves are very poorly developed. According to FN Kirillov (Kirillov, 1972), the total number of lakes in Yakutia with an area of 1 hectare or more is about 709,000. The approximate number of lakes in the basins of the main rivers is as follows: Lena-Vilyuy region - 1,400 rivers; Yano-Kolymsky - 3500; Anabar-Oleneksky - 1400; South Yakutsk - 700. Currently, 347 lakes with an area of 453,400 hectares are covered in Yakutia by research with varying degrees of completeness, which is 6% of the total area of the lake fund.

In 1971-1994, a re-study of a number of the most promising lakes for fish breeding purposes, located in the Central Yakutsk lowland, was carried out in connection with the commissioning of the Chernyshevsky fish hatchery. The bulk of the lakes in Yakutia are concentrated in three geographic zones: in the tundra zone between Yana and Kolyma; in the northern taiga zone along Indigirka, Alazeya and Kolyma and in the Central Yakutsk lowland, as well as in the Vilyuy reservoir (Kirillov, 1972; Tyaptirgyanov, 2016).

Lakes of Yakutia are divided into 6 groups by origin: thermokarst, karst, floodplain, glacial, lagoon and tectonic (Tyaptirgyanov, 2016). The most widespread are lakes of the first group - thermokarst. There are many such lakes on the plains and lowlands of the central and northern regions. The lakes are mostly small in size, round or oval in shape. Average depths are 2-3 m, maximum depths are 10-15 m. Many thermokarst lakes dry up over time due to depletion of fossil ice reserves and a lack of precipitation.

In connection with the increased anthropogenic impact on the river systems of Yakutia, there is a decrease in the species diversity and number of valuable fish species, as well as a decrease in the level of production processes in them, which necessitated the revival of lake (cage) fish farming in the republic's water bodies (Tyaptirgyanov, 2016).

This makes it possible to use this indicator in monitoring studies of the state of populations, especially in places of anthropogenic impact on them, along the edges of the range, during artificial reproduction, hybridization, etc. (Romanov, Mikheev,2020).

The main sources of pollutants entering the mouth area are river runoff (these are phenols, oil products, heavy metals, organic substances). Taking into account the fact that human health and satisfaction of his life and needs are influenced not so much by individual chemical substances contained in surface waters, but by a complex of substances simultaneously present in the water of water bodies, a comprehensive assessment of the state of water bodies is very relevant at the moment (Silin,1982; Petrechenkova, Radovan, 2020).

Coregonus peled, Golden crucian carp in lakes and Oncorhynchus keta in rivers are the most suitable for the initial period of fish-breeding work in the reservoirs of Central Yakutia.

3. Methods

The analysis was carried out on fresh material according to methods generally accepted in ichthyology (Methodological manual…,1974, 1982; Pravdin, 1966;Chugunova, 1959). The body length to the end of the scale cover was measured in floodplain fish. Fishing was carried out with 10-70 mm nylon standard nets, seines up to 100 m long with a mesh size of 20 mm in the reel, as well as fry drags with a mesh size of 10 mm in the reel. The body length of the fish was measured with an accuracy of 1 cm, the total body weight and without viscera was measured with an accuracy of 1 g, and the gonad weight was measured on a pharmaceutical balance with an accuracy of 0.1 g. The age of the river perch was determined by the scales, which were taken from 2 - 3 rows above the lateral line in front of the dorsal fin. The determination of the age of the fish along the front edge of the scales was carried out using an MBS-9 binocular microscope.

The absolute fertility of river perch was determined by the gravimetric method (Pravdin,1966), while the number of eggs in the sample taken (3 grams) was calculated and the diameter of the eggs fixed in formalin was measured. A morphometric analysis was carried out with the measurement of plastic (dimensional) and meristic signs.

The collection of field material and office processing were carried out in accordance with the “Methodological manual for the study of nutrition and food relations of fish in natural conditions” (Methodological manual,1974). Food samples were taken from net catches 2 - 4 hours after their setting, from non-aquatic catches - immediately after a complete bioanalysis of fish with subsequent fixation of the gastrointestinal tract with a 4% formalin solution.

Cameral processing of fish was carried out at the Institute of Natural Sciences of M.K. Ammosov North-Eastern Federal University.

4. Results

Spawning migrations of Coregonus peled begin in late August and early September. Sexually mature individuals approach coastal areas with a depth of 2-3 meters. The age of onset of sexual maturity in this species, even in closely located lakes, due to different temperature, forage and hydrological conditions, is different and ranges from 3+ to 6+ years. Spawning of Coregonus peled is highly stretched. In the Vilyuy group of lakes, it runs from mid-September to December inclusive (Ignatiev, Ivanova, 1980;Kirillov,1972).

Coregonus peled spawns both on sandy and silty soils with an admixture of plant residues. Its fertility depends on age, size, as well as on habitat conditions and ranges from 36,000 to 200,000 eggs. The body weight of Coregonus peled, depending on age, ranges from 603-1210 g (Table 1).

This makes it possible to use this indicator in monitoring studies of the state of populations, especially in places of anthropogenic impact on them, along the edges of the area, during artificial reproduction and hybridization (Romanov, Mikheev, 2020).

It was found that during river regulation, migration modifications of juvenile river fish species primarily occur due to the transformation of the hydrophysical and morphological structure of the watercourse, which creates a different biotopic picture that affects different aspects of fish life, including migration behavior. Unlike a natural river, in which the conditions that determine the characteristics of downstream migration change gradually from upstream to downstream, ecological barriers such as reservoirs and a dam are formed in a regulated river, which significantly change these conditions. The leading role in the formation of these barriers and the regulation of downstream migration is played by the morphological complexity of the reservoir and the intensity of water exchange. The synergistic effect of these factors can reduce the intensity of emigration of juvenile fish from reservoirs by several orders of magnitude (Pavlov, Mikheev, Kostin, 2019).

Until the 1990s, Coregonus peled caviar was mainly harvested on the lakes of the Syalakh system of the Kobyai region. Breeders were selected from non-aquatic catches and kept in cages until maturation of reproductive products. Currently, for the stable production of Coregonus peled eggs, it is necessary to create broodstock on the basis of the lakes Syalakh, Uyulu, Sanga-Kyuel, which are compactly located, with a total area of 1170 hectares. This farm can produce up to 100 million Coregonus peled eggs under rational management.

Golden crucian carp is a valuable object of industrial fishing and recreational fishing. The high nutritional qualities of the "Yakut" golden carp make it possible to distinguish it among the carp of other regions. When determining the market value of fish, the degree of their fat content (up to 7%) is of great importance. The "Kobyai" golden crucian carp, which accumulates a significant supply of intracavitary and muscle fat for the winter, has a particularly high taste.

Table 1. Size and weight indicators of Coregonus peled lake Syalakh, August-September 2018 (n=173 fish)

Age	Fishinglength, cm		Weight, g		Quantity, pcs
	hesitation	average	hesitation	average	
3+	29-34	33	410-690	603	95
4+	35-37	36	610-840	745	63

5+	37-39	38	650-960	810	12
6+	40-42	41	990-1250	1210	3

Crucian carp lives in lakes with different areas (less than one and up to 10 thousand hectares) and habitat conditions. The lakes inhabited by the crucian carp are usually isolated and silted. This species withstands both very acidic waters (pH 4.5) and alkaline (pH 9.0), and is also able to withstand oxygen deficiency in water up to 0.6 mg / l. In winter, when oxygen deficiency occurs in the water, the crucian carp is buried in silt, sometimes to a considerable depth (up to 1 m), and is in a sedentary state. In malnourished, polluted and swampy lakes, crucian carp forms a slowly growing large-headed dwarf form, which at the age (4 + -7 +) does not exceed 8-12 cm in length and 20-45 g in weight. On the territory of Central Yakutia, lakes with a dwarf form of crucian carp are quite common. Therefore, when carrying out fish-breeding operations, it is necessary to select (for transportation and stocking) carp producers according to their exterior characteristics (broad-backedness, length, weight, etc.). The life cycle of a crucian carp is quite long (up to 16 years). There are also fish of older age groups weighing 3-4 kg (basin of the Vilyuy River, Lena River) (Kirillov, 1972).

Average size indicators of Golden crucian carp are as follows: average body length 16 cm and weight up to 200 g. Sexual maturity occurs at the age of 4-5 years. The multiplicity of spawning, depending on the living conditions, is different. In the lakes of the Kobyai region, one-time caviar per season will be spawned from crucian carp, less often some individuals will spawn twice and stretch out for the whole summer. In the Zarechnaya group of lakes, the crucian carp spits out two portions of caviar. More than 60% of caviar in reproductive products accounts for the first portion and 30% for the second (Kirillov, 1972). Individual absolute fertility of crucian carp ranges from 23 to 120 thousand, on average 65 thousand eggs. The overall survival rate of eggs in natural spawning grounds is rather low and varies from 10 to 30%.

It is known that before the beginning of the acclimatization work, Oncorhynchus keta visits to the rivers of Yakutia were rare and non-annual, for example, in the lower reaches of the Lena River. In the Yana River, it was occasionally found not only in its deltaic part, but sometimes ascended to the village of Verkhoyansk and even to the confluence of the Sartanga and Dulgalakh rivers (Tyaptirgyanov, 2016). In the lower reaches of the Indigirka River, this species was recorded singly by F.N. Kirillov (1972). Its autumn visits to the Lena River were noted in the second half of August. Spawning took place on stretches with small pebble soil. Females usually bury eggs with their tail and head in the form of a bump. On the Kolyma River, larvae hatch in winter, in January-February, 70-100 days after laying eggs (Tyaptirgyanov, 2016). For the first 3 months, the larvae feed on the yolk sac, after its resorption, they switch to feeding on phytoplankton, which develops in places of mass death of spawned fish, and then on zooplankton food. Subsequently, juveniles intensively feed on chironomid larvae and pupae. In the process of natural reproduction, the mortality of fish eggs to the fry stage is very high and amounts to 50-90% of the absolute fecundity. With artificial breeding of fish during incubation, the death of eggs does not exceed 16%.

Until recently, on the Kolyma River, the autumn course of Oncorhynchus keta was very rarefied, with an interval of 4-5 years. In 2020, a massive entry of Oncorhynchus keta breeders into this river was noted. All of them went to spawn with well-developed reproductive products (Table 2) (Tyaptirgyanov, 2016. On the Mangazeyka site, its spawning course began in August 2020.

During this period, in the net catches, only large males were found (average fishing length 65 cm and average weight 4500 g), and by September 5, the number of females in the catches was 30%. As follows from Table 3, the average body weight of female Oncorhynchus keta in 2020 slightly decreased compared to 1995, while in males they remained practically unchanged (Tyaptirgyanov, 2016).

At the beginning of the spawning run of Oncorhynchus keta (early September - late October 2005), males prevailed in catches from 57 to 70%. From the first days of November, the percentage of male and female Oncorhynchus keta became the same (Table 4).

The state of maturity of the genitals in females and males of the spawning herd was different. In the period from August 20 to September 15, 2020г., the bulk of Oncorhynchus keta females had gonads of stage IV of maturity of reproductive products, males in a state of fluidity (stage V). After freeze-up, among the females, there were also individuals with ovaries of the IV stage of maturity (3%) (Tyaptirgyanov, 2016). The coefficient of maturity of individuals is quite high, in male Oncorhynchus keta it averaged 5.0%, in females - 17.4%.

The collected caviar of Oncorhynchus keta was inseminated immediately and stored in a humid environment (Table 5). However, for the first time in 1995, a high mortality was observed - up to 90% of eggs (Tyaptirgyanov, 2016). Among the representatives of the salmon family, Oncorhynchus keta is one of the most economically advantageous species.

It is a fast-growing species and after 3-5 years has a body weight of 5-6 kg. For comparison: a species such as muksun reaches sexual maturity at the age of 9-14 years, with a mass of no more than 2 kg (Tyaptirgyanov, 2016).

Since the entry of Oncorhynchus keta into the rivers of Yakutia is small, in 1998 it was decided to start acclimatizing it from other regions of the country, in particular, from Sakhalin Island. In 1999, the appropriate permits were obtained and for the first time live caviar of the Far Eastern Oncorhynchus keta was brought. It was donated free of charge from the Salmo LLP fish hatchery in the Yuzhno-Sakhalin Oblast. The planting material was subsequently brought to the Chernyshevsky fish hatchery. She was incubated there, and the hatched larvae were grown to a weight of 0.5 grams.

Table 2. Biological indicators of Oncorhynchus keta during the spawning run at theMangazeyka site, the Kolyma river, 2020 (n = 72 fish)

Date	Sex	Length, (ac), cm	Length (ad), cm	Weight, g	Fishovary mass, g	Absolutefe rtility, pcs	Workingfer tility, pcs
05.09.	females males	62 69	58 65	3055 4520	700	3850	-
15.09.	females males	58 67	55 64	2829 4620	-	-	-
25-30.09.	females males	65 68	61 64	3589 4508	650	3900	3280
04-08.11.	females males	64 65	60 61	2643 3700	600	3290	2880
Average	females males	63 68	59 64	3280 4410	650	3600	3000

Table 3. Average weight (g) of Oncorhynchus keta breeders, Kolyma river.

Numberoffish	Females		Males	
	hesitation	average	hesitation	average
1995				
26	2600-5100	3586	3500-5600	4395
2020				
72	2000-4100	3278	2700-6200	4459

Table 4. Changes in the sex composition of Oncorhynchus keta during the spawning run in2020

Time of catching fish samples	Females, %	Males, %	Numberoffish, n
September 5	30	70	3
September 15	40	60	15
October 25-30	43	57	11
November 4-8	50	50	8

After the ice has melted (June), the grown fry are released in the northern rivers of the republic.

Live caviar of the Far Eastern Oncorhynchus keta was delivered to the Chernyshevsky fish hatchery for 4 years (from 1999 to 2002).

The whole cycle of its development from the stable stage of eggs to the stage of fry took about 7-8 months. At the same time, natural death reached 20-50%. Viable planting material at the fry stage was released into the water bodies of Yakutia (Table 5) (Tyaptirgyanov, 2016)

5. Conclusion

Artificial breeding of commercial fish is divided into stages, each of which is characterized by its own characteristics. In the ChRZ workshop, the breeding technology, for example, of Oncorhynchus keta (incubation, aging and rearing) is as follows (Tyaptirgyanov, 2016):

1. Pre-incubation of eggs was carried out at a temperature of 2-3 ° C, since the content of eggs above 3.5 ° C led to increased mortality and the appearance of a fungal disease (saprolegnia);

2. The hatching of embryos took place at the beginning of January, and already in the first ten days of January, the larvae were transferred to the stage of holding, the so-called "dormant" stage;

3. The rearing of the larvae in the pools was a little over 3 months. At this stage of development, they fed on the yolk sac. During the holding period, the larvae showed up to 30% of the mortality, and also ugly forms (2 heads, 2 tails, etc.) were found;

4. The content of larvae in the basins lasted until the end of June due to the late melting of ice on the northern rivers;

5. Trout feed was used to raise the larvae to the fry stage. It turned out that the larvae ate the food produced by the German company well, and the food produced in Russia was very weak;

6. Transportation of Oncorhynchus keta to the place of stocking was carried out by air. At the same time, standard plastic bags with a stocking density of 500 pieces per bag were used to transport the fry.

In total, more than 400 thousand fry were raised at the ChRZ. They were released in the basins of the Vilyuy, Yana, Indigirka, Kolyma, Lena, Olenka, Anabar and Aldan rivers.

During the acclimatization process, it was established:

1. Spawning migration of Oncorhynchus keta occurs only in those rivers where fry were released. Its spawning course becomes more and more intensive every year, and this fish can become a commercial species. Spawning migrations take place along all river beds, and its greatest distance reaches 2000 km;

Table 5. Data on the incubation of eggs and the rearing of juvenile Oncorhynchus keta in the workshop of the Chernyshevsky fish hatchery in different years.

Indicator	Year of release of juvenile fish			
	2000	2001	2002	2003
Total amount of caviar	200	100	200	100

(thousand pieces) from Sakhalin				
Pre-incubationofeggs	09.12.09-06.01.00	30.11.00-03.01.01	06.12.01-07.01.02	08.12.02-09.01.03
Water temperature during incubation and holding until the stage of melting	4 °C. After 5 days up to 2-3 ° C	2-3 °C	2-3 °C	2-3 °C
Hatch	06 - 09.01	03 – 07.01	07 – 09. 01	05 – 09. 01
Time to float and start feeding	04 – 05.04	09 – 10.04	03. 04	05. 04
Feeding period	05.04-27.06 8 times a day	10.04-28.06 6 times a day	03.04-8.06 6 times a day	05.04-28.06 6 times a day
Discharge of eggs and larvae,%	49	20	25	20
Number of juveniles, thousand pieces	101,2	80,0	150,0	80,0
Stockingriversites	Lena river Anabar river Olenek river Indigirka river Kolyma river Yana river	Lena river Aldan river Vilyuy river Anabar river Indigirka river Yana river	Lena river Kolyma river	Vilyuy river

2. The most suitable reservoirs for the acclimatization of Oncorhynchus keta turned out to be the Kolyma, Indigirka and Yana rivers, to a lesser extent the Lena river, where it can rise to the Undyulyung river. In other water bodies of Yakutia: the rivers Vilyuy, Aldan, Olenek and Anabar - the acclimatization of Oncorhynchus keta can lead to drastic restructuring of existing ecosystems towards simplification of biological diversity, due to individual elements of the geosystems of basins polluted as a result of prolonged anthropogenic impact, landfills of solid municipal waste, agricultural and transport infrastructure facilities, etc., as was observed in other places in Russia (Petrechenkova, et-al 2020; Petukhov, et-al 2019. , Polyakov, 2017; Skripkina, 2019;Troyanskaya, et-al 2017;Fashevskaya, et-al 2020;Lapteva, 2019);

3. The spawning stock of Oncorhynchus keta on the Kolyma River has an average age of 3 + -6 + years, the most productive are fish of the age group 5 + -6 + years. This age group made up about 70% of the spawning stock;

4. In 2020, the dimensions of the entering Oncorhynchus keta (ac) were 55-77 cm, weighing from 2 to 6.2 kg;

5. The spawning run of Oncorhynchus keta in the Kolyma River began on August 20 and ended on November 8 at a water temperature of 3-4 ° C;

6. Established a spawning site for Oncorhynchus keta on the Kolyma River - the mouth of the Mangazeyka River. It can also rise above the cascade of the Seimchan hydroelectric power station in the Magadan region. Spawns on stretches with small pebble soil. Fecundity of females ranges from 1980 to 5110 eggs. After spawning, producers die;

7. Breeding of the Far Eastern Oncorhynchus keta in the water bodies of Yakutia proved to be effective for the development of the fisheries of the Republic of Sakha (Yakutia). This work should be continued and the formation of a new direction - managed salmon farming - should be started.

It was shown that the main food of juvenile chum salmon was the older copepodites Neocalanus ssp. and Pseudocalanus spp., which accounted for 78% of the total mass of zooplankton in the surface water layer up to 10 m. The identified local feeding characteristics of juveniles are associated with the specificity of the formation of zooplankton at different shores and may periodically repeat, and this circumstance should be taken into account when assessing the receiving capacity of the coastal area and planning the construction of fish hatcheries (Chebanova, Frenkel et al.,2018).

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