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Creation of trout farms on the basis of power plant water cooler reservoirs

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Abstract. Increase of production of fish by traditional methods, based primarily on the extensive use of natural resources, has certain natural limitations. The limiting factors are land, water and the environment. Considering this fact, the perspective expansion of industrial farms, provided with superintensive technologies, is actual. The role of abiotic environmental factors in the life of fish is enormous. For example, the water temperature determines the intensity of metabolism and is a natural stimulus determining the beginning of spawning migration of fish. Water temperature has a very important influence on the life of the organism, particularly on the metabolic processes, the behavior and dispersion of organisms. Water quality is one of the most important factors stimulating the development of water biotechnology. In this regard, we explored the physical and-chemical features of the Volga water from the viewpoint of the trout-breeding. The analysis revealed that the water does not fully meet the required water quality for trout ponds. Characteristics as pH, absence of hydrogen sulfide meet the requirements; such indicators as permanganate and bichromate oxidation, BPK5, ammonium ion, nitrates and nitrites, oxygen content are noted exceeding the standard values for trout farms. Power engineering and fish farming are connected closely – power plants contribute to the creation of favorable conditions for the cultivation of commercial fish, including valuable and fish-breeding complexes based on water coolers help to improve their environmental condition. At the same time in Russia in recent years, this industry is beginning to receive attention it deserves. The experience of Western countries shows a new direction of the industry development: in the previous period the favorable conditions for growing and breeding fish were created on the basis of the warm water for increasing production capacity of energy enterprises due to energy production and fish production, nowadays the power plants are built at fish-breeding enterprises in order to optimize costs and increase profitability of fish production.

Introduction

In the context of the ever-growing global demand for food, fish farming comes to the fore in the field of providing the population with animal protein. In the ecological sense, fish farming is a more productive way of getting animal protein, as fish use feed for growth more effectively than farm animals. The annual growth in the fishing industry for about two decades is caused by aquaculture, as the volume of fish caught only decreases.

Increasing the production of fish by traditional methods, based primarily on the extensive use of natural resources, has certain natural limitations. The limiting factors are land, water and the environment. Considering this fact, the perspective expansion of industrial farms, provided with



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superintensive technologies, is actual. These is especially true for fish-breeding systems with a closed cycle of water supply, allowing for year-round cultivation of all types of aquaculture, regardless of climatic conditions, achieving maximum growth and productivity rate while conserving resources and keeping environmental cleanliness of the production process [1].

The role of abiotic environmental factors in the life of fish is enormous. For example, the water temperature determines the intensity of metabolism and is a natural stimulus determining the beginning of spawning migration of fish. Water temperature has a very important influence on the life of the organism, particularly on the metabolic processes, the behavior and dispersion of organisms. The highest concentration of fish is observed in the areas of contact between cold and warm flows - where frontal zones are formed.

Fish is highly dependent on the ambient temperature. For most fish body temperature is only 0.5-1°C different from the temperature of the surrounding water. The water temperature affects the change in the intensity of metabolism and is the main reason determining the beginning of such processes as spawning, migration, wintering, etc. In addition, the water temperature changes have big impact on the growth and development of fish.

Rainbow trout is one of the most promising aquaculture objects, but in Russia the growth rate of commercial trout production is significantly behind foreign ones. Including for this reason, about 90% of the red fish consumed in Russia is imported.

The development of trout farming in the Republic of Tatarstan is particularly relevant from the point of solving the problems of import substitution and providing the region population with high-quality fish products. There are some objective preconditions for it. Back in 1915, in the summary of M. Somov, the existence of two trout farms with a total area of 9.8 hectares located on the territory of the Kazan province was indicated. During this period, in the region were cultivated: American Palia; river trout; rainbow trout; whitefish and salmon[2].

Water quality is one of the most important factors stimulating the development of water biotechnology. In this regard, let's explore the physical-chemical features of the Volga water from the viewpoint of the trout-breeding.

Results and discussions

The quality of water as an important section of trout fish farming development in Middle Volga region.

Geographical zoning in the Volga cascade reveals itself in the change of a number of abiotic characteristics: increase in transparency and general mineralization from North to South, decrease in color and suspended solids. These patterns are broken on the area of the Middle Volga, which is characterized by high anthropogenic impact [3]. The Volga basin accounts for more than a third of Russia's wastewater discharge.

Volga is usually divided into three main parts – Upper, Middle and Lower. The border between the Upper and Middle Volga is the confluence of the river Sheksna in Rybinsk city. The border between the Middle and Lower Volga river passes through the Volga hydroelectric dam [4].

The Middle Volga region is rich in water resources. There are such large rivers as Volga, Kama, and their tributaries: Vyatka, Sviyaga, Mesha, Sesma, Ik, Toyma, Izh, Stepnoy Zay, Kuibyshev and Nizhnekamsk reservoirs, lakes and complex purpose irrigation reservoirs. Kuibyshev reservoir – lake-reservoir - is the largest in Europe - 6450 km² [4,5]. In recent years, the waters of the Kuibyshev reservoir are estimated as «moderately polluted». The main pollutants are copper compounds, petroleum products, phenols and others [6]. The water quality is influenced by the transfer of polluted water from the upper reaches of rivers flowing into reservoirs, as well as the discharge of insufficiently treated wastewater from industrial enterprises. Because of the surface water quality deterioration, there are problems not only of its purification by physical and chemical methods, but also by biological methods [7-9].

Requirements for the quality of water entering the trout farms ponds are presented in the Table 1.

Table 1 presents the requirements to the quality of water entering the trout ponds. It shows the data of the chemical quality of water at the test sites of the Volga reach of Kuybyshev water reservoir, that has the highest preserved fluvial regime of the Volga river and chemical quality of water of small rivers of the Kama basin. The authors studying the small rivers water quality are noting that the maximum permissible concentration (MPC) of harmful substances in this water is almost never seeing, a high total iron content is typical for natural waters of the region [14]. Water quality in the Volga river, according to different authors, is given in Table 2.

As can be seen from the data above (Table 1, 2) the water of Volga river in the region of the Middle Volga and small rivers of the Kama basin does not meet required water quality for the trout ponds. Such characteristics as pH, absence of hydrogen sulphide are meeting the requirements; such indicators as permanganate and dichromate oxidability, BOD₅, ammonium ion, nitrates and nitrites recognised as regulatory for trout farms.

Table 1. Requirements for the quality of water entering the trout farms in comparison with the quality of natural surface waters.

Characteristic	Regulatory values for trout ponds	Control plot Volga reach Kuibyshev reservoir [11]	Kama pool small rivers [14]
Transparency, m	1.5	-	-
pH	7.0-8.0	-	7.45-8.1
Suspended solids, mg/dm ³	Less than 10	-	0.129-0.263
Oxygen dissolved, mg/ dm ³	Not less than 9.0	7.53±0.75	-
Free carbon dioxide, mg/ dm ³	10.0	-	-
Hydrogen sulfide, mg/L	absense	abs.	-
The permanganate oxidability, mg O/dm ³	10.0	8.9±0.89	-
Dichromate oxidability, mg O/dm ³	30.0	50±12	-
Indicator biological oxygen (BOD ₅), mg O ₂ /dm ³	2.0	1.08±0.28	1.5-2.5
Ammonium ion, mg/dm ³	0.5	0.2±0.07	0.05-0.07
Nitrates, mg/dm ³	1.0	0.5±0.0	3.9-4.5
Nitrites, mg/dm ³	0.02	0.02±0.0	0.43-0.59
Phosphates, mg/dm ³	0.3	0.05±0.01	0.68-0.80
Total iron, mg/dm ³	0.1		0.42-0.61

Table 2. Water quality in Volga river.

Characteristic	Volga river [4]	Volga river above Kazan [6, 15]	Volga river 2 km below Ulyanovsk [12]	Volga river near Astrakhan [13]
Transparency, m	0.90-2.10			29-30
pH	7.87-8.96	6.9-7.0	6.78-8.0	7.83-7.87
Suspended solids, mg/dm ³		9.76-12.0	2.3-12.0	20.5-23.5
Oxygen dissolved, mg/dm ³	7.1-13.6	7.6-9.8	9.2-10.3	7.9-10.2
Hydrogen sulfide, mg/L	-	-	-	-
Perm. the oxidability, mg O/dm ³	7.1-10.1	8.8-11.4		4.4-7.89
Dichromate oxidability, mg O/dm ³		25.5-31.4		34.5-43.74
BOD ₅ , mg O ₂ /dm ³	1.2-7.8	1.1-1.4	3.22-3.50	1.17-1.55
Ammonium ion, mg/dm ³	0.17-1.50	0.32-0.45	0.198-0.354	0.395-0.401
Nitrates, mg/dm ³	0.3-2.9	0.3-0.48	0.285-0.382	1.24-3.795
Nitrites, mg/dm ³	0.03-0.15	0.01-0.6	0.047-0.054	0.044-0.051
Phosphates, mg/dm ³	0.016-0.28	0.07-0.10	0.050-0.110	-
Total iron, mg/dm ³	0.03-0.05	0.04-0.09	0.12-0.21	0.255-0.315

A similar situation is observed in water quality of small rivers of the Kama basin (Table 1) indicators: such characteristics as pH, absence of hydrogen sulphide meet the requirements; for trout farms of the values indicators such as BOD₅, nitrates and nitrites, phosphates and iron marked with regulatory.

Heat-water fish farming experience

The fish farming use of warm water is one of the fish farming types closely related to the energy complex. It includes a set of activities to improve the efficiency of hydrobionts cultivation by optimizing the conditions of cultivation and growing through using warm water waste of heat power plants (HPP) and nuclear power plants (NPP). This method of fish farming is actively practiced in Germany, Poland, Japan, USA and in a number of other countries. Fish farms on warm waters do not depend on natural and climatic conditions, the growing season lasts all year round. Thus, the efficiency of fish farming significantly increases, including through the use of cooling water bodies it is possible to supply fish farms with larger and more resilient young fish.

The development of fish farming in warm waters refers to the end of the 1960s, when fish began to grow in cages and pools at 8 condenser and heat power plants in Russian Federation, two condenser power plants in Kazakhstan and Belarus, 5 energy facilities in Ukraine, as well as in Lithuania, Moldova and Uzbekistan. In total at 21 condenser and heat power plants [15]. Rainbow trout is among the main objects of cultivation. Back in the USSR, there were more than 200 thermal power plants with an area of cooler reservoirs of 140 thousand hectares, by 1990 it was 1 million hectares, with more than 4 billion gigacalories of heat per year discharged into reservoirs [16].

Thereafter, fish farming on warm waters arose and formed into an independent direction of modern aquaculture in Russia, going from the first experiments to the development of scientific foundations and the creation of fish farms with controlled temperature regime. The relevance of this direction is primarily due to the lack of heat in most of the territory of our country, which prevents the effective reproduction and cultivation of the main objects of domestic fish farming [17].

Nowadays, the biological melioration of cooling water from thermal power plants and nuclear power plants has become important for both power engineers and fish farmers. Heat loads and eutrophication of such water increase, as a result of which the amount of oxygen in the area of farms decreases, the intensity of zooplankton development increases, which leads to disruption of the power plants cooling systems. Directly in the water cooling reservoirs herbivorous fish can be bred: white and black Amur, white and motley carp, which not only have valuable biological qualities, but also are biological «meliorators». They purify the water from water plants and biofouling.

Power engineering and fish farming are connected closely – power plants contribute to the creation of favorable conditions for the cultivation of commercial fish, including valuable, and fish-breeding complexes based on water coolers help to improve their environmental condition.

It is necessary to take into account the experience of other countries for the development of this technique of fish farming. The experience of some European countries is interesting in this regard. For example, in Turkey, in a country with a mild climate and, as a result, the absence of problems with maintaining stable conditions of the water environment, there is also a practice of growing fish in warm waters of cooling ponds. KonyaSeker Corporation, which owns a giant food production (animal products, sweets, vegetable, plant) uses its own power plants in order to optimize its production [18]. They decided not to cool the condensed water, but to fill the pools for the cultivation of valuable fish - Tilapia with it. Such production is waste-free, as the feces from these pools are processed and used as fertilizer on the KonyaSeker plantations for vegetable and crop production. Since the Corporation is also engaged in the production of its own combined fodder, the profitability of such enterprise should be impressive. This production can be attributed to the energy-biological complexes, where priority is given to the production of food products.

Species and breeds of rainbow trout are promising among the objects of cultivation, for which temperatures of about 25°C are suitable, the possibility of active growth of fish in winter is especially important.

In Western Europe, where, unlike Russia, there are not so many power plants in absolute numbers, the relationship between aquaculture and electricity is carried out in a different way. For example, in Mecklenburg (Germany) for the supply of recirculation system for the cultivation of African catfish, solar thermal power plant has been assembled, which was developed by a unique technology Solarlite [19]. The optimum temperature for African catfish cultivation is considered 26°C [20]. At this fish farm, such temperature is maintained around the clock throughout the year, which makes it possible to obtain the maximum possible volume of production of the African catfish.

Conclusions

Power engineering and fish farming are not only mutually beneficial in their interaction, but also constantly develop, finding more and more points of contact. In the previous period the favorable conditions for growing and breeding fish were created on the basis of the warm water for increasing production capacity of energy enterprises due to energy production and fish production, nowadays the power plants are built at fish-breeding enterprises in order to optimize costs and increase profitability of fish production

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