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# Pasture and industrial aquaculture as actual elements of the use of hydro and heat power facilities

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**Abstract.** Aquaculture products provide about 58% of the total production of aquatic ecosystems. The global trend of population growth, increasing the press on the environment, the requirements for improving the quality of life and consuming products make the trend of growth in aquaculture products sustainable both in the world and in Russia. The role of abiotic environmental factors in the life of fish is enormous. Thus, the water temperature determines the intensity of metabolism and is a natural stimulus determining the onset of spawning migration of fish. The water temperature has a very important effect on the vital activity of the organism, in particular, on metabolic processes, on the behavior and distribution of organisms. Since the beginning of the 20th century, aquaculture has been closely linked to the development of energy. At the first stage - with hydropower, and then with thermal power. If the use of water reservoirs - hydropower facilities is based on extensive technologies that are related to pasture aquaculture, aquaculture farms - live fish farms - highly intensive industrial farms. These areas of aquaculture development coexist and complement each other. Modern pasture fish farming today is not possible without the release of valuable species of fish to form a species composition of ichthyocenoses. At the same time, the development of highly industrial commodity farms implies the use as a brood of individuals of valuable species of fish seized from the natural environment to improve the genetic characteristics of juveniles. At the present time, there is an increase in the range of fish grown due to the use of warm waste waters of energy facilities.

## Introduction

Aquaculture currently belongs to globally significant world production [1, 2]. Currently, more than 600 species of animals and plants are grown both in monoculture farms and in multicultural production with a very high degree of intensification. Aquaculture products provide about 58% of the total production of aquatic ecosystems. The global trend of population growth, increasing the press on the environment, the requirements for improving the quality of life, and consuming products make the trend of growth in aquaculture products sustainable both in the world and in Russia. Since the beginning of the 20th century, aquaculture has been closely linked to the development of energy [3, 4].

## Results and discussions

### Pasture aquaculture at hydropower facilities

In 1931, the working hypothesis of a comprehensive scheme for the use of the Volga for energy and transport purposes was developed, various projects for the construction of hydroelectric power stations were put forward, however, among them there were no projects that took into account the



whole complex of problems that were considered in the complex scheme for the use of the Volga. In the subsequent period, the problem of the “Great Volga” was solved by creating a cascade of reservoirs: the Upper Volga (1944), Ivankovsky (1937), Uglich (1939-1943), Rybinsk (1940-1949), Gorky (1955-1957), Cheboksary (1981), Kuibyshev (1955-1957), Saratov (1967-1968), Volgograd (1958-1960 gg.), Kamsky (1954-1956 gg.), Votkinsky (1961 -1964 gg.), Nizhnekamsk (1978) [1]. The catches in the largest reservoirs of the Volga cascade in the early 21st century are shown in Table 1 from [5].

**Table 1.** Fish catches in the largest reservoirs of the Volga cascade, ths. tons.

| Reservoir | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|-----------|------|------|------|------|------|------|------|------|------|
| Rybinsk   | 1.4  | 1.5  | 1.6  | 1.7  | 1.0  | 1.3  | 1.04 | 1.0  | 1.1  |
| Kuibyshev | 3.2  | 2.8  | 2.7  | 2.7  | 2.0  | 1.94 | 2.11 | 2.62 | 2.7  |
| Saratov   | 0.8  | 0.5  | 0.7  | 0.8  | 0.6  | 0.67 | 0.6  | 0.69 | 0.7  |
| Volgograd | 1.0  | 1.0  | 1.3  | 1.3  | 1.5  | 1.69 | 1.72 | 2.17 | 2.05 |

At the stage of planning the construction of reservoirs, they were expected to be used by pasture aquaculture methods (Table 1, 2). For this purpose, hatcheries and spawning-vigorous farms were built, which were to ensure the directional introduction of valuable fish species. When planning fish catches in the Kuibyshevsky reservoir, the main attention was paid to bream, carp, pike perch, pike and sturgeon fishes (Table 2) [4]. The remaining species had to provide 30% of catches.

The planned catch volumes in the Kuibyshev Reservoir and the actual state of the fish herd structure are shown in Table 2.

**Table 2.** The planned catches of fish in the Kuibyshev reservoir in connection with hydro-construction in the 1950s and the current state of the catch.

| Period | Catch,<br>ths. tons | Fish species (% in catch) |      |           |      |          |       |
|--------|---------------------|---------------------------|------|-----------|------|----------|-------|
|        |                     | Bream                     | Carp | Pikeperch | Pike | Sturgeon | Other |
| 1950s  | 20-24               | 35                        | 15   | 10        | 8    | 2        | 30    |
| 2017   | 3.438               | 22.85                     | 0.84 | 6.52      | 0.56 | 0.17     | 69.06 |

In the construction of hydroelectric power plants, simultaneously with the solution of the tasks of supplying electricity to the production sector of the economy, the foundations of the ecological problems of the day, connected both with changes in the hydrological and hydrochemical characteristics of the reservoir. These problems can be solved by aquaculture methods.

The current state of catches in comparison with the planned indicators is presented in Table 3. Data on catches indicate an increase in the proportion of low-value fish in the recent period. If in 2010 low-value species accounted for 53.4% in catches, in 2014 for 64.8%. Analyzing the planned indicators for catches in the Kuibyshev reservoir, it can be noted that the planned harvest of sterlet was 480 tons. Actual catches of sterlet in the beginning of the XXI century varied about 0.850 tons.

**Table 3.** Catches (%) of valuable and low-value fish species in the Kuibyshev Reservoir.

| Species | 2010                    | 2014 | Quotas<br>2017 г. | Species           | 2010                     | 2014 | Quotas<br>2017 |
|---------|-------------------------|------|-------------------|-------------------|--------------------------|------|----------------|
|         | % in catches            |      |                   |                   | % in catches             |      |                |
|         | <i>Valuable species</i> |      |                   |                   | <i>Low-value species</i> |      |                |
| sterlet | 0.04                    | 0.02 | 0.17              | Blicca bjoerkna   | 16.7                     | 17.2 | 22.31          |
| carp    | 1.59                    | 1.23 | 0.84              | Ballerus ballerus | 11.3                     | 14.4 | 16.99          |

|             |       |      |       | Ending of Table 3 |     |      |      |
|-------------|-------|------|-------|-------------------|-----|------|------|
| catfish     | 0.57  | 0.19 | 0.26  | Rutilus           | 9.1 | 12.0 | 7.50 |
| pike perch  | 5.82  | 5.38 | 6.52  | Pelecus cultratus | 4.8 | 5.1  | 3.40 |
| pike        | 0.80  | 0.11 | 0.56  | Sander            | 2,9 | 3.1  | 3.32 |
|             |       |      |       | volgensis         |     |      |      |
| burbot      | 0.24  | 0.31 | 0.46  | Perca fluviatilis | 2.5 | 5.1  | 4.13 |
| bream       | 31.06 | 23.7 | 22.85 | Carassius         | 3.0 | 4.5  | 2.33 |
| silver carp | 0.08  | 0.07 | 0.06  | Abramis           | 3.1 | 3.4  | 5.09 |
|             |       |      |       | alburnus          |     |      |      |
|             |       |      |       | Clupeonella       |     | 2.93 | 1.54 |
|             |       |      |       | Aspius aspius     |     | 0.60 | 0.73 |
|             |       |      |       | Leuciscus idus    |     | 0.36 | 0.47 |
|             |       |      |       | Cyprinidae        |     | 0.45 | 0.47 |

The tendency of decline in the number of valuable fish species in the Kuibyshev reservoir was clearly revealed by the 2000s [2, 4, 6] (Table 3). In the catches it was noted not only an extremely small number of sterlets, but also pike, catfish and others (Table 3), at the same time the number of low-value and weedy species of fish has grown. If the statistics of catches revealed only a decrease in the number of valuable commercial fish species, the 1999 survey of amateur fishermen revealed an increase in the share in catches of silver crucian, rotan, gobies. For example, in the Mesha river the number of silver crucian was estimated as 6% in catches, and as much zope (*Ballerus ballerus*) and sabrefish (*Pelecus cultratus*) [6]. The average annual catch in the Kuibyshev Reservoir within the Republic of Tatarstan for amateur fishermen was  $269 \pm 60$  tonnes, the average annual catch of poachers was  $2504 \pm 93$  tons [4]. It was shown that the catch of fish from the reservoirs of the Republic by amateur fishermen and poachers is 1.8 times higher than its catch by fishing organizations. In 1989, the catch was 5981.1 tons, in 1994 - 2619.7 tons, in 2005 - 2114.2 tons, in 2008 - 3140.2 tons. In the last period, the total catch of fish in the Kuibyshev Reservoir is 3,093.5 tons (2010) - 4196.8 tons (2014). Analysis of data on catches clearly demonstrates a decrease in the catches of valuable fish species, including sterlet, which is currently included in the Red Book of the Republic of Tatarstan. There is little carp, catfish, pike, burbot and pike-perch in the catches (Table 3). The share of bream in catches also decreases. Especially it should be noted an extremely small amount of silver carp. As bioremediators, it is most beneficial to improve the state of the ecosystem of the reservoirs of the central Russia, by releasing silver and bighead carps. Evaluation of the production potential of the Kuibyshev reservoir confirms the possibility of releasing silver carp in the reservoir with a density of planting 100 pc / ha in high productivity zones. Directed ichthyofauna formation is the most effective in the long term to maintain high water quality while simultaneously addressing the problems of maintaining a high number of valuable fish species. Since the share of benthophagous fish accounts for 12.7% of potential fish products, carp is no longer the best target for the work on the directed formation of the ichthyofauna. Sturgeon producing factories, established in the 1950s to compensate for the loss of natural spawning grounds of sturgeon on the Volga in connection with hydroelectric construction, over the years of its existence, released into the river more than 2.7 billion exemplars of young sturgeon. This indicates that a powerful sturgeon industry has been created in Russia. Since 1990, the production of sturgeon juveniles has declined and has now reached a minimum.

The crisis of sturgeon farming at the end of the 20th century, the reduction of broodstock in the Volga River in connection with the reduction of spawning grounds and the demand for high costs for the reproduction of valuable species, while regulating their numbers in reservoirs, stimulated the development of aquabiotechnologies. These problems served as an impetus to the solution of scientific and technological problems: the development of methods for pituitary injection with the replacement of the pituitary hormone for a wide range of gonadotropic drugs, the lifetime determination of stages of puberty of gonads [7], ultrasound - diagnosis, lifetime caviar receiving. In

recent years, the most effective method of selecting ovulated caviar from sturgeon is the method of incision of oviducts with subsequent pouring of eggs [8]. This least invasive microsurgical method has been used for more than 20 years, and many females of different sturgeon species have been subjected to a pouring procedure more than seven times.

The development of aquabiotechnologies and the reduction in the catches of valuable fish species in virtually all water bodies stimulated the development of industrial commercial aquaculture, which is interfaced with energy facilities.

#### Industrial aquaculture on warm waters of energy facilities

In Russia, the dominant variants of commercial breeding of fish, including sturgeon, are pond, cage and breeding in closed water circulation installation (CWCI). In the 1970s-1990s, the country's industrial fish farming was created on the basis of cage farms on cooler reservoirs of power facilities in the structure of thermal power plants, nuclear power plants, and hydroelectric power stations, which had warm water in excess. Such farms functioned practically in all regions. Output of commercial products from one square meter of basins and cages reached 100-150 kg per year. The total production of commercial fish exceeded 30 thousand tons per year [9].

In the middle zone of Russia at the end of the 20th century, industrial fish farming: trout breeding and sturgeon breeding was based on the use of floating cages in reservoirs, which were stocked by whitebait weighing 3-5 g [10]. The most successful of sturgeon was a bester on the basis of cooler reservoirs of the state district power stations, which reached in the third year a mass of 0.85 kg. For example, it was successful to grow a bester in cages on the discharge channel of Novocherkasskaya GRES.

Methods of cage culture by the beginning of the 21st century were replaced by the cultivation methods in the CWCI. This was due to the possibility of complete control of habitat, mechanization of fish-breeding processes, reducing the impact on the environment [10, 11].

Commercial living fish factories of open or closed type of various capacities were built on the exhausted waters of the state district power stations, for example at Konakovskaya GRES - a closed type with a capacity of 360 tons of commercial fish per year (Table 4). At present, the term of use of warm waters of thermal power stations for fish farming can range from four to twelve months (live fish farms, cage farms, cooling ponds). Such enterprises allow the most efficient use of warm water from TPPs in any water supply system of a power plant irrespective of its geographic location. In the pools, commercial fish are grown with high density, strong flow of warm water and intensive feeding with artificial feeds.

**Table 4.** Fish farms at energy facilities.

| Power station      | Fish farm                                         | Farm type / tonnage                                            | Grown objects                                                                                      |
|--------------------|---------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Konakovskaya GRES  | Konakovsky factory of commodity sturgeon breeding | Basins / 360 tons                                              | Sturgeon; sterlet, beluga, bester                                                                  |
| Karmanovskaya GRES | Karmanovskiy fish farm                            | Cages / 1200 t carp, 150 t sturgeon, 150 t trout.              | Carp, white amur, silver carp; sturgeon, bester, sterlet; rainbow and gold trout; channel catfish. |
| Belovskaya GRES    | Belov fish industry                               | Cages / 1000 t                                                 | Carp, white amur, silver carp, carp koi, trout, sturgeon, channel catfish                          |
| Cherepovets GRES   | LLC "Fish Company "Diana"                         | Cages, basins / 1000 t carp, 400 t sturgeon, 20 t black caviar | Beluga, sturgeon, sterlet, stellate sturgeon                                                       |

Ending of Table 4

|                         |                                                        |                                                                      |                                                              |
|-------------------------|--------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------|
| Cherepovets<br>GRES     | LLC "Fish<br>Company "Diana"                           | Cages, basins / 1000 t<br>carp, 400 t sturgeon,<br>20 t black caviar | Beluga, sturgeon, sterlet,<br>stellate sturgeon              |
| Nazarovskaya<br>GRES    | LLC "Nazarovo<br>Fish Farm"                            | Cages, incubation shop<br>/ 170 t                                    | Carp, carp koi, channel catfish,<br>sturgeon, trout          |
| Permskaya GRES          | LLC "Dobryansk<br>Fish Center"                         | Basins, incubation<br>shop / 1650 t                                  | Carp, sterlet, sturgeon, beluga,<br>stellate sturgeon, trout |
| Pechora GRES            | LLC<br>"Aquacomplex"                                   | Cages, incubation shop                                               | Lena sturgeon, sterlet, rainbow<br>trout                     |
| Sredneuralskaya<br>GRES | LLC ACE<br>"Sredneuralsky<br>fish-breeding<br>complex" | Cages (winter), basins<br>(summer), incubation<br>shop / 200 t       | Carp, white amur, silver carp,<br>sturgeon, trout            |
| Mainskaya GRES          | LLC "Sayan trout"                                      | Cages / 300 t                                                        | Trout                                                        |
| Kursk NPP               | Kurchatov                                              | Cages                                                                | Carp, carp koi, black and white<br>amur, silver carp, shrimp |
| Ust-Ilim CHPP           | "Fishery of Ust-<br>Ilimsk CHPP"                       | Basins, incubation<br>shop / 600 t                                   | Carp, silver carp, sturgeon,<br>тиляпия, trout, omul, peled. |
| Krasnodar CHP           | LLC "Kuban<br>Institute of<br>Sturgeon"                | Cages                                                                | Sturgeon, sterlet, beluga,<br>stellate sturgeon              |

Thus, the effective use of waste warmed-up waters, the utilization of secondary energy resources by aquaculture methods in the context of the need to ensure food security and human health are of particular relevance.

## Conclusions

The development of energy and the creation of reservoirs led to the need for work on the formation of ichthyocenoses and the development of pasture aquaculture. At the same time, incentives were laid for the improvement of aqua-biotechnologies for the artificial production of eggs and juveniles of various fish species, which served as an impetus for the development of industrial forms of commercial fish farming: cage, basin, the use of installations with a closed cycle of water supply. These areas of aquaculture development coexist and complement each other. Modern pasture fish farming today is not possible without the release of valuable species of fish to form a species composition. At the same time, the development of highly industrial commodity farms implies the use as a brood of individuals of valuable species of fish seized from the natural environment to improve the genetic characteristics of juveniles. At the present time, there is an increase in the range of fish grown due to the use of warm waste waters of energy facilities.

## References

- [1] FAO 2014 The State of World Fisheries and Aquaculture. Opportunities and challenges
- [2] Bartley D M, Brugere C, Soto D, Gerber P and Harvey B 2007 Comparative assessment of the environmental costs of aquaculture and other food production sectors: methods for meaningful comparisons *FAO Fisheries Proceedings* **10** 241
- [3] Kalayda M L 2001 *History and prospects of development of the fish industry of Tatarstan* (Kazan: Matbugat Yorty) p 96
- [4] Kalayda M L 2017 the tasks of aquaculture development in the republic of tatarstan at the present stage *Fish farming and fisheries* **8(139)** 7-16
- [5] Dyomin A P 2010 Water management complex in Russia: concept, state, problems *Water*

- resources* **37(5)** 617-32
- [6] Kalayda M L 2002 The need to take into account amateur and poaching fisheries in the aquaculture of reservoirs *Aquaculture of the beginning of the XXI century: sources, condition, development strategy. Materials of the International Scientific and Practical Conference* (Moscow: VNIRO) pp 88-91
  - [7] Chebanov M S and Galich E V 2013 *Manual on artificial reproduction of sturgeon* (Ankara: The Food and Agriculture Organization of the United Nations) p 370
  - [8] Podushka S B 1986 Method for obtaining caviar from female sturgeon *Certificate of authorship USSR* 1412035
  - [9] Raspopov V M, Chipinov V G and Sergeeva U V 2007 Formation of fish stocks in market conditions *Thermal aquaculture and biological productivity of arid climate basins* (Astrakhan: AGTU) pp 85-6
  - [10] Mikheev V P 1982 *Cage culture of marketable fish* (Moscow: Light and food industry) 216
  - [11] Filatov V I, Dokukina K N and Petrov F A 2002 *Fish farming in closed systems* (Dmitrov: The North of Moscow region) **2(III-IV)** 100-2