Aquaculture in The World and Russia: State and Prospects

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Abstract. The consumption of fish and seafood occupies a significant place in the world's supply of food to the population. According to FAO, fish accounts for 17% of animal protein in the diet of the world's population and 7% of all protein consumed. The consumption of fish products is also growing against the background of the active development of aquaculture. The subject of the study is aquaculture in the world and in Russia, the purpose of the work is to analyze the state and generalization of the Russian experience, as well as measures and tools to support the development of the industry. In the preparation, statistical information from FAO, state statistics of Russia, statistics from scientific institutions of the Russian Academy of Sciences, scientific monographs, and scientific papers were used. To achieve this objective, the global and domestic state of the aquaculture industry, as well as measures and instruments of the state, federal, and non-state support provided to producers were analyzed.

1. Introduction

Aquaculture is a type of activity for breeding, keeping, and raising fish, other aquatic animals, plants, and algae to be carried out under full or partial human control to obtain marketable products, replenish commercial stocks of aquatic biological resources, and preserve their biodiversity and recreation [1]. With a decrease in the commercial fish production size and an increase in the world's population, it is possible to saturate the consumer market with fish products using aquaculture. Aquaculture is actively developing in many countries as a separate sector according to FAO being present in the economy of 202 countries and territories. The development of aquaculture is facilitated by an increase in the world's population, a decrease in the production of commercial fish, and an increase in the efficiency of cultivation of aquaculture facilities associated with selection and breeding work and industrial production technologies. According to FAO, farmed biological objects already account for more than half of the world's total food fish. The increase in the world's population dictates the need for the transition of agriculture to intensive forms of production and the production of ever-larger amounts of food. By 2050, according to FAO, it will be necessary to provide food for more than 9 billion people on Earth, i.e. 60% more food will be needed to be produced than it is currently produced [2].

Quantifying targets will clarify the scale of the challenges agriculture must face in the coming decades, focus research and policy on delivering results, and ensure that sustained intensification efforts lead to measurable environmental improvements [3]. The consumption of fish and seafood occupies a significant place in the world's supply of food to the population. According to FAO, fish accounts for 17% of animal protein in the diet of the world's population and 7% of all protein consumed. Against the background of the active development of aquaculture, the consumption of fish products is also growing. In the period from 1961 to 2016, the growth rate of fish consumption in the world (3.2%) exceeded the growth rate of the world's population (1.6%) and showed an increase higher than the consumption of other types of meat. Per capita, fish consumption increased from 9.0 kg in 1961 to 20.5 kg in 2018. In
addition to production growth, other factors contributed to the increase in consumption, including the reduction of losses and production waste [2, 4].

Fish and seafood as a key element are included in the diet of most coastal countries, including Japan, Norway, Denmark, and Southeast Asian countries. Fish products are significantly consumed in the USA and China. In terms of population consumption of fish, the most economically developed countries, such as the EU countries, are significantly ahead of countries with low income and food shortages [2, 3].

According to FAO, aquaculture is one of the fastest-growing industries that can play a large role in providing the population with food. FAO monitoring confirmed that the share of fish stocks to be fished in amounts that provide biological sustainability decreased from 90% in 1974 to 65.8% in 2017 against the background of declining profitability of fisheries in the context of depletion of stocks of the main commercial fish [4].

2. Materials and methods
The materials used were the results of research by domestic and foreign scientists, information from FAO, the Federal State Statistics Service of Russia (Rosstat), scientific organizations of the Russian Academy of Sciences (RAS) and the Ministry of Agriculture of Russia, materials of state programs for the development of the agricultural sector, aquaculture, and other strategic documents. In the process of research, general methods (a method means a method of research in the broad sense) of scientific knowledge were used: analysis, comparison, generalization; special scientific methods, such as abstract-logical and economic-statistical ones, which made it possible to analyze the world and domestic state of the aquaculture industry and identify development problems.

3. Results and discussion
In 2018, the world produced 179 million metric tons of fish, of which 156 million were used for food purposes. The aquaculture sector produced 46% of the total production and 52% of all edible fish. In 2018, record levels of industrial fishing production in the entire history were achieved, which amounted to 96.4 million metric tons, i.e. 5.4% higher than the average amount over the previous three years (Table 1). Seven leading manufacturers of industrial fishery products (Vietnam, Indonesia, China, Peru, the Russian Federation, and the United States of America) supplied almost 50% of these products to world markets. The global amount of inland water fisheries production also grew annually and also reached its highest level equal to over 12 million metric tons in 2018. The amount of aquaculture production in the world amounted to 114.5 million metric tons in live weight in 2018. Between 2001 and 2018, global production of farmed aquatic animals grew at an average annual rate of 5.3%; the growth rate decreased to 4% in 2017, and it was only 3.2% in 2018. Slow growth in production in the aquaculture sector has recently been driven by a slowdown in the sector in China, the largest producer. In 2018, 51.3 million metric tons of aquatic animals were raised in inland waters or 62.5% of cultured food fish in the world (the share of aquaculture in inland waters was 57.9% in 2000). Mariculture and coastal aquaculture farms produced 30.8 million metric tons of aquatic animals in aggregate in 2018 [2, 4].

According to FAO estimates, the share of aquaculture production will be about 2/3 of the total fish consumption by 2020, while aquaculture accounted for only 1/4 of the total consumption 20 years ago. FAO experts expect global aquaculture production to surpass 100 million metric tons in 2025 and reach 102 million metric tons by 2026 [5].

The leader of the aquaculture production is China, which has been raising more fish since 1991 than all other countries in total. Besides, since 2002, China has also been the main exporter of fish and fish products. Norway ranks second in the world in terms of export size since 2004, and Vietnam is in third place since 2014 [4].

Currently, the global aquaculture market is experiencing steady growth and is predicted to accelerate in the coming years. According to the Technavio report, the aquaculture market currently valued at $180.2 billion is projected to reach $224.2 billion by 2022. The Global Aquaculture Market 2018-2022 Report forecasts that the average annual growth rate of the global aquaculture industry will be 4.12% starting from 2018, 4.50% in 2020, 4.83% in 2021, and already 5.15% in 2022. The leader in growth,
according to forecasts, will be Indonesia, which will show a growth rate of 17.24% over five years, and South Korea will show a level of 14.77%. Growth in China will amount to 3.99%, that in the USA will amount to 4.1%, in other countries, it will be 4% to 9% from 2017 to 2022 [6].

### Table 1. Production, use, and sale of fishery and aquaculture products\(^1\) (million metric tons, live weight)

| Years          | Average annual amount |
|---------------|-----------------------|
| 1986-1995     | 1996-2005             | 2006-2015 | 2016 | 2017 | 2018 |
| Industrial fishing: |                       |           |      |      |      |
| In internal waters | 6.4       | 8.3       | 10.6  | 11.4 | 11.9 | 12.0 |
| In seas        | 80.5      | 83.0      | 79.3  | 78.3 | 81.2 | 84.4 |
| Total industrial fishing | 86.9 | 91.4 | 89.8 | 89.6 | 93.1 | 96.4 |
| Aquaculture:   |                       |           |      |      |      |
| In internal waters | 8.6       | 19.8      | 36.8  | 48.0 | 49.6 | 51.3 |
| In seas        | 6.3       | 14.4      | 22.8  | 28.5 | 30.0 | 30.8 |
| Total aquaculture | 14.9     | 34.2      | 59.7  | 76.5 | 79.5 | 82.1 |
| Total world fishery and aquaculture | 101.8 | 125.6 | 149.5 | 166.1 | 172.7 | 178.5 |
| Use            |                       |           |      |      |      |
| Human consumption | 71.8      | 98.5      | 129.2 | 148.2 | 152.9 | 156.4 |
| Non-food use   | 29.9      | 27.1      | 20.3  | 17.9 | 19.7 | 22.2 |

\(^1\)Excludes marine mammals, crocodiles, alligators and caimans, marine algae, and other aquatic plants. The final figure may not coincide with the sum of the terms due to rounding.

Despite the huge variety of aquaculture subjects, the main products on a global scale are provided by several main species, which have become the most convenient and economically profitable subjects for commercial cultivation. The undisputed leader in this list belongs to fish capable of assimilating products of aquatic plants and zooplankton. These are grass carp (*Ctenopharyngodonidella*) (6 million metric tons) and silver carp (*Hypophthalmichthys molitrix*) (5.3 million metric tons), which are grown in huge quantities in the ‘traditional’ aquaculture of China. These fish make it possible to obtain cheap animal protein that successfully competes with the products of poultry farms. Another group of fish that provide inexpensive products is a species that can assimilate artificial plant food with a minimum share of animal components (2-4%): common carp (*Cyprinidscarpio*) (4.5 million metric tons), *Oreochromis Niloticus* (4.2 million metric tons), and other types of *Tilapia* species (1.2 million metric tons), crucian carp (*Carassius*) (3 million metric tons), *Catla Catla* (3 million metric tons), *Pangasiadonhypophthalus* (1.7 million metric tons), and false trevally (*Chanos Chanos*) (1.2 million metric tons) [1, 7].
Limiting factors for the development of world aquaculture are as follows:

1. Deficiency of fishmeal and fish oil: From 1995 to 2015, the production of feed in the world increased 6 times, i.e. from 8 to 48 million metric tons, and the production of fishmeal decreased 2 times, i.e. from 30 to 15 million metric tons in the equivalent of live fish. As a result, the share of fishmeal in feed for predatory fish is constantly decreasing, when it reached an average value of 24% in 2013 (65% in 1990). The fish oil content dropped to 11% (to 19% in 1990). The quality of fishmeal has also deteriorated due to the replacement of whole fish with fish processing waste. While feed formulations and feeding methods are constantly improving, fish farmers are approaching the biological limits of reducing the proportion of animal components, especially fishmeal and fish oil, in feed for predatory fish. A large number of works are devoted to the study of new sources of feed protein [7, 8].

2. Pollution of the natural environment through the fish waste exit from the fish-ponds: In addition to industrial and agricultural effluents, fish-pond sediments are very stressful for natural ecosystems. FAO views the reduction of discharges of various pollutants by 2025 as essential to the implementation of the 2030 plans to increase aquaculture production [2, 4].

3. Leaving of aquaculture subjects from commercial farms: Some species, which have become the main subjects of world aquaculture, have spread throughout the world and have caused irreparable damage to the local ichthyofauna. The United States, for example, has declared some successful world aquaculture subjects as ‘dangerous invasive species’ [silver carp (Hypophthalmichthys), grass carp (Ctenopharyngodon Idella), snakehead (Channaargus), carp (Cyprinus), crucian carp (Carassius), Sharptooth catfish (Clarias Gariepinus)], which imposes great restrictions or a complete ban on their cultivation in aquaculture. The cultivation of native fish is also dangerous for the natural environment, since leaving the fish-ponds of aquaculture individuals leads to the ‘genetic pollution’ of the populations. Besides, gone fish are a source of the spread of infections and infestations [1, 3, 8].

4. Relatively high cost of farmed fish with a low purchasing power of the population in most developing countries of the world. The exception is traditional forms of aquaculture (small family farms) with the cultivation of herbivorous fish without the use of factory pelleted feed. Due to the inaccessibility of farmed products for the majority of the population, the fish-pond aquaculture is poorly developed in African countries (except for Egypt) [2, 9-11].

It is expected that the total volume of fish production will reach 204 million metric tons in 2030, including 109 million metric tons of aquaculture production, which is 32% (26 million metric tons) more than in 2018. At the same time, the average annual growth rate of aquaculture is expected to be decreased: if it was 4.6% in 2007–2018, then it will be 2.3% in 2019–2030 [6, 8].

The Russian Federation ranks 17th in the world in the production of aquaculture (185,000 metric tons), the share of aquaculture is 4.5% of the total production and fishing. The government pays great attention to stimulating the development of aquaculture. The federal law titled ‘On aquaculture (fish farming)’ came into force on January 1, 2014, which defined this area of activity and established the legal regulation of relations in the field of aquaculture. The property rights to subjects and products, the procedure, and economic foundations for the implementation of aquaculture, the use of water bodies, and the creation of fish breeding sites on them were determined [12].

Commercial aquaculture occupies a small share in the production and economic structure of the fishery system. The pace and scale of development of commercial aquaculture in Russia lag significantly behind the level of the leading countries in this field, in particular China, Vietnam, Norway, etc. Regarding promising commercial fish farming subjects, the Russian aquaculture industry is having trouble in the supply of highly productive fish seedlings, highly efficient compound feeds, and state-of-the-art diagnostic tools intended for the prevention and treatment of diseases of aquaculture subjects, as well as special equipment and appliances for growing [1, 12].

The sectoral program titled ‘Development of commercial aquaculture (commercial fish farming) in the Russian Federation for 2015-2020’ approved for the implementation of the Federal Law on Aquaculture, the State Program for the Development of Agriculture and Regulation of Markets for Agricultural Products and Raw Materials and Food for 2013 - 2020 (State Program), and the Federal Scientific and Technical Program for the Development of Agriculture for 2017 - 2025 stimulate the
aquaculture development and define its strategic guidelines. The aquaculture development program aims to create conditions for the integrated development of commercial aquaculture (commercial fish farming) and increase the production of aquaculture products from 140,200 metric tons in 2012 to 315,000 metric tons by 2020 and the production of fish seed from 28,600 metric tons up to 38,700 metric tons [12, 13].

As part of the implementation of the Federal Scientific and Technical Program for the Development of Agriculture for 2017 - 2025, the subprogram titled ‘Development of aquaculture’ is being developed, the purpose of which should be to ensure stable growth in outputs and sales of high-quality aquaculture products using new high-tech Russian projects [14].

As a result of state support action implementation, there is a positive dynamics of growth in the production of commercial fish products. The share of Russian fish products in the total amount of its commodity resources amounted to 81% in 2018, which was at the level of the threshold value stipulated by the Food Security Doctrine (80%) [12, 13]. In terms of the pace of development, aquaculture is ahead of other sectors of the fish industry. Aquaculture products are getting cheaper due to the development of innovative biotechnologies. This creates conditions for the growth of the aquaculture sector [15].

According to Rosstat data in the form of ‘Information on fish catch, production of other aquatic biological resources and withdrawal of commercial aquaculture (commercial fish farming)’, the extraction (catch) of aquatic biological resources amounted to 5.11 million metric tons in 2018 and exceeded by 570,000 metric tons or by 12.6% the planned amount (4.54 million metric tons) that the aquaculture development program had specified. The dynamics of the release of aquatic biological resources into water bodies of fishery importance within the framework of the approved state task amounted to 140% (the planned value was 121.6%) in 2018 [16].

The output of commercial aquaculture products amounted to 238,600 metric tons (the planned value was 207,300 metric tons for 2018) in 2018, which is 8.6% higher than in 2017. In 2018, the production of processed and canned fish, crustaceans, and mollusks amounted to 4.1643 million metric tons (it was by 5% higher than the target). The export of fish products amounted to 2.236 million metric tons or $5.174 billion (17.3% more than in 2017); an increase was 4.5% (95,000 metric tons) as compared to 2017. The imports of fish, fish products, and seafood remained in 2018 at the 2017 level and were about 600,000 metric tons or $2.199 billion (in monetary terms, it is by 14% more than in 2017) [14, 16].

The number of aquaculture enterprises in Russia is increasing every year. Four thousand three hundred enterprises are engaged in fish farming. Eighty-six percent of them are small farms (annual production output is less than 100 metric tons per year). The average production capacity of the enterprise (from 100 metric tons up to 1,000 metric tons annually output) is about 13%. Large companies (over 1,000 metric tons annually output) account for only 1%. A significant part (72%) of production is obtained on farms with a low degree of industrialization: these are carp and herbivorous. Subjects of industrial aquaculture, despite their small share, account for almost a third of all production, namely 62,700 metric tons [16].

Following the aquaculture development program, the output of commercial aquaculture production in 2020 should reach 232,300 metric tons. Strategic guidelines for the further development of the industry were determined by the Strategy for the Development of the Fisheries Industry of the Russian Federation until 2030 (Strategy), which should ensure an increase in gross added value by 2030 through the development of deep processing; an increase in the number of jobs by 24,500 positions; 1.4 times growth of labor productivity as compared to 2018; development and implementation of a national system for environmental certification of extracted aquatic biological resources and products of their processing; an increase to 3 million tons per year in the cargo handling of domestic fish and other products from aquatic biological resources through Russian seaports; increasing up to 80% of the share of servicing domestic vessels of the fishing fleet in Russian ports [1, 17]

Support at the federal level is carried out in the form of projects and programs of the State Program, the sectoral target program titled ‘Development of the fishery complex’ by providing differentiated subsidies for the maintenance and/or purchase of broodstock, etc. [12, 18]. The regions can independently determine the areas and amounts of spending in a ‘unified’ regional subsidy.
also support measures that are financed only from the budgets of the constituent territories of the federation and non-state funds, including those within the cluster initiative development [19-21].

There are some problems in the industry, including the dependence of domestic producers on the supply of feed, breeding material, and equipment. The solution to these problems is laid down in the Strategy, which involves the implementation of measures to reduce the industry's dependence on imports: the creation of centers for the production of compound feed for fish farming, the construction of factories for breeding juveniles of valuable fish species, the construction of enterprises for the production of smolt for the implementation of industrial salmon farming, as well as for obtaining a planting material of valuable species of aquatic organisms for the industrial cultivation of mariculture subjects. [1, 19]

To stimulate the development of the industry, we propose to envisage the following government support measures: to increase government subsidies in the form of direct financial support for aquaculture enterprises; to introduce 50% tax incentives; to provide for subsidies on electricity and fuel, part of the capital expenditures for the creation of fish farming infrastructure, the purchase of juveniles and the development of organic aquaculture, since the Russian Federation can take a significant share in the segment of organic products.

It is necessary to also provide for the allocation of grants for selection and breeding work using modern methods of genetic and genomic engineering, the development of technologies for full-cycle cultivation of complex species, the introduction of new promising fish [freshwater eels (Anguilla anguilla); tuna (Thunnus); whitefish (Coregonidae); Siberian white salmon (Stenodusleucichthys); anadromous carps (Cyprinidae), such as black sea roach (Rutilus Frisii Kutum) and royal fish (Chalcalburnus); pike perch (Stizostedion)], research in the development and testing of new feed formulations and new feeding methods, including starting ones, for which there is a great dependence.

It is advisable to implement the listed support measures in the developed subprogram titled ‘Development of aquaculture’ included in the Federal Scientific and Technical Program for the Development of Agriculture for 2017 - 2025.

4. Conclusions

In Russia, aquaculture occupies a small share in the production and economic structure of the fishery system, while the pace and scale of development lag significantly behind the level of the leading countries in this area. Development prospects look ambiguous. On the one hand, we can note the natural and climatic conditions that allow developing various areas of aquaculture (warm water, cold water, fresh water, and marine ones) and significant government support. On the other hand, one can note the dependence on foreign supplies of fish seed, mixed feed, special machinery and equipment for growing, etc. Solving these issues, including that through the introduction of the proposed additional measures to support the industry, will make it possible to achieve the tasks set by the Strategy for the Development of the Fisheries System in threefold increased aquaculture production.

To stimulate the development of the industry, it is necessary to minimize bureaucratic obstacles in aquaculture. We also propose to provide the following measures of state support in the following areas: increase government subsidies in the form of direct financial support for aquaculture enterprises; introduce 50% tax incentives; provide subsidies for electricity and fuel, part of capital costs for the creation of fish farming infrastructure, the purchase of juveniles and the development of organic aquaculture, since the Russian Federation can take a significant share in the segment of organic products.

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