



DOI 10.23859/estr-230731

EDN MBZDMF

UDC 639.31

Article

Current state and development of aquaculture in Vologda Oblast

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Abstract. The article considers the peculiarities of aquaculture development and summarizes the long-term studies of establishing fish farms in Vologda Oblast. Industrial cage-type cultivation of fish (primarily rainbow trout) in volume of 3.3 thousand tons per year is recommended for 14 out of 25 water bodies investigated by the Vologda Branch of FSBSI "VNIRO". The estimated volumes of commercial cultivation meet the requirements of environmental safety of water bodies. Currently, 19 fish farming grounds are in operation, 15 of which provide industrial cage and 4 – pasture fish farming. In the region, there are also pond fish farms and enterprises equipped by closed water supply systems. A total of 21 enterprises engaged in fish farming keep different species of sturgeon, whitefish, rainbow trout, clarid catfish, carp, grass carp and produce edible black caviar and planting (sturgeon, rainbow trout) material. The aquaculture production for 2013–2022 in Vologda Oblast has been analyzed. By 2022, commercial cultivation in the region reached 1100 tons per year.

Keywords: industrial fish farming, pasture fish farming, fish farming and biological substantiation

Acknowledgements. The authors would thank all the employees of the Vologda Branch of FSBSI "VNIRO" involved in the long-term comprehensive studies of water bodies and the development of fish farming and biological substantiation for aquaculture use in the region.

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To cite this article: Borisov, M.Ya. et al., 2023. Current state and development of aquaculture in Vologda Oblast. *Ecosystem Transformation* 6 (4), 64–78. <https://doi.org/10.23859/estr-230731>

Received: 31.07.2023

Accepted: 23.08.2023




Published online: 25.10.2023

DOI 10.23859/estr-230731

EDN MBZDMF

УДК 639.31

Научная статья**Развитие аквакультуры в Вологодской области и ее современное состояние**

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Аннотация. В статье рассмотрены особенности развития аквакультуры в Вологодской области и обобщены многолетние результаты научных исследований по созданию в регионе рыбоводных хозяйств. На 14 из 25 изученных Вологодским филиалом ФГБНУ «ВНИРО» водных объектов рекомендовано индустриальное выращивание рыбы (прежде всего радужной форели) в объеме 3.3 тыс. т в год. Расчетные объемы товарного выращивания должны обеспечить соблюдение требований экологической безопасности водных объектов. В настоящее время сформировано 19 рыбоводных участков, из которых 15 предоставлено для осуществления индустриального садкового рыбоводства, а 4 – для пастбищной аквакультуры. Также в регионе функционируют прудовые рыбоводные хозяйства и предприятия с использованием установок замкнутого водоснабжения. Рыбоводством в Вологодской области занимается 21 предприятие, на которых содержатся разные виды осетровых и сиговых рыб, радужная форель, клариевый сом, карп, белый амур, производится пищевая черная икра, посадочный материал осетровых и радужной форели. Проанализированы объемы производства объектов аквакультуры в Вологодской области за 2013–2022 гг.; к окончанию этого периода товарное выращивание достигло 1100 т в год.

Ключевые слова: индустриальное рыбоводство, пастбищное рыбоводство, рыбоводно-биологическое обоснование

Благодарности. Авторы благодарят всех сотрудников Вологодского филиала ФГБНУ «ВНИРО», в разные годы принимавших участие в проведении комплексных исследований водных объектов региона по разработке рыбоводно-биологических обоснований для их использования под аквакультуру.

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Для цитирования: Борисов, М.Я. и др., 2023. Развитие аквакультуры в Вологодской области и ее современное состояние. *Трансформация экосистем* 6 (4), 64–78. <https://doi.org/10.23859/estr-230731>

Поступила в редакцию: 31.07.2023

Принята к печати: 23.08.2023

Опубликована онлайн: 25.10.2023

Introduction

Aquaculture is among strategically important and promising in agricultural production of Vologda Oblast. It is worth noting that starting from 2014 the region has paid a special attention to its development (Konovalov and Borisov, 2015; Konovalov et al., 2020). For instance, the Vologda government annually supports the enterprises specializing in aquaculture and partially reimburses the costs for the equipment purchase, the construction, reconstruction and modernization of fish farming infrastructure, including the production of marketable fish. The Vologda Branch of FSBSI “VNIRO” provides a scientific support for aquaculture enterprises and develops the related fish farming and biological substantiations. Based on the results of a comprehensive survey of the studied water bodies, the environmentally grounded recommendations are proposed. They involve the issues of selecting the cultivation objects in accordance with the environmental safety requirements; calculated permissible volumes of commercial farming and adapted technological schemes for fish breeding. The undertaken support measures have allowed to significantly increase the number of fish farming enterprises, diversify the composition of aquaculture species and raise the commercial fish production. The purpose of this work is to systematize the data on aquaculture development in the Vologda Oblast and analyze its current state.

Material and methods

The article is based on the research findings of aquaculture (2013–2022) obtained by the “VNIRO”, which performed the comprehensive studies of 25 different-type water bodies in Vologda Oblast in order to prepare the related fish farming and biological substantiation (Fig. 1). These are small and medium-size lakes located in the following municipal districts: Belozersky (Lozskoye, Azatskoye, Motkozero, Kozhino), Vozhegodsky (Pertozero, Dolgoe, Svyatoye), Ust-Kubinsky (Bolshoye Zaozerskoye, Ozeretskoye, Glukhoye), Vologodsky (Koskovskoye, Dmitrovskoye), Babaevsky (Serkhlovskoye), Chagodoshchensky (Sinichye), Kirillovsky (Uzbinskoye), and Vashkinsky (Volotskoye). In addition, lake Kuzhozero, Kovzha Reservoir and Flood (Razliv) of the river Nagazhma of the Belousovsk Reservoir in the Vytegorsky district, Flood (Razliv) of the river Kovzha of the Sheksna Reservoir in the Sheksninsky district, a inundated quarry in the Kirillovsky district, two ponds in the city of Sokol, including Suda sections in districts Kaduisky and Cherepovets were examined.

Field studies were implemented during the decisive (for fish survival) seasons, i.e. at the end of the ice-covered period (late winter – early spring) and in mid-summer (June–July). To determine the suitability of water bodies for fish farming, bathymetric surveys were performed; temperature and oxygen stratification were checked; total mineralization, pH, dissolved oxygen content and transparency of water were measured. For assessing the aquatic environment quality, we took water samples and made their chemical analysis in the certified laboratories. To identify the food base potential of the reservoirs, the state of natural food supply was investigated, i.e. the qualitative composition and quantitative characteristics of phytoplankton, zooplankton and macrozoobenthos communities. In each studied water body, the species composition of the ichthyofauna, the qualitative and quantitative characteristics of

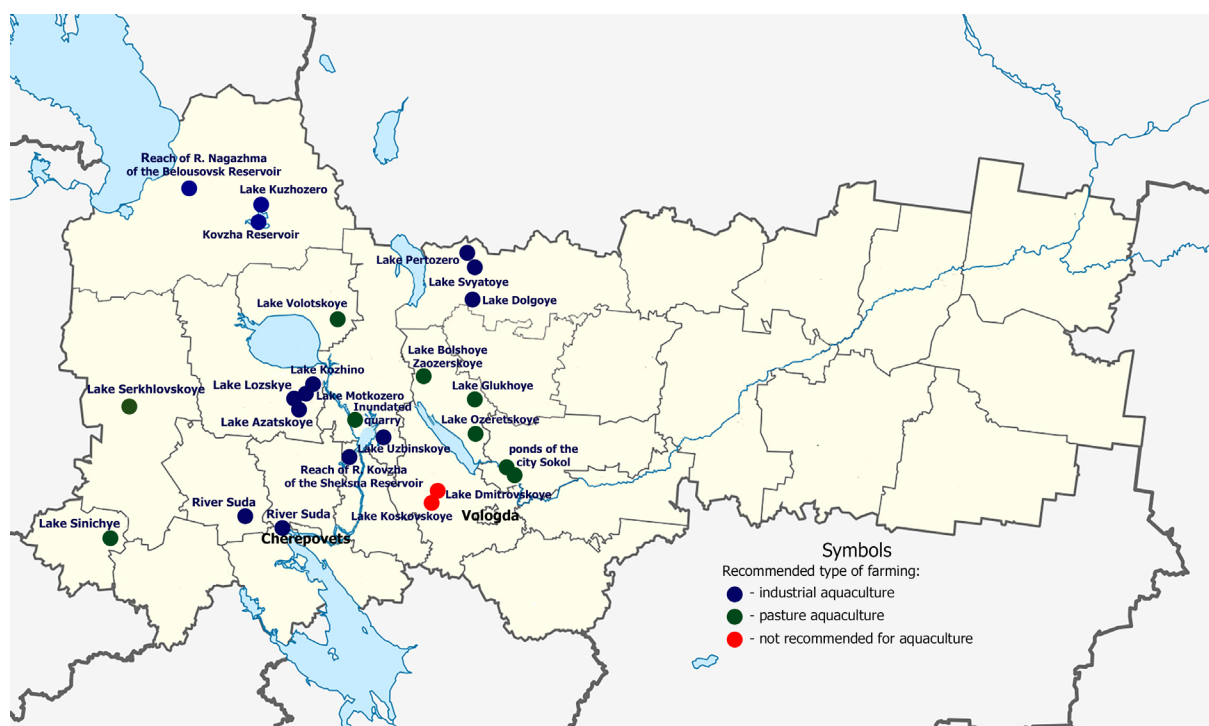


Fig. 1. Schematic map of Vologda water bodies studied for further placement of aquaculture enterprises.

local fish populations were studied. For implementation of pasture farming, the possibility of introducing new types of aquatic biological resources into reservoirs was assessed.

The conducted fish farming and biological descriptions allowed to estimate maximum permissible volumes of fish cultivation with minimal negative impact on the reservoir ecosystems. Biological grounding of specific to each reservoir measures on fish farming arrangement, environmentally sound recommendations on selecting appropriate cultivation objects in a given reservoir (types and forms of farmed fish), calculations and substantiations of permissible volumes of commercial cultivation meeting the environmental safety requirements played a key role here.

To assess the results of aquaculture development, statistical materials from the Department of Fisheries Development and Protection of Aquatic Biological Resources of the Department of Agriculture and Food Resources of Vologda Oblast were used. The data on the total commercial aquaculture production, cultivation objects and types of fish farming enterprises, including the number of established fish breeding grounds were analyzed.

Results and discussion

Fishery-biological substantiations and scientific recommendations for aquaculture development

Based on the results of the studied 25 different-type water bodies in the Vologda Oblast, it was proposed to exploit 14 reservoirs and watercourses for industrial cage-type farming of fish. Rainbow trout *Oncorhynchus mykiss* Walbaum, 1792 was recommended as a priority cultivation species. In natural temperature regime of water bodies and at intensive and productive feeding, rainbow trout grows quite quickly (Table 1). Due to prolonged fish growth and optimal conditions, by the end of the first year of cultivation rainbow trout juveniles with initial weight of 100–120 g reached 1.0 kg, and by the end of the second year – 2.0 kg at initial weight of 25 g. From the data on the average long-term

Table 1. Characteristics of the temperature regime of water bodies in Vologda Oblast (2013–2022) and the estimated growth rates of rainbow trout.

Month	Year											One-year cycle	Two-year cycle	
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average		1-st year	2-nd year
	Mean water temperature, °C											Initial weight, g		
												100	25	—
Mass of trout, g														
V	8.4	11.2	10.8	12.4	5.8	10.5	11.6	8.0	8.6	6.3	9.3	140	40	620
VI	19.5	16.5	17.2	17.9	13.0	15.9	19.2	16.5	20.2	16.1	17.2	250	100	950
VII	21.4	20.2	18.1	22.0	16.0	20.9	18.3	19.6	20.4	21.5	19.8	370	150	1210
VIII	18.8	20.4	17.4	20.1	18.9	19.5	15.2	18.6	19.1	21.5	18.9	550	250	1550
IX	11.4	12.4	13.9	12.2	12.9	14.1	12.9	14	13.3	16.2	13.3	820	400	1980
X	5.1	3.8	5.4	5.2	5.2	6.4	5.3	8.3	6.8	7.8	5.6	1000	550	2100
Average	13.9	14.1	13.8	14.9	12.0	14.2	13.7	14.2	14.7	14.9	14.0			
Date of temperature transition through +4 °C	spring	10.05	26.04	29.04	28.04	13.05	03.05	27.04	02.05	08.05	10.05	03.05	—	
	autumn	12.11	16.10	21.10	21.10	01.11	25.10	27.10	10.11	31.10	03.11	29.10	—	
Number of days with temperature above +4 °C		187	174	176	177	173	176	178	193	176	178	179	—	
Number of days with temperature above +22°C		21	24	0	25	0	24	1	0	12	15	13	—	

water temperature it follows that at temperatures above +4 °C the duration of the trout growth period makes up 173–193 days (averaging 179 days) (Table 1). The third decade of May–June and August–September with water temperature of +14–+18 °C turned out to be the most favorable for fish growth.

In some years, the trout growth slowed down followed by the increased mortality. It occurred in July when a prolonged hot windless weather with water temperature of +22 °C (and higher) was set. According to water temperature monitoring of Vologda reservoirs (Lake Beloye), the most unfavorable conditions for keeping trout were observed in 2013, 2016 and 2022 when the average water temperature in July was above +21 °C, and the number of days with temperatures exceeding +22 °C ranged from 15 in 2022 to 25 in 2016. Over the past ten years, the average monthly water temperature in July rose above +20 °C six times. In 2016, it reached +22 °C (Table 1). Thus, the temperature regime is currently the main factor limiting the cage farming development of trout in the region and creating risks for its survival in some years.

In rainbow trout farming, hydrographic characteristics of the reservoirs, water exchange and water quality are critical as well (Kuchko and Dzyubuk, 2016). In the region, among the largest studied reservoirs recommended for trout farming is the Kovzha Reservoir with its area of 6.5 th. ha, while the smallest is lake Uzbinskoye of 11 ha (see Appendix). The average depth varies from 2.7 m (lake Uzbinskoye) up to 8.1 m (lake Azatskoye); its maximum – from 5.5 m (the river Suda) up to 29.1 m (lake Motkozero). The majority of the surveyed water bodies are shallow that also significantly limits the potential of fish farming in the region.

In summer, the content of dissolved oxygen in the surface water layer was high and varied from 7.8 mg/l in the Suda section up to 11.4 mg/l in the Kovzha Reservoir; the concentration of organic substances and nutrients was within the established (for fishery reservoirs) standards¹. Thus, the content of phosphates, ammonium ions, nitrates, nitrites and BOD₅ ranged as 0.03–0.2 mg/l, 0.05–0.47 mg/l, 0.1–1.81 mg/l, 0.01–0.04 mg/l, and 1.0–1.8 mgO₂/l, respectively (Table 2).

Based on the analysis of hydrographic features of water bodies and their hydrochemical regime, it was proposed to grow the main body of trout in the following largest and deep water bodies: Kovzha Reservoir (650 tons), lakes Azatskoye (400 t), Kuzhozero (200 t), Lozskoye (150 t), Flood (Razliv) of rivers Nagazhma of the Belousovsk Reservoir (200 t) and Kovzha of the Sheksna Reservoir (200 t) and the river Suda (900 t). In lakes with an area of up to 100 ha, the annual volume of this species was estimated as 30–50 tons. In general, the cultivation potential of the 14 studied water bodies makes up 3.3 thousand tons of rainbow trout per year.

Because of high environmental value of lakes Koskovskoye and Dmitrovskoye (the Vologodsky district) and despite their (suitable for rainbow trout farming) hydrographic and hydrochemical features, these water bodies are not recommended for industrial aquaculture development. Being of karst origin and rather deep, they are considered to be unique elements of the natural landscape of the southern part of Vologda Oblast. Interestingly, the employees of the Vologda State University identified here the cenopopulations of the relict aquatic moss quillwort *Isoetes echinospora* Durieu included in the Red Book of Russia (2008) and in the list of rare and endangered species (intraspecific taxa) of plants and fungi of the Red Book of Vologda Oblast². Besides, fish breeding areas were not established on lake Svyatozero of the Vashkinsky district distinguished by their rare species of invertebrates, for example, a crustacean species *Limnocalanus macrurus* Sars, 1863 and relict mysid *Mysis relicta* Loven, 1862 (Filonenko et al., 2022; Lobunicheva et al., 2022), as well as in the mouth area of the river Kubena with migration routes and spawning grounds of nelma *Stenodus leucichthys nelma* Pallas, 1773 and whitefish *Coregonus lavaretus* L., 1758 (Borisov et al., 2019).

It is not reasonable to place industrial cage farms in small lakes, ponds and inundated quarries.

¹ Order of the Ministry of Agriculture of the Russian Federation dated December 13, 2016 No. 552 "On approval of water quality standards for water bodies of fishery importance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fishery importance".

² Decree of the Government of the Vologda Oblast dated July 25, 2022 No. 942 "On approval of lists of rare and endangered species (intraspecific taxa) of plants, fungi and animals listed in the Red Book of the Vologda Oblast, lists of species (intraspecific taxa) of plants, fungi and animals in need in scientific monitoring on the territory of the Vologda Oblast, and on introducing amendments to the decree of the regional government of March 29, 2004 No. 320 and declaring certain resolutions of the regional government to have lost force".

Such reservoirs can be used as recreational farms with released silver crucian carp *Carassius auratus* L., 1758, tench *Tinca tinca* L., 1758, carp *Cyprinus carpio* L., 1758, or hybrids of silver crucian carp and carp. When farming more valuable fish species (e.g. trout, sturgeon), it is necessary to release (into small cages) fish specimens of larger mass. In large shallow lakes with high stocks of small-size fish species (perch *Perca fluviatilis* L., 1758, roach *Rutilus rutilus* L., 1758, bleak *Alburnus alburnus* L., 1758), the release of predatory species (e.g. pike *Esox Lucius* L., 1758 and pike perch *Sander lucioperca* L., 1758) is reasonable.

State regulation and support for aquaculture development

For aquaculture development in the region, a Commission at the Department of Agriculture and Food Resources of Vologda Oblast was set up in 2015. It was responsible for establishing the boundaries of fish breeding areas on Vologda water bodies. As a result, a total 19 fish breeding grounds for industrial cage farming were created in eight municipal districts. Thus, six sites were set up in the Vytegorsky district on lake Kuzhozero, reservoirs Belousovsk and Kovzha; three – in the Belozersky district on lakes Azatskoye, Motkozero and Kozhino; two – in the Vozhegodsky district on lakes Pertozero and Svyatoye, the Sheksninsky district at Floods of rivers Kovzha and Irdomka of the Sheksna Reservoir, as well as in the Kharovsky district – on lake Kumzerskoye and in the Kaduisky district – on the river Suda. One site was created in districts Kirillovsky (lake Uzbinskoye) and Syamzhensky (lake Yakhrengaskoye). The total area of fish breeding areas for industrial fish farming in the Vologda Oblast made up 1421 ha.

According to the auctions held by the Northwestern Territorial Administration of Rosrybolovstvo, all fish-breeding sites were transferred (for use) to the fisheries enterprises. Minimum annual volumes (7460 t) of cultivated aquaculture were estimated from the concluded transfer agreements and the methodology-based calculations³. Currently, cage fish farming is carried out only at 10 sites, i.e. on lakes Azatskoye and Motkozero in the Belozersky district, reservoirs Belousovsk and Kovzha in the Vytegorsky district, lakes Pertozero and Svyatoye in the Vozhegodsky district, lake Uzbinskoye of the Kirillovsky district, the river Suda of the Kaduisky district and the Kovzha channel section of the Sheksna reservoir of the Sheksninsky district.

For pasture fish farming, fish breeding grounds were created on lakes Volotskoye in the Vashkinsky district, Serkhlovskoye in the Babayevsky district, Sinichye in the Chagodoshchensky district and Mukhinskoye in the Kharovsky district with a total area of 541 ha. All fish-breeding sites were transferred (for use) to fish-breeding enterprises. It follows from the concluded transfer agreements that minimum volume of cultivated aquaculture in all reservoirs makes up 4.5 tons per year.

The government of Vologda Oblast stimulated the development of the fish farming industry in the region through subsidizing fishery enterprises from the regional budget within the state program “Development of the agro-industrial complex and consumer market of Vologda Oblast for 2013–2020”. In particular, the government had covered 20% of actual costs for the purchase of planting material and 50% – of the equipment, some costs of paying interest on loans received from the Russian banks for the development of aquaculture (fish farming) and commercial sturgeon farming. Since 2021, due to the state program “Development of agro-industrial and fishery complexes of Vologda Oblast”, the government partially reimburses the costs of paying interest on loans received from the Russian banks for the development of aquaculture (fish farming) and commercial sturgeon farming; the purchase of fishery equipment; the construction, reconstruction or modernization of production facilities for aquaculture development and fish products output; the purchase of planting material; production of commercial fish and payment of insurance premiums accrued under agricultural insurance contracts in the field of commercial aquaculture (Stepanov and Bolotova, 2021). In 2018–2022, the total state support for aquaculture enterprises of Vologda Oblast exceeded 50 million rubles.

³ Order of the Ministry of Agriculture of the Russian Federation dated March 15, 2017 No. 124 “On approval of the Methodology for determining the minimum volume of aquaculture objects subject to breeding and (or) maintenance, cultivation, as well as release into a water body and removal from a water body within the boundaries of a fish breeding area”.

Major results of aquaculture development in Vologda Oblast

Until 2014, the only fish farm in the Vologda Oblast was “Diana” Fishing Company LLC founded in 1978 as the Kaduisky warm-water fish farm. By the early 1990s, this enterprise specialized in cage farming of carp in the warm wastewaters of the Cherepovets HPP. Breeding places were located in a warm discharge channel and a cooling pond. In the early 1990s, volumes of cultivated carp reached 700 tons per year (Konovalov, 2015). Experiments on sturgeon production (which is currently the major breeding object) began in 1989.

This company maintains brood stocks of various species of sturgeon, implements a full cycle of obtaining planting material, as well as the production of marketable fish and black caviar. The enterprise has created brood stocks of beluga *Huso huso* L., 1758, Russian sturgeon *Acipenser gueldenstaedtii* Brand, 1833, Siberian sturgeon *Acipenser baerii* Brand, 1869, sturgeon *Acipenser stellatus* Pallas, 1771, ship *Acipenser nudiiventris* Lovetsky, 1828, Sukhonsk and Volga sterlet *Acipenser ruthenus* L., 1758, including various hybrids of sturgeon fish (Borisov et al., 2019). Commercial cultivation of sturgeon species in the last ten years ranged from 25 to 360 tons per year.

Since 2006, the enterprise has started the industrial production of sturgeon caviar. In 2021–2022, it reached 18–19 tons per year. Currently, “Diana” Fishing Company LLC is the absolute leader in this delicacy output and the largest full-system sturgeon breeding enterprise in Russia. The fish are kept both in pools equipped with a closed water supply system and in breeding places in the cooling pond and the river Suda. In Vologda Oblast, the “Vologda Sturgeon Company” LLC and the Fishing Artel (collective farm) “Rusryba” deal with growing sturgeon as well. Recently, almost 400 tons of sturgeon, 5–7 tons of planting material and 15–19 tons of black caviar were produced in the region annually (Table 2).

Rainbow trout farming is being intensively developed in the Vologda Oblast. Its commercial production started in 2016 from the first 10 tons of fish grown by “Chistoye Ozero” Agricultural Enterprise LLC. By 2022, 16 enterprises were already engaged in rainbow trout breeding, which produced about 700 tons per annum of aquaculture (Table 2). Cage farming provides a bulk trout in the following natural reservoirs: lake Azatskoye of the Belozersky district, reservoirs Kovzha and Belousovsk of the Vytegorsky district, lakes Pertozero and Svyatoye of the Vozhegodsky district, the flood of the river Kovzha of the Sheksna reservoir of the Sheksninsky district and the river Suda of the Kaduisky district. The largest trout breeding enterprises “Aquaculture” LLC and “Chistoye Ozero”

Table 2. Dynamics of aquaculture production (t) in Vologda Oblast for 2013–2022.

Aquaculture objects	Year									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Carp	160.0	44.0	69.0	28.0	41.0	34.0	–	4.0	18.0	1.7
Sturgeon	79.0	38.4	67.0	72.0	85.0	84.0	404.5	396.5	394.0	360.5
Black caviar	–	14.7	22.0	18.0	18.0	17.0	18.7	15.2	19.0	18.1
Clarid catfish	–	–	–	1.0	1.0	12.5	24.8	44.1	23.0	9.4
Rainbow trout	–	–	–	10.0	15.0	45.0	169.8	576.5	590.5	697.3
White fish	–	–	–	–	–	–	2.0	7.6	9.6	5.8
Total	239.0	97.1	158.0	129.0	160.0	192.5	619.8	1043.9	1054.1	1092.8



Fig. 2. Schematic map of actual location of aquaculture enterprises in Vologda Oblast.

Agricultural Enterprise LLC farmed 585 tons of fish in 2022, or 84% of the total annual rainbow trout production in the region. In much smaller quantities (70 tons per year) it is farmed by LLC “Fish-breeding complex “Immid”, IP Koreshkov A.I., “Vologda Lakes” LLC, “Delta Service” LLC. A number of recreation enterprises in districts Vytegorsky, Kirillovsky, Ust-Kubinsky, Verkhovazhsky, Nyuksensky and Nikolsky keep trout in small quantities, mainly for amateur and recreational fishing.

To supply fish farms with planting material for commercial cultivation of rainbow trout, the “Aquafish” enterprise was founded in the Cherepovets district in 2022. In addition, a large fish-breeding complex of the “Aquaproduct” company specializing in salmon cultivation (including juveniles) using the closed water supply systems was built in the Vologda district in 2023. Along with rainbow trout farming, “Aquaculture” LLC and “Delta Service” LLC are involved in breeding whitefish species – nelma, whitefish *Coregonus lavaretus* L., 1758, muksun *Coregonus muksun* Pallas, 1814 and whitefish *Coregonus nasus* Pallas, 1776. The total volume of whitefish production is under 10 tons per year (Table 2).

The development of catfish farming in the region started in the early 2000s, when the caviar of channel catfish *Ictalurus punctatus* Rafinesque, 1818 was imported by “Diana” Fishing Company LLC. The commercial cultivation of this species was initiated in 2002, and in 2002–2007 its total production reached 54 tons (varying in some years from 0.8 to 21.9 tons) (Konovalov, 2014). The cultivation of this fish has been ceased today because of the reduced warm water discharge during the reconstruction of the Cherepovets HPP.

Since 2016, the breeding of the clariid catfish *Clarias gariepinus* Burchell, 1822 began in small quantities using the closed water supply systems. In 2020, its volumes were maximum (44 t) (Table 2). The production was concentrated at the large fish-breeding complex “Aquaculture” LLC in the village of Irdomatka, the Cherepovets district. In 2022, Vologda “Fish Farm” LLC was also involved in catfish farming. Being the main fishery object in the region in 1980–1990, carp is not currently in the lead and bred in pond farms in small amounts for amateur fishery. As for grass carp *Ctenopharyngodon idella* Valenciennes, 1844, it was released into ponds for reclamation purposes.

Nowadays, a total of 21 enterprises are engaged in fish farming in the Vologda Oblast. The production sites are located in Chagodoshchensky, Kaduysky, Belozersky, Vashkinsky, Kirillovsky, Ust-Kubinsky, Vozhegodsky, Kharovsky, Verkhovazhsky, Tarnogsky, Nikolsky, Vologodsky, Vytegorsky, Sheksninsky and Cherepovets districts (Fig. 2). Fish breeding of pasture and cage types is implemented in natural water bodies, pools with closed water supply systems and ponds. It is expected that another 6 enterprises will be also involved in fish farming in the coming years.

Conclusion

The Vologda Branch of FSBSI “VNIRO” has studied 25 different-type water bodies in Vologda Oblast and recommended 14 to be used for industrial cage farming, primarily, of rainbow trout. The temperature regime of water bodies ensures the one- and two-year cycle cultivation of this species. However, in some years, hot weather at the end of June - July can rise water temperature above +22 °C, cause high fish mortality and significantly reduce the annual yield of marketable products. In addition, the annual production of commercial aquaculture is limited by hydrographic characteristics, flowage and water quality of water bodies. To maintain the safe ecological state of water bodies, it is not recommended to exceed the maximum permissible volumes calculated by the VologodNIRO. When creating fish farming sites, a comprehensive survey of water bodies is required in order to assess their fish farming potential, to give environmentally sound recommendations for selecting cultivation objects, to calculate and substantiate the permissible production volumes. It is advisable to avoid the establishment of fish breeding areas where the habitats of rare and endangered species of aquatic organisms exist.

In the last decade, the number of fish farming enterprises in Vologda Oblast increased significantly, and the species composition of aquaculture became more diverse. In 2022, the aquaculture production reached 1100 tons, 700 tons of which – rainbow trout, 360 – sturgeon, 18 – black caviar, 9 – clarid catfish, 6 – whitefish and almost 2 tons of carp. Most of fish is cultivated in lakes, reservoirs and rivers of the region due to cage farming. Industrial farming is implemented at 19 grounds (the total area of 1421 ha) and pasture aquaculture – on 4 sites (541 ha). The annual minimum volume of cultivated industrial and pasture aquaculture makes up 7460 tons and 4500 tons, respectively, that is much higher than maximum permissible volumes indicated in the fish farming and biological substantiation (3300 tons). “Diana” Fishing Company LLC specializing in keeping sturgeon species and producing black caviar, as well as “Aquaculture” LLC and “Chistoye Ozero” Agricultural Enterprise LLC dealing with rainbow trout farming are the largest fish-breeding enterprises in the region.

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APPENDIX

Characteristics of water bodies recommended for aquaculture development in Vologda Oblast based on the results of fish farming and biological studies of the Vologda Branch of FSBSI "VNIRO". I – industrial, P – pasture, N – not recommended.

Name of water body	Reach of riv. Nagazhma of the Belousovsk Reservoir	Inundated quarry	Lake Azatskoye	Lake Belozersky	Lake Lozskoye	Lake Pertozero	Lake Dolgoye	Lake Ozeretskoye	Lake B. Zaozerskoye
Year of study	2014	2014	2015	2015	2015	2015	2015	2016	2016
Municipal district	Vytegorsky	Kirillovsky	Belozersky	Belozersky	Belozersky	Vozhegodsky	Vozhegodsky	Ust'-Kubinsky	Ust'-Kubinsky
Water body area, ha	273	12	1823	1435	119	77	5	40	40
Average depth, m	5.5	1.0	8.1	6.2	5.7	3.9	7.3	2.7	2.7
Maximum depth, m	13.5	3.2	14.0	10.5	14.3	11.1	15.6	3.3	3.3
O ₂	8.3	9.6	10.1	9.4	9.1	8.5	7.0	7.0	7.0
BOD ₅	1.6	1.3	1.6	1.6	1.4	1.6	2.0	2.2	2.2
PO ₄ ³⁻	0.05	0.05	0.15	0.17	0.13	0.15	0.05	0.15	0.15
NH ₄ ⁺	0.13	0.15	0.05	0.06	0.12	0.09	0.08	0.05	0.05
NO ₃ ⁻	0.30	0.17	0.30	0.35	0.43	0.30	0.24	0.30	0.30
NO ₂ ⁻	0.03	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02
Recommended type of farming	I	P	I	I	I	I	P	P	P
Recommended (for farming) aquaculture objects	Rainbow trout	Silver crucian carp, carp, <i>Carassius gibelio</i> × <i>Cyprinus carpio</i>	Rainbow trout	Rainbow trout	Rainbow trout	Rainbow trout	Silver crucian carp, carp, <i>Ca. gibelio</i> × <i>Cy. carpio</i>	Silver crucian carp, <i>Ca. gibelio</i> × <i>Cy. carpio</i>	Silver crucian carp, <i>Ca. gibelio</i> × <i>Cy. carpio</i>
Recommended volumes of aquaculture production, t per year	200	0.13	400	150	50	25	0.11	0.25	0.25

Name of water body	Kovzha Reservoir	Lake Motkozero	Lake Volotskoye	Lake Koskovskoye	Lake Dmitrovskoye	Pond in city Sokol	Lake Kozhino
Year of study	2017	2018	2018	2018	2018	2018	2019
Municipal district	Vytegorsky	Belozersky	Vashinsky	Vologodsky	Vologodsky	Sokolsky	Belozersky
Water body area, ha	6524	250	513	57	35	13	50
Average depth, m	5.9	7.8	2.6	11.7	8.4	3.9	6.0
Maximum depth, m	16.4	29.1	4.7	37.6	38.3	7.8	15.3
Concentrations, mg/l	O ₂	11.4	11.0	9.5	11.3	9.8	9.3
	BOD ₅	1.6	1.7	1.8	1.6	1.3	1.7
	PO ₄ ³⁻	0.06	0.08	0.05	0.05	0.05	0.05
	NH ₄ ⁺	0.47	0.32	0.05	0.38	0.31	0.05
	NO ₃ ⁻	0.14	0.30	0.10	0.14	0.10	0.20
	NO ₂ ⁻	0.02	0.04	0.02	0.03	0.02	0.02
Recommended type of farming	I	I	P	N	N	P	I
Recommended (for farming) aquaculture objects	Rainbow trout	Rainbow trout	Silver crucian carp, Ca. gibelio × Cy. carpio pike, tench	Silver crucian carp, Ca. gibelio × Cy. carpio	Silver crucian carp, Ca. gibelio × Cy. carpio	Silver crucian carp, Ca. gibelio × Cy. carpio	Rainbow trout
Recommended volumes of aquaculture production, t per year	650	100	3.0	–	–	0.10	9

Name of water body		River Suda	Lake Uzbinskoye	Lake Sinichye	Lake Glukhoye	Lake Kuzhozero	Lake Svyatoye	River Suda	Reach of riv. Kovzha of the Sheksna Reservoir	Lake Serkhlovskoye
Year of study		2019	2019	2019	2019	2020	2020	2020	2021	2022
Municipal district		Kaduisky	Kirillovsky	Chagodoshchensky	Ust'-Kubinsky	Vytegorsky	Vozhegodsky	Cherepovetsky	Sheksninsky	Babaevsky
Water body area, ha		15	11	8	6	722	52	93	115	24
Average depth, m		3.1	2.7	1.4	6.1	4.9	4.1	4.8	4.3	3.3
Maximum depth, m		5.5	7.1	5.1	13.2	13.9	11.0	9.5	9.8	5.2
O_2		9.4	9.3	8.6	10.3	9.1	8.2	7.8	10.3	6.8
BOD_5		1.6	1.0	1.3	1.9	1.5	1.8	1.8	1.8	1.9
PO_4^{3-}		0.12	0.09	0.16	0.13	0.03	0.20	0.20	0.15	0.02
NH_4^+		0.06	0.06	0.23	0.26	0.10	0.10	0.26	0.16	0.54
NO_3^-		0.18	0.11	0.12	0.20	0.58	0.57	1.43	1.81	0.57
NO_2^-		0.04	0.02	0.02	0.02	0.01	0.01	0.04	0.02	0.02
Recommended type of farming		I	I	P	P	I	I	I	I	P
Recommended (for farming) aquaculture objects		Rainbow trout, sturgeon	Rainbow trout	Silver crucian carp, Ca. <i>gibelio</i> x <i>Cy. carpio carpio</i>	Silver crucian carp, Ca. <i>gibelio</i> x <i>Cy. carpio carpio</i>	Rainbow trout	Rainbow trout	Rainbow trout, sturgeon	Rainbow trout	Silver crucian carp, Ca. <i>gibelio</i> x <i>Cy. carpio carpio</i>
Recommended volumes of aquaculture production, t per year		900	5	0.30	0.10	200	30	400	200	0.17