*Review*

# The current state of fishery in water bodies of the Vologda Oblast and its impact on commercial stocks of aquatic biological resources

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**Abstract.** The article presents a scientific review of the current state of industrial and amateur fisheries in the most important fishery water bodies of Vologda Oblast. In 2013–2022, the total annual catch of aquatic biological resources averaged 1627 tons, including 703 tons in lake Beloye, 328 – in the Rybinsk reservoir, 222 – in lake Onega, 171 – in lake Kubenskoye, 129 – in the Sheksna reservoir, and 74 tons in lake Vozhe. Bream dominated in the catches of lakes Beloye, Kubenskoye and the Sheksna reservoir (28.5–39.0%). European smelt accounted for 93.2% of the total capture in lake Onega; zope dominated in the Rybinsk Reservoir (28.4%) and pike perch – in lake Vozhe (42.5%). Lakes Beloye, Kubenskoye, Vozhe, including the Rybinsk reservoir, demonstrated maximum commercial catch (22–35%) in December, the Sheksna reservoir – from January to March (about 48%), and lake Onega in May due to European smelt fishing (over 96%). Over the past 10 years, the stocks of the main commercial fish species in lakes Beloye and Kubenskoye, the Sheksna reservoir and lake Vozhe made up 6299, 2880 2644 and 1903 tons, respectively. Development of the total allowable catches (TAC) and the recommended volumes of production (catch) of aquatic biological resources (RC) in lake Beloye was within 59.7%; in lake Kubenskoye – 33.7%, in lake Vozhe – 31.9%, in the Sheksna reservoir – 25.8%.

**Keywords:** industrial fishery, amateur fishery, commercial fish biomass, catch

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*Научный обзор*

# Современное состояние рыболовства на водоемах Вологодской области и его влияние на промысловые запасы водных биоресурсов

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**Аннотация.** В статье выполнен обзор современного состояния промышленного и любительского рыболовства на важнейших рыбохозяйственных водных объектах Вологодской области. Общий годовой улов водных биоресурсов в водоемах региона в 2013–2022 гг. в среднем составлял 1627 т, в том числе 703 т в оз. Белом, 328 т в Рыбинском водохранилище, 222 т в оз. Онежском, 171 т в оз. Кубенском, 129 т в Шекснинском водохранилище и 74 т в оз. Воже. В составе уловов в озерах Белом и Кубенском, а также в Шекснинском водохранилище доминировал лещ, обеспечивая 28.5–39.0% от общего. В Онежском озере 93.2% уловов давала корюшка европейская, в Рыбинском водохранилище преобладал синец (28.4%), а в озере Воже – судак (42.5%). В озерах Белом, Кубенском, Воже, Рыбинском водохранилище в течение года наибольший промышленный вылов приходился на декабрь, когда добывалось 22–35% от годового улова. В Шекснинском водохранилище около 48% годового вылова осуществлялось в январе–марте, а в оз. Онежском свыше 96% уловов приходилось на май за счет корюшки европейской. Промысловые запасы основных видов рыб в оз. Белом за последние 10 лет в среднем составляли 6299 т, в оз. Кубенском – 2880 т, в Шекснинском водохранилище – 2644 т, в оз. Воже – 1903 т. Освоение общих

допустимых уловов и рекомендованных объемов добычи водных биоресурсов в оз. Белом за рассматриваемый период в среднем составляло 59.7%, в оз. Кубенском – 33.7%, в оз. Воже – 31.9%, в Шекснинском водохранилище – 25.8%.

**Ключевые слова:** промышленное рыболовство, любительское рыболовство, промысловая биомасса рыб, уловы

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## Introduction

The water fund (over 550 th. ha) of Vologda Oblast includes about 20 thousand watercourses (more than 70 th. km long) and over 5 thousand lakes, eight of which have a surface area exceeding 25 km$^2$ (Priroda Vologodskoi oblasti, 2007). The largest water body of the region - lake Beloye, is of great fishery importance in terms of the total catch and commercial fish biomass (Borisov et al., 2019). In recent years, lake Beloye accounted for about 41% of the total annual fish catch in the region. The share of the Rybinsk reservoir (located within the boundaries of the region) was about 19%, Onega – 13%, lake Kubenskoye – 10%, the Sheksna reservoir – 7%, lake Vozhe – 4%, and other (small and medium) lakes and rivers about 6%. Fisheries and resource monitoring studies of these water bodies (except for the Rybinsk Reservoir and lake Onega) were carried out by the Vologda Branch of VNIRO (formerly the Vologda Branch of GosNIORKh). Its last generalized reports on the fishery state and exploited aquatic biological resources in the water bodies under study were published about ten years ago or even earlier (Borisov et al., 2011; Konovalov and Borisov, 2014; Konovalov et al., 2011, 2014; Pechnikov and Konovalov, 2004a–d; Tropin, 2020). Therefore, the aim of this work was to update and summarize the information (2013–2022) about the modern state of industrial and amateur fisheries in the fishery reservoirs of Vologda Oblast, including the impact on stocks of the main commercial fish species.

## Material and methods

For a general assessment of current fisheries in the most important fishery reservoirs of Vologda Oblast, we considered major trends in the long-term dynamics of the total fish catch for the period from 1980 to 2022. The up-to-date description of industrial and amateur fisheries in the Sheksna and Rybinsk reservoirs, in lakes Beloye, Kubenskoye, Vozhe and Onega was given based on the

averaged data for 2013–2022. To do this, we used the materials of the official fishery statistics of the North-Western and Moscow-Oka Territorial Departments of the Federal Agency for Fishery on seasonal and long-term production dynamics of the main aquatic biological resources, as well as the data on the number of users and fishing permits issued, etc. For the Rybinsk reservoir, the statistics of commercial fish captures was provided by the Department of Agriculture and Food Resources of Vologda Oblast. Amateur fishery was analyzed due to the materials of the North-Western Branch of the |"ain Basin Administration for Fisheries and Conservation of Aquatic Biological Resources" ("Glavrybvod"). Nowadays, amateur fishery in the Rybinsk reservoir (within the boundaries of the region) is not monitored anymore. The information about seasonal irregular low-productive fishing on small, medium-size lakes and rivers of Vologda Oblast was excluded from our review.

In order to assess abundance and biomass of the majority of commercial fish populations in the water bodies studied by the Vologda Branch of VNIRO, i.e. lakes Beloye, Kubenskoye, Vozhe and the Sheksna reservoir, the fished water method for evaluating stocks when fishing with stake nets was used (Treshchev, 1974, 1983). To estimate commercial fish stocks in lake Beloye until 2019, the method of direct accounting at trawl operations was applied (Sechin, 1990). In addition, the composition of commercial catches implemented with drift nets in lakes Beloye, Vozhe and by throw nets in Kubenskoye was analyzed to evaluate fish stocks. Since other branches of VNIRO are in charge for lake Onega and the Rybinsk reservoirs, we do not present any quantitative data on their commercial fish stocks in this review.

In accordance with the Federal Law[1], the main measure of the exploitation of commercial fish stocks in natural water bodies is annually established volumes of total allowable catches (TAC) and recommended volumes of production (catch) of aquatic biological resources (RC). In this paper, we analyze these indicators for water bodies located in the zone of responsibility of the Vologda Branch of "VNIRO".

## Results and discussion

### *Lake Beloye*

Lake Beloye represents both a lake part of the Sheksna reservoir (built in 1963–1964) and a part of the Volga-Baltic waterway. The lake has the shape of an almost regular oval; its depths (average: 4.1 m) increase gradually reaching the maximum of 6.3 m in the central part. By water area, lake Beloye is the largest water body (more than 1284 km$^2$) located entirely within the boundaries of Vologda Oblast (Anthropogennoe vliyanie..., 1981). Its considerable water area, shallow waters and even bed structure are favorable for extraction of aquatic biological resources with both passive and active fishing gears.

#### *Commercial species*

The commercial ichthyofauna of lake Beloye includes 21 fish species, 9 of which are the main commercial objects providing more than 90% of the total catch over the past four decades: European smelt *Osmerus eperlanus* L., 1758, bream *Abramis brama* L., 1758, sabrefish *Pelecus cultratus* L., 1758, pike perch *Sander lucioperca* L., 1758, roach *Rutilus rutilus* (L., 1758), zope *Ballerus ballerus* L., 1758, perch *Perca fluviatilis* L., 1758, Volga zander *Sander volgensis* Gmelin, 1789, and pike *Esox lucius* L., 1758 (Table 1). For the forty-year period, zope has practically lost the status of a commercial species; by the end of 2010, its average catch reduced by almost 25 times, not exceeding one ton in the last five years. In the fishery of the lake, ruff and vendace (found only in by-catch) are in very low demand because of the absence of specialized fishing tools.

#### *Total catches*

For the past four decades, maximum total catch was noted in lake Beloye in the 1980s (about 859 tons) (Table 1); in some years it exceeded 1100 tons. About 55% of the total catch in that period fell on the most important fishery objects, i.e. pike perch and smelt. In the 1990s distinguished by new economic relations and insufficient control over catches (Bolotova et al., 2003), smelt fishing reduced on average to 627 tons. In the 2000s, there was a further drop to an average of 345 tons as a result of a large-scale decrease in commercial stocks and captures of smelt and pike perch (Konovalov, 2019), the total share of which declined to 14%. At the same time, bream providing 41% of the total catch became the main fishing species. Since the 2010s, the stocks and catches of pike perch and smelt

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[1] Federal Law of December 20, 2004 No. 166-FZ "On fisheries and conservation of aquatic biological resources".

**Table 1.** Long-term dynamics of the total catch of the main commercial fish of lake Beloye. Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – burbot, asp, ide, white-eye, rudd, bleak, crucian carp, tench, carp, unidentified small-size fish.

| Fish species | Years | | | | |
| --- | --- | --- | --- | --- | --- |
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Bream | $\frac{92}{11}$ | $\frac{115}{20}$ | $\frac{128}{41}$ | $\frac{199}{29}$ | $\frac{172}{29}$ |
| Sabrefish | $\frac{88}{11}$ | $\frac{63}{8}$ | $\frac{50}{14}$ | $\frac{125}{18}$ | $\frac{92}{15}$ |
| Pike perch | $\frac{145}{17}$ | $\frac{112}{20}$ | $\frac{24}{7}$ | $\frac{44}{6}$ | $\frac{88}{15}$ |
| Smelt | $\frac{329}{38}$ | $\frac{185}{28}$ | $\frac{39}{7}$ | $\frac{74}{10}$ | $\frac{69}{12}$ |
| Perch | $\frac{8}{1}$ | $\frac{16}{2}$ | $\frac{25}{7}$ | $\frac{62}{9}$ | $\frac{65}{11}$ |
| Volga zander | $\frac{22}{2}$ | $\frac{17}{3}$ | $\frac{9}{3}$ | $\frac{64}{9}$ | $\frac{50}{8}$ |
| Roach | $\frac{12}{1}$ | $\frac{21}{3}$ | $\frac{39}{11}$ | $\frac{79}{12}$ | $\frac{34}{6}$ |
| Pike | $\frac{43}{5}$ | $\frac{22}{4}$ | $\frac{13}{5}$ | $\frac{22}{3}$ | $\frac{20}{3}$ |
| Silver bream | – | – | $\frac{2}{1}$ | $\frac{11}{2}$ | $\frac{4}{1}$ |
| Ruff | $\frac{0.8}{0.1}$ | $\frac{9}{1}$ | $\frac{4}{1}$ | $\frac{8}{1}$ | $\frac{3}{0.5}$ |
| Vendace | $\frac{0.5}{0.1}$ | $\frac{0.4}{0.1}$ | $\frac{0.2}{0.05}$ | $\frac{1}{0.1}$ | $\frac{1}{0.1}$ |
| Zope | $\frac{80}{9}$ | $\frac{48}{7}$ | $\frac{10}{3}$ | $\frac{3}{0.5}$ | $\frac{0.5}{0.1}$ |
| Others* | $\frac{40}{5}$ | $\frac{19}{4}$ | $\frac{2}{1}$ | $\frac{3}{0.4}$ | $\frac{2}{0.3}$ |
| **Total** | **859** | **627** | **345** | **696** | **600** |

have been partially restored, but in contrast to bream, sabrefish, roach, perch and Volga zander they remained just subdominant species. Though the total catches in the reservoir have recently increased to an average of 600–700 tons (or 820–860 tons in some years), nevertheless, the level of the 1980s is still unachievable.

***Industrial fishery***

In 2013–2022, industrial fishery largely dominated in lake Beloye and reached on average 662 tons (94.1% of the annual catch). Currently, 13 fishing sites occupying more than 860 km$^2$ (almost 70% of the total area) operate here. Annually, from 115 (in 2017) to 45 permits (in 2022) for extraction of aquatic biological resources were issued. During, the period under review, industrial fishery in the lake was implemented by four fish producers having the long-term lease of fishing plots and fixed quotas for extraction of aquatic biological resources. For the past 10 years, an average of 43.8% of the total commercial catch was conducted by "Aprel" LLC, 12.5% – by "Lipin Bor" LLC, 21.5% and 22.3% – by individual entrepreneurs Myakishev B.Yu. and Sobolev S.E., respectively. In 2020, "BelozerskRybProm" LLC was also involved in fisheries (about 4.1%).

In December, commercial catches in the lake were the largest. For instance, in December of 2013–2022 on average 144.6 tons, or almost 22% of the annual catches were captured (Fig. 1), fishing of pike perch reached almost 60% of the annual catch, while of bream, pike and Volga zander varied within 27–40% of the total. This indicator remained high in the rest months of the ice fishing
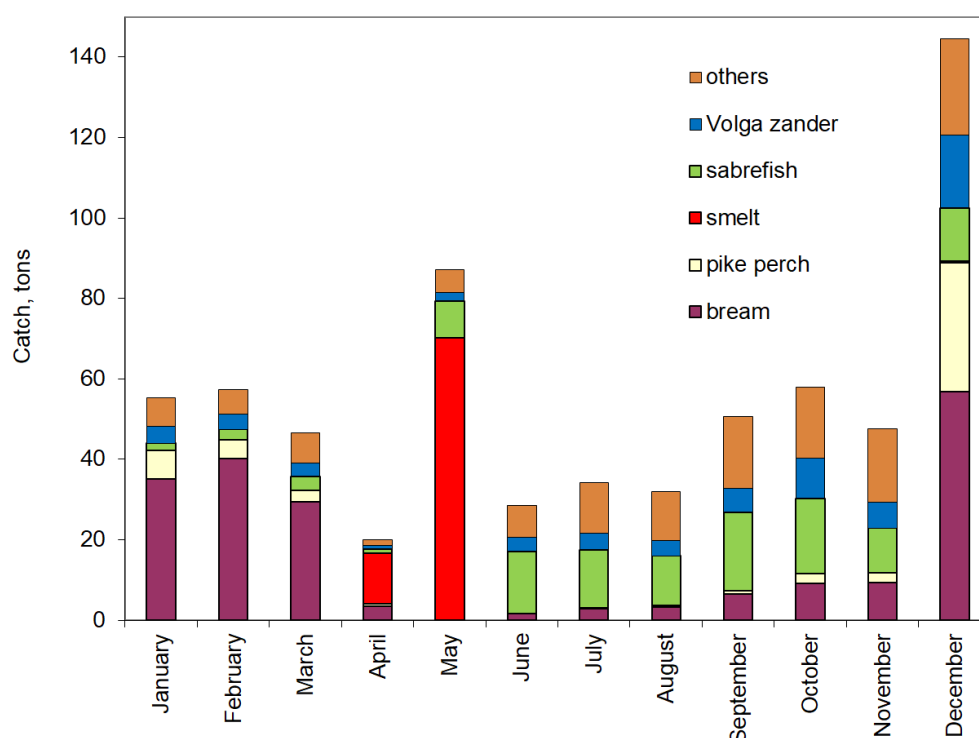
**Fig. 1.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in lake Beloye on average for 2013–2022.

period (January – March), when bream, pikeperch, Volga zander, pike, and sabrefish predominated in catches.

In late April – the first decade of May, when the ban on bream, pike perch and pike was in effect, a specialized fishing of migrating to spawning areas smelt provided 60–80% of the total catch in these two months. Depending on the temperature regime, fishery usually lasted from 7 to 10 days. About 83 tons were caught on the average, or 4 (2022) to 152 tons (2019). From May to December, more intensive production of sabrefish, Volga zander and other small-size fish (especially roach and perch) was also noted in the lake. With water cooling, poor summer catches of bream and pike perch tended to grow in September–November.

The seasonal dynamics of the main commercial fish catch largely depended on the specifics of fishing gears used in different months of the year. Here, stake nets, hooked set lines and fixed traps, including smelt traps and traps, as well as drift nets and fixed nets were used. During the ice period, large-size fish (bream, pike perch, and pike) were mainly captured by large-mesh fixed nets with a mesh size of 60–80 mm. In autumn, drift nets with a mesh size of 50–70 mm were also set. In lake Beloye, these major types of fishing gear provided high shares of the most valuable commercial fish species: 30.1% of bream, 8.5% of pike perch, and 3.1% of pike (Fig. 2**A**). Fishing of small-size species, i.e. sabrefish (18.3%), Volga zander (9.8%), roach (7.8%), and perch (7.1%), was mainly implemented by small-mesh fixed nets (with a mesh size of 32–40 mm) and set traps. Due to the use of the specialized fishing gear – small-mesh set traps (smelt traps**)**, the share of smelt exceeded 95% of the total catch and in spring it reached 12.5% of the annual commercial catch in the lake.

*Amateur fishery*

There are numerous settlements on the shores of lake Beloye and the adjacent territories, the lake is surrounded by convenient access roads that greatly contributes to the development of amateur fishery here. In the period 2013–2022, it provided about 40 tons, or 5.8% of the total annual catch. Perch (37.4%), roach (21.4%) and pike perch (19.5%) dominated in amateur catches of lake Beloye (Fig. 2**B**). When fishing during the ice period with a line, perch and roach volumes prevailed. The
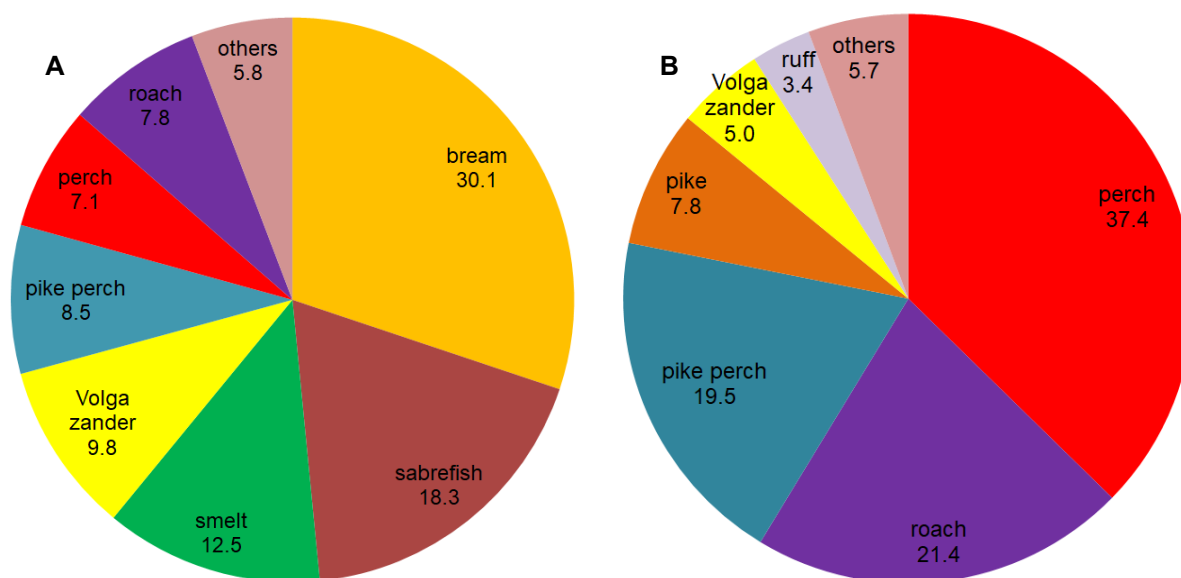
**Fig. 2.** The ratio (%) of the main fish species in commercial (**A**) and amateur (**B**) catches in lake Beloye on average for 2013–2022.

average catch per fisherman per visit made up 0.5–1.5 kg (0.3–2.0 kg); in April it reached 3–4 kg. During the ice-free period, the catch with a line per fisherman was around 0.5 kg (0.2–0.5 kg) and 2.5 kg in September. When fishing with a spinning rod and on a "track", the catches mainly consisted of pike perch and pike.

### Commercial fish stocks and their development

For the past ten years, the estimated stocks of the twelve main commercial fishes of lake Beloye varied as 5410–6931 tons (Table 2). Note that in 2016–2018 and 2020–2022, the total volumes of TAC and RC tended to increase, while the total catch, on the contrary, decreased. Such a drop was, apparently, caused by the organizational reasons and a market demand; it occurred primarily because of a reduction in captures of roach, sabrefish, perch, bream, Volga zander, ruff *Gymnocephalus cernuus* L., 1758, silver bream *Blicca bjoerkna* L., 1758 and zope. Along with decreased fishing loads, the recommended catch volumes increased mainly due to sabrefish, roach, silver bream, ruff, and partially due to bream and perch. As a result, the development of TAC and RC dropped from 70.2–89.5% in 2013–2015 to 42.2–46.0% in 2020–2022.

Over the past decade, the total stocks of the main commercial fish species of lake Beloye were approximately 6300 tons (Table 3). At the same time, TAC and RC amounted to 1111 tons, or about 17.6% of biomass of the reserves.

Bream with its highest commercial biomass and predominance in annual catch had maximum volumes (92.2%). Similar situation was also noted for pike perch (75.3%) and Volga zander (87.5%) having the highest retail prices on the market, as well as sabrefish (about 69.8%) due to good demand and its ability of mass production when using small-mesh fishing gear. This indicator was relatively small for smelt (56.4%) because of its varying commercial stocks in some years. Comparatively low RC volumes of pike (41.4%) and zope (27.8%) were noted because of their less commercial stocks (compared to bream mainly caught together). Poor exploitation of RC of roach (53.4%), perch (50.7%), and silver bream (44.4%), caught mostly in by-catch of sabrefish and partly bream, was caused by low commercial demand for these fishes. The lack of specialized fishing was the reason of a very poor development of RC of vendace (*Coregonus albula* L., 1758) (8.5%) and ruff (4.0%). Moreover, the absence of a sales market for ruff and little commercial stocks of vendace contributed to their low catches in lake Beloye.

**Table 2.** Dynamics of commercial stocks of aquatic biological resources of lake Beloye and their actual development in 2013–2022; * - industrial and research fisheries.

| Indicator | Year | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | |
| Commercial stock, t | 6206 | 6931 | 6442 | 6026 | 5410 | 5826 | 6384 | 6327 | 6556 | 6880 | **6299** |
| TAC and RC, t | 822 | 920 | 856 | 1172 | 1200 | 1188 | 1124 | 1190 | 1265 | 1369 | **1111** |
| Catch*, t | 577 | 799 | 766 | 809 | 610 | 639 | 761 | 547 | 540 | 578 | **663** |
| Development of TAC and RC, % | 70.2 | 86.9 | 89.5 | 69.0 | 50.8 | 53.8 | 67.7 | 46.0 | 42.7 | 42.2 | **59.7** |
| Development of stock, % | 9.3 | 11.5 | 11.9 | 13.4 | 11.3 | 11.0 | 11.9 | 8.6 | 8.2 | 8.4 | **10.5** |

**Table 3.** Stocks of the main commercial fish of lake Beloye and their actual development on average for 2013–2022; * - industrial and research fisheries. The stock of smelt was estimated on average for 2013–2019, for roach - for 2013–2014 and 2019–2022, silver bream – for 2019–2022, zope – for 2019–2022, and ruff – for 2018–2022.

| Fish species | Indicator | | | | | |
|---|---|---|---|---|---|---|
| | Commercial stock, t | TAC or RC, t | Share of TAC or RC of stock, % | Catch*, t | Development of TAC or RC, % | Development of stock, % |
| Bream | 1320 | 215 | 16.2 | 198 | 92.2 | 15.0 |
| Ruff | 1022 | 125 | 12.2 | 5 | 4.0 | 0.5 |
| Sabrefish | 872 | 176 | 20.2 | 123 | 69.8 | 14.1 |
| Smelt | 613 | 148 | 24.1 | 83 | 56.4 | 13.6 |
| Roach | 549 | 98 | 17.9 | 52 | 53.4 | 9.6 |
| Perch | 459 | 92 | 20.1 | 47 | 50.7 | 10.2 |
| Pike perch | 413 | 72 | 17.4 | 54 | 75.3 | 13.1 |
| Volga zander | 406 | 76 | 18.8 | 67 | 87.5 | 16.4 |
| Pike | 271 | 49 | 18.0 | 20 | 41.4 | 7.4 |
| Silver bream | 192 | 21 | 10.8 | 9 | 44.4 | 4.8 |
| Zope | 102 | 7 | 6.4 | 2 | 27.8 | 1.8 |
| Vendace | 80 | 11 | 14.0 | 0.9 | 8.5 | 1.2 |
| Others | – | 22 | – | 2 | 8.2 | – |
| **Total** | **6299** | **1111** | **17.6** | **663** | **59.7** | **10.5** |

### The Sheksna reservoir

The river part of the Sheksna reservoir is represented by a flooded valley of the river Sheksna stretched for about 120 km and having a water area of about 381 km² (Antropogennoe vliyanie..., 1981). More than 10 th. ha, or almost 50% of fishing sites are snaggy areas unusable for fisheries because of dead trees and shrub vegetation remained here after the reservoir filling in 1963. As compared to other reservoirs under review, this water body is characterized by both low fishery intensity and the most stable situation in the past decades.

#### Commercial species

The catches of the river part of the Sheksna reservoir consisted of 21 fish species. The main commercial species of the reservoir included bream, pike and pike perch showing relatively stable catches (70% of the total catch) over the past 40 years (Table 4). In the last two decades, the role of roach, perch and silver bream also noticeably increased in the reservoir. Burbot fishing (*Lota lota* L., 1758) tended to decrease, not exceeding 3% of the total.

#### Total catches

In the 1980s, the total catch averaged 106 tons (Table 4); in some years, it varied from 69 to 153 tons. The recorded catches made up on average 85 tons per year. In 2000–2010, the average capture increased to 137 and 134 tons, respectively. The growth of the total catch in the last two decades was largely due to the increased fishing of small-size species: perch, roach, silver bream, zope, sabrefish, rudd (*Scardinius erythrophthalmus* L., 1758), etc. For instance, if in 1980–1990 the total share in the captures of these fishes made up approximately 8.2%, in 2000–2010 it increased to 28.4%. The role of small-size species in catches was growing due to more intensive use of small-mesh fixed nets and traps.

#### Industrial fishery

For industrial fishery in the Sheksna reservoir, 6 fishing sites of about 203 km² (or 53.2% of the total reservoir area) were put in operation. In 2013–2022, from 24 (2020) to 11 (2022) fishing permits were annually issued. Five users fished in this reservoir: the fishing artel "Rybak", which provided about 74.5% of the total production, individual entrepreneurs Burlakov N.N. (8.6%) and Mishichev V.F. (7.8%),

**Table 4.** Long-term dynamics of the total catch of the main commercial fish in the river part of the Sheksna reservoir. Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – sabrefish, zope, Volga zander, ide, rudd, bleak, asp, ruff, crucian carp, carp, tench, chub, vendace, smelt, unidentified small-size fish.

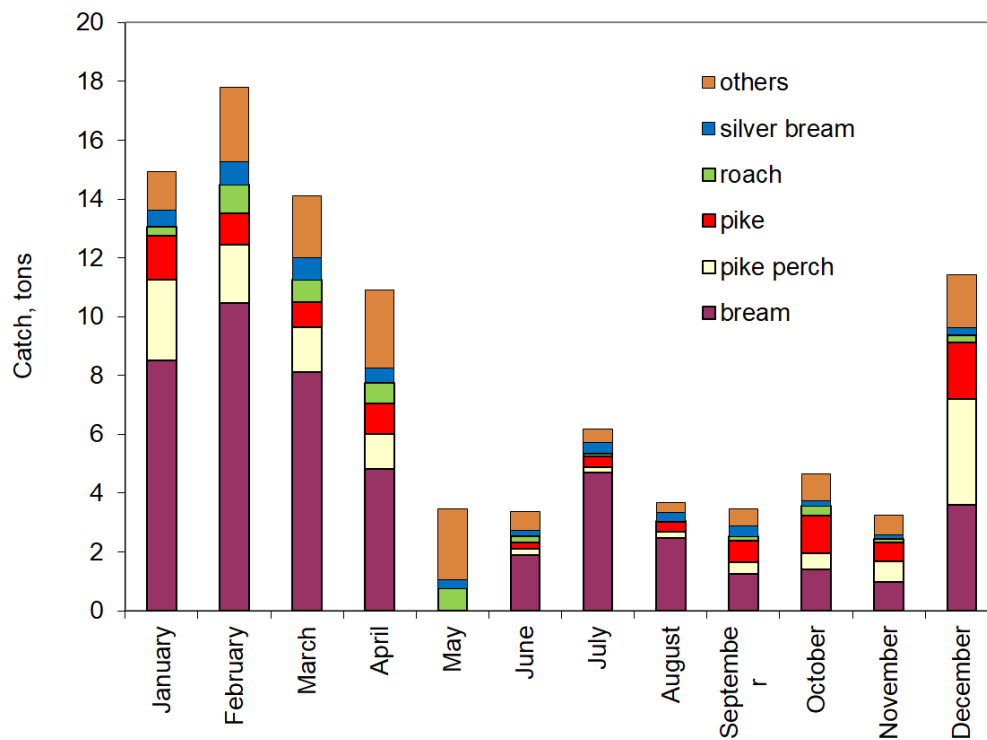| Fish species | Years | | | | |
| --- | --- | --- | --- | --- | --- |
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Bream | $\frac{59}{54}$ | $\frac{47}{55}$ | $\frac{51}{38}$ | $\frac{54}{40}$ | $\frac{45}{39}$ |
| Pike | $\frac{15}{15}$ | $\frac{11}{13}$ | $\frac{20}{14}$ | $\frac{18}{14}$ | $\frac{16}{14}$ |
| Pike perch | $\frac{10}{10}$ | $\frac{8}{10}$ | $\frac{12}{9}$ | $\frac{14}{11}$ | $\frac{17}{14}$ |
| Roach | $\frac{4}{4}$ | $\frac{6}{7}$ | $\frac{14}{10}$ | $\frac{10}{7}$ | $\frac{7}{6}$ |
| Perch | $\frac{1}{1}$ | $\frac{1}{2}$ | $\frac{15}{10}$ | $\frac{13}{10}$ | $\frac{11}{9}$ |
| Burbot | $\frac{7}{7}$ | $\frac{6}{8}$ | $\frac{6}{5}$ | $\frac{4}{3}$ | $\frac{3}{3}$ |
| Silver bream | 0 | $\frac{1}{1}$ | $\frac{8}{6}$ | $\frac{7}{5}$ | $\frac{6}{5}$ |
| Others* | $\frac{10}{9}$ | $\frac{4}{4}$ | $\frac{11}{8}$ | $\frac{13}{10}$ | $\frac{11}{10}$ |
| **Total** | **106** | **85** | **137** | **134** | **115** |

**Fig. 3.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in the Sheksna reservoir on average for 2013–2022.
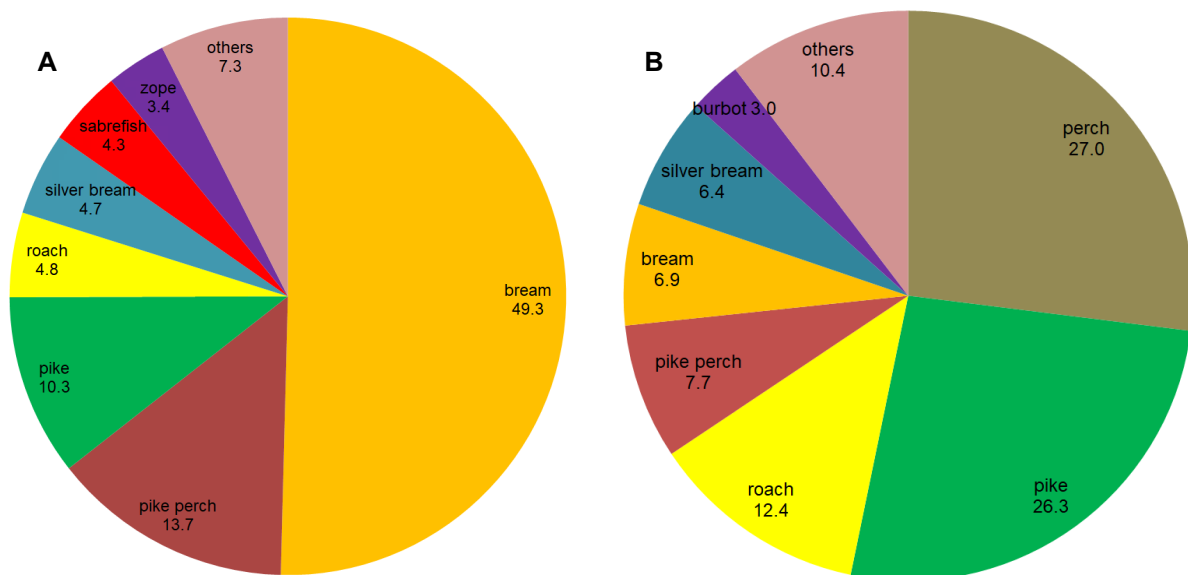


**Fig. 4.** The ratio (%) of the main fish species in commercial (**A**) and amateur (**B**) catches in the Sheksna reservoir on average for 2013–2022.

the collective farm "Niva" (6.0%) and "Raduzhnoye" LLC (3.1%). During the period under review, the average annual catch of these enterprises and entrepreneurs reached 97.5 tons (75.7% of the total).

Maximum production in the Sheksna reservoir was recorded during the period of ice fishing, i.e. from January to April and in December (over 70% of the annual catch) (Fig. 3). Bream fishing dominated in the first three months of the year (almost 60% of the total), as well as in April and December – 44 and 32%, respectively. Pike perch in this period also accounted for over 83% of the annual catch, however, in December, it provided about 32% of the total, in January its share declined to 18%, and in February–April – to 11%. Pike catches during the ice period were also quite high, ranging from 17% (in December) to 6% (in February–March); their role increased markedly in autumn (20–28% of the total catch). In May–November, pike fishing was the lowest and made up only 29% of the annual catch.

In the river part of the Sheksna reservoir, two types of fishing gears were used to implement industrial fishery – stake nets and fixed traps. Among major fishing tools were large-mesh fixed nets with a mesh size of 60–80 mm providing most (75%) of the annual catch of bream, pike perch and pike in the reservoir (Fig. 4**A**). In particular, the share of bream in commercial catches made up 49.3%, pike perch – 13.7%, and pike – 10.3%. Small-size fish species prevailed in the catches were fished with small-mesh nets (mesh size: 32–45 mm and fixed traps), while bream, pike perch, and pike, as a rule, were found only in by-catch. When fixed traps were used**,** burbot made up 20% of the catch. In general, the total share of small-size fish in commercial catches reached 16%, of which mostly roach, silver bream, sabrefish and zope predominated in approximately equal proportions.

### Amateur fishery

Unorganized amateur fishery is well developed in the river part of the Sheksna reservoir due to rather convenient geographical location of the Sheksna reservoir. In 2013–2022, amateur fishermen caught on average 32 tons (24.5% of the total annual catch), where perch (27.0%), pike (26.3%) and roach (12.4%) predominated in captures (Fig. 4**B**). About 8–10 thousand people were engaged in ice fishing in the reservoir every year, and about 15 thousand – in open water fishing. When fishing from ice, fishing rods and nets for catching fish of prey were used; the average catch per fisherman per visit was 1–2 kg. In open water, fishermen mainly used bottom, float rods and spinning. In this case, the average catch per fisherman per visit increased to 3–5 kg and sometimes up to 25 kg if fished with spinning rods.

### Commercial fish stocks and their development

Stocks of the main commercial species of the Sheksna Reservoir in 2013–2022 ranged from 2386 to 2850 tons (Table 5). It is noteworthy that since 2018, the total recommended catch volumes in the

**Table 5.** Dynamics of commercial stocks of aquatic biological resources of the Sheksna reservoir and their actual development in 2013–2022; * – industrial and research fisheries.

| Indicator | Year | | | | | | | | | | **Mean** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | |
| Commercial stock, t | 2441 | 2837 | 2522 | 2850 | 2386 | 2596 | 2743 | 2620 | 2710 | 2729 | **2644** |
| TAC and RC, t | 277 | 291 | 296 | 282 | 274 | 459 | 437 | 474 | 483 | 492 | **377** |
| Catch*, t | 111 | 93 | 90 | 96 | 109 | 121 | 95 | 82 | 87 | 88 | **97** |
| Development of TAC and RC, % | 40.2 | 31.8 | 30.5 | 34.1 | 39.7 | 26.3 | 21.7 | 17.4 | 17.9 | 17.9 | **25.8** |
| Development of stock, % | 4.6 | 3.3 | 3.6 | 3.4 | 4.6 | 4.7 | 3.5 | 3.1 | 3.2 | 3.2 | **3.7** |

**Table 6.** Stocks of the main commercial fish of the Sheksna reservoir and their actual development on average for 2013–2022; * – industrial and research fisheries.

| Fish species | Indicator | | | | | |
|---|---|---|---|---|---|---|
| | Commercial stock, t | TAC or RC, t | Share of TAC or RC of stock, % | Catch*, t | Development of TAC or RC, % | Development of stock, % |
| Bream | 767 | 105 | 13.7 | 48 | 45.9 | 6.3 |
| Roach | 750 | 75 | 9.9 | 5 | 6.4 | 0.6 |
| Silver bream | 339 | 25 | 7.4 | 5 | 18.6 | 1.4 |
| Pike perch | 218 | 30 | 13.7 | 13 | 44.1 | 6.1 |
| Perch | 174 | 33 | 19.2 | 3 | 9.8 | 1.9 |
| Zope | 133 | 11 | 8.4 | 3 | 28.6 | 2.4 |
| Sabrefish | 129 | 16 | 12.1 | 4 | 26.8 | 3.2 |
| Pike | 124 | 35 | 27.9 | 10 | 28.8 | 8.0 |
| Volga zander | 10 | 5 | 47.6 | 1.0 | 20.5 | 9.8 |
| Others | – | 42 | – | 5 | 11.3 | – |
| **Total** | **2644** | **377** | **14.2** | **97** | **25.8** | **3.7** |

reservoir have increased by almost 1.7 times, mainly due to small-size fish species (roach, perch, sabrefish, zope and silver bream). Initially, RC values of these fishes were determined from the results of the expert analysis of production dynamics. However, since 2018, they were calculated taking into account the actual and predicted commercial stocks. In general, the catches and development of fish stocks remained at a relatively stable level averaging to 97 tons and 3.7%, respectively for the period under review.

Exploitation of stocks of the main commercial fish species of the Sheksna reservoir was not intensive (Table 6). The best development of TAC and RC (close to 45%) was typical for the most significant fishing species – pike perch and bream. This indicator for pike, zope and sabrefish was less than 30%, Volga zander and silver bream – only about 20%, perch and roach – less than 10%. As mentioned above, the poor development of fish stocks in the reservoir was associated with the presence of snaggy sites, covered with flooded trees and shrub vegetation.

### The Rybinsk reservoir (Vologda Oblast)

The northeastern part of the Rybinsk Reservoir, partly located within the boundaries of Vologda Oblast, was built in 1941–1947 by flooding the Sheksna and Mologa river valleys. The water surface area of the reservoir at a normal headwater level is about 4550 km², and its average depth – 5.6 m (Rybinskoe vodokhranilishche..., 1972). According to rough estimates, about 896 km² of its water area, which is a large part of the Sheksna and Molozhsky Reaches of the reservoir, are located within the boundaries of the Vologda Oblast.

#### Commercial species

The catches of the Rybinsk reservoir (within the boundaries of the region) consisted of 15 fish species. Over the past 40 years, 7 species, i.e. bream, roach, zope, burbot, pike, pike perch and perch provided over 90% of the total catch (Table 7). Smelt became almost an extinct species in the composition of catches over the past two decades, while the role of sabrefish, silver bream and Volga zander, on the contrary, increased.

**Table 7.** Long-term dynamics of the total catch of the main commercial fish in the Rybinsk Reservoir (Vologda Oblast). Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – catfish, asp, crucian carp, unidentified small-size fish.

| Fish species | Years | | | | |
|---|---|---|---|---|---|
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Bream | $\frac{261}{30}$ | $\frac{128}{26}$ | $\frac{92}{29}$ | $\frac{83}{26}$ | $\frac{76}{25}$ |
| Roach | $\frac{183}{21}$ | $\frac{123}{24}$ | $\frac{61}{20}$ | $\frac{68}{21}$ | $\frac{61}{20}$ |
| Zope | $\frac{131}{14}$ | $\frac{92}{17}$ | $\frac{83}{27}$ | $\frac{97}{29}$ | $\frac{88}{29}$ |
| Burbot | $\frac{121}{14}$ | $\frac{49}{11}$ | $\frac{14}{5}$ | $\frac{7}{2}$ | $\frac{6}{2}$ |
| Pike | $\frac{100}{12}$ | $\frac{26}{5}$ | $\frac{12}{4}$ | $\frac{10}{3}$ | $\frac{11}{4}$ |
| Pike perch | $\frac{30}{3}$ | $\frac{28}{6}$ | $\frac{27}{8}$ | $\frac{15}{5}$ | $\frac{16}{5}$ |
| Perch | $\frac{16}{2}$ | $\frac{5}{1}$ | $\frac{16}{5}$ | $\frac{23}{7}$ | $\frac{19}{6}$ |
| Smelt | $\frac{26}{3}$ | $\frac{21}{4}$ | 0 | 0 | 0 |
| Sabrefish | $\frac{1.2}{0.1}$ | $\frac{4}{0.8}$ | $\frac{4}{1}$ | $\frac{8}{2}$ | $\frac{8}{2}$ |
| Silver bream | $\frac{3}{0.3}$ | $\frac{2}{0.3}$ | $\frac{1}{0.4}$ | $\frac{6}{2}$ | $\frac{9}{3}$ |
| Volga zander | $\frac{1}{0.1}$ | $\frac{0.1}{0.01}$ | $\frac{0.8}{0.3}$ | $\frac{7}{2}$ | $\frac{11}{4}$ |
| Ide | $\frac{3}{0.4}$ | $\frac{1.0}{0.2}$ | $\frac{2}{0.5}$ | $\frac{1}{0.4}$ | $\frac{0.8}{0.2}$ |
| Others* | $\frac{3}{0.4}$ | $\frac{13}{3}$ | $\frac{1}{0.4}$ | $\frac{1}{0.4}$ | $\frac{2}{0.5}$ |
| **Total** | **881** | **491** | **315** | **328** | **309** |

***Total catches***

In the 1980s, the total catch in the reservoir within the boundaries of Vologda Oblast averaged to 881 tons, but by 2000–2010 it dropped by almost 3 times reaching 315 and 328 tons, respectively (Table 7) because of the reduced captures of the main commercial species: bream, roach, burbot and pike. Captures of zope remained relatively stable; in the early 2010s, it became the main fishing species in the reservoir.

***Industrial fishery***

In the Rybinsk Reservoir (within the boundaries of Vologda Oblast), 12 fishery sites operated. These sites covered 458 km², or 51% of the total area of the considered section of the reservoir. In 2013–2022, fisheries were conducted by three users: "Avangard" LLC, the cooperative society "Myaksinskoye" – on the Sheksna Reach, and "Molozhskoye" LLC – on the Molozhsky Reach of the reservoir. The main fishery actor was "Avangard" LLC (average: 87.6% of the total catch). The "Molozhskoye" LLC accounted for 8.7% and the cooperative society "Myaksinsky" –3.7%.

In 2022, approximately 22% of annual commercial fish (about 67.9 tons) were captured in December (Fig. 5). Bream noticeably dominated in the catches (36.7% of the total catch for this month); the shares of zope and roach were equal (17.9 and 14.1%. respectively). In some years, their catch was also high during the ice period, i.e. in January – March. High total catch occurred from July to October mainly due to zope, roach and bream. To implement industrial fishery in the Rybinsk Reservoir, stake nets and fixed traps were mainly used.

In commercial catches, cyprinid fish species, i.e. zope, bream and roach, (the share of which in the total catch amounted to 74%) clearly dominated (Fig. 6). The shares of the most valuable fish species (pike perch and pike) in commercial catches were relatively small (4.7 and 3.3%, respectively).
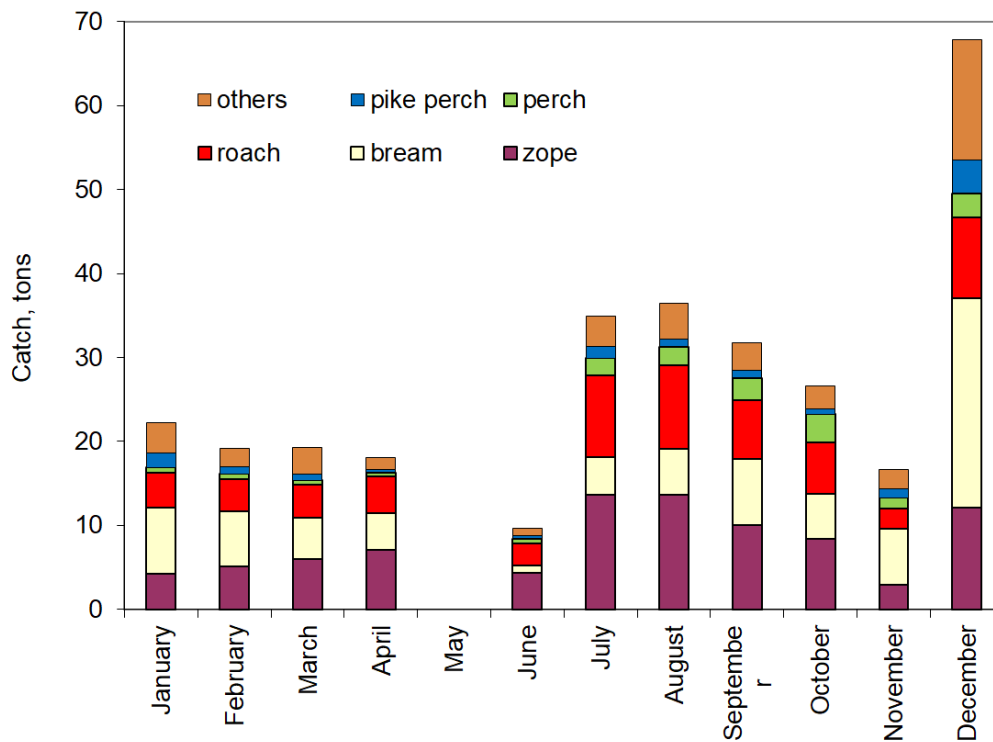
**Fig. 5.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in the Rybinsk Reservoir in 2022.
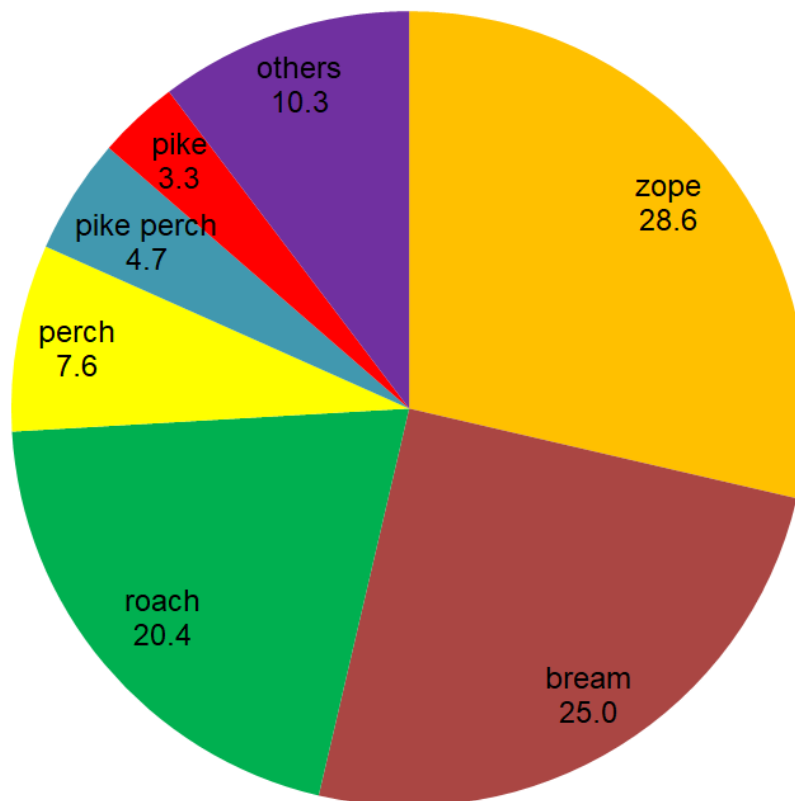


**Fig. 6.** The ratio (%) of the main fish species in commercial catches in the Rybinsk Reservoir on average for 2013–2022.

## *Lake Kubenskoye*

Lake Kubenskoye is a large shallow reservoir located in the central part of the Vologda Oblast. This water body is a part of the North Dvina Water System and belongs to the basin of the river Northern Dvina, which flows into the White Sea. The lake has an elongated shape stretched from northwest to southeast. The total area of the lake is about 417 km$^2$; the average depth – 2.5 m (Ozero Kubenskoye**...,** 1977). Proximity of the lake to the regional center contributes to its intensive use and complex economic development. Here, industrial and amateur fisheries, tourism and shipping are well-developed. In addition, lake Kubenskoye is a reserve source of water supply for the city of Vologda, especially in dry years. As for its main tributaries, the rivers Kubena and Uftyuga have been used for timber rafting for many decades (Polyakov et al., 1997).

### *Commercial species*

The commercial ichthyofauna of lake Kubenskoye consisted of 16 fish species. Five species of aquatic biological resources: bream, roach, pike, perch and pikeperch (90% of the total production), were the main fishery objects (Table 8). In the mid-2000s, nelma (*Stenodus leucichthys nelma* Pallas, 1773) completely disappeared from the recorded catches, and whitefish (*Coregonus lavaretus* L., 1758) was found only in by-catch.

In lake Kubenskoye, the largest capture over the past four decades was registered in the late 1980s (average: 384 tons) (Table 8); in some years it reached 507 tons. In the 1990s, the total catch sharply decreased, but at the beginning of the 2000s – exceeded 300 tons. However, a gradual decline in the total capture has been observed since 2001. In 2000–2010, it was on average 240 and 182 tons, respectively. Over the past five years, the total catch of aquatic biological resources in lake Kubenskoye did not exceed 170 tons. The reduced catches over the past two decades were caused by socio-economic reasons and hardly by long-term dynamics of commercial stocks of aquatic biological resources.

### *Industrial fishery*

Currently, 12 industrial fishery sites (260 km$^2$, or 62% of the total area) operate on lake Kubenskoye. Since 2019, fishing is conducted only in 9 sites; another 3 sites are not exploited for fishing because of the bankruptcy of the major actor – the "Kubenskoye Rybzavod" LLC. Annually, from 36 (2015) to 15 fishery

**Table 8.** Long-term dynamics of the total catch of the main commercial fish of lake Kubenskoye. Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – burbot, silver bream, nelma, whitefish, bleak, chub, crucian carp, asp, dace, unidentified small-size fish.

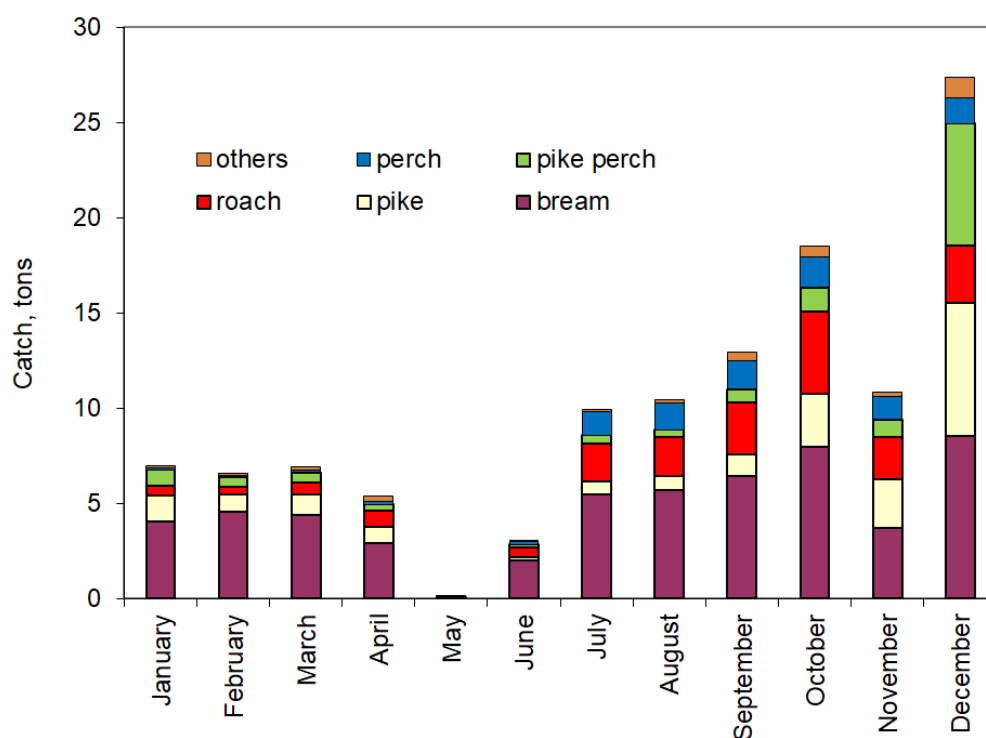| Fish species | Years | | | | |
|---|---|---|---|---|---|
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Bream | $\frac{179}{47}$ | $\frac{135}{50}$ | $\frac{97}{41}$ | $\frac{66}{36}$ | $\frac{39}{28}$ |
| Roach | $\frac{36}{9}$ | $\frac{44}{16}$ | $\frac{72}{30}$ | $\frac{32}{17}$ | $\frac{12}{9}$ |
| Pike | $\frac{64}{16}$ | $\frac{30}{11}$ | $\frac{23}{10}$ | $\frac{29}{16}$ | $\frac{26}{19}$ |
| Perch | $\frac{14}{4}$ | $\frac{19}{7}$ | $\frac{27}{11}$ | $\frac{36}{20}$ | $\frac{28}{20}$ |
| Pike perch | $\frac{24}{6}$ | $\frac{12}{4}$ | $\frac{6}{2}$ | $\frac{10}{6}$ | $\frac{26}{19}$ |
| Ide | $\frac{14}{4}$ | $\frac{10}{4}$ | $\frac{7}{3}$ | $\frac{4}{2}$ | $\frac{3}{2}$ |
| Ruff | $\frac{11}{4}$ | $\frac{10}{4}$ | $\frac{4}{1}$ | $\frac{1}{1}$ | $\frac{1}{0.4}$ |
| Others* | $\frac{42}{8}$ | $\frac{13}{3}$ | $\frac{5}{1}$ | $\frac{3}{1}$ | $\frac{4}{1}$ |
| **Total** | **384** | **273** | **240** | **182** | **138** |

**Fig. 7.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in lake Kubenskoye on average for 2013–2022.
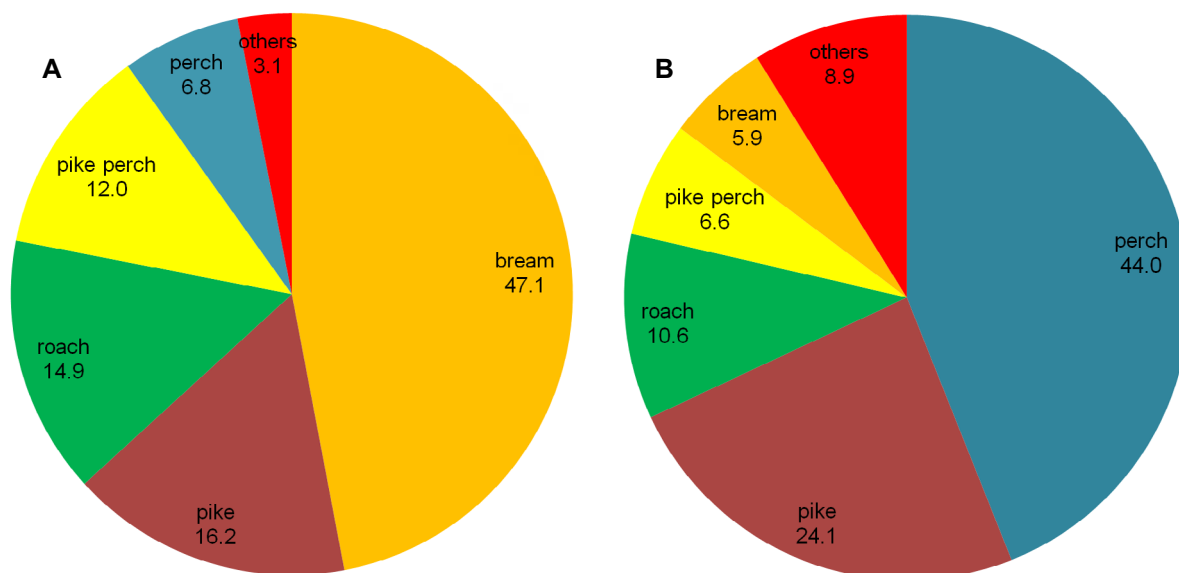


**Fig. 8.** The ratio (%) of the main fish species in commercial (**A**) and amateur (**B**) catches in lake Kubenskoye on average for 2013–2022.

permits (2022) were issued. In 2013–2022, four users were involved in fisheries: "Kubenskoye Rybzavod" LLC (until 2018), which produced 56.1% of the total production, including individual entrepreneurs Lazarev S.A. (28.2%), Averyanov V.V. (21.4%) and Karelin S.A. (16.0%). In 2022, "BelozerskRybProm" LLC and individual entrepreneur Travinov G.V. provided insignificant fish volumes. In general, for the period under review, the average annual commercial catch made up 119.2 tons, or about 69.7% of the total captures in the reservoir.

Over the past ten years, almost 23% (about 27.4 tons) of the annual catch fall on December (Fig. 7). Three most valuable commercial species (bream – 31.3%, pike –25.5% and pike perch – 23.3%). dominated in December captures in approximately equal proportions. In the first four months of the year, fishing in lake Kubenskoye was insignificant, (only 21.7% of the annual catch). From July to October, the volumes gradually increased. Bream (49.5%), roach (21.4%), perch (11.1%) and in autumn – pike (10.1%) and pike perch (5.5%) had high shares in the total catches.

In the period under review, fishermen used stake nets, throw nets and traps (weels). During the ice period, mainly stake nets with a mesh space of 50–80 mm were used that provided high shares in commercial catches of bream (47.1%), pike (16.2%) and pike perch (12.0%) (Fig. 8**A**). Until 2018, 2–3brigades of "Kubenskoye Rybzavod" LLC fished from the second half of June until the beginning of November. They employed throw nets. Along with the harvesting of traditional commercial objects, seine fishing ensured rather high shares of roach (14.9%) and perch (6.8%) in the catches. Note that seine fishing is currently ceased because of the "Kubenskoye Rybzavod" bankruptcy (2019).

### Amateur fishery

Proximity to the regional center, numerous settlements situated along the shores, and good road accessibility make lake Kubenskoye one of the most popular water bodies of Vologda Oblast. Over the past decade, the share of amateur fishery exceeded 30% (or 53 tons per year) of the total catches of the lake. Here, perch (44.0% of the total) dominated; pike (24.1%) and roach (10.6%) had a high proportion as well (Fig. 8**B**). The total number of amateur visitors to lake Kubensky reached 80–120 thousand people a year. On weekends and holidays, fishing intensity increased. In recent years, during the period of ice fishing, perch and roach prevailed in the total seasonal catch when using fishing rods (average: 52 and 15%, respectively) and pike fished on baits (8%). The catch per fisherman per visit varied from 0.25 to 5.5 kg (average 1.0–2.5 kg). Single catches up to 7.0–8.5 kg were recorded in March and April. During open water with fishing on spinning and "track", the catches mostly consisted of pike (55%) and perch (26%). When spinning was used, the catch for a fisherman per trip ranged as 0.13–6.7 kg (average 1.0–2.0kg) and if float and bottom rods – from 0.2 to 6.1 kg (average 2.0–3.5 kg).

**Table 9.** Dynamics of commercial stocks of aquatic biological resources of lake Kubenskoye and their actual development in 2013–2022; * – industrial and research fisheries.

| Indicator | Year | | | | | | | | | | Mean |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | |
| Commercial stock, t | 2902 | 3348 | 2901 | 2714 | 2776 | 2423 | 2536 | 2902 | 3198 | 3099 | **2880** |
| TAC and RC, t | 326 | 296 | 281 | 306 | 284 | 392 | 379 | 365 | 433 | 444 | **351** |
| Catch*, t | 127.2 | 167.4 | 123.6 | 191.5 | 124.4 | 135.4 | 69.2 | 58.4 | 94.1 | 90.0 | **118** |
| Development of TAC and RC, % | 39.0 | 56.6 | 44.0 | 62.6 | 43.8 | 34.5 | 18.3 | 16.0 | 21.7 | 20.3 | **33.7** |
| Development of stock, % | 4.4 | 5.0 | 4.3 | 7.1 | 4.5 | 5.6 | 2.7 | 2.0 | 2.9 | 2.9 | **4.1** |

**Table 10.** Stocks of the main commercial fish of lake Kubenskoye and their actual development (average) for 2013–2022; * – industrial and research fishing; ** – assessment of silver bream stocks was performed (on average) for 2019–2022.

| Fish species | Indicator | | | | | |
|---|---|---|---|---|---|---|
| | Commercial stock, t | TAC or RC, t | Share of TAC or RC of stock, % | Catch*, t | Development of TAC or RC, % | Development of stock, % |
| Bream | 1115 | 111 | 9.9 | 55 | 50.1 | 5.0 |
| Roach | 494 | 61 | 12.4 | 19 | 31.1 | 3.9 |
| Perch | 460 | 65 | 14.1 | 9 | 13.5 | 1.9 |
| Silver bream** | 372 | 9 | 2.3 | 0.9 | 11.0 | 0.3 |
| Pike | 210 | 41 | 19.3 | 19 | 46.8 | 9.0 |
| Pike perch | 119 | 22 | 18.4 | 12 | 57.0 | 10.5 |
| Ide | 103 | 13 | 12.7 | 2 | 12.4 | 1.6 |
| Whitefish | 7 | 1 | 13.9 | 0.4 | 36.3 | 5.1 |
| Others | – | 29 | – | 0.4 | 1.5 | – |
| **Total** | **2880** | **351** | **12.2** | **118** | **33.7** | **4.1** |

### *Commercial fish stocks and their development*

During the ten-year period under review, the stocks of the main commercial fish species of lake Kubenskoye varied as 2423–3348 tons (Table 9). From 2019, an almost two-fold decrease in the total fish catch, TAC and RC was caused by the bankruptcy of the main fishery enterprise – the "Kubensky Rybzavod" LLC. A trend towards an increase in biomass of commercial fish stocks has been noted from 2019.

In 2013–2022, the stocks of almost all commercial fish of lake Kubenskoye were poorly exploited (Table 10). In particular, the development of TAC and RC of the most demanded fish (pikeperch, bream and pike) was within 50% for each species; and the share of catches from commercial stocks was only 5–11%. Other fish species distinguished by high stocks (roach, perch, silver bream and ide *Leuciscus idus* L., 1758) were exploited much worse (0.3 to 3.9% of biomass).

## *Lake Vozhe*

Lake Vozhe, located in the north of the Vologda Oblast, belongs to the basin of the river Onega, which flows into the White Sea. From northwest to southeast, the lake has an elongated shape and an indented coastline. The lake area is about 418 km$^2$; the average depth – 1.4–1.8 m; the maximum depth – 5 m (Gidrologiya ozer.., 1979). There are almost no settlements on its shores; the lake is hard to access both by land and water transport that strongly hinders the development of fisheries.

### *Commercial species*

The commercial catches in lake Vozhe consisted of 12 fish species. Over the past three decades, three main species were predominantly harvested in the lake: bream, pike and pike perch, which on average accounted for almost 90% of the total (Table 11). Other fish species were captured in small amounts as by-catch. In the second half of the 1990s, smelt and vendace completely disappeared from the catches.

### *Total catches*

Over the past four decades, maximum captures in lake Vozhe were recorded in the 1980s (130 tons on average per year). Bream and pike fishing (together) accounted for about 78% of the total (Table 11). In the 1990s, fishing volumes were almost halved. In the catches, pike perch (acclimatized in 1987) appeared. In the 2000s, the average catch was nearly recovered to the levels of the 1980s. By catches, pike perch became the second (after bream) in this lake. Since 2010s, the total catches dropped to an average of 75 tons, and in the last three years – up to 68 tons. This was due to the reorientation of the fishery from bream to commercially more valuable pike perch.

**Table 11.** Long-term dynamics of the total catch of the main commercial fish of lake Vozhe. Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – silver bream, smelt, vendace, bleak, ruff.

| Fish species | Years | | | | |
|---|---|---|---|---|---|
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Bream | $\frac{65}{50}$ | $\frac{48}{62}$ | $\frac{68}{55}$ | $\frac{29}{39}$ | $\frac{23}{34}$ |
| Pike | $\frac{37}{28}$ | $\frac{14}{19}$ | $\frac{14}{11}$ | $\frac{11}{15}$ | $\frac{9}{14}$ |
| Pike perch | – | $\frac{5}{6}$ | $\frac{28}{23}$ | $\frac{28}{36}$ | $\frac{31}{45}$ |
| Perch | $\frac{6}{5}$ | $\frac{2}{3}$ | $\frac{6}{5}$ | $\frac{4}{5}$ | $\frac{3}{5}$ |
| Burbot | $\frac{7}{5}$ | $\frac{2}{3}$ | $\frac{1}{1}$ | $\frac{1}{1}$ | $\frac{0.5}{1}$ |
| Roach | $\frac{4}{4}$ | $\frac{1}{1}$ | $\frac{4}{3}$ | $\frac{1}{1}$ | $\frac{0.2}{0.3}$ |
| Ide | $\frac{3}{2}$ | $\frac{1}{1}$ | $\frac{2}{2}$ | $\frac{1}{2}$ | $\frac{1}{1}$ |
| Others* | $\frac{9}{6}$ | $\frac{3}{5}$ | $\frac{1}{1}$ | $\frac{1}{1}$ | $\frac{0.2}{0.2}$ |
| **Total** | **130** | **76** | **124** | **75** | **68** |

### *Industrial fishery*

A total of 11 fishing sites covering the area of 309 km² (73.8% of the total lake area) operated on lake Vozhe. Annually, from 15 (2019) to 8 fishing permits (2022) were issued. Over the past ten years, fishing in this water body was conducted by four users: "Neptun" LLC, which provided on average 15.1% of the total fish catch, individual entrepreneurs Lazarev R.S. (45.2%), Sudakov V.A. (34.4%; ceased his operation in 2022) and Shaminin V.A. (5.3%; ceased his activities in 2020). On average, the share of industrial fishery in lake Vozhe for the period under review made up 82.7% of the total, or approximately 60.8 tons per year.

Around 21.4 tons (35.3% of the total commercial catch) were captured in December (Fig. 9) when pike perch fishing considerably prevailed (54.1% of the total). At the same time, the share of bream reached only 26.0% and pike – 15.7%. Maximum catch of aquatic bioresources occurred in autumn when bream accounted for 44.7% of the total, and the shares of pike perch and pike made up 41.7 and 12.0%, respectively. In the first four months of the year, fish catches in lake Vozhe reached only 22.4% of the annual catch; in May - July, fishery was almost completely ceased.

In 2013–2022, fishermen largely used two types of tools for industrial fishing, i.e. stake and drift nets. During the period of ice fishing, as well as in late summer and autumn, fixed nets with a mesh size of 60–70 mm were mostly set. In autumn (until 2021), entrepreneurs Sudakov V.A. and Lazarev R.S. fished with drift nets. The use of large-mesh stake and drift nets ensured high shares of pike perch (43.0%), bream (40.8%) and pike (13.3%) in commercial catches (Fig. 10**A**).

### *Amateur fishery*

Poor development of amateur fishery at lake Vozhe is explained by its considerable remoteness from large settlements and poor access ways. Over the past ten years, amateur fishermen captured on average 12.7 tons per year (only 17.2% of the total catch), where pike perch markedly dominated (38.0%); pike (21.1%) and perch (21.1%) had also high shares in the catches (Fig. 10**B**). In view of modern trends towards large-size species fishing, burbot and roach accounted for 70–80% of the total annual catch, perch – around 60–70% of its total catch, and ide – approximately 40–50%. Stocks of ruff and silver bream were developed only by amateurs who used fishing rods and nets for catching fish for prey during the ice period. The first tool was used for fishing of perch, roach, ruff, bream, silver bream (on bait), whereas the second – for pike perch, pike, perch, and burbot. The average catch per fisherman per trip was approximately 2–3 kg. During the ice-free period, amateurs used mainly fishing and spinning rods. Perch, roach, bream, and ruff were caught on bait, whereas large perch, pike perch and pike – with a spinning. The catch per fisherman per trip reached on average 4–6 kg of fish.
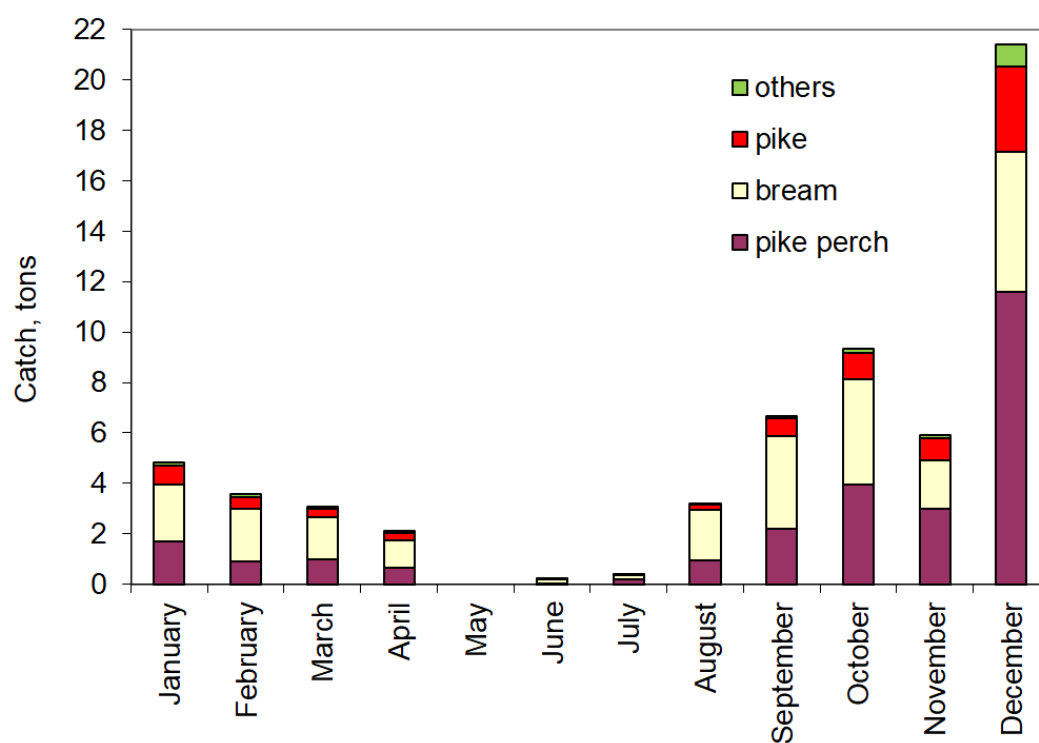
**Fig. 9.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in lake Vozhe on average for 2013–2022.
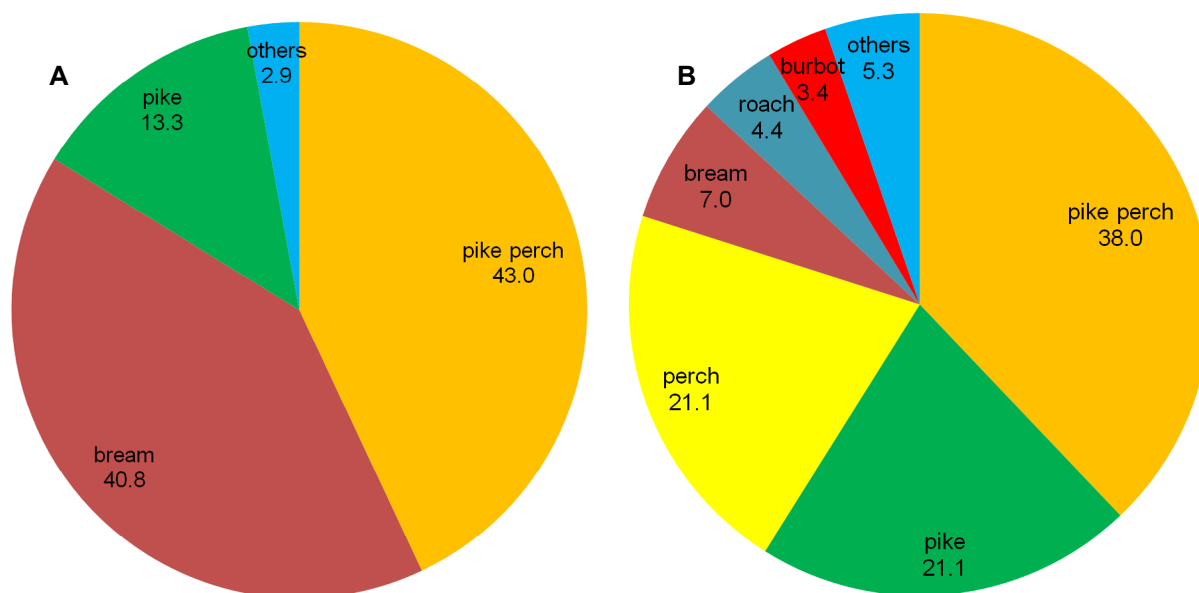


**Fig. 10.** The ratio (%) of the main fish species in commercial (**A**) and amateur (**B**) catches in lake Vozhe on average for 2013–2022.

### Commercial fish stocks and their development

In 2013–2022, the stocks of the main commercial fish species of lake Vozhe ranged from 1757 to 2056 tons (Table 12). Starting from 2018, the estimated commercial stocks slightly increased. The total recommended catch volumes also increased by 1.4 times mainly due to small-size fish (perch, roach and silver bream) and the fished water method applied for assessing stocks when fishing with stake nets. The average long-term catches of aquatic biological resources amounted to 61 tons, the total development of commercial stocks was within 3.2%. Since 2020, we registered the reduced catches and worse development of commercial fish stocks along with industrial fishery of low intensity.

In 2013–2022, the low-level exploitation of stocks of the main commercial fish of lake Vozhe was noted (Table 13). In particular, the volumes of TAC of pike perch were developed only by 60%, while RC of other two commercially demanded species (bream and pike) – by 35% for each. The catches of all three species amounted to 5–6% of their commercial stocks. The rest fish species with high rates of commercial stocks (perch, roach, silver bream and ide) were exploited extremely poor (0.01–0.5%).

**Table 12.** Dynamics of commercial stocks of aquatic biological resources of lake Vozhe and their actual development in 2013–2022; * – industrial and research fisheries.

| Indicator | Year | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | |
| Commercial stock, t | 1808 | 1873 | 1890 | 1757 | 1816 | 1844 | 1951 | 1992 | 2045 | 2056 | **1903** |
| TAC and RC, t | 182 | 162 | 157 | 157 | 146 | 217 | 218 | 216 | 222 | 235 | **191** |
| Catch*, t | 63.3 | 57.9 | 67.6 | 64.0 | 56.5 | 58.8 | 78.4 | 49.0 | 64.0 | 50.1 | **61** |
| Development of TAC and RC, % | 34.8 | 35.7 | 43.1 | 40.8 | 38.7 | 27.1 | 36.0 | 22.7 | 28.8 | 21.3 | **31.9** |
| Development of stock, % | 3.5 | 3.1 | 3.6 | 3.6 | 3.1 | 3.2 | 4.0 | 2.5 | 3.1 | 2.4 | **3.2** |

**Table 13.** Stocks of the main commercial fish of lake Vozhe and their actual development (on average) for 2013–2022; * – industrial and research fishing; ** – assessment of stocks of silver bream was performed on average for 2016–2022.

| Fish species | Indicator | | | | | |
|---|---|---|---|---|---|---|
| | Commercial stock, t | TAC or RC, t | Share of TAC or RC of stock, % | Catch*, t | Development of TAC or RC, % | Development of stock, % |
| Bream | 511 | 70 | 13.7 | 24.8 | 35.4 | 4.9 |
| Pike perch | 431 | 44 | 10.2 | 26.2 | 59.6 | 6.1 |
| Perch | 269 | 17 | 6.3 | 0.5 | 3.0 | 0.2 |
| Roach | 206 | 11 | 5.2 | 0.2 | 2.1 | 0.1 |
| Silver bream** | 200 | 7 | 3.3 | 0.02 | 0.3 | 0.01 |
| Pike | 139 | 22 | 15.9 | 8.1 | 36.7 | 5.8 |
| Ide | 146 | 9 | 6.3 | 0.7 | 8.0 | 0.5 |
| Others | – | 12 | – | 0.4 | 3.1 | – |
| **Total** | **1903** | **191** | **10.0** | **61** | **31.9** | **3.2** |

## Lake Onega (within Vologda Oblast)

The southeastern part of lake Onega (with its water area of about 1258 km$^2$ and average depths of 20.4 m) is located within the boundaries of Vologda Oblast (Borisov and Tropin, 2018). Its relative shallowness and the presence of small lakes connected with large tributaries ensure high fish productivity and lake's demand for fishing.

### Commercial species

In commercial catches (in the Vologda part of lake Onega), 15 fish species were registered, among which four cold-water species noticeably dominated in the period under review: European smelt, vendace, burbot and whitefish provided over 90% of the total catch (Table 14). In the past decade, whitefish almost disappeared, and the role of vendace and burbot in the lake fishery greatly decreased.

### Total catches

For the forty-year period under consideration, maximum fish catches in lake Onega were recorded in the 1980s when on average 689 tons were captured per year (Table 14). In the 1990s, officially registered amounts dropped to 390 tons, however, in the 2000s, they increased to 430 tons. Since 2010, fishery in the reservoir was mainly focused on European smelt, which provided about 92% of the total catch. A major accident with the oil tanker occurred in November 2007 at spawning vendace sites (Konovalov et al., 2014) violated the conditions for spawning and feeding of most commercial fish and could make a negative effect on other fish species as well.

### Industrial fishery

For industrial fishery on lake Onega (within the boundaries of Vologda Oblast), 13 fishing sites with an area of 1134 km$^2$, or 90.2% of the total area of the lake were created. Annually, the users of aquatic biological resources got from 49 (2019) to 13 fishing permits (2022). Long-term fishing in the reservoir was conducted by two users: "Onezhsky" LLC, which annually provided on average 87.3% of the total catch, and Fishing Artel "Prionezhye" LLC (12.6%), which operated till 2020. In 2019–2022, the farm head Erofeev V.A. and CJSC "ART-FISH LLC" (in 2020) made insignificant catches. On average, over a ten-year period, the share of industrial fishery in lake Onega accounted for about 97.7% of the total, or approximately 218.6 tons per year.

**Table 14.** Long-term dynamics of the total catch of the main commercial fish of lake Onega (Vologda Oblast). Above the line – the average annual catch, t; under the line – the share of the total catch, %; * – lake salmon, lake char, lake trout, pike, roach, ruff, banstickle, ide, unidentified small-size fish.

| Fish species | Years | | | | |
| --- | --- | --- | --- | --- | --- |
| | 1980s | 1990s | 2000s | 2010s | 2020–2022 |
| Smelt | $\frac{435}{63}$ | $\frac{269}{68}$ | $\frac{315}{73}$ | $\frac{204}{92}$ | $\frac{218}{92}$ |
| Vendace | $\frac{108}{16}$ | $\frac{30}{9}$ | $\frac{84}{20}$ | $\frac{7}{3}$ | $\frac{4}{3}$ |
| Burbot | $\frac{49}{7}$ | $\frac{39}{10}$ | $\frac{10}{2}$ | $\frac{3}{1}$ | $\frac{2}{1}$ |
| Whitefish | $\frac{32}{5}$ | $\frac{26}{7}$ | $\frac{10}{2}$ | $\frac{0.3}{0.2}$ | $\frac{0.4}{0.2}$ |
| Bream | $\frac{11}{2}$ | $\frac{6}{2}$ | $\frac{6}{1}$ | $\frac{2}{1}$ | $\frac{2}{1}$ |
| Pike perch | $\frac{4}{1}$ | $\frac{1}{0.4}$ | $\frac{1}{0.2}$ | $\frac{1}{0.4}$ | $\frac{2}{1}$ |
| Perch | $\frac{3}{0.5}$ | $\frac{1}{0.4}$ | $\frac{2}{1}$ | $\frac{2}{1}$ | $\frac{1}{1}$ |
| Others* | $\frac{46}{7}$ | $\frac{18}{4}$ | $\frac{3}{1}$ | $\frac{2}{1}$ | $\frac{2}{1}$ |
| **Total** | **689** | **390** | **430** | **221** | **230** |

About 210.3 tons (96.2% of the total catch) in the lake were captured in May. This was due to European smelt fishing - the main commercial fish (Fig. 11). Due to spawning vendace, the total catch in October and November ranged as 1.3–3.4 tons that was much higher than in the rest months of the year (within 1 ton).

For fishing in lake Onega, state nets, fixed nets and traps, as well as throw nets and set lines were used. In recent years, only stake nets were employed for smelt and vendace fishing, as well as few in number fixed nets for other species. On average, the share of smelt made up approximately 95.2% of the total catches. The shares of vendace and other fish species were equal (1.8% and 3%, respectively) (Fig. 12**A**).

### Amateur fishery

Amateur fishery on lake Onega (within the considered boundaries) is poorly developed because of remoteness of the lake from large settlements. Therefore, the local population mostly fish on the inflowing rivers, the Onega Bypass Canal and the adjacent small lakes. For the ten-year period under review, amateur fishermen captured only 2.3% of the total recorded catches in the reservoir, or an average of 5.2 tons per year. In amateur catches of lake Onega and its tributaries, predatory fish dominated, i.e. pike (34.0% of the total), perch (26.7%), pike perch (19.5%) and burbot (11.5%) (Fig. 12**B**). The average catch per fisherman per trip was 0.5–1.5 kg. In recent years, poaching of the species listed in the Red Book of the Russian Federation[2] (e.g. lake salmon *Salmo salar* L., 1758 and common trout *Salmo trutta* L., 1758) has happened. In 2016–2020, the transport police confiscated 29 illegally caught (by trolling) specimens of salmon in the considered sections of lake Onega.
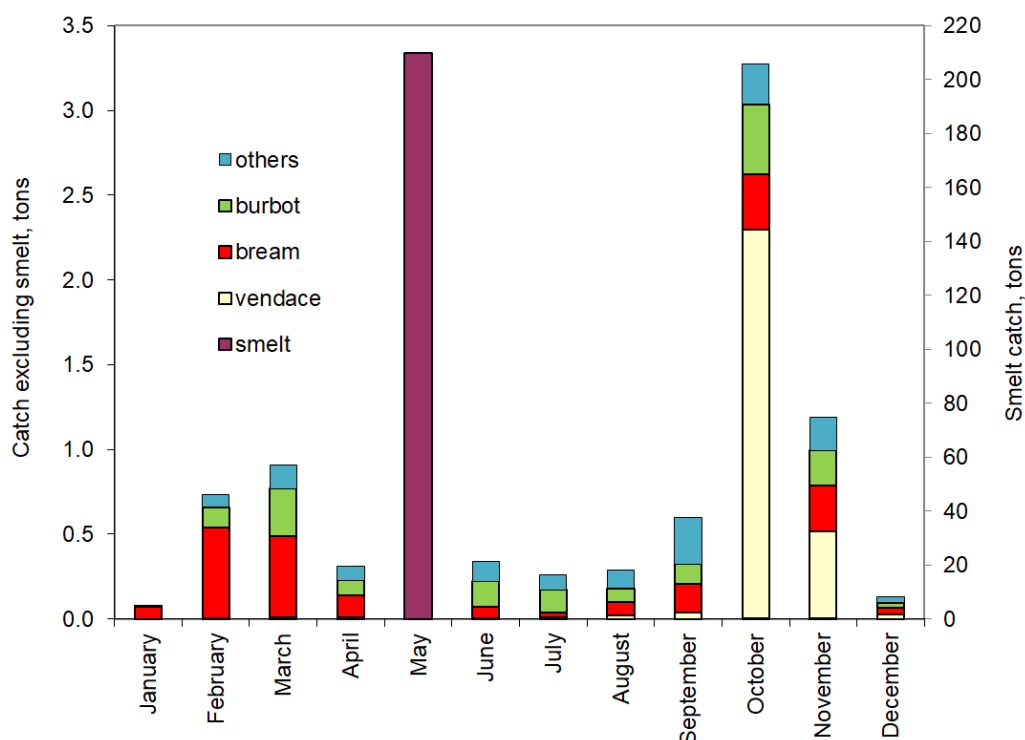


**Fig. 11.** Seasonal dynamics of commercial catches of the main types of aquatic biological resources in lake Onega on average for 2013–2022.

[2] Order of the Ministry of Natural Resources of Russia dated March 24, 2020 No. 162 "On approval of the List of fauna objects listed in the Red Book of the Russian Federation".
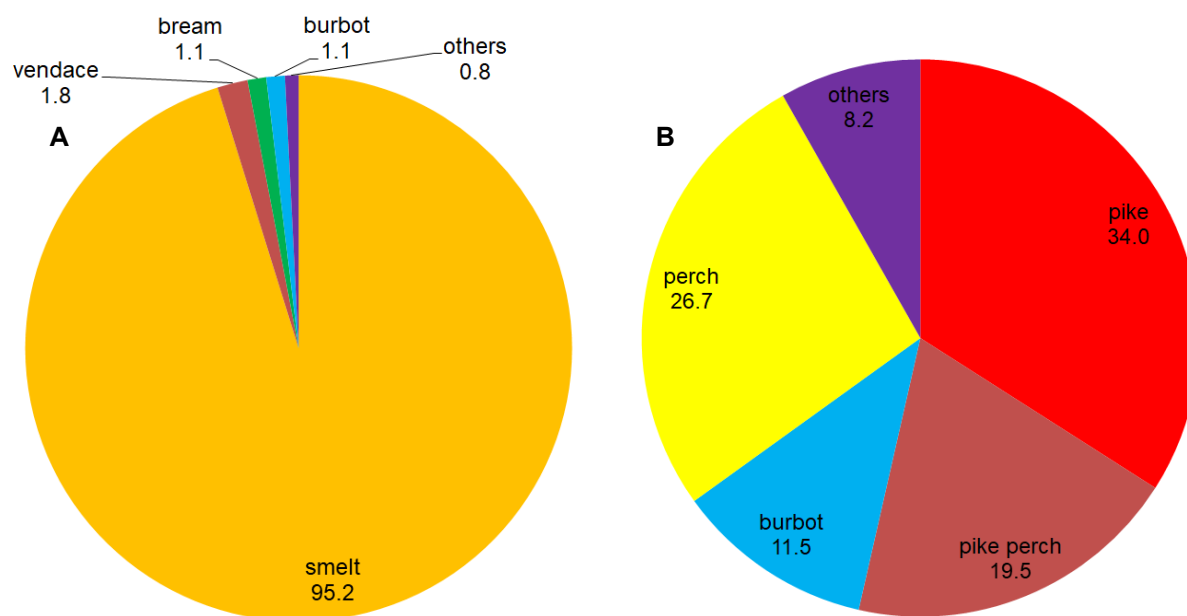
**Fig. 12.** The ratio (%) of the main fish species in commercial (**A**) and amateur (**B**) catches in lake Onega on average for 2013–2022.

## Conclusion

The total annual catch of aquatic biological resources in water bodies of Vologda Oblast in 2013–2022 averaged 1627 tons, including lake Beloye – 703, the Rybinsk reservoir – 328, lake Onega – 222, lake Kubenskoye – 171, the Sheksna reservoir – 129, and lake Vozhe – 74 tons. After significant decline in the 2000s, the total fish captures in lake Beloye almost recovered. A change of dominant species in the catches, and an increase in volumes of bream, sabrefish, Volga zander and small-size fish were recorded. In large lakes Kubenskoye and Vozhe, the total catches tended to reduce over the past two decades due to socio-economic situation and falling fishery profitability. In the snaggy river part of the Sheksna Reservoir, the catch volumes remained relatively constant, but their probable growth was hampered by numerous flooded trees and shrubs present in the water. Most valuable commercial fish species, the stocks of which ensured mass production (bream in lakes Beloye, Kubenskoye, and the Sheksna Reservoir, zope and bream - in the Rybinsk Reservoir, bream and pike perch – in lake Vozhe, European smelt – in lake Onega) dominated in all captures. In almost all water bodies, the most intensive fishing was observed during the ice period. In lakes Beloye, Kubenskoye and Vozhe, almost a quarter of the annual amount was fished in December, while in lake Onega (over 96% of the annual catch) – in May due to captured pre-spawning assemblages of European smelt. In 2013–2022, the best development of total allowable catches and recommended catch volumes was observed on lake Beloye (average: 59.7%). In the rest important fishery reservoirs of the region, these indicators were almost 2 times less: in lake Kubenskoye – 33.7%, in lake Vozhe – 31.9%, and in the Sheksna reservoir – 25.8%. In general, this indicates a moderate impact of fisheries on the stocks of the main aquatic biological resources of lake Beloye and low – of lakes Kubenskoye and Vozhe, including the Sheksna reservoir. Thus, modern fishery insignificantly affects the long-term dynamics of commercial fish stocks in the Sheksna reservoir, in lakes Kubenskoye and Vozhe.

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