

The impact of fish farming on the Tarasmozero Lake ecosystem, Onega Lake basin

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Abstract. The Tarasmozero Lake ecosystem (Onega Lake basin), affected by fish farming was assessed prior to and after the construction of a rainbow trout farm. Lake Tarasmozero receives waste water from the farm. The results of our studies show that when the farm began operating, phosphorus and nitrogen concentrations in the water have increased, affecting aquatic organisms and their environment. It was shown that phytoplankton is now dominated by diatoms, zooplankton species, characteristic of eutrophic water bodies, have appeared, and amphipods now make up the bulk of zoobenthos' biomass. This evidence indicates that Lake Tarasmozero gradually passes from an oligotrophic type to a mesotrophic type.

1 Introduction

Aquaculture is the world's most dynamically developing sector of food production. Now it makes up over 60% of the world's aquatic products. Fish production accounts for 65-70% of aquaculture [1-2]. The Republic of Karelia is a region most conducive to commercial rearing of valuable fish species. Rearing fish (mainly the rainbow trout *Parasalmo mykiss*) in ponds is promising and economically profitable, because Karelia has a good climate (a long light period during vegetation, an optimum temperature, huge clean water resources, etc.), a transportation network and skilled farming staff.

Launched in the 1980s, Karelia's commercial rainbow trout production has considerably increased over the past 40 years (36 600 tons in 2022). Recognized as Russia's leading trout producer, Karelia now has about 70 fish farms.

Vigorous trout farming in Karelia has a considerable impact on its lake ecosystems. Environmental changes affect the species composition, taxonomic groups' ratio, population structure and abundance of plankton, benthos and fish [3-5].

Trout farms are now a local but essential source of eutrophication of water bodies, which increases the risk of spreading of various fish diseases.

2 Material and methods

Tarasmozero Lake is part of the Lizhma River's lake-river system (Kedrozero – Tarasmozero – Lizhma Bay of Onega Lake). The lake covers an area of 1.1 km². It has an

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average depth of 3.7 m and a maximum depth of 5.6 m (Table 1). It has stable temperature stratification, as indicated by its thermal regime, and its arbitrary water exchange index is high. Its active water reaction (pH 7.2) is close to neutral [6]. Its water is oligomesohumic, as indicated by its colour index, permanganate oxidizability and organic matter content [7].

The young rainbow trout farm on Tarasmozero Lake has been operating since 1993. Water for egg incubation, rearing of juveniles and maintaining trout producers comes from Kedrozero Lake, which is located upstream. Waste water from the farm flows into Tarasmozero Lake and farther down the Lizhma River into minor Lizhma Bay of Onega Lake.

Table 1. Main morphometric characteristics of Lake Tarasmozero.

Index	Value
Lake area, km ²	1.1
Coastline length, km	5.2
Water volume, km ³	0.0041
Lake length, km	2.3
Average width, km	0.5
Largest width, km	0.9
Average depth, m	3.7
Greatest depth, m	5.8
Catchment area, km ²	703
Conditional water exchange period	71.0

Plankton samples were taken with a 2-litre Ruttner's bathometer in summer-autumn from the surface and all other water layers at 1 m intervals. Integrated (surface-bottom) samples were filtered through чepez gas No. 70 , concentrated to 100 mm and fixed with 4% formalin. The samples were processed using standard methods [8]. The degree of water contamination with organic matter was calculated from indicator organisms' ratio and saprobity indices.

Quantitative samples of macrozoobenthos were taken in autumn with a DAK-250 bottom grab (a version modified by Ekman-Berge with a grabbing area of 1/40 m²), ground was washed through sieve No. 19 (0.5 mm mesh) and fixed with 8% formaldehyde solution.

Fish samples were taken in summer-autumn from net catches (nets with 15-60 mm mesh). Nets were put throughout the lake. The samples were processed by standard methods [9, 10], measured and weighed, and their sex, age and degree of gonad maturity were determined.

3 Results

The results of chemical analysis of water before and after the functioning of the farm show that total phosphorus increased from 0.007 to 0.028 and mineral phosphorus from 0.001 to 0.002 mg/l. Organic nitrogen, nitrate and nitrite concentrations were shown to grow. Total phosphorus and nitrogen concentrations in the lake are typically revealed at the lower boundary of oligotrophic water bodies [7]. The quality of Tarasmozero Lake water meets all incubating and rearing requirements for juvenile and commercial fish.

The composition of algal flora prior to the construction of the Kedrozero Fish Farm on Tarasmozero Lake was typical of northern water bodies unaffected by human activities [11]. The biomass of phytoplankton was 0.10 – 0.35 g/m³ and primary production was 0.14 – 0.80 mg O₂/l/day, which is characteristic of α – oligotrophic water bodies.

After the trout farm was put into operation, the composition of phytoplankton in Tarasmozero Lake began to be dominated by diatoms. The relative abundance of blue-green, yellow-green and green algae was as low as 3–9%. The abundance and biomass of phytoplankton were generally as low as 13–106 000 cells/l (median value 47 000 cells/l and its biomass: was 3–113 $\mu\text{g/l}$ (median value is 96 $\mu\text{g/l}$ (0.096 g/m^3). In the waste water discharge area its abundance is 985 000 cells/l and its biomass is 643 $\mu\text{g/l}$ (0,643 g/m^3), which is characteristic of β – oligotrophic water bodies. The same pattern is indicated by the chlorophyll A content of the water, 1.9 mg/l^3 [3]. Differences in algal flora structure could be due to the presence of nutrient-rich waste water from the fish farm.

Zooplankton in Tarasmozero Lake consists of 61 species: 18 Rotifera species, 30 Cladocera species, 13 Copepoda species, 3 Calaniformes species and 10 Cyclopiformes species. Before the launching of trout farming (1989–1991), the bulk of zooplankton biomass in Tarasmozero Lake (50 to 90%) consisted of water fleas, mainly *Bosmina* [12]. Cyclopoida (*Mesocyclops leuckarti*, *Thermocyclops oithonoides* and *Cyclops strenuus*) made up 10 to 40%. Zooplankton in the littoral zone consisted of more rotifer species (up to 7) than that in the pelagic zone. After the launching of trout farming (1992), the most substantial changes in the species composition of the lake's zooplankton were exhibited by rotifers. In 1989-2024, the number of rotifer species increased from 7 to 13.

The abundance of zooplankton has changed since 2000. Average summer biomass is now twice as high (1.0 g/m^3). The lake is gradually becoming mesotrophic, as indicated by its trophic coefficient. Pantle-Bukk's saprobity index has increased from 0.95 to 1.42. Zooplankton now consists of more species indicative of increased nutrient content at temperate latitudes (*Bosmina longirostris*, *Polyarthra luminosa*, *Filinia longiseta*, *Trichocerca insignis*, *Daphnia longispina* and *Cyclops kolensi*). As trout farming began, the $B_{\text{crus}}/B_{\text{rot}}$ index decreased markedly, indicating the growing contribution of rotifers to the total biomass of zooplankton. These indices, together with the abundance of zooplankton in Tarasmozero Lake, show that the lake gradually passes from an oligotrophic to mesotrophic type due to fish farming and natural factors.

Prior to the functioning of the farm, Tarasmozero Lake's macrozoobenthos was dominated by chironomids, oligochaeta, molluscs, caddis flies and mayflies. When the farm began functioning, the ground near the lakeshore was washed out, and a maximum macrozoobenthic biomass of 33.7 g/m^2 , dominated by chironomids and oligochaeta, was reported in the autumn of 1994. The total biomass of macrozoobenthos varied from 0.5 to 7.4 g/m^2 .

Tarasmozero Lake's fish fauna consists of 13 species (8 families). Roach, perch and bream dominate in abundance and biomass. Lake trout and grayling are scarce. Salmon occurs only during spawning, when it migrates from Onega Lake. Species diversity is supported by a link to Onega Lake via the Lizhma River, where water is abundant. Therefore, small Tarasmozero Lake is now similar in the abundance of fish species to Kedrozero Lake. Changes in the Onega Lake ecosystem, provoked by human activities, e.g. illegal fishing, have badly affected salmon. There were 2500 salmon individuals in the river earlier and no more than 200 individuals nowadays.

4 Discussion

An aquatic environment inhabited by various organisms is the most vulnerable constituent of the biosphere, which may be changed considerably by human economic activities. Continental water bodies, such as lakes and water reservoirs, are most heavily affected by human activities. Geologically young water systems in the Republic of Karelia and other parts of Northern Europe are most sensitive to the harmful effect of human interference [3]. To maintain fish production, the deleterious impact on the water bodies used for fish

farming should be minimized throughout the entire technological cycle and the region's population should be provided with high-quality fish products.

In the Republic of Karelia, fish farms are located mainly in freshwater bodies. This has a deleterious effect on water quality and the condition of aquatic organisms. This is highly essential in a cold-water region, because the self-purification of its water bodies is very slow. To assess and control the effect of fish farming on Karelia's water bodies, regular monitoring is needed.

Analysis of the literature shows that intensive fish farming in North European Russia's aquatic ecosystems will provoke the man-induced eutrophication of its water bodies [3]. Apart from trout production, various fish diseases, caused by high fish concentrations in fish ponds, are likely to arise on fish farms or in water bodies used for fish farming. In addition, the structure and functioning of fish fauna in water bodies contaminated by fish pond farming may be disturbed. Fish may escape from ponds due to the incorrect use or malfunctioning of relevant equipment and external factors [13, 14]. The loss of fish or the damage of the equipment is economically unprofitable and has a bad effect on the environment [15]. These days, no cases of reproduction of pond trout which has escaped have been reported from Karelia, but in Lake Imandra located on the Kola Peninsula this species has naturalized [16].

Trout farming in the Republic of Karelia has a bad impact on the region's ecosystem [17-19]. It has been shown that fish food and metabolic products are the main sources of contamination of rainbow trout ponds. Hydrochemical analyses, performed in the past few years, have shown that nutrients, such as nitrogen and phosphorus, are involved as limiting factors. The additional supply of nutrients into the water bodies provokes a decline in water transparency and an increase in the biomass of primary phytoplankton production and other initial links of the trophic chain. An oxygen regime is deteriorated, new periphyton associations are formed, water "bloom" takes place every year, detritus is formed vigorously and the lake bottom is silted up [3]. Variations in ambient conditions affect the species composition, taxonomic groups' ratio, population structure and abundance of plankton, benthos and fish.

Tarasozero Lake receives waste water from the fish farm. The lake is a running water body, but phosphorus, nitrogen, nitrate and nitrite concentrations in its water were shown to increase. Hence, the lake's hydrobiological regime has changed.

5 Conclusions

Trout farming on Tarasozero Lake provokes changes in the structure of algal flora, zooplankton and benthos. Forms, characteristic of an eutrophic water body, appear in Tarasozero Lake. The abundance and biomass of benthos increase abruptly by about one order of magnitude, and amphipods now make up a high percentage of benthic biomass. The fish population is dominated by spring-spawning fish (cyprinid and percid species). Changes in the Tarasozero Lake ecosystem are not disastrous yet, but the lake's hydrochemical and hydrobiological regimes should be analyzed in more detail.

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