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FISHERY MANAGEMENT OF OMUL (*COREGONUS AUTUMNALIS MIGRATORIUS*) AS PART OF THE CONSERVATION OF ICHTHYOFAUNA DIVERSITY IN LAKE BAIKAL

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A b s t r a c t

The ecosystem of Lake Baikal has been recognized for its uniqueness as well as the need to preserve its natural structure and functions. Commercial fishery, and especially large catches of Baikal omul, *Coregonus autumnalis migratorius*, influence the general biological diversity of the lake. The paper discusses main guidelines for managing commercial fishing and presents the population structure of Baikal omul. The idea of sustainable fishery that involves preservation of the entire community of Lake Baikal's ichthyofauna is proposed.

GOSPODAROWANIE RYBOSTANEM OMULA (*COREGONUS AUTUMNALIS MIGRATORIUS*) JAKO CZĘŚĆ OCHRONY RÓŻNORODNOŚCI ICHTIOFAUNY W JEZIORZE BAJKAŁ

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S ł o w a k l u c z o w e: rybołówstwo, ochrona ichtiofauny, jezioro Bajkał, *Coregonus autumnalis migratorius.*

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Abstrakt

Ekosystem jeziora Bajkał jest znany ze swojej unikatowości, jak również z potrzeby ochrony jego naturalnej struktury oraz funkcji. Rybołówstwo przemysłowe, a w szczególności duże połowy omuli bajkalskich (*Coregonus autumnalis migratorius)*, wpływają na biologiczną różnorodność jeziora. W artykule omówiono główne wytyczne dotyczące gospodarowania rybostanem i przedstawiono strukturę populacji omuli bajkalskich. Zaproponowano strategię gospodarki zrównoważonej, która objęłaby ochronę całej ichtiofauny jeziora Bajkał.

Introduction

Technological progress and the associated gradual changes in the human environment have altered the hierarchy of priorities as regards the use of natural resources. The challenge of ensuring pure potable water has come to the forefront, along with the problem of preserving those areas which so far have not been modified by economic activities. In the 1970s and 1980s, Lake Baikal began to be regarded as a source of pure potable water of national and global significance. Since the 1990s, the lake has served this purpose. In 1996, in response to the application submitted by Russia, Lake Baikal and the adjacent territory were listed as one of the UNESCO World Natural Heritage sites. In 1999, the Federal Law on Protection of Lake Baikal was passed. The lake's ecosystem was recognized as a unique one and in need of the preservation of its natural structure and functions (DOBRETSOV 2003). Since then, it has been necessary to cope with the problem of how to reconcile the status of a special protected territory with plans for socioeconomic development of the region, in which commercial fishery has an important role.

Background: Fishing on Lake Baikal

Compared with other economic activities in the region, the exploitation of fish resources in Lake Baikal has the longest history. Lake Baikal has been known for its extremely rich resources of fish from time immemorial. The earliest written mentions on commercial catches date back to the 17th and 18th centuries. Most catches comprised omul (*Coregonus autumnalis migratorius* (Georgi)). During the above period, as much as 8–10 thousand tonnes of this fish were caught annually. At the turn of the 18th and 19th centuries, first reports on fluctuations in fish catches started to emerge.

A drastic and persistent decline in catches, down to 2.5–1.0 thousand year, was observed in the late 19th c. and early 20th c. It was suggested then that omul could disappear completely and therefore it was necessary to undertake protection and artificial breeding measures. A new increase in catches started in the mid-1930s. As early as 1937–1942, the annual catch of omul reached 6–9 thousand tonnes. However, it was a short-lived increase. The mid-1940s witnessed another decline in catches. Towards 1968, the annual catches decreased to 1 000 t (Figure 1). The simultaneous drastic reduction in the spawning herds was responsible for the total cessation of commercial fishing of the omul in 1969 (SMIRNOV and SMIRNOVA-ZALUMI 1979).

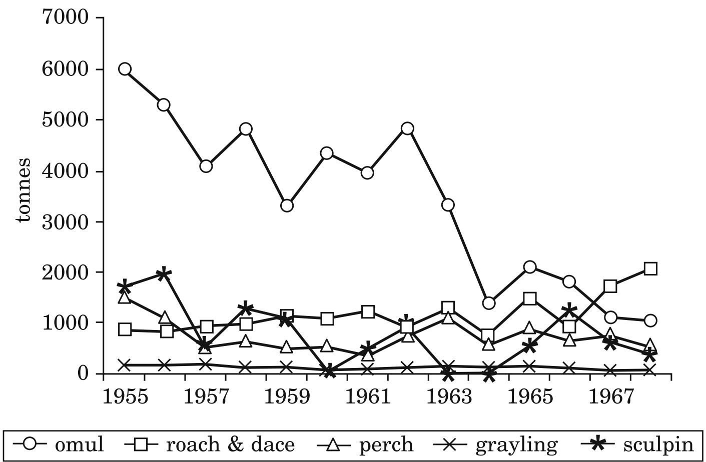

Fig. 1. Annual catches of the main commercial fishes during 1955–1968

The fishing companies, while struggling with lower Baikal omul catches in the 1950s and 1960s, were trying to maintain the previous level of the overall fish catch by harvesting more river perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), dace (*Leuciscus leuciscus*) and other fish species living in Lake Baikal's gulfs and in the deltas of its large tributaries as well as the lakes within their basins (Figure 1). More intensive catches of the above fish, however, led to depleting their resources. Such near-shore species as Baikal whitefish (*Coregonus lavaretus*), grayling (*Thymallus arcticus*) and sturgeon (*Acipenser baeri*) have lost their commercial significance.

Main guidelines for managing commercial fishing

In 1982, when commercial exploitation of Baikal omul was resumed after the 13-year-long prohibition period, the underlying fishing regulations were modified. The ecological principles of managing fishing intensity, developed during the period of prohibition, were adopted. Thus, the intensity of commercial fishing was not regulated with quotas but through the spatiotemporal structure of fishing expressed in terms of the number of fishing implements used, their distribution in areas of commercial fishing, and seasons of fishing (SMIRNOV 1977, 1979). The planned volume of total catch was achieved with the smallest possible number of fishing teams engaged in fishing operations (Figure 2), a solution which was accompanied by the enhanced economic efficiency of fishing operations and financial incentives offered to fishermen as well as by a decrease in unaccountable fish catches.

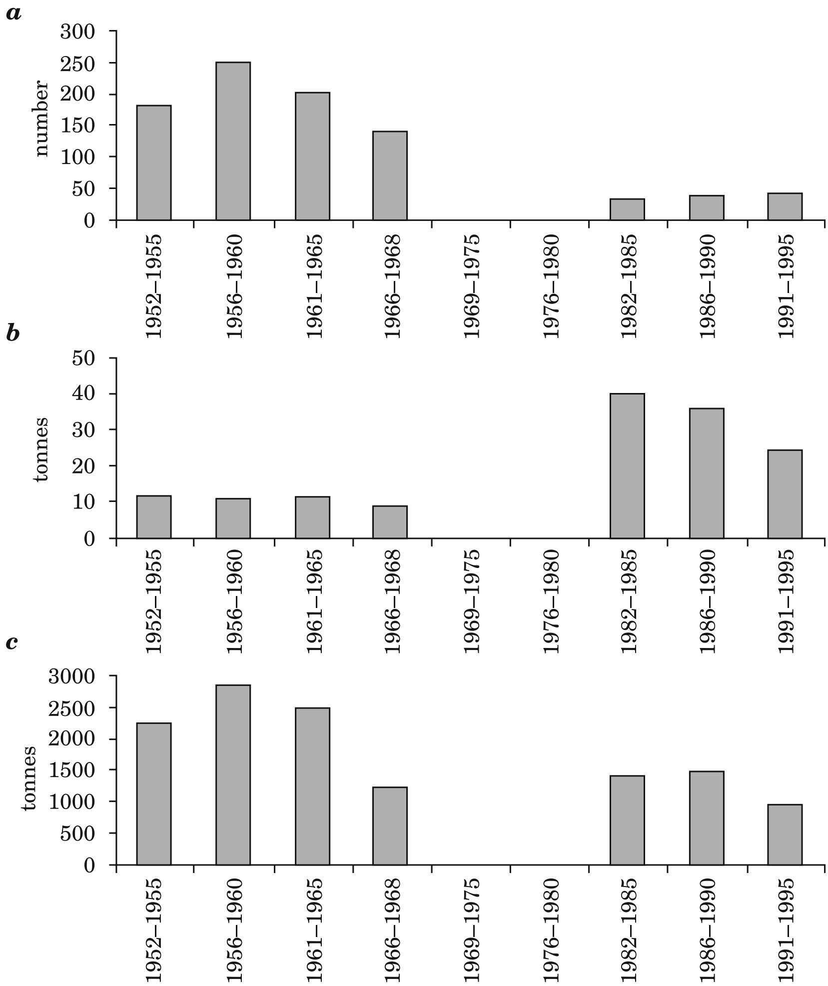

Fig. 2. Structure of commercial omul fishing prior to its prohibition by the fishery industry of the Republic of Buryatia, without limitation on catch intensity (1952–1968), and after it was resumed, with annual catch intensity planning expressed in terms of the quantity and composition of fishing implements, and areas and periods of fishing (1982–1995). The mean indices for periods covering 5 years are given: *a* – number of commercial fishing teams; *b* – annual catch of omul per team; *c* – total annual catch of omul by all teams

The transition of Russia to market economy coincided with a decreased significance of large fish factories on Lake Baikal during 1990–2000, and a growing number of smaller cooperatives engaged in fishing, processing and sales of omul and other fishes. As a result, a marked increase in the fishing seasons occurred and the quality of fish products improved substantially.

However, a very important question has been completely neglected, i.e. how does the fishing of omul (Figure 1) influence the resources of other fishes? Both prior to the prohibition of commercial omul fishing (before 1969) and at the present time, this fish was and still is captured in the near-shore waters, i.e. in habitats of other fish species, e.g. grayling, whitefish and sturgeon, which are less numerous, but equally valuable commercial fishes. During the 1950s–1960s, in shallow-water areas along the eastern shores of the lake, as many as 90 fixed seines and 40 haul seines, and up to 320 km of gill nets were installed in the summer season every year (Figure 3). The use of such a large number of fishing implements, designed for fishing omul specimens weighing on average 200–300 g, led to a mass destruction of sturgeon and whitefish fry. A single set of gill nets totalling 2000 m in length yielded a catch of 40–100 small sturgeon individuals up to 300 g in weight (YEGOROV 1960). From 1960 to 1980, seasonal distribution, abundance and biological state of Baikal omul were monitored by scientists, who noticed that up to 10 individuals of sturgeon fry were present in a catch performed in the lake's near-shore zone with standard 300-meter-long sets of gill nets of the mesh size ranging from 16 to 40 mm. However, it is only the mass catches of younger age groups of

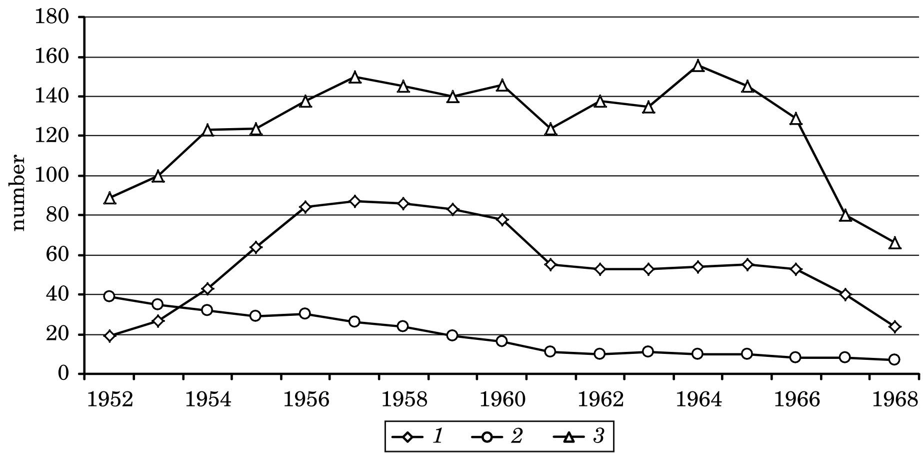

Fig. 3. Number of fishing implements as used in commercial omul fishing by the fishery industry of the Republic of Buryatia during 1952–1968 years: *1* – fixed seines; *2* – haul seines; *3* – gill seines two thousand meters long

sturgeon during the summertime fishing of omul that can be held responsible for a nearly complete ineffectiveness of fish-breeding operations aiming at increasing the abundance of sturgeon.

In the 1950s, a high number of Baikal whitefish *C. lavaretus* was caught while fishing omul in the shallow waters and bays of Lake Baikal (STERLYAGOVA 1958). In the 1960s, the fry of Baikal whitefish (from 1 to 5 years old) made up 30–90% of the total catch found in shutter and wind-seine (SKRYABIN 1969). Intensive fishing of omul in 1950–1960 had an adverse influence on the resources of Baikal grayling as well (TUGARINA 1981).

The threat to commercially valuable species inhabiting the near-shore waters (sturgeon, grayling, Baikal lake whitefish and lake-river whitefish) can only be overcome by relocating omul fishing operations from the near-shore zone to the main habitat of omul populations in the lake's open pelagic zone.

Population structure of Baikal omul

Most reports on protection and sustainable management of renewable natural resources use the term 'biological diversity' to refer to the composition of species. However, a water body is populated not by species as such, but by populations of species that have adapted themselves to its particular biotopes (BEKLEMISHEV 1951). The system of these populations treated as elementary self-reproducing units of a given species, i.e. the form of its existence (TIMOFEYEV-RESOVSKY 1958, SHVARTS 1967, MAYR 1970), is what the term 'biological diversity' covers more precisely.

The reproductive isolation of Baikal omul populations (SMIRNOV et al. 2009, 2011) was confirmed by biochemical (TALIYEV 1941, USHAKOV et al. 1962, MAMONTOV and YAKHNENKO 1987) and genetic investigations (SUKHANOVA 2004), as well as by labelling mature fishes in spawning rivers (MISHARIN and TYUMENTSEV 1965, SMIRNOV and SHUMILOV 1974). For their reproduction, the populations have colonized the river basins which are highly different in many parameters. The omul population in the Selenga River is the most numerous one because of a large area covered by the spawning habitats in this river (which is 1590 km long), where spawning herds migrate as far as 400–500 km upstream from the mouth (SELEZNEV 1942, SOROKIN 1981, VORONOV 1993). The omul of the North Baikal population is less numerous. The distance covered by spawning herds of this population in the Upper Angara and Kichera Rivers is 100–300 and 50–70 km, respectively (TYURIN and SOSINOVICH 1937, SMIRNOV and SHUMILOV 1974). Spawning sites of less numerous populations (the Posolsky, Chivyrkui, Kikinsky and some other populations reproducing in small rivers flowing into the lake) are just 3–30 km from the river mouth (MISHARIN 1958, SMIRNOV and SHUMILOV 1974, STERLYAGOVA and KARTUSHIN 1980).

Reproducing in different zones (in the latitude and landscapes), the populations of Baikal omul differ not only in their number but also in the rhythms of their fluctuations. The river basins of the northern termination of Baikal (the Upper Angara and Kichera), and of the Selenga river are under the influence of opposing air masses (arriving from the North Atlantic and the Pacific, respectively) (AFANASYEV 1976, OBOLKIN 1977). The regime of atmospheric precipitation and the river runoff difffish in the early stages of ontogenesis (SMIRNOV and SMIRNOVA-ZALUMI 1999).

The dynamic characteristics of the abundance of populations, maturing age and age structure of populations are associated with the birth rate rhythms of generations and their foraging habitat. In the 1950s–1977s, the age when mass reproduction of individuals in omul populations occurred was 5–6 years in the North Baikal population (SMIRNOV and SHUMILOV 1974) and 10–11 years in the Selenga and Posolsky populations (SMIRNOVA-ZALUMI 1977, SMIRNOV et al. 1987).

The main biotope of populations. The adaptability of populations to the conditions for their reproduction in the river basins coincides with the adaptation to living in the conditions present in Lake Baikal's upper 350-meter water column (SMIRNOV 1969, 1992, SMIRNOVA-ZALUMI and SMIRNOV 1973, SMIRNOV et al. 2009):

1. Pelagic omul. The extensive spawning habitat of omul of the Selenga population is correlated with the exploitation by omul of food resources from Lake Baikal's largest biotope, i.e. the entire epipelagic zone. The highest concentrations of omul of the Selenga population occur in the layers of seasonal and deep thermocline. The seasonal thermocline in the summer-autumn period is observed at a depth of up to 10–20 m, and the deep thermocline occurs throughout the entire summer at a depth of 100–150 m from the water surface.

2. Coastal-pelagic omul. Feeding migrations of omul of the North Baikal population, having smaller areas of spawning sites, encompass the near-shore-pelagic biotope of Lake Baikal. During the daytime, North Baikal omul is distributed in the benthic water layers. At nightfall, omul ascends to the upper 5-meter layer following its food, i.e. zooplankton (AFANASYEVA 1977), young brood of benthic amphipods (BESSOLITSYNA 2002), and larvae and fry of yellowfin (*Cottocomephorus grewingki*) and longfin (*Cottocomephorus inermis*) sculpins (KORYAKOV 1972), thus forming nighttime concentrations.

3. Benthic-deepwater omul. The omul reproducing in small tributaries of the lake (of the Posolskaya, Chivyrkaya and Kikinskaya populations) has colonized the least extensive biotopes in the narrow slope area of the pelagic

zone adjoining the areas of reproduction. In these biotopes, in the zone where vertical hydrological fronts interact, in the benthic water layer at a depth of 50–350 m, vertical diurnal migrations result in considerable concentrations of food for omul, e.g. medium and large Macrohectopus (*Macrohectopus branizkii*), fry of little *Comephorus dybowskii* and big *Comephorus baicalensis* Baikal oilfish, yellowfin (*C. grewingki*) and longfin (*C. inermis*) sculpins (SMIRNOV 1974, KASTORNOV 1983, NAGORNY 1984).

Shutter and wind seines (principal modern industrial fishing gear) are used in the biotope of the Severobaikalskaya omul population. The Selenginskaya population and omul populations of the lake's small tributaries concentrate here for a short time in spring and during pre-spawning migrations in autumn (SMIRNOV et al. 2009). Basically, the fishing operations here focus on these concentrations of fish. During the year, most omul fish are not available to fishermen. At the same time, whitefish, sturgeon, and grayling are found in the zone where fishing takes place.

Variability in distribution of omul and in commercial catches

High variability of the seasonal distribution and associated fluctuations of commercial catches between years are another characteristic of Baikal omul (SMIRNOV et al. 2009). The main factor generating these fluctuations is the variability of temperatures of Lake Baikal's waters. The instability warming-up of the lake's different areas and zones in particular years is reflected by the distribution dynamics specific for each fish population. It mainly affects migrations of the most numerous (Selenga) omul population. Surveys from 1966–1968 showed that the yield of omul catches depended on the formation a layer of water where temperature jumped, and on the surface waters (epilimnion) being warmed up to 7–9°C (SMIRNOV and SHUMILOV 1974).

The importance of the degree of warming of the water masses in Lake Baikal's deep-water areas for omul's foraging behaviour is quite well illustrated by the data from surveys carried out in June in 1971–1982, which covered the main areas of springtime concentrations of the fish. The higher the values of water temperature and water heat content in the lake's deep-water areas, the higher the production of phytoplankton in the 0–25 m layer and the larger the total biomass of zooplankton in the 0–250 m layer (SHIMARAYEV 1971, 1977, SHIMARAYEV and AFANASYEVA 1977, BEKMAN and SMIRNOV 1977). This in turn means that this zone is more extensively colonized by omul in the summer season and therefore fewer omul individuals remain in shallow-water areas. Another analysis of the annual values of water temperature in May in the Peschanaya Bay (the most representative of the thermal conditions of the Selenga area and the adjacent water masses of Central and South Baikal (SHIMARAEV 1971) compared to average catches of omul with experimental arrays of gill nets in the shallow-water areas in June showed contrary changes of these indicators in the series for 1972–1981 (r = 0.8). That is to say, the better the habitat conditions for omul in the lake's deep-water areas, the larger the numbers in which the populations are distributed in their biotopes and the lower its concentration in the shallow-water areas. A significant increase in commercial catches was observed during the years (1945, 1947, 1951, 1954–1958) with low enthalpy waters of the lake in spring, when more omul individuals would migrate from deep waters to the lake's littoral zone. Dislocation of fishing in the coastal-pelagic zone limits the capacity of fishing effort – omul fishing is effective here for 1–2 months, but not in every year.

Rational commercial fishing in general must take into consideration the interannual and seasonal changes in the distribution of populations in biotopes.

Fishery management of omul – recommendations

Biological diversity conservation in Lake Baikal is only possible by adopting the biocenotic approach to exploitation of natural resources, including fish stocks. In order to promote sustainable fishery management in Lake Baikal, the authors recommend:

– to restore the abundance and commercial fishing significance of such commercially valuable species as Baikal sturgeon and Baikal lake and lake--river whitefish through relocation of commercial fishing of omul from the near-shore zone to the pelagic zone of the lake's deep-water areas.

– to establish rational fishery which will involve maintenance of the natural structure of commercial fish populations.

– to plan catches of particular populations of omul, having regard to their importance in the formation of the overall number and biomass of the species, characteristics of their seasonal distribution, variability of foraging and spawning migrations.

– to resume omul catches with drifting nets in pelagic deep-water districts of the lake so as to promote rational distribution of fishery load on omul populations.

– to monitor continuously the fish stocks, which is necessary if the fishery industry on Lake Baikal is to progress. The monitoring should include observations of the species, population size, age and weight structure of commercial catches. These indicators will form a basis for a method to assess the number and biomass of populations of commercial species.

– to use bio-statistical methods for assessment of the commercial stock of fish (DERZHAVIN 1922), which is not only economically advantageous estimate of commercial reserves, but also the most reliable method (RICKER 1971) under the conditions of rational (intensive) exploitation of fish stocks. The fishing operations will furnish the necessary information for planning their structure and intensity for each subsequent year and for the short- and long- term future.

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