Inland capture fisheries of the USSR

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Inland capture fisheries of the USSR

by

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PREPARATION OF THIS DOCUMENT

This document has been compiled in response to numerous requests for information on inland fisheries of the USSR. The material collected in this study is of importance especially to the EIFAC and IPFC member countries, many of which have a common border with the USSR and have water bodies with similar or identical fish fauna complexes. Another document on the Soviet experience, prepared by D.S. Pavlov, appeared in 1989 under the title: Structures assisting the migrations of non-salmonid fish: USSR (FAO Fisheries Technical Paper, No. 308).

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ABSTRACT

The USSR has about 26 million ha of lakes, 7 million ha of reservoirs and 500 000 km of running waters on which inland fisheries can be practised. The principal characteristics of these water bodies are presented here, together with a survey of the most important species of fish, both indigenous and exotic, inhabiting the lakes and reservoirs. Details of inter-specific fish relationships are also discussed. Annual fish production from all inland waters, including aquaculture, had reached 988 000 tons by 1987. In addition anglers probably landed another 200 000 tons per year. Lake catches accounted for approximately 40-44% of the commercial catches, while the reservoir and riverine catches contributed 28-34% and 23-30% respectively. Methods of fishery management are discussed, with emphasis on intensification practices. These include the establishment of highly productive fish farms and hatcheries, the conversion of reservoir shallows and small lakes into fish farms, the use of warmed effluent water from power stations, and the problems of introducing and acclimating new species, particularly Coregonidae and Chinese carps. The basic technical designs of fish passes and barriers are described, also details, design and operation of active and passive fishing equipment. Mention is made of legislation which governs fishing in the USSR, and some account is given of the development and current status of fisheries in the Aral and Caspian Seas.

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1. INTRODUCTION

Fisheries make an important contribution to the national economy of the USSR. Fish is a traditional food which comprises 20 percent of the total protein consumed by the population, and the government and other political bodies are currently concerned to increase production. The territory of the Soviet Union occupies almost one sixth of the global land surface, with one third in Europe and two thirds in Asia. The 15 Soviet Socialist Republics are shown in *Figure 1.*

The rate of development of Soviet fisheries has been unique. At the inception of the Soviet state, in 1917, fishery production was minimal, but by 1940 the combined marine and freshwater catch had reached 1.4 million tons per year. This declined almost to zero during World War II, but grew again subsequently, so that recently the annual production of fish and other aquatic organisms has exceeded 10 million tons. The USSR now ranks second, after Japan, in fisheries production. The inland fisheries component constitutes an increasingly important part of the total production and comes from fish farms as well as capture fisheries, but the latter are most important in the USSR, where there are millions of hectares of lakes, reservoirs and water courses.

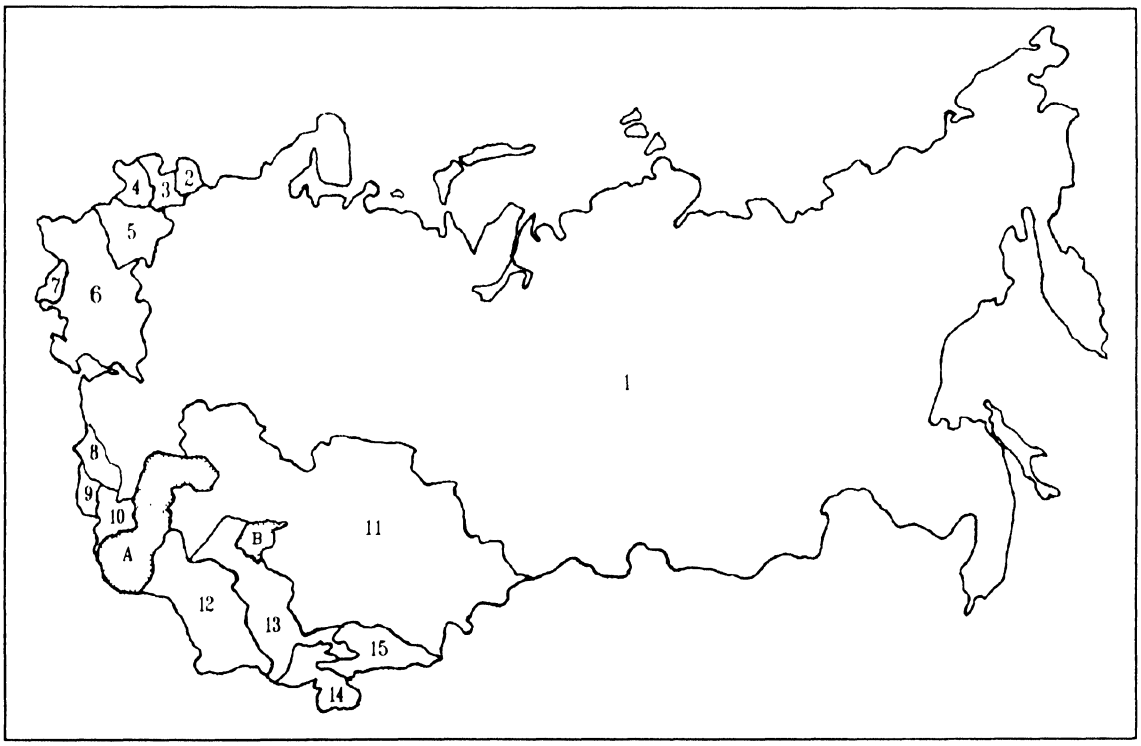


Figure 1.—The Soviet Republics: 1. Russian SFSR, 2. Estonian SSR, 3. Latvian SSR, 4. Lithuanian SSR, 5. Byelorussian SSR, 6. Ukrainian SSR, 7. Moldavian SSR, 8. Georgian SSR, 9. Armenian SSR, 10. Azerbaidzhanian SSR, 11. Kazakh SSR, 12. Turkmenian SSR, 13. Uzbek SSR, 14. Tadjik SSR, 15. Kirghiz SSR; A. Caspian Sea, B. Aral Sea.

Soviet inland water bodies are typically subject to multiple use, providing for power generation, irrigation, transport, recreation, and domestic and industrial water supply as well as fisheries. In consequence they are now subject to increasing levels of pollution. The other uses of inland waters often take priority over fisheries and tend to affect fisheries adversely.

This review was compiled from more than 130 sources of Soviet scientific and technical literature. However, where sources disagree about levels of production those of the Ministry of Fisheries of the

USSR have been preferred. The study endeavours to provide a comprehensive survey of the development of Soviet inland capture fisheries. It documents the problems and changes experienced in the past few decades and evaluates the biology and technology involved. It also outlines methods for intensifying production by 1990, the intention being to increase yields 180% by the year 2000. Although this is ambitious the major impediments will be created by man himself, and it is conceivable, that with careful management of small and medium sized water bodies, the target can be met.

2. AREAS OF LAKES, RESERVOIRS AND RUNNING WATERS

The USSR has an enormous number of water bodies, but not all of them are managed for fishery purposes. Many are isolated, with poor communications, while others are situated in areas where the climate is extreme and fishing is impossible (*e.g.* in high mountains and at high latitudes). The balance of the nature of the total water surface changes when new dams are built because the reservoirs created extend lacustrine conditions and reduce the riverine lengths of the systems concerned. The area of natural lakes tends to remain more or less constant, but available statistics do not include the smallest lakes. Those larger than 20 ha are generally included in lists, but in parts of Siberia and the Far East lakes of up to 40 ha may be excluded (Titova, 1984). The geographical distribution of the lakes and reservoirs most frequently cited in this survey is shown in *Figure 2*.*

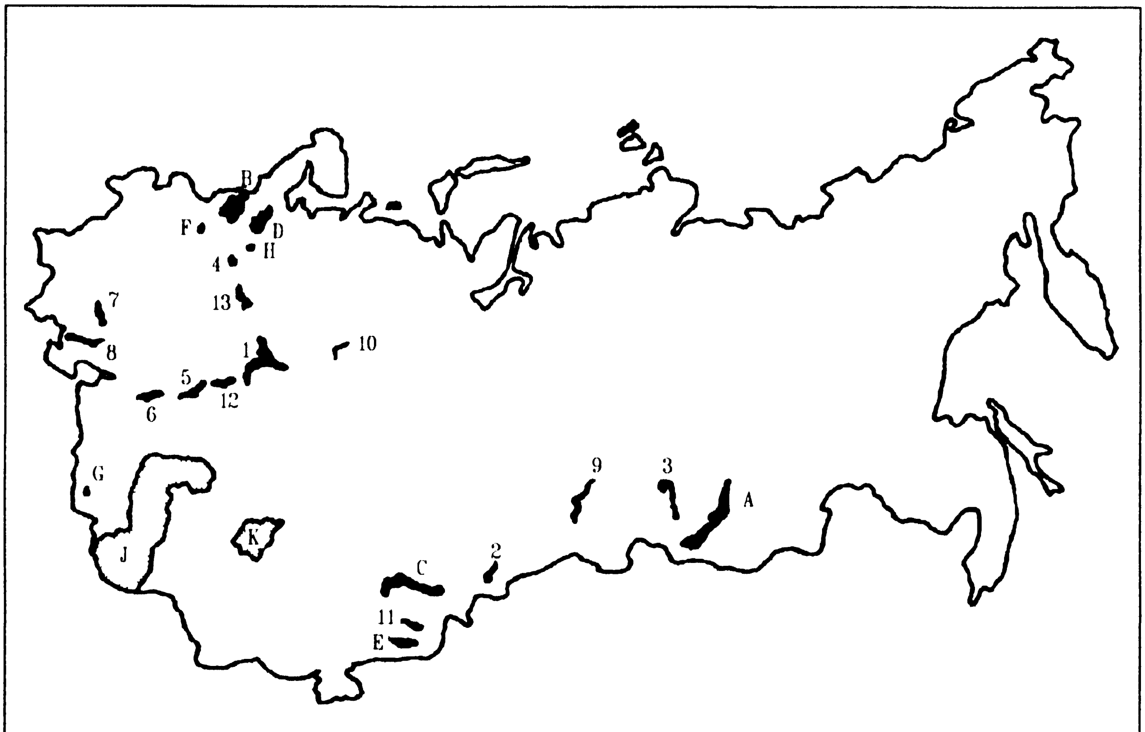


Figure 2. – Location of large lakes and reservoirs in the USSR: Lakes: A. Baikal, B. Ladoga, C. Balkhash, D. Onega, E. Issyk-Kul, F. Pskov-Chudskoe, H. Beloe, I. Ilmen, J. Caspian Sea, K. Aral Sea. Reservoirs: 1. Kuibyshev, 2. Bukhtarminskoe, 3. Bratsk, 4. Rybinskoe, 5. Volgograd, 6. Tsimlyansk, 7. Kremenchug, 8. Kakhovskoe, 9. Krasnoyarsk, 10. Kamskoe, 11. Kapchagayskoe, 12. Saratov, 13. Gorky.

2.1 LAKES

The total area of lakes in the USSR is close to 50 million ha, which is approximately 2% of all Soviet territory. *Table 1* classifies lakes by surface area and indicates the total surface area of each class, together with its proportional contribution to the national total.

*Note (Ed.):In the Russian language, reservoirs are usually named after the town/place situated nearby. The reservoir name is an adjective, usually ending with -oe or -skoe. In this publication, where the town after which a reservoir was named, is well known and easy to find on a map, only the town name is used (*i.e.* without the ending).

About 50% of the total registered area, *i.e.* 25 million ha of lake surface, is theoretically important for fish production, but this does not include lakes in inaccessible regions. The distribution of the important and accessible lakes is shown in *Table 2*.

TABLE 1. SUMMARY OF LAKES IN THE USSR (Studenetsky, 1979)

Lake area (ha)	Number of lakes	Total water area (ha)	% of total lake area
less than 100	2 844 890	15 922 500	32.8
100-999	36 660	8 647 000	17.7
1 000-4 999	2 145	3 966 700	8.2
5 000-9 999	228	1 555 800	3.2
10 000-100 000	154	4 115 500	8.5
over 100 000	27	14 362 500	29.6
Total	2 851 044	48 600 000	1000.0

TABLE 2. DISTRIBUTION OF LAKE AREA SIGNIFICANT FOR FISHERIES IN THE REPUBLICS OF THE USSR (Berka, 1978)

Republic	Total area of lakes (in 1 000 ha)	Proportion %
Russian SFSR	19 998.0	81.9
Kazakh SSR	2 883.0	11.8
Kirghiz SSR	666.3	2.8
Estonian SSR	221.6	0.9
Armenian SSR	139.5	0.6
Byelorussian SSR	129.0	0.6
Latvian SSR	98.0	0.4
Lithuanian SSR	85.0	0.3
Ukrainian SSR	81.0	0.3
Uzbek SSR	57.0	0.2
Azerbaidzhanian SSR	28.6	0.1
Turkmenian SSR	14.2	0.1
Georgian SSR	8.8	-
Moldavian SSR	3.0	-
Tadjik SSR	1.6	-
USSR Total	24 414.6	100.0

According to Studenetsky (1979) and Shimanovskaya *et al.* (1983) about 15 million ha were already in use for fishery purposes by the end of the 1970s. In Soviet fishery literature, lakes are usually classified as large (over 10 000 ha), medium (1 000-10 000 ha) and small (less than 1 000 ha). According to Kudersky

(1981) the bulk of the large lakes (12.1 million ha) are situated in just five of the fifteen Republics *(Table 3)*.

TABLE 3. DISTRIBUTION OF LARGE LAKES IN FIVE REPUBLICS OF THE USSR (Kudersky, 1981)

Republic	Total area of large lakes (in 1 000 ha)	Proportion (%)
Russian SFSR	8 852.4	73.1
Kazakh SSR	2 343.0	19.1
Kirghiz SSR	620.0	5.1
Estonian SSR	157.0	1.3
Armenian SSR	137.0	1.1
USSR Total	12 108.4	100.0

The twelve largest lakes supporting capture fisheries are listed in *Table 4* . However, small and medium sized lakes are more important than large lakes for fishery purposes in the USSR, and the most recent data (Titova, 1984) indicate 14.9 million ha in the former category in the USSR. *Table 5* lists the distribution of these lakes and also reveals that the total area of small lakes is approximately 2.6 times greater than that of medium sized lakes.

TABLE 4. THE LARGEST LAKES SUPPORTING CAPTURE FISHERIES (Studenetsky, 1979)

Lake	Area (in 1 000 ha)
Baikal	3 390.0
Ladoga	1 800.0
Balkhash	1 750.0
Onega	1 000.0
Issyk-Kul	620.0
Pskov-Chudskoe	355.0
Khanka	350.0
Tchany	270.0
Sevan	137.0
Beloe	112.5
Ilmen	112.4
Ubinskoe	50.0
Total	9 946.9

According to Titova (1984) about 96% of all the lakes in the USSR lie in three regions, the North West, Siberia and the Far East. The northwestern region is particularly rich in lakes. According to Shimanovskaya *et al.* (1979), 5.5 million ha of lakes are situated here, including, as well as the large lakes Ladoga, Onega and Pskov-Chudskoe, 685 000 ha of small ones. During the late 1970s, only 393 200 ha of the small and medium sized lakes were used for fisheries. Those not used were either too remote or contained fish of poor quality. Details of the small lakes in this area are given by Pokrovsky (1977a, 1980).

TABLE 5. DISTRIBUTION OF SMALL AND MEDIUM SIZED LAKES IN THE REPUBLICS OF THE USSR

Republic	Total area of small and medium lakes (1 000 ha)	Proportion (%)
Russian SFSR	13 697.7	92.2
Kazakh SSR	541.0	3.6
Byelorussian SSR	129.0	0.9
Lithuanian SSR	98.0	0.7
Latvian SSR	85.0	0.6
Ukrainian SSR	81.0	0.5
Estonian SSR	64.6	0.4
Uzbek SSR	57.0	0.4
Kirghiz SSR	46.3	0.3
Azerbaidzhanian SSR	28.6	0.2
Turkmenian SSR	14.2	0.1
Georgian SSR	8.8	0.06
Moldavian SSR	3.0	0.02
Armenian SSR	2.5	0.01
Tadjik SSR	1.6	0.01
USSR Total	14 858.3	100.00

2.2 RESERVOIRS

Most large reservoirs in the USSR have been built since the end of the second world war and have been used principally for the generation of hydroelectric power or the supply of cooling water to nuclear and thermal power stations. Many of these reservoirs support fisheries. According to Isaev and Karpova (1980), there are more than 11 million ha of reservoirs in the Soviet Union, but about 40% of this area is unsuitable for commercial fisheries for reasons of remoteness or the physical nature of the reservoir. A classification of Soviet reservoirs is given in *Table 6*.

Information on the historical development of the use of reservoirs for fisheries varies between sources. The data of Studenetsky (1979) and Kudersky (1981) are summarised in *Tables 7* and *8*. However, despite differences of opinion, it is generally agreed that by the 1980s about 7 million ha of reservoirs were fished (Isaev & Karpova, 1980; Kudersky, 1981; Negonovskaya, 1982; Shimanovskaya *et al.*, 1983). The largest area (about 5 million ha) of fished reservoirs is in the Russian SFSR, followed by the Ukrainian SSR (0.75 million ha) and the Kazakh SSR (0.65 million ha), as indicated by Isaev & Karpova (1980) and Shimanovskaya *et al.* (1983). The number of fished reservoirs reported varies from 80 (Studenetsky, 1979) to more than 270 (Negonovskaya, 1982), the latter figure probably being the more accurate.

TABLE 6. CLASSIFICATION OF SOVIET RESERVOIRS ACCORDING TO AREA (Isaev and Karpova, 1980)

Reservoirs	Water area of individual reservoirs (1 000 ha)	Number of reservoirs	Total water area of reservoirs (1 000 ha)	Proportion (%)
very large	over 500	5	6 008.4	50.8
large	500-100	21	4 560.5	38.6
medium	100-10	25	1 128.6	9.5
small	10-1	34	119.6	1.0
very small	less than 1	28	12.5	0.1
Total		113	11 829.6	100.0

TABLE 7. GROWTH IN NUMBERS AND AREA OF RESERVOIRS (Studenetsky, 1979)

Year	Number of reservoirs	Area (million ha)
1950	12	0.8
1955	23	1.1
1960	40	3.4
1965	49	4.1
1970	59	5.3
1975	80	6.0

TABLE 8. GROWTH IN AREA OF RESERVOIRS (Kudersky, 1981)

Year	Area of reservoirs (million ha)
1951	1.9
1955	2.4
1960	4.7
1965	5.5
1970	5.8
1975	6.0
1980	7.1

The largest areas of fishery reservoirs are in the drainage basins of the Volga, Dnieper, Don and Ob Rivers. According to Berdichevsky *et al.* (1979) there are twelve reservoirs in these drainage basins, each of which exceeds 100 000 ha, with a total area in excess of 4 000 000 ha. Shimanovskaya *et al.* (1983) name the most important systems as the Volga-Kama cascade of 11 reservoirs, with a total area of more than 2 500 000 ha, the reservoirs on the Don with a total area of 400 000 ha, and the six reservoirs on the Dnieper which together exceed 700 000 ha.

The characteristics of the 20 largest reservoirs, taken from Isaev and Karpova (1980), are given in *Table 9*. There are however, discrepancies between these figures and those of other authors, regarding the areas of some reservoirs, *e.g.* the area of the Kuibyshev reservoir is given as 645 000 ha by Isaev and

Karpova (1980), but as 590 000 ha by Monakov (1983). However, such discrepancies, although large, do not significantly alter the national statistics with regard to fisheries.

TABLE 9. THE TWENTY LARGEST RESERVOIRS IN THE USSR (Isaev and Karpova, 1980)

Reservoir	River	Year of filling	Area (1 000 ha)	Shallow area (1 000 ha)	Length of reservoir (km)	Width of reservoir (km)	Maximum depth (m)
Kuibyshev	Volga	1955-57	645.0	103.0	650	27	32
Bukhtarminskoe	Irtysh-Zaisan	1960-67	550.0	58.0	510	35	80
Bratsk	Angara	1961-67	547.0	27.0	565	33	106
Rybinskoe	Volga	1940-43	455.0	95.0	112	56	30
Volgograd	Volga	1958-60	311.7	56.5	540	17	40
Nizhnekamskoe	Kama	1979	279.0	55.0	283	25	25
Tsimlyansk	Don	1952-53	270.0	31.4	360	38	35
Zeiskoe	Zeia	1974-78	241.9	1.2	225	24	93
Bogutchanskoe	Angara	1984	232.6	1.5	375	14	70
Kremenchug	Dnieper	1959-61	225.2	41.0	185	30	20
Tcheboksarskoe	Volga	1984	221.4	-	341	16	20
Vilyuisk	Vilyui	1965-70	217.0	-	469	15	69
Kakhovskoe	Dnieper	1955-58	215.5	10.7	230	25	25
Krasnoyarsk	Yenisei	1967-70	210.0	9.7	388	15	105
Kamskoe	Kama	1954-56	191.5	40.0	272	30	30
Kumskoe	Kuma	1962-66	191.5	11.0	75	30	8
Ust-Ilimskoe	Angara	1974-77	187.3	7.8	300	12	190
Kapchagayskoe	Ili	1970	184.7	46.0	118	22	40
Saratov	Volga	1968	183.1	33.9	353	20	30
Sheksninskoe (Cherepovetskoe)	Sheksna	1963-64	167.0	32.0	167	20	17

N.B. data on area, length, width and depth of reservoirs refer to normal water level.

The total area of reservoirs supporting fisheries is expected to increase in the future. Shimanovskaya *et al.* (1983) estimate that a further 1.1 million ha of reservoirs suitable for fishing will be built by 1990, while Negonovskaya (1982) considers that 200-250 new reservoirs, totalling 4-6 million ha, will be completed by the year 2000. Most of these new reservoirs will be built primarily for hydroelectric power on rivers in Siberia and the Far East (*e.g.* on the Yenisei, Lena and Angara Rivers), or for irrigation in the republics of Central Asia, Kazakhstan, Ukraine, Moldavia and parts of the Russian SFSR.

2.3 RUNNING WATERS

In recent times many of the rivers of the USSR have become less important for fishing. Thousands of kilometres of rivers have been flooded following the construction of reservoirs, and many rivers are polluted. In general, only the rivers of Siberia and the Far East are now of any importance to the fishing industry. Many rivers are so remote, and communications are so poor, that large scale mechanised fishing on them is not viable.

Kazakov (1980), Kudersky (1981) and Shimanovskaya *et al.* (1983) estimate that the total length of rivers used for fisheries is over 500 000 km. The distribution of these rivers is summarised in *Table 10.* The total length of rivers suitable for fishing in the USSR is expected to continue to shrink as a result of the construction of future reservoirs, and because of increases in pollution.

TABLE 10. DISTRIBUTION OF RUNNING WATERS WHICH ARE IMPORTANT FOR FISHERIES (Kudersky, 1978)

Republic	Length of running waters (1 000 km)	Proportion (%)
Russian SFSR	416.1	79.3
Byelorussian SSR	51.0	9.7
Ukrainian SSR	19.0	3.6
Kazakh SSR	10.5	2.0
Latvian SSR	6.3	1.2
Estonian SSR	6.2	1.2
Lithuanian SSR	3.2	0.6
Turkmenian SSR	3 1	0.6
Uzbek SSR	3.1	0.6
Tadjik SSR	2.0	0.4
Georgian SSR	1.4	0.3
Azerbaidzhanian SSR	1.2	0.3
Moldavian SSR	1.0	0.1
Armenian SSR	0.8	0.1
Kirghiz SSR	n.d.	< 0.1
USSR total	524.9	100.0

n.d. – no data

3. CHARACTERISTICS OF LAKES, RESERVOIRS AND RUNNING WATERS

This chapter deals with the physical geography, hydrology, chemistry and biology of the open waters of the USSR, with emphasis on reservoirs since these are of the greatest interest to the fishing industry. Reservoir fisheries are a comparatively new and promising feature of the Soviet fishing industry, and more information concerning reservoirs is available than natural lakes. Many studies on reservoirs have been concerned with the changes they undergo following their creation, in particular, the conversion of their ichthyofaunas from riverine to lacustrine type.

3.1 PHYSICO-GEOGRAPHICAL AND HYDROLOGICAL CHARACTERISTICS

There are no general summaries of the hydrology of Soviet lakes, but a number of publications on individual lakes are available, *e.g.* Lake Baikal (Norenko, 1976; Oganesyan and Smolei, 1979), Lake Onega (Pokrovsky, 1983) and the small lakes of the Leningrad region (Pokrovsky, 1977, 1980). All these lakes tend to be stable and such variations as they exhibit do not affect fisheries significantly. By contrast the situation with reservoirs is different. Although they share some features with lakes they differ from them because of greater fluctuations in their water levels and in their bottom characteristics, both of which exert a profound influence on fisheries.

All the large reservoirs in the USSR have been created as part of hydroelectric power schemes and several have areas in excess of 500 000 ha with lengths greater than 500 km. *Table 9* summarises the salient features of the twenty largest. Water from these reservoirs is used to drive the generators of hydroelectric power stations, but in addition, they all also supply water for domestic and industrial purposes, and for irrigation. They all also provide navigable waterways, and the discharges from some are used to control downstream water levels for river navigation. In all but a few, the requirements of the resident fishery are subordinate to those of the other uses. However, there is some reason to believe that, in the future, the status of the fisheries may improve.

Since reservoirs are created by flooding river valleys, they tend to have some characteristics of both rivers and lakes. The submerged river channels may continue to be scoured by strong currents , but water in the upper layers may flow more slowly, and the shallows may become stagnant, especially along shores and in bays. Thus there are usually differential rates of water replacement in different parts of a reservoir; in some instances the ratios of the residence times for different parts of a reservoir may be as great as 1:50. The bottom topography of a new reservoir is generally much less even than that of a natural lake and since most former river valleys were forested, old trees and stumps may remain for many years. The surfaces of reservoirs manifest characteristics similar to those of natural lakes, including the development of waves and ice, and responses to wind patterns such as mixing. Large reservoirs tend to alter the climate locally. Many are long and narrow and create conditions under which winds blow more severely and swiftly along them than they did along the unflooded river valley. Surface currents may be increased by 1 m/sec or more when these winds blow, and frosts may develop 6-10 days earlier each year over reservoirs, than they did previously.

Most reservoirs have lower residence times and greater fluctuations of water levels than natural lakes. During autumn and winter, a massive increase in demand for electric power in the USSR invariably results in a lowering of water levels in the reservoirs, *e.g.* as much as 15 m in the Krasnoyarsk Reservoir. In many reservoirs, the shallow peripheral regions, often less than 2 m deep, are exposed whenever there is a substantial drawdown. As much as 300 000 ha may be exposed at low water in the Kuibyshev Reservoir. Such reductions of water area are detrimental to fish stocks. They particularly affect the survival of fry which tend to inhabit shallows in the spring, before the reservoirs have fully refilled. Indeed, some reservoirs have taken up to eight years to refill completely, following a major draw-down. Other reservoirs lose water during arid periods, when there is an increased demand for irrigation. This is most common in the south European parts of the USSR, in the catchments of the Dnieper, Don and Volga, from spring until harvest time. It has been known for a reservoir to be reduced to such an extent that its former river channels became apparent. Some idea of the magnitude of water level fluctuations in the major reservoirs of the USSR, is given by *Table 11.*

TABLE 11. FLUCTUATION OF THE WATER LEVEL IN SOME MAJOR RESERVOIRS IN THE USSR

	Reservoir	Fluctuation of water level (m)
mild fluctuation (up to 2 m)	Saratov	1.0
	Sheksninskoe	1.2
	Gorky	2.0
medium fluctuation (2-10 m)	Volgograd	3.0
	Kakhovskoe	3.5
	Rybinskoe	5.0
	Tsimlyansk	5.0
	Kamskoe	7.0
	Bukhtarminskoe	7.0
	Kuibyshev	7.5
	Vilyuisk	8.0
	Bratsk	10.0
strong fluctuation (more than 10 m)	Bugunskoe	11.0
	Pavlovskoe	11.5
	Priklinskoe	11.5
	Karatamarskoe	11.5
	Mamakanskoe	12.0
	Sengileyevskoe	12.5
	Mingechaurskoe	15.2
	Kattakurganskoe	18.0
	Pachkamarskoe	up to 40.0

The duration of ice on reservoirs is closely related to water temperature patterns. Data for water temperatures and ice regimes on selected reservoirs are given in *Tables 12* and *13* respectively.

TABLE 12. WATER TEMPERATURES OF SELECTED RESERVOIRS (°C) (Isaev and Karpova, 1980)

Reservoir	April	May	June	July
Bratsk	0.4-2.0	0.9-6.8	12.0-15.7	17.0-20.9
Vilyuisk	0.1-3.0	0.2-5.4	5.2-15.5	12.2-18.3
Volgograd	0.5-4.5	6.3-10.6	15.2-19.8	20.1-23.0
Gorky	0.3-1.8	7.3-11.2	14.8-18.6	17.8-19.1
Kakhovskoe	3.4-7.4	14.4-17.4	19.2-21.8	21.2-23.0
Krasnoyarsk	2.2-2.6	3.4-7.7	6.7-16.2	10.3-19.6
Kuibyshev	0.5-1.0	11.2-14.7	18.4-19.8	20.3-20.5
Rybinskoe	0.4-3.0	7.7-11.4	16.5-18.0	19.8-21.8
Ust-Ilimskoe	1.0-4.0	3.6-4.5	6.5-14.6	7.8-18.6
Tsimlyansk	3.9-6.8	12.6-18.5	18.2-25.4	20.2-26.5

Reservoir	August	September	October	November
Bratsk	17.5-19.4	10.8-14.1	6.2-9.0	0.2-4.0
Vilyuisk	13.2-17.1	6.1-11.2	0.1-0.5	1.0-0.4
Volgograd	20.2-22.9	16.1-20.3	8.8-14.2	1.4-7.4
Gorky	16.8-19.6	11.9-18.9	6.2-7.8	0.2-2.6
Kakhovskoe	22.2-23.7	17.8-20.7	11.5-14.5	2.7-9.8
Krasnoyarsk	11.1-20.0	8.9-16.0	6.8-11.3	3.5-5.2
Kuibyshev	18.4-21.3	12.7-19.6	6.8-8.3	0.2-2.6
Rybinskoe	14.8-16.3	12.6-17.5	5.5-6.7	0.2-3.0
Ust-Ilimskoe	8.9-16.5	7.6-8.3	1.5-5.1	0.2-1.3
Tsimlyansk	22.6-23.9	12.5-20.2	9.5-15.5	1.7-8.0

The water regime of Soviet reservoirs varies considerably. Some may be capable of refilling completely several times per year, *e.g.* 10 times per year in the Kamskoe, while others may take several years to fill. Most filling occurs during spring, but some reservoirs seldom reach maximum levels, even in years of heavy rainfall.

Figures 3-14 show some of the major Soviet reservoirs. The following information on these reservoirs is abstracted from: Monakov (1983) for the Kuibyshev reservoir; Kozhevnikov (1979) for the Gorky reservoir; Vladimirova (1979) and Zimbalevskaya (1979) for the Kremenchug reservoir; Butorin (1980) for the Ivankovskoe reservoir; and Butorin (1978) for the cascade of reservoirs on the Volga.

TABLE 13. ICE REGIME IN SELECTED RESERVOIRS (averaged over many years)

Reservoir	Appearance of ice	Disappearance of ice
Bratsk	November 1	May 6
Bukhtarminskoe	December 13	May 3
Vilyuisk	October 15	May 25
Volgograd	December 15	April 20
Gorky	November 29	April 23
Kamskoe	November 15	May 13
Kakhovskoe	December 25	March 23
Krasnoyarsk	December 10	May 10
Kremenchug	December 20	April 1
Kuibyshev	November 29	May 1
Rybinskoe	November 14	April 30
Saratov	December 8	April 20
Ust-Ilimskoe	October 30	May 5
Tsimlyansk	December 24	April 1
Sheksninskoe	November 6	April 20

The Kuibyshev Reservoir on the Volga *(Figure 3)* is the largest man-made lake in the USSR. The needs of the local fishery are given low priority. Winter water consumption causes the reservoir to shrink to about half its normal area each year with a maximum recorded reduction of 337 000 ha. About 16% of the total area of the reservoir is occupied by water less than 2 m deep when the reservoir is full. Fish stocks are exposed to severe water level fluctuations, especially in spring, during the spawning season, since at this time large quantities of water are abstracted for irrigation and for re-filling downstream reservoirs.

The Bukhtarminskoe Reservoir in the Kazakh Soviet Socialist Republic *(Figure 4)* was constructed to supply the hydroelectric power station, but its waters are also used for irrigation, industry and general domestic consumption. The needs of the fishery are given low priority. The climate does not favour the fishery, and the water levels decline substantially during years of reduced rainfall. The hydrology for several low rainfall years is given in *Table 14*, but water levels may be 3 m lower than indicated during the winter when a further 126 000 ha may be exposed, and are unavailable for spring spawning

TABLE 14. CHANGES IN HYDROLOGICAL CONDITIONS OF BUKHTARMINSKOE RESERVOIR AS A CONSEQUENCE OF POOR RAINFALL DURING THE PERIOD 1974-1978

	1974	1975	1976	1977	1978
volume of water (km^3)	32.5	25.6	22.7	23.2	21.5
area (ha)	442 400	386 300	356 600	359 500	350 500

The Bratsk Reservoir on the Angara River was built for hydroelectric power. Its water is replaced every two years. In winter, increased power consumption may lead to a 10 m drawdown exposing 40-50 000 ha of shallows.

Over 20 % of the Rybinskoe Reservoir, on the upper Volga *(Figure 6)*, has a depth of less than 2 m at high water. Although it was constructed for hydroelectric power it is also important for supplying industrial and domestic requirements, and for providing a navigable route along the upper Volga. Again, the fishery is accorded only low priority. Autumn and winter power production may necessitate a drawdown of 4-5 m, and during dry winters the water surface may shrink by 50%.

The dam of the Volgograd Reservoir *(Figure 7)* closes the system of man-made lakes on the Volga. At 540 km, it is one of the longest reservoirs in the Soviet Union. It provides water for the Volzhskaya hydroelectric power station, and for keeping the lower river navigable. It also supplies water for irrigation and the fishery is accorded only low priority. The periphery becomes dry each winter.

The Tsimlyansk Reservoir on the Don River *(Figure 8)* was built primarily for hydroelectric power, but is now a multi-use reservoir. The average winter drawdown leads to a shrinkage of 82 000 ha, which is severely detrimental to the fishery.

The Kremenchug Reservoir *(Figure 9)* is the largest reservoir of the Dnieper cascade, but its waters have a short residence time, just 2-3 months. It is used by the Kremenchug hydroelectric power station and also for irrigation and fisheries. The reservoir is navigable even for large river vessels. The water volume in the reservoir is replaced 4-5 times per year. During winter the water level may fall by 5-6 m. Warm water fish thrive in this reservoir.

The Kakhovskoe Reservoir *(Figure 10)* is also part of the Dnieper cascade. It supplies the Kakhovskaya power station but is a multi-use reservoir. There is a fishery. The water level falls up to 3.5 m in winter and returns to normal in the spring. Fluctuations of the water level in the shallows during the reproductive season are especially damaging to fish stocks.

The Krasnoyarsk Reservoir *(Figure 11)* on the Yenisei River in Siberia was created primarily to supply the Krasnoyarsk power station, but is now subject to multiple use. Fishery is accorded low priority. Logs from the Siberian forests are transported along it when the river is in flood in spring. In winter the water level may fall by 15 m when the reservoir shrinks by 87 000 ha. During the Siberian winter as much as 50 000 ha (nearly one quarter) of the lake freezes to the bottom.

The Kamskoe Reservoir *(Figure 12)* supplies the Kamskaya power station, and also provides water for industrial and domestic use. The fishery is given low priority. The water volume of the reservoir is replaced ten times per year. During both autumn and winter, the water level may fall by 7.5 m and the water area may shrink by 126 000 ha. The upper part of the reservoir is subject to substantial pollution by industrial wastes.

The Ust-Ilimskoe multi-use Reservoir supplies the Ust-Ilimskaya power station on the Angara River in Siberia. Again the local fishery is given a low priority among the several uses of the reservoir. The water volume in the reservoir is replaced 1.5-2 times a year and during winter the water level falls by 1.5 m exposing about 8 000 ha of shallow bottom. The climate is Siberian, with long winters and short summers. Ice is present for some 200 days each year.

The Saratov Reservoir *(Figure 13)* is part of the Volga cascade. It is a typical multi-use reservoir. Water levels fall in winter when the surface is reduced by some 17 000 ha. However, since it was first constructed conditions in the reservoir have changed. Water flow has decreased, water temperatures have altered, and water depths have changed in different parts.

The Sheksninskoe (Cherepovetskoe) Reservoir *(Figure 14)* is a multi-use reservoir. The surface area shrinks by 23 000 ha (14%) during the winter season.

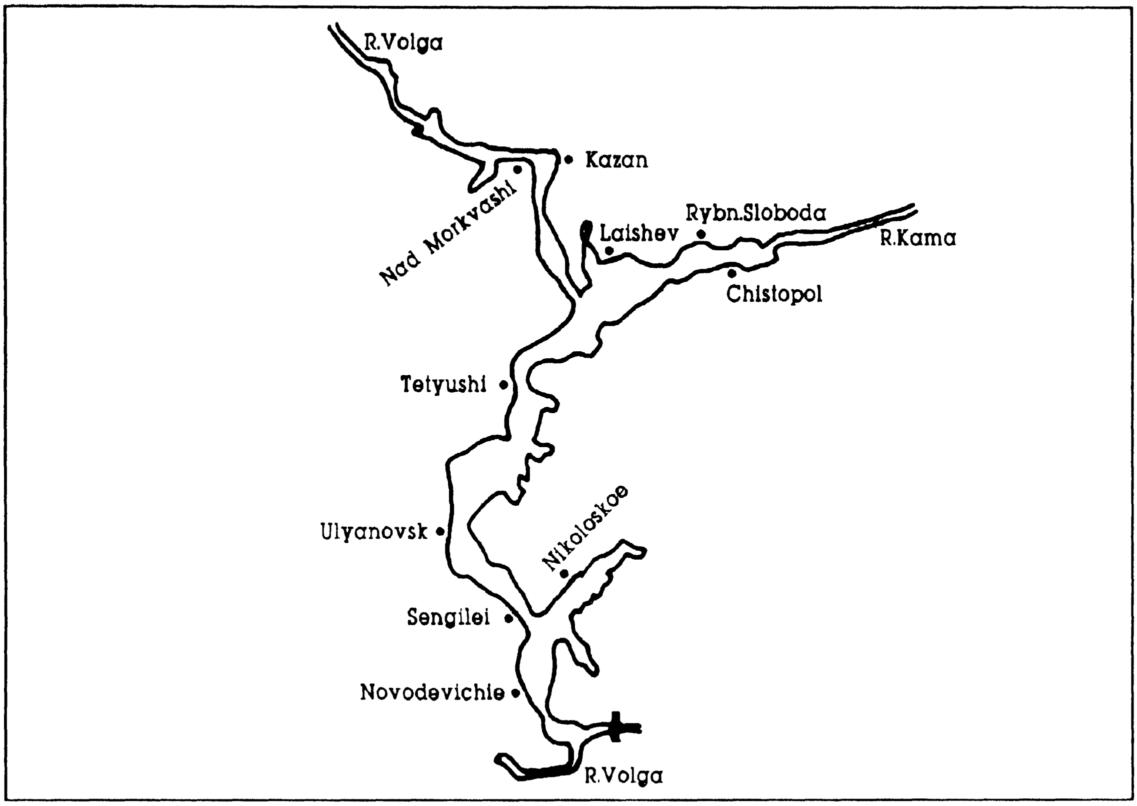


Figure 3. – Kuibyshev Reservoir (Isaev and Karpova, 1980)

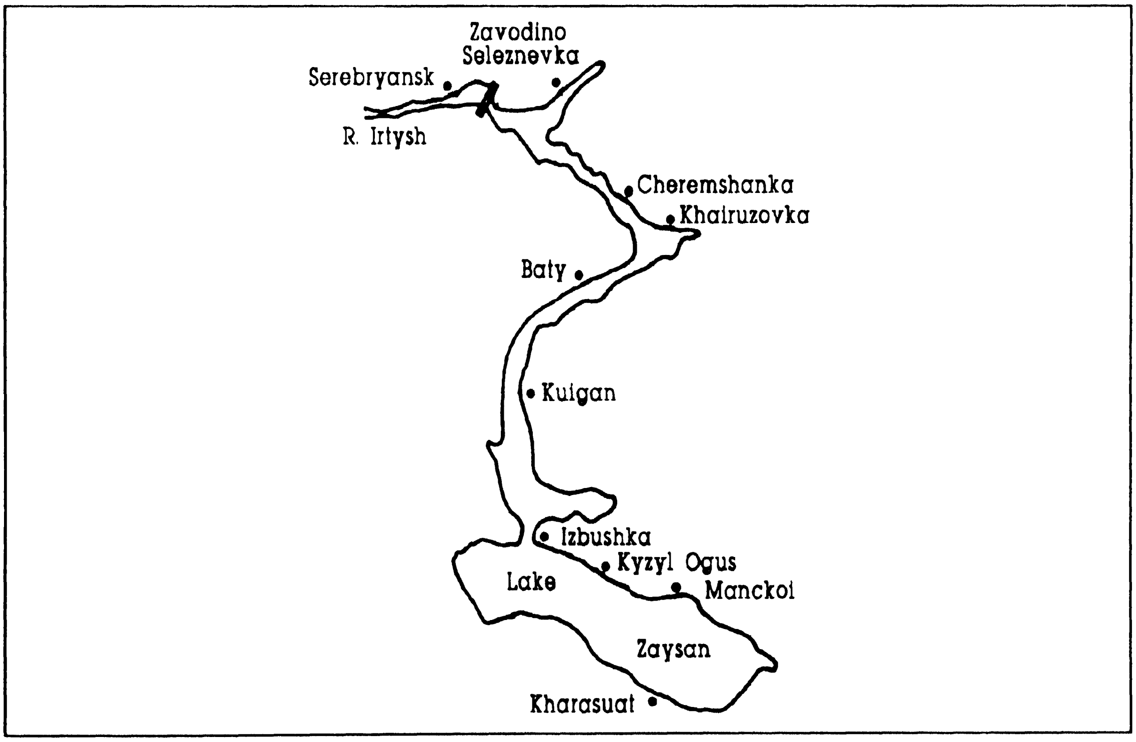


Figure 4. – Bukhtarminskoe Reservoir (Isaev and Karpova, 1980)

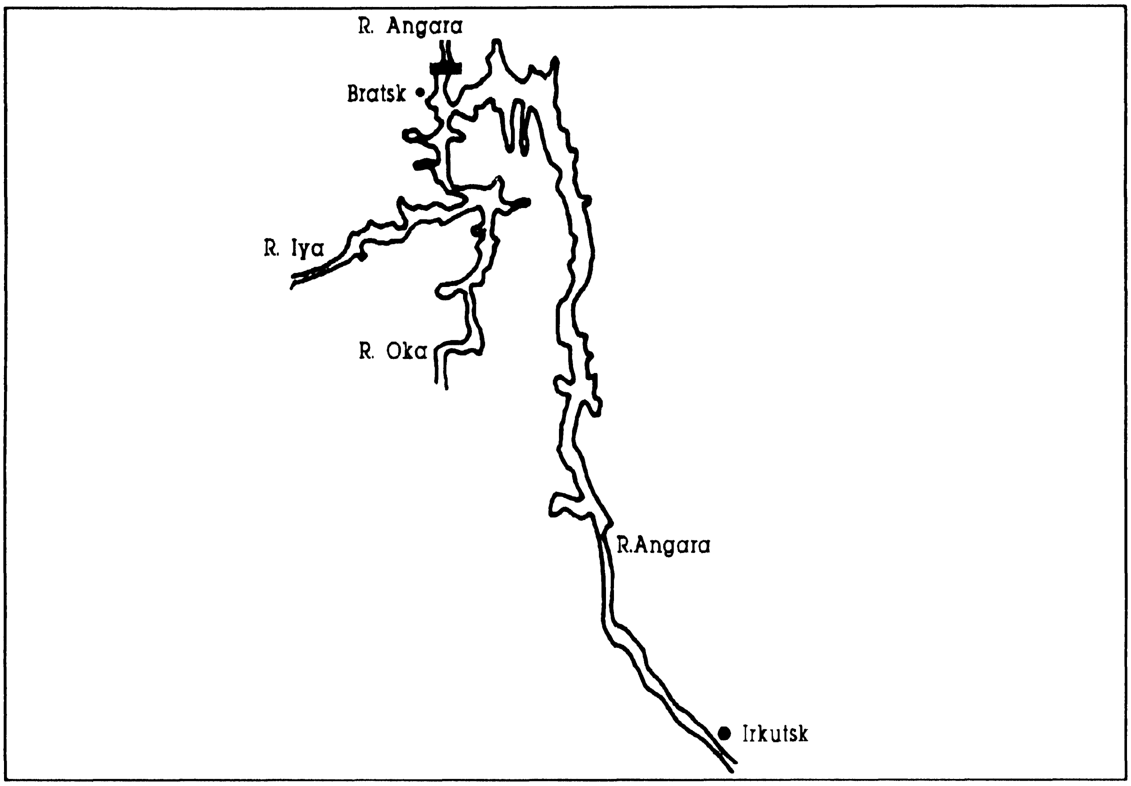


Figure 5. – Bratsk Reservoir (Isaev and Karpova, 1980)

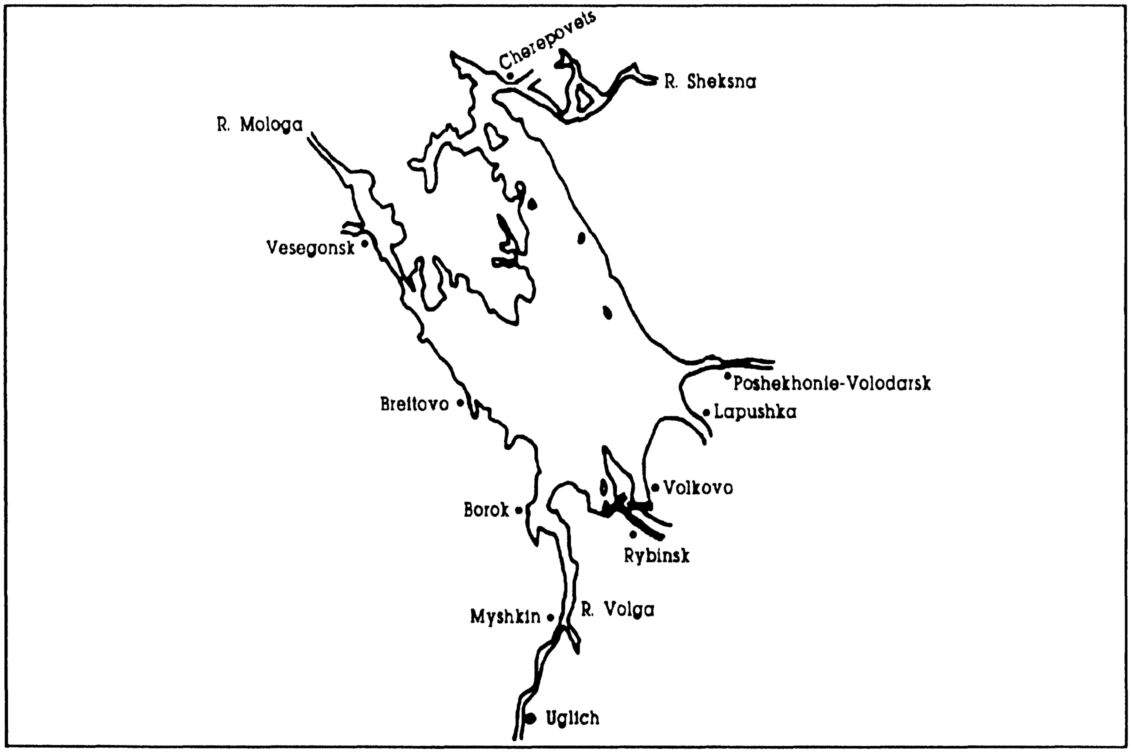


Figure 6. – Rybinskoe Reservoir (Isaev and Karpova, 1980)

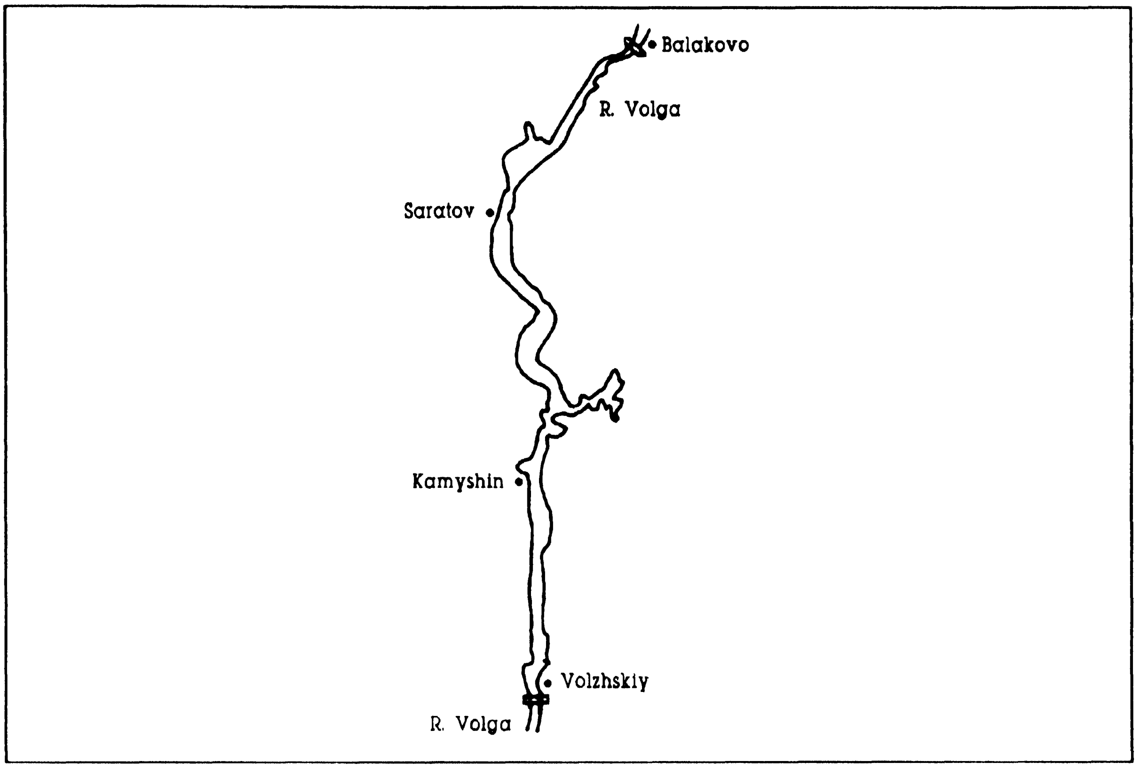


Figure 7 —Volgograd Reservoir (Isaev and Karpova, 1980)

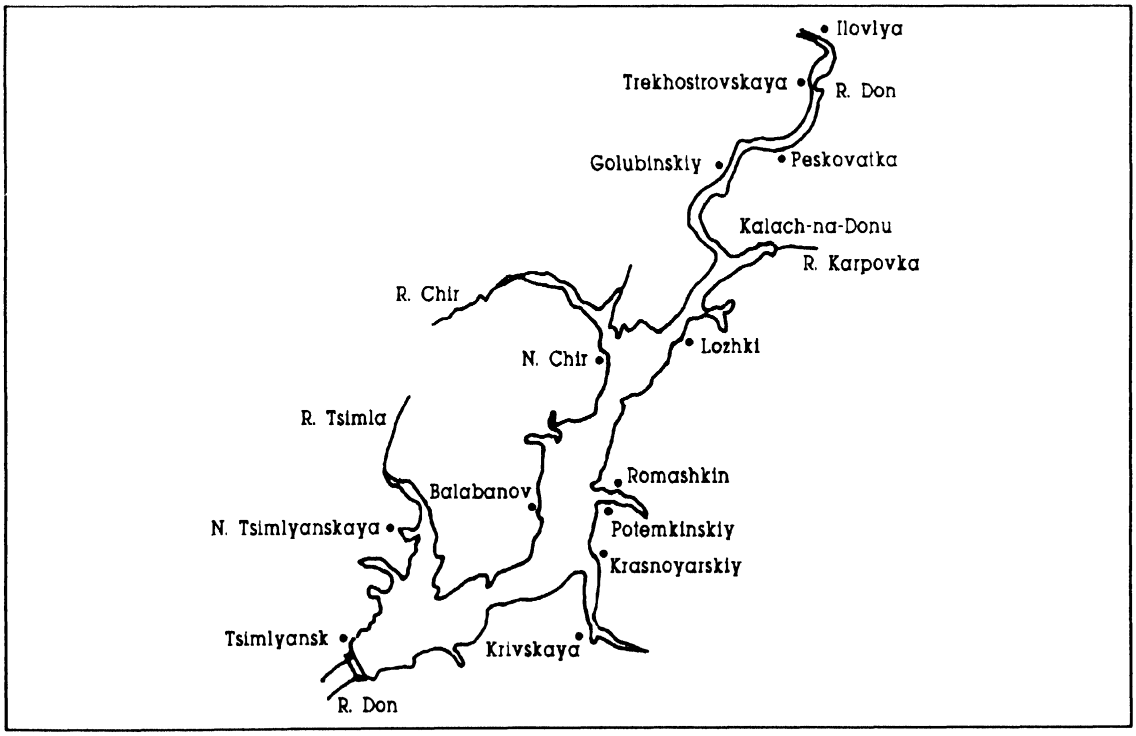


Figure 8.—Tsimlyansk Reservoir (Isaev and Karpova, 1980)

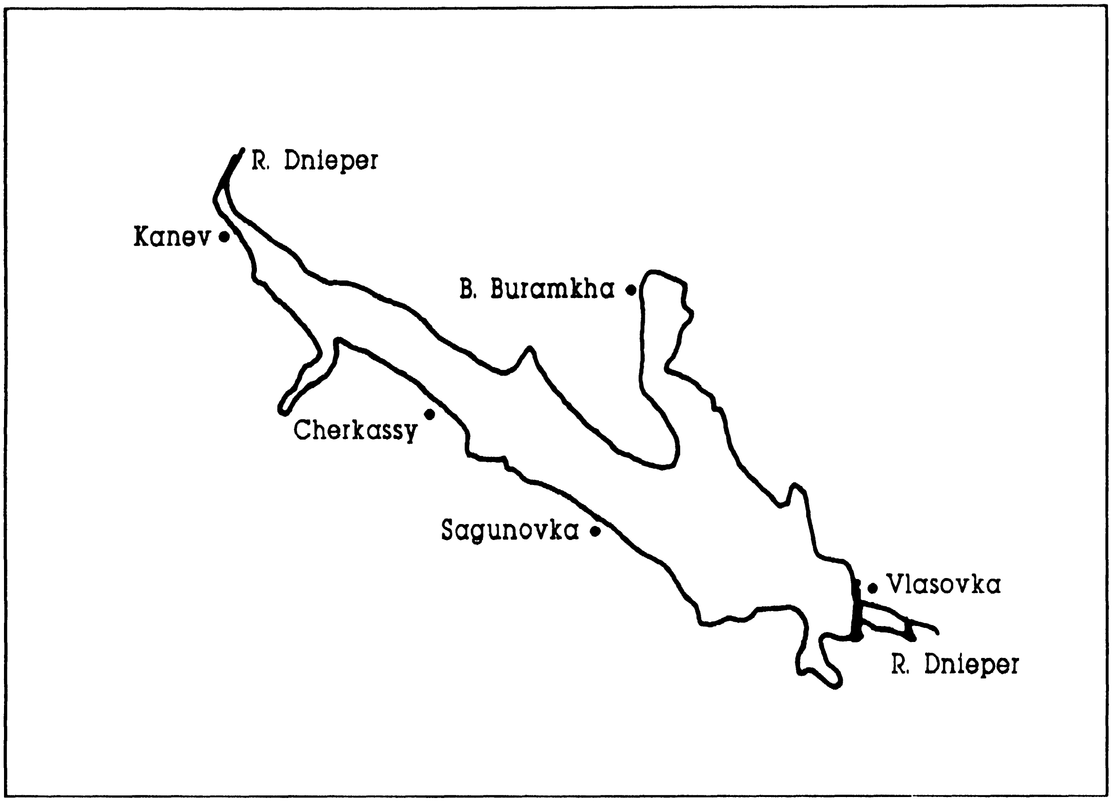


Figure 9. – Kremenchug Reservoir (Isaev and Karpova, 1980)

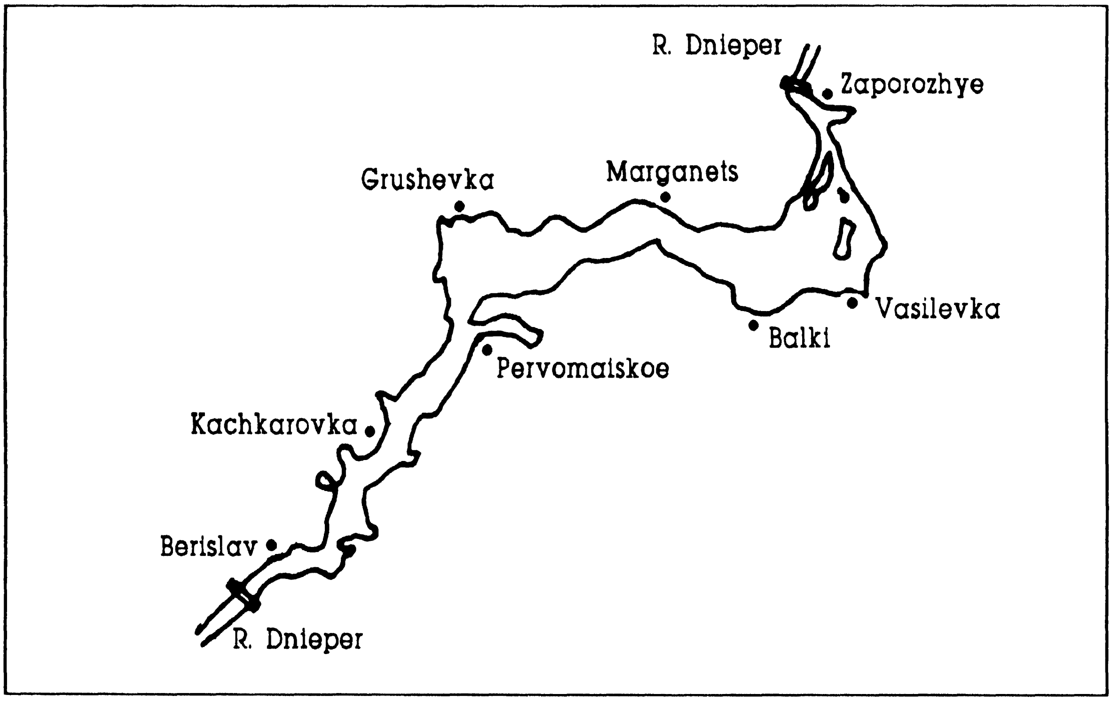


Figure 10. – Kakhovskoe reservoir (Isaev and Karpova, 1980)

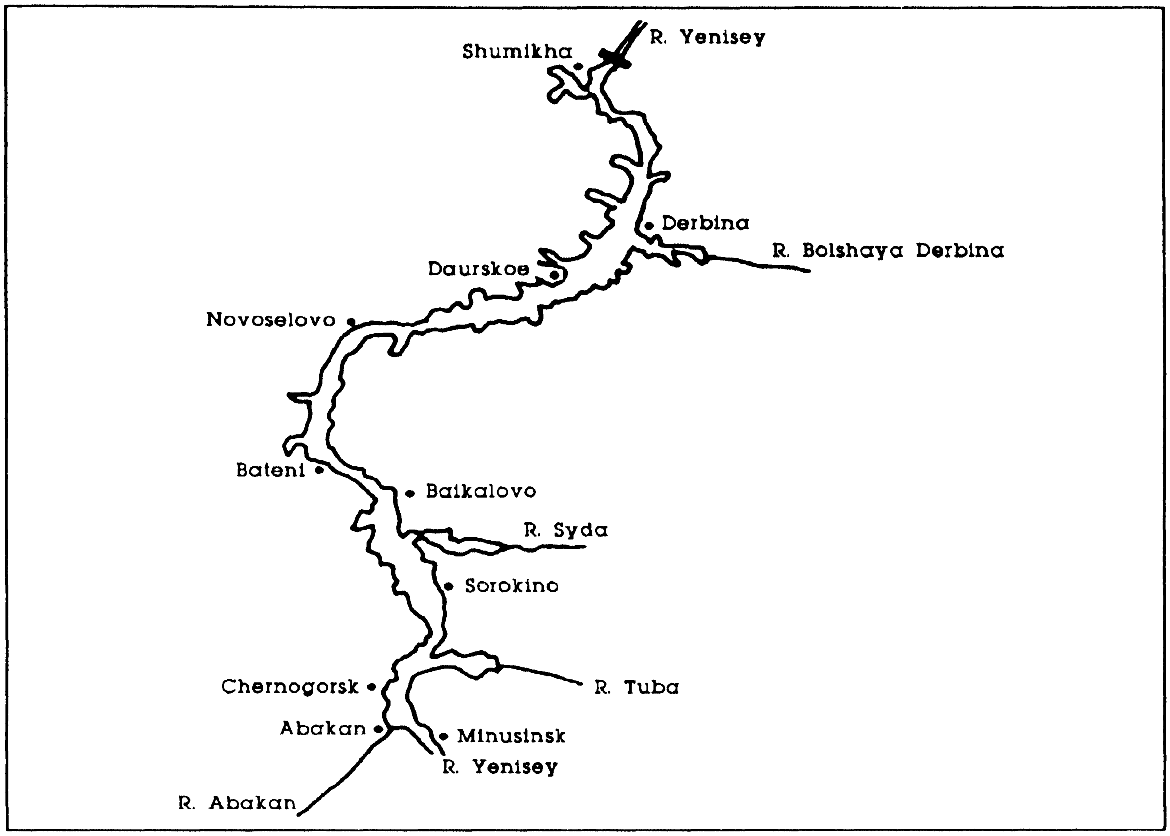


Figure 11. – Krasnoyarsk Reservoir (Isaev and Karpova, 1980)

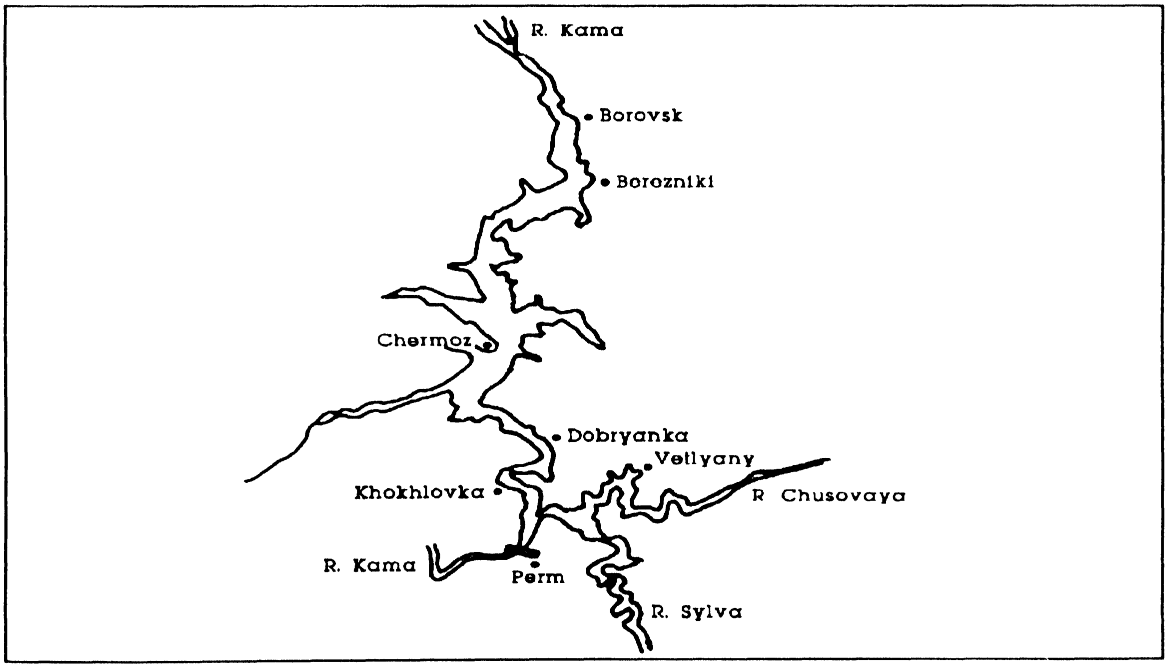


Figure 12. – Kamskoe Reservoir (Isaev and Karpova, 1980)

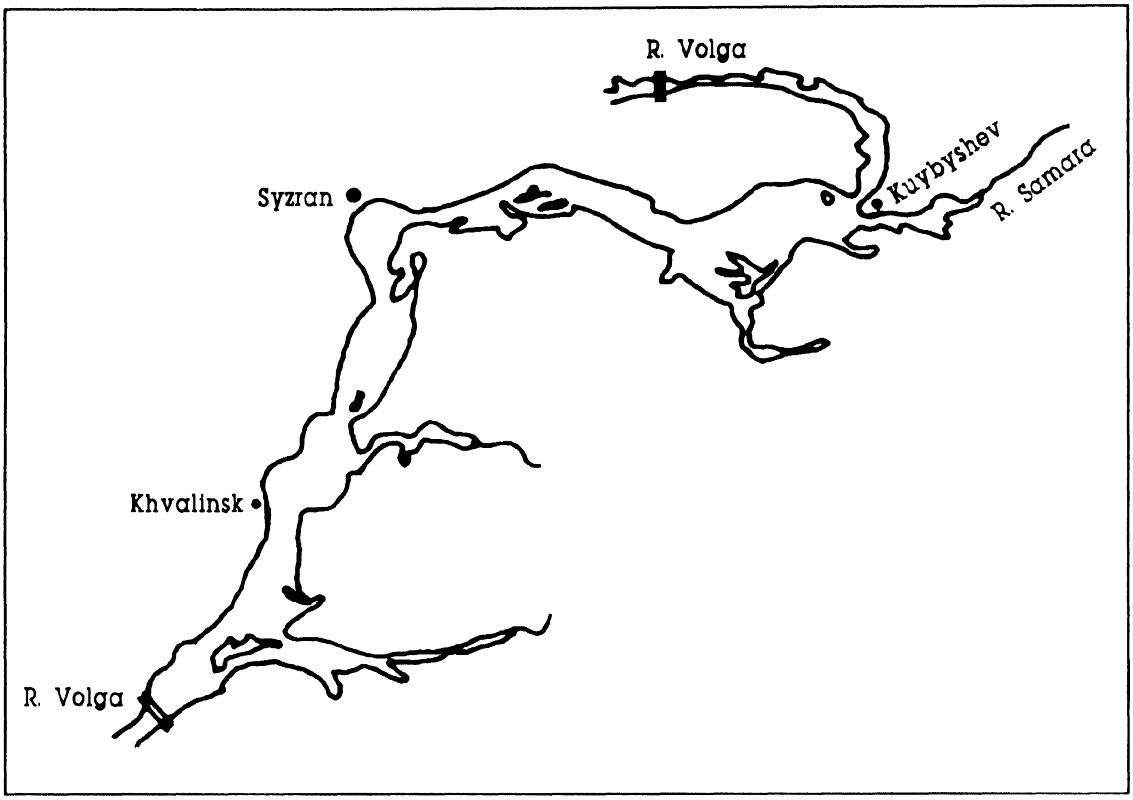


Figure 13. – Saratov Reservoir (Isaev and Karpova, 1980)

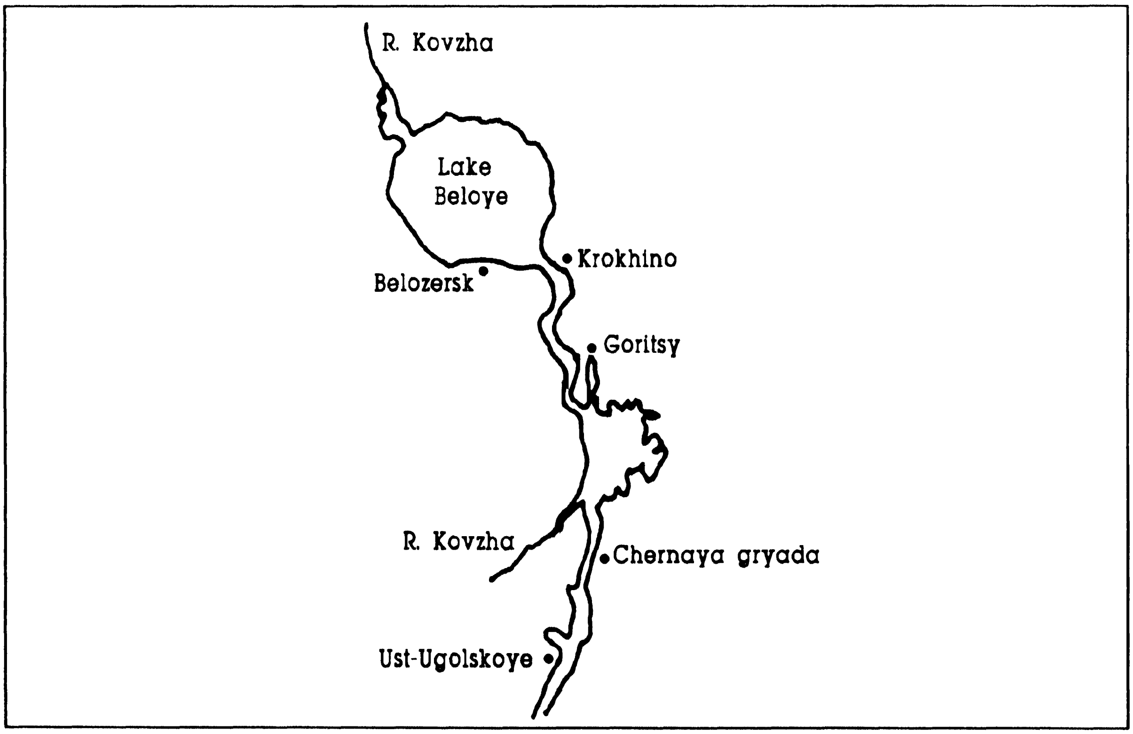


Figure 14. – Sheksninskoe (Cherepovetskoe) Reservoir (Isaev and Karpova, 1980)

3.2 WATER CHEMISTRY

Fish productivity in a water body reflects the available food supply. Primary production, which underlies the development of the food supply, is highly dependent upon the hydrochemical regime. Rates of primary production depend upon the nature and concentration of minerals and organics present, upon the concentrations of oxygen and carbon dioxide, and upon certain physical conditions which govern plant growth.

Factors which determine water chemistry include the nature of the soil in the catchment, the nature of the watershed, the nature of the substratum, and in the case of lakes and reservoirs, rates of evaporation and the residence times of the water in them. Concentrations of dissolved gases depend upon temperature, pH, pressure, wind action, patterns of mixing in the water body and levels of photosynthesis. The physical conditions include things such as the nature and depth of the bottom, and the intensity of illumination of the water column. This latter depends upon the turbidity of the water, and this in turn depends upon the nature of the load carried by the affluent streams, the rate and pattern of flow in the water body, and wind action. All these parameters can vary both annually and seasonally.

Small water bodies are normally subject to greater fluctuations in hydrochemical regime than large ones, while reservoirs are subject to greater extremes than natural lakes, especially in the first few years after flooding when any submerged vegetation rots.

Water bodies in the central parts of the USSR are characterised by low rates of evaporation. They contain moderate concentrations of organic matter and are low in mineral nutrients. In the southern regions, water bodies are subject to high rates of evaporation and have high mineral but low organic matter content. *Table 15* summarises the classification of Soviet reservoirs advanced by Isaev and Karpova (1980).

Studies of the water chemistry of Soviet lakes include those of Lake Baikal (Norenko, 1976), Sevan Lake (Oganesyan and Smolei, 1979), Lake Onega (Pokrovsky, 1983), and the small lakes of the Leningrad region (Pokrovsky, 1977,1980). Similar studies for reservoirs include those for the Kuibyshev Reservoir (Monakov, 1983), the Kremenchug Reservoir (Vladimirova, 1979; Zimbalevskaya, 1979), the Gorky Reservoir (Kozhevnikov, 1979) and the Ivankovskaya Reservoir (Butorin,1978), while Butorin (1978a) discusses the water chemistry of the Volga River and its tributaries. The water chemistry of some Soviet reservoirs is summarised in *Table 16*.

3.3 BIOLOGICAL CHARACTERISTICS

The principles of biological productivity in natural lakes were investigated by Kitaev (1984), while studies of the food chains in specific lakes were made by Norenko (1976) for Lake Baikal, by Oganesyan and Smolei (1979) for Lake Sevan, by Pokrovsky (1983) for Lake Onega, and by Pokrovsky (1979, 1980) for small lakes in the northwestern region of the Russian SFSR. The processes underlying food chains in reservoirs are more complex than those in lakes, at least immediately after filling, and the principles involved here were elaborated by Kudersky (1977b). Studies of individual reservoirs to date include those of Lukin (1977) and Monakov (1983) for the Kuibyshev Reservoir, of Vladimirova (1979) and Zimbalevskaya (1979) for the shallows of the Kremenchug Reservoir, of Kozhevnikov (1979) for the Gorky Reservoir and of Butorin (1978) for the Ivankovskoe Reservoir.

Food resources for fish consist of organic substances; bacteria, algae, protozoa, macrophytes, invertebrates and detritus. In lakes and reservoirs these resources may be allochthonous, *i.e.* carried in from outside, or autochthonous, *i.e.* generated within the water body itself. Detritus arises from the breakdown of all dead matter, promoted by a spectrum of organisms.

TABLE 15. CLASSIFICATION OF SOVIET WATER BODIES ACCORDING TO HYDROCHEMICAL ZONES
(Isaev and Karpova, 1980)

Hydrochemical zones	Types of water bodies
Water with low mineral content on gley soils	Deep reservoirs, all of poor productivity
Tundra and taiga, up to about 60°N	Reservoirs of medium depth and poor productivity
Water of medium mineral content on sod podzolic soils	Reservoirs of medium and high productivity
Taiga south of 60°N, mixed forest and the northern part of the forest steppe	All reservoirs with high productivity
Water of low, medium and high mineral content on chernozem soils, southern forest steppe, and the steppe	Reservoirs all of high productivity; reservoirs of high productivity; reservoirs of medium productivity
Water rich in nutrients on chernozem and calcaric soils	Reservoirs of high productivity with good water flow
Steppe (region of high mineral content)	Reservoirs of medium and poor productivity, with slight or no water flow
Highlands	Reservoirs of medium productivity

TABLE 16. CHEMICAL CHARACTERISTICS OF SELECTED SOVIET RESERVOIRS
(adapted from Isaev and Karpova, 1980)

Reservoir	pH	Dissolved oxygen (mg/l)	$KMnO_4$ (mg O_2/l)	Phosphates (mg/l)	Iron (mg/l)	Σ Ca + Mg (mg/l)
Bratsk	6.0-7.5	6.2-14.4	3.9-5.2	0.001-0.015	0.02-0.12	1.32-2.86
Vilyuisk	7.0-8.0	1.5-13.6	8.0-12.4	0.04-0.6	0.01-0.04	1.78-2.86
Volgograd	7.5-8.0	6.9-13.9	7.1-8.1	0.07-0.08	0.06-0.08	2.86-3.21
Gorky	7.3-8.1	8.5-10.6	6.0-12.0	0.02-0.07	0.06-1.8	1.43-2.86
Kamskoe	6.6-8.3	1.6-8.4	8.7-13.2	0.02-0.04	0.8-3.2	1.43-2.50
Kakhovskoe	9.0-10.0	3.5-7.5	4.5-20.0	0.01-0.03	0.5-1.3	1.43-2.86
Krasnoyarsk	7.2-8.0	2.2-6.5	1.8-4.7	0.003-0.001	traces	1.00-1.61
Kuibyshev	7.0-8.4	8.1-10.2	7.2-10.0	0.03-0.04	0.08-0.32	1.43-3.21
Rybinskoe	7.8-8.3	8.4-10.3	10.3-17.5	0.002-0.007	0.01-0.3	1.43-3.21
Saratov	7.2-8.1	7.0-10.6	6.4-16.0	0.02-0.04	0.3-0.6	1,43-2.50
Tsimlyansk	7.4-9.0	5.8-9.0	9.5-12.5	0.07-0.1	0.28	3.68-6.50

A review of the conditions underlying the development of the food base for fish in reservoirs is given by Isaev and Karpova (1980). Initially, basic organic substances are derived from the flooding of large areas of soil surface, but frequently thereafter, reservoirs derive regular supplies of organics whenever shallows are exposed and reflooded. Exposed land is quickly colonised by both plants and animals, especially if exposure occurs during the warmer months. The development of terrestrial plants is advantageous in that their growth not only provides a rich food source, but also promotes aeration of the bottom soil and improves its pH and structure. Small periodic reductions in water level desiccate the eggs of chironomid midges, and sunlight may disinfect the soil surface by destroying some harmful organisms. However, fluctuations in water level also bring disadvantages since fish eggs laid in the shallows are lost if exposure occurs soon after spawning, and as drying progresses, mature fish are often isolated in pools where they perish. Thus exposure of shallows can lead to heavy fish loses. Further, oxygen concentrations may be reduced by rotting vegetation and streams of anoxic muddy water may flow to deeper parts of the reservoir.

Low water levels during winter are almost all of negative influence on the systems concerned. Frost kills any exposed vegetation and there is little or no accumulation of organics. The areas of reeds which grow around the periphery are frequently smaller than usual the following year, and the numbers of planktonic organisms may also be reduced.

Table 17 is based upon a model calculation and indicates how the proportion of production by phytoplankton in a reservoir might fall off with reducing transparency. If such a calculation is available for a given water body, then daily changes in phytoplankton productivity can be determined from a table following a simple determination of transparency. If the model calculation refers to a water column of 1m^2, then the total productivity for the whole water body can be deduced provided its area is known. This will vary with water level. *Table 18* summarises the ecological characteristics of the main zones of long valley reservoirs.

The biological development of reservoirs occurs in three phases. The first stage is short. The flooded flora and fauna decompose, and new communities, some of which are ephemeral, arise. In particular, chironomid larvae appear on the bottom in very large numbers, and a number of planktonic organisms appear in the water column.

The second stage lasts 1-3 years, during which the development of life in the reservoir is intense. The initial release of high levels of minerals and organic compounds into the water encourages explosive development of phytoplankton and phytobenthos. Layers of filamentous algae cover large areas of the shallow bottom. However, planktonic populations form more quickly than the benthic ones and have usually stabilised within 3 years. Decomposition of dying phytoplankton results in greatly increased numbers of saprophytic bacteria on the bottom. This in turn leads to the mass development of zooplankton and benthos, feeding on algae, bacteria and detritus.

The third stage is reached when a dynamic equilibrium is reached among the various populations of the reservoir. Sometimes this may occur as soon as three years after the initial filling of the reservoir, and it may involve reductions of both biomass and numbers of species from those present during stage two. The abstraction of minerals from the initially flooded land is usually complete within 3 years, after which the nutrient reserves shrink.

The average biomass of phytoplankton, zooplankton and zoobenthos in selected Soviet reservoirs is given in *Table 19*. However, some additional data for the Kuibyshev Reservoir are offered by Monakov (1983), who monitored two distinct peaks in the numbers and biomass of zooplankters during the early 1980s. The first peak occurred in summer when there were 70 000-400 000 individuals/m^3 (with a mass of 0.5-3.5g/m^3) and the second in autumn with 20 000-400 000 individuals/m^3 (with a mass of 0.7-4.2g/m^3).

TABLE 17. VARIATION OF PHYTOPLANKTON PRODUCTION WITH DEPTH IN THE TOP THREE METRES OF THE WATER COLUMN, EXPRESSED AS PERCENTAGES OF THE TOTAL

Transparency by Secchi disc (m)	Percentage of the total production
0.00-0.25	14.5
0.25-0.50	15.7
0.50-0.75	16.2
0.75-1.00	15.7
1.00-1.25	12.3
1.25-1.50	7.6
1.50-2.00	11.3
2.00-2.50	5.3
2.50-3.00	1.4

TABLE 18. ECOLOGICAL CHARACTERISTICS OF THE MAJOR ZONES OF RESERVOIRS

Zone of reservoir	Character of flooded area	Development and characteristics of flora and fauna
Lower zone (next to the dam)	Greatest depth, very mild flow	Rich development of plankton, algae, and in protected areas, submerged macrophytes, chironomids, oligochaetes, molluscs. Poor development of reeds, cat-tails. Organic substances accumulate in deep depressions of the original river-bed; oxygen deficiencies occur.
Medium zone	Medium depth and flow	Rich development of emergent plants, which shade the water and prevent intensive algal development. Optimum conditions for chironomids, leeches and molluscs
Upper zone	Limited water area, low depth, flow similar to that in the river	Limited numbers of bacteria and algae, therefore poorly developed benthic organisms and plankton. Submerged plants occur in a very narrow coastal strip

The phytoplankton usually undergoes prolific development in the first few years after a reservoir is filled, but stabilises thereafter. Two groups dominate the phytoplankton; diatoms and cyanophytes. The former are most common in spring and autumn, while the cyanophytes reach their peak in late summer. During 'blooms', blue-green algae may constitute more than 90% of the phytoplankton biomass, but their dominance occurs only between June and September. For the rest of the year they tend to exist on the bottom at depths of 10-15 m.

Among the zooplankton, Rotifera and Cladocera are more common than Copepoda. All large reservoirs, situated in fairly flat terrain, contain large numbers of *Cyclops* and *Daphnia*, and there is usually a marked reduction in the zooplankton biomass in July and August. The distribution of zooplankters is uneven within reservoirs, their biomass increasing down the reservoir towards the dam, but the shape of the reservoir also influences this. Numbers and biomass are greater in bays than in the open water zones, often from 2-5 times greater. In narrow reservoirs, more or less confined to the shape of the former river, where flow rates are high, the biomass and spectrum of zooplankters tends to be more riverine. There is a preponderance of rotifers and a low total biomass.

TABLE 19. AVERAGE BIOMASS OF PHYTOPLANKTON, ZOOPLANKTON AND ZOOBENTHOS IN SOME SOVIET RESERVOIRS DURING SUMMER-AUTUMN (Isaev and Karpova, 1980)

Reservoir	Average biomass		
	Phytoplankton (g/m^3)	Zooplankton (g/m^3)	Zoobenthos (g/m^2)
Kuibyshev	13.0	4.4	4.3-24.3
Bukhtarminskoe	4.0	n.d.	n.d.
Bratsk	4.0	1.9	4.8-15
Rybinskoe	3.0	2.0	2.1-58.0
Volgograd	2.5	2.5	2.5-12.1
Tsimlyansk	15.0	10.0	0.8-26.0
Kremenchug	n.d.	10.9	10.0-50.1
Vilyuisk	n.d.	5.0	12.0-34.6
Kakhovskoe	10.0	8.0	0.5-99.0
Krasnoyarsk	4.0	3.0	0.2-2.6
Kamskoe	n.d.	1.4	1.2-8.0
Saratov	1.5	1.0	0.9-20.0
Sheksninskoe	n.d.	n.d.	3.4-5.2

n.d. – no data

Chironomid larvae usually provide 80% of the zoobenthos of the reservoirs. The dams of the Dnieper, Don and Volga are characterised by the mass development of the mollusc *Dreissena*. The larvae of this species may number 300 000-400 000/m^3 in the water column, while adults may number 5 000-10 000/m^2 on the bottom with a biomass of 3-5 kg/m^2.

4. ICHTHYOFAUNA OF LAKES, RESERVOIRS AND RUNNING WATERS

The natural fish fauna varies substantially over the vast expanse of the USSR, with its wide spectrum of water bodies situated in different climatic and physiographic zones, but recent introductions have added to the complexity. A list of the principal species found in the lakes and reservoirs of the USSR is given in *Table 20*. This is related to *Table 21*, which indicates the relationships and competition for food between different species. Another important ecological consideration is the time of occurrence and location of fish fry in lakes and reservoirs, and this is summarised in *Table 22*.

TABLE 20. PRINCIPAL FISH SPECIES OF LAKES AND RESERVOIRS IN THE USSR (Isaev and Karpova, 1980)

Fish species	Max weight (kg)	Max length (cm)	Max age (years)	Spawning temp (°C)	Fertility (1 000 eggs)	Egg development (days)	Food
ACIPENSERIDAE							
Acipenser baeri (Siberian sturgeon)	65	160	35	9-20	70-840	2-12	Culicidae larvae, Ephemeroptera, Mollusca, Cyclopoidae, *Esox lucius*, *Gobio gobio*
Acipenser güldenstädti (Russian sturgeon)	100	200	40	11-23	70-840	2.5-120	Chironomidae, Amphipoda, Oligochaeta, small Mollusca
Acipenser nudiventris (glassy sturgeon)	22	100	30	10-25	80-850	5-7	Mollusca, insect larvae, Chironomidae, Amphipoda, fish eggs, crayfish
Acipenser ruthenus (sterlet)	16	100	20	9-12	11-100	6-11	Amphipoda, Chironomidae, *Corophium* sp., small Mollusca, Oligochaeta
Acipenser stellatus (stellate sturgeon)	27	200	25	13-30	155-240	2-5	Gobiidae, *Harengus* spp. *Rutilus rutilus caspius*, Mollusca, Amphipoda
Huso huso (great sturgeon)	1300	900	75	8-15	300-2800	3-12	Gobiidae, Mollusca, shrimps, *Harengus* sp., *Sprattus* spp., *Engraulis encrasicholus*, *Rutilus rutilus caspius*
Bester (hybrid of *Huso huso* and *Acipenser ruthenus*)	10-16	150	-	8-12	100-400	3-8	Chironomidae, Mysidacea, insect larvae, Amphipoda, small fish
POLYODONTIDAE							
Polyodon spathula (paddlefish)	15-20	80-100	-	15-18	70-300	3-12	phyto- and zooplankton, insect larvae, detritus
CLUPEIDAE							
Clupeonella delicatula (tyulka)	0.009	8-9	7	4-24	5-20	1-4	zooplankton (*Cladocera*, Copepoda, Mysidacea)

Fish species	Max weight (kg)	Max length (cm)	Max age (years)	Spawning temp (°C)	Fertility (1 000 eggs)	Egg development (days)	Food
SALMONIDAE							
Brachymystax lenok (lenok)	3	70	45	2-5	2-7	28	small fish, Amphipoda insect larvae and adults, salmonid eggs and fry
Coregonus albula (vendace)	0.2-0.6	14-30	10	4-5	3-20	160-180	*Cladocera*, Copepoda, terrestrial insects Rotifera, algae
Coregonus albula ladogensis (ripus)	0.4-0.8	30-40	10	4-5	21-57	160-180	*Cladocera*, Copepoda, terrestrial insects, Rotifera
Coregonus autumnalis (omul)	7	60	20	3-7	7-40	180-200	planktonic Crustacea, fish eggs and fry, insects
Coregonus muksun (muksun)	4	65	20	4 before ice formation	42-126	130-180	Chironomidae, Mollusca, small Crustacea, algae, plant detritus, fish eggs
Coregonus nasus (large bottom white fish)	3.6	70	10-14	2.5	13-136	120-140	Chironomidae, small Mollusca, planktonic Crustacea, plant detritus, Amphipoda
Coregonus peled (peled)	4-5	50	14	4	29-105	180-200	planktonic Crustacea
Stenodus leucichthys nelma (Caspian inconnu)	30	110	25	3-8	135-400	180-200	juvenile fish, planktonic Crustacea
Hucho taimen (taimen)	31	150	20	6-8	10-34	35-40	plankton, invertebrates, insect larvae and adults, fish
Salmo salar sebago (lake salmon)	8	85	10	5-8	4-15	180-200	small fish,
Salmo gairdneri (rainbow trout)	1.6	50	10	8-10	0.5-2.5	45-60	Amphipoda, Mollusca, insect larvae, terrestrial insects, small fish
Salmo trutta fario (brown trout)	2.0	60	12	6-8	0.2-3.5	65-200	small Crustacea, insect larvae, terrestrial insects, small Mollusca, fish eggs, tadpoles, frogs
Salvelinus fontinalis (brook trout)	8	75	20	8-15	3-7	142	*Coregonus* spp., bleak, smelt, etc.
THYMALLIDAE							
Thymallus thymallus (grayling)	2.8	50	8-10	0 after ice	10	20-25	invertebrates, insect larvae and adults, fish eggs and fry, Chironomidae
OSMERIDAE							
Osmerus eperlanus (smelt)	0.012	10-12	7	4-7	2-6	1-2	zooplankton, fish eggs and fry

Fish species	Max weight (kg)	Max length (cm)	Max age (years)	Spawning temp (°C)	Fertility (1 000 eggs)	Egg devel-opment (days)	Food
ESOCIDAE							
Esox lucius (pike)	65	250	100	3-15	18-500	7-26	frogs, fish
CYPRINIDAE							
Abramis brama (bream)	6	75	28	11-15	130-940	4-6	algae, Chironomidae, Crustacea, Mollusca, insect larvae
Abramis ballerus (blue bream)	0.4-0.6	45	12	10-17	4-76	12-13	zooplankton, some benthos
Aristichthys nobilis (bighead carp)	20	100	20	26-30	460-550	2-3	phyto- and zooplankton
Aspius aspius (asp)	12	80	8	5-10	300	6-8	small fish
Barbus barbus borysthenicus (Dnieper barbel)	5	46	10	8-10	15-41	10-15	Chironomidae, worms, Ephemeroptera, sedge fly larvae, Mollusca, fish eggs, small fish
Blicca bjoerkna (white bream)	1.2	34	10	9-17	9-315	4-6	Chironomidae, Mollusca, some zooplankton
Carassius carassius (Crucian carp)	5	50	8	18-20	100-400	3-5	algae, Chironomidae, small Crustacea
Carassius auratus gibelio (giebel carp)	4	40	8	20-22	160-400	3-6	Chironomidae, zooplankton, diatoms, filamentous algae, parts of plants
Chalcalburnus chalcoides (Danube bleak)	0.4	30	7-8	12-18	10-50	8-10	planktonic Crustacea, terrestrial insects, small fish
Ctenopharyngodon idella (grass carp)	50	120	14	26-30	100-800	1-2	aquatic and terrestrial plants, worms, fish fry
Mylopharyngodon piceus (black carp)	36	110	14	26-30	100-800	1-2	aquatic insects, Mollusca
Cyprinus carpio (wild carp)	20	100	30	18-20	96-810	3-8	aquatic plants, benthos, plankton, fish fry
Hypophthalmichthys molitrix (silver carp)	20	100	20	26-30	460-550	2-3	diatoms, blue-green algae, plankton, insect larvae, small Mollusca
Leuciscus idus (ide or orfe)	6-8	80	14	7-12	38-290	8-10	diatoms, filamentous algae, worms, small Mollusca, fish
Pelecus cultratus (sichel)	1.5	50	6-8	10-15	100	8-10	Amphipoda, insect eggs larvae and adults
Rutilus rutilus (roach)	0.2	25	19	10-12	100	8-14	algae, angiosperms, plankton, insect larvae, Mollusca

Fish species	Max weight (kg)	Max length (cm)	Max age (years)	Spawning temp (°C)	Fertility (1 000 eggs)	Egg development (days)	Food
CYPRINIDAE (continued)							
Rutilus frisii	8	70	8	8-12	90-270	7-8	Chironomidae, Crustacea, Mollusca, Megaloptera larvae
Scardinius erythrophthalmus (rudd)	2	36	7	18-20	100-230	3-4	phytoplankton, soft aquatic plants, young reeds, worms, Amphipoda, small Crustacea, Chironomidae, fish eggs and fry
Vimba vimba (vimba)	0.8	40	8	19-27	28-116	2-3	plant seeds, Amphipoda, Chironomidae, Mollusca, Ephemeroptera larvae
SILURIDAE							
Silurus glanis (sheat fish)	300	500	30	18-22	10-480	4-5	aquatic insects, frogs, fish fry, *Sprattus* spp., *Rutilus rutilus caspius*
OPHICEPHALIDAE							
Ophicephalus argus warpachowskii (snake head)	7	85	8	25-30	1.3-15.0	2-3	small fishes e.g *Gobio* spp., *Rhodeus sericeus*
PERCIDAE							
Gymnocephalus cernua (pope)	0.2	20	8	6-10	4-200	5-6	Amphipoda, *Chaoborus*, Chironomidae, Mollusca, Mysidacea, fish eggs and fry
Stizostedion lucioperca (pike-perch)	20	130	15	12-15	120-1000	3-10	Amphipoda, Mysidacea, *Clupeonella delicatula*, *Sprattus* spp., *Engraulis encrasicholus, Osmerus eperlanus, Alburnus alburnus, Rutilus rutilus*, fish fry
Perca fluviatilis (perch)	5	70	15	6-10	13-300	5-18	Amphipoda,benthos, worms, Mollusca, fish eggs, small fish
GADIDAE							
Lota lota (burbot)	12	120	25	around 0	60-300	28-75	Salmonidae, Cyprinidae, Percidae, Osmeridae and their eggs
ICTALURIDAE							
Ictalurus punctatus (channel catfish)	25-30	120	40	24-30	5-34	5-10	Chironomidae, small fishes, Oligochaeta, insect larvae, detritus
CATOSTOMIDAE							
Ictiobus niger (buffalo)	40	80	20	15-18	300-750	8-10	phyto- and zooplankton, benthos

TABLE 21. FOOD COMPETITION IN FISHES FROM LAKES AND RESERVOIRS IN THE USSR
(Isaev and Karpova, 1980)

Fish species	Food competitors
Acipenser baeri (Siberian sturgeon)	sterlet, ide
Acipenser güldenstädti (Russian sturgeon)	bullhead, partly stellate sturgeon, other fishes consuming benthic fauna
Acipenser nudiventris (glassy sturgeon)	sturgeons, large cyprinids
Acipenser ruthenus (sterlet)	barbel and other fishes consuming benthic fauna
Acipenser stellatus (stellate sturgeon)	sturgeons, pike-perch, cyprinids consuming benthic fauna
Clupeonella delicatula (tyulka)	plankton eating fish
Brachymystax lenok (lenok)	burbot, grayling, taimen
Coregonus albula (vendace)	juvenile coregonids, perch, pike-perch, smelt, bleak
Coregonus autumnalis (omul)	muksun, vendace and other coregonids, smelt
Coregonus muksun (muksun)	large bottom white fish, *Coregonus lavaretus*, pope, sturgeon, partially omul, dace, roach, ide
Coregonus nasus (large bottom white fish)	dace, coregonids, partially muksun
Coregonus peled (peled)	juvenile coregonids
Stenodus leucichthys nelma (Caspian inconnu)	burbot, pike, partially taimen,lenok
Coregonus spp.	juveniles – vendace, adults – bream
Hucho taimen (taimen)	Caspian inconnu
Salmo salar sebago (lake salmon)	lake trout, brook trout
Salmo gairdneri (rainbow trout)	minnow, bullhead, eel, brook trout
Salmo trutta fario (brown trout)	grayling, minnow, nase, bullhead
Salvelinus fontinalis (brook trout)	lake trout and salmon
Thymallus thymallus (grayling)	various trout
Esox lucius (pike)	lake salmon, various trout, pike-perch, sheat fish, eel, taimen, burbot
Abramis brama (bream)	roach, nase, wild carp, eel, tench, pope
Alburnus alburnus (bleak)	juveniles of other fish species, vendace, sichel, blue bream
Aspius aspius (asp)	pike, pike-perch,
Blicca bjoerkna (white bream)	bream, wild carp, pope,eel, roach

Fish species	Food competitors
Barbus barbus borysthenicus (Dnieper barbel)	sterlet and other benthophages
Carassius carassius (Crucian carp)	carp, pope
Chalcalburnus chalcoides (Danube bleak)	bleak, vendace, other plankton feeders
Ctenopharyngodon idella (grass carp)	nase, roach, rudd, fishes consuming aquatic plants
Mylopharyngodon piceus (black carp)	wild carp, bream and other mollusc eaters
Cyprinus carpio (wild carp)	bream, crucian carp, pope
Hypophthalmichthys molitrix (silver carp)	bleak, vendace and other planktonophagous fish
Aristichthys nobilis (bighead carp)	bleak, vendace and other planktonophagous fish
Leuciscus idus (ide)	bream, roach, chub
Pelecus cultratus (sichel)	bleak
Rutilus rutilus (roach)	white bream, partially bream
Scardinius erythrophthalmus (rudd)	crucian carp, roach, pope
Silurus glanis (sheat fish)	pike-perch, pike, perch
Stizostedion lucioperca (pike-perch)	juveniles – planktonophagous fish, bleak, smelt, vendace; adults – lake trout, pike, sheat fish
Perca fluviatilis (perch)	pike-perch, eel, pike, bream

Three methods are used to determine the size of fish populations in lakes and reservoirs according to Pankratov and Strel'nikov (1984):

1. Direct calculation by trawling clearly delimited areas and extrapolating from the results to give estimates for numbers in the whole reservoir. This method is far from satisfactory.
2. Obtaining a total count by poisoning all the fish. This method is sometimes used in small lakes, which will thereafter, be used for fish farming.
3. Using sonars to count the fish in carefully delimited areas and extrapolating from this to estimate numbers for the whole reservoir.

Mathematical methods are becoming increasingly important for the estimation of the numbers and sizes of fish in lakes and reservoirs. However, to be useful, such models require accurate inputs regarding population sizes, reproductive success, and the effects of various environmental influences. A model of a lake type multi-species fish community was proposed by Labanov and Tichonov (1985), who used data from Lake Ladoga. Inter-population trophic relationships are included in the model which is designed for the study of the entire fish community. Further, models of fish communities in the northwestern part of the USSR were constructed by Umon and Rudenko (1979) and Zhakov (1984) which allow for estimates of individual population sizes within the overall community, and for many years Kazansky (1982) used a model to study patterns of change in the numbers of individuals and the biomass of fish populations in the Tsimlyansk Reservoir. His model also includes an appreciation of inter-population trophic relationships, as well as the conditions required for spawning.

TABLE 22. FISH FRY LOCALITIES IN LAKES AND RESERVOIRS OF THE USSR (Isaev and Karpova, 1980)

Growth stage	Fish species	Range
Larvae	*Abramis brama, Rutilus rutilus, Leuciscus idus, Aspius aspius, Blicca bjoerkna, Alburnus alburnus*	At first they occur in the water column of the spawning ground, then move to the coastal zone, where they stay for spring, summer and autumn. Bream larvae move from the coastal zone to areas with at least 2 m water, in July. When they reach 20-21 mm, they return to the coastal zone.
	Abramus ballerus	They move from the shallows to deeper parts, where they remain until autumn.
	Abramis sapa	Found in both coastal zones and open waters
	Pelecus cultratus	At first stay in coastal zones. Later move to open waters.
	Percidae	At first found in open waters, where they remain until last developmental stage. Afterwards they move to the coastal zone. Their survival is very high in reservoirs. They are not affected by spring fluctuation of water level.
Fry	*Abramis brama, Rutilus rutilus, Leuciscus idus, Aspius aspius, Perca fluviatilis, Stizostedion lucioperca, Stizostedion volgense*	In summer occur in shallows, moving later to deeper regions.
	Esox lucius, Cyprinus carpio, Carassius carassius	Remain permanently in shallows.
Fertilised eggs and fry	*Clupeonella delicatula*	Develop in the water column of bays, where water depth is 2-25 mm. In September, the juveniles create dense shoals in shallows.

4.1 NATURAL LAKES

Every large lake is ecologically unique (Kudersky, 1981). All commercially important fish found in these lakes can be divided into two groups; those that are confined to the lake throughout their life cycles, and those that move out of the lakes to spawn in water courses. The former group includes species that spawn in the shallows created temporarily by spring floods each year.

Numerous papers relate to individual lakes. Among those dealing with **Lake Baikal**, those of Norenko (1976) and Volerman *et al.* (1983) analyse the ichthyofauna and consider patterns of reproduction and fish productivity, especially as these are related to the main commercial species, *Coregonus autumnalis*. Holcík (1987) discusses the enormous diversification of species in this lake, and the development of a high proportion of endemism, as a consequence of its great size and geological age. The lake has very many distinct ecological niches, some of which are quite bizarre.

Pelagic and demersal species comprise the bulk of the ichthyomass of old lakes, such as Lake Baikal, whereas river species prevail in geologically young lakes. River fish, not being adapted to lacustrine conditions, tend to be confined to the littoral zone. They are not found at depths greater than 20-30 m, thus leaving the pelagic and profundal zones empty. For this reason, trophic effectiveness and fish crop sizes are much lower in young lakes than in old lakes, despite the fact that productivity is similar in both types.

Lake Ladoga has also been studied quite intensively. Fedorova (1977, 1982) edited the proceedings of two volumes containing studies of the biology and ecology of fish in this lake, where the most important commercial species are coregonids, notably *Coregonus albula* ssp. *ladogensis*, and Salmonidae. However, less important species such as *Gymnocephalus cernua*, *Perca fluviatilis* and *Rutilus rutilus* are also mentioned. The population size of the economically important coregonids and *Stizostedion lucioperca* were estimated by Shirkova (1977), who found *Coregonus lavaretus ludoga* to be the most widespread of the seven coregonid species present. In the 1970s this species constituted 90% of all whitefish catches. *Stizostedion lucioperca*, which is also an important commercial species, is concentrated in southern parts although it occurs throughout the lake.

Lake Balkhash is another very old lake, where shallow water, high summer temperatures and large area (*c.* 17 500 km^2) favour introduced species. *Cyprinus carpio* has acclimated well since its introduction in the 1970s, and in consequence is now economically important (Strel'nikov, 1978). *Silurus glanis* and *Stizostedion lucioperca* are also naturalised, but *Silurus glanis* has become a nuisance in that it consumes about 9 000 tons of other fish in the lake each year, including 1 500 tons of *Cyprinus carpio*.

Other lake studies include one edited by Pokrovsky (1983) on the development and status of the ichthyofauna of **Lake Onega**, another edited by Oganesyan and Smolei (1979) on the ichthyofauna of **Lake Sevan** (with special reference to the effect of decreasing water levels) and collections of papers edited by Lavrent'eva (1976) and Fedorova (1980) on the fish fauna of **Pskovsko-Chudskoe Lake**.

Changes that occur in lacustrine fish communities under conditions of eutrophication are discussed by Reshetnikov (1979) and Reshetnikov and Severtsev (1981). These authors say that the primary production of northern lakes is relatively poor, but that the fish biomass may be comparatively high (*c*.50 kg/ha),which seems to indicate a slow rate of flow of energy through the ecosystem. Total primary production in the northern lakes of the USSR for the growing season is estimated to be not more than 200 kcal/m^2, with a monthly phytoplankton production of 60-70 kcal/m^2.

The coregonid and salmonid populations of the northern lakes comprise slow growing species with non-annual spawning patterns and a longevity of 20-25 years. Most of the energy entering the ecosystems is used to support large and old fish, so that intensive fishing often leads to changes and successions in the fish community. A decrease in the ecological diversity of coregonids and salmonids, in combination with various other factors, may result in large and long-lived fish being ousted by small slow-growing species with short life-cycles. The effect of a combination of factors on the fish communities of Lake Syam and Lake Sevan are shown in *Tables 23* and *24*. However, the larger and more northerly a lake, the less strongly are these changes manifested. Initially, a little eutrophication has a positive influence on the growth and maturation of coregonids, but as the process continues conditions for breeding deteriorate while those for feeding, growth and rapid maturation improve. Alteration of food chains, silting of the spawning grounds and lack of oxygen during winter result in a decline, first of salmonids, then of coregonids. As a lake continues to eutrophy salmonids and coregonids are replaced by percids and cyprinids. The following diagram shows the survival of different groups under conditions of increasing eutrophication:

Salmonidae	⇒	Coregonidae	⇒	Coregonidae	⇒	Osmeridae	⇒	Cyprinidae
		Coregonidae		Percidae		Cyprinidae		Esocidae
				Cyprinidae		Percidae		

With increasing water colour and reduced transparency the series is different:

Salmonidae	⇒	Coregonidae	⇒	Cyprinidae	⇒	Percidae	⇒	Esocidae

With increasing pollution and silting the proportion of cyprinid fish increases, but with increasing eutrophication, percids, cyprinids and esocids all have an advantage because of their early spring spawning and short incubation periods. As an example, in Lake Syam, in Karelia, the biomass of the zooplankton has increased fourfold (from 0.39 to 1.55 g/m^3) over the last 25 years, while its production is said to have increased fivefold (from 4.14 to 21.78 g/m^3, maximum 44.54 g/m^3). During this period the Shannon-Wiever index of plankton species diversity has decreased from 2.86 in 1955 to 2.50 in 1979. This lake, which was formerly classified as a 'cisco-whitefish' lake is now an 'osmerid-cyprinid' lake. Although data show that the biomasses of predatory (14-15 kg/ha) and bottom-feeding fish (11-25 kg/ha) have remained unchanged, the biomass of plankton feeding species has increased sharply, from 16.8 kg/ha to 66.8 kg/ha. At present the total ichthyomass is estimated at 107 kg/ha, with annual fish production at 64 kg/ha and the annual catch at about 10 kg/ha. The main energy flux is clearly from phytoplankton to zooplankton to plankton feeding fish to predatory fish.

TABLE 23. CHANGES IN THE LAKE SYAM ECOSYSTEM DURING THE LAST 25 YEARS

Parameters	1951-1955	1975-1980
Lake area (km^2)	266	256
Mean depth (m)	6.7	6.0
Transparency (Secchi disc) (m)	2.6-4.5	0.7-3.0
Mean water temperature, May-October (°C)	11.3	11.8
Dissolved oxygen concentration (mg/l)		
superficial	9.17	8.35
bottom	6.32	3.99
CO_2 at bottom level (mg/l)	4.4	8.5
Available nitrogen, N (mg/l)	0.07-0.28	0.40-0.86
Mineral phosphate, P (mg/l)	trace	0.003-0.005
Organic phosphate, P (mg/l)	-	0.024-0.057
Zooplankton biomass (g/m^3)	0.384	2.000
Zooplankton production (g/m^3)	4.14	21.87
Benthos biomass (g/m^2)	3.13	2.10
Total annual catch (kg/ha)	4.20	6.80
coregonids	1.12	0.21
osmerids (smelt)	0.00	4.27
perch and ruff	1.05	2.37
cyprinids	0.88	1.00

There is a substantial literature on small and medium-sized lakes, especially those of the northwestern part of the European part of the USSR, which form a significant part of the total lake area of the country, and the abundance and biomass of fish in these lakes is documented by Rudenko and Umnov (1982). These are lakes of the *Perca fluviatilis-Rutilus rutilus* type, which although they contain sizeable stocks of predatory fish, have an abundance of species such as *Alburnus alburnus*, *Blicca bjoerkna*, *Gymnocephalus cernua*, *Perca fluviatilis* and *Rutilus rutilus* which have little commercial importance (Kazakov 1980; Kudersky, 1981). A similar situation prevails in the small lakes of the Leningrad region (Pokrovsky, 1977, 1980). It has been suggested that these lakes could be successfully restocked with *Aristichthys nobilis*, *Coregonus peled*, *C. nasus*, *C. muksun*, *Cyprinus carpio* and *Hypophthalmichthys molitrix* (Kazakov, 1980). Berdichevsky *et al.* (1979) share this view having demonstrated that, compared with *Coregonus peled*, coarse fish utilise food less effectively, *e.g.* the food coefficients of *Rutilus rutilus* in this region are 8.7 -

27.5, whereas those of *Coregonus peled* are approximately half this. Further, growth analysis showed that a 2 year old *Rutilus rutilus* weighs 5-6 g, whereas a 2 year old *Coregonus peled* from the same region weighs about 340g. This is due, at least in large part, to the fact that peleds continue to grow during the long winter season. Pakhorukov (1980) gives methods for determining the abundance and distribution of fry in lakes and reservoirs.

TABLE 24. CHANGES IN THE LAKE SEVAN ECOSYSTEM DURING THE LAST 20 YEARS

Parameters	1958-1960	1975-1979
Lake area (km^2)	1413	1244
Mean depth (m)	41.3	27.6
Transparency (Secchi disc) (m)	10.9	4.4
Minimum conc. of dissolved oxygen – bottom (mg/l)	6.2	0.0
Relation of max O_2 in hypolimnion: max O_2 in epilimnion	1.2	0.84
Phosphate, P (mg/l)	0.19	0.06
Nitrogen, N (mg/l)	trace	0.14
Phytoplankton production (kcal.10^3/m^2/year)	1.58	10.00
Zooplankton production (g/l)	1.76	11.80
Total annual catch (kg/ha)	10.0	20.9
Sevan trout	3.3	0.8
white fish	1.0	15.9
Varicorhinus and *Barbus*	5.7	4.2

4.2 RESERVOIRS

In a reservoir it takes many years for the original river ichthyofauna to change into the equivalent of a stable lake fauna. Usually natural changes are augmented by the introduction of exotic species, the more important of which are *Aristichthys nobilis*, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Mylopharyngodon piceus*, and *Coregonus peled* which is suitable for introduction to the more northern reservoirs. The fluctuation of water levels during the spawning season markedly affects the development of a fish fauna. In addition, fishing fails to regulate the ichthyofauna, and species which become dominant initially may be unable to utilise the full spectrum of food available in the system. All this leads to poor fish crops.

Recent studies (Butorin, 1978a) have shown that fish living in the reservoirs of the Volga watershed gather to form local shoals. Each shoal contains but a single species, but comprises fish of different ages. The shoal is a self-maintaining group attached to a single spawning ground and having common feeding and wintering environments. If the spawning ground is disturbed, the numbers of progeny fall and the shoal diminishes. In river-type reservoirs, which are in the majority, a population comprises a number of shoals, each with strictly defined spawning grounds and adjacent feeding and wintering areas *(Figure 15)*. In lake-type reservoirs fish density and the behaviour of shoals is variable. Here differences are associated with the spatial distribution of shoals in relation to one another, and with the quality of biotypes present *(Figure 16)*.

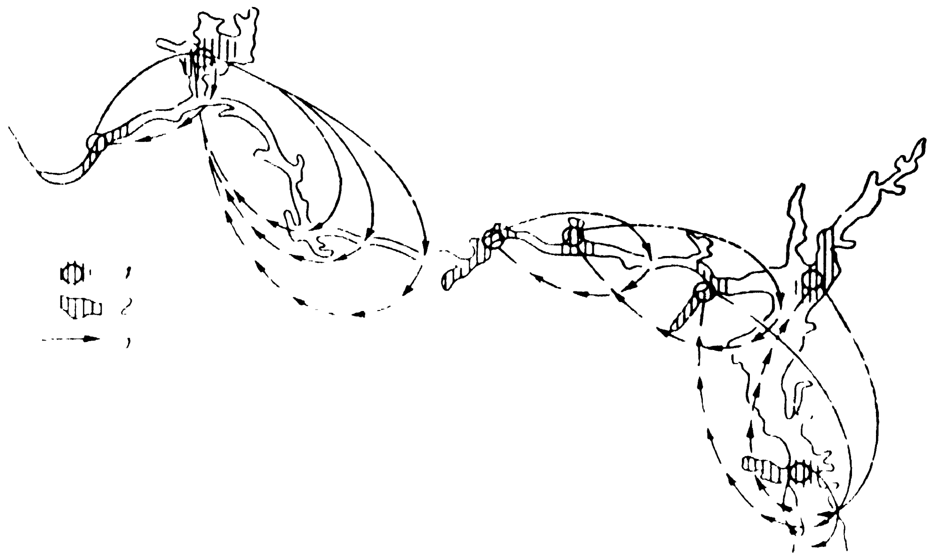


Figure 15. — Bream migration in river and river-like reservoirs (e.g. Volga Cascade): 1. spawning ground of local shoal, 2. localities of prevailing fish, 3. migration of individual fish for feeding and wintering.

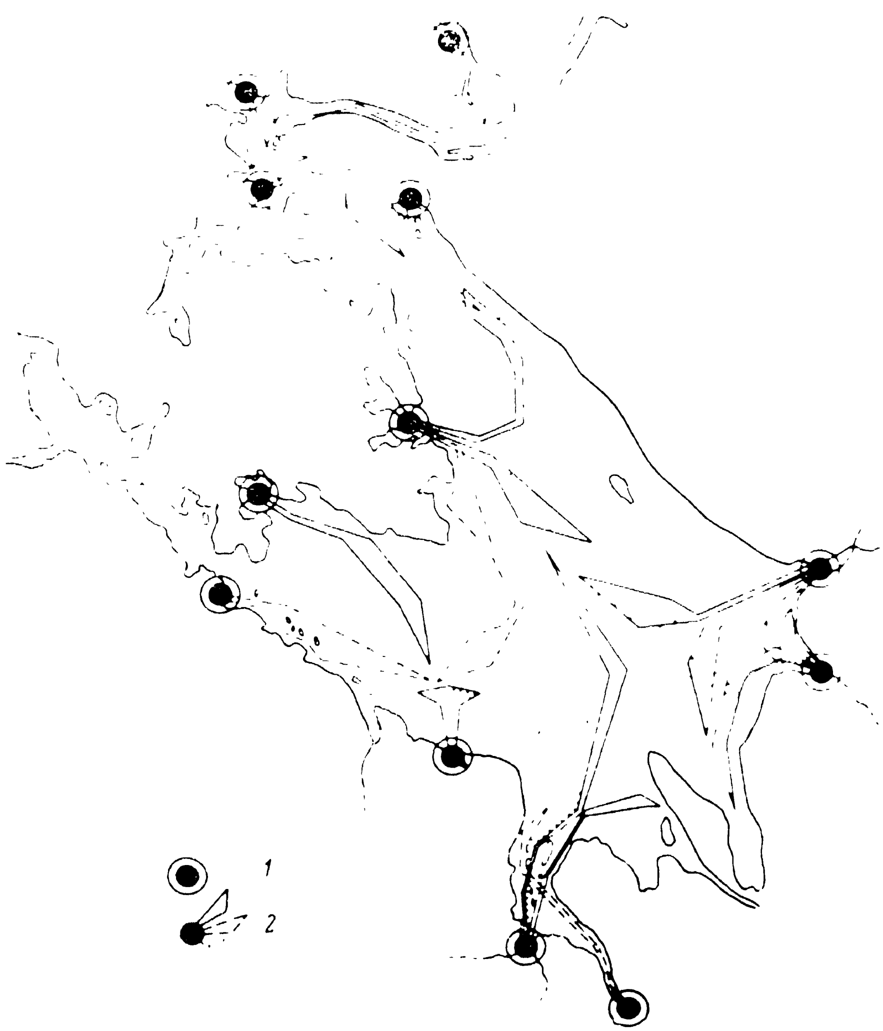


Figure 16. — Migration cycles of bream in the Rybinskoe lake-like reservoir: 1. spawning grounds, 2. annual migration cycles.

Phytophilous fish are of primary importance in reservoirs, a fact documented by many authors, including Isaev and Karpova (1980) who arranged species of various ecological groups in order of the importance of their commercial yields, as summarised in *Table 25.* From this data *Abramis* spp. appear as major commercial fish. The development of *Abramis* populations in the Volga reservoirs is described by Volodin (1981).

TABLE 25. PROPORTION OF FISHES IN COMMERCIAL CATCHES FROM VOLGA RESERVOIRS BASED ON CHARACTER OF SPAWNING (Isaev and Karpova, 1980)

Ecological group of fish	Proportion (%)
Exclusively phytophilous (*e.g. Abramis ballerus,Abramis brama, Alburnus alburnus, Blicca bjoerkna,Carassius carassius, Esox lucius*)	70-85
Phyto- and lithophilous (*e.g. Gymnocephalus cernua, Leuciscus idus*)	2-7
Exclusively lithophilous (*e.g. Coregonus albula, Osmerus eperlanus*, and other Coregonidae).	0.2-2.5
Nest-spawners (*e.g. Silurus glanis, Stizostedion lucioperca*)	3-11
Spawning on any substratum (*e.g. Perca fluviatilis*)	3-17
Psamnophilous (*e.g. Lota lota*)	0.5-90
Pelagophilous (*Clupeonella delicatula, Pelecus cultratus*)	2.0-5.5
Others	1.5-25

The introduction of commercially valuable fish into the Volga reservoirs has been evaluated by Butorin (1978a) and details are given in Chapter 7. General information on the fish fauna of reservoirs is provided by Avakyan and Sharapov (1986) and Shimanovskaya *et al.* (1986) while Vovk and Stetsenko (1985) deal solely with introduced phytophagous species. Brief comment on the situation in individual reservoirs follows.

The ichthyofauna of the **Kuibyshev Reservoir** consists of indigenous Volga River species, augmented by *Abramis brama*, *Cyprinus carpio* and *Stizostedion lucioperca*. Of the 40 or so fish species which inhabit this reservoir, Isaev and Karpova (1980) consider that *Abramis brama*, *Carassius carassius*, *Cyprinus carpio*, *Esox lucius* and *Stizostedion lucioperca* are commercially important. Together with Lukin (1977) and Tsyplakov (1980) they consider that the great fluctuations of water level prevent the commercially important species from forming large populations in the reservoir. By contrast, the coarse and weed species show greater ecological plasticity, and are present in large numbers. In addition, some ecological niches have been filled by new and undesirable species which have recently invaded the reservoir (*e.g. Clupeonella* sp.). Monakov (1983) estimates the number of *Clupeonella* present in the reservoir in 1980 as 1.6×10^9, and deduces that they would have consumed 45.7% of the total zooplankton eaten by fish. According to him economically important fish constitute only 39% of the fish biomass of the reservoir, and consume only 22.5% of the total food available to all fish. Insufficient stocking results in coarse fish being able to usurp a substantial portion of the available space and food. The situation is exacerbated by fluctuations in water level due to abstraction, and by commercial dredging of the bottom.

The ichthyofauna of the **Bratsk Reservoir** has developed naturally. According to Isaev and Karpova (1980) it comprises 26 river and 4 introduced species *(Abramis brama, Carassius carassius, Coregonus autumnalis, Cyprinus carpio,)*. The most important fish are *Esox lucius*, *Gymnocephalus cernua, Leuciscus cephalus*, *Lota lota, Rutilus rutilus* and *Perca fluviatilis*. Mamontov (1977) considers introductions as important, but indicates that this will take 8-10 years for stocks of coregonids and bream to develop, and 16-18 years for sturgeon stocks to develop should these fish be introduced.

The **Dnieper Reservoir System** contains riverine species and introduced Chinese carps. The acclimation of the introduced species shows that their growth rates are higher than they are in their original habitat (the watershed of the Amur River) and indeed, higher than they are in fish ponds in the Ukraine (Ozinskovskaya, 1982). This is especially so for *Hypophthalmichthys molitrix*, which does not migrate and remains close to sites of its release in the reservoir.

There are 28 species of fish in the **Kremenchug Reservoir**, of which 16 are of commercial value, *with Abramis ballerus, Abramis brama, Cyprinus carpio, Esox lucius, Hypophthalmichthys molitrix and Stizostedion lucioperca* among the most important. There are large stocks of fish of low commercial value, such as *Alburnus alburnus, Blicca bjoerkna, Perca fluviatilis* and *Rutilus rutilus*. The growth of *Abramis brama*, the most important commercial species, is evaluated by Vyatchanina and Konstantinova (1981), and that of *Stizostedion lucioperca* by Demchenko (1982). The reproductive dynamics of all the commercial species is analysed by Vyatchanina and Demchenko (1981, 1982), and the ecology of their fry by Koval (1979), Zimbalevskaya (1979) and Vladimirova (1979). Reproduction is hindered by fluctuating water levels, sporadic precipitation, decrease in the area suitable for reproduction and increasing levels of pollution.

The **Kakhovskoe Reservoir** also contains elements of the original Dnieper ichthyofauna, together with two introduced Chinese carps, *Aristichthys nobilis* and *Hypophthalmichthys molitrix* (Ozinkovskaya and Chechun, 1981). Species of major economic value are *Abramis brama, Aristichthys nobilis, Cyprinus carpio, Esox lucius, Hypophthalmichthys molitrix, Silurus glanis* and *Stizostedion lucioperca*. *Blicca bjoerkna, Clupeonella* sp. and *Rutilus rutilus* prevail among the coarse fish. The fish in this reservoir encounter the same problems as found in the other Dnieper reservoirs, namely fluctuations in water level, pollution and an unfavourable ratio of commercial to coarse fish.

Forty-four species of fish are found in the **Tsimlyansk Reservoir** (Isaev and Karpova, 1980), of which *Abramis brama, Cyprinus carpio, Hypophthalmichthys molitrix, Silurus glanis* and *Stizostedion lucioperca* are of commercial value, the latter having been successfully introduced (Mukhamedova, 1982).

The ichthyofauna of the **Bukhtarminskoe Reservoir** comprises 30 species, of which *Abramis brama, Cyprinus carpio, Esox lucius* and *Stizostedion lucioperca* are of commercial value, and *Gymnocephalus cernua, Perca fluviatilis* and *Rutilus rutilus* are abundant among those which are not.

The fish fauna of the **Volgograd Reservoir** also developed from riverine species with the early introduction of *Abramis brama, Cyprinus carpio* and *Stizostedion lucioperca*. Today it comprises about 50 species among which *Abramis brama, Acipenser ruthenus, Cyprinus carpio, Esox lucius* and *Stizostedion lucioperca* (Isaev and Karpova, 1980) are of commercial value. The Chinese carps *Aristichthys nobilis, Ctenopharyngodon idella, Hypophthalmichthys molitrix* and *Mylopharyngodon piceus* were introduced in 1967. The dam is equipped with a fish lift.

In the **Kamskoe Reservoir** the fish fauna evolved naturally, from the original fish. There are now 32 commercially fished species, , including *Abramis brama, Esox lucius* and *Stizostedion lucioperca*, and the coarse fish *Blicca bjoerkna, Perca fluviatilis* and *Rutilus rutilus* (Isaev and Karpova, 1980). Conditions do not favour the important species: the water level fluctuates, the littoral zone is poorly vegetated and the water is polluted.

The fish fauna of the **Krasnoyarsk Reservoir** developed from that of the Yenisei River. It now comprises 28 species of which *Acipenser ruthenus, Brachymystax lenok, Esox lucius, Hucho taimen*, and various Coregonidae are of the greatest commercial value (Isaev and Karpova, 1980). However, as conditions changed after the filling of the reservoir, the numbers of rheophilous species declined, including *Acipenser ruthenus, Hucho taimen* and Coregonidae, while populations of *Gymnocephalus cernua, Perca fluviatilis* and *Rutilus rutilus* increased.

The ichthyofauna of the **Rybinskoe Reservoir** comprises 29 indigenous species among which *Abramis brama*, *Esox lucius* *Silurus glanis* and *Stizostedion lucioperca* are of commercial importance. The most abundant coarse fish are *Abramis ballerus*, *Blicca bjoerkna* and *Rutilus rutilus*.

In the **Saratov Reservoir** there are 45 species, all from the Volga River, with 28 being of commercial importance (Isaev and Karpova, 1980). The most abundant species in catches are *Abramis brama*, *Abramis ballerus*, *Acipenser ruthenus*, *Alburnus alburnus*, *Blicca bjoerkna*, *Esox lucius*, *Lota lota*, *Perca fluviatilis*, *Rutilus rutilus*, *Silurus glanis* and *Stizostedion lucioperca*. Fluctuations in water level tend to impede reproduction in most fish.

The **Ust-Ilimsk Reservoir**, on the Angara River in Siberia, has an ichthyofauna of 24 local species, including *Acipenser ruthenus*, *Brachymystax lenok*, *Esox lucius*, *Hucho taimen* and various Coregonidae, all of commercial importance (Isaev and Karpova, 1980). As lacustrine conditions became established the rheophilous species such as *Brachymystax lenok* and *Hucho taimen* declined in importance, being ousted especially by fishes such as *Gymnocephalus cernua*, *Perca fluviatilis* and *Rutilus rutilus*. Recently *Coregonus autumnalis*, *Coregonus peled* and *Abramis brama* have been introduced.

Similar data are given for **Vilyuisk Reservoir** by Kirillov (1977) and for the **Gorky Reservoir** in proceedings edited by Kozhevnikov (1979).

4.3 RUNNING WATERS

There is little recent information on the fish fauna of running waters in the USSR, and except for the rivers of Siberia and the Far East, the importance of riverine fisheries is diminishing. In his monograph on the Volga, Butorin (1978a) states that the original ichthyofauna of the Volga comprised 74 taxa, but that after new species were introduced in the wake of the dam construction, this number rose to 88, with about 20 of commercial value. Sturgeon contribute the best quality fish, and these are caught in the lower reaches of the river and in the delta.

The river systems of the Ob and Irtysh basins are the most important for river fishing in the USSR, although catches and stocks are substantially affected by periodic fluctuations in the volumes of water carried (Shimanovskaya *et al.*,1983). The large rivers of the Krasnoyarsk region, the Yenisei, Pyasina, Khatanga and Taimyr, are characterised by low aquatic productivity, including low numbers and biomass of fish.

Human interference with the rivers of the USSR, is particularly associated with dam building and pollution. It has a deleterious effect on the riverine fish fauna, especially in the European part of the USSR. In the last three decades catches of sturgeon and salmonids have decreased by more than 20% (Berka, 1978; Shimanovskaya *et al.*, 1983). To keep the fish stocks at healthy levels, hatchery produced fry and fingerlings are regularly released in selected parts of water courses.

5. FISH CATCHES FROM LAKES, RESERVOIRS AND WATER COURSES

The total catch from lakes, reservoirs and water courses in the USSR constitutes a substantial part of the overall fresh water fish yield, which includes fish farming. According to Treshchev (1983) the total yield from fresh water sources for 1980 was 800 000 tons. However, the development of capture fisheries in open waters has proved to be slower than the government intended, and in most cases outputs have remained stable and the projected catches have not been realised (Delova, 1976; Isaev and Karpova, 1980; Shimanovskaya *et al.*, 1983). Reasons given for this include the deleterious effects of human activity on the quality of inland waters, the deleterious effect of riverine regulation, successive years of low rainfall, delay in implementing modern methods for increasing fish production, poor utilisation of investments and fishing equipment, lack of understanding of the economics of inland fisheries, and the low level of priority that inland fisheries command generally. It is widely agreed that the reservoirs are not utilised optimally, and that fishing intensity on them is too low, with under-exploitation of species of lower commercial values.

TABLE 26. FISH CATCHES FROM LAKES, RESERVOIRS AND WATER COURSES IN THE REPUBLICS OF THE USSR (1 000 tons) (Shimanovskaya and Kudersky, 1978; Shimanovskaya *et al.*, 1977, 1983)

Republic	1960	1965	1970	1975	1976	1977	1978	1979	1980
Russian SFSR	137.32	145.20	102.10	126.72	127.67	126.77	109.60	116.34	124.03
Ukrainian SSR	8.84	14.37	21.80	30.71	26.84	25.33	21.25	23.20	20.20
Byelorussian SSR	3.06	2.62	2.13	2.50	2.25	1.99	2.55	2.13	1.58
Uzbek SSR	0.77	0.57	1.37	1.43	1.27	0.84	1.06	1.01	1.31
Kazakh SSR	28.85	35.92	30.67	39.11	39.36	34.64	33.18	31.88	31.21
Georgian SSR	0.13	0.18	0.18	0.36	0.30	0.26	0.37	0.31	0.47
Azerbaidzhanian SSR	1.54	1.37	1.04	0.94	1.21	1.02	1.39	1.34	1.28
Lithuanian SSR	0.68	0.91	0.85	0.76	1.21	1.15	1.00	0.74	0.86
Moldavian SSR	0.51	0.54	0.38	0.40	0.37	1.01	0.23	0.25	0.24
Latvian SSR	1.14	1.97	1.73	3.68	3.90	1.67	0.94	0.54	2.11
Kirghiz SSR	1.05	1.05	0.96	0.93	0.99	0.83	0.80	0.47	0.40
Tadjik SSR	0.17	0.27	0.45	0.24	0.15	0.21	0.18	0.26	0.34
Armenian SSR	0.97	0.96	0.97	1.43	1.41	1.10	1.17	1.28	1.27
Turkmenian SSR	0.18	0.35	0.66	1.32	1.15	1.48	1.22	1.17	1.25
Estonian SSR	2.98	4.15	5.82	4.51	4.91	5.43	4.92	3.86	5.77
USSR – total	189.19	210.43	171.12	215.04	213.00	203.73	179.86	184.78	192.32

A summary of the fish catches from the individual republics of the USSR is given in *Table 26* and 5-yearly averages are shown in *Table 27*. During the three decades from 1951 to 1980, catches from open waters in the USSR varied between 185 000 and 210 000 tons/year. By comparison, fish pond production over the same period rose from 6 000 tons in 1950 to 153 000 tons in 1980. Monakov (1981) anticipated an 18% growth in the yield from inland open waters between 1980 and 1985.* The Russian SFSR produces 60-65% of the open water fish catch of the USSR. It should be noted that the official fisheries statistics do

Note (Ed.): Estimates of total production from inland capture fisheries vary. Kotljar (1988) gives 589 000 t for 1987, but does not say if aquaculture is included, and 1.2 million t, when salt lakes are included. FAO (1989) gives 988 381 t for 1987, including aquaculture.

not include catches by anglers, despite the fact that sport fishing is important and that angling catches in some areas are greater than those of the local commercial enterprises.

TABLE 27. FIVE-YEAR AVERAGES OF ANNUAL FISH CATCHES FROM ALL TYPES OF INLAND CAPTURE FISHERIES IN THE USSR (Kudersky, 1981)

Years	Average annual catch (1 000 tons)
1951-1955	187.9
1956-1960	189.2
1961-1965	210.4
1966-1970	185.9
1971-1975	198.9
1976-1980	191.3

It is believed that increasing the water area by building new dams has little influence on the overall fish catch, and that increases in reservoir catches tend to be balanced by decreases in riverine catches. However, the average annual catch from all open waters during the period 1976-80 had declined from that recorded during 1961-65 by some 19 100 tons/year. Reasons for this fall are given in the separate sub-sections which deal with the different types of open waters, *i.e.* lakes, reservoirs and rivers.

TABLE 28. MAJOR FISH GROUPS IN THE CAPTURE FISHERIES FROM ALL INLAND WATERS OF THE USSR (1 000 tons)

Fish	1960	1965	1970	1975	1976	1977	1978	1979	1980	1980 (%)
Commercially valuable species										
Acipenseridae	1.96	1.55	0.99	0.76	0.94	0.74	0.82	0.90	0.82	0.4
Salmonidae	1.64	1.59	0.81	1.37	1.33	1.06	1.11	0.84	1.74	0.9
Coregonidae	24.14	21.16	16.78	26.24	26.09	27.63	25.66	28.02	31.68	16.5
others	70.80	82.89	74.20	83.71	79.80	75.44	70.20	70.83	71.40	37.1
Commercially less valuable species										
Clupeonella sp.	12.08	10.52	11.34	12.47	10.93	11.86	10.50	8.54	9.08	4.7
others	78.57	92.72	67.00	90.49	93.91	87.00	71.57	75.65	77.60	40.4
Total	189.19	210.43	171.12	215.04	213.00	203.73	179.86	184.78	192.32	100.0

However, since the construction of reservoirs, the species structure of the catches has improved slightly, so that a greater proportion of commercially valuable fish are caught than formerly. From 1976 to 1980 the average catch of commercially valuable fish was 103 414 tons/year, compared with 98 792 tons/year during the period 1971 to 1975, and with 92 780 tons in 1970. Of the total catch in 1980 (192 320 tons) 54.9% comprised commercially valuable species *(Table 28)*. Increased proportions of coregonids in catches, especially of the widely introduced *Coregonus peled*, have been the most notable improvement.

The distribution of catch sizes according to the type of water body has remained stable for some time (Shimanovskaya *et al.*, 1977, 1983) and is summarised in *Table 29*. From 1971-80, 40.1-43.7% of the total open water catch came from natural lakes, 27.8-33.6% from reservoirs and 23.5-30.2% from rivers. However, during this decade the proportion of the catch from reservoirs has declined, largely because of a lack of interest in the commercially less valuable species. Catches from lakes and running waters are little changed, the latter because abundant precipitation in recent years provided good conditions for fish reproduction. In 1980 the proportion of the catch from rivers exceeded that from reservoirs for the first time in 20 years.

TABLE 29. PERCENTAGE DISTRIBUTION OF THE FISH CATCH FROM DIFFERENT TYPES OF INLAND WATERS OF THE USSR (Shimanovskaya *et al.*, 1977, 1983)

Water body	1971	1975	1976	1977	1978	1979	1980
Lakes	42.9	40.1	42.2	42.6	43.7	40.8	42.0
Reservoirs	33.6	32.8	31.0	31.6	30.6	31.3	27.8
Rivers	23.5	27.1	26.8	25.8	25.7	27.9	30,2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 30. FISH CATCHES FROM LAKES OF THE USSR, (1 000 tons) (Shimanovskaya, 1978; Shimanovskaya *et al.*, 1977, 1983)

Republic	1966	1970	1975	1976	1977	1978	1979	1980
Russian SFSR	49.11	41.51	50.34	53.41	52.29	45.83	45.23	47,68
Ukrainian SSR	1.03	0.21	0.18	0.19	0.18	0.37	0.18	0.09
Byelorussian SSR	1.80	1.51	1.63	1.55	1.50	1.30	1.25	1.15
Uzbek SSR	0.60	0.83	1.17	1.20	0.66	0.95	0.90	1.20
Kazakh SSR	26.30	20.57	23.72	24.20	22.66	21.00	20.47	20.98
Georgian SSR	0.14	0.14	0.27	0.22	0.19	0.19	0.19	0.26
Azerbaidzhanian SSR	0.13	0.15	0.14	0.20	0.20	0.33	0.25	0.21
Lithuanian SSR	0.57	0.44	0.51	0.48	0.50	0.52	0.54	0.52
Moldavian SSR	0.02	0.22	0.18	0.18	0.11	0.11	0.11	0.10
Latvian SSR	1.75	0.53	0.57	0.49	0.63	0.27	0.25	0.42
Kirghiz SSR	1.18	0.96	0.93	0.99	0.83	0.80	0.49	0.40
Tadjik SSR	0.02	-	0.02	-	-	-	-	-
Armenian SSR	1.05	0.97	1.43	1.30	1.10	1.17	1.28	1.27
Turkmenian SSR	0.15	0.35	0.62	0.52	0.62	0.88	0.45	0.58
Estonian SSR	4.29	5.80	4.51	4.91	5.43	4.91	3.86	5.77
USSR – total	88.14	74.19	86.22	89.84	86.90	78.63	75.45	80.63

5.1 LAKES

Fish capture from lakes within individual Soviet republics is summarised in *Table 30* for the years 1966-1980. This indicates that the average annual catch per republic has remained fairly constant, varying by less than 10%. The Russian SFSR, by far the largest republic, produces the largest catch, followed by the Kazakh SSR, and together these two contribute about 80% of the total lake fish catch. The species composition of the catches from lakes are summarised in *Table 31.* About 50% of the catches are considered to be commercially valuable.

TABLE 31. SPECIES COMPOSITION OF CATCHES FROM ALL LAKES OF THE USSR (1 000 tons)
(Shimanovskaya, 1978; Shimanovskaya *et al.*, 1983).

Groups of fish	1972	1976	1977	1978	1979	1980	1980 (%)
Commercially valuable species							
Acipenseridae	included in others	0.01	0.03	0.03	0.09	0.05	0.1
Salmonidae	0.18	0.22	0.21	0.24	0.33	0.35	0.4
Coregonidae	9.05	11.43	11.08	11.27	11.95	12.98	16.1
others	27.88	33.04	29.48	28.05	28,24	28.53	35.4
Commercially less valuable species							
Osmeridae	4.17	5.35	4.86	6.28	5.20	9.67	12.0
others	38.59	39.79	41.24	32.76	29.64	29.05	36.0
Total	79.87	89.84	86.90	78.63	75.45	80.63	100.0

5.1.1 LARGE LAKES

Fishing is most intensive in large lakes, *i.e.* those over 10 000 ha. The total catch from these lakes ranges from 45 000-56 000 tons/year which comprises 60-70% of the total fish catch from lakes *(Table 32).*

TABLE 32. FISH CAPTURE FROM ALL LARGE LAKES OF THE USSR (tons)

1971	1975	1976	1977	1978	1979	1980
46 270	52 980	55 820	54 650	49 020	45 230	46 780

The species composition of catches from large lakes is given in *Table 33*, which shows that well over 50% of the catch from these lakes is of commercial value. The sizes of catches from some of the major lakes, and the development of these catches over a decade, are surveyed in *Table 34.*

Fish yield in large lakes is considered to be low. Kudersky (1977b) estimates it at 4.5 kg/ha, while Shimanovskaya *et al.* (1977, 1983) consider it to have been 6-7 kg/ha in the early 1970s reducing to 4-6 kg/ha by the late 1970s. The highest yields have been obtained from Pskov-Chudskoe Lake (29 kg/ha) and Ilmen Lake (28 kg/ha), but by contrast yields from the Arctic lakes are less than 1 kg/ha.

A decline in the population sizes of some commercially valuable species in a number of large lakes was observed in the decade 1971-1980 (Shimanovskaya *et al.*, 1977, 1983). In 1970 the Ili River, a tributary of Lake Balkhash, was impounded by Kapchagai dam. For several years, while the reservoir was filling, there was a major reduction in the water supply to the lake. In consequence the water level fell 1.4 m, the surface area was reduced and salinity increased. Catches of common carp fell due largely to low recruitment following the loss of former shallows, which had been breeding grounds. However, compensation for the reduced catch was achieved through the expansion of introduced species such as *Silurus glanis* and *Stizostedion lucioperca*. As a result there has been little perceptible change in the total catch from this lake.

TABLE 33. SPECIES COMPOSITION OF THE FISH CATCH FROM LARGE LAKES OF THE USSR (1 000 tons)
(Kudersky, 1981; Shimanovskaya *et al.*, 1983)

Groups of fish	1976	1977	1978	1979	1980	1980 (%)
Commercially valuable species						
Acipenseridae	0.01	0.03	0.03	0.09	0.05	0.1
Salmonidae	0.15	0.14	0.11	0.15	0.15	0.3
Coregonidae	6.58	6.27	6.66	6.58	7.14	15.3
others	22.82	23.13	21.84	19.96	19.89	41.5
Commercially less valuable species						
Osmeridae	5.26	4.74	6.12	5.07	9.41	20.1
others	21.00	20.34	14.26	13.38	10.64	22.7
Total	55.82	54.65	49.02	45.23	46.78	100.0

TABLE 34. FISH CATCHES FROM SOME LARGE LAKES OF THE USSR (1 000 tons)
(Shimanovskaya *et al.*, 1977; 1983)

Lake	1971	1975	1976	1977	1978	1979	1980
Pskov-Chudskoe	11.66	10.24	11.30	11.02	9.82	7.58	10.60
Ladoga	4.78	5.67	4.91	4.94	5.92	6.29	6.61
Ilmen	3.24	3.15	2.09	3.11	3.33	2.30	2.18
Onega	1.42	2.39	2.44	2.11	1.93	2 17	1.98
Baikal	3.60	3.52	4.02	3.93	3.32	2 77	2.70
Balkhash	11.80	13.23	12.63	12.31	13.87	12.45	12.36
Sevan	0.58	1.43	1.31	1.10	1.17	1.28	1.39

Changes in fish stocks have also been recorded in other lakes. Populations of *Stizostedion lucioperca* in Beloe Lake, of *Osmerus eperlanus* in Pskov-Chudskoe and Ilmen Lakes, and of *Coregonus albula* in Pskov-Chudskoe and Onega Lakes have all been reduced in recent years. In Ladoga Lake there has been a marked fall in the abundance of Coregonidae, apparently due to severe eutrophication and the consequent worsening of conditions for reproduction. The loss of river spawning sites has also led to a decline in the populations of lake salmon and trout in many northern lakes.

The variations in annual catches in most lakes are a consequence of declining stocks brought about essentially by a combination of human influence and natural changes. Catches vary because conditions in the lakes vary. Sport fishing has also been detrimental to commercial fishing.

However, in certain large lakes the status of some species has improved considerably since the introduction of controlled fishing, land reclamation practices, and conservation efforts. Thus, for example, commercial fishing for *Coregonus autumnalis* was banned on Lake Baikal in 1969 when annual catches had fallen below 500 tons. Reclamation procedures were put into practice and the lake was re-stocked from hatcheries. By 1982 limited fishing for this species was reintroduced with an initial catch of 2 200 tons. The abundance of *Abramis brama* has increased in many large lakes in northwestern USSR, and in some there have also been increases in the numbers of *Coregonus albula* and *Stizostedion lucioperca*.

Stizostedion lucioperca has also become important in Balkhash Lake, having acclimated very successfully (Strel'nikov, 1978). In 1957, 3 000 *Stizostedion lucioperca* were released into the lake and by 1962 the catch was 2 650 tons. Unfortunately, fishing pressure for this species was too low and consequently shortage of food led to mass mortality during the 1965-66 season. After some years the annual catch was stabilised near 4 000 tons, but with improved fishery practices this rose to 5 000 tons by 1978.

Other commercially valuable species have acclimated well in Balkhash Lake. Whereas in 1955 one third of the catch comprised coarse species such as *Perca fluviatilis* and *Schizothorax argentatus* (marinka), by the early 1970s 98% was made up of commercially valuable fish which included the introduced species *Abramis brama*, *Cyprinus carpio* and *Stizostedion lucioperca* (Berka, 1978).

TABLE 35. FISH CATCH FROM LADOGA LAKE AND ITS SPECIES COMPOSITION (tons) (Fedorova, 1985)

Groups of fish	1970-1978 (mean annual)	1979	1980	1981	1982	1983
Coregonidae	1 616	1 949	1 752	1658	1 791	2 035
of this:						
Coregonus lavaretus	536	515	383	291	297	329
Salmonidae	3	2	2	-	1	1
Other commercially valuable species	861	1 303	1 469	1 352	1 389	1 323
of these:						
Stizostedion lucioperca	579	893	942	1 006	1 006	1 049
Abramis brama	176	252	354	207	147	143
Esox lucius	80	68	78	63	71	59
Commercially less valuable species	1 106	1 123	1 060	1 307	895	855
of these:						
Perca fluviatilis	361	523	420	635	309	298
Rutilus rutilus	374	424	386	488	354	340
Others	1 692	1 911	2327	2 596	1 601	2493
Total	5 278	6 288	6 610	6 913	5 677	6 707

The fish reserves of Ladoga Lake have been well surveyed for commercial fishing (Shirkova, 1977; Fedorova, 1977, 1982, 1985). Catches have increased steadily, from an average of 3 500 tons/year during the period 1964-69, to 5 200 tons/year in 1970-75, and 6 000 tons/year during 1978-80. Increases were recorded in the catches of both commercially valuable (*e.g. Coregonus albula*, *Stizostedion lucioperca*) and lower value fishes (*e.g. Gymnocephalus cernua*, *Perca fluviatilis*, *Rutilus rutilus*). The higher catches of coarse fish might be beneficial in that they should theoretically leave more food for the economically important species. Shirkova (1977) analysed the fish fauna from 1934 to 1974, during which time the number of Coregonidae ranged from 0.99-6.85 million individuals, while commercial stocks of *Stizostedion lucioperca* ranged from 0.7-2.5 million individuals. Fishing removed 14-32% Coregonidae and 10-26% *Stizostedion lucioperca*. According to Fedorova (1985) eutrophication of the lake in the last two decades has affected the southern, Leningrad, part of the lake most. Associated with this eutrophication, Cyprinidae and Percidae have increased in abundance in the shallows of this part of the lake, so that the catches *e.g.*, of *Stizostedion lucioperca*, have been exceptionally high. An increase in the catch of low value Cyprinidae was also recorded. Of the total catch for the lake, about 90% comes from the southern part, and the lake is underfished. The stocks of *Perca fluviatilis*, *Rutilus rutilus* and other commercially less interesting fish remain more or less neglected. The total annual catches are listed in *Table 35*, and catches from some other large lakes are given, for comparison, in *Tables 36-40.*

TABLE 36. FISH CATCH FROM ONEGA LAKE AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Groups of fish	1971	1975	1976	1977	1978	1979	1980
Gadidae (*Lota lota*)	#	#	133	136	110	104	113
Salmonidae	10	20	20	15	16	18	26
Coregonidae	460	550	908	762	790	924	767
other commercially valuable species	170	420	117	127	88	72	68
of these							
Stizostedion lucioperca	30	90	54	58	43	33	36
Abramis brama	10	14	40	46	36	32	26
Perca fluviatilis	130	190	23	23	9	7	6
Osmeridae	600	1 190	950	834	750	854	755
commercially less valuable	180	250	311	233	180	194	233
Total	1 420	2 430	2 440	2 107	1 934	2 166	1 982

Gadidae included under *Perca fluviatilis*

TABLE 37. FISH CATCH FROM PSKOV-CHUDSKOE LAKE AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Groups of fish	1971	1975	1976	1977	1978	1979	1980
Gadidae (*Lota lota*)	200	120	120	130	130	170	233
Coregonidae	970	2 040	1 840	1 850	1 750	1 380	1 818
other commercially valuable spp	630	560	670	710	590	500	486
of these							
Stizostedion lucioperca	20	10	10	10	20	50	10
Abramis brama	160	310	400	500	320	220	238
Esox lucius	450	240	260	200	250	230	238
Osmeridae	1 960	40	2 970	2 110	1 960	1 960	5 567
less valuable spp.	7 900	7 480	5 880	6 220	5 390	3 540	2 497
Total	11 660	10 240	11 300	11 020	9 820	7 580	10 601

The dependence of fish production and fish catches on the average primary production of large lakes was determined by Bul'on (1983) who demonstrated a direct, and generally linear, correlation. According to him the catch in some lakes accounted for just 0.02-0.05% of the primary production, and pointed out that this was clear indication that many lakes could support more intensive fishing.

TABLE 38. FISH CATCH FROM BAIKAL LAKE AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Groups of fish	1971	1975	1976	1977	1978	1979	1980
Lota lota	100	80	94	80	72	58	72
Salmoniformes	40	30	43	54	49	74	82
of this:							
Brachymystax lenok	-	-	2	-	-	-	-
Thymallus thymallus	40	30	41	54	49	74	82
Coregonidae	560	570	1 087	1 211	1 180	817	821
of these:							
Coregonus autumnalis	560	570	1 083	1 209	1 177	815	819
other coregonids	-	-	4	2	3	2	2
other commercially valuable spp.	190	230	234	170	86	70	36
of these:							
Esox lucius	140	130	111	50	25	45	30
cyprinids	50	100	123	120	61	25	6
less valuable spp.	2 710	2 610	2 567	2 414	1 937	1 747	1 694
Total	3 600	3 520	4 025	3 929	3 324	2 766	2 705

TABLE 39. FISH CATCH FROM SEVAN LAKE AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Groups of fish	1971	1975	1976	1977	1978	1979	1980
trout	70	60	21	19	8	4	2
Coregonidae	430	1 130	1 005	830	882	1 012	1 095
other valuable spp.	80	240	285	255	279	262	294
Total	580	1 430	1 311	1 104	1 169	1 278	1 391

5.1.2 SMALL AND MEDIUM SIZED LAKES

Compared with the group of large lakes, the small and medium sized lakes contribute only a small proportion of the total lake fish catch. This is chiefly because these lakes are subject only to extensive fishing, so that yields are low. Shimanovskaya *et al.* (1977, 1983) estimated the average annual catch on these lakes at 7-8 kg/ha in the northwestern and Urals region, and a mere 1-3 kg/ha in the northern regions. According to Kudersky (1977b), the average catch from all small lakes was close to 2.7 kg/ha in 1975, but Rudenko and Pechnikov (1988) give 10-12 kg/ha. The average annual tonnages of fish caught in all medium and small lakes from 1951 to 1980 are given in *Table 41.* This reveals an overall decrease during the 3 decades. However, there is some disagreement with regard to these figures since Shimanovskaya *et al.* (1983) gives lower figures for 1976-80 (29 600-34 000 tons/year), while Titova (1984) cites the average annual catch as only 20 000 tons during 1971-1980 period, and 21 700 tons in 1982. Despite the discrepancies all these authors agree that this group of lakes does not play a very important role in Soviet capture fisheries. This is especially so because barely half the annual catch is commercially valuable (*Table 42*).

TABLE 40. FISH CATCH FROM BALKHASH LAKE AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Groups of fish	1971	1975	1976	1977	1978	1979	1980
Acipenser nudiventris	-	-	9	32	35	86	32
Cyprinus carpio	5 440	4 190	3 450	2 040	1 630	910	614
Stizostedion lucioperca	3 720	3 640	2 960	2 790	2 340	1 720	1 574
Abramis brama	1 830	3 860	4 820	6 310	8 650	8 740	9 025
Silurus glanis	550	880	750	630	740	650	734
Hypophthalmichthys molitrix	-	-	20	-	3	39	24
other valuable spp.	120	-	461	330	280	190	207
less valuable spp.	140	660	160	170	190	120	153
Total	11 800	13 230	12 630	12 302	13 868	12 455	12 363

TABLE 41. FISH CATCH FROM THE GROUP OF SMALL AND MEDIUM SIZED LAKES OF THE USSR (1000 tons) (Kudersky, 1981)

Period	Average annual catch
1951-1955	60.0
1956-1960	36.1
1961-1965	40.2
1966-1970	31.9
1971-1975	32.6
1976-1980	39.3

TABLE 42. SPECIES COMPOSITION OF THE FISH CATCH FROM SMALL AND MEDIUM SIZED LAKES OF THE USSR (1000 tons)

Groups of fish	1976	1977	1978	1979	1980
Anguilla anguilla	0.04	0.13	0.02	0.04	0.03
Salmonidae	0.07	0.07	0.13	0.17	0.19
Coregonidae	4.85	4.81	4.60	5.38	5.85
other valuable spp.	10.18	6.22	6.19	8.24	9.11
less valuable spp.	18.88	21.02	18.66	16.40	18.67
Total	34.02	32.25	29.60	30.23	33.85

Fish numbers, ichthyomass and potential fish yield are directly related to limnological characteristics (Rudenko and Pechnikov, 1988). These authors summarised such relationships in *Table 43.* The catches from small and medium-sized lakes do not reflect the productivity of these lakes, but rather the low intensity at which they are fished. As a group they are underfished for many reasons. Some are situated far from major fishing centres, many have rough bottoms which preclude the use of trawl nets, many more are practically inaccessible, while the high percentage of poor quality fish which they all supply means that catches from them command only very low prices. The numbers of fishermen employed on them have declined in recent years and there is little good, selective, fishing equipment available (Titova, 1984). This lack of suitable fishing gear reduces the possibilities for regulated fishing, which would be of great advantage on these lakes. The most abundant species are currently under-utilised which leads to a general decrease in the growth rate of the fish and a high proportion of coarse species in commercial catches.

TABLE 43. RELATIONSHIPS BETWEEN FISH STOCK AND LAKE-TYPE IN SMALL AND MEDIUM SIZED LAKES

Lake-type	Number of fish (x1000)	Surface area (x1000 ha)	Ichthyomass (kg/ha)	Potential fish yield (kg/ha)
oligotrophic	1.7	110.9	23±	12±4
oligo-mesotrophic	16.2	515.7	85±12	39±14
mesotrophic	29.2	727.7	162±34	93±12
eutrophic	122.8	565.3	265±23	146±14
dystrophic	9.1	60.3	23±2	12±4

TABLE 44. FISH CATCHES FROM RESERVOIRS OF THE REPUBLICS OF THE USSR (1000 tons)
(Shimanovskaya, 1978; Shimanovskaya *et al.* 1977, 1983)

Republic	1966	1970	1975	1976	1977	1978	1979	1980
Russian SFSR	30.36	26.24	30.55	29.56	30.45	26.71	28.03	26.49
Ukrainian SSR	18.32	20.15	22.63	19.63	19.44	14.57	17.00	14.72
Byelorussian SSR	0.03	0.03	0.05	0.05	0.04	0.04	0.06	0.1
Uzbek SSR	0.19	0.54	0.26	0.08	0.19	0.14	0.11	0.11
Kazakh SSR	4.57	8.93	15.39	15.10	11.79	11.48	10.73	10.10
Georgian SSR	0.03	0.03	0.07	0.08	0.06	0.18	0.12	0.07
Azerbaidzhanian SSR	0.59	0.31	0.43	0.45	0.47	0.62	0.51	0.66
Lithuanian SSR	0.14	0.13	0.14	0.15	0.15	0.08	0.13	0.10
Moldavian SSR	0.10	0.06	0.11	0.11	0.82	0.12	0.14	0.14
Latvian SSR	-	0.01	0.05	0.07	0.04	0.26	0.04	0.03
Kirghiz SSR	-	-	-	-	-	-	-	-
Tadjik SSR	0.29	0.46	0.22	0.10	0.19	0.18	0.26	0.34
Armenian SSR	-	-	-	-	-	-	-	-
Turkmenian SSR	0.30	0.31	0.70	0.63	0.77	0.34	0.72	0.67
Estonian SSR	-	-	-	-	-	-	-	-
USSR-Total	54.92	57.12	70.60	66.01	64.41	55.08	57.85	53.53

Angling is prevalent on these lakes, but the quantities taken by sport fishermen are not known. Titova (1984) estimates that the sporting catch equals the commercial catch, but with the important difference that anglers take only large sized individuals of economically valuable species. It seems possible that small and medium sized lakes could be developed as sites for the culture of commercially valuable species (see Chapter 8).

5.2 RESERVOIRS

Annual catches from all the reservoirs of each of the Soviet Republics are given in *Table 44*. Here it can be seen that the small increase in the catches of the mid-1970s was followed by a decrease. The Russian SFSR produced almost half the total reservoir fish catch in 1980, the Ukrainian SSR 27.5% and the Kazakh SSR 18.9%. Once again these figures do not include the high numbers of fish caught by anglers. They take the best fish and their annual catches on some reservoirs exceed the commercial catches.

A summary of the tonnages of fish caught in all Soviet reservoirs during the period 1951-80 is given in *Table 45*. This shows that reservoirs are the only class of open water bodies in the USSR from which catches have increased. This is to be attributed in large part to the fact that new reservoirs are continuously added to those in existence. The species composition of catches from reservoirs is given in *Table 46*. It can be seen that economically important species always account for more than 50% of the catch.

TABLE 45. FISH CATCHES FROM RESERVOIRS OF THE USSR DURING THE PERIOD 1951-1980 (1000 tons) (Kudersky, 1980)

Period	Average annual catch
1951-1955	8.0
1956-1960	23.7
1961-1965	44.3
1966-1970	55.5
1971-1975	65.6
1976-1980	59.4

TABLE 46. SPECIES COMPOSITION OF FISH CATCHES FROM RESERVOIRS OF THE USSR (1000 tons) (Kudersky, 1980)

Group of fish	1972	1976	1977	1978	1979	1980	1980 (%)
Valuable spp.							
Acipenseridae	0.02	-	0.01	0.01	-	0.01	-
Salmonidae	0.01	-	-	-	0.01	-	-
Coregonidae	0.26	0.30	0.32	0.31	0.42	0.44	0.8
others	33.37	34.55	33.35	32.16	31.45	29.79	55.7
Less valuable spp.							
Clupeonella delicatula	6.46	6.21	8.15	6.04	4.20	5.42	10.1
others	27.47	24.95	22.58	16.56	21.76	17.87	33.4
Total	67.59	66.01	64.41	55.08	57.85	53.53	100.0

Fish catches are still low and lie well below original projections, yet they are higher than for lakes. The average yield is 10-12 kg/ha (Pankratova, 1986) with a range from 1 kg/ha (Kudersky 1977b) to 100 kg/ha in certain reservoirs of the Ukraine, North Caucasus, Moldavia and Central Asia, where the climate is favourable and water regimes can be regulated (Pankratova, 1986). A classification of large reservoirs by level of fish productivity is given in *Table 47*, while the relationship between fish yield and geographical location is shown in *Table 48*. The average annual reservoir fishery yield for the years 1976-1980 is given in *Table 49*. As with natural lakes, reservoirs are not being fished to their full potential, with catches accounting for just 0.02-0.17% of the primary production (Bul'on, 1983).

TABLE 47. SCALE OF COMMERCIAL PRODUCTIVITY IN LARGE RESERVOIRS (Isaev and Karpova, 1980)

Class	Level of fish productivity in reservoir	Potential yield (kg/ha)
I	very high	over 60
II	high	30-60
III	medium	15-30
IV	low	7-15
V	very low	2-7

TABLE 48. RESERVOIR FISH YIELD IN RELATIONSHIP TO GEOGRAPHICAL LOCATION (Isaev and Karpova, 1980)

Locality of reservoir	Fish yield (kg/ha)
North of 58°N	5-20
52-58°N	20-50
South of 52°N	50-80

The reservoirs of Siberia are important among the reservoirs of the USSR, having a total water area of 1.3 million ha. They were constructed on rivers where fish of high commercial value occurred naturally, *e.g.* Acipenseridae, Coregonidae and Salmonidae, but they altered the conditions under which the fish lived. The water in the reservoirs becomes warmer than it did in the former rivers, and water levels fluctuate in winter. In the first few years after filling, species of low commercial value multiplied greatly (Shimanovskaya, 1977c) and their stocks are still poorly utilised. Only 62% of the total reservoir area is used for fisheries and fish yield has been as low as 1.2-1.7 kg/ha.

However, some positive steps have been taken. A major achievement has been the introduction of Chinese carps into reservoirs of the Ukraine and Central Asian Republics, and *Abramis brama* and *Stizostedion lucioperca* have become established in some reservoirs in Siberia. The large scale use of artificial spawning nests is an important development. Shimanovskaya *et al.* (1983) state that more than 1 200 000 nests were installed in reservoirs in the Russian SFSR in 1981.

There is still potential to exploit the large reserves of species of lower commercial value in the reservoirs, *e.g.* Monakov (1983) states that *Blicca bjoerkna* and *Rutilus rutilus* are under-exploited in the Kuibyshev Reservoir. Here the less valuable species comprise 40-42% of the catch, but their percentage representation in the community is greater than this. The catch of low value species is not limited and it is estimated that the capture of these fish could be increased by 35-40%. Another improvement could be made by a more equable distribution of catches over the seasons; increasing the intensity of ice-fishing in the winter could be advantageous. At present 17% of the total catch is obtained in the first quarter of the year, 38.9% in the second quarter, 30.7% in the third quarter and 13.4% in the fourth quarter of the year. The average fish yield from the Kuibyshev Reservoir was 7-8 kg/ha in the early 1980s, but ranged from 5-24 kg/ha over different zones of the reservoir, although these figures also reflect differential fishing intensity (Monakov,1983).

TABLE 49. AVERAGE ANNUAL FISHERY YIELD (kg/ha) OF SELECTED LARGE RESERVOIRS FOR THE PERIOD 1976-1980 (Shimanovskaya, 1983)

Reservoir	*Abramis brama*	*Cyprinus carpio*	*Esox lucius*	*Stizostedion lucioperca*	*Lota lota*	*Silurus glanis*	Coregonidae	herbivorous spp.	*Clupeonella delicatula*	less valuable spp.	total
Rybinskoe	1.8	-	0.4	0.4	0.3	0.1	-	-	-	2.4	5.4
Gorky	1.6	-	0.1	0.1	-	-	-	-	-	1.4	3.2
Kuibyshev	3.1	-	0.3	0.6	0.2	0.1	-	-	-	3.6	7.9
Saratov	1.8	-	0.3	0.4	-	-	-	-	-	3.5	6.0
Volgograd	3.5	-	0.3	1.4	-	0.6	-	-	-	3.7	9.5
Tsimlyansk	10.2	0.2	0.3	4.7	-	1.1	-	-	-	18.7	35.2
Kremenchug	5.2	0.7	0.7	2.2	-	-	-	-	5.5	10.7	25.0
Kakhovskoe	7.5	0.2	0.2	2.8	-	0.1	-	1.5	17.9	1.7	31.9
Kamskoe	0.9	-	0.1	-	-	-	-	-	-	0.6	1.6
Bratsk	-	-	-	-	-	-	-	-	-	1.6	1.6
Krasnoyarsk	-	-	-	-	-	-	-	-	-	1.6	1.6
Vilyuisk	-	-	2.2	-	0.3	-	0.2	-	-	1.2	3.9

The Tsimlyansk Reservoir is characterised by a low level of fish productivity, especially in years of low water. Further, fish stocks are regularly reduced because large numbers are carried away with irrigation water (Shimanovskaya *et al.*, 1983). In some years the reservoir has been over-fished (catches have exceeded the recommended limit), and this has had an adverse effect on the valuable species. Kazansky (1982) confirmed this using a mathematical model of fish population dynamics and abundance. He drew attention to the danger that any further increase in selective fishing might lead to over-exploitation of the fish populations. The volume of fishing in the reservoir is close to optimum and according to the model may not be safely increased by more than 4%. *Stizostedion lucioperca* is among the commercially important species and comprised up to 20% of the total catch between 1970 and 1979 (Koval, 1982). However, while catches of this species were higher than in any other Soviet reservoir, during the early 1970s, when they reached 10.2 kg/ha, they have declined in recent years in response to over-exploitation. Analyses suggest that the optimum annual catch of *Stizostedion lucioperca* should remove only 35-40% of the commercial size stock present, but over the ten years from 1970-79 the figure was well above 40%.

Fish productivity in the reservoirs of the Volga River is generally significantly lower than that in the reservoirs of the Don and Dnieper Rivers. Over the entire Volga system of reservoirs catches decreased from an average of 15 000 tons/year between 1976 and 1980 to 11 600 tons in 1982 (Shimanovskaya *et al.*, 1983). This latter figure is equivalent to a yield of 5.6 kg/ha, but if angling figures are included the yield rises to about 10.4 kg/ha. Reasons given for low yields of the Volga reservoirs include unfavourable fishing conditions and the neglect of species of low economic value on the upper Volga. Also, stocks of *Abramis brama* are under-exploited in the Saratov and Volgograd Reservoirs.

TABLE 50. FISH CATCH FROM THE KUIBYSHEV RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Acipenseridae	24	38	10	10	-	-	10
Other commercially valuable spp.	2 158	3 028	2 780	2 670	2 820	2 460	2 067
of these:							
Abramis brama	1 603	1 964	1 890	1 980	2 060	1 720	1 406
Stizostedion lucioperca	135	354	450	380	460	430	363
Esox lucius	167	259	290	220	210	180	249
Silurus glanis	82	127	90	70	70	90	47
Lota lota	5	18	40	10	10	20	1
Aspius aspius	12	7	20	10	10	20	1
Chinese carps	-	3	-	-	-	-	-
Cyprinus carpio	3	12	-	-	-	-	-
Stizostedion volgense	151	284	-	-	-	-	-
less valuable spp.	1 819	1 620	1 870	2 010	2 150	2 340	2 053
Total	4 001	4 686	4 660	4 690	4 970	4 800	4 130

TABLE 51. FISH CATCH FROM THE TSIMLYANSK RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Commercially valuable spp.	7 485	5 382	5 860	5 490	4 720	4 660	5 373
of these:							
Abramis brama	3 838	2 730	3 430	2 860	2 220	2 370	2 960
Stizostedion lucioperca	1 501	1 573	1 380	1 320	1 330	1 170	1 221
Esox lucius	89	80	80	20	80	160	121
Cyprinus carpio	112	33	40	40	30	80	75
Silurus glanis	232	418	350	420	270	250	198
Hypophthalmichthys molitrix	-	2	-	10	10	30	12
Aspius aspius	156	47	-	110	90	80	-
Stizostedion volgense	1 499	419	340	600	520	410	640
others	58	80	240	110	170	110	146
less valuable spp.	3 498	4 063	4 080	4 890	3 410	4 690	4 620
Total	10 983	9 445	9 940	10 380	8 130	9 350	9 993

Fish production in the reservoirs of the Dnieper River is lower than river fish production prior to the construction of the dams (Pikush and Sukhoivan, 1978). From 1978 data it appears that the fish yield over the entire reservoir system was one half of that of the river. The only fish which has maintained its numbers in the catch is *Clupeonella* sp. In the original river, benthophagous species such as *Abramis brama*, *Blicca bjoerkna*, *Carassius carassius*, *Cyprinus carpio*, *Leuciscus idus*, *Rutilus rutilus* and *Tinca tinca* constituted 62.7% of the fish community, planktonophagous species, such as *Abramis ballerus*, *Alburnus alburnus* and *Pelecus cultratus*, 9.1%, and predatory species, mainly *Aspius aspius*, *Esox lucius*, *Perca fluviatilis*, *Silurus glanis* and *Stizostedion lucioperca* 28.2%. In the reservoirs the respective proportions for these groups are 72.8, 9.6 and 17.6%. It is anticipated that the introduction of Chinese carps will be successful because the prevailing conditions are most favourable to them.

The catches on some large reservoirs in the USSR are given in *Tables 50-57*, based on the work of Shimanovskaya *et al.* (1977, 1983). However the figures are not consistent with those of Isaev and Karpova (1980).

TABLE 52. FISH CATCH FROM THE BUKHTARMINSKOE RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Commercially valuable spp.	2 338	6 817	7 404	6 130	8 216	6 438	7 748
of these:							
Abramis brama	870	4 369	5 806	4 737	6 530	5 070	6 710
Stizostedion lucioperca	6	1 285	1 100	1 166	1 490	1 170	994
Esox lucius	993	773	315	82	90	118	23
Cyprinus carpio	310	300	111	110	80	60	20
Tinca tinca	148	45	35	5	1	-	-
Lota lota	11	45	37	30	25	20	1
less valuable spp.	7 232	5 845	4 762	2 609	1 526	1 168	775
Total	9 570	12 662	12 166	8 739	9 742	7 606	8 523

TABLE 53. FISH CATCH FROM THE BRATSK RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Lota lota	5	7	12	10	2	2	5
Thymallus thymallus	-	-	1	1	-	-	-
Abramis brama	-	-	1	-	-	-	-
Esox lucius	4	1	-	-	-	-	-
less valuable spp.	838	1 189	928	772	1 036	934	793
Total	847	1 197	942	783	1 038	936	798

TABLE 54. FISH CATCH FROM THE KREMENCHUG RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
commercially valuable spp.	4 857	4 183	3 581	2 112	1 304	1 659	1 280
of these:							
Abramis brama	4 028	2 808	2 594	1 191	659	742	634
Stizostedion lucioperca	459	721	515	589	395	616	380
Cyprinus carpio	182	329	183	177	124	122	144
Aspius aspius	34	49	13	11	1	1	3
Esox lucius	146	266	260	137	120	170	80
Silurus glanis	4	7	16	7	2	3	3
Chinese carps,-	-	-	-	3	5	36	
Tinca tinca	4	3	-	-	-	-	-
less valuable spp.	2 917	4 894	3 714	4 836	3 113	4 069	2 503
of these:							
Clupeonella delicatula	320	1 437	1 319	2 648	1 277	412	506
Total	7 774	9 077	7 295	6 948	4 417	5 728	3 783

TABLE 55. FISH CATCH FROM THE KAKHOVSKOE RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Commercially valuable spp.	3 946	3 595	2 769	2 111	2 347	3 314	2 781
of these:							
Abramis brama	2 709	2 492	2 144	1 201	1 252	1 773	1 735
Stizostedion lucioperca	1 044	996	459	718	686	691	482
Cyprinus carpio	77	27	47	25	27	47	30
Aspius aspius	4	-	-	-	-	-	-
Esox lucius	31	37	34	38	48	36	32
Silurus glanis	77	37	33	37	26	27	24
Chinese carps	4	6	52	92	308	740	478
less valuable spp.	4 496	3 801	4 436	4 994	4 100	3 528	4 009
of these:							
Clupeonella delicatula	3 443	3 047	3 991	4 523	3 833	3 231	3 661
Total	8 442	7 396	7 205	7 105	6 447	6 842	6 790

TABLE 56. FISH CATCH FROM THE VOLGOGRAD RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
commercially valuable spp.	1 576	2 347	2 653	2 512	2 165	1 935	1 667
of these:							
Acipenseridae	8	-	-	-	-	-	-
Abramis brama	794	1 432	1 430	1 428	1 240	960	920
Stizostedion lucioperca	277	272	470	565	470	461	447
Esox lucius	94	82	110	96	30	70	67
Aspius aspius	19	-	10	1	10	4	7
Silurus glanis	263	339	330	195	110	182	88
Lota lota	1	-	3	1	5	5	20
Stizostedion volgense	120	222	300	226	300	253	118
less valuable spp.	1 229	1 430	1 407	1 348	460	1 265	773
Total	2 805	3 777	4 060	3 860	2 625	3 200	2 440

TABLE 57. FISH CATCH FROM THE RYBINSKOE RESERVOIR AND ITS SPECIES COMPOSITION (tons)
(Shimanovskaya *et al.*, 1977, 1983)

Group of fish	1971	1975	1976	1977	1978	1979	1980
Commercially valuable spp.	1 195	1 556	1 373	1 503	1 446	1 440	1 341
of these							
Abramis brama	602	1 017	910	1 010	862	780	553
Stizostedion lucioperca	225	171	190	170	230	240	179
Esox lucius	146	213	190	200	228	180	204
Silurus glanis	-	1	1	2	-	-	5
Lota lota	221	123	80	110	119	204	334
others	1	1	2	11	7	36	66
less valuable spp.	1 023	1 225	1 247	1 307	1 114	960	894
Total	2 218	2 781	2 620	2 810	2 560	2 400	2 235

5.3 RUNNING WATERS

Information concerning total fish catches from Soviet rivers is given by Shimanovskaya *et al.* (1977, 1983) and Berka (1978), and is summarised in *Table 58*. In the period 1975-1980, annual catches ranged from 46 000-58 000 tons, contributing 26-30% of the catches from all open waters. The Russian SFSR provides the bulk of the riverine catch (85.7% in 1980), with the Ukrainian SSR second in importance (9.3% in 1980).

TABLE 58. FISH CATCHES FROM THE RUNNING WATERS OF THE REPUBLICS OF THE USSR (1000 tons)
(Shimanovskaya, 1978; Shimanovskaya *et al.*, 1977, 1983)

Republic	1966	1970	1975	1976	1977	1978	1979	1980
Russian SFSR	54.16	34.35	45.83	44.70	44.04	37.06	43.08	49.86
Ukrainian SSR	0.95	1.44	7.90	7.02	5.71	6.31	6.01	5.38
Byelorussian SSR	0.56	0.59	0.82	0.67	0.45	0.84	o.83	0.33
Uzbek SSR	-	-	-	-	0.01	-	-	-
Kazakh SSR	3.15	1.17	-	0.06	0.19	0.70	0.68	0.13
Georgian SSR	0.02	0.01	0.02	0.01	0.01	-	-	0.13
Azerbaidzhanian SSR	0.53	0.68	0.37	0.56	0.34	0.44	0.57	0.41
Lithuanian SSR	0.42	0.28	0.11	0.58	0.50	0.40	0.06	0.24
Moldavian SSR	0.64	1.19	3.06	3.33	1.00	0.40	0.25	1.67
Kirghiz SSR	-	-	-	-	-	-	-	-
Tadjik SSR	-	-	-	0.05	0.01	-	-	-
Armenian SSR	-	-	-	0.10	-	-	-	-
Turkmenian SSR	-	-	-	-	0.08	-	-	-
Estonian SSR	-	0.02	-	-	-	-	-	-
USSR - total	60.79	39.81	58.22	57 16	52.42	46.15	51.48	58.15

Catches for the period 1951-1980, (*Table 59*) are not directly comparable with the data in *Table 58*, except for the years 1976-1980. The differences indicate that there is a need for a standard approach in the collection of statistical data and their evaluation.

TABLE 59. FISH CATCH FROM RUNNING WATERS OF THE USSR 1951-1980 (1 000 tons) (Kudersky, 1981)

Period	Average annual catch
1951-1955	76.5
1956-1960	77.8
1961-1965	72.8
1966-1970	47.0
1971-1975	49.8
1976-1980	49.6

It can be seen from *Table 59*, that catches from running waters declined abruptly after 1965. This reflects the construction of numerous dams which flooded thousands of kilometres of rivers, especially in the European part of the USSR and Siberia. Increasing levels of water pollution also contributed to the decline in riverine catches. There was a minor recovery in the 1970s due to an increase in catches from Siberia, and from *Clupeonella* sp. caught in the lower Dnieper River.

A breakdown of the composition of river fish caught between 1972-1980 is given in *Table 60*, which relates to the gross catches quoted in *Table 58*. The commercially valuable species account for more than half the total catch. Acipenseridae, Salmonidae and Coregonidae constitute one third of the total.

TABLE 60. COMPOSITION OF THE FISH CATCH FROM RUNNING WATERS OF THE USSR (1000 tons)
(Shimanovskaya *et al.*, 1983)

Group of fish	1972	1976	1977	1978	1979	1980	1980 (%)
Commercially valuable species							
Acipenseridae	0.70	0.93	0.70	0.77	0.81	0.76	1.3
Salmonidae	0.52	1.10	0.84	0.87	0.50	1.39	2.4
Coregonidae	13.69	14.36	16.23	14.09	15.64	18.25	31.4
others	12.50	12.22	12.62	9.99	11.14	13.09	22.5
Less valuable spp.							
Clupeonella delicatula	3.40	4.72	3.71	4.46	4.34	3.66	6.3
others	16.50	23.83	18.32	15.97	19.05	21.00	36.1
Total	47.31	57.16	52.42	46.15	51.48	58.15	100.0

TABLE 61. FISH CATCHES FROM THE IMPORTANT RIVER BASINS OF THE USSR (1 000 tons)

River basin	1976	1977	1978	1979	1980
Volga	0.25	0.37	0.32	0.31	0.28
Don	0.59	0.48	0.60	0.27	0.34
Ob-Irtysh	35.79	36.94	28.78	32.95	39.86
Yenisei	2.91	3.2	3.58	4.31	3.89
Pyasina	0.43	0.37	0.43	0.43	0.44
Khatanga	1.33	1.22	1.29	1.21	1.48
Lena	3.70	3.55	3.10	2.19	3.09
Indigirka	0.96	1.23	1.28	1.16	0.99
Kolyma	1.70	1.94	2.00	1.40	1.80

The importance of fisheries on the rivers of the European part of the USSR has been greatly reduced in recent years, and the industry has now effectively contracted to the lower courses and deltas. Even here catches have fallen, *e.g.*, at the beginning of the twentieth century the average annual catch on the lower Volga was 200 000 tons, but this had fallen to 100 000 tons by the 1950s, and the decline continues today, albeit erratically. However, despite this, the lower Volga is still the richest fishery watercourse in the European SFSR, and the most important fish caught there are Abramis brama, Rutilus rutilus caspius and Stizostedion lucioperca. Catches of Acipenseridae have decreased considerably. Sport fishing competes with commercial fishing on the Volga, but figures for this are not available, nor are those for commercial catches in the delta, and the statistics in this chapter are compiled without this information.

TABLE 62. COMPOSITION OF THE FISH CATCHES FROM THE BASIN OF THE OB AND IRTYSH RIVERS (1000 tons) (Shimanovskaya *et al.*, 1983)

Group of fish	1976	1977	1978	1979	1980
Commercially valuable spp.	20.93	20.87	16.37	20.77	26.42
of these:					
Acipenseridae	0.35	0.31	0.26	0.16	0.22
Salmonidae	0.16	0.12	0.11	0.13	0.12
Coregonidae	10.76	11.76	9.64	12.75	15.86
Osmeridae	0.19	0.09	0.20	0.19	0.09
Gadidae *(Lota lota)*	2.01	1.62	2.08	2.22	2.31
Cyprinidae	4.50	4.64	2.69	2.37	3.48
Esocidae *(Esox lucius)*	2.95	2.32	1.36	2.94	4.33
Percidae *(Stizostedion lucioperca)*	0.01	0.01	0.03	0.01	0.01
less valuable spp.	14.86	16.07	12.41	12.18	13.44
Total	35.79	36.94	28 78	32.95	39.86

TABLE 63. COMPOSITION OF THE FISH CATCHES FROM THE BASIN OF THE YENISEI RIVER (1000 tons) (Shimanovskaya *et al.*, 1983)

Group of fish	1976	1977	1978	1979	1980
Commercially valuable spp.	2.24	2.30	2.42	2.88	2.67
of these:					
Acipenseridae	0.01	0.01	0.01	0.01	0.02
Salmonidae	0.18	0.16	0.21	0.15	0.16
Osmeridae	0.02	0.02	0.01	0.01	0.02
Gadidae *(Lota lota)*	0.38	0.40	0.49	0.46	0.56
Coregonidae	1.00	1.30	1.30	1.45	1.19
Cyprinidae	0.21	0.08	0.08	0.09	0.07
Esocidae *(Esox lucius)*	0.44	0.33	0.32	0.71	0.65
less valuable spp.	0.67	0.90	1.16	1.43	1.22
Total	2.91	3.20	3.58	4.31	3.89

From the point of view of commercial fisheries, the only rivers of major importance are those of Siberia and the Far East, which yield more than 70% of the total annual catch from Soviet rivers (Berdichevsky *et al.* 1979; Treshchev, 1983; Shimanovskaya *et al.*, 1983). The watersheds of greatest importance are those of the Ob and Irtysh in western Siberia, the Yenisei, Pyasina and Khatanga in eastern Siberia, and the Lena, Indigirka and Kolyma in the Yakut ASSR. Data from these rivers are given in *Table 61*, where they are compared with similar data from the Volga and the Don (excluding their deltas). The commercially important fish families caught in the three most important river systems of the USSR are given in *Tables 62-64.*

TABLE 64. COMPOSITION OF THE FISH CATCHES FROM THE BASIN OF THE LENA RIVER (1000 tons)
(Shimanovskaya *et al.*, 1983)

Group of fish	1976	1977	1978	1979	1980
Commercially valuable spp.	2.15	2.43	1.96	2.04	2.14
of these:					
Acipenseridae	-	0.01	0.01	0.01	0.01
Salmonidae	0.10	0.11	0.09	0.11	0.08
Coregonidae	1.88	2.06	1.64	1.70	1.87
Gadidae *(Lota lota)*	0.11	0.14	0.07	0.08	0.10
Cyprinidae	0.01	0.01	0.01	-	-
Esocidae *(Esox lucius)*	0.05	0.10	0.14	0.14	0.08
less valuable spp.	1.55	1.12	1.14	0.15	0.95
Total	3.70	3.55	3.10	2.19	3.09

In conclusion it seems likely that rivers will continue to decline in importance for commercial fisheries in the USSR because anthropogenic pressures, which are chiefly responsible for the decline, are unlikely to be adequately compensated by stocking.

6. FISHERIES MANAGEMENT OF LAKES AND RESERVOIRS

The management of fisheries has to take into account the combined adverse effects of the other uses to which lakes, and in particular, reservoirs are put, *e.g.* generation of power, transport, irrigation, industrial and domestic water supplies, and recreation. These may be aggravated by changes in the water flow pattern and water quality, and by technical problems, such as the use of imperfect gates which allow fish to escape into irrigation channels. Sometimes commercial fisheries have to spend money counteracting the negative effects of these other activities.

Sport fishing has a significant influence on the management of open waters for fisheries. It has been estimated from rough data that there are more than 20 million anglers, who each catch about 10 kg/year of fish, giving a total of 200 000 tons/year. This is more than the total commercial catch from all lakes, reservoirs and running waters taken together. Dryagin and Kozhevnikova (1974) called for strict measures to control fishing for valuable species by anglers, since their practices interfere with the effort of establishing healthy stocks of transferred fish species. In the middle course of the Volga alone, about 400 000 anglers catch more than 10 000 tons/year (25 kg/person), whereas commercial fishing in the same waters yields just 5 000 tons/year (Shimanovskaya *et al.*, 1983). The number of anglers is growing annually on the Kuibyshev Reservoir (Monakov, 1983). In winter, about 2 400 anglers frequent the reservoir on each working day, and about 4 400 on each non-working day. In summer, about 3 400 are there on working days and 5 500 on non-working days. In 1979, anglers caught 2 620 tons of fish, and commercial fishermen 4 800 tons. The fish caught by anglers during the summer, accounts for 75% of their total catch. *Abramis brama* is the favourite species for both anglers and commercial fishermen. In summer each angler catches on average, 3.2 kg per visit, and in winter about 1.5 kg. According to Shimanovskaya *et al.* (1983), a similar situation prevails on the Don and Dnieper Rivers, on rivers in the Baltic republics, in the central regions of European RFSR and in Byelorussia. In this latter place it appears that anglers have a greater preference for predatory fish, and catch three times as much of this type as the commercial fishermen. Another problem is that anglers tend to catch large numbers of young fish.

Good fishery management depends upon a number of practices, which have been summarised by Skorupskas (1986), Kudersky (1984), Strel'nikov *et al.* (1984), Poddubny *et al.* (1984), Kudersky *et al.* (1982), Knyazev (1981) and Kudersky (1981), and include:

- regulation of water quantity and maintenance of good water quality to meet fishery requirements;
- removal of obstacles from reservoir bottoms to create optimal conditions for commercial fishing;
- improvement of spawning grounds to enhance fish reproduction;
- installation of artificial spawning nests in suitable areas;
- introduction of suitable food organisms to fill vacant niches;
- hatchery production of fry/fingerlings of commercial fishes.

Unfortunately, improving the water quality and maintaining suitable hydrological regimes depends largely upon agencies outside the control of fisheries. However, some improvement may be achieved by altering the species composition, through introduction of species which are more tolerant of the new conditions. Loss of spawning grounds may be counteracted by regular stocking.

Clearing and modifying the bottoms of reservoirs has led to a marked increase in the average catch per hectare, and may even double the yield compared with untreated areas. Up to eight million roubles is expended annually for this reconstruction programme, but considering the vast areas that need to be treated, this sum enables only slow progress towards a final solution.

Great attention is paid to the adjustment of spawning sites, and the installation of artificial spawning nests are important measures. Eggs laid in spawning nests tend to incubate more successfully than those in natural sites so that the numbers of hatchlings may be 2-5 times greater in the artificial sites than in natural ones (Speshilov *et al.*, 1985). *Abramis brama*, *Blicca bjoerkna*, *Rutilus rutilus* and *Stizostedion lucioperca* spawn most successfully in artificial nests.

Managerial measures such as production of fish seed and fingerlings for release into reservoirs, reconstruction of reservoir bottoms, installation of artificial spawning nests and introduction of food organisms have been implemented since the 1970s (Kudersky, 1981), but they do not compensate for the adverse effects occurring in the reservoirs. Other fishery management practices are discussed in Chapters 7 and 8.

6.1 LAKES

The development of fisheries in large lakes will depend upon improving the species composition of the existing fish stocks. Kudersky (1981) and Shimanovskaya *et al.* (1983) consider that a number of basic measures should be taken:

- expansion of the food base through the introduction of suitable species of invertebrates,
- stocking of fry/fingerlings of valuable fish,
- enforcement of size limits,
- maintenance of suitable water quality, and
- establishment and improvement of breeding grounds for natural fish spawning.

Since every lake has its own individual characteristics, each lake needs its own set of requirements for maximum production. Most of the large lakes already have their own management programmes, comprising biological, economic, technical and organisational aspects. When they have been fully implemented, it is anticipated that the following annual production may be reached: Ladoga Lake 8 000 tons, Onega Lake 3 500 tons, Pskov-Chudskoe Lake 1 600 tons, Ilmen Lake 4 000 tons, Baikal Lake 4-12 000 tons, and the large lakes taken all together 100 000 tons. The catches are expected to consist largely of economically valuable species.

The large lakes of the northwestern parts of the Russian SFSR were analysed by Shimanovskaya (1977b). Here the stocks of commercial fish cannot be enhanced by the introduction of new fish species, and the best way to success lies in the regular stocking of hatchery produced fingerlings of local commercial species. If this is not carried out coarse fish will become dominant, which has indeed already happened in some lakes. In Pskov-Chudskoe Lake low value fish account for 80% of the total harvest.

In Balkhash Lake an important part has been played by the introduction of *Ctenopharyngodon idella*, *Cyprinus carpio*, *Silurus glanis* and *Stizostedion lucioperca* (Strel'nikov, 1978). *Silurus glanis* has been most successful having now formed the largest population of the species in Soviet waters. *Cyprinus carpio* and *Stizostedion lucioperca* have also adapted well, but *Ctenopharyngodon idella*, which suffered heavy predation pressure, is now bred in hatcheries from where the lake is regularly stocked with large-sized fingerlings.

Most small and medium sized lakes need better management. It is necessary to remove many lower value and coarse fish species, and to introduce a managed lake system, similar to fish pond culture, with a high yield (see also Chapter 8).

Not all lakes are suitable for intensive fish culture, and some other management practices may then be recommended. For instance, in Byelorussia there is great emphasis on the production of *Stizostedion lucioperca* (Kirilenko, 1984). Thirty-four lakes, with a total area of 11 700 ha, were selected as suitable for the stocking with this species. These lakes have average depths of 3.2-6.6 m, maximum depths of 6-16 m, and are eutrophic, with a well defined pelagic zone. Fish are stocked in spring or autumn, when the water temperature is 0-10°C. Each hectare is stocked with 1 brood fish, 3-5 individuals of different ages and 30-35 yearlings of *Stizostedion lucioperca*. The initial cost is recouped within six years, by which time the numbers of coarse fish should have decreased and those of the valuable species increased.

Berdichevsky *et al.* (1979) recommended the introduction of *Coregonus peled* into lakes. The food conversion rates of *Coregonus peled* are one third to one half those of *Rutilus rutilus*. A 2-year old *Coregonus peled* weighs about 340 g, whereas a 2-year old roach weighs only 5-6 g. *Coregonus peled* is also able to grow throughout the winter season. Thus the replacement of coarse fish species with *Coregonus peled* has a considerable economic effect. Dmitrienko (1983) has also recommended changes in the ichthyofauna of northern lakes into Coregonidae-type lakes, with *Coregonus peled* dominating.

Pechnikov (1980) has recommended an increase in fishing intensity in the lakes of northwestern USSR. The total ichthyomass of these lakes is comparatively large, 300-400 kg/ha, but present catches are poor and fisheries are not viable in some of them. Intensive fishing should improve the food supply for the fish that remain, which should then increase their rate of growth. Low value species may be caught without limit, but catches of *Abramis brama*, *Esox lucius* and other commercial species should be restricted to 55% of the stocks of these fish in the lake. Rudenko and Umnov (1982) estimated that the fast growing species, utilising the maximum amount of food, would create an ichthyomass of 58-212 kg/ha, and that commercial catches should reach 24-80 kg/ha. When all these measures are implemented the lakes of the northwestern part of the USSR could yield an annual catch of 90 000 tons.

In some small and medium sized lakes, extensive management practices have been of little use. Releases of fry and fingerlings into lakes in Byelorussia resulted in poor returns. During the period 1945-1982, 6 600 tons of fry and yearlings of *Coregonus lavaretus*, *Cyprinus carpio* and *Cyprinus carpio haematopterus* (Amur wild carp), were released, but only 1 900 tons were caught. The recovery rate was therefore less than 30% of the biomass released, and realised only 17% of the initial expenditure. Part of the reason for this failure may be attributed to the high proportion of predatory fishes, such as *Esox lucius* and large *Perca fluviatilis* in the lakes. The average annual commercial catch for Byelorussian lakes is 2.8 kg/ha of *Esox lucius* and 1.2 kg/ha of *Perca fluviatilis*, in addition to that caught by anglers, which is about three times greater. To support these predatory species, about 100 kg/ha of food fish are required. Thus if stocks are released in the form of fry or yearlings, with an average mass of 25 g, they will be consumed by the predators before they have time to mature. In order to resist this pressure, fish of not less than 250 g need to be stored. However, the capacity of the present facilities is not great enough to produce such stocks, the cost is high, and transport of the larger fish to distant lakes is difficult. It is still more advantageous to rear fish to market weight in fish ponds. It has therefore been proposed that lake fisheries should be converted to closed, intensive, fish farming systems (see also Chapter 8).

6.2 RESERVOIRS

In most Soviet reservoirs the predicted fish yields have not been achieved (Belova, 1976). This is often due to factors outside the control of the fisheries, such as adverse hydrological regimes in the reservoirs and pollution of the water, but sometimes it has been due to inadequate fishery management. According to Shimanovskaya *et al.* (1983), facilities needed to produce stocking material were sometimes not built, and others sometimes did not meet specifications. In many cases fishing boats and equipment were not used as much as expected. Sport fishing has also had an adverse effect on catches from reservoirs. More recent measures to improve the effectiveness of fishery management of reservoirs are based on experience and instant remedial measures as well as long term improvement programmes.

It is anticipated that fish production will increase when water levels are stabilised, and it is hoped that this will be achieved in some large reservoirs with considerable fisheries potential, by the year 2000, by which time auxiliary reservoirs should have been built (Shimanovskaya *et al.*, 1983).

As with natural lakes, it has been found that stocking reservoirs with fry and small fingerlings seldom produces expected results, especially where *Cyprinus carpio* is concerned. This problem is now largely avoided by releasing two-year old fish into the reservoirs, but supplies are currently limited. Artificial spawning nests have also contributed to the successful reproduction of local fish. However, as Belova (1976) has pointed out, the use of artificial spawning nests does not solve all the problems, and natural spawning grounds should be protected.

Another method for increasing yields is to introduce large numbers of plankton feeding species. The reservoirs of the southern part of the USSR (Kuibyshev, Saratov, Volgograd, Tsimlyansk, Bukhtarminskoe Reservoirs and those of the Dnieper System) are particularly suited to such changes in their ichthyofaunas. However, again, the introduced fish need to be about two years old, and again facilities for producing such large fingerlings for release, are lacking. Nevertheless, results with these species have been encouraging. *Aristichthys nobilis* and *Hypophthalmichthys molitrix* have been introduced to small reservoirs in the North Caucasus increasing catches to 200-400 kg/ha, with an annual weight gains of 1 kg/fish which is much greater than for local species (Berdichevsky *et al.*, 1979). These data are confirmed by Abaev (1980), who reported that the introduction of plankton feeding species and *Cyprinus carpio* increased catches from 2-12 fold within a period of 2-3 years.

The introduction of *Coregonus peled* has been recommended for the reservoirs of Siberia, the Far East and regions to the north (Pankratova, 1986). However, large scale stocking of this species is hampered by shortage of stocking material. The majority of fish farms produce young *Coregonus peled* of low viability. These die soon after they are released into reservoirs or are quickly consumed by predators.

It is also important to improve the production of valuable local fish. Such measures include installing artificial spawning substrates or nests, and protecting selected shallows by building levees to establish zones with regulated water supply. This permits natural spawning and helps to protect early fish stages. Pankratova (1986) complains about the slow rate of progress of such measures in the Gorky and Kuibyshev reservoirs.

Other methods for improving organisation and management of fisheries have been suggested by Abaev (1980) and Pankratova (1986). They propose that catches of the lower value fishes should be increased so that more food remains for the higher value fishes. They also suggest that the bottoms of reservoirs should be adapted for the better use of haul and trawl nets. In addition there needs to be greater mechanisation of fishing. At present arduous manual handling of gear makes fishing an unattractive profession, with the result that the numbers of fishermen are declining. Measures for fishery management of reservoirs are also discussed by Rolle (1984), Avakyan and Shrapov (1986), Altaev (1986), Kudersky (1986) and Negonovskyaya (1986).

Low dissolved oxygen levels frequently cause problems in the waters of southern reservoirs of the European part of the USSR. A rapid decrease in oxygen content occurs in February and March, when the surfaces of the reservoirs have been frozen for long periods and after maximum consumption of water by power stations. In summer there are long periods of hot windless weather, when there is no mixing of the water masses, so that oxygen levels again become very low. Such occurrences lead to fish mortalities, and are especially common in Tsimlyansk, Kakhovskoe and Kremenchug Reservoirs. Huge aerators are required to increase oxygen content and in winter ice breakers are used to free the water surface.

Aeration equipment may be classified as either: traditional mechanical aerators or modern jet aerators (Isaev and Karpova (1980). One type of mechanical aerator consists of a floating station, with two concentric pumps and an output of 1.1 m^3/sec. Another type of aerator, the 'Cyklon', has a mixing chamber from which a mixture of air and water is driven under the water surface of the reservoir. The angle of tilt may be changed, which regulates the depth of aeration. The maximum depth of aeration is 8 m, and the length of the aerated stream is 50 m. With an oxygen concentration of 5 mg/litre, and a water temperature of 0.2°C, aeration reaches 170 kg/hour of oxygen. Fifteen floating pump stations work on the Tsymlansk Reservoir in winter, with a total water flow capacity of 59 400 m^3/hour.

Jet aerators are more sophisticated. *Figure 17* shows a diagram of a three stage venturi aerator with 19 nozzles. The ejectors are designed to provide the maximum air/water interface. The intensity of aeration is controlled by the numbers of nozzles engaged. High pressure inside the mixing chamber completely dissolves the oxygen in the water, and this is then driven into the reservoir. The depth of penetration of the aerated stream depends upon the angle of tilt of the aerator. With a zero concentration of oxygen in the water, and with water temperature of 0.2°C, oxygen output is 40 kg/hour, and the water pumping capacity of the aerator is 0.55 m^3/sec.

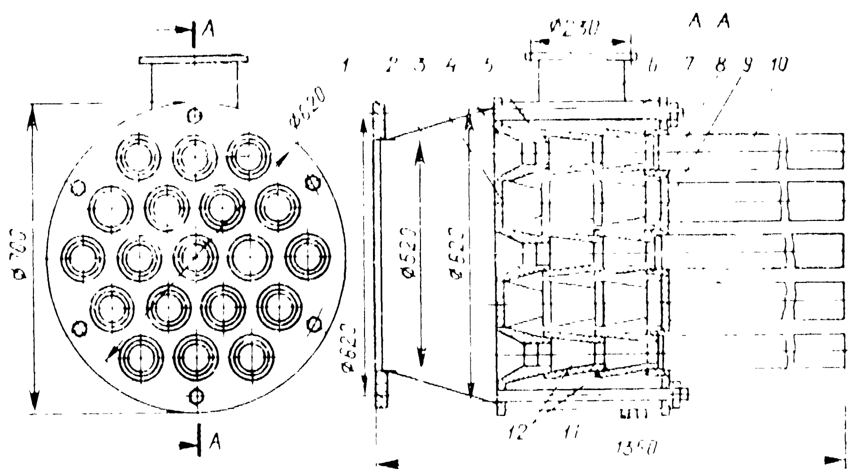


Figure 17. – Diagram of a three-stage jet aerator: 1., 3., 8. flanges, 2. diffuser, 4. nozzle, 5. mixing chamber, 6. air inflow, 7. connection bolt, 9. intake, 10 outlet tube, 11. bung hole, 12. bellmouth.

Another type of jet aerator, supported by a catamaran-type structure, is shown in *Figure 18*. Water is driven under pressure into the nozzles, while air is sucked in and mixed with the water. The mixture is then forced into the reservoir. With a zero concentration of oxygen and a water temperature of 0.2°C, dissolved oxygen output is 20 kg/hour. The water pumping capacity of the aerator is 2 500 m^3/hour.

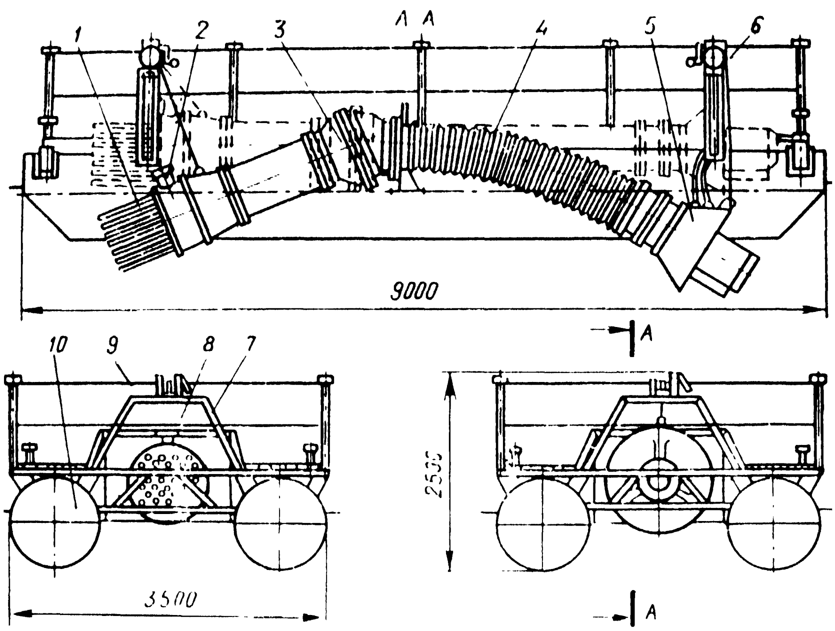


Figure 18. – Diagram c' a multi-jet aerator: 1. multi-jet aerator, 2. air intake, 3. universal coupling, 4. rubber textile sleeve, 5. submersible electric pump, 6. winch, 7. beam, 8. rope, 9. rope rail, 10. catamaran float tubes.

A single jet aerator is shown in *Figure 19.* Here the air/water mixture passes along the nozzle at a controllable angle, and into the water of the reservoir. At zero concentration of oxygen and at 0.2°C, the oxygen output is 35 kg/hour. The pumping capacity of the aerator is up to 0.55 m^3 water/second.

A number of fishery management studies on large reservoirs are available, particularly on the Kuibyshev Reservoir, which is the largest reservoir in the USSR. Shchukina (1980), for example, analysed the food relationships and food conversion coefficients of the fish in the Kuibyshev Reservoir, as a basis for evaluating fish productivity. *Abramis brama* has the widest food spectrum of the benthophagous fishes, consuming large numbers of chironomid larvae and much zooplankton. Older individuals of this species also eat molluscs and plants. *Rutilus rutilus*, like *Abramis brama*, eats zooplankton and plants. Large individuals consume molluscs, mainly *Dreissena* spp., which contribute up to 87% by weight of their total food intake. A single individual of *Rutilus rutilus* may consume 107-109 g of *Dreissena*/year. The food conversion coefficients of all age classes of *Rutilus rutilus* are much higher than those of *Abramis brama*. *Blicca bjoerkna* has a food spectrum similar to that of *Rutilus rutilus*, but eats more molluscs, in fact 984-1 319 g/year. *Pelecus cultratus* has an omnivorous diet, of which zooplankton forms a major part, but it becomes predatory at 6 years. *Stizostedion lucioperca* becomes a predator in its first year, and its food conversion coefficient, depending on age, ranges from 3.2-15, with an average of 7. Of the benthophagous species, *Abramis brama* utilises its food most effeciently and shows the quickest growth, but overall, predatory species use their food most effectively, because of its high calorific value. The food conversion coefficients of some fishes in the Kuibyshev Reservoir (*Table 65*) indicate that intensive fishing for lower value species, *e.g. Clupeonella delicatula*, would leave more food for the commercially valuable species. *Clupeonella delicatula* consumes 31.8% of the total volume of natural food in the reservoir, including 45.7% of all the zooplankton consumed by fish (Tsyplakov, 1980). As the numbers of predators in the reservoir decline, so the abundance of *Clupeonella* increases, and it was estimated that there were some 1.2×10^9 individuals in the Kuibyshev Reservoir in 1980.

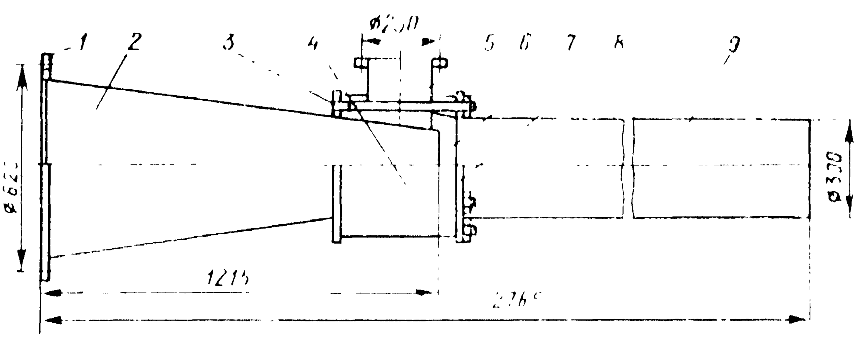


Figure 19. – Diagram of a single jet aerator: 1, 3, 8. flange, 2. outlet, 4.mixing chamber, 5.air intake, 6. bolt, 7. inlet, 9. water intake

TABLE 65. FOOD CONVERSION COEFFICIENTS OF SOME TYPICAL FISHES OF THE KUIBYSHEV RESERVOIR

Fish species	Food conversion coefficient
Blicca bjoerkna	51.4
Rutilus rutilus	34.7
Acipenser ruthenus	28.2
Abramis brama	23.4
Pelecus cultratus	18.1
Clupeonella sp.	14.0
Esox lucius	5.4-8.1
Stizostedion lucioperca	7.0

The fish upon which predatory species feed, have themselves consumed vast amounts of food, including zooplankton and chironomid larvae. In 1974, predatory species consumed 70 000 tons of fish (1.4×10^9 individuals) in the Kuibyshev Reservoir, which in turn had consumed 70 000 tons of zooplankton and 50 tons of chironomid larvae. These figures are based on the assumption that the average annual food ration of *Clupeonella* sp. was 50 g (Tsyplakov, 1980). The rate at which fish utilise the full range of food organisms in the reservoir, including fish which later are eaten by predators, is 9.8% of the annual production, with an absolute value of 255 200 tons (*Table 66*).

TABLE 66. UTILISATION OF NATURAL FOOD PRODUCTION BY FISH IN THE KUIBYSHEV RESERVOIR

Fish groups	% utilisation of food organisms				
	zooplankton	chironomid larvae	Oligochaeta	Mollusca	total
valuable	12.5	55.5	100.0	17.7	22.5
less valuable	41.8	42.4	-	82.3	40.0
coarse	45.7	2.1	-	-	37.5
total	100.0	100.0	100.0	100.0	100.0
production of food organisms (1 000t)	731.0	50.4	59.9	1 757.0	2 598.3
utilisation by fish (1 000t)	177.4	43.0	0.3	34.5	255.2
% utilisation	24.3	85.3	0.5	2.0	9.8

It appears that with the present ichthyofaunal structure, the species of the reservoir do not make maximum use of the available food, with chironomid larvae consumed most intensively. Sufficient use is not made of the enormous reserves of zooplankton and Mollusca, and an estimated 60 000 tons of Oligochaeta remains untouched. It has been calculated that if this untapped source of food were to be used at a food co-efficient of 40, it should be possible to produce another 11 000 tons of fish a year. A considerable proportion of the available food, especially zooplankton, is lost to fishes of no commercial importance, while those of commercial value share just 22.5% of the utilised food. There are an estimated 1.757 million tons of molluscs available, and if only half of this was consumed, then at a food co-efficient of 50, an additional 43 000 tons of fish would be produced. Here, a significant role might be played by the introduction of a mollusc eater. The plankton feeding *Aristichthys nobilis* and *Hypophthalmichthys molitrix* have already been introduced to the reservoir, since 1971, but not on a sufficient scale to fully utilise the available food resources.

Monakov (1983) draws similar conclusions for the Kuibyshev Reservoir, adding that basic management should include artificial breeding of fish and the rearing of stocking material in specialised farms. He too recommends the intensive fishing of *Clupeonella* sp.

The situation is markedly different in Tsimlyansk Reservoir. A mathematical model has shown that for many years the fishing intensity has been close to optimum. Intensification of fishing for all species would lead to depletion of the existing stocks. *Stizostedion lucioperca* plays an important role in this reservoir, but in recent years its stock has begun to decline. Analysis of age structure, abundance dynamics and fecundity of the species have shown that this is due to over exploitation (Koval, 1982). Measures necessary to reverse this trend include a ban on catching more than 30-40% of the commercial stock in the reservoir each year, strict adherance to the seasonal schedule for fishing, leaving a substantial part of the annual catch for the autumn and winter, and controlling the numbers of fishing gear and fishing days. The catch might then increase to 1 300-1 400 tons. Phytoplankton - feeding Chinese carps should be stocked at the age of two years (Mukhamedova (1982) to achieve their high survival rate.

Phytoplankton - feeding Chinese carps are also becoming important in the reservoirs of the Dnieper, but again only when larger sized fingerlings are released (Ozinskovskaya, 1982). Pikhush and Sukhoivan (1978) and Vyatchanina and Demchenko (1981, 1982) state that in the reservoirs on the Dnieper, fish of commercial value do not have adequate spawning grounds and that the only way to increase fish stocks is through regular releases of hatchery produced fingerlings.

The potential yield from cold, oligotrophic waters of Siberian reservoirs is estimated to be 6-8 kg/ha (Shimanovskaya, 1977c). The development of the fish fauna follows the same general pattern as in the reservoirs of European Russia. For example, during the first years of the Bratsk Reservoir the fish fauna became dominated by *Perca fluviatilis* and *Rutilus rutilus*, and there were very few limnophilic species. The rheophilic types, Acipenseridae, Coregonidae, *Brachymystax lenok* and *Hucho taimen* migrated to the tributaries, leaving few in the reservoirs. Later, they were replaced by *Gymnocephalus cernua*, *Leuciscus idus*, *Perca fluviatilis* and *Rutilus rutilus lacustris*. The stocks of these low value species are currently underfished. A number of management measures need to be implemented in Siberian reservoirs. These are:

- increased fishing of coarse species,
- production of high quality seed/fingerlings in hatcheries for stocking purposes,
- reclamation of the parts of reservoirs where fishing is impossible at present,
- introduction of new species,
- reclamation of natural spawning grounds,
- control of sport fishing which at present endangers breeding stocks in some reservoirs, and
- introduction of more efficient fishing methods for low-value fish.

The annual fish harvest from the Siberian reservoirs could reach 12 000 tons, including 20% of high value Acipenseridae, Coregonidae and Salmonidae, if management measures are introduced (Shimanovskaya, 1977c).

7. THE INTRODUCTION OF FISH SPECIES AND THEIR FOOD ORGANISMS

Many species of fish and their food organisms have been introduced to inland waters of the USSR. Such introductions are made for different reasons, including the provision of a better food base for fish, the reduction in population sizes of coarse fish, and to improve fish stock composition in different water biotopes. The Soviet Ministry of Fisheries issued a directive in 1975 governing the introductions of fish, invertebrates and plants, listing reasons and prerequisites for such introductions, and the methods and techniques to be employed when making them.

The productivity of an ecosystem depends upon the basal energy input and the effectiveness of the energy transfers between the different trophic links and levels of the food web. If all the niches in an ecosystem are fully utilised then there is no introduction which can increase the overall productivity. Thus introducing a new species of fish into a water body, where all available food is used by the resident fish stock, will not increase productivity, even though it may alter the structure of the ichthyofauna. For example, the average fish harvest from Lake Balkhash from 1932-49 was 12 500 tons/year, during which time there was no large scale introduction of fish. From 1959-75 fish were introduced on a large scale, but the average harvest remained virtually the same, *viz.* 12 000 tons/year (Holcík, 1987).

Apart from the transfer of indigenous species from one region to another, introductions of exotic species are also considered. However, data from the past 25 years indicate that most such introductions have proved less successful than anticipated. In many cases the introduced species failed to establish themselves and eventually disappeared from the system. According to Burmakov (1987), 51 species of fish were introduced into almost 1 400 water bodies in the USSR before 1957, but only 12% of the introductions were successful. Even where acclimation did occur, this was not usually accompanied by an increase in catches. Only 3% of all introductions made before 1978 led to the development of fish stocks large enough to support commercial fishing (Lifshits and Belousov, 1987). In many cases fish were released at too young a stage to survive, but there were also other reasons why they failed to establish themselves.

Some introduced species have played a positive role in the commercial fisheries of both lakes and reservoirs. The most successful introductions were probably those of plankton feeding and herbivorous Chinese carp species to southern reservoirs, but even these were not without their negative side; they contributed to the spread of parasites and infectious diseases to hitherto uninfected areas. *Bothriocephalus gowkongensis* (or *Khawia sinensis*) was spread by *Cyprinus carpio haematopterus*, and a whole range of Trematoda, Cestoda and Nematoda extended their ranges (Bauer in Berka 1978). This experience shows that strict fish quarantine and disease control measures need to be applied when transfer and introductions are considered. *

Transportation of fish is an important aspect. Fish transfer is dealt with by Berka (1986) with special consideration of the Soviet experience.

7.1 FISH INTRODUCTION AND ACCLIMATION

Herbivorous and plankton-feeding Chinese carps are noteworthy for their successful adaptation in Soviet waters. They consume primary producers directly, thus maximising energy transfer. *Ctenopharyngodon idella* (grass carp) feeds on aquatic macrophytes, while both *Aristichthys nobilis* (big-head carp) and

* Note (Ed.): The Code of Practice and Manual of Procedures for consideration of introductions and transfers of marine and fresh water organisms (Turner, 1988), prepared by the International Council for the Exploration of the Sea (ICES) and the European Inland Fisheries Advisory Commision (EIFAC), addresses some of the concerns, and provides advice related to proposed introductions or transfers. Areas covered are inspection and certification, quarantine, pathology, genetics and ecology. Specific examples of protocols, mainly related to controlling the spread of disease organisms, are included.

Hypophthalmichthys molitrix (silver carp) consume phytoplankton, although the former also feeds on zooplankton. These species grow quickly and are readily marketable.

Early attempts to transfer these fish from the Far East were made in 1937 and 1949, but with little success. Viable offspring were obtained in 1961. The fish were introduced to the Russian SFSR, the Ukraine, and the Kazakh and Turkmenian SSRs. They have been induced-bred in commercial fish farms since 1964. Initially they were stocked in ponds, and later, in selected open water. Among other species *Abramis brama*, *Cyprinus carpio*, *Stizostedion lucioperca* and various Coregonidae, especially *Coregonus peled*, were successfully introduced to a number of reservoirs of the USSR.

In recent years a large acclimation project was carried out in Lake Balkhash. Here *Cyprinus carpio*, *Silurus glanis* and *Stizostedion lucioperca* have all been naturalised (Strel'nikov, 1978). Remarkably the introduction of just 23 individuals of *Silurus glanis* led to annual harvests of 700-800 tons, but the negative side of this introduction is that predation pressure on the other fish has increased. *Silurus glanis* now consumes about 9 000 tons of other species in the lake each year, including 1 500 tons of *Cyprinus carpio*. This latter is now, however, also a major commercial species. Catches of *Stizostedion lucioperca*, 3 000 individuals of which were released in 1958, now amount to about 5 000 tons/year. As far as phytophagous species are concerned, it is planned that large numbers of *Ctenopharyngodon idella* will be released.

Some lakes and reservoirs in the northern USSR have been stocked with large numbers of *Coregonus peled* with good results. A hybrid between *Coregonus peled* and *Coregonus nasus* was produced for introduction into the waters of the Baltic Republics, the Urals, Siberia and the northwestern regions of the USSR. These hybrids differ from the parents both morphologically and biologically. They are noted for their high growth and survival rates, their resistance to infection, and their utilisation of a wider food base than their parents. They are therefore more adaptable than the parents and give a higher yield per hectare.

TABLE 67. INTRODUCTIONS IN RESERVOIRS OF THE USSR
(1 000 individuals) (Isaev and Karpova, 1980)

Years	Brood fish	Fish of various ages	Fry	Yolk-sac fry
1957-69	2 236	-	77 383	687 777
1970	223	-	9 511	149 940
1971	160	-	39 898	103 045
1972	243	-	89 126	110 073
1973	307	-	74 763	17 076
1974	42	-	56 146	-
1975	-	6 027	23 384	-
1976	-	13 008	29 665	-
1977	-	10 624	41 311	
1978	-	4 276	52 988	60 851

More introductions were made in reservoirs than natural lakes. Rather incomplete figures for the years 1957-78 are given in *Table 67*. The data suggest that yolk-sac fry and fry were most widely used but that the stocking with older fish proved most effective. A list of species introduced to selected reservoirs is given in *Table 68*.

TABLE 68. FISH SPECIES INTRODUCED INTO SOME LARGE RESERVOIRS OF THE USSR IN THE PERIOD 1971-78 (in 1 000 individuals) (Isaev and Karpova, 1980)

Reservoir	Fish species	Stage	Numbers (x1 000)
Bratsk	Ladoga whitefish	yolk-sac fry	4 600.0
	Bauntow whitefish	yolk-sac fry	445.0
	Baikal omul	various ages	0.56
	Baikal omul	yolk-sac fry	150 382.0
	Coregonus peled	yolk-sac fry	5 659.0
Bukhtarminskoe	*Ctenopharyngodon idella*	fry	2 880.0
	Hypophthalmichthys molitrix	fry	400.0
	Cyprinus carpio	fry	22 333.0
	Cyprinus carpio	2 year old	44.0
	Stizostedion lucioperca	yolk-sac fry	5 067.0
	Salmo gairdneri	fry	407.0
	Coregonus peled	yolk-sac fry	2 781.0
Volgograd	*Ctenopharyngodon idella*	fry	13 846.0
	Hypophthalmichthys molitrix	fry	15 580.0
	Aristichthys nobilis	fry	5 832.0
	Coregonus peled	fry	300.0
Gorky	*Coregonus peled*	fry	300.0
Kuibyshev	*Aristichthys nobilis*	fry	1 131.0
	Hypophthalmichthys molitrix	fry	2 069.0
	Ctenopharyngodon idella	fry	1 940.0
	Coregonus peled	fry	14 720.0
Kremenchug	*Ctenopharyngodon idella*	fry	562.0
	Ctenopharyngodon idella	2 year old	543.0
	Hypophthalmichthys molitrix	fry	5 355.0
	Hypophthalmichthys molitrix	2 year old	1 439.0
	Aristichthys nobilis	yearling	1 500.0
	Aristichthys nobilis	2 year old	474.0
	Abramis ballerus	fry	2 500.0
	Cyprinus carpio	2 year old	148.0
	Carassius auratus gibelio	2 year old	1 430.0

Reservoir	Fish species	Stage	Numbers (x1 000)
Kakhovskoe	*Hypophthalmichthys molitrix*	fry	9 270.0
	Hypophthalmichthys molitrix	2 year old	9 795.0
	Aristichthys nobilis	fry	980.0
	Aristichthys nobilis	2 year old	1 246.0
	Ctenopharyngodon idella	yearling	300.0
	Ctenopharyngodon idella	2 year old	20.0
Kapchagayskoe	*Cyprinus carpio*	brood fish	44.0
	Cyprinus carpio	fry	4 034.0
	Salmo gairdneri	fry	200.0
	Abramis brama	various ages	26.0
	Aspius aspius	various ages	49.0
	Ctenopharyngodon idella	fry	1 247.0
	Hypophthalmichthys molitrix	fry	411.0
	Acipenser nudiventris	various ages	0.4
	Stizostedion lucioperca	brood fish	0.3
	Stizostedion lucioperca	various ages	0.9
	Coregonus peled	yolk-sac fry	1 700.0
	Barbus sp.	various ages	0.6
	crayfish	yolk-sac fry	6.0
Krasnoyarsk	*Coregonus autumnalis*	larvae	15 173.0
Rybinskoe	*Coregonus peled*	fry	903.0
	Coregonus peled	yolk-sac fry	3 990.0
Ust-Ilimskoe	*Coregonus peled*	fry	650.0
	Coregonus peled	yolk-sac fry	150.0
	Coregonus autumnalis	yolk-sac fry	199 000.0
	Abramis brama	various ages	8 100.0
Tsimlyansk	*Aristichthys nobilis*	2 year old	159.0
	Aristichthys nobilis	fry	269.0
	Hypophthalmichthys molitrix	various ages	3.0
	Hypophthalmichthys molitrix	2 year old	208 0
	Hypophthalmichthys molitrix	fry	145 600.0

The success of introductions, measured by the volume of the commercial catches of some introduced fish species, is shown in *Table 69.* Good results have been obtained with *Abramis brama* and *Stizostedion lucioperca* in Bukhtarminskoe Reservoir, *Stizostedion lucioperca* in the Rybinskoe and Gorky Reservoirs, and with *Abramis brama* and *Cyprinus carpio* in Kapchagayskoe Reservoir. But by contrast other promising starts were followed by failures and in a few cases no stocks developed at all. It is not known whether repeated stocking would lead to better results

TABLE 69. CATCHES OF SOME INTRODUCED FISH SPECIES IN SELECTED RESERVOIRS DURING THE PERIOD 1971-80 (in tons) (Isaev and Karpova, 1980; Shimanovskaya *et al.*, 1983)

Reservoir and species	1971	1975	1976	1977	1978	1979	1980
Bukhtarminskoe							
Cyprinus carpio	310	300	111	110	80	60	20
Stizostedion lucioperca	6	1 285	1 100	1 166	1 490	1 170	994
Abramis brama	870	4 369	5 806	4 737	6 530	5 070	6 710
Kuibyshev							
Stizostedion lucioperca	135	354	450	380	460	430	363
Cyprinus carpio	3	12	-	-	-	-	-
Rybinskoe							
Stizostedion lucioperca	225	171	190	170	230	240	179
Coregonus peled	-	5	2	89	46	?	?
Gorky							
Abramis brama	192	-	-	-	1	-	-
Stizostedion lucioperca	14	308	263	262	315	-	-
Cyprinus carpio	-	-	-	-	-	-	-
Saratov							
Stizostedion lucioperca	30	-	-	-	-	-	-
Cyprinus carpio	-	50	75	-	-	-	-
Volgograd							
Cyprinus carpio	3	-	-	-	-	-	-
Kapchagayskoe							
Cyprinus carpio	-	191	255	201	180	-	-
Stizostedion lucioperca	-	180	140	67	50	-	-
Aspius aspius	-	2	32	16	10	-	-
Silurus glanis	-	1	9	3	4	-	-
Abramis brama	-	241	608	955	1 010	-	-

Experience has shown that the highest survival rate of herbivores and plankton-feeding fish is achieved when stocking with 2 year old fish. However this requires large hatcheries or fish farms. According to Shimanovskaya *et al.* (1983), 25 new hatcheries were needed to raise such fish stocking material during 1981-85 to a level which would permit a three-fold increase in catches. Work with these species is most advanced in the Dnieper system of reservoirs, where yearlings were released to the Kakhovskoe and Kremenchug Reservoirs in the late 1960s (Isaev and Karpova, 1980).

Ozinkovskaya (1982) records that 29.4 million herbivorous and plankton-feeding, 2 year old fish, with a preponderance of silver carp, were released into the Dnieper Reservoirs between 1974-81. Their average weight was 130-200 g, of which about 70% were released into the Kakhovskoe Reservoir. Conditions in these reservoirs are very favourable and the annual growth rate of silver carp is 0.6-4.0 kg. This species is non-migratory in reservoirs. Catches are also highest in March, April, June and November, and the fish caught are 4-6 years old with weights of 1.5-3 kg (*Table 71.*)

TABLE 70. NUMBERS OF CHINESE CARP RELEASED INTO THE DNIEPER RESERVOIRS
(million individuals) (Isaev and Karpova, 1980)

Period	*Hypophthalmichthys molitrix*	*Aristichthys nobilis*	*Ctenopharyngodon idella*
1966-73	21.04	-	-
1973-78	-	2.48	-
1968-78	-	-	1.26

TABLE 71. CATCHES OF SILVER CARP FROM DNIEPER RESERVOIRS (IN TONS)

Year	1974	1975	1976	1977	1978	1979	1980	1981
Total catch	3.3	6.8	33.7	92.3	313.5	744.0	509.6	1 015.8
of this:								
Kakhovskoe Reservoir	2.4	5.7	31.6	90.9	307.0	739.0	474.7	996.2

The Kakhovskoe Reservoir is the most important water body for the production of silver carp in the Dnieper reservoir system. With an annual release of 2-3 million two year old silver carp, there has been an increase in catches in recent years, but the species still ranks second, in terms of catch size, to those of the indigenous *Abramis brama* (*Tables 72* and *73*). The production of silver carp from Kakhovskoe Reservoir could be greater than at present, but it will be necessary to use modern fishing techniques and equipment to achieve this. See *Table 74.*

TABLE 72. POPULATIONS OF SILVER CARP IN THE KAKHOVSKOE RESERVOIR
AND THE INTENSITY OF THEIR EXPLOITATION

Year	Population		% Exploitation	
	(1 000 individuals)	1 000 tons	abundance	biomass
1976	188.9	0.23	3.9	6.9
1977	1 380.8	1.82	2.0	3.4
1978	3 197.0	5.02	2.8	5.5
1979	4 814.1	9.47	4.6	7.7
1980	6 138.8	14.79	2.2	3.2
1981	6 950.0	21.56	5.9	4.6

TABLE 73. CATCHES OF THE MOST IMPORTANT FISH SPECIES FROM THE KAKHOVSKOE RESERVOIR (in tons)

Fish species	1978	1979	1980	1981
Abramis brama	1 252	1 773	1 735	1 510
Hypophthalmichthys molitrix	307	739	475	1 000
Stizostedion lucioperca	686	691	482	670

TABLE 74. PRODUCTION OF SILVER CARP IN THE KAKHOVSKOE RESERVOIR (in kg/ha)

Year	Production	
	real	potential
1976	0.16	8.4
1977	0.42	16.0
1978	1.43	30.9
1979	3.43	53.3
1980	2.20	75.4
1981	4.65	110.6

The Tsimlyansk Reservoir, on the Don River, is also regularly stocked with silver carp, with a heavy preponderance of young fingerlings (Mukhamedova, 1982). During 1968-81, 227 million six month olds were released, but only 800 000 two year olds. It is estimated that annual releases of 20-30 million individuals would result in a catch of 500-800 tons/year. However, present day catches are well below this (*Table 75*). This reservoir was stocked with a second species, bighead carp, beginning in 1977-78, with the release of 5.7 million individuals.

TABLE 75. CATCHES OF SILVER CARP FROM THE TSIMLYANSK RESERVOIR (tons)

Year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Catch	0.6	0.5	0.3	2.4	11.5	10.4	12.4	21.3	12.2	19.4

The commercial catch of silver carp from the Tsimlyansk Reservoir, for 1972-81, amounted to 5.5% of the biomass of the young released, and a recovery of just 0.05% of the numbers of young released (Mukhamedova, 1982). Two year old fingerlings, 20-25 cm long, weighing 200-220g, would survive much better than the smaller fingerlings mainly used to date, but the shortage of facilities for rearing these has already been mentioned. During the period 1979-81 the abundance of predatory species (*Aspius aspius*, *Esox lucius*, large *Perca fluviatilis*, *Silurus glanis* and *Stizostedion lucioperca*) was of the order of 34-38 individuals/ha. Over the same period, silver carp were released at a stocking rate of 95 individuals/ha, and the low predator prey ratio of 1:3.5 (Mukhamedova, 1982).

Commercial catches are made with bottom set nets with a 50-70 mm mesh. These were used traditionally for the local species, and are still employed on the reservoir despite the fact that they trap younger silver carp than is desirable. In some years, almost 75% of the catch comprises 2-3 year old specimens, indicating the lack of rationale in the commercial exploitation of this species.

The release of Coregonidae into reservoirs has not been successful. With rare exceptions these fish fail to reach sizes suitable for commercial exploitation, although they have been introduced repeatedly. Failure is generally attributed to the fluctuation of water levels, the strong flow of water through the reservoirs, competition for food with native species, and inadequate stocking (Yankovskaya, 1982). Nevertheless, since in some reservoirs Coregonidae have a higher growth rate and mature earlier than in their original habitat, it may be anticipated that introductions will be successful in some reservoirs. Yankovskaya (1982) recommends those with slower flow rates and more stable water regimes in the Urals, Kazakhstan, Siberia, and European Russia beyond 55°N. Coregonid introductions during the 1970s are listed in *Table 76.*

TABLE 76. STOCKING OF SOME RESERVOIRS WITH *COREGONUS PELED* AND *COREGONUS AUTUMNALIS* (1971-79) (Yankovskaya, 1982)

Reservoir	Species	Age	Numbers released (1000s)	Stocking rate (1000/ha)
Bratsk	*Coregonus autumnalis*	various	0.6	0.0001
	Coregonus autumnalis	yolk-sac fry	150 382.0	34.40
Bukhtarminskoe	*Coregonus peled*	yolk-sac fry	2 781.0	0.63
Volgograd	*Coregonus peled*	fry	300.0	0.12
Gorky	*Coregonus peled*	6 month old	800.0	0.60
	Coregonus peled	yolk-sac fry	200.0	0.15
Kuibyshev	*Coregonus peled*	fry	14 720.0	2.85
Krasnoyarsk	*Coregonus autumnalis*	yolk-sac fry	15 173.0	9.03
Rybinskoe	*Coregonus peled*	yolk-sac fry	3 990.0	1.10
	Coregonus peled	fry	903.0	0.24
Ust-Ilimskoe	*Coregonus peled*	yolk-sac fry	150.0	0.10
	Coregonus peled	fry	650.0	0.43
	Coregonus autumnalis	yolk-sac fry	199 000.0	132.80

Fry of *Polyodon spathula* (paddlefish) from the USA were imported in the early 1970s for rearing in ponds. However, the intention is to release some specimens in the Dnieper reservoirs, since the shallows of some of these might provide a favourable habitat. The biomass of zooplankton in the shallows of some reservoirs reaches 30-100 g/m^3, which is ideal for *Polyodon*, although being a migratory species, it will probably not breed naturally here. Young will probably have to be released each year to maintain a population (Burtsev and Gershanovich, 1976). Other exotic species imported into the USSR, for use solely in fish ponds, include *Ictiobus cyprinellus, I. niger* (buffaloes), *Morone saxatilis* (bass) and catfish.

7.2 INTRODUCTION AND ESTABLISHMENT OF FOOD ORGANISMS

Among food organisms, mysids of the Caspian Sea complex have acclimated most successfully, and large populations have become established in the Tsimlyansk, Kaunas, Kattakurgan and Kairakkum reservoirs, from where they are now transferred to other reservoirs (Isaev and Karpova, 1980). The programme of introducing food organisms was particularly intensive from 1957-78, during which time more than 911 million individuals were introduced into Soviet reservoirs.

Preliminary data suggest that 70% of all introductions were successful with huge populations developing in the reservoirs concerned. These organisms have become an important part of food webs and are consumed by commercially valuable fish. Mysids now are eaten by *Abramis ballerus*, *Acipenser ruthenus*, *Aspius aspius*, *Pelecus cultratus*, *Perca fluviatilis*, *Rutilus rutilus*, *Stizostedion lucioperca* and *S. volgense*, and the fry of almost all species. Amphipoda have become a substantial ingredient of the diet of *Cyprinus carpio* and *Rutilus rutilus caspius*.

Fish crops have increased in size in several major reservoirs since the acclimation of new invertebrate populations (Isaev and Karpova, 1980). Increases of 400-500 tons/year were recorded in the Volgograd Reservoir, 600-800 tons/year in the Kuibyshev Reservoir, and 1 000 tons/year in the Tsimlyansk Reservoir. Berdichevsky *et al.*, (1979) estimate that about 20% of the catch from the Tsimlyansk Reservoir is obtained as a result of the introduction of new food organisms.

8. FISHERIES ENHANCEMENT IN LAKES AND RESERVOIRS

A number of practices have been introduced in attempts to increase catches of fish from lakes and reservoirs. Some have been tailored to suit individual water bodies, but others are of more general application. Methods so far employed include the reclamation of water bodies, hatchery production of stocking material and market sized fish, fish farming in coves or cages, the introduction of new species to southern water bodies, and the improvement of conditions for natural fish breeding. Criteria used to select water bodies for these practices included accessibility to fishery landing sites, transport costs, suitability of the shoreline for mechanised fishing equipment, ease of netting in designated water areas and prevention of poaching.

Attention was focused on small and medium sized lakes, since yields in these lakes had declined by 50% over a thirty year period (Titova, 1984). Reasons advanced to explain this decline include undue emphasis being placed on marine fisheries, poor organisation of labour, poor mechanisation making the work arduous, little job satisfaction for inland fishermen and little incentive to catch lower value species. In consequence prospects did not look good and the work force dwindled. All these matters were considered when fisheries improvement measures were proposed. The new practices emphasize mechanisation, good management, the prior assessment of economic viability, and the introduction of cost accounting.

8.1 MANAGEMENT OF LAKE FISHERIES

Procedures for the transition from extensive to intensive fisheries on small and medium sized lakes were devised in the late 1960s. They were adapted for lakes of 100-5000 ha, with a total area of 1.4 million ha, and sought to turn 'wild' lakes into lake fish farms, replacing the natural fish populations with stocks of commercial species (Titova, 1984). The first such lake fish farm was established in 1970. Fish culture in small and medium sized lakes is similar to fish culture in non-drainable ponds, and advantages of using small lakes is that there is little interference from power production and irrigation, and pollution levels are generally low. Moreover, less capital is needed to convert existing lakes than to build new ponds, and the natural food supply can be used with little supplement.

The process of preparing lakes for intensive fish farming are detailed by Titova (1976a), Kudersky (1977a), Berka (1978), Perevoznikov (1979), Kudersky (1981), Kudersky et al. (1982), Zhukov (1983) and Rudenko (1984). The process involves:

- reclamation and isolation of the lake,
- removal of the original fish fauna, either by fishing or the application of piscicides,
- stocking with commercially valuable species (monoculture or polyculture),
- fertilising, weed control, aeration of water, and possible supplementary feeding of the fish, and
- capture of fish of marketable size.

Technical reclamation involves levelling the lake bottom to facilitate netting, and adjusting the shore to permit net pulling. Active fishing gear uses 85-90% of the lake area. Screens with bars at 10-12 mm intervals are used to isolate lakes and prevent the passage of fish in and out of designated areas.

Removal of the original fish fauna is not easy. The ideal situation is to remove 100% of the fish, but this is difficult with standard fishing equipment. Nevertheless, the greatest possible number of fish should be removed in the year preceding stocking. Zonov (1984) suggests methods for the 'complete' removal of fish from small lakes by intensive fishing, but considers 80-85% removal as very satisfactory.

Zhukov (1983) recommends the following schedule for 'complete' fish removal:

- Commence fishing during the period of pre-spawning fish concentration.
- Install fyke nets in combination with trammel nets of 30-40 mm mesh in routes to spawning grounds to catch *Esox lucius* and large *Perca fluviatilis*.
- Use gill nets to catch coarse fish.
- Collect eggs from the spawning grounds.
- Use nets in places overgrown by aquatic vegetation after spawning, and again in summer.
- When coarse fish move to the upper strata in June, use large seines of small mesh.
- In October and November, when most of the fish move away from the shorelines, and *Alburus alburnus* and small bass form large shoals, use large-sized, small-meshed seine nets.
- In lakes larger than 200 ha, first contain part of the lake with nets, then harvest with seines.
- In winter use deep nets to catch fish wintering in deep parts of the lake.

Standard yearlings of 25-30 g should be released in spring, after 80-85% of the original fish fauna has been removed. Stocking should not take place at any other time of year. The new releases are protected from the remnants of the original fish fauna by 10-14 mm mesh nets, and left for two months. The enclosed area should be stocked at a density of 10 000 fish/ha. At that time food is abundant and the fish may grow to 150 g in two months. This gain can be further increased by artificial feeding. After two months the fish are allowed to disperse throughout the lake, where there is ample food. When *Cyprinus carpio* is farmed in this way it reaches a marketable weight of 450-500 g by the end of the first growing season.

If only 70% of the original fish are removed, then the released fingerlings should weigh 150-200 g. A minimum of 60% of the original fish fauna must be removed if a lake is to be changed into a commercial fish farm (Pechnikov, 1980).

In some small lakes, fish die each winter because of a fall in dissolved oxygen concentration. Such lakes can still be used effectively to rear fish which grow to marketable size in one season. In this case, well grown fingerlings of approximately 6 months old, are released into the lake in spring and are harvested in autumn. Such small lakes are widespread in southern parts of Western Siberia and southern parts of the Ural Mountains.

Coregonus peled, other coregonids, *Cyprinus carpio*, *Stizostedion lucioperca*, Chinese carps and various local species are suitable for commercial lake fish farms, and may be grown in mono- or polycultures. Coregonidae, in particular *Coregonus peled*, are most favoured for lake fish culture. Not only has this species a good flavour, but it has a number of advantages for fish farmers. It grows fast, becomes sexually mature at an early age, and will grow in locations throughout the Soviet Union. A one year old fish weighs 100-140 g, a two year old 400-500 g, while some individuals may reach 800 g in this time. *Coregonus muksun* has an equally good flavour, and weighs 140-300 g within two years in northwestern lakes, and more than 350 g in the Urals. Three year old fish weigh 550-1 250 g. A quick growing hybrid, between *Coregonus peled* and *Coregonus lavaretus pidschian*, shows promise for lake culture (Niyazov, 1983). Eggs hatch at the end of April – early May, at a time when suitable food becomes abundant. Optimal water temperatures for the growth of the hybrid are 13-15°C, when 60% of the energy consumed is channelled into growth. Some standards for production of market size fish in lake farms are given in *Tables 77* and *78*.

TABLE 77. STANDARDS FOR PRODUCTION OF MARKET FISH IN LAKES (Zhukov, 1977)

Fish species	Mean lake depth (m)	Age of fish used for stocking	Mean wt of fish stocked (g)	Stocking density (indiv/ha)	Recovery rate (%)	Average wt of fish marketed (g)	Annual production (kg/ha)
Cyprinus carpio	0-5	1 year	25-30	350	50	400-500	70-80
Cyprinus carpio	0-5	2 year	150-200	150	70	900-1 100	100-110
Coregonus peled	0-5	larvae	-	12 000	50	20-25	110-130
Coregonus peled	5 +	1 year	20-25	1 000	50	250-300	110-130
Hypophthalmichthys molitrix and *Aristichthys nobilis*	2 +	2 year	150-200	210	70	800-900	110-130
Ctenopharyngodon idella	2 +	2 year	150-200	210	70	800-1 000	120-140
Stizostedion lucioperca	5 +	natural spawning	3-4 years	-	-	-	up to 15
Abramis brama	5 +	natural spawning	-	-	-	-	up to 20

TABLE 78. STANDARDS FOR REARING FISH TO MARKET SIZE IN LAKES IN ONE YEAR (Rudenko, 1983)

Fish species	Weight of fish stocked (g)	Stocking density (indiv/ha)	Recovery rate (%)	Production of market sized fish (kg/ha)
Mesotrophic lakes				
Cyprinus carpio	150-250	350-400	60	up to 200
Coregonus peled	25 +	200	up to 40	15-20
local species (*Rutilus rutilus*,, *Esox lucius*, *Perca fluviatilis*)	-	-	-	25
Total				240
Eutrophic lakes				
Cyprinus carpio	150-250	450-500	over 60	250 +
Coregonus peled	25 +	250	40 +	25
local species (*Rutilus rutilus*, *Esox lucius*, *Perca fluviatilis*)		-	-	25
Total				300

The application of mineral fertilisers improves fish production and recommended rates of application for different types of lakes are given in *Table 79*. The impact of fertilisation is shown in *Table 80*. Rudenko (1977) does not recommend fertilising eutrophic lakes, and for mesotrophic lakes he recommends only one or two applications of fertiliser in the first year, one in the second, and none in subsequent years. In fertilised mesotrophic lakes of the northwestern USSR, Kudersky (1977a) advises that Coregonidae dominate the fish fauna, with *Stizostedion lucioperca* and some local species present (*Table 81*).

TABLE 79. APPLICATION RATES OF MINERAL FERTILISERS FOR SMALL LAKES (kg/ha)
(Kudersky, 1977a)

Lake type	Superphosphate	Ammonium nitrate
oligotrophic	30	50
mesotrophic	20	25
eutrophic	15	20

TABLE 80. CHANGES IN ZOOPLANKTON AND BENTHIC BIOMASS IN FERTILISED LAKES
(Kudersky, 1977a)

	Zooplankton (g/m^3)	Benthos (kg/ha)
before fertiliser application	1.5	34
3rd-4th year of fertiliser application	5.8	103
5th-7th year of fertiliser application	7.9	199
8th year of fertiliser application	7.5	168

TABLE 81. PRODUCTION OF MARKETABLE FISH IN FERTILISED MESOTROPHIC LAKES (Kudersky, 1977a)

Fish species	Mean wt of stocked fish (g)	Stocking density (indiv/ha)	Annual production (kg/ha)
Coregonus peled	25	300-350	40-50
Benthophagic Coregonidae	25	150-200	50-60
Stizostedion lucioperca	10	up to 150	10-15
Local fishes	-	-	40-50
Total			140-175

Mixed culture in small lakes may include Chinese carps and *Cyprinus carpio*, as well as Coregonidae. Yield reaches 240 kg/ha in mesotrophic lakes and 300 kg/ha in eutrophic lakes *(Table 78)*. Supplementary feeding can increase these yields. In polycultures comprising plankton feeders (*Aristichthys nobilis*, *Coregonus peled*), macrophyte feeders (*Ctenopharyngodon idella*) and *Cyprinus carpio* as a bottom feeder, yields of 350-550 kg fish/ha can be obtained if the carp are given supplementary food (Kudersky, 1977a). Grain is supplied at a rate of approximately 2 kg per carp per growing season (Rudenko, 1977). About 10% of the feed is given in May, 25% in June, 45% in July and 20% in August. The production of polyculture, in which *Cyprinus carpio* was given grain during the warmer months, is shown in *Table 82*. However, there are fears that mineral fertilisation and supplementary feeding may change the lake environment, such that the culture of *Coregonus peled* is hindered or altogether precluded (Malashkin, 1976). It has therefore been suggested that if *Cyprinus carpio* is to be fed it is raised only in association with *Aristichthys nobilis*. Data for such a culture are given in *Table 83*.

TABLE 82. MARKET FISH PRODUCTION BY POLYCULTURE IN LAKE FARMS (WITH SUPPLEMENTARY FEEDING OF CARP) (Kudersky, 1977a)

Species	Age of stock fish	Stocking density (indiv/ha)	Av wt of stocked fish (g)	Average market wt (g)	Annual production (kg/ha)
Cyprinus carpio	1-2 year +	721	365	660-1 300	306.3
Aristichthys nobilis	1 year +	152	340-352	1 088	161.8
Coregonus peled	0 year +	359	24	231	2.4
Hypophthalmichthys molitrix	1 year +	16	258	579	3.6
Total stocked species					474.1
Local species					72
Total					546.1

TABLE 83. PRODUCTION GUIDELINES FOR POLYCULTURE OF *CYPRINUS CARPIO* AND *ARISTICHTHYS NOBILIS* IN LAKE FARMS

	Cyprinus carpio	*Aristichthys nobilis*	Total
Age of stocked fish	2 year	2 year	
Stocking density (ind/ha)	500	200	700
Av weight of stocked fish (g)	200-250	300-350	
Recovery rate (%)	55	90	
Av weight of market fish (g)	900	1 000	
Production of 3 year old fish (kg/ha)	250	180	430
Production of fish more than 3 years old (kg/ha)	60-70	-	60-70
Total market production (kg/ha)	310-320	180	490-500

Experiences from lake fish farms have been reported by Balashev (1976), Belov and Lavrova (1976), Leptanovich (1976), Berdichevsky *et al.* (1979), Rudenko and Mel'nichuk (1979), Baranov and Likharev (1981), Kudersky (1981), Shimanovskaya *et al.* (1983), Zhukov (1983), Evgrafov and Kershtein (1985) and Monakov (1986). Modelling and fish yield predictions are discussed by Stergilov and Novosel'tsev (1980) and L'vov and Sechin (1984).

In 1985, there were 61 lake fish farms under the control of the Soviet Ministry of Fisheries in small and medium sized lakes totalling 513 000 ha. Together they produced 19 600 tons of fish in the year, which included 10 000 tons of *Cyprinus carpio*, and smaller catches of *Abramis brama*, *Coregonus peled*, *Stizostedion lucioperca* and some Chinese carps. The average yield was 38 kg/ha (Mukhachev 1986), which was several times higher than that obtained from similar, but un-farmed lakes. Lake fish farms have the potential to raise catches to 250 - 500 kg/ha. Such yields have already been attained on some farms. At present, only 4% of the total area of small and medium sized lakes are farmed. They thus constitute a most valuable resource. In 1980, the Ministry proposed measures to increase the production from fish farms by 230% by 1985. These entailed opening new farms so that the water surface in use was enlarged by 180%. This has not yet been achieved.

Reasons for the slow development of fish farms have been analysed by Obukhov and Lavrova (1984) and Titova (1984). These authors observe that there has frequently been a reluctance to intensify fish culture techniques and to build adequate facilities for producing fish for stocking. Thus many lakes were under-stocked. Rearing facilities require substantial investment and Malashkin *et al.* (1976) estimate that a lake of 100 ha, intensively stocked with *Cyprinus carpio*, herbivores and plankton feeders requires no less than 70 ha of rearing ponds to produce the fish for stocking required. Many lake fish farms failed to reach targets, and some that had made small increases in production in recent years, had done so because they were catching low value species rather than cultured species. Fisheries employees are frequently poorly qualified, there are shortages of fertilisers, piscicides, high performance aerators, fertiliser spreaders, good fishing equipment, trucks for the transport of live fish and off-the-road vehicles (Titova, 1985). The problems of mechanising fishing are far from being solved. Thus productivity of lake fish farms tends to remain close to the levels of ordinary lakes. The average output from extensively fished lakes is 6-7 tons/fisherman/year, while it is 3.5-7 tons/fisherman/year on the majority of farmed lakes, but 10-16 tons/fisherman/year on the best managed and most advanced fish farms. It is clear that, in future there must be better management, and planning should encompass regional groups of lakes rather than individual lakes.

8.2 LAKE FISH FARMS AND THE PRODUCTION OF FISH FOR STOCKING

Selected small lakes are being used to produce fish for stocking, almost exclusively Coregonidae. In most cases 2-3 species are reared together, although in ideal feeding conditions this may be increased to 3-4 species (Erofeev, 1983). Rudenko and Mel'nichuk (1979) recommend a stocking density of 35-40 000 fish fry/ha, including 30% *Coregonus peled*, 40% *Coregonus peled* x *Coregonus nasus*, and 30% *Coregonus muksun*. It is possible, either to produce large numbers of small fingerlings, or smaller numbers of larger ones. Production guidelines for Coregonidae (*Table 84*) assume a survival rate of 50% and that available food concentrations are 2-3 g/m^3 in the lake where the young fish are released.

8.3 CAGE FISH CULTURE

Many water bodies are suitable for cage culture. So far it has been practised mainly in the Baltic Republics, where *Salmo gairdneri* is the main species produced. A small quantity of *Cyprinus carpio* is also produced. Cage systems require a high level of investment, provision of high quality feeds and qualified personnel. This technique will probably become more important in the future.

8.4 ARTIFICIAL SPAWNING NESTS

The deleterious effects of fluctuating water levels on spawning may be partially eliminated by the provision of artificial spawning nests. The design of these is simple. They generally consist of woven rings of reeds or synthetic materials, about 40-60 cm in diameter, into which spawning substrates are woven. These latter consist of plants, twigs, old bits of net, or patches of plastic bristles. The nests are then placed, in 50-60 cm of water, in the migration paths of the spawning fish. *Abramis brama, Blicca bjoerkna, Rutilus rutilus and Stizostedion lucioperca* readily lay their eggs in these devices. When the water level falls, the nests are relocated to more suitable sites. After hatching, when the fry have swum away, the nests are removed, dried and stored for future use. Incubation of eggs in spawning nests was found to be 2-5 times more successful than it was in natural spawning grounds (Speshilov *et al.*, 1985). Large scale use of spawning nests is now made in the Volga and Dnieper reservoirs, where more than 1.2 million nests were installed during the period 1976-80 (Knyazev, 1981). One spawning nest results in the production of 4-8 kg fish (Berdichevsky *et al.*, 1979 and Kazakov, 1980). Belova (1976) gives a similar figure for *Rutilus rutilus*, and estimates the final production effect as 120 kg/nest.

TABLE 84. PRODUCTION GUIDELINES FOR COREGONIDAE REARED AT DIFFERENT DENSITIES IN SMALL LAKES

Stocking density	Survival	Av. individual wt of fish for stocking	Production	
(1 000 ind/ha)	%	(g)	(1 000 ind/ha)	(kg/ha)
10	50	70.0	5.0	350.0
15	50	51.0	7.5	382.5
20	50	39.0	10.5	390.0
25	50	30.0	12.5	375.0
30	50	22.0	15.0	330.0
35	50	17.5	17.5	306.2
40	50	14.0	20.0	280.0
45	50	12.0	22.5	270.0
50	50	10.5	25.0	262.5

8.5 HATCHERIES AND REARING FACILITIES FOR STOCKING RESERVOIRS

Hatcheries and rearing facilities produce material for release into reservoirs. They comprise small pond fish farms and use traditional fish culture techniques, mineral fertilisation and feeding. In southern regions, outputs range from 1.8-2.0 t/ha. Natural yields are about 0.3 t/ha, but they increase to 0.9 t/ha as a result of fertilising, and to 2.0 t/ha with feeding (Isaev and Karpova, 1980). The principal species reared belong to Coregonidae and Cyprinidae. The sizes of some hatcheries are given in *Table 85*. There were 70 such facilities in the USSR before 1981 (Knyazev, 1981). Most include hatcheries, fingerling ponds, wintering ponds, brood stock ponds. Many of these facilities aim to produce large fingerlings, better able to withstand predation pressures so that hatcheries serving the Dnieper and Volga reservoirs, breed Chinese carps which are now released after two years (Butorin *et al.*, 1978a; Kazakov, 1980; Kokhanova, 1980; Knyazev, 1981). During the 1975-80, more than 26 million two year old fish, mostly silver carp were released into the Dnieper reservoirs, which raised the commercial catch by 700-750 t/year. When stocked with only 6 month old fish, commercial catches of this species were negligible. The capacity of existing hatcheries is still insufficient to meet current stocking requirements. If reservoir fisheries are to improve there must be a prior improvement of hatchery facilities.

TABLE 85. HATCHERIES AT SELECTED RESERVOIRS (1979) (Isaev and Karpova, 1980)

Reservoir	Rearing facility (ha)
Bratsk	241
Bukhtarminskoe	1 060
Volgograd	681
Gorky	271
Kapchagayskoe	430
Kakhovskoe	760
Krasnodar	389
Krasnoyarsk	90
Kremenchug	760
Kuibyshev	125
Tsimlyansk	950

8.6 HATCHERIES, REARING AND PRODUCTION FACILITIES IN THE SHALLOWS OF RESERVOIRS

In many reservoirs, shallow bays and zones, which are frequently subject to low water levels, have been converted into hatcheries to supply stock for the reservoir proper. Dams are built to retain water in coves, leaving them as isolated fish ponds, after the water level in the main body of the reservoir falls. Within the ponds water is maintained at optimal depths, *i.e.* 1.2-2.5 m, which is suitable for fry/fingerling production. Outlet boxes are built inside the dams to control water level, and the bottoms of the ponds have a network of drainage ducts.

Fish culture in these ponds includes the use of fertilisers and feeds. Brood fish are released for natural spawning. The fry are fed and reared throughout the summer, and removed at the end of summer for grading and transfer to the reservoir. When fry are released in the autumn they are not graded.

In some reservoirs, fish ponds have been established over hundreds of hectares, and the stocking material they produce makes a major contribution to the success of the fishery. The use of ponds and coves for the production of stocking material eliminates the detrimental effects which fluctuating water levels have on nursery sites and fish reproduction. However, capital expenditure for ponds is high, and lack of finance has so far hindered progress in this field.

Many fish ponds built in the shallows of reservoirs go farther than the production of stocking material for the reservoir, and also produce market-sized fish. Polyculture of *Cyprinus carpio* and Chinese carps on fish farms in the south yields 500-600 kg/ha, with some farms producing 1 t/ha or more (Pankratova, 1986). These results approach those of the most advanced fish culture ponds (Berdichevsky *et al*, 1978). Many fish farms on reservoirs have large pond complexes, *e.g.* 1 200 ha on the Volgograd Reservoir, 552 ha on the Ivankovskoe Reservoir, and 1800 ha on the Tsimlyansk Reservoir (Berdichevsky *et al*, 1979). The 7 300 ha fish farm in Suskansky Bay on the Kuibyshev Reservoir is the largest to date, and has an estimated annual output of 10 500 tons (Kazakov, 1980). The old bay, where coarse fish used to spawn, has been transformed into a highly productive farm supplying the market with high quality fish. Other fish farms operate on the Kakhovskoe Reservoir, and nine more are planned for the Tsimlyansk Reservoir (Pankratova, 1986).

The construction of fish farms in reservoirs should be important to managers since they have obvious potential for improving the overall economics of reservoirs. According to Kazakov's (1980) estimates, the reservoir fish farms should increase the yields from all reservoirs by 200 000-250 000 tons fish/year.

8.7 ECONOMIC ASPECTS OF FISHERIES ENHANCEMENT IN LAKES AND RESERVOIRS

Studies of the economic implications of fishery intensification measures are still in the initial stages. Titova (1976a) estimates that for a 1 rouble increase in the value of fish production per hectare, the cost effectiveness of lake fish farms will improve by 6%. Using a calculated co-efficient of regression it appears that fish farms can be profitable on small and medium sized lakes with current fish prices. Thus if current production is 14 kg/ha, which translates to 7.2 roubles/ha, then every additional kg/ha caught will produce an extra 1.94 roubles, increasing cost effectiveness by 11.64%. In a later study, Titova (1984) compared the cost effectiveness of commercial fisheries in Tsimlyansk Reservoir with fisheries on other reservoirs, and large, medium and small lakes of the Russian SFSR *(Table 86.)*. From this it appears that human productivity is lower, and fishing costs are higher in small and medium sized lakes than in large lakes and reservoirs. This is at least partly due to the fact that the small and medium lakes are scattered over vast areas, so that time is lost in transport and less time is left for fishing.

The influence of lake size on the economics of commercial fishing was also studied by Titova (1984), who investigated costs and worker productivity on lakes of different sizes in the northwest of the Russian SFSR (Leningrad, Pskov and Novgorod regions). The results of her investigation are summarised in *Table 87* and suggest that on of more than 1 000 ha, worker productivity is 200-400% greater than on lakes 51-100 ha in size, and 400-800% greater than on lakes smaller than 50 ha.

TABLE 86. COMPARISON OF THE COST-EFFECTIVENESS OF COMMERCIAL FISHERIES ON DIFFERENT TYPES OF OPEN WATERS IN THE RUSSIAN SFSR. Data expressed as % of those for Tysmlansk Reservoir (Titova, 1984)

Parameter	Reservoirs		Large lakes		Small and Medium lakes			
	Tsimlyansk	Rybinskoe	Pskov-Chudskoe	Ilmen	Pskov region	Novgorod region	Sverdlovsk region	Bashkir ASSR
Catch/fisherman/yr/kg/ha	100	62.3	82.0	55.7	58.2	41.0	58.2	28.7
Catch/fisherman/year/rouble/ha	100	59.4	50.7	39.1	37.7	21.7	40.6	18.8
Costs per rouble of catch value (roubles)	100	156.2	137.5	152.0	316.7	291.7	314.6	333.3

TABLE 87. COMPARISON BETWEEN FISHING COSTS AND LABOUR PRODUCTIVITY DEPENDENT UPON LAKE SIZE (Titova, 1984)

	Lake Area (ha)				
	0-50	51-100	101-500	501-1 000	1 000+
Leningrad region					
number of lakes in group	5	11	14	26	10
catch (kg/ha)	7.9	5.6	9.3	8.0	6.0
use of working time (hr/ha)	17.5	3.0	2.9	1.9	1.8
human productivity (kg/hr)	0.4	1.9	3.3	4.2	3.3
Pskov region					
number of lakes in group	12	3	36	33	9
catch (kg/ha)	5.6	6.0	7.0	6.5	6.0
use of working time (hr/ha)	6.0	4.0	2.5	2.0	1.0
human productivity (kg/hr)	0.9	1.5	2.8	3.3	6.0
Novgorod region					
number of lakes in group	7	-	27	19	6
catch (kg/ha)	19.4	-	13.5	13.8	19.2
use of working time (hr/ha)	11.4	-	5.0	4.6	2.8
human productivity (kg/hr)	1.7	-	2.7	3.0	6.9

TABLE 88. RELATIONSHIP BETWEEN LAKE AREA AND PRIME COST OF FISH CATCH (Titova, 1984).

Lake area (ha)	Number of lakes in group	Catch (kg/ha)	Prime costs/ton fish expressed as a % of the cost/ton from a 750 ha lake
0-50	12	5.6	450
51-100	3	5.0	185
251-500	15	4.3	111
501-750	27	8.0	109
751-1 000	6	7.1	85
1 000+	9	6.0	79
Average		6.6	100

Lake size, and its relationship with levels of worker productivity, affects the prime costs of catches, as indicated in *Figure 88*. It is seen from this that prime costs per unit catch are 180-450% above 'average' in lakes below 100 ha. Lakes of 750 ha produce 'average' costs. In lakes larger than 750 ha, costs are below 'average' because catches are larger and fishing proceeds for longer periods without lengthy transport times. This in turn leads to better organised work time and reduced costs. Thus, the smaller the lake the greater the need for good planning if the fishery is to prove economically viable.

9. FISHERY MANAGEMENT OF POWER STATION COOLING RESERVOIRS

Management of the cooling reservoirs of thermal and nuclear power stations for fisheries is an entirely novel discipline in the USSR, serious study of which did not begin until the late 1960s. Heated waters are advantageous to fisheries and the effluent temperatures of 8-35°C permit fish to grow all year, giving high yields. Warm water also favours spawning, and with the advent of cooling reservoirs, commercial fish production spread farther north, to regions where it has previously been impossible. Several types of fish farm now depend on heated effluents. They include hatcheries and rearing facilities, pond complexes with special wintering ponds, and cage systems. The intensity of culture is high, producing both stock material and marketable fish. Species include *Anguilla anguilla*, *Cyprinus carpio*, *Huso huso x Acipenser ruthenus*, *Ictalurus punctatus*, *Ictiobus niger*, *Salmo gairdneri* and Chinese carps.

There were 27 farms using warmed waste water in operation in the late 1970s, comprising 160 000 m^2 of tanks or cages. Fourteen were in the Russian SFSR and 12 in the Ukraine (Isaev and Karpova, 1980). Increases in the output of marketable fish, especially *Salmo gairdneri*, from these farms is shown in *Table 89*. In addition to market fish, these facilities produced 6 million fingerlings for stocking in 1978. The Soviet Ministry of Fisheries estimates that 220 000 tons of fish could be raised in warmed waters every year.

TABLE 89. DEVELOPMENT OF MARKET FISH PRODUCTION IN FISH FARMS UTILISING HEATED EFFLUENTS FROM POWER STATIONS

Republic	1970-74	1975	1976	1977	1978
Russian SFSR	620	160	180	410	700
Ukrainian SSR	450	220	600	1 530	1 700
Byelorussian SSR	80	4	3	1	30
Total	1 150	384	783	1 941	2 430

In the early 1980s the total area of cooling reservoirs of all power stations in the USSR was about 140 000 ha (Isaev and Karpova, 1980). It is intended to convert these reservoirs into intensively managed fishing areas, producing *Cyprinus carpio*, *Ictalurus punctatus*, and Chinese carps. Each reservoir will have a customised programme, reflecting the composition of its fish fauna, its stocking density, the optimum size of fish stock, and intensity of fishing and anticipated yields. Large fingerlings will be released to withstand predation pressure.

The Zelenodolskoe Reservoir is an example of such a system. It is located at the Krivoi Rog power station near Dnepropetrovsk in the Ukraine (Voronin *et al.*, 1987). The reservoir was built in 1966, it has an average depth of 5 m and an area of 1 500 ha, of which 1 000 ha is available for fisheries. It is connected with the Kakhovskoe Reservoir on the Dnieper which supplies it with water. The original ichthyofauna consisted of species from the Kakhovskoe Reservoir, notably *Abramis brama*, *Carassius carassius*, *Clupeonella delicatula*, *Morone saxatilis*, *Rutilus rutilus*, *Silurus glanis* and *Stizostedion lucioperca*. Six month old *Cyprinus carpio*, *Ictalurus punctatus*, *Ictiobus niger* and Chinese carps were released into the reservoir during 1980-84 (*Table 90.*), and were fished during 1982-86. Chinese carps were considered to be the key to achieving high production, but there was insufficient stocking material to achieve it. Prior to the intensification measures, the average annual catch was 25 tons, but by 1985 it had increased to 418 tons, with an average yield of 420 kg/ha. Over 88% of the catch comprised introduced species. Development of the fishery is indicated in *Table 91*.

TABLE 90. NUMBERS OF 6 MONTH OLD FISH RELEASED INTO ZELENODOLSKOE COOLING RESERVOIR
(1 000 individuals)

Fish species	1980	1981	1982	1983	1984
Ictalurus punctatus	23	-	-	-	-
Cyprinus carpio	-	1 618	2 120	2 920	647
Aristichthys nobilis (bighead carp)	-	419	-	109	-
Hypophthalmichthys molitrix (silver carp)	-		250	-	-
Ctenopharyngodon idella	-	-	-	617	169
Ictiobus niger	-	-	1 260	1 155	1 188

TABLE 91. CHANGES IN FISH PRODUCTION IN THE ZELENODOLSKOE COOLING RESERVOIR

	1981	1982	1983	1984	1985
Total fish production (kg/ha)	33	49	74	206	420
of which introduced spp. (unspecified)	17	36	60	164	370
Aristichthys nobilis and *Hypophthalmichthys molitrix*	10	10	30	130	330

The most important commercial species in the Zelenodolskoe Reservoir are the Chinese plankton feeding carp (bighead and silver carp) both of which have excellent growth rates (*Table 92*). They contribute 16.9% of the value of the overall annual catch. Satisfactory results are also obtained with grass carp and *Ictalurus punctatus*, which have become naturalised in the reservoir; they now spawn there and their numbers increase annually. *Cyprinus carpio* and *Ictiobus niger* are abundant in the reservoir, but together they contribute less than 3% of the value of the annual catch. This is entirely due to selective fishing for other species and suggests that there is a substantial reserve capacity in the reservoir.

TABLE 92. AVERAGE WEIGHT OF *HYPOPHTHALMICHTHYS MOLITRIX* AND *ARISTICHTHYS NOBILIS* IN THE ZELENODOLSKOE RESERVOIR

Fish species	Age (years)					
	1+	2+	3+	4+	5+	6+
Hypophthalmichthys molitrix	1.7	-	7.4	10.1	-	-
Aristichthys nobilis	1.3	-	5.0.	11.0	15.9	22.0

Silver carp and bighead carp have great potential for use in cooling reservoir fisheries, and a comparison of results following their introduction to various reservoirs of the Ukraine is given in *Table 93*. Management practices on these reservoirs are similar to those of large reservoirs in the south of the country, with the exception that 6 month old fingerlings may be safely released into cooling reservoirs.

TABLE 93. STOCKING WITH, AND PRODUCTION OF, SILVER CARP AND BIGHEAD CARP IN COOLING RESERVOIRS IN THE UKRAINIAN SSR DURING 1980-85 (Annual averages)

	Mironovskoe	Uglegorskoe	Starobeshevskoe	Kurakhovskoe	Zelenodolskoe
Area (ha)	420	1 200	692	1 310	1 500
Age of stocked fingerlings (yrs)	1+	1+	1+	1+	1+
Average weight (g)	100	100	100	100	30
Stocking density (1 000 ind/ha)	520	225	380	190	150
Stocking density (kg/ha)	52	23	38	19	4.5
Yield (kg/ha)	107	231	400	230	200
Stocking material required to produce 1 ton of marketable fish (numbers)	4 860	970	940	840	1 100
Stocking material required to produce 1 ton of marketable fish (kg/ha)	490	97	94	84	33

10. FISH PASSES AND BARRIERS IN RESERVOIRS AND WATER COURSES

Various structures have been designed to permit fish to move up and down stream, past dams and other constructions. This is especially important for maintaining spawning migrations and preserving natural populations in rivers. Similarly, barriers have been developed to keep fish away from danger zones such as occur near the water intakes of power and pumping stations.

10.1 FISH PASSES

Information on fish passes in the Soviet Union is given by Isaev and Karpova (1980) and Pavlov (1989). There are five major types of fish passes:

- Simple fish passes. A continuous water flow enables fish to pass upstream.
- Hydraulic and mechanical fish lifts. Migrating fish enter a chamber and are periodically lifted to the reservoir upstream of the dam.
- Fish passes that work on the principal of locks.
- Floating equipment. Fish are gathered into containers, which are then transported to up stream reservoirs.
- Fishing complexes. Fish are caught, then gathered into containers for transportation by truck to upstream reservoirs. This system is used where there are no navigation locks.

Simple fish passes comprise fish ladders, troughs and by-pass channels. The fish are able to overcome height differences without assistance. These types of passes are used world wide.

Hydraulic fish lifts are built where dams are high. They may have one or two chambers. The fish, attracted by a stream of water coming from the lower part of the lift, are herded by a moving mechanical screen into a chamber full of water. They are then lifted to the level of the water surface of the reservoir on the upstream side, where they are released. These lifts are used mainly for Acipenseridae and Coregonidae, but other species also use them, including *Abramis brama*, *Cyprinus carpio*, *Pelecus cultratus*, *Stizostedion lucioperca* and *Vimba vimba*. Of the fish lifts in the Soviet Union, those at the dams of the Tsimlyansk and Volgograd Reservoirs deserve special mention.

The Tsimlyansk Fish Lift was built in 1955 to assist migrating Acipenseridae, *Clupeonella delicatula* and *Vimba vimba*. This lift has one chamber. The inlet channel is 110 m long and 6 m wide, with water depths of 6.5-13.6 m. A controllable water stream of 25 m^3/sec., produced by a pump, serves to attract fish into the channel. They are then driven along the channel into a collecting chamber by means of a moveable screen. The collecting chamber has an area of 5 x 18 m, with a water depth of 11.6 m. When the fish have moved from the inlet channel into the collecting chamber, the entrance is closed, the lift shaft is filled with water, and the horizontal screen pushes the fish up the shaft to the upper outlet channel. The lift proper consists of a vertical shaft 36.8 m high, with a cross section of 7x5 m. At the top, the lift empties into an outlet channel 65 m long and 6 m wide, with water depths of 2-7 m. The fish are released into the outlet channel when the screen returns to its starting position. Water is discharged from the lift shaft into the inlet channel, and the process is repeated. The lift operates from April until November. The quantities of fish lifted have fallen in recent years, because the migration of fish has been affected by a number of smaller reservoirs which have recently been built on the Don. Details of fish moved by this lift are given in *Table 94.*

TABLE 94. NUMBERS OF FISH TRANSPORTED BY THE TSIMLYANSK FISH LIFT (1 000 individuals)

Species	1955	1961	1972	1975	1976	1977	1978
Abramis brama	306	26	1 388	20	26	13	423
Stizostedion lucioperca	2	24	3	-	-	3	3
Cyprinus carpio	28	-	-	-	-	-	-
Vimba vimba	1	-	-	-	-	-	-
Esox lucius	-	-	-	-	-	-	-
Pelecus cultratus	153	141	796	24	14	13	73
Stizostedion volgense	-	52	59	-	1	1	-
Perca fluviatilis	-	-	-	-	-	-	-
Abramis ballerus	117	-	983	19	135	40	217
Clupeonella delicatula	-	-	49	-	-	-	-
Silurus glanis	2	1	2	-	-	-	-
Total	609	244	3 280	63	176	69	716

The Volgograd Hydraulic Fish Lift was built in 1961 with a view to assisting migration of Acipenseridae. It has two shafts connected to twin inlet channels, each 85.25 m long and 8.5 m wide, with water depths of 5.7-14.4 m. Attracting streams, with velocities of 1.2 m/sec., and an aggregate flow of 75m^3/sec., entice fish into the channels. An attraction stage lasts about 30 minutes, depending on the abundance of fish downstream of the dam. A gathering screen drops within one minute of the attracting flow being shut off. A moving screen then herds the fish into one of the two gathering chambers, a process which takes about 12 minutes. The chambers each measure 8.5x8.5 m. The gathering chamber closes and the lift shaft, 36.9 m high, fills with water in 12 minutes. The vertical shaft is equipped with a horizontal screen, which lifts the fish up through the water column to the level of the water in the reservoir, where they are released into the outlet channel. The horizontal screen returns to its starting position, water is discharged from the shaft and the process is repeated. The cycle lasts 1.5-2 hours and is controlled automatically. The two inlets and collecting chambers are operated alternately, one fills while the other empties. Fish transported by this system arrive in good physiological condition. Statistics regarding fish transported this fish lift are given in *Table 95*.

TABLE 95. NUMBERS OF FISH TRANSPORTED BY THE VOLGOGRAD FISH LIFT (×1 000 individuals)

Fish species	1962	1965	1970	1975	1976	1977	1978
Acipenseridae	27	20	33	28	28	20	36
Stenodus leucichthys leucichthys	-	-	-	1	2	1	2
Clupeonella sp.	861	1 228	319	463	407	240	508
Silurus glanis	26	12	21	8	11	7	5
Others	63	54	71	18	21	20	19
Total	977	1 314	444	518	469	288	570

With mechanical fish lifts, containers are used to transfer fish up to reservoir level. These systems are easier to build than hydraulic fish lifts and require less capital. Examples are found at the Krasnodar and Saratov Reservoirs. The Krasnodar Mechanical Fish Lift consists of a rectangular tank which moves between upper and lower collecting chambers. It is used to transfer spawners moving upstream, and fry migrating downstream. The mechanism of the lift is controlled automatically. The numbers and species of fish transported by the lift are shown in *Table 96.*

TABLE 96. NUMBERS AND SPECIES OF FISH TRANSPORTED BY THE KRASNODAR FISH LIFT (x1 000 individuals)

Fish species	1974	1975	1976	1977	1978
Vimba vimba	4	24	10	7	2
Chalcalburnus chalcoides	25	22	7	4	3
Cyprinus carpio	4	9	5	1	7
Stizostedion lucioperca	9	39	34	21	31
Abramis brama	481	904	644	172	472
Hypophthalmichthys molitrix and *Aristichthys nobilis*	14	3	6	4	7
Ctenopharyngodon idella	2	1	2	1	1
Silurus glanis	7	13	10	2	5
Aspius aspius	1	-	1	1	3
Esox lucius	2	1	1	-	-
Blicca bjoerkna	29	148	92	12	38
Pelecus cultratus	3	11	10	5	72
Perca fluviatilis	3	-	-	-	-
Chondrostoma nasus	5	4	2	-	-
Rutilus rutilus	5	14	3	-	2
Alburnus alburnus	9	19	3	4	-
others	3	5	4	2	5
Total	607	1 217	834	236	648

The Saratov Mechanical Fish Lift was built in 1969, mainly to enable the migration of Acipenseridae, *Abramis brama, Cyprinus carpio and Stizostedion lucioperca.* The gathering chamber is 100x8 m. The bottom of the lift shaft (6x8 m) is situated in the gathering chamber. The fish are attracted to the chamber by a stream of water, and a gathering screen herds them into the lift shaft. Some of the water is discharged from the lift shaft, which is lifted to the upper channel, where the fish are released into the reservoir. The cycle is then repeated, and may be controlled automatically. The numbers of fish transported by this lift are given in *Table 97.*

TABLE 97. NUMBERS OF FISH TRANSPORTED BY THE SARATOV FISH LIFT (x1 000 individuals)

Year	1969	1972	1975	1976	1977	1978
number of fish	735	3 881	796	938	598	513

Fish passes of the lock type have been built at some of the reservoirs on the Don. They usually have two independently acting chambers. The inlet channel leading to the lock is usually 6-8 m wide, and 40-50 m long, so that the entrance is far enough away from the fast flowing water beneath the dam. Water passes through the lock chamber into the inlet channel at a rate of 0.8-1.2 m/sec which is suitable for attracting fish. This stage lasts about 30 minutes. The inlet channel is then closed and the lock chamber fills with water from below. The fish tend to congregate in the upper layers, and when the required height is reached, the chamber opens and the fish readily swim upstream. When the fish have left the chamber the upper gate is closed, water is discharged and the cycle is repeated, the whole process lasting about 1.5-2 hours. While one chamber is filling with fish, the other one is discharging.

Floating equipment for the transfer of fish over a dam is used, to a limited extent on the lower course of the Volga. The equipment (*Figure 20*), patented in the USSR in 1965, consists of a catamaran type collector, which is connected to a removable container. The fish collector has pumps which generate a stream of water, at a rate of 0.2-0.3 m/sec, to attract the fish. The outlets from the pumps may be raised or lowered under the water, so that fish may be attracted from different depths. A crowding screen drives the fish from the collector into the container, which is then closed by a net. A small platform for observation also serves for sampling and tagging the fish. The full container is separated from the collector, and, self-powered, moves at a speed of 5 km/hour to a navigation lock. It passes to the upstream reservoir, where the fish are released.. The system uses two containers at the same time. One carries fish upstream, while the other is gathering fish, so that transfer is almost continuous. The operating cycle lasts 1.5-2 hours. Technical details of the system are given in *Table 98.* This type of equipment costs one sixth of that of a stationary fish lift.

TABLE 98. FLOATING EQUIPMENT USED FOR TRANSFER OF MIGRATING FISH

	Fish container	Fish gatherer
Outer dimensions (m)		
length	21.7	51.3
width	13.2	13.2
height	4.0	4.0
waterline (m)		
during fish gathering	2.8	2.8
during fish transfer	1.8-2.2	-

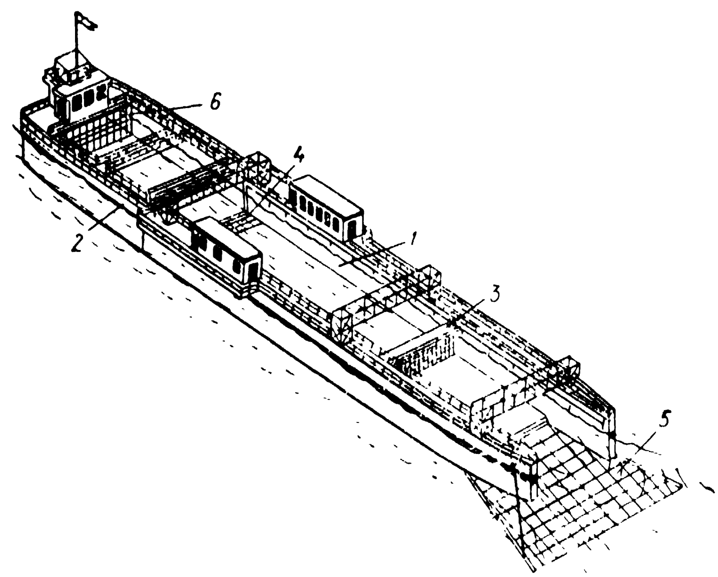


Figure 20. – Floating equipment for the transfer of fish over the dams of reservoirs: 1. space for collecting fish, 2. transporter, 3. crowding screen, 4. platform for fish counting etc., 5. adjustable inlet, 6. screen gate.

10.2 FISH BARRIERS

Diversion of water for industrial use, irrigation of farm land, and for cooling circuits in power stations has become an integral part of the management of reservoirs. In 1979 there were more than 18 000 pumping stations in the USSR (Isaev and Karpova, 1980) and the number continues to increase. Some reservoirs support dozens of such stations (*Table 99*). Many pumping stations have no fish barriers at the intakes, and of those that do, many do not work properly. Even the most effective barriers are not entirely fish proof. Yudanova and Fil'chagov (1975) state that although the Inguletskaya pumping station, which pumps water at a volume of 35 m^3/sec, is equipped with an electric barrier, it is still penetrated by 55-78 tons of fish every year. The fish are from all age groups, but fry are the most prevalent and 80% of these are from commercial species.

The function of fish barriers depends largely upon the etiological reactions of fish to artificial stimuli. Most barriers are designed to prevent fish, either mechanically or physiologically, from entering a pumping site. A general survey of fish barriers used in the USSR is given by Yudanova and Fil'chagov (1975), Isaev and Karpova (1980) and Pavlov (1989).

The simplest, yet most effective, barriers consist of various filters placed in front of intakes. Some of the most important of these are shown in *Figure 21*. Some may be used only in cases of comparatively small water intakes. For high volume intakes, box filters are used. These prevent fish entering systems which pump several m³/sec with filter velocities of 5-10 cm/sec. Filter boxes have the advantage that they need to be removed for cleaning only once per season.

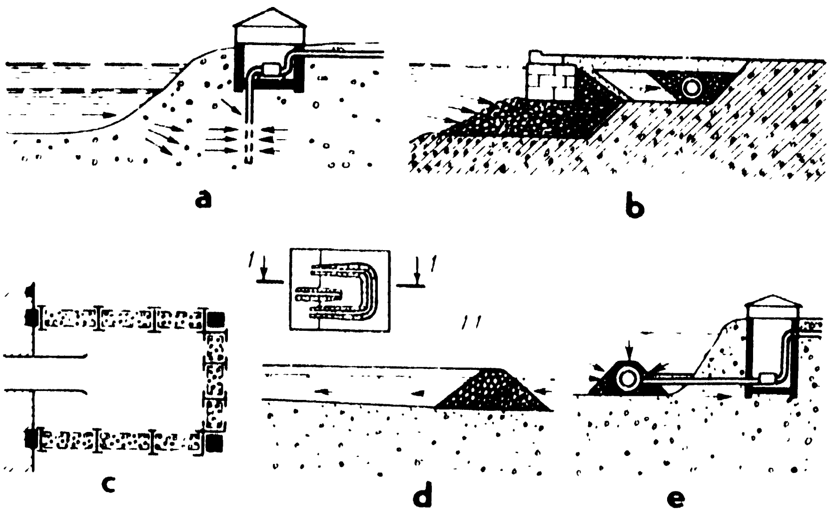


Figure 21. – Gravel filter fish barriers: a. vertical hole, b. horizontal off-take, c. box filters, d. filtering dam, e. off-take with horizontal filtered intake

TABLE 99. NUMBERS OF PUMPING STATIONS IN SOME RESERVOIRS

Reservoir	Number of pumping stations
Bukhtarminskoe	54
Volgograd	10
Gorky	22
Kamskoe	16
Saratov	17
Kakhovskoe	43
Kremenchug	10
Kuibyshev	25
Kapchagayskoe	12
Irtysh-Karaganda complex	120

Several types of straight net barriers are used, but fish have to be removed from them where through-flow is greatest. A generalized diagram of a fish barrier with a straight net is given in *Figure 22.* A variant of

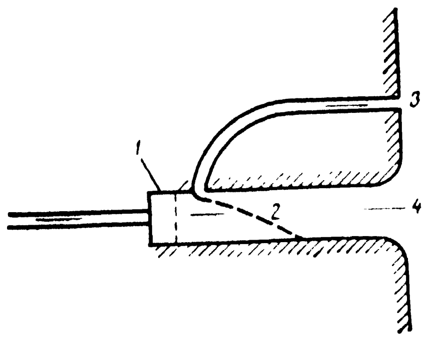


Figure 22. – Diagram of a straight net fish barrier: 1. pumping station, 2. net barrier, 3. channel for sending fish back to the reservoir, 4. reservoir.

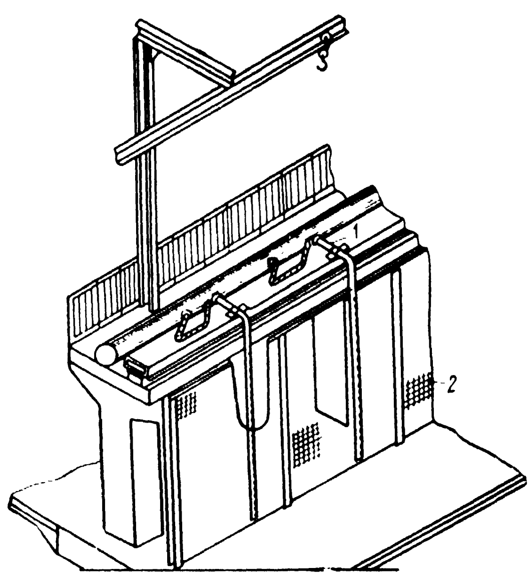


Figure 23. – A straight net fish barrier: 1. water pipe with spray nozzles to clean net barrier, 2. net barrier.

this, where the nets are cleaned with water from spray nozzles, is shown in *Figure 23.* The coefficient of fish protection by this type of barrier is 76.8% (Yudanova and Fil'chagov, 1985).

A simple type of barrier, especially popular in the Ukraine, is type ZRZ-1, known as the 'umbrella'. This is shown in *Figure 24.* Here the change in hydraulic pattern of the water stream prevents the clogging of the suction and discharge pipes (with sand and mud). At the same time it tends to prevent fish from entering the pump, since they are unable to get close to the inlet. In monitoring equipment of this type with a pumping capacity of 7.5 m^3/sec, over a June-August period, Yudanova and Fil'chagov (1975) recorded the entry of 301 000 fish, including 236 000 *Abramis brama*, of an average length of 4.6 cm.

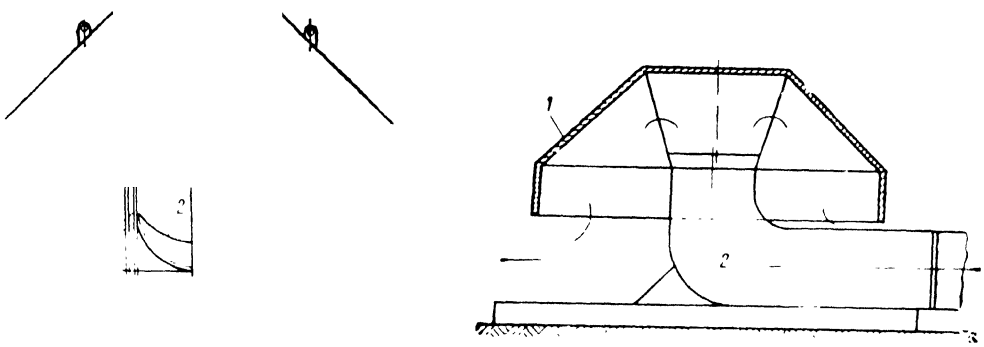


Figure 24. – Fish barrier ZRZ-1 'umbrella': 1. umbrella cover, 2. suction (intake) pipe

Ring-shaped net drums represent a more advanced type of fish barrier, in which the walls of the drum are cleaned by a water spray. There are a number of variations on this theme, but the basic design is shown in *Figure 25.* The net walls are cleaned automatically. A relay turns the cleaning elements inwards when the rate of flow through the net screen decreases. In the case of failure, as may be caused by clogging of the net or excessive rate of flow, operators are automatically alerted. In another type of drum barrier, the nets are cleaned by rocking hydraulic nozzles, as shown in *Figure 26.* Where drum barriers are used, water flow is usually about 0.25 m/sec, which protects all sizes of fry. Flow never exceeds 0.4 m/sec, which still protects fry more than 15 mm long.

Ring shaped barriers with conical net sections are generally considered the most effective mechanical fish barriers (*Figures 27, 28*). They are installed next to concrete pre-cleaning chambers with screens of 30x30 mm mesh to trap coarse debris. The barrier consists of a drum which turns around a central discharge pipe at a speed of 0.5-1 rpm. Water, containing fish and fry, enters the sectors of the drum, and the fish, together with the debris, leave the drum, passing along the discharge pipe into a separate channel. Fry are not traumatised and remain fully viable. This type of barrier is suitable for stations pumping up to 500 *l*/sec. The velocity of water flow is generally within the range 0.15-2.25 m/sec, mesh size is 1x1 mm, the

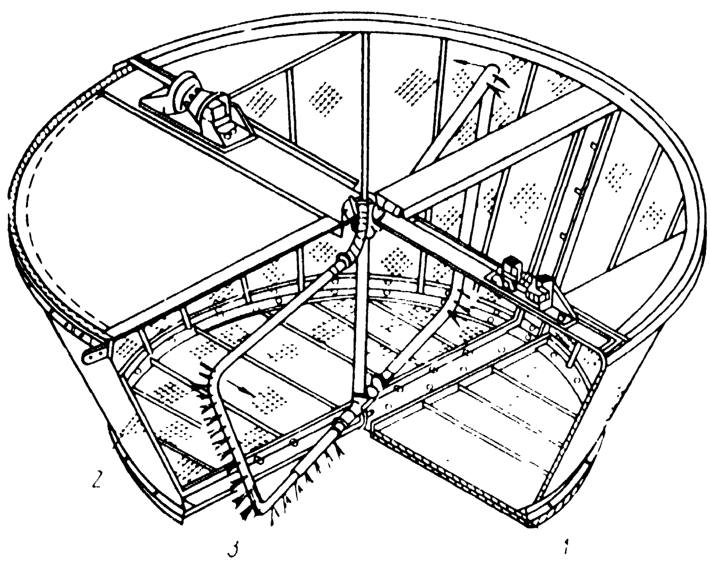


Figure 25. — Net drum fish barrier: 1. body of fish barrier, 2 net walls, 3. rotating nozzles cleaning net walls

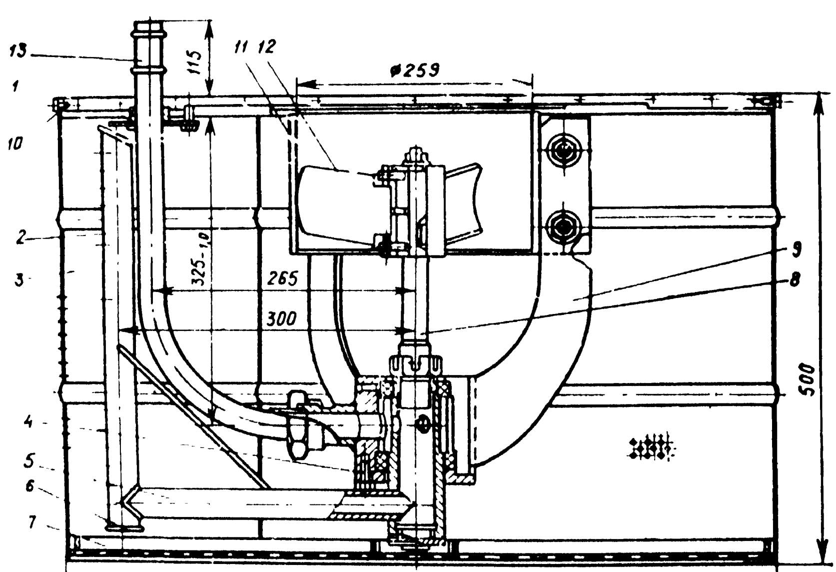


Figure 26. — Net drum fish barrier: 1. supporting frame, 2. revolving washnozzles, 3. net wall of drum, 4. central bearing structure, 5. water inflow to nozzles; 6. closed end of nozzle pipe; 7. bottom of drum; 8. main axle; 9. counterbalancing foot; 10. upper lid of drum; 11. propellor shaft housing; 12. propellor, activated by water flow; 13. water inflow pipe.

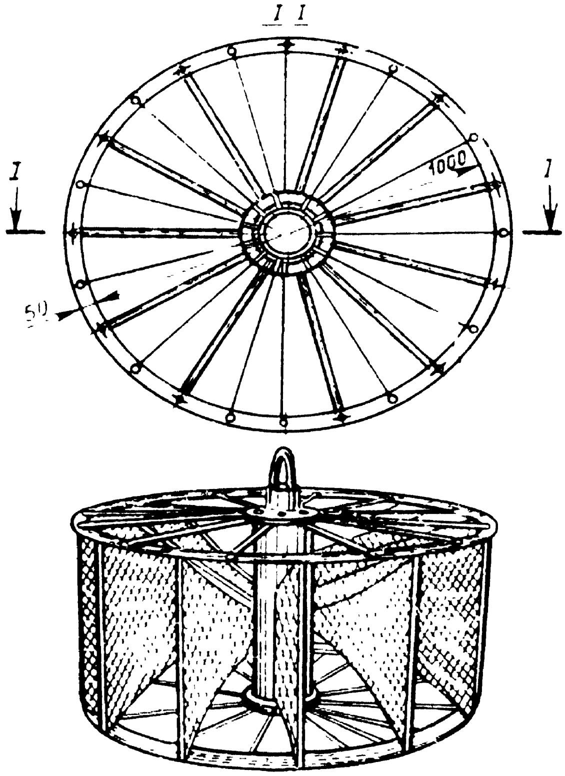


Figure 27. — Fish barrier with conical net sections

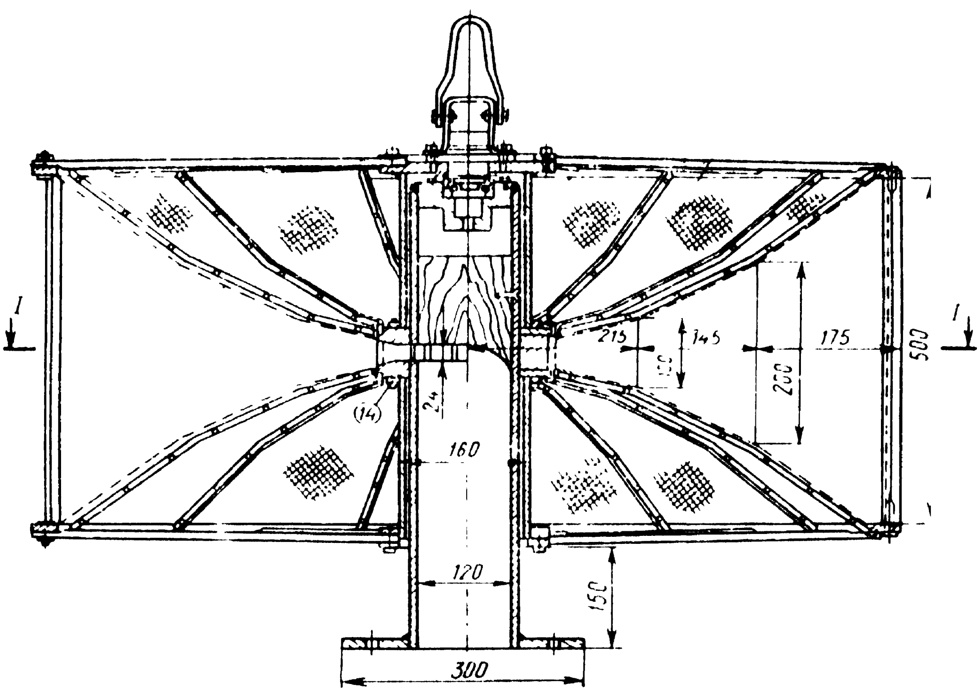


Figure 28. — Cross-section of fish barrier with conical net sections

diameter of the ring barrier is 1.06 m and its height 0.5 m. The diameter of the discharge pipe for the fish is 120 mm, and the power input of the electric motor turning the barrier is 0.4 KW. These barriers are up to 99.6% efficient in fish protection.

Other types of barrier used in the USSR involve the physiological reactions of fish. Electrical fish barriers are fairly common, while pneumatic barriers have found more limited application. Systems using optical and acoustic signals are presently being evaluated.

Electric barriers are based on the avoidance of electric fields by fish. The most widely used electric barrier is code-named ERZU-1, a one-row electric barrier, suitable for use in water courses. There is an even decline in voltage with distance from the electrodes. The smaller the fish, the higher the voltage needed to deter them. Thus the design of the barrier depends on the size of the fish to be protected. The minimum size of fish to be deterred by the ERZU-1 type is 35-40 mm. Larger fish would be killed by this current, so they have to be deterred before they reach the vicinity of the barrier. The voltages used around barriers of the ERZU-1 design are shown in *Table 100.* These barriers are very effective in preventing the penetration of brood fish upstream, but not in stopping migrating fry, or preventing fry from entering pumping systems. It is recommended that ERZU-1 barriers are installed where water velocities are less than 25 cm/sec. The problems encountered with the use of ERZU-1 barriers on reservoirs and water courses, and the possibility of using these devices for fishing, are discussed by Maizelis and Mischelovich (1973), Maizelis and Nusenbaum (1973), Mischelovich (1974), Maizelis *et al.*, (1974), Zonov (1974a), Petrov (1975) and Strakhov (1975). The use of this system for catching migrating fish on the Volga and other rivers, is documented by Strakhov (1975). It is possible, in selected parts of a river, to catch up to 100% of the fish migrating upstream, even in waters of very low electrical conductivity.

Pneumatic fish barriers involve the principle of inhibiting fish movement with a 'wall' of air bubbles. There are two general designs. In the first, fish are floated towards the surface by a combination of the bubbles and a vertical water flow. Once the fish reach the surface they are driven towards a catchment area. In the other design, fish are kept away by means of a blast of air bubbles produced by jets, and this is suitable mainly for fish drifting passively with the stream. Under ideal conditions an effectiveness of 80% has been recorded by Isaev and Karpova (1980). The optimum bubble size is 2-3 mm. At increased air pressure the bubbles are bigger, 7-15 mm, reducing the effectiveness of the barrier by one half.

TABLE 100. CHARACTERISTICS OF THE ELECTRIC BARRIER ERZU-1, FOR PROTECTION OF FISH OF DIFFERENT SIZES (Isaev and Karpova, 1980)

Length of fish (mm)	Voltage (V/cm)	Distance of electrodes (mm)
40	0.23	500
50	0.19	580
60	0.17	660
80	0.14	780
100	0.12	920
150	0.10	1 100
200	0.085	1 300

11. FISHING METHODS

Traditional fishing gear, including nets, beach seines and various types of trap nets, still prevail in Soviet inland fisheries. At present, the size of catches made by trawling and electro-trawling is not very great, and does not reflect the potential of the techniques. Nevertheless, partial mechanisation of fishing has accounted for increased production. Most fish caught in the Soviet Union come from the Russian SFSR, where between 1961 and 1983, the catch per fisherman increased by 25% (Sechin, 1986). However, equipment and techniques are still far from realising projected catches. There is certainly not enough specialised equipment for catching the plankton-feeding species, particularly *Aristichthys nobilis* and *Hypophthalmichthys molitrix*. This problem is discussed by Ozinkovskaya and Malitsky (1983). There is also a lack of equipment for catching the over-abundant nuisance species, and for the total fishing of small lakes destined for conversion to fish farms.

Denisov (1978) states that in the latter half of the 1970s Soviet inland fishermen used 380 000 gill nets, with which they made about 55% of the total catch. In addition, some 4 500 beach seines were used, yielding 33% of the catch, and 205 000 fish traps, producing 9%. The remaining 3% was caught with a miscellany of other equipment. However, these figures had increased substantially by the 1980s, since Treschev (1983) indicates that 4 000 mechanised equipments and 12 000 boats were in use, and that in the Russian SFSR alone, about 4 500 beach seines and tow nets, more than 245 000 gill nets, over 130 000 traps and trap nets, and about 300 trawl nets were in operation. In addition about 1 500 vehicles (trucks, tractors, amphibious vehicles and snow trucks) were available for reaching fishing grounds in distant lakes (Treshchev, 1983). Of all the fish caught, 40% were caught with beach seines, about 35% with gill nets and about 20% with trap nets.

TABLE 101. PERCENTAGE DISTRIBUTION IN TIME OF CATCHES OF COMMERCIALLY VALUABLE SPECIES FROM THE KUIBYSHEV RESERVOIR (Monakov, 1983)

	Quarter of year			
	1st	2nd	3rd	4th
Abramis brama	12.9	38.8	37.2	11,1
Stizostedion lucioperca	33.1	27.9	20.4	18.6
Esox lucius	31.3	45.2	5.3	18.2
% of total annual catch (av)	19.1	37.5	29.8	13.6

Using the cascade of dams on the Volga, and the Tsimlyansk Reservoir, as an illustration, Denisov (1978) documents the discrepancies that arise between plans and reality in fishing. For example, the projected rational exploitation foresaw 53% of the total catch being taken with seines and tow nets, 10% with pair trawls, 30% with gill nets and 7% with trap nets or other types of traps. In fact however, 85% of the catch is taken with gill nets, and on the Kuibyshev Reservoir over 90% is taken this way. On the Kuibyshev Reservoir there are 2.7 gill nets/100 ha, and one gill net catches 220-1180 kg fish/annum. Another discrepancy arises with the temporal distribution of catches. According to Denisov (1978), 40% of the annual catch should be made in spring, 30% in summer and autumn, and 30% in winter. In reality, however, most of the catch is obtained in summer, while the winter catch is less than 20%. Similarly, on the Kuibyshev Reservoir, most fish are caught in the pre-spawning period and at the time of intensive food intake (the second and early third quarters of the year), as shown in *Table 101*.

There needs to be an increase in the use of active fishing gear, although many lakes and reservoirs need reclamation before such equipment can be used satisfactorily. This would help to remove the prevalence of one particular technique, which leads to non-rational exploitation of fish resources. Denisov (1978) states, for example, that gill nets are used almost exclusively in the Rybinskoe Reservoir, and that about 90% of the fish are caught in these nets (75% are caught in large mesh size nets). As a result, the catch consists largely of large individuals of the commercially valuable species, whereas stocks of the lower value fishes (*Blicca bjoerkna, Pelecus cultratus, Perca fluviatilis* and *Rutilus rutilus*) are virtually unutilised.

Fishing methods in Soviet inland capture fisheries, including descriptions of fishing gear, are reviewed by Denisov (1978), Isaev and Karpova (1980), Treshchev (1983) and Zonov (1983). Valuable information on fishing is also found in the reports by Denisov (1980), Sechin (1980, 1986), Solov'ev (1984) and Negonovskaya and Tsyplakov (1984).

11.1 ACTIVE FISHING GEAR

This category comprises mainly drag nets, seines, traditional trawls and electric trawls. Each type has variants with specific names (*e.g.* there are about eight different variations in design and use of drag seines, irrespective of size difference).

Symmetrical beach seines are used for fishing along the shore (*Figure 29b*). Asymmetrical seines (*Figure 29a*), where the length of the wings of the seine are one third to two thirds of the total length, are used in rivers and on some reservoirs (*e.g.* Tsimlyansk). Symmetrical seines are 50-1500 m in length, with depths of 1-25 m depending upon length. Up to 30 ha may be fished in one haul. The length of the bag of the seine is 1.5-2 times the height of the seine. Where haul seining is carried out over an uneven bottom, an additional strip of netting, usually 1 m wide, is attached to the seine, to catch any additional fish remaining there (*Figure 30*).

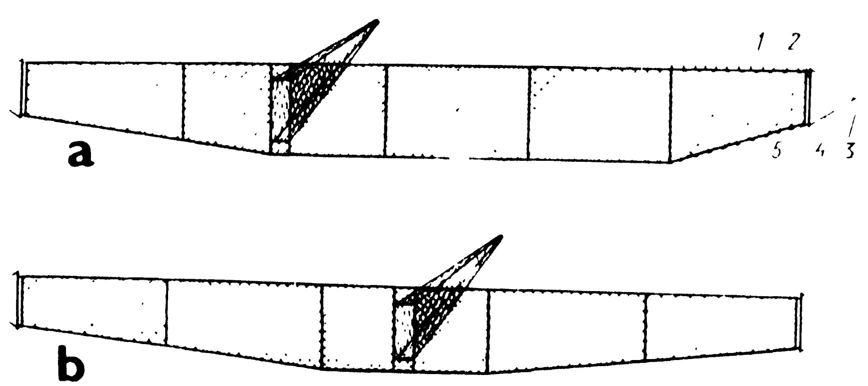


Figure 29. – Diagram of seine net: a. asymmetrical river seine, b. symmetrical beach seine; 1. floats, 2. pole, 3. haul rope, 4. rope connection, 5. lead weights.

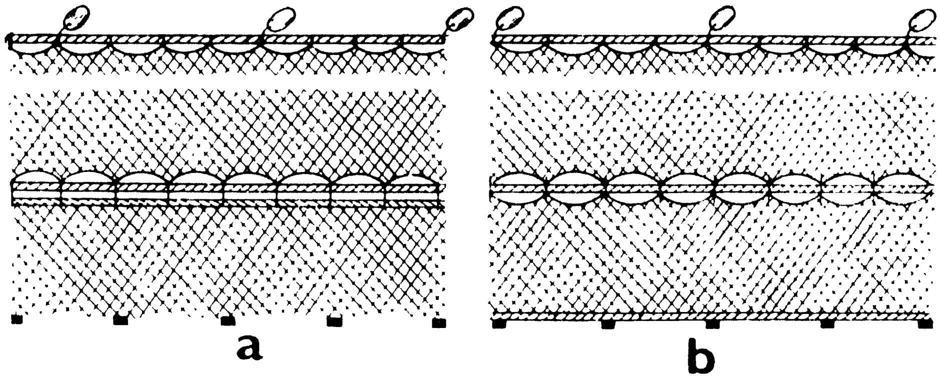


Figure 30. – Seine net with additional strip of net: a. with top row on lower lip and without ground line, b. without lip rope and with a ground line.

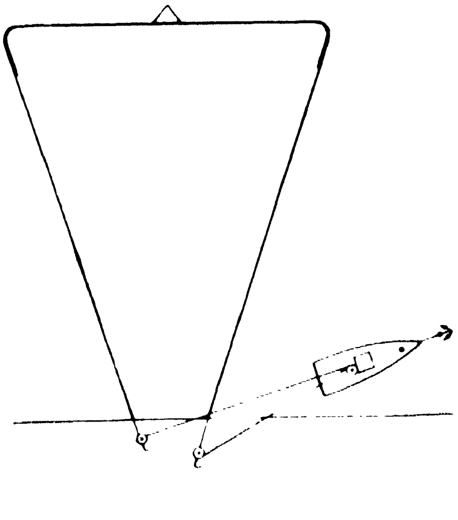


Figure 31. – Diagram of mechanised haul of seine net

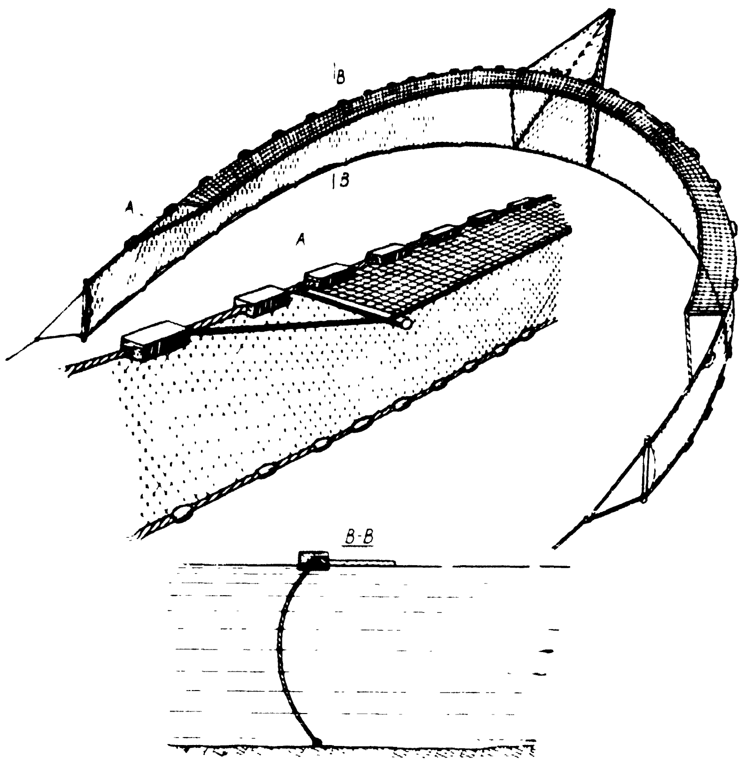


Figure 32. – Seine net with shield

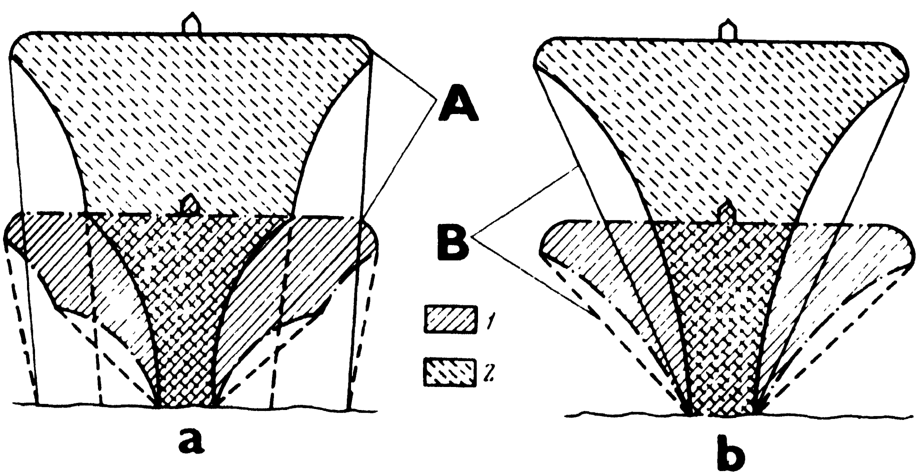


Figure 33. – Forms of seining in open areas of reservoirs: a. haul rope perpendicular to the base of the haul, b. triangular form of haul; 1. area fished by seine nets with short ropes, 2. area fished by seine net with long ropes; A. seine net, B. haul ropes.

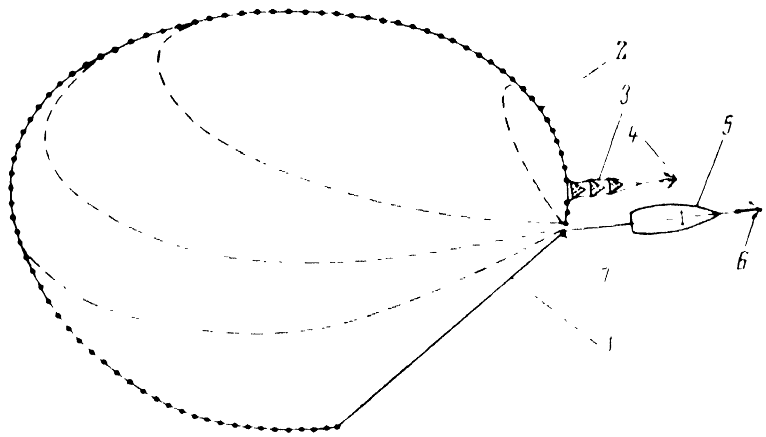


Figure 34. — One-wing seine ('vorotnitsa'): 1. haul rope, 2. seine net, 3. bag of net, 4. bag anchor, 5. boat with net hauler, 6. boat anchor, 7. stakes.

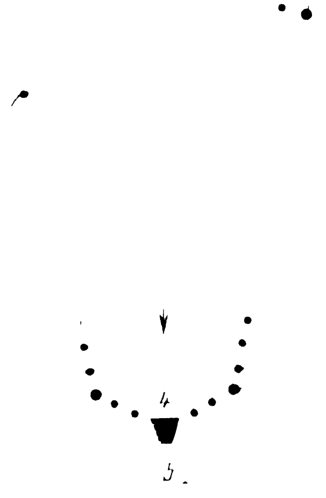


Figure 35. Form of haul for ice fishing: 1. hole for spreading seine net, 2. stakes limiting the width of seining, 3. draw through holes, 4. hole for pulling the net, 5. hole for removing the net.

A boat and winch are used in mechanised fishing with a symmetrical seine (*Figure 31*). Three quarters of the length of the seine is spread parallel with the shore line. Guide pulleys, not more than 50 cm apart, are fixed on the shore and the hauling ropes drawn over them. When the whole seine is spread the boat is anchored close inshore and the winch started.

Silver carp (*Hypophthalmichthys molitrix*) often jump over the cork line of the net and escape in warm weather, but a screening shield helps prevent this, as shown in *Figure 32*. The length of the seine is 500-1200 m, depth is 3 m and the length of the haul ropes 600 m. The aforementioned screen is 400 m long and 1 m wide with a mesh of 40 mm. With the screen, 90% of silver carp is retained, and even more in cold weather.

Symmetrical haul seines are used on open water areas of reservoirs. They are usually 300-1000 m long, and net height does not vary along the middle and wings. Both lead and cork lines are hauled with a winch, and 30-40 kg of extra lead is often suspended from the lead line to keep it close to the bottom. Such a seine can only be used effectively where fish concentrations are high, and this is determined by echo sounders. Ropes as long as the seine itself are used when seining in open water, and the haul is triangular *(Figure 33b)*. This form of haul significantly reduces the number of undersized fish caught, and ensures a higher total catch. Reservoirs have been fished with seines 1 000-1 200 m long, with catches of about a ton being accomplished in 2 hours, and Zonov (1980) recommends the use of these large seines for fishing deep lakes.

A one-wing seine with a bag ('vorotnitsa') is used in shallow waters *(Figure 34)*. The length of the seine wing is 150-200 m while the haul rope is about 300 m. The bag is ring shaped, with several hoops to keep its shape, and twice as long as the seine is high. The seine is hauled from one boat in places where there is a high concentration of fish. Two stakes, not more than 50 cm apart, are driven into the bottom. The end of the seine is fixed to one of the stakes and the bag is anchored. The wing of the seine is spread from the boat to form a ring. The haul rope is then drawn over the other stake, the boat is anchored and the seine winched in.

Seines 400-800 m long are used for ice fishing, but the technique employed varies locally. However, the principle is as follows. Decisions are taken as to where the seine is to be spread from, and from where it is to be pulled out, and holes are made in the ice for drawing it *(Figure 35)*. The line of spread is no more than 70% the length of the seine. The haul line is usually half as long as the seine, but may rarely be of equal length or even twice as long. The hole from where the seine is spread is usually 2-3 m long and 1-1.5 m wide. The draw holes are 30-50 cm in diameter, and the rate of hauling is not more than 8-10 m/minute.

To complete the picture, mention should be made of the 'breden', a small drag net without a bag. It is 5-20 m long and does not have haul ropes, but is drawn by men wading through the water. The effectiveness of this method is, however, low.

Trawling is used for intensive commercial fishing. In the northern lakes and reservoirs it is carried out for four months each year and in the southern ones for six months (Denisov, 1978). Good results have been obtained when fishing for *Pelecus cultratus* in the Tsimlyansk Reservoir, *Osmerus eperlanus* in the Rybinskoe Reservoir, *Silurus glanis* in the Volgograd and Kuibyshev Reservoirs, *Clupeonella delicatula* in the Dnieper Reservoirs, and *Rutilus rutilus* and *Carassius carassius* in the reservoirs of Western Siberia (Isaev and Karpova, 1980). Trawling is also used in the deeper parts of the Volga reservoirs. Here traditional netting yielded an average of 10-11 tons//fisherman/year. When trawling was introduced this increased to 36 tons/fisherman/year, and costs per unit catch were reduced concurrently (Sechin, 1986).

Pair trawling, where two boats haul one trawl net, is the most widely practised form of trawling. Otter boards are not used. The shape and size of the trawl net depends on a number of factors including, the tractive power of the boats, whether trawling is to be carried out on the bottom or within the water column, and on the species to be caught. Most frequently the nets are 10-50 m long (measured along the cork line). An auxiliary boat is frequently used as this permits almost uninterrupted fishing *(Figure 36)*. The trawl bag is emptied into the auxiliary boat while the towing boats slow down, after which fishing is immediately resumed. The entire operation lasts only 3-7 minutes. Voit (1983) recommends replacing boats with catamarans equipped with winches for the trawl nets and shelters for the crews *(Figure 37.)*.

At temperatures below 10°C, the trawling rate for *Albumus albumus* and *Clupeonella delicatula* may be 2.5-3.5 km/hour. During summer, trawling for *Abramis brama*, *Pelecus cultratus*, *Rutilus rutilus and Stizostedion lucioperca* is carried out at 4-5 km/hour, while *Cyprinus carpio*, *Silurus glanis* and plankton-feeding species are harvested at 7-8 km/hour. Trawling speeds with different types of nets are given in *Table 102.*

TABLE 102. TRAWL NETS AND TRAWLING SPEEDS FOR SOME COMMERCIAL FISH SPECIES (after Denisov, 1978)

Size of trawl net (length of head rope) (m)	Mesh sizes of wing, walls and cod-end of trawl net respectively (mm)			Maximum trawling speed (km/hr)	Species
10	12	8	4	3.8	*Clupeonella delicatula*
15	12	8	4	3.5	*Clupeonella delicatula*
15	50	40	30	5.5	*Abramis brama & Pelecus cultratus*
15	80	60	50	8.4	*Cyprinus carpio & Silurus glanis*
18	50	40	30	4.8	*Abramis brama & Pelecus cultratus*

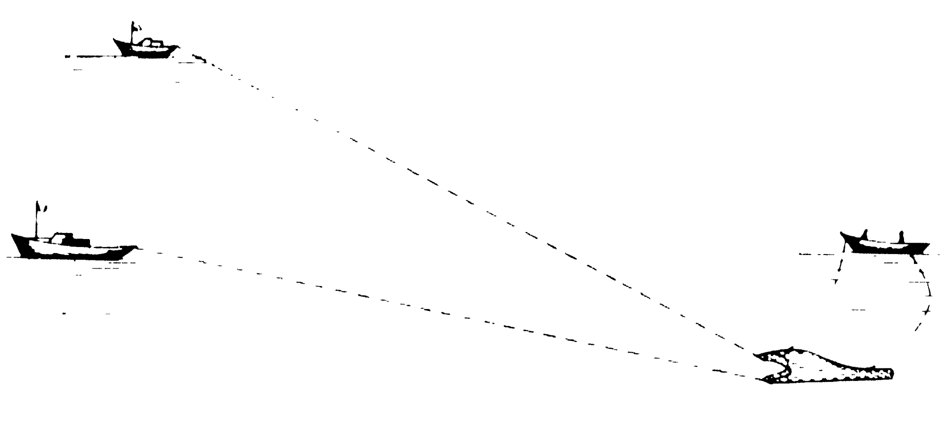


Figure 36. – Pair trawling in conjunction with an auxiliary boat.

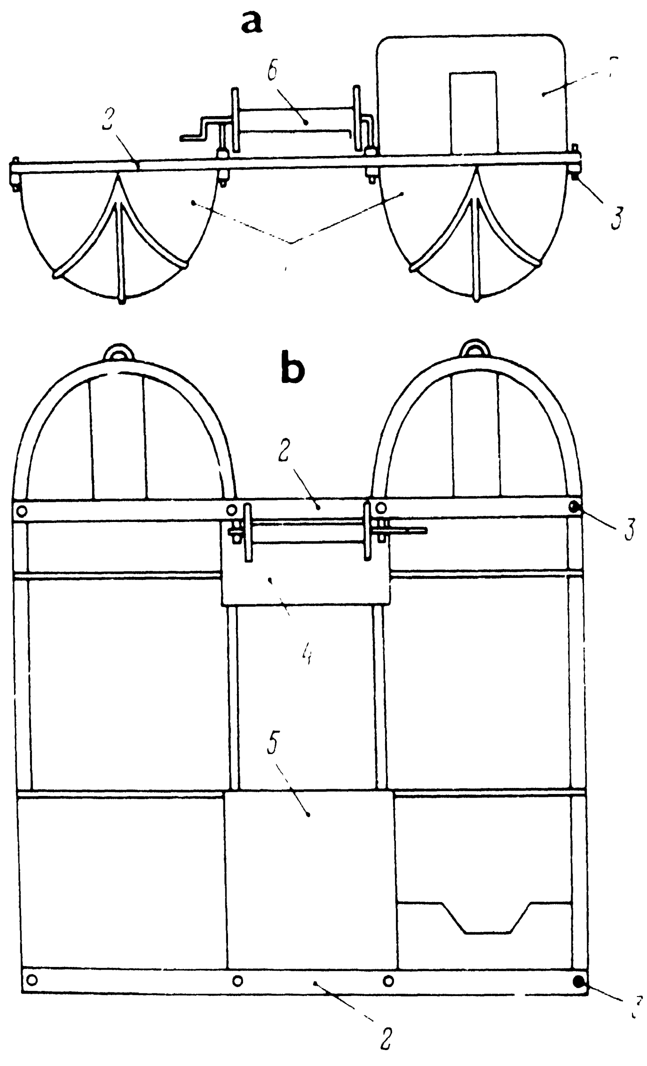


Figure 37.—Trawling catamaran: a. front view, b. plan view, 1. hulls, 2. cross-braces, 3. bolts, 4. foredeck, 5. deck, 6. net hauler, 7. shelter.

Techniques of pair trawling are described by Voit (1983). The optimum period for trawling at different depths is June-September, when the vertical distributions of fish are most marked. In October-November the fish leave the shallows alongshore and move out into deeper water where they overwinter. Trawling for coarse fish species is most effectively carried out in the shallows in daytime, when catches often reach 600 kg/hour. However, if the shallows are unsuitable for bottom trawling, an alternative is to trawl the surfaces at night, when a lot of fish are in the upper part of the water column. Trawling for *Coregonus peled* is best accomplished with large nets at speeds of 3.6-7.2 km/hour. There is no need to use larger meshes in the anterior section of the trawl, as with marine practice, because of the low transparency of the water and the absence of luminescent micro-organisms in freshwaters.

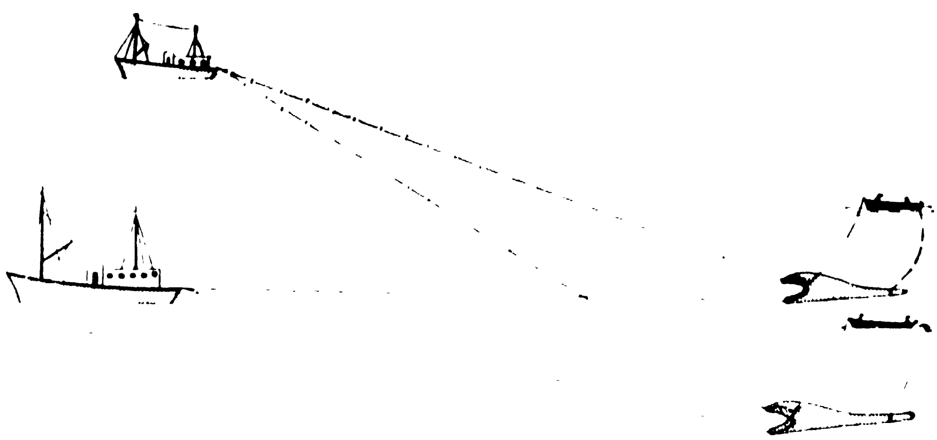


Figure 38. – Fishing with twin trawl nets

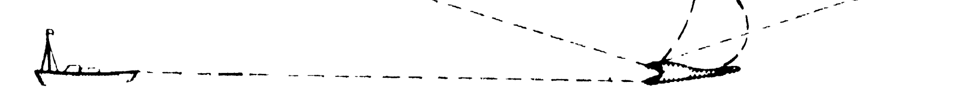
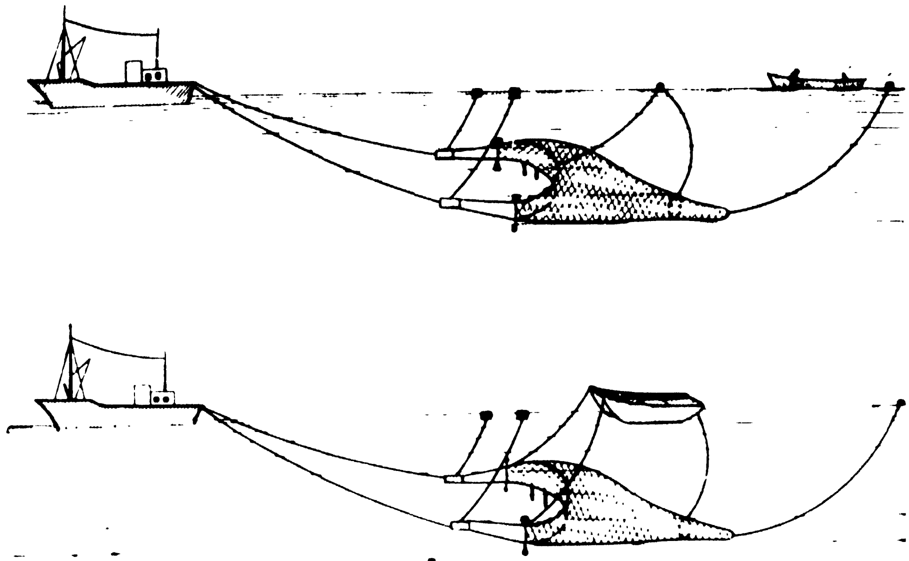


Figure 39. – Group trawling



b

Figure 40. – Trawling with one boat: a. with an auxiliary boat, b. with an auxiliary catamaran

A protective frame, consisting of a rope 30% thicker than the lead line is used to prevent the trawl from being damaged by objects on the bottom. This frame is fixed in front of the trawl mouth and has a haul and a lead line tied together by connecting lines 1 m long. Twin trawls may be pulled by a pair of boats as a variant technique *(Figure 38)*. The two boats must have the same tractive power and, no otter boards are used. In group trawling, three nets are hauled together by three boats *(Figure 39)*. In this case the outer boats must exert equal tractive force, while the central boat must be 3-4 times more powerful than the wing boats.

Some trawling is carried out by single boats, but this is less effective than pair trawling. An auxiliary vessel is almost always used for emptying the trawl bag while fishing is in progress *(Figure 40)*, and the trawl net must have otter boards. Anticlockwise circular trawling in a 3 m layer of water is more productive than straight line trawling, yielding almost twice the weight of *Abramis brama*, *Rutilus rutilus* and *Stizostedion lucioperca* (Denisov, 1978).

'Burilo' trawling, often used for *Clupeonella delicatula*, is where the mouth of the trawl net is expanded horizontally by using 8-9 m long poles from the boats to spread the haul ropes to the trawl *(Figure 41)*. It is effective only at water temperatures above 6°C, since if the water is colder the fish descend and concentrate in the deepest parts of the water body. *Clupeonella delicatula* may also be caught with cone-shaped nets attached to the sides of the boats *(Figure 42)*. The nets are 12 m long with wide square mouths, 4x4 m, supported on wooden frames, but they are hard to handle and cannot be used at depths below 1 m. Thus, because this species only comes to the surface at night, this method can only be used then. Sometimes boats will push a net in front of them when fishing for *Clupeonella delicatula (Figure 43)*. The leading edges of the mouth of the net are supported by catamaran-type floats, and the fish which enter the net are taken straight into the boat so that fishing is continuous. Catches are 200-400% higher than with aforementioned methods, and it is assumed that the fish are not scared by the bow wave or engine noise of the advancing boat when a front net is used.

Figure 41. – Trawling with one boat by means of extended poles

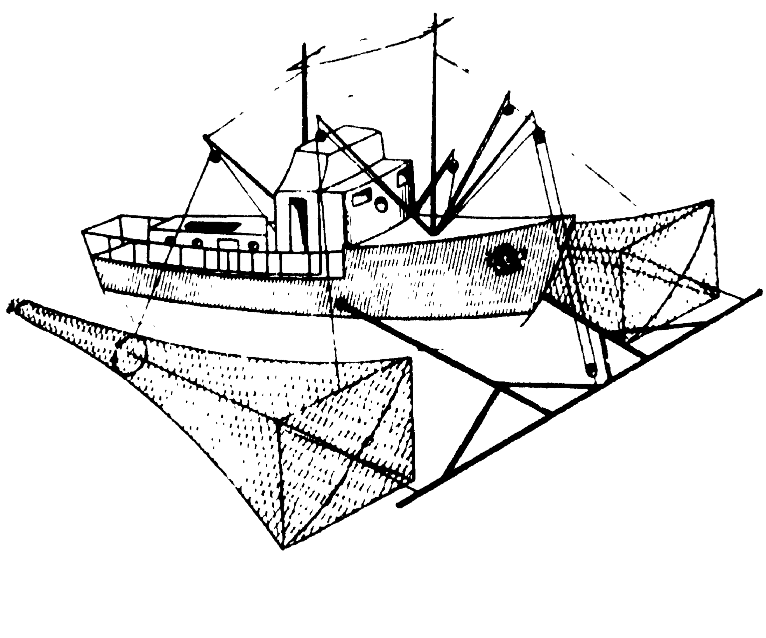


Figure 42. – Fishing with cone shaped nets at the sides of the boat

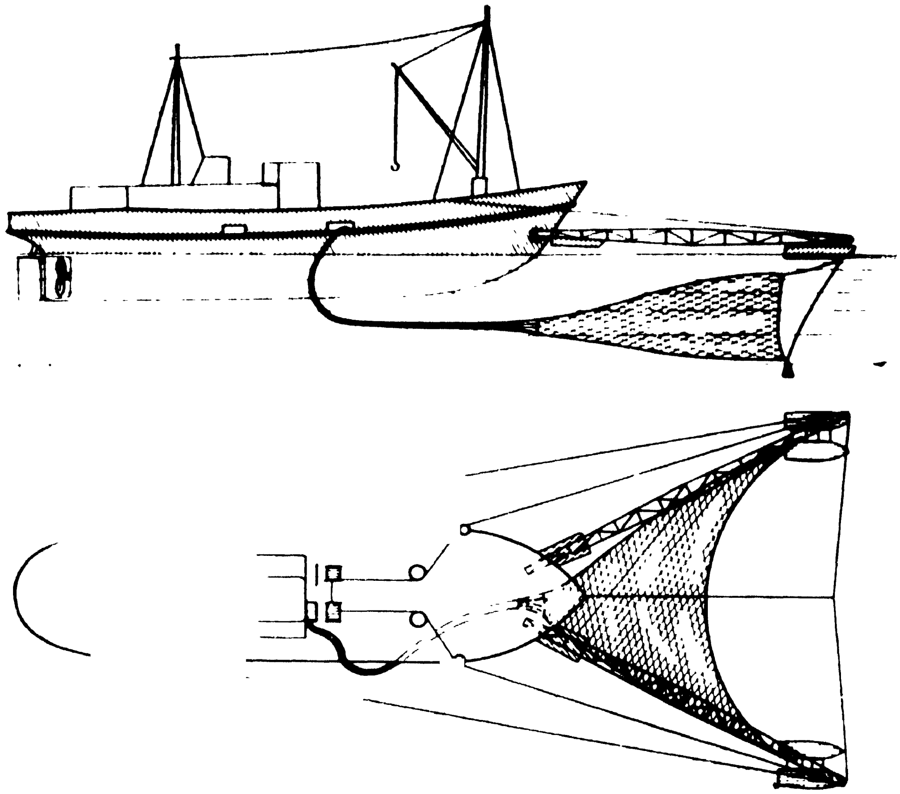


Figure 43. – Fishing by pushing the net in front of the boat

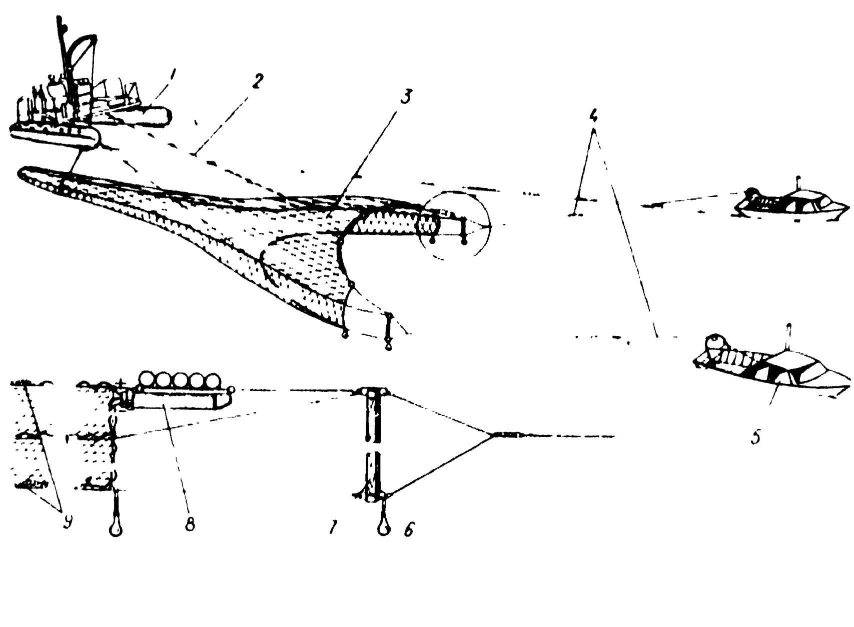


Figure 44. – Electro-fishing complex ELU-4, comprising hauled electro-trawl net and catamaran manipulator: 1. catamaran, 2. feeder cables, 3. trawl net, 4. haul ropes, 5. boats, 6. lead weights, 7. poles, 8.pulse generator, 9. electrodes

On some reservoirs gill nets are drawn by boats. In this case the nets are about 30 m long and 4 m high, and are suspended between cork lines at the surface and lead lines at the bottom. Two motor boats haul the net at a speed of 2.5-3 km/hour, for periods up to 30 minutes. Best results are achieved in summer and autumn. If the bottom is unsuitable for fishing, the haul is done above the bottom, and at night. In central and southern areas, drag nets are used from July to mid-October, from 23.00-04.00 hours in summer and from 20.00-06.00 hours in autumn. Threefold nets are used for *Aristichthys nobilis* and *Hypophthalmichthys molitrix* in the daytime, the nets being pulled at 6-7 km/hour.

Electric trawl nets have been gaining in popularity in recent years. Aslanov (1980) believes that the technique can double worker productivity by comparison with traditional trawling methods. By the mid-1970s the national catch from electric trawling was very low, *c.* 2 500 tons/year, but the method was at that time being introduced to Lithuania, the Ukraine, and some of the other republics (Aslanov, 1975). The ELU-4 complex *(Figure 44)* prevails among the electric fishing systems. It tows its own power source astern of the trawl, on a catamaran. A paired trawl can work at depths of 1.5-20 m at speeds of 1.5-3 km/hour, but outside this narrow range of trawling speeds the electric field is ineffective. The mouth of the trawl is 15 m wide and 5 m deep and electrical impulses are produced by an underwater generator attached to the cork line of the trawl, near the electrodes. The mesh of the wings is 40-60 mm, that of the front 20-24 mm, and that of the bag 14-16 mm. The catamaran provides shelter for the crew and electrical power, and also acts as an auxiliary boat where the fish can be sorted and stored after they have been removed from the trawl net during continuous fishing operations. The entire complex can be operated by 4 men. Detailed accounts of this fishing complex are given by Shaurin (1975) and Aslanov (1980).

Results with the ELU-4 complex are generally good. Worker productivity on Ilmen Lake was 7.5 tons/fisherman/season using drag seines, but is now 21.1 tons/fisherman/season with electric trawling

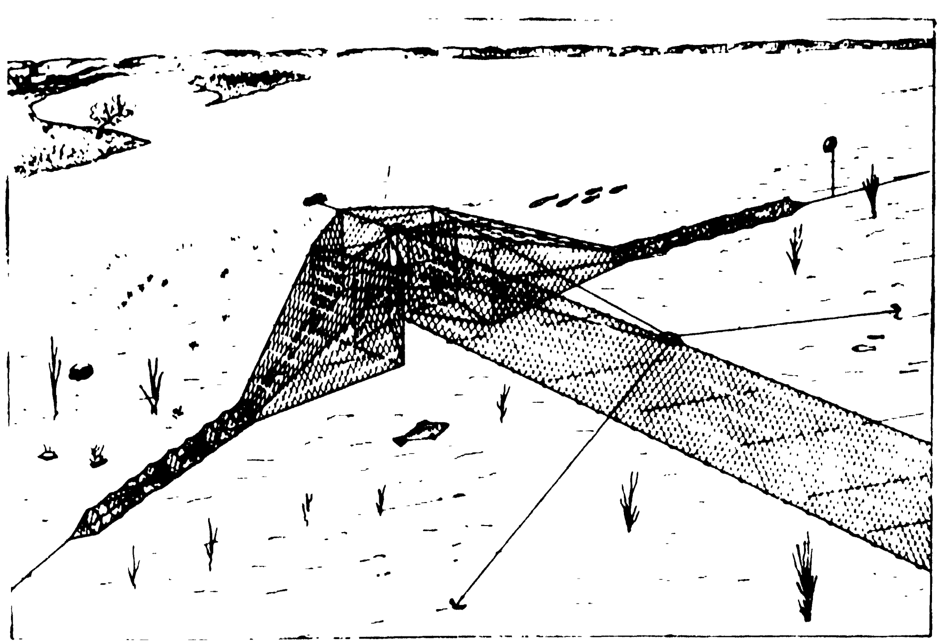


Figure 45. – Fyke net installed on bottom

(Sechin, 1986). Electric trawls also do a good job on cooling reservoirs, where using them, the seasonal catch per worker can exceed 40 tons. Hydro-acoustic methods (sonars), which are used to detect fish stocks for trawling, are also becoming common in the USSR.

11.2 PASSIVE FISHING GEAR

Straight nets, gill nets, fyke nets and traps are still very common in the USSR. This is because, with their simple designs, they cost little and can be made easily, but in terms of fishing effectiveness they cannot compare with modern equipment. About one third of all fish in Soviet inland waters is captured using passive gear (Aslanov and Solov'ev, 1985). There are substantial regional variations in a particular type of gear. Both Denisov (1978) and Isaev and Karpova (1980) estimate that some 200 variations of simple nets (gill nets, fyke nets and traps) are used.

Figure 45 shows a commonly used fyke net device installed on the bottom. It has two wings and a central leading fence. Fyke nets and traps *(Figure 46)* are most effective in spring when fish move towards the shore, and in early winter when fish often migrate *en masse*, escaping from areas where concentrations of dissolved oxygen have been reduced.

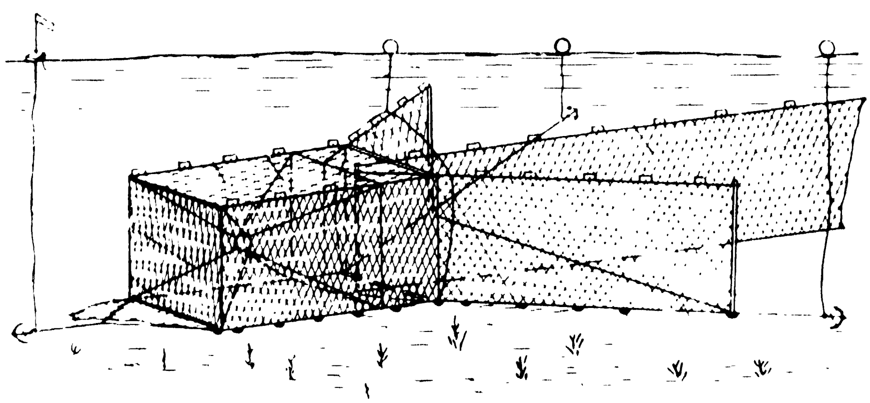


Figure 46. – Fish trap installed on bottom

Handling nets is hard work, but Aslanov and Solov'ev (1985) developed a small power block to assist *(Figure 47)*. This is driven by a hydraulic pump, powered by a chain saw motor, and can manage nets up to 10 m high. The block weighs 95 kg and the net is pulled at 9-60 m/minute. Other advances are still being made with traditional passive types of gear, *e.g.* the plane of straight nets is inclined in the Volgograd and Saratov Reservoirs, so that fish moving vertically can be trapped. This practice has led to 50% increases in catches (Sechin, 1986).

Passive gear will have an important role in Soviet inland capture fisheries for a long time yet. This is evident from the fact that passive gear comprised 16 000 gill nets, over 300 drift nets and 3 500 fyke nets and traps on the Kuibyshev Reservoir at the beginning of the 1980s, compared to the active gear repre-

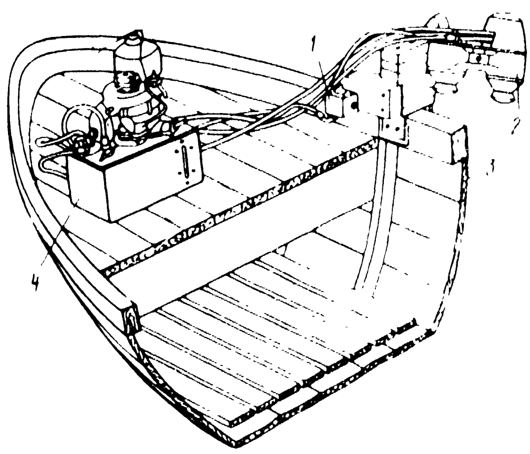


Figure 47. – Small power block for handling straight nets. 1. speed controller, 2. power block, 3. boat, 4. hydraulic pump with petrol engine

sented by only 6 beach seines and 4 trawl nets. Passive gear thus accounted for most of the catch from this largest artificial water body in the USSR (Monakov, 1983). Mesh sizes of the passive gear varied from 24-36 mm for species of low commercial value, to 65-70 mm for good quality fish, to 100-120 mm for *Silurus glanis*.

11.3 FISHING EFFICIENCY AND SELECTIVITY OF GEAR

The efficiency of a given piece of fishing gear is dependent upon several different parameters. It is influenced especially by the shape and behaviour of a particular fish species, and by the season. Knowledge of the efficiency of a particular type of gear is essential for determining the intensity of fishing to be undertaken on a given water body at a given time of year. For example, the effectiveness of nets is reduced, if they are left in the water for long periods without periodic removal of the catch, if they are made of easily visible material, if water transparency rises, if water temperature falls, if atmospheric pressure falls, and if northerly winds blow. The last three factors reduce the swimming activity of the fish.

Data on the effect of the diurnal vertical migrations of fish in the Tsimlyansk Reservoir, and on fishing efficiency, were compiled by Denisov (1978) and a summary of these is given in *Table 103*. Some species manifest a regular diurnal movement between the top and bottom of the water column, but this may depend upon the time of year, and different species may move in opposite directions at a given season. Isaev and Karpova (1980) give optimum trawling speeds for different species, as summarised in *Table 104*.

TABLE 103. – DIURNAL DIFFERENCES IN CATCHES ON THE TSIMLYANSK RESERVOIR

Depth of trawl (m)	Catch per hour of trawling							
	Clupeonella delicatula (kg)		*Pelecus cultratus* (numbers)		*Abramis ballerus* (numbers)		*Abramis brama* (numbers)	
	day	night	day	night	day	night	day	night
0 - 3	102	1	345	51	-	498	6	-
3 - 6	60	20	141	60	15	402	6	234
6 - 10 (bottom)	15	82	69	27	126	-	126	6

TABLE 104. – OPTIMUM TRAWLING SPEEDS FOR DIFFERENT FISH SPECIES

Species	Trawling speed (km/hr)
Abramis brama, *Stizostedion lucioperca*, *Pelecus cultratus* and *Rutilus rutilus* in warm season	4-5
Cyprinus carpio,, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Silurus glanis* in warm season	7-8
Clupeonella delicatula, *Alburnus alburnus* in water below 10°C	2.5-3.5

Choice of fishing methods will depend on the size and configuration of the water body, underwater obstacles, ice cover and some other factors. *Table 105* summarises data from Denisov (1978) and Isaev and Karpova (1980) with respect to the influence of the season upon the utilisation of different fishing gear in different types of water body. Data concerning the selectivity of different fishing gear are given in *Table 106*. There is also selectivity with regard to sex. Some gear catches more females than males, but this is more pronounced in some species (*e.g. Blicca bjoerkna, Cyprinus carpio, Esox lucius*, *Pelecus cultratus*, *Rutilus rutilus* and Acipenseridae) than in others. Sex differentiation in catches is most strongly manifested during the spawning period (*Tables 107-109*).

Changes in the mesh size of nets leads to changes in the species selectivity of the gear and data reflecting this are presented in *Tables 110-112.* As seen from *Table 111*, the proportion of *Abramis brama* caught in gill nets in Kakhovskoe Reservoir increases with the size of the mesh used, up to the maximum mesh size (70-90 mm). By contrast, *Abramis ballerus, Blicca bjoerkna* and *Rutilus rutilus* are held only by the smaller mesh sizes; these species escape from nets with meshes above 50 mm. With fyke nets *(Table 112)*, catches of *Blicca bjoerkna*, *Pelecus cultratus*, *Rutilus rutilus* and *Stizostedion volgense* decrease with an increase in mesh size, whereas catches of *Abramis ballerus*, *A. brama*, *Cyprinus carpio, Esox lucius*, *Silurus glanis* and *Tinca tinca* increase with increasing mesh size. The data in *Table 112* refer exclusively to fyke nets installed in sites where the transparency of the water was less than 10 cm, so no fish could see the trap. It is clear that by using smaller mesh sizes, coarse fish species can be fished out selectively.

TABLE 105. – USE OF FISHING GEAR IN RELATION TO SEASON AND TYPE OF WATER BODY

Year/season	Reservoirs with open water and modified bottom	Reservoirs with limited open water and unmodified bottom
From disappearance of ice cover until protected season	Drag nets and traps with mesh sizes of 30 mm and over	Gillnets with mesh sizes of 26-40 mm and 85-110 mm and traps with 24-40 mm mesh.
During protected season	Limited number of gill nets with meshes of 100-130 mm or 85-90 mm (in some reservoirs). Traps with meshes of 24-28 mm for catching *Rutilus rutilus* and *Carassius carassius*, or 36-40 mm for *Tinca tinca* and *Silurus glanis*	
Between the protected season and autumn	Seines and other drag nets	Smaller drag nets and gill nets with mesh sizes of 85-130 mm.
During autumn before the ice	Seines, trawls and gill nets with mesh over 26 mm	Gill nets with mesh over 26 mm, smaller drag nets, trawls for *Clupeonella delicatula*
During ice cover	Seines for ice-fishing, gill nets with large mesh sizes and large fyke nets	Gill nets with large mesh sizes and large fyke nets

TABLE 106. – PERCENTAGES OF FISH SPECIES CAUGHT BY DIFFERENT TYPES OF GEAR ON TSIMLYANSK RESERVOIR (Isaev and Karpova, 1980)

Fishing Gear	*Abramis ballerus*	*Cyprinus carpio*	Silurus glanis	*Esox lucius*	*Stizostedion lucioperca*	*Abramis brama*	*Stizostedion volgense*	*Pelecus cultratus*	Coarsespp.
Gill nets	5	1	3	1	2	37	10	1	40
Drift nets	-	-	-	-	3	86	2	7	2
Seines	14	4	2	1	3	32	11	12	21
Fykes and traps	-	-	12	7	2	26	12	5	36
Pair trawls	-	-	-	-	5	29	-	57	9
% of each species in total catch	6	1	3	1	2	38	10	2	37

TABLE 107. SELECTIVITY FOR MALES AND FEMALES OF *ESOX LUCIUS* BY DIFFERENT FISHING GEAR IN TSIMLYANSK RESERVOIR

Fishing gear	Total catch		% males				
	females (1000s)	males (1000s)	1954	1955	1956	1957	1958
Gill nets (30-40 mm mesh)	2.1	0.9	42	41	27	29	16
Fyke nets (30-40 mm mesh)	1.5	2.1	51	45	65	55	60
Seines (30 mm mesh)	1.3	0.9	45	34	41	33	42

TABLE 108. SELECTIVITY OF GILL NETS FOR MALES OF *RUTILUS RUTILUS* IN KREMENCHUG RESERVOIR

Age of fish (years)	2	3	4	5	6	7	8	9	10
% males in catch	64	67	56	53	36	17	13	-	-

TABLE 109. SELECTIVITY OF GILL NETS FOR *CYPRINUS CARPIO* OF DIFFERENT AGES IN KAKHOVSKOE RESERVOIR.

Mesh size (mm)	Average age (years)	Minimum and maximum ages (years)
90	6.7	3 - 14
100	9.3	5 - 14
110	10.5	7 - 14
120	12.2	9 - 14

TABLE 110. COMPOSITION OF TRAWL CATCHES FROM TSIMLYANSK RESERVOIR AND THEIR DEPENDENCE ON THE MESH SIZE OF THE TRAWL BAG

Species	Catch in kg per 10 hrs trawling		
	14 mm mesh	24 mm mesh	30 mm mesh
Abramis brama	1 142	1 291	1 494
Pelecus cultratus	709	91	-
Blicca bjoerkna	429	289	207
Abramis ballerus	82	67	51
Stizostedion volgense	81	17	8
Gymnocephalus cernua	65	7	-
Rutilus rutilus	58	32	5
Esox lucius	42	32	36
Stizostedion lucioperca	35	22	22
Cyprinus carpio	15	32	93
less valuable spp.	82	47	37
Total	2 740	1 910	1 953

TABLE 111. PERCENTAGE COMPOSITION OF CATCHES IN GILL NETS OF VARIOUS MESH SIZES ON KAKHOVSKOE RESERVOIR .

Mesh size (mm)	*Abramis brama*	*Stizostedion lucioperca*	*Rutilus rutilus*	*Blicca bjoerkna*	*Abramis ballerus*	*Perca fluviatilis*	*Pelecus cultratus*	*Cyprinus carpio*	*Silurus glanis*	*Esox lucius*	others	
32	17.5	1.2	19.0	46.8	1.4	2.2	0.4	-	-	1.1	10.4	100
36	25.4	2.1	26.3	35.7	2.1	1.5	0.8	-	-	0.3	5.8	100
40	36.0	1.9	40.7	17.8	1.0	0.6	-	-	-	0.3	1.7	100
50	56.5	2.3	27.8	10.2	1.1	0.3	-	-	0.1	0.3	1.4	100
70	96.0	1.9	0.9	0.6	-	-	-	0.1	0.1	0.2	0.2	100
80	96.9	1.5	0.3	0.3	-	-	-	0.5	0.4	0.1	-	100
90	96.6	2.0	-	-	-	-	-	1.0	0.2	0.2	-	100
100	77.6	4.9	-	-	-	-	-	9.8	7.7	-	-	100

TABLE 112. PERCENTAGE COMPOSITION OF CATCHES IN FYKE NETS OF VARIOUS MESH SIZES ON TSIMLYANSK AND KAKHOVSKOE RESERVOIRS

Species	Tsimlyansk Reservoir			Kakhovskoe Reservoir	
	24 mm mesh	30 mm mesh	45 mm mesh	24 mm mesh	36 mm mesh
Blicca bjoerkna	38.0	23.7	6.8	5.2	1.0
Rutilus rutilus	35.5	13.7	0.6	11.3	3.6
Stizostedion volgense	5.8	4.4	1.0	-	-
Abramis ballerus	-	-	-	9.7	5.4
Pelecus cultratus	3.5	4.1	1.2	-	-
Tinca tinca	-	-	-	3.5	5.1
Silurus glanis	9.2	16.6	16.7	49.3	41.4
Abramis brama	5.8	16.4	38.2	17.8	39.3
Esox lucius	2.2	16.1	35.5	2.5	3.1
Cyprinus carpio	-	-	-	0.7	1.1
Totals	100.0	100.0	100.0	100.0	100.0

11.4. THE ECONOMICS OF FISHING

Differences in worker's productivity with different types of equipment was evaluated by Denisov (1978) on the basis of data from Tsimlyansk Reservoir. Here the highest daily productivity during spring fishing was recorded when drift nets were used to catch *Pelecus cultratus*, and the highest autumn productivity was obtained by trawling. By contrast the lowest productivity was recorded for gill nets *(Table 113)*. The monetary value of the catch was lowest from pair trawling and fyke netting, and highest from seining, particularly from seining under the ice *(Table 114)*. This is because trawling and fyke netting catch species of lower monetary value than seining and gill netting, and because seining can take place in winter. The monetary value of a catch depends upon both the time of fishing and on the species caught, rather than on the design or type of gear. The winter prices for a given species are 10% higher than the summer prices.

TABLE 113. CATCH PER FISHERMAN WITH DIFFERENT TYPES OF FISHING GEAR ON TSIMLYANSK RESERVOIR

Fishing Gear	Catch per fisherman (kg/day)
Drift nets for *Pelecus cultratus*	296
Pair trawls	210
Summer straight nets	108
Seines	93
Fyke nets	87
Winter seines	76
Winter gill nets	53

TABLE 114. MONETARY VALUE OF CATCHES FROM THE TSIMLYANSK RESERVOIR BY TYPES OF FISHING GEAR.

Fishing gear	Value of catch (roubles/100kg)
Pair trawls	6.9
Fyke nets	7.6
Seines (ice-fishing)	10.6
Summer gill nets	10.7
Drag nets	12.9
Winter gill nets	13.6

The numbers of full time fishermen employed by the fishing cooperatives on the reservoirs were collated by Isaev and Karpova (1980), and data for selected large reservoirs are given in *Table 115*. These reveal a general decline in numbers over the years, but this has been compensated for by increased productivity and better organisation of the fishing effort. Thus catches have even increased in some reservoirs.

TABLE 115. NUMBERS OF FULL-TIME FISHERMEN AND CATCH PER FISHERMAN ON SOME LARGE RESERVOIRS OVER THE PERIOD 1964-1978.

Reservoir	Numbers of fishermen				Catch per fisherman			
	1964	1968	1973	1978	1964	1968	1973	1978
Rybinskoe	900	710	670	399	4.3	4.0	3.3	6.5
Gorky	180	140	135	173	4.4	3.8	4.8	3.4
Kuibyshev	1 113	933	795	765	4.7	4.2	5.2	6.5
Volgograd	740	937	550	512	3.7	3.0	5.7	6.1
Tsimlyansk	1 122	1 057	995	734	9.4	11.4	8.7	11.0
Kakhovskoe	1 358	1 344	1 050	700	5.6	4.6	5.0	3 7

12. REGULATION OF CAPTURE FISHERIES IN INLAND WATERS AND THE PROTECTION OF FISHERY RESOURCES.

Hand in hand with the development of inland capture fisheries in the USSR has come the need to control fishing intensity. However, since there is such a great diversity of water bodies, scattered over such a large geographical area, the implementation of a single unified policy has been impossible. Nevertheless, efforts for the effective regulation of inland fisheries have been intensified in recent years.

Sport fishing influences the status of fishery resources significantly. Anglers take about 200 000 tons of fish annually, chiefly of the most valuable species, and although this has an adverse effect upon commercial fisheries, the effects of angling are not currently considered when planning fishing efforts and trying to determine fishing intensity for a given water body. There are parts of the USSR where anglers catch more than the commercial fishermen each year.

TABLE 116. – MINIMUM ALLOWABLE SIZES OF MAJOR COMMERCIAL SPECIES IN SELECTED RESERVOIRS (cm) (Isaev and Karpova, 1980)

Reservoir	*Cyprinus carpio*	*Abramis brama*	*Stizostedion lucioperca*	*Esox lucius*	*Pelecus cultratus*	*Leuciscus idus*	*Aspius aspius*	*Abramis ballerus*	*Silurus glanis*	plankton feeding carp	*Anguilla anguilla*	*Coregonus albula*	*Acipenser ruthenus*	other coregonids
Bratsk	35	-	-	-	-	33	-	-	-	-	-	16	44	33
Volgograd	40	30	43	32	-	-	40	-	-	-	-	-	38	-
Gorky	40	30	43	32	-	-	40	-	-	-	-	13	-	30
Ksamskoe	40	30	40	32	-	-	40	-		-	-	-	-	-
Kakhovskoe	35	32	42	35	24	28	-	24	70	40	50	-	-	-
Kremenchug	35	32	42	35	24	28	-	24	70	40	50	-	-	-
Kuibyshev	40	30	43	32	-	-	40	-	-	-	-	-	36	-
Rybinskoe	40	30	43	32	-	-	40	-	-	-	-	13	-	30
Saratov	40	30	43	32	-	-	40	-	-	-	-	-	-	-
Tsimlyansk	35	27	40	-	24	27	35	26	-	-	-	-	-	-

According to Rusanov *et al.* (1984), protection of fishery resources in the USSR requires the following:

estimates of fish stocks in each water body and their maximum sustainable yields. This to be based upon the optimum harvest of all fish species;

the formulation and implementation of rules governing fisheries. These to be based upon biological principles, and to include identification of closed areas and closed seasons, and the prohibition of illegal fishing methods to protect fish stocks;

determination of a minimum allowable size for fish caught commercially;

- determination of minimum allowable mesh sizes for nets and other gear;
- limitation of catches of commercially important species.

The protection of fishery resources is a responsibility of the Soviet Ministry of Fisheries, which issues rules and regulations stating which species are protected at which sites and in which seasons. These rules also specify the mesh of the gear to be used for each species, and the minimum sizes of each which may be caught. Fishing rules and regulations apply to not only to lakes and reservoirs, but also to 25 km stretches of affluents above them.

TABLE 117. MINIMUM ALLOWABLE MESH SIZE OF NETS

Region	Lithuanian SSR	NW Russian SFSR	Volga and Kama Basins	Reservoirs of the Dnieper cascade	Tsimlyansk Reservoir
Mesh size in seines (mm) for commercially valuable species					
seine bag	32	-	30	30	30
seine walls	36	-	40	36	36
seine wings	40	-	45	40	40
Mesh size in seines (mm) for less valuable species					
seine bag	10	18	24	-	28
seine walls	22	26	26	-	28
seine wings	26	30	32	-	32
Mesh in gill nets (mm) to catch fish of length given below	50	32-65	24-65	30-70	36-110
Abramis brama (cm)	29	30	30	32	27
Stizostedion lucioperca (cm)	40	40	43	42	40
Cyprinus carpio (cm)	30	-	40	35	35
Esox lucius (cm)	30	30	45	35	50
Acipenser ruthenus (cm)	40	-	36	-	46
Extra catch (%)	8	10	10	8	10
Length of closed season (days)	65	30	60	45-75	105

The minimum allowable sizes of the principal commercial species are shown in *Table 116*, and the minimum mesh sizes in *Table 117*. This table includes the by-catch which represents the percentage estimate of undersized specimens which inevitably, are also caught. The by-catch is acceptable if it does not exceed 8-10% of the total catch. By-catch of this size were taken into account when determining the mesh sizes and will not lead to over-fishing. To complement the picture *Table 118* shows how large the mesh sizes must be if fish of different sizes are to be able to escape.

Fishery interests are also protected by directives that regulate navigation, reclamation, mining, diversion of water, harvest of aquatic plants, water pollution, felling of trees within 1 km of the shorelines of water bodies, and the disinfection of all fishing gear transferred between water bodies. It is illegal to keep, or to handle, banned fishing gear, explosives or poisons near water bodies. It is illegal to catch fish close to dams and within 500 m of pumping stations and the intakes of irrigation canals. It is illegal to close more than 66% of the width of a water body with nets, to haul seines that could close the whole width of a water body, to prolong the wings of seines, to install gill nets less than 100 m apart, to introduce new biota to water bodies, and to use unregistered boats for fishing.

Both commercial fishermen and anglers are penalized for breaches of the rules. The penalty for an angler is a fine of 10 roubles, while for a commercial organisation it is 50 roubles. In addition another fine is imposed for every single fish caught illegally, *e.g.* with illegal gear or in a forbidden zone, as detailed in *Table 119*. A state authority supervises the rules and inspects catches on each individual water body.

TABLE 118. – MINIMUM ALLOWABLE MESH SIZES REQUIRED TO ENSURE ESCAPE OF FISH OF GIVEN LENGTHS (Denisov, 1978)

	Mesh sizes (mm)				
	30	36	40	50	60
Species	Lengths in cm				
Cyprinus carpio	13	16	18	23	27
Abramis brama	14	17	19	24	28
Stizostedion lucioperca	22	27	30	37	45
Esox lucius	25	31	34	42	51
Acipenser ruthenus	37	45	50	62	75

TABLE 119. – PENALTIES EXACTED FOR CATCHING FISH ILLEGALLY

Species	Penalty for each fish regardless of its weight and size (roubles)
Huso huso and *Huso dauricus*	400
Polyodon spathula, other Acipenseridae	100
Hucho taimen and *Salmo trutta trutta*	50
Acipenser ruthenus, *Barbus* spp. and *Salmo trutta lacustris*	20
various salmonids, *Coregonus autumnalis*, *Coregonus peled*, *Brachymystax lenok*, *Anguilla anguilla*	10
Vimba vimba, *Cyprinus carpio*, *Ctenopharyngodon idella*, *Aristichthys nobilis*, *Hypophthalmichthys molitrix*, *Thymallus thymallus*	5
Coregonus albula, *Stizostedion lucioperca*, *Aspius aspius*	3

13. INLAND SEAS

There are two inland seas in the USSR, the Aral and Caspian Seas. Both have undergone marked biological and hydrological deterioration over the past three decades which has affected their fisheries adversely. These changes are the consequences of a combination of climatic and anthropogenic factors and unfortunately the magnitude of the latter continues to increase. The most important single change has been a progressive reduction in the volumes of water which reach these seas each year, which has been accompanied by steady falls in surface levels. The overall development of the unfavourable situation in these two water bodies is traced by Karpevich (1986), while Berdichevsky *et al.*, (1979) comment upon certain aspects.

13.1 THE ARAL SEA

It has been clear since 1960 that the shrinking area of the Aral Sea is largely due to human interference with the flow of the principal affluents, the Amu Darya and Syr Darya. In 1960 the waters of these two rivers began to be used for irrigation. Prior to 1960 they carried more than 60 km^3 of water to the Sea each year, but today they carry a mere 4 km^3/year and it is estimated that a minimum of 25 km^3/year is required to 'keep the sea alive'. Today the Syr Darya River disappears in the middle of fields although maps still show it as reaching the Aral Sea, while flow in the Amu Darya reaches the Sea only during the winter. Practically no water has reached the Aral Sea in summer since 1978, and in 1982 the surface was 9 m below its average level prior to 1960. Salinity of the water had reached 19‰ in open areas and 30‰ in the shallows. Progressive changes in the hydrology of the Aral Sea are depicted in *Figure 48*, and *Table 120*.

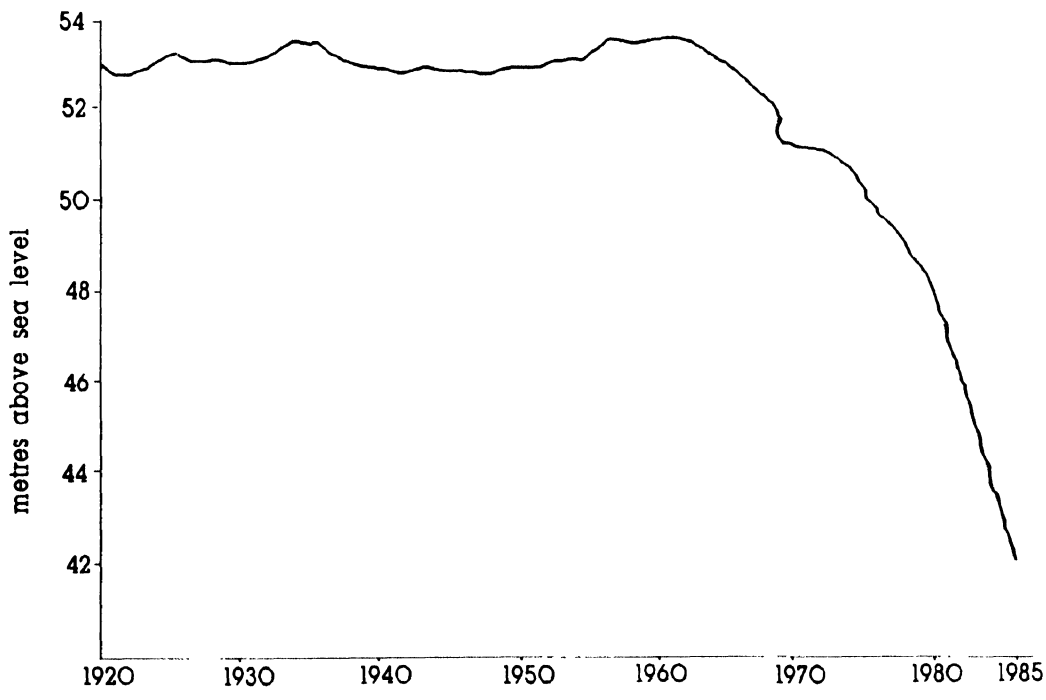


Figure 48. – Changes in the hydrology of the Aral Sea (in metres above world ocean sea level).

TABLE 120. – CHANGES IN THE HYDROLOGY OF THE ARAL SEA
(Karpevich, 1986)

Characteristic	Average for 1925-1960	1978	1982
Water inflow (km^3/year)	61.3	26.2	no data-
Water surface above sea level (m)	53.0	47.2	44.0
Water area (1000 km^2)	66.0	53.2	48.0
Volume of water (km^3)	1 070.0	734.0	563.0
Average depth (m)	16.4	13.8	no data-
Salinity ‰	10.1	15.0	19.2

TABLE 121. – SPECIES (I), BIOMASS (II) AND PRODUCTION (III) OF AQUATIC ORGANISMS IN THE ARAL SEA.

	Before 1960 (a)			1961-1970 (a)			1971-1978 (b)			1982-1984		
	I	II(c)	III(d)	I	II(c)	III(d)	I	II(c)	III(d)	I	II(c)	III(d)
Phytoplankton	68	150	1 000	-	120	700	-	129	-	-	-	-
Zooplankton	25	150	312	15	12	20	15	30	50	-	123	120
Macrobenthos	48	24	2 000	42	9	760	15	150	8 000	32[e]	321	-
Fish catch	20	6.9	32	34[f]	2.3	15	10	0.8	7	12[f]	-	-
of this:												
planktonophages	1	0.3	2.1	5	0.2	-	2	-	-	2	-	-
benthophages	16	4.2	26.5	25	0.6	5	7	0.3	2.9	9	-	-
predators	3	2.5	3.4	4	1.5	10	1	0.5	4.1	1	-	-

Notes

(a) data refer specifically to the endemic spp.

(b) invertebrates: - acclimated spp.; fish: -endemic spp.

(c) phytoplankton and zooplankton biomass in mg/m^3; macrobenthos in g/m^2; fish biomass in kg/ha

(d) average annual catch (in 1000 tons)

(e) includes 21 introduced species

(f) includes introduced species

(-) no data

The Aral Sea is an estuary type shelf reservoir. Prior to the reduction of water level a benthic food chain was predominant, *viz.* macrophytes - zoobenthos - benthic fish. Now the eastern shallows have disappeared so that a large part of the original macrophyte population has been lost. Many invertebrate species have disappeared from the plankton and benthos as a result of increased salinity and overall, the number of species and their biomass has declined significantly *(Table 121)*. Production of zooplankton decreased from a stable level of 200 000 tons before 1960 to 20 000 tons by 1984, while the production of zoobenthos declined from 2-3 million tons to 800 000 tons during the same period. The spawning grounds of important commercial species *e.g., Abramis brama, Cyprinus carpio, Rutilus rutilus caspius* and *Stizostedion lucioperca* have largely disappeared, and their feeding grounds have been drastically reduced.

Progressive changes in the Aral Sea fauna, monitored over the period 1978-1982, revealed that fresh water fish were slowly replaced by species more tolerant of salinity. In the zooplankton the biomass of *Calanipeda* increased dramatically to form almost 50% of the total (107 mg/m^3). An increase in salinity was anticipated 30 years ago and it was proposed, at that time, that the invertebrate fauna should first be restructured, followed by the fish fauna. This was to be achieved by the introduction of euryhaline and marine species. However, in practice the work did not follow the scheme elaborated and began with the introduction of fish, *Acipenser stellatus*, *Clupea harengus membrans* and *Mugil cephalus*. Of these, only *Clupea harengus membrans* adapted well, but its population remains small due to insufficient zooplankton food reserves. Attempts to reconstruct the stocks of invertebrate food species was better prepared. Large populations of the mysids *Paramysis intermedia* and *P. lacustris* were established together with lesser populations of *Abra ovata*, *Calanipeda aquadulcis* and *Nereis diversicolor*. These species have become major food sources for fish. Populations of predatory fish, *e.g. Aspius aspius* and *Stizostedion lucioperca*, increased threefold between 1964 and 1975; however, subsequent increases in salinity destroyed their food chain and thus the predators themselves, and they have now virtually disappeared. Freshwater benthophagic fish also disappeared from the Aral Sea after 1980.

As far as fisheries are concerned, the total commercial catch from the Aral Sea was close to 30 000 tons/year before 1960, but this had declined to 2 900 tons by 1977. Total fish productivity, which was estimated as 60 000 tons/year before 1960, was thought to have halved over this same period. All fishing on the Aral Sea was banned in 1978, after a final catch of 7 000 tons.

It has been suggested that future introductions should be of marine species, especially marine plants, including plankton, as salinity is expected to increase to 25-30‰ in open waters. Steps should be taken to increase the abundance of *Clupea harengus membrans*, by providing it with a better food base. Reconstruction will however, be hindered by fluctuations of water temperature since these have increased in recent years; the upper layers can now rise to 26°C in summer and fall to -1°C in winter. This regime suits Lena sturgeon which might therefore be introduced, but the cold winters rule out the Caspian sturgeon. Turbot is another cold resistant species which might acclimate well.

13.2 THE CASPIAN SEA

With an area of 371 000 km^2, the Caspian Sea is the largest endorheic lake in the world; it has no outflow but its rate of salinization is low. The average depth of the northern part is about 6 m and the surface here freezes for about 3 months of the year. The maximum depth of the southern part is 980 m. The water level and salinity depend largely upon influxes from affluent rivers. The salinity of the northern sector, which is warm in summer and rich in nutrients, is low, *c.*0-7‰, being fed by the Ural and Volga Rivers. This part of the sea is therefore important for the growth and nutrition of fish. Salinity reaches 12.6-12.9‰ in the southern and central sectors where the water is relatively warm to depths of 100-150 m, but below this temperatures of 4-8°C prevail. The central and southern sectors are less important for fish production than the north as the nutrient supply in them is largely provided by circulation and upwelling. As a consequence of its long isolation a characteristic fish fauna has developed in the Caspian Sea; most species are salt tolerant and 89% are endemic. The remaining 11% have either freshwater or marine affinities.

The abundance of freshwater fish in the sea has always depended upon the volumes of the spring flows in the affluent rivers, where the fish spawn, and upon the preservation of their natural spawning and feeding grounds. The larvae of the fish remain in fresh water for a period after hatching, then young fry move to waters of low salinity (0-3‰), while older fry and adults migrate to waters with salinities up to 8‰. All these conditions used to be available in the nutrient rich northern half of the Sea. The more euryhaline species, Acipenseridae, Salmonidae and *Stenodus leucichthys leucichthys*, used to migrate to the central and southern parts of the sea to feed and overwinter. Typical marine species, *e.g. Clupea harengus*, also inhabit the warm southern parts, feeding on pelagic zooplankton.

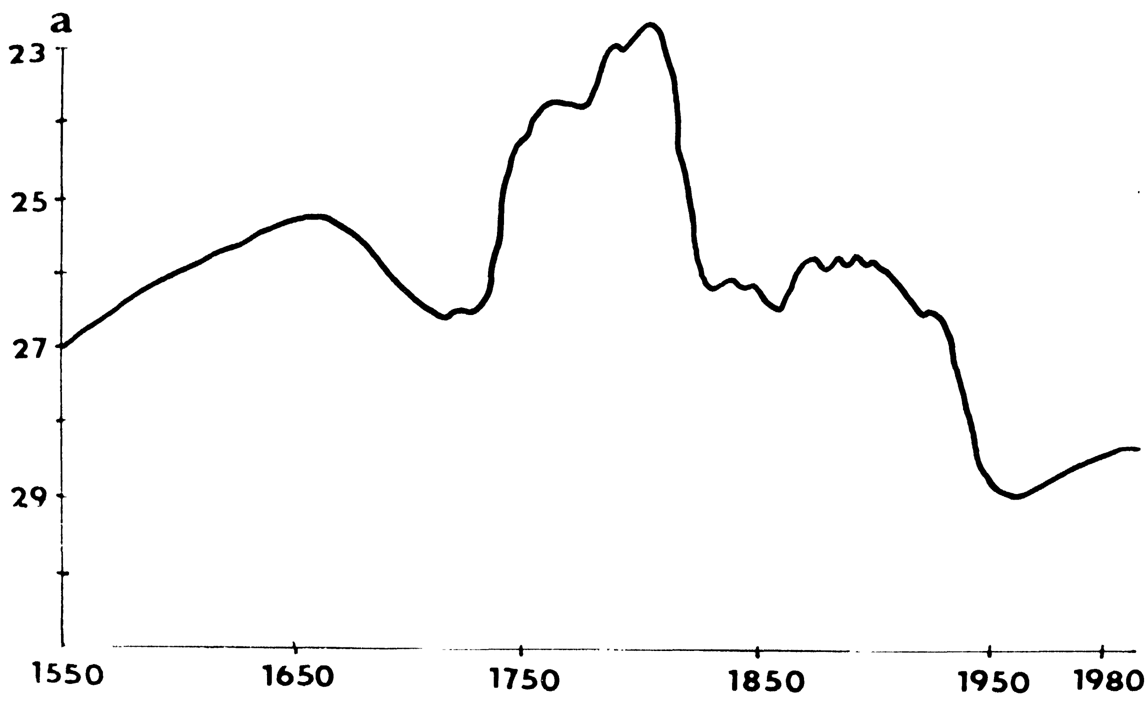


Figure 49. – Fluctuation of water level in the Caspian Sea

As the flow of water in the rivers, especially the Volga, has fluctuated and decreased, so the level of the Caspian Sea has fallen. The long term (1550-1980) fluctuation of the surface level is shown in *Figure 49.* The levels for the past 150 years are accurately documented, and reveal a steady decline between the years 1931-1950, to an absolute low value of 29 m below mean sea level. Many productive shallows around the northern part of the sea were desiccated during this period; the water surface fell by 2.5 m, the shore line receded by 30-50 km and salinity rose to 9-12‰. Abstraction of water, mainly from the Volga River, for irrigation, exacerbated the situation.

In addition to the progressive decrease in the absolute volumes of water which entered the sea, there were also changes in the seasonal patterns of influx. Perhaps most importantly, the spring influx declined markedly, adversely influencing the stocks of semi-migratory freshwater fish (*Abramis brama*, *Rutilus rutilus caspius* and *Stizostedion lucioperca*) and the typical migratory species (*Clupea harengus*, Salmonidae and Acipenseridae). A depletion of the food base for fish in the northern part of the sea also occurred at this time, partly due to the loss of aquatic vegetation in what were once shallows, and partly due to increasing salinity. Following this, biological productivity in the Caspian Sea then developed in two ways. An estuarine type of productivity came to prevail in the north, entirely dependent upon riverine influxes, while an oceanic type now prevails in the south. Here productivity depends upon the intrinsic circulation of the water masses, and utilises biogenic substances from the lower strata when and where upwelling takes place.

Further changes occurred in the ichthyofauna. Fish showing high growth rates (*e.g. Cyprinus carpio* and *Rutilus rutilus caspius*) became dominant among the benthophages in the north, quickly escaping predation pressure by virtue of their rapid growth. In consequence they came to comprise the bulk of the commercial catch, and now contribute up to 60% of the annual catch. After good spawning years these species are estimated to exploit up to 80% of the zoobenthos produced in the northern part of the sea. Their total annual biomass, *i.e.* the total catch (40 000-50 000 tons), plus the biomass consumed by predators, plus the biomass of survivors, is estimated to range between 100 000 and 120 000 tons. At the same time certain freshwater species disappeared from the northern part of the sea altogether, *e.g. Stenodus leucichthys leucichthys*, while the populations of some others were substantially diminished.

Facilities for rearing fish for release into the Caspian Sea are being built, in order to minimise or halt the decline of its fish stocks. Thirty-six hatcheries had been completed by 1984 and more have been built since then. Encouraging results have been obtained in hatcheries raising Acipenseridae, *Stenodus leucichthys leucichthys* and some semi-migratory species. However, in order to recover the natural spawning grounds, an annual influx of 120 km^3 of water from the Volga is needed.

After many dry years since the end of the 1970s river discharges increased again, exerting a favourable influence upon the Caspian Sea. The surface rose by 1 m and salinity in the north decreased. In the mid 1980s conditions remain favourable, with discharges from the Volga River being above the long term average. Thus there is presently a good base for the implementation of skillful fishery management measures. These should include the further development of stocks of food organisms, the rehabilitation of indigenous fish stocks, and the introduction of species tolerant of changing salinity. Measures to introduce and increase the abundance of planktonophages (*e.g.* Azov and Baltic herrings), benthophages and *Mugil cephalus* have been suggested. The introduction of herbivores to the northern part of the sea is also considered feasible. Past and potential fish production from the Caspian Sea is outlined in *Table 122.*

Under ideal conditions, the annual catch of Acipenseridae, which stood at 27 500 tons in 1975, could reach 50 000 tons, and the prevalence of commercially unimportant species is to be reduced by increasing predation pressure following the introduction of *Morone saxatilis*, *Oncorhynchus keta*, *O. kisutch*, *O. nerka*, *Salmo irideus* and some Black Sea species. In this way an additional annual yield of 50 000 tons is envisaged (Berdichevsky *et al.*, 1979). Introduction of these predators must be monitored so that an optimum ratio of predators to prey of 1:20 is achieved in the sea, with a ratio of 1:10 in catches.

There is scope to increase the fishing pressure on species of low economic value, such as *Atherina mochon pontica*, sculpines and some other species which compete for food with *Clupea harengus* and *Mugil cephalus*. The catch of low value species could then reach 100 000-200 000 tons annually. Aquaculture, particularly cage culture, is to be developed around the central and southern coasts, while in the north it is proposed to build a network of fish farms over 500 000 ha of the Volga delta (Berdichevsky *et al.*, 1979). Here, they say, outputs of 1-1.2 tons/ha could be achieved by exploiting the natural food base produced in fertilised ponds. Similar farms could be built on the deltas of other rivers entering the Caspian Sea.

TABLE 122. – FISH PRODUCTION, FROM BOTH CAPTURE AND FARMING, UNDER VARIOUS HYDROLOGICAL REGIMES IN THE CASPIAN SEA (in 1 000 tons)

	Annual average		Potential		
	1930-1939	1976-1978	optimum conditions	under stressful conditions	dominant fish groups
Based on natural fish resources					
Northern area	290-390	60	200-250	14-20	demersal
Central and southern areas	200	313	300-400	190-280	pelagic
Based on introductions and regular stocking	-	30 (est)	70-80	50-60	demersal
Total	490-590	373	570-730	254-360	-
of this:					
Commercially valuable species (% of total)	250-350 (50-60)	60 (16)	300-400 (55)	60-70 (24)	-

14. CONCLUSIONS

In the Soviet Union, as in many other countries, the interests of inland fisheries are often ranked last in order of priority among the various uses to which water resources are put. Further, anthropogenic effects, chief among which are water pollution and abstraction, arise from the preferred uses of water bodies and exert an adverse influence over capture fisheries. This combination of factors affects the overall economic performance of inland fisheries. However, Soviet inland capture fisheries have enormous potential by virtue of the large areas of lakes, reservoirs, cooling reservoirs, rivers and inland seas available for exploitation. Important management practices are being introduced to ameliorate the many adverse influences and to enhance fish stocks. The conversion of small lakes to fish farms, and the construction of fish farms in the shallow parts of reservoirs, are amongst the most promising new measures. These farms are highly productive and produce both market quality fish and material for stocking other water bodies. Outstanding results have also been obtained following the well-planned introduction of phytophagous species to warm water reservoirs, *e.g.* cooling reservoirs and the big reservoirs in the south. There is considerable potential for increasing fish yields through better utilisation of less economically valuable fish stocks and improved mechanisation of fishing.

REFERENCES

Abaiev, Yu.I., Market fish farming in inland lakes and reservoirs. Moscow, Pishchevaya promyshlennost,
1980 110p. (in Russian)

Altaiev, B.Sh., The problem of evaluating effectiveness of small reservoir management. *In* Perspektivy
1986 rybokhozyaistvennogo ispol'zovanyia vodokhranilishch, Moscow, pp.7-8 (in Russian)

Aslanov, G.A., Results of electro-fishing in inland water bodies and tasks in the field of introducing new
1975 fishing methods. *In* Elektrolov ryby vo vnutrennikh vodoemakh. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.* (96):21-24 (in Russian)

.... Technology of commercial electro-fishing. Moscow, Pishchevaya promyshlennost, 214p.
1980 (in Russian)

Aslanov, G.A. and V.Ya. Solov'ev, Improving net fishing in inland water bodies. *Rybn.Khoz.*, (6):57-8
1985 (in Russian)

Avakyan, A.B. and V.A. Sharapov, Soviet reservoirs as water bodies with fishery management. *In*
1986 Perspektivy rybokhozyaistvennogo ispol'zovaniya vodokhranilishch, Moscow, pp.4-5 (in Russian)

Balashev, R.I., Present state and prospects of coregonid management in the lake farms of the Soviet
1976 north-west. *In* Razvitie intensivnykh ozernykh khozyaistv na baze vyrashchivaniya sigovykh ryb. Leningrad, GosNIORKH, pp.18-22 (in Russian)

Baranov, I.V. and E.I. Lichareva, Importance of primary production in improving fish productivity in
1981 lakes of the Leningrad region. *In* Bioproduktsionnye faktory abioticheskoi sredy v vodoemakh raznogo troficheskogo tipa. *Izv.Gos.Nauchno-Issled Inst.Ozern.Rechn. Rybn.Khoz.* (164):3-16 (in Russian)

Belov, E.V. and O.G. Lavrova, Organisation of lake market fish farms and problems in their
1976 management. *In* Razvitie intensivnykh ozernykh khozyaistv na baze vyrashchivaniya sigovykh ryb. Leningrad, GosNIORK, pp.13-7 (in Russian)

Berdichevsky, L.S., B.V. Verigin and B.G. Ioganzen, Biological bases for improving fish production and
1979 fisheries development in inland water bodies. *In* Biologicheskie resursy vnutrennikh vodoemov SSSR. Moscow, Nauka, pp.15-36 (in Russian)

Berka, R., Fisheries and fish culture in the Soviet Union. *Stud.Inf. (Zivoc.Vyr.)*, Prague (6): 104p.
1978 (in Czech)

............................The transport of live fish: a review. *EIFAC Tech.Pap.*, (48):52p.
1986

Bogdanov, G.A. and M.A. Pavlov, Ways of intensifying fisheries in inland water bodies. *In* Biologicheskie
1985 resursy gidrosfery - voprosy ekonomiki. Moscow, Nauka, pp.79-81 (in Russian)

Bugai, K.S., Reproduction of fish in the lower Dnieper River. Kiev, Naukova dumka, 214 p. (in Russian)
1977

Bul'on, V.V., Dependence of fish productivity upon primary production in water bodies.
1983 *Sb.Nauchn.Trud.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (196):3-11 (in Russian)

Burcev, I.A. and A.D. Gershanovich, Acclimation of paddlefish in the USSR. *Rybn.Khoz.*, (10):13-6
1976 (in Russian)

Butorin, N.V. (ed.), Ivan'kovskoe reservoir and its life. Leningrad, Nauka, 304 p. (in Russian)
1978a

............................The Volga River and its life. Leningrad, Nauka, 349 p. (in Russian)
1978b

Demchenko, M.F., Commercial and biological characteristics of the pike-perch population in the
1982 Kremenchug reservoir. *Rybn.Khoz.*, Kiev, (35):42-8 (in Russian)

Denisov, L.I., Fishing in reservoirs. Moscow, Pishchevaya promyshlennost, 284 p. (in Russian)
1978

.............................The present state of, and ways of improving the fisheries of inland water bodies of the
1980 Ukrainian SSSR. *Rybn.Khoz.*,Kiev, (31):13-21 (in Russian)

Dmitrenko, Yu.Yu., Growth and food of peled in the lakes of Karelia. *Rybn.Khoz.*, (9):32 (in Russian)
1983

Erofeev, Yu.Yu., Management of lakes supporting polyculture of coregonids. *In* Promyshlennaya
1983 gibridizatsiya ryb. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (195):71-80
(in Russian)

Evgrafov, N.S. and A.M. Kershtein, Market fish farming in lakes: present state and prospects. *In*
1985 Biologicheskie resursy gidrosfery: voprosy ekonomiki. Moscow, Nauka, pp.91-7
(in Russian)

FAO, FAO Yearbook Fishery statistics, catches and landings 1987. *FAO Fish. Series* No.32. Rome, Italy
1989

Fedorova, G.V. (ed.), Fish resources of the Ladoga Lake. *Izv.Gos.Nauchno-Issled.Inst.Ozern. Rechn.*
1977 *Rybn.Khoz.*, (125):132 p. (in Russian)

.... Biology and commercial fisheries in the large lakes of the north-west region.
1980 *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (159):117 p. (in Russian)

.... Biology and utilisation of commercial fish in Lagoda Lake. *Izv.Gos.Nauchno-*
1982 *Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (179): 128p. (in Russian)

.... Abundance of commercial fish in Lagoda Lake and their utilisation. *In* Biologiya,
1985 chislennost i ratsional'noe ispol'zovanie ryb vodoemov Severo-Zapada. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (237):3-12 (in Russian)

Holcík, J., Some problems of fish introduction. *In* Perspektivní druhy ryb pro CSSR. Vodnany, CSVTS,
1987 pp.7-26 (in Czech)

Ioganzen, B.G., R.G. Pushkina and G.P. Siginevich, Productivity of water bodies in different climatic
1980 zones of the Russian SFSR and the prospects of their utilisation for fisheries.
Vopr.Ikhtiol., 20(2):378-81 (in Russian)

Isaev, A.I. and E.I. Karpova, Fisheries in reservoirs. Moscow, Pishchevaya promyshlennost, 303 p.
1980 (in Russian)

Karpevich, A.F., Changes in the hydrological regime, environment and bioproductivity of the Aral and
1986 Caspian Seas. *In* Antropogennye vozdeistviya na pribrezhno-morskie ekosistemy. Moscow, VNIRO, pp.12-34 (in Russian)

Kazakov, R.V., Basic ways of freshwater fish production in the USSR. *In* Biologiya i promysel ryb
1980 krupnykh ozer Severo-Zapada. *Nauch. Tr.*, (159):3-9 (in Russian)

Kazanski, A.B., Study of the Tsimlyansk reservoir fish population by means of mathematical modelling.
1982 *Vopr.Ikhtiol.*, 22(3):355-64 (in Russian)

Kirilenko, L.V., Stocking lakes with pike-perch. *Rybn.Khoz.*, (6):32 (in Russian)
1984

Kirillov, F.N., Fisheries utilisation of the Vil'yuskoe reservoir. *In* Rybokhozyaistvennoe osvoenie
1977 vodokhranilishch Sibiri. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (115):24-36 (in Russian)

Kitaev, S.P., Ecological basis of lake bioproductivity. Moscow, Nauka, 206 p. (in Russian)
1984

Knyazev, A., Inland water bodies: reproduction of fish resources. *Rybov.Rybolov.*, (5):5 (in Russian)
1981

Kokhanova, G.D., Tasks and prospects of the Dnieper rearing farms. *Rybn.Khoz.*, Kiev, (31):30-4
1980 (in Russian)

Koskova, L.A., Evaluation of fish reproduction effectiveness in the shallows of the Saratov dam reservoir.
1984 *In* Biologiya vnutrennikh vod. *Inf.Byull.*, Leningrad, (62):41-4 (in Russian)

Kotljar, N., Stand und Perspektiven von Fischzucht und Fischfang in den Binnengewässern der UdSSR.
1988 *Z.Binnenfisch.DDR* (2):378-81

Koval', N.V., Ecology of the young commercial fishes of the Kremenchug dam reservoir. *Gidrobiol.Zh.*,
1979 (5):44-8 (in Russian)

............................Population and commercial fisheries of pike-perch in the Tsimlyansk reservoir.
1982 *Rybn.Khoz.*, (5):37-9 (in Russian)

Kozhevnikov, G.P. (ed.), The Gorky reservoir. *Nauch.Tr.Gos.Nauchno-Issled.Inst.Ozern. Rechn.*
1979 *Rybn.Khoz.*, (142):167 p. (in Russian)

Krasnokutsky, V.N., Method of calculating the economic productivity of a water body. *Rybn.Khoz.*,
1978 (9):84-7 (in Russian)

Krupitsky, Yu.G., *et al.*, Protection of fish resources and improving the productivity of water bodies.
1982 *Rybn.Khoz.*, (1):18-27 (in Russian)

Kudersky, L.A., Scientific basis of lake fishery intensification. *In* Biologiya promyslovykh ryb i
1977 intensifikatsiya ozernogo rybovodstva. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn. Rybn.Khoz.*, (111):3-16 (in Russian)

.... Effect of waterworks on fisheries. *In* Rybokhozyaistvennoe osvoenie vodokhranilishch
1977a Sibiri. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (115):4-16 (in Russian)

....................Present state, and ways to develop lake and reservoir fisheries. *Sb.Nauch.Tr.Nauchno-*
1981 *Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (117):3-15 (in Russian)

.... Present state of fisheries use of reservoirs. Moscow, Nauka, pp.266-77 (in Russian)
1984

.... Present state of reservoir fisheries and their prospects . *In* Perspektivy
1986 rybokhozyaistvennogo ispol'zovaniya vodokhranilishch. Vsesoyuz.soveshch., Kiev. Moscow, pp.43-5 (in Russian)

Kudersky, L.A., B.V.Verigin and B.G. Ioganzen, Basic trends in the commercial utilisation and
1982 management of the biological resources of inland water bodies. *Gidrobiol.Zh.*, 18(5):15-26 (in Russian)

Labanov, Yu.V. and S.V. Tikhonov, Modelling of lake fish populations. *Vopr.Ikhtiol.*, 25(6):925-32
1985 (in Russian)

Lapicki, I.I., *et al.*, Standards for rearing two year old silver and bighead carp in ponds for stocking
1982 the Tsimlyansk reservoir. *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (180):11-27 (in Russian)

Laptanovich, A.M., Development of fish farming and fisheries in small and medium sized lakes in the
1976 framework of the Ministry of Fisheries of the Russian SFSR in the period 1971-1973. *In* Razvitie intensivnykh ozernykh khozyaistv na baze vyrashchivaniya sigovykh ryb. Leningrad, GosNIORKH, pp.3-12 (in Russian)

Lavrent'eva, G.M., Present state and prospects of fisheries management in lakes and reservoirs.
1976 *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (94):215 p. (in Russian)

Lukin. A.V., (ed.), Regularities of the fauna developing in the Kuibyshev reservoir. Kazan',izd.
1977 Kazan Universiteta, 116 p. (in Russian)

L'vova, L.M. and Yu.T. Sechin, Some problems of fish capture in market production in lake fish farms.
1984 *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (215):174-8 (in Russian)

Maizelis, M.R., Present state of electrofishing in inland water bodies of the Russian SFSR, and prospects
1975 of developing both electro-fishing and other fishing methods. *In* Elektrolov ryby vo vnutrennikh vodoemakh. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (96):4-20 (in Russian)

Maizelis, M.R. and G.M. Mishelovich, Manual for application of the fish barrier, type ERZU-1.
1973 *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (91):3-24 (in Russian)

Maizelis, M.R., G.M. Mishelovich and V.A. Strakov, Some theoretical and practical problems of the
1974 electric fish barrier, type ERZU-1. *In* Promyshlennoe rybolovstvo na vnutrennikh vodoemakh. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (90):52-75 (in Russian)

Maizelis, M.R. and L.M. Nusenbaum, Manual for electro-fishing gear and electric fish barrier utilisation
1973 in inland water bodies. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (91):3-31 (in Russian)

Makhotin, Yu.M., Effectiveness of fish reproduction in the Kuibyshev reservoir and factors
1977 influencing it. *Vopr.Ikhtiol.*, 17(1):27-38 (in Russian)

Malashkin, N.N. *et al.*, Fish farming in three-year cycles in lake farms. *In* Sostoyanie i perspektivy
1976 rybokhozyaistvennogo osvoeniya ozer i vodokhranilishch. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (94):103-11 (in Russian)

Mamontov, A.M., Fishes of the Bratsk reservoir. Novosibirsk, Nauka, 246 p. (in Russian)
1977

Mishelovich, G.M., Calculation of the electric parameters of the electric fish barrier. *In* Voprosy
1974 rybokhozyaistvennogo izucheniya presnovodnykh vodoemov SSSR. *Tr.Gos.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (92):188-201 (in Russian)

Monakov, B.D., Basic trends in development of fisheries in inland water bodies. *Rybn.Khoz.*,(5):6-10
1981 (in Russian)

.... Development of fisheries in Soviet inland water bodies in the period of the eleventh
1982 five-year plan. *Rybn.Khoz.*, (5):5-9 (in Russian)

............................(ed.),The Kuibyshev reservoir. Leningrad, Nauka, 215 p. (in Russian)
1983

.... Scientific and technological progress in fisheries. *Rybovodstvo*, (1):2-3 (in Russian)
1986

Moskul, G.A. *et al.*, Some results of stocking silver and bighead carp in the multi-purpose water bodies of
1982 North Caucasus. *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (180):30-5 (in Russian)

Mukhachev, I., Fish farming in lakes - advanced technology. *Rybovodstvo*, (3):24-6 (in Russian)
1986

Mukhamedova, A.F., Some data on stocking phytophagous fishes in the Tsimlyansk reservoir.
1982 *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (80):53-67 (in Russian)

Negonovskaya, I.T., Basic trends in research on biological resource utilisation of reservoirs. *In*
1982 Rybokhozyaistvennoe osvoenie vodokhranilishch Severnogo Kavkaza. *Sb.Nauch.Tr. Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (186):3-42 (in Russian)

............................Fish production potential and forms of fisheries organisation in different types of
1986 reservoirs. *In* Perspektivy rybokhozyaistvennogo ispol'zovaniya vodokhranilishch, Moscow, pp. 60-3 (in Russian)

Negonovskaya, I.T. and E.P. Tsiplyakov, Fishing for species of low commercial value during the
1984 spawning period. *In* Biologicheskie osnovaniya k usovershenstvovaniyu deistvuyushchikh pravil rybolovana vodokhranilishchakh Volzhsko-Kamskogo kaskada, Leningrad. *Sb.Nauch.Tr.Nauchno-Issled.Inst. Ozem.Rechn.Rybn.Khoz.*, (210):66-76 (in Russian)

Niyazov, N.S., Polyculture farming of a peled hybrid in the lakes of West Siberia. *Rybn.Khoz.*, (2):36-38
1983 (in Russian)

Norenko, D.S., Fisheries in Baikal Lake. *Rybn.Khoz.*, (12):18-9 (in Russian)
1976

Obukhov, N.N. and O.G. Lavrova, Present state and prospects of fish farming in lakes.
1984 *Rybn.Khoz.*, (4):47-8

Oganesyan, R.O. and A.I. Smolei (eds), Ecology of the Sevan Lake hydrobionts. *Izv.Akad.Nauk*
1979 *Armyan . SSR*, (17): 232 p. (in Russian)

Ozinkovskaya, S.P., Acclimation of phytophagous fishes in the reservoirs of the Dnieper cascade.
1982 *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (180):36-52 (in Russian)

Ozinkovskaya, S.P. and I.S. Chechun, Estimation of population and fisheries utilisation of silver and
1981 bighead carp in the Kakhovskoe reservoir. *Rybn.Khoz.*, Kiev, (33):48-51 (in Russian)

Ozinkovskaya, S.P. and I.K. Malitsky, Possibility of the specialised fishing for silver and bighead carp in
1983 the Kakhovskoe reservoir. *Rybn.Khoz.*, (6):36-7 (in Russian)

Pakhorukov, A.M., Study of the distribution of young fish in lakes and reservoirs. Moscow, Nauka,
1980 65 p. (in Russian)

Pavlov, D.S., Structures assisting non-salmonid fish: USSR. *FAO Fish.Tech.Pap.* 308, 101p.
1989

Pankratova, E., Reservoirs: problems of fisheries management. *Rybovodstvo*, (6):11-2 (in Russian)
1986

Pankratova, E. and A. Strel'nikov, Methods of estimating abundance of fish in inland water bodies.
1984 *Rybov. Rybolov.*, (12):5 (in Russian)

Pechnikov, A.S., Effects of intensive fishing on fish resources in lakes. *In* Rybokhozyaistvennoe
1980 izuchenie vodoemov. *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (28):10-3
(in Russian)

Perevoznikov, M.A., Basic principles of ichthyocide application into lakes. *In* Khimicheskie sredstva
1979 zashchity tsennych vidov ryb. *Nauch.Tr.Nauchno-Issled.Inst.Ozern.Rechn. Rybn.Khoz.*,
(146):14-22 (in Russian)

Petrov, S.G., Utilisation of the fish barrier ELU-1 in the Tobel River. *In* Elektrolov ryby vo vnutrennikh
1978 vodoemakh. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (90):54-5 (in Russian)

Pikush, N.V. and P.G. Sukhoivan, Evaluation of fish productivity in the Dnieper reservoirs.
1978 *Gidrobiol.Zh.*, 14(4):49-51 (in Russian)

Poddubnyi, A.G. *et al.*, Effectiveness of fish reproduction in reservoirs. *In* Biologicheskie resursy
1984 vodokhranilishch, Moscow, Nauka, pp.204-27 (in Russian)

Pokrovski, V.V. (ed.), Fishery cadastre of the small lakes in the Leningrad region. *Izv.Gos.Nauchno-*
1977 *Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (124):168 p. (in Russian)

.... Fishery cadastre of the small lakes in the Leningrad region. *Sb.Nauch.Tr.Nauchno-Issled.*
1980 *Inst.Ozern.Rechn.Rybn.Khoz.*, (148):102 p. (in Russian)

............................Fishes of Onega Lake and their commercial utilisation. *Sb.Nauch.Tr.Nauchno-Issled.Inst.*
1983 *Ozern.Rechn.Rybn.Khoz.*, (205):168 p. (in Russian)

Pushkina, R.G., Basic trends in improving the fish productivity of the Bratsk reservoir. *In*
1977 Rybokhozyaistvennoe osvoenie vodokhranilishch. *Izv.Gos.Nauchno-Issled.Inst.Ozern.*
Rechn.Rybn.Khoz., (115):55-64 (in Russian)

Reshetnikov, Yu.S., Coregonids in lake ecosystems. Warsaw, Third European Ichthyological Congress,
1979 4 p.

Reshetnikov, Yu.S. and A.N. Severtsev, Changes in the fish communities of lake ecosystems under recent
1981 conditions. *In* Topical problems of Ichthylogy (Proc.Symp., Brno-Czechoslovakia),
pp.113-118

Rolle, N.N., Optimum fisheries utilisation of reservoirs. *In* Ratsional'noe ispol'zovanie prirodnykh
1984 resursov i okhrana okruzhayushchei sredy, Leningrad, (7):83-86

Rudenko, G.P., Tasks of research on fisheries intensification in the small lakes of the north-west region.
1977 *In* Biologiya promyslovykh ryb i intenzifikatsiya ozernogo rybovodstva. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (111):17-27 (in Russian)

.... Biological basis for rational utilisation of small lakes. *Sb.Nauch.Tr.Nauchno-Issled.Inst.*
1984 *Ozern.Rechn.Rybn.Khoz.*, (223):34-42 (in Russian)

Rudenko, G.P. and G.L. Mel'nichuk, Present state and prospects of fisheries development in small lakes
1979 of the north-west region. *In* Rybokhozyaistvennoe osvoenie vnutrennikh vodoemov Severo-Zapada. Leningrad, GosNIORKH, pp.29-37 (in Russian)

Rudenko, G.P. and A.S. Pechnikov, Small lakes: fish productivity and fisheries management. *Rybn.Khoz.*
1988 (1.):69-72 (in Russian)

Rudenko, G.P. and A.A. Umnov, Fisheries characteristic of various small lakes in the north-west region
1982 of the European part of the USSR. *Vopr.Ikhtiol.*, 22(5):746-59 (in Russian)

Ruzanov, V.I., *et al.*, Regulation of fisheries in inland water bodies. *Rybn.Khoz.*,(4):44-6 (in Russian)
1984

Sechin, Yu.T., Development of trawl fishing in reservoirs. *In* Promyshlennoe rybolovstvo na
1980 vnutrennikh vodoemakh. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (151):8-88 (in Russian)

.... Present technological research on fishing in inland water bodies. *Rybn.Khoz.*, (5):53-5
1986 (in Russian)

Shaurin, Ya.P., I.M. Safonov and A.B. Vaverin, Development of electro-fishing gear for inland water
1975 bodies. *In* Elektrolov ryby vo vnutrennikh vodoemakh, (96):176-188

Shchukina, A.A., Annual food consumption and food coefficients of fish in the Kuibyshev reservoir.
1980 *In* Biologiya vnutrennikh vod. *Inf.Bull.*, Leningrad, (47):49-50 (in Russian)

Shimanovskaya, L.N., To the problem of predicting fishing effectiveness *In* Sostoyanie rybnogo
1977a khozyaistva vnutrennikh vodoemov i metody prognozirovaniya rybnykh zapasov. *Izv.Gos.Nauchno-Issled. Inst.Ozern.Rechn.Rybn.Khoz.*, (126):63-8 (in Russian)

.... Fisheries utilisation of large lakes in the north-west region of the Russian SFSR.
1977b *In* Biologicheskie osnovy ratsionalnoi ekspluatatsii rybnykh zapasov v krupnykh vodoemakh Severo-Zapada. *Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (116):3-12 (in Russian)

.... Area of the Siberia reservoirs and their utilisation for fisheries.
1977c *In* Rybokhozyaistvennoe osvoenie vodokhranilishch Sibiri. *Izv.Gos.Nauchno-Issled.Inst.Ozern. Rechn.Rybn.Khoz.*, (115):17-23 (in Russian)

Shimanovskaya, L.N., Tanasiichuk, L.N. and A.S. Sulimov, Fisheries utilisation of the reservoirs of
1986 the Russian SFSR. *In* Perspektivy rybokhozyaistvennogo ispol 'zovaniya vodokhranilishch Moscow, pp.106-7 (in Russian)

Shimanovskaya, L.N., *et al.*, Fisheries utilisation of Soviet inland water bodies in the period 1971-1975.
1979 *In* Sostoyanie rybnogo khozyaistva vnutrennikh vodoemov i metody prognozirovaniya

rybnykh zapasov. *Izv.Gos.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (141):3-28 (in Russian)

............................Fisheries utilisation of Soviet lakes, rivers and reservoirs. *In* Rybnoe khozyaistvo
1983 vnutrennikh vodoemov i perspektivy ego razvitiya. *Sb.Nauch.Tr.Nauchno-Issled.Inst.Ozem. Rechn.Rybn.Khoz.*, (193):3-91 (in Russian)

Shirkova, A.P., Effect of fishing on populations of coregonids and pike-perch in Lagoda Lake.
1977 *In* Biologicheskie osnovy ratsional'noi ekspluatatsii rybnykh zapasov v krupnykh vodoemakh Severo-Zapada. *Izv.Gos.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (116):36-45 (in Russian)

Skorupskas, E.F., Fisheries evaluation of lakes and reservoirs. Vil'nyus, Mokslas, 95 p. (in Russian)
1986

Solov'ev, Yu.Ya., Mechanisation of fishing processes in lakes and reservoirs. *In* Voprosy
1984 prognoznogo obespecheniya rybnogo khozyaistra na vnutrennikh vodoemakh. *Sb.Nauch.Tr. Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (215):208-16 (in Russian)

Speshilov, L., *et al.*, Possibilities of artificial spawning grounds. *Rybovodstvo*, (4):18-20 (in Russian)
1985

Stergilov, A.V. and G.E. Novosel'tsev, Calculation of the productivity potential of the coregonid rearing
1980 farms, together with energetic and food requirements of the fish. *In* Biologiya vnutrennikh vod. *Inf.Bull.*, Leningrad, (47):58-60 (in Russian)

Strakhov, V.A., Application of electric fish barriers in the concentrated fishing of migrating species.
1975 *In* Elektrolov ryby vo vnutrennikh vodoemakh. *Izv.Gos.Nauchno-Issled.Inst.Ozem. Rechn.Rybn.Khoz.*, (96):56-62 (in Russian)

Strel'nikov, A.S., V.M. Volodin and M.M. Smetanin, Ichthyofauna development and the structure of fish
1984 populations in reservoirs. *In* Biologicheskie resursy vodokhranilishch. Moscow, Nauka, pp.161-204 (in Russian)

Studenecki, S.A., Basic trends in development of fisheries in the inland water bodies of the USSR.
1979 *In* Biologicheskie resursy vnutrennikh vodoemov SSSR. Moscow, Nauka, pp.5-15 (in Russian)

Titova, G.D., Intensification - basic trends in the development of fisheries in medium and small lakes.
1976a *In* Voprosy ekonomiki rybnogo khozyaistva vnutrennikh vodoemov. *Izv.Gos. Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (106):3-11 (in Russian)

.... Economic evaluation of intensification in lake fisheries. *In* Voprosy ekonomiki rybnogo
1976b khozyaistva vnutrennikh vodoemov. *Izv.Gos.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (106):12-23 (in Russian)

.... Economic evaluation of fisheries intensification in small and medium sized lakes.
1984 Moscow, Legkaya i pishchevaya promyshlennost, 102 p. (in Russian)

Treshchev, A.I., Intensity of fishing. Moscow, Legkaya i pishchevaya promyshlennost, 236 p. (in Russian)
1983

Tsyplakov, E.P., Prediction of fish catch in the Kuibyshev reservoir. *In* Sostoyanie rybnogo
1977 khozyaistva vnutrennikh vodoemov i metody prognozirovaniya rybnykh zapasov. *Izv.Gos.Nauchno-Issled.Inst.Ozem.Rechn.Rybn.Khoz.*, (26):93-8 (in Russian)

............................Possibilities in production of fish in the Kuibyshev reservoir. *In* Biologiya
1980 vnutrennikh vod. *Inf.Bull.*, Leningrad, (47):46-9 (in Russian)

Turner, G.E., Code of practice and manual of procedures for consideration of introductions and
1988 transfers of marine and freshwater organisms. *EIFAC/CESPI Occasional Paper* No.23, 44p.

Umnov, A.A. and G.P. Rudenko, Estimation of average fish abundance, biomass and productivity in
1979 small lakes: a bio-mathematical model for predicting populations. *Gidrobiol.Zh.*, 15(1):43-9 (in Russian)

Vladimirova, K.S., Shallows of the Kremenchug reservoir. Kiev, Naukova dumka, 280 p. (in Russian)
1979

Voit, I.Ya., Pair trawling in small and medium-size lakes. *In* Promyshlennoe rybolovstvo na vnutrennikh
1983 vodoemakh. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (193):3-18 (in Russian)

Volcrman, I.B., *et al.*, Dynamics of fish production in Baikal Lake. Novosibirsk, Nauka, 238 p.
1983 (in Russian)

Volodin, V.M., Some features in the development and structure of bream populations in the Volga
1981 reservoirs. *In* Biologiya vnutrennikh vod. *Inf.Bull.*, Leningrad, (51):42-8 (in Russian)

Voronin, V., *et al.*, Some results of ecosystem reconstruction. *Rybovodstvo*, (5):13-4 (in Russian)
1987

Vovk, P.S. and L.I. Stetsenko, Phytophagous fishes in the ecosystem of reservoirs. Kiev, Naukova
1985 dumka, 135 p. (in Russian)

Vyatchanina, L.I., Fisheries utilisation of dam reservoirs of the Dnieper cascade and methods of
1980 improving their fish production. *Rybn.Khoz.*, Kiev, (31):3-9 (in Russian)

Vyatchanina, L.I. and M.F. Demchenko, Fertility dynamics of commercial fishes in the Kremenchug
1981 reservoir - Part II. *Rybn.Khoz.*, Kiev, (33):34-58 (in Russian)

Yankovskaya, L.A., Results of introduction of coregonids into reservoirs. *Sb.Nauch.Tr.Nauchno-*
1982 *Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (180):96-115 (in Russian)

Yudanova, R.S. and L.P. Fil'chagov, Utilisation of fish barriers in pumping stations of the south of the
1975 Ukrainian SSR. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (107):156-60 (in Russian)

Zhakov, L.A., Development and structure of populations in lakes stocked with fish in the north-west
1984 region of the USSR. Moscow, Nauka, 143 p. (in Russian)

Zhukov, P.I., Fish resources of the Byelorussian SSR. Minsk, Urozhai, 127 p. (in Russian)
1983

Zimbalevskaya, L.N. (ed.), Shallows of the Kremenchug reservoir. Kiev, Naukova dumka, 284 p.
1979 (in Russian)

Zonov, A.I., Manual for the total fishing of small lakes. Leningrad, GosNIORKH, 19 p. (in Russian)
1974

....................Determination of the optimum length of electrodes. *In* Promyshlennoe rybolovstvo na
1974a vnutrennikh vodoemakh. *Tr.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz.*, (90):47-51 (in Russian)

....................Intensification of lake fish farming. *In* Promyshlennoe rybolovstvo na vnutrennikh
1980 vodoemakh. Leningrad, GosNIORKH - Nauch.Trudy, (151):3-8 (in Russian)

....................(ed.), Commercial fisheries in inland water bodies. *Sb.Nauch.Tr.Nauchno-Issled.Inst.*
1983 *Ozern.Rechn.Rybn.Khoz.*, (198): 236 p. (in Russian)

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