

# ATTACHMENT

## Ivan'kovskoe Reservoir

Ivan'kovskoe reservoir was created in 1938 by closing the Volga river waterway in the area of the town of Dubna.

### *Major Specifications*

Type:	River-like
Water surface area:	3,278.0 km <sup>2</sup>
Volume:	1.12 km <sup>3</sup>
Length:	133 km
Maximum width:	8.0 km
Average depth:	3.4 m
Maximum depth:	20.0 m
Average annual water intake:	
through Ivan'kovskaya HPP	7.74 km <sup>3</sup>
through Moscow Channel	6.82 km <sup>3</sup>
Annual water exchange coefficient:	13

The major HPP facilities include the following: locks for navigation, concrete dam with eight openings designed for the maximum flow rate of 7,350 m<sup>3</sup>/sec and the hydroelectric station itself. The Ivan'kovskaya HPP is a low head facility, with the headwaters/tailwaters water level difference of 11.0 m and the headwaters depth of 20.0 m.

The HPP power unit is located between the two (300 m from the right shore and 330 m from the left shore) dams. The power unit consists of two Kaplan turbines with the maximum water flow rate of 130 m<sup>3</sup>/s. The width of clearance between the runner blades is 10 mm, and the height of this clearance is 0.9 m. The water is taken to the turbine from the gateway, the upper edge of which is located 9.5 m deep and the lower edge is located 0.5 meters above the bottom.

The most fish species in the reservoir are as follows<sup>1</sup>: carp bream, roach, Northern pike, pikeperch, European perch, bleak, silver bream, ruffe. The following species are rare: asp, burbot, dace, Wels catfish, chub, ziege, crucian carp. carp, nase, blue bream, rudd, ide, tench, European smelt, moderlieschen, European eel, gudgeon, and bullhead.

The species that are caught for commercial needs are as follows: carp bream, Northern pike, roach, and European perch. In 1978 –1988, 200 – 450 t of fish were caught in the

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<sup>1</sup> Note of the translator: Here and below please refer to scientific names of fish given in Table 1.2.

reservoir annually. The commercial fish yield of the reservoir is 7 – 14 kg/hectare, but taking into account amateur fishing it is about 15 – 20 kg/hectare (Isaev, Karpova, 1989).

**Table 1 Data obtained on the reservoir**

Parameter	1979 - 1980	1989 – 1990
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Fish downstream migration through the HPP dam

Number of:

Daily fish catching stations	36	45
Ichthyological samples	1,442	924
Fish caught	1,596	3,044

Distribution of young fish near the dam

Number of:

Ichthyological samples	131	81
Fish caught	13,000	403

**Table 2 Species specific structure of migrants, %**

Species	1979 - 1980	1989 - 1990	Species	1979 - 1980	1989 – 1990
Bleak	30.4	29.3	Pikeperch	9.2	8.5
Carp bream	10.0	24.6	European Smelt	5.7	*
European perch	25.5	22.7	Ruffe	9.0	*
Roach	3.1	10.9	Other	7.1	4.0

\* Included in “Other” row.

**Table 3 Age of migrants, %**

Species	Prolarvae	Early larvae	Late larvae	Fry	Fish age	
					0+	≥ 1+
Bleak	0	12	50	38	36	64
Carp bream	0.2	3.8	1	95	66	34
European perch	0	17	62	21	45	55
Pikeperch	2	37	16	45	93	7
Roach	0	0	4	96	20	80
Other	-	-	-	-	70	30
Average	1	12	25	62	49	51

The fish downstream migration through Ivan’kovskaya HPP was studied in 1979 – 1980 and 1989 – 1990. These studies included year-round observations on the intensity of migration through the HPP turbines and observations on the young fish distribution near the HPP dam from June through August. The scope of the data is given in Table 1.

Over 20 species have been observed as downstream migrants. The information on the major migratory species is given in Table 2. Other migrants were as follows: silver bream, ziege, bullhead, gudgeon, Volga pikeperch, carp, ide, asp, Moderlieschen, burbot, Northern pike, European eel, Wels catfish, European smelt, and ruffe. The following species are the most exposed to downstream migration: bleak, carp bream, European perch, and roach.

Practically all age groups are presented in the reservoir, from prolarvae to adult fishes. On the whole, for small size species, there are more migrants over 1 year old and older (bleak and roach), while for large size fish (pikeperch and carp bream), the situation is just the reverse, i.e., there are more younger migrants (see Table 3). As fry, carp bream and roach migrate the most, while as prolarvae and larvae, bleak, European perch and pikeperch migrate the most.

The average concentration of the migrants in 1979 – 1980 was 5.09 /1,000 m<sup>3</sup>, and in 1989 – 1990 – 1.82 /1,000 m<sup>3</sup>. The downstream migration is the most intense in summer, with June being the downstream migration peak (Table 4). It is the least intense in winter, especially in January. From summer to winter the concentration of the migrants gradually goes down, while from winter to summer, the concentration of the migrants drastically increases, especially from April to June.

The number of migrants in the reservoir in various years stayed practically the same, and there were always about 4 times more young fish than adult fish (over one year old) there (Table 5).

**Table 4 Average Concentration of Fish Migrants (no./1,000 m<sup>3</sup>)**

Year	Jan	Feb	Mar	Apr	May	Jun
1979	0.15	0.19	0.19	1.49	3.18	20.62
1989	0.02	0.07	0.12	1.17	0.37	13.36
Year	Jul	Aug	Sep	Oct	Nov	Dec
1979	10.37	4.37	4.77	2.91	1.80	0.78
1989	2.24	1.75	1.04	1.05	0.45	0.22

**Table 5 Quantity of migrants (thousands of individuals)**

Species	1979 - 1980	1989 – 1990		
		Total	0+	≥ 1+
Bleak	5,846	4,800	3,273	1,527
European perch	5,042	3,373	2,641	732
Carp bream	1,636	3,562	2,963	599
Pikeperch	1,328	1,159	1,128	31
European smelt	923	31	21	10
Roach	410	640	310	330
Ziege	0	134	0	134
All species	17,751	15,969	12,625	3,344

**Table 6 Fish injuries resulting from HPP downstream migration**

Body size, mm	Percentage of injured fish, %	
	All species	<i>Cyprinidae</i> sp.
40 – 80	6.0	5.1
81 – 100	6.4	7.1
101 – 150	11.2	15.3
151 – 200	8.6	10.7
201 – 600	11.1	14.3

Fish injuries and losses, resulting from their HPP downstream migration, have been observed during both periods of studies. In 1989 – 1990, 2,414 species over 40 mm long were examined to determine mechanical injuries (without pressure induced injuries) in HPP turbines. The following kinds of injuries were observed: cuts, bruises and crushed wounds; absence of body parts, and damaged fins. Totally, 196 fishes of various species had these kinds of injuries (Table 6), which is 8.1% of the total number of the examined species. A number of injuries varied from species to species. For example, 5.3% of Percidae species were injured, compared to 9.0% of *Cyprinidae* species.

The conclusion has been made that all these injuries result in the fish loss. On the whole, from July 1989 through July 1990, 271,000 of all fish species over one year old were lost due to mechanical injuries.

## Ust'-Khantajskoe Reservoir

Ust'-Khantajskoe reservoir was created in 1970 on the Khantajka river, the Enisey river tributary. The reservoir has two branches located on both sides of the HPP dam: right branch in the Khantajka river and left branch in the Kulumba river.

### *Major Specifications*

Type:	River-like, with two branches
Water surface area:	2,120.0 km <sup>2</sup>
Volume:	23.5 km <sup>3</sup>
Length	160 km
Maximum width	27.0 km
Average depth	27.0 m
Maximum depth	50.0 m
Average annual water flow through HPP	19.5 km <sup>3</sup>
Annual coefficient of water exchange	1.3

The major HPP facilities are as follows: river dam, left shore earthen dam, right shore dam, concrete dam with two openings designed for 3,600 m<sup>3</sup>/sec water flow rate, and gatewell. Ust'-Khantajskaya HPP is a high head HPP with 55.5 m difference between the headwater level and tailwater level and a headwater depth in the gatewell area of 31.0 m.

The HPP power unit is installed between the earthen and concrete dams. It consists of seven Kaplan turbines with the maximum water flow rate of 165 m<sup>3</sup>/sec each.

The water is taken to the turbine from the gatewell, the upper edge of which is located 15 meters deep and the lower edge is 2 meters above the bottom. There is a special channel that connects the gatewell with the reservoir. This channel is 200 m long, 38 m wide and 23 m deep. In its outflow, the bottom of the channel is 22 meters above the bottom of the reservoir.

There are 18 fish species in the reservoir. The most common species are as follows: sardine cisco, peled, humpback whitefish, roach, European perch, Northern pike and burbot. There are also minnow, taimen, goldfish, dace, broad whitefish, grayling, ide, and ten-spined stickleback. In 1978 – 1988, 290 – 480 tons of fish were caught in the reservoir annually. The commercial fish yield of the reservoir ranges from 1.5 to 2.0 kg/hectare (Isaev, Karpova, 1989).

The studies of fish downstream through the Unst'Khantajskaya HPP dam were performed in 1991 – 1992. These studies included seasonal monthly observations over the intensity of downstream migration through the HPP turbines. Altogether, there were 16 daily stations where 384 ichthyological samples were taken and 980 fish species were caught. In August – September of 1991, the young fish distribution in the reservoir was studied.

Seven species have been observed as migrants (Table 7), The major migrant species are burbot, roach, humpback whitefish, and ide.

**Table 7 Species specific structure of the migrants**

Species	Percentage in downstream migration, %
European perch	49.4
Sardine cisco	25.9
Peled	23.5
Other	1.2

**Table 8 Age of fish migrants, %**

Species	Age	
	0+	≥ 1+
European perch	96	4
Sardine cisco	86	14
Peled	94	6
Burbot	0	100
Roach	96	4
other	3	97
Average	62	38

**Table 9 Average concentration (no./1,000 m<sup>3</sup>) of fish migrants**

Year	Apr	May	Jun	Jul	Aug	Sep	Oct
1991 – 1992	0.54	1.83	0.86	0.36	2.46	0.14	0.27

Practically all age groups have been presented by the migrants, from prolarvae to adult species. Almost all species, except burbot, migrate during the first year of life, i.e., as larval fish and fry (Table 8). *Coregonus* species mostly migrate as adult fish, i.e., three years old and older.

The average concentration of the migrants in April – October was 0.92 /1,000 m<sup>3</sup>. There are two periods of the highest migration intensity (Table 9). The first period is the downstream migration of *Coregonus* larvae (sardine cisco and peled) in May - June, and the second period is the European perch larvae migration in August. In the fall and in spring, most of the migrants are one year old or older.

To compare the scope of migration with the scope of commercially caught fish in Ust'-Khintajskoe reservoir, the quantity of migrants per year, as well as their mass and percentage of the total quantity of fish in the reservoir, have been calculated for 1989 and 1991. The comparison does not take into account the young fish migration (Table 10). The table shows the correlation between the percentage of the migrated fish and commercially caught fish, specifically 45% of peled, 70% of European perch and over 100% of sardine cisco migrate from the reservoir.

**Table 10 Quantity and percentage of fish migrants vs commercially caught fish quantities**

Species	Migrated Fish				Fish
	0+, no.	≥ 1+, no.	> 1+, kg	% of the commercially caught fish	Caught per year, kg
European perch	5,240,000	294,000	39,300	70	56,000
Sardine cisco	2,850,000	399,000	24,100	118	20,500
Peled	2,000,000	143,000	13,800	45	30,400
other	320,000	30,000	-	-	-
All species	10,410,000	866,000	-	-	-

**Table 11 Fish injuries**

Species	Body size, mm	Fish caught, no.	Mechanical injuries, %		
			Total	surface injuries	deep injuries
<i>Coregonus</i>	50 - 150	74	88	83	55
<i>Coregonus</i>	> 150	199	98	81	78
Percidae	50 - 150	89	28	0	22
Percidae	> 150	24	100	0	100

Fish injuries and losses, resulting from their migration through the HPP, were observed during all periods of observations. Most fishes had typical mechanical injuries and pressure induced injuries. Only 10% of migrants have been analyzed. The most common injuries were as follows: absence of body parts, spine fracture, cuts and crush wounds, scale damage, internal bleeding and eye bleeding, as well as swim bladder rupture, resulting from mechanical impact, and pressure induced injuries. No additional injuries were induced by catching the fish because the caught fish and the fish collected in the

surface and from the bottom in the vicinity of the turbine have similar injuries. The injuries data are given in Table 11 where the mechanical injuries are divided into surface injuries (scale and fins damage) and deep injuries (wounds, absence of body parts, internal bleeding, and swim bladder rupture). It should be noted that the percentage of the fish injuries is pretty high and most migrants have been killed.

## Sheksninskoe Reservoir

Sheksninskoe reservoir was created in 1963 in the Sheksna river that goes into Rybinksoe reservoir. It has both lake (Beloe Lake) and river portions. The reservoir is connected with the Volga-Baltic channel and has an outlet to the Sheksna River and the Vytegra River. Only the 1982 – 1983 studies provide data on the fish downstream migration through the Sheksninskaya HPP.

### *Major Specifications*

Type:	River-like
Water surface area:	1,665.0 km <sup>2</sup>
Volume:	6,521 km <sup>3</sup>
Length	262 km
Maximum width	9.0 km
Average depth	3.9 m
Maximum depth	25.0 m
Average annual water flow through HPP	5.07 km <sup>3</sup>
Annual coefficient of water exchange	0.733

The major HPP facilities are as follows: river dam, right shore earthen dam, concrete HPP dam, and navigation lock installed between the HPP and the left shore. Sheksninskaya HPP is a low head HPP with the maximum difference of 15 m between the headwaters and tailwaters, and a headwaters depth near the gatewell of 26 m.

The HPP power unit is installed between the earthen dam and the navigation lock. It has four Kaplan turbines with a maximum flow rate of 175 m<sup>3</sup>/s each.

The water is taken from four water intake gatewells, the upper edges of which are 13.0 m deep and the lower edges of which are 1.0 m above the bottom.

There are 30 fish species in the reservoir. The most common species are as follows: European smelt, Northern pike, roach, carp bream, blue bream, ziege, pikeperch, Volga pikeperch, and ruffe. European perch, vendace, bleak, and silver bream are also common. The following species are rare: burbot, dace, ide, rudd, and asp. The fewest are sterlet, goldfish, tench, chub, loach, moderlieschen, gudgeon, bullhead, common whitefish, and European eel. The volume of commercially caught fish in 1968 – 1988 was 397 to 1,374 tons per year. The commercial fish yield of the reservoir is 2.4 – 8.3 kg/hectare (Isaeva, Karpova, 1989).



The studies on downstream fish migration through Sheksninskaya HPP were performed in 1982 – 1983. These studies included observations on the intensity of downstream migration performed every 10 days and observations on young fish distribution in the reservoir in July – October of 1982 and June – August of 1983. Thirty eight daily stations were held where 633 ichthyological samples were taken and 28,452 fish were caught. Sixty eight daily stations were held for studies of the young fish distribution where 420 ichthyological samples were taken and 28,242 fish were caught.

**Table 12 Species specific structure of the migrants**

Species	Percentage in downstream migration, %
European perch	78.3
Pikeperch	9.4
European smelt	7.9
Volga pikeperch	1.8
Ruffe	1.1
Bleak	0.8
Other	0.7

**Table 13 Age of fish migrants, %**

Species	Age	
	0+	≥ 1+
European perch	99.99	0.01
Pikeperch	100.0	0.0
Volga pikeperch	100.0	0.0
Ruffe	46.3	53.7
Roach	96.2	3.8
Carp bream	97.7	2.3
Bleak	95.9	4.1
Silver bream	97.2	2.8
European smelt	95.8	4.2
All species	99.7	0.3

**Table 14 Average concentration of migrants (no./1,000 m<sup>3</sup>)**

Year	Jan	Feb	Mar	Apr	May	Jun
1982 - 1983	2.0	0.9	0.7	0.5	0.9	781.2

  

Year	Jul	Aug	Sep	Oct	Nov	Dec
1982 - 1983	703.0	69.0	79.8	9.1	3.5	32.4

**Table 15 Quantity of fish migrants**

Species	Quantity of fish migrants, thousands of individuals	
	total	sexually mature fish
European perch	116,000.0	2,100.0
European smelt	33,000.0	1,321.0
Pikeperch	6,940.0	87.7
Volga pikeperch	1,300.0	7.4
Bleak	1,002.0	67.9
Ruffe	577.0	459.0
Roach	200.0	22.0
Carp bream	147.0	25.2
Silver bream	43.7	7.6

Twenty fish species have been registered as downstream migrants (Table 12). The migrants include, but not limited to, the following species: roach, carp bream, vendace, ziege, silver bream, peled, rudd, dace, bullhead, ide, gudgeon, blue bream, and common whitefish. Practically all age groups were represented, from prolarvae to adult fish. All species, except ruffe, migrate during the first year of life, i.e., as larval fish and fry (Table 13).

There are two periods of the most intense migration in the seasonal downstream migration dynamics (Table 14). The first period is June and July and is mostly associated with migration of larval fish, and the second period is in late August and September, and it is mostly associated with downstream migration of fry of pikeperch, European perch and Cyprinidae species.

The Volgogradsky Division of the National Research Institute of Fish Resources data indicate that, as of January 1, 1983, Sheksninskoe reservoir has 2,124,000 carp bream and 1,807,000 pikeperch at the age of 4+ years old. Table 15 shows the correlation between

the total number of migrants and the total number of sexually mature migrants. In 1982, 1.2% of sexually mature carp bream and 4.9% of sexually mature pikeperch migrated through the HPP.

## Ozerninskoe Reservoir

Ozerninskoe reservoir was generated in 1967 by closing the Ozerna river waterway. The Ozerna river is a tributary of the Moskva river.

### *Major Specifications*

Type:	River-like
Water surface area:	23 km <sup>2</sup>
Volume:	0.14 km <sup>3</sup>
Length	30 km
Maximum width	3.0 km
Average depth	6.3 m
Maximum depth	20.5 m
Average annual water flow through HPP	0.24 km <sup>3</sup>
Annual coefficient of water exchange	1.66

The major HPP facilities include an earthen dam and hydroelectric plant. The HPP is a low head HPP with the difference between the headwaters and tailwaters of about 5 m, and the headwaters depth of 20.0 m.

The HPP power unit is located in the earthen dam (400 m away from the right shore and 600 m away from the left shore). It consists of one Kaplan turbine with the maximum water flow rate of 20 m<sup>3</sup>/s.

**Table 16 Species specific structure of the migrants**

Species	Percentage in downstream migration, %
European perch	76.6
Pikeperch	10.9
Silver bream	6.6
Carp bream	3.1
European smelt	1.4
Roach	0.6
Bleak	0.5
Ruffe	0.2
Moderlieschen	0.1

**Table 17 Age of fish migrants, %**

Species	Percentage of fish in the age of 0+
European perch	99
Pikeperch	100
Silver bream	87
Carp bream	100
European smelt	100
Roach	42
Bleak	100
Ruffe	35
Moderlieschen	100

**Table 18 Average concentrations (no./1,000 m<sup>3</sup>) and quantity of migrants**

Date	European perch	Pikeperch	Silver bream	Carp bream	European smelt	Roach	All species
April 28, 1981	0.04	0	0	0	0.04	0	0.12
April 22, 1982	0	0	1.01	0.86	0	0	1,87
June 7, 1982	56.00	6.60	0	0	0	0	62.20
August 4, 1982	0		0.10	0	0	0	0.10
August 16, 1982	0.30	0.80	0	0.30	0	0.20	1.60
August 30, 1982	0	0.24	0	0.24	0	0	0.72
September 10, 1982	0.43	0.31	1.80	0.60	0	0.14	3.42
October 20, 1982	0.02	0	1.12	0.12	0.04	0.04	1.54
October 30, 1982	0	0	0.42	0	0.05	0.03	0.50
November 10, 1982	0	0	0.51	0.16	0.93	0.02	1.62
Migrated per year, thousands of individuals	1,100	140	59	28	20	5	1,356

The water is taken to the turbine from the gatewell, the upper edge of which is installed 16 m deep and the lower edge is 0.5 m above the bottom.

There are the following species in the reservoir: European smelt, Northern pike, European eel, roach, ide, dace, chub, asp, moderlieschen, tench, nase, bleak, carp bream, crucian carp, burbot, pikeperch, Volga pikeperch, European perch, and ruffe. The most

common of them are as follows: European perch, roach, Northern pike, bleak, ruffe, and pikeperch.

No commercial fishing is conducted in the reservoir, there is only amateur fishing.

The studies on Ozerninskaya HPP downstream migration were performed in April 1981 and April – November 1982. These studies included daily seasonal observations on the intensity of migration through the HPP turbine penstock. Totally, 10 daily stations were held, 176 samples were taken and 501 fish specimen were caught.

Nine species have been registered as downstream migrants (Table 16). European perch, pikeperch and silver bream are the most exposed to downstream migration.

The migrants represent practically all age groups from prolarvae to adult fish. Most species usually migrate during the first year of life (Table 17). Only some small fish (roach and ruffe) primarily (over 50%) migrate at an older age (1+ and older).

The maximum concentration of the migrants was observed in June for the downstream migration of early larvae (Table 18). In early September, the second intense period of migration was observed, mostly associated with the migration of silver bream fry.

Over 1 million fish migrate from the reservoir annually, and the major migrant is European perch (81.1%).

## Kapchagajskoe Reservoir

Kapchagajskoe reservoir was built in 1970 in the Ili River (a tributary of the Balkhash River) and it is located in a semi-arid area of the Northern type. The reservoir goes from west to east, its left shore has a gently sloping, sandy and shallow bottom and its right shore has a steep, deep and rocky bottom. The littoral zone has a lot of vegetation.

### *Major Specifications*

Type	River-like
Water surface area	1,847 km <sup>2</sup>
Volume	2.81 km <sup>3</sup>
Length	118 km
Maximum width	220 km
Average depth	40 m
Maximum depth	15 m
Water surface area with up to 2 m depth	25%
Average annual water flow through HPP	5.63 km <sup>3</sup>
Annual coefficient of water exchange	2

The HPP major facilities are as follows: concrete dam with the idle water release from the upper layers and four turbine penstocks that take water from 25 – 30 m deep levels. The water flow of each Kaplan turbine is 100 – 120 m<sup>3</sup>/s. The HPP head is 35.7 m.

There are 24 – 30 fish species in the reservoir (Erestchenko et al.; Mitrofanov, Dukravets, 1975). Over 19 species have been observed during our studies: fringebarbel sturgeon, dace, *Ctenopharingodon idella*, asp, carp bream, barbel, topmouth minnow, *Schizothorax pseudoksaiensis*, sharpbelly, crucian carp, carp, stream loach, Wels catfish, pikeperch, Balkhash perch and *Rhinogobius brunneus*. Currently, there are 28 fish species in the reservoir (Isaev, Karpova, 1989).

Five species are caught for commercial needs. They are as follows: carp bream, pikeperch, Wels catfish, asp and carp. The fish yield of the reservoir is estimated as 5.3 – 5.5 kg/hectare. During 1980 – 1987, the total volume of the fish caught ranged from 791.5 to 1,352.5 tons per year (Isaev, karpova, 1989). The most common fish species that are not commercially caught are: sharpbelly, *Rhinogobius brunneus*, and topmouth minnow.

The studies on the fish downstream migration through Kapchagajskaya HPP were performed in 1972 – 1975. In 1973 – 1974, the fish was caught for sampling all year round, about once every 10 days, or even daily, once at night and once in the daytime.

The following input material has been obtained for the studies: 26 complete daily stations, 2,221 fish samples and 17,000 young fish for studies of downstream migration, and 453 fish samples and about 23,000 young fish for studies of the fish distribution.

Eleven species have been observed as migrants: pikeperch, *Rhinogobius brunneus*, balkhash perch, asp, dace, roach, Wels catfish, fringebarbel sturgeon, crucian carp, and carp. The most frequent migrants were as follows: pikeperch – 64%, *Rhinogobius brunneus* – 30%, and, partially, carp bream – 4%. The downstream migration of the following species have not been observed: *Schizothorax pseudoksaiensis*, *Ctenopharingodon idella*, barbel, topmouth minnow, sharpbelly, and stream loach.

In most cases, fish migrated during the first year of life. They are: pikeperch larvae, *Rhinogobius brunneus* fry, roach, fringebarbel sturgeon, dace, and Wels catfish. Carp bream, asp, crucian carp and carp mostly migrated when one year old and older.

Three intense periods of downstream migration have been identified (Table 19). The first was in spring (March), when mostly *Rhinogobius brunneus*, carp bream and pikeperch migrated, the second was in summer (May – August) when pikeperch larvae and *Rhinogobius brunneus* larvae and fry migrated, and the third period was in late November – December when the species over one year old migrated, including sexually mature species. During the third period, the greatest number of various species migrated, and the most common migrating species were pikeperch, *Rhinogobius brunneus* and Cyprinidae species.

**Table 19 Average concentration (no./1,000 m<sup>3</sup>) of migrants**

Year	Jan	Feb	Mar	Apr	May	Jun
1973 – 1974	3.17	0.53	8.00	1.33	56.3	24.4

  

Year	Jul	Aug	Sep	Oct	Nov	Dec
1973 - 1974	12.8	14.5	4.63	1.07	7.63	16.4

**Table 20 Quantity of migrants**

Species	Quantity of migrants per year, thousands	Species	Quantity of migrants per year, thousands
Pikeperch	274,240	Carp bream	20,140
<i>Rhinogobius brunneus</i>	68,300	All species	362,680

**Table 21 Pikeperch with various kinds of injuries resulting from their passage through Kapchagajskaya HPP Turbines, %**

Injured body parts	Body size, mm				
	100 – 200	201 – 300	301 - 400	401 - 500	501 – 600
Skin	6.4	39.3	55.9	37.5	55.8
Fins	6.4	14.3	5.9	7.1	5.7
Eyes	6.4	16.4	54.4	30.4	11.5
Gills	3.2	32.1	33.8	20.1	11.5
Swim bladder	71.0	63.3	55.6	36.4	58.3
Muscles	0	7.1	11.7	10.3	25.0
Internal organs	9.7	3.6	4.4	2.2	7.1
Mortality, %	51.6	64.3	61.1	63.6	71.4
Quantity, specimen	31	28	68	184	52

The estimated quantity of migrants (Table 20) shows that about 50% of pikeperch larvae migrate from the reservoir. Injuries have been observed in practically all migrants. On visual examination, the following injuries have been observed: bulging eyes (pikeperch, European perch, *Rhinogobius brunneus*), inversion of stomach through mouth and gills

(pikeperch and European perch), scale damage (all species), various body injuries (fringebarbel sturgeon, pikeperch, carp, carp bream and asp), gas bubbles in muscles, gills and blood vessels (pikeperch and carp bream), hemorrhages in eyes, fins, muscles, internal tissues, brain, and kidneys (all species), swim bladder rupture (pikeperch, European perch, and carp bream), irregular breathing (pikeperch, etc.) Apart from the injuries mentioned, the killed fish also had some pigmentation changes, i.e., some of them experienced discoloration (fringebarbel sturgeon), others, on the contrary, had intensified pigmentation (Wels catfish). Table 21 illustrates various injuries received by pikeperch species.

## Mostiste Reservoir

Mostiste reservoir is located in the center of Europe in the hilly area of Southern Moravia. It was created by construction of a dam in 1957 – 1961 in the Oslava River (a tributary of the Danube River). The reservoir is mostly used for water supply.

### *Major specifications*

Type	River-like
Water surface area	0.86 km <sup>2</sup>
Volume	0.0104 km <sup>3</sup>
Length	5.5 km
Maximum width	2.5 km
Average depth	12.1 m
Maximum depth	30 m
Flow rate through the turbine:	
through Jonson's spillway	1.5 m <sup>3</sup> /s
through water supply system spillway	16 m <sup>3</sup> /s
through flood spillway	115 m <sup>3</sup> /s
Average annual water flow through HPP	0.052 km <sup>3</sup>
Annual coefficient of water exchange	5

The major hydrofacilities there include a concrete and stone dam with four spillways, i.e. to HPP Kaplan turbine, Jonson's emergency spillway, water purification spillway with three gatewells – 5, 10 and 16 meters deep, as well as the flood water spillway 54 m wide. During our observations, the water was only supplied to the HPP penstock and to the water supply system.

The power unit is located deep underground. The water is supplied to the turbine from the bottom water layers via a special tunnel. The inlet of the tunnel is located in the central part of the small cove near the left shore of the reservoir, approximately 30 m deep.

There are 26 fish species in the reservoir. According to Lusk (1978) and Gaydusek, Lusk (1984), these species are the same that were originally found in the Oslava River. During our observations, we have registered 15 fish species there. They are as follows:



whitefish\*, Northern pike, roach, chub, rudd, asp, tench, gudgeon, bleak, carp bream, European eel, pikeperch, European perch, and ruffe.

**Table 22 Scope of collected material**

Data	Quantity		
	Daily stations	Samples	Fish caught
Fish downstream migration through HPP	15	488	579
Fish downstream migration through water supply system	15	607	460
Fish distribution in the reservoir	-	504	793
Other observations	-	59	3,323

**Table 23 Species specific structure of fish migrants through HPP and water supply system, and resident fish of the reservoir, %**

Species	HPP	Water Supply System	Reservoir
Roach	0.17	0.35	2.26
Bleak	0.17	-	0.16
Carp bream	0.17	-	0.48
Pikeperch	0.17	6.67	10.34
European perch	82.38	92.85	86.43
Ruffe	8.64	1/05	0.16
European eel	8.29	-	-
All species, number of specimen	579	285	619

**Table 24 Ages of fish species migrating through the turbine and water supply spillways, %**

Type of spillway	Species	Larvae	Fry and older
HPP	European perch	97.0	3.0
	European eel	-	100.0
	Ruffe		100.0
	Carp bream		100.0
	Other		16.7
Water supply system	European perch		15.3
	Ruffe		100.0
	Roach		100.0
	Pikeperch		0.0

There is no commercial fishing, only amateur fishing, primarily with hook tackle.

The fish downstream migration studies were performed in 1982 – 1983. The migrants were caught on a daily and seasonal basis in the HPP and water supply system spillways. The nets were installed in the tailwaters for their entire width, thereby preventing the fish from entering the tailwaters. The scope of collected data is given in Table 22.

**Table 25 Average concentration (no./1,000 m<sup>3</sup>) of migrants**

Year	Jan	Feb	Mar	Apr	May	Jun
1982 – 1983	0.12	0.11	0.04	0.17	4.33	0.06
Year	Jul	Aug	Sep	Oct	Nov	Dec
1973 - 1974	0.17	0	0.46	0.01	0.42	0.20

**Table 26 Young European perch injuries, %**

Number of fish	Norm	Swim bladder		Buoyancy		Hemorrhages			Inversion of internal organs	Mechanical injuries
		expanded	ruptured	+	-	eyes	fins	internal organs		
20	-	10.00	65.0	10.0	50.0	20.0	35.0	5.0	10.0	15.0
46	6.5	19.6	80.4	45.6	47.8	21.7	52.2	10.9	54.4	0.0

The migrants through the HPP included the following seven species: European perch, ruffe, European eel, pikeperch, roach, bleak, and carp bream (Table 23). The first three were the most frequent migrants (99.3%), others were very few.

The fish migrated as larvae (European perch, pikeperch and carp bream) and as fry, as well as older fish, including sexually mature species (European perch, ruffe, and European eel). Table 24 shows the correlation between two age groups of the fish migrants, i.e., larvae of 4.5 – 17.8 mm long and fish one year old and older. On the whole, larvae prevailed in the migration through both the HPP (94.1%) and the water supply system (81.2%).

The downstream migration was the most intense in May (Table 25) with the larvae migration concentration of 6.41/1,000 m<sup>3</sup>. The second peak of migration was in

September (0.46/1,000 m<sup>3</sup>) when the older fish migrated. The average annual concentration of the migrants was 0.28/1,000 m<sup>3</sup> at HPP and 0.53 at the water supply system. The estimations on the downstream migration have been performed for the European perch species because it appears to be the most common migrant. Within a year, about 27,000 larvae and about 3,500 older fish migrated from the reservoir.

Fish injuries and losses through their HPP migration were observed throughout the entire period of observations (but the fish were very rarely injured while migrating through the water supply system). Table 26 shows that in November – December 1982, all fish that migrated through the turbine had injuries. Their major injuries were as follows: swim bladder rupture, negative buoyancy, and hemorrhages in the fins and eyes.

## Volgogradskoe Reservoir

Volgogradskoe reservoir was created in 1958 – 1960 by blocking the Volga River in the Volgograd area for the purposes building an HPP, providing navigation, irrigation and fishing.

### *Major Specifications*

Type	River-like
Water surface area	3,117 km <sup>2</sup>
Volume	31.45 km <sup>3</sup>
Length	540 km
Maximum width	4.6 km
Average depth	10.1 m
Maximum depth	40 m
Water surface area with up to 2 m depth	18.1 %
Water surface areas with up to 5m depth	37 %
Average annual water flow through HPP	251 km <sup>3</sup>
Annual coefficient of water exchange	8.0

The major HPP facilities include the left shore and right shore earthen dams, HPP building, and concrete dam. The navigation lock is installed between the earthen dam and the concrete dam. Besides, there is a fish transfer station located between the HPP building and the concrete dam. The HPP head is 27 m. The HPP power unit contains 22 Kaplan turbines with the nominal water flow rate of about 680 m<sup>3</sup>/s each. The gatewells are located 79 m away from the trash rack. The trash rack is 820 m long and the water flow enters the trash rack at 27.5 m deep.

The most common fish species in the reservoirs are those frequently found in the Volga River. Beyond that, the reservoir, upon its creation, was stocked with carp bream, carp,

and pikeperch. Fifty fish species have been registered in the reservoir. They include but not limited to the following species: Caspian anadromous shad, sprat, Northern pike, burbot, Wels catfish, carp bream, carp, roach, dace, chub, rudd, ide, asp, tench, blue bream, ziege, crucian carp, bleak, silver bream, nase, pikeperch, Volga pikeperch, European perch, and ruffe. Beyond that, Sterry sturgeon, beluga, Russian sturgeon, sterlet, connie, *Caspiomyzon wagneri*, and various Gobiidae species can also be found there. In 1967, the reservoir was stocked with such vegetarian fishes as *Hypophthalmichthys molitrix*, *Ctenopharingodon idella* and *Mylopharingodon piceus*.

The fishing yield in the reservoir ranges from 3,129 to 4,104 tons per year. The actual fishing yield in the reservoir is 10 – 13 kg/hectare.

The fish downstream migration studies in the reservoir were performed in 1990 – 1991. The fish migrants were caught on a daily and seasonal basis, but not in the tailwaters, as in all other studied reservoirs, but in the headwaters, in front of the gatewell, but 79 m away from it. The filtration velocity in the net ranged from 0.26 to 1.6 m/s, depending on the seasonal and daily modes of HPP operation. The applied methods did not make it possible to estimate precisely the number of the fish migrants older than one year. However, there were no further significant differences between this method and the methods applied in other reservoirs.

During the period of observations, 26 daily stations were sampled, 921 samples were taken, and about 30,000 young fish were caught. This work was performed by the Volgograd Division of Hydroproekt Institute under our supervision.

Over 27 species have been registered as migrants (Table 27). The most frequent young fish migrants were pikeperch (29.1%), sprat (29.0%), and European perch (19.5%).

The prevailing age of the migrants ranged from early to late larvae, and only *Clupeiformes* sp. also migrated as fry (30%). It should be noted that no fish older than one year old have been registered as migrants.

**Table 27 Species specific structure of migrants**

Species	Percentage as migrants, %
Pikeperch	29.1
European perch	19.5
Volga pikeperch	2.6
Ruffe	1.3
TOTAL for Percidae sp.	52.5
Sprat	29.0
Caspian anadromous shad	6.8
TOTAL for Clupeiformes	35.8
Silver bream, bleak, roach, carp bream, each	1.2
Ide	1.0
TOTAL for Cyprinidae sp.	10.2
Gobiidae sp.	1.5
Other species	< 0.1

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**Table 28 Average concentration (no./1,000 m<sup>3</sup>) of the migrants**

Month	1 <sup>st</sup> decade of month	2 <sup>nd</sup> decade of month	3 <sup>d</sup> decade of month
Jan	-	0.8	-
Feb	-	0.7	-
Mar	-	0.7	-
Apr	-	0.7	-
May	-	1.0	2,520.0
Jun	1,310.0	2,580.0	2,300.0
Jul	780.0	630.0	70.0
Aug	60.0	33.0	25.0
Sep	22.0	42.0	100.0
Oct	140.0	500.0	180.0
Nov	90.0	10.0	30.0
Dec	30.0	-	-

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The downstream migration was the most intense in summer, i.e., in late May and June (Table 28) when mostly early and late larvae migrated. The second downstream migration peak was registered at the end of September and in October when mostly sprat and Caspian anadromous shad fry migrated.

The quantity of the fish migrants younger than 12 months old was 72,867 million fish per year, with pikeperch being the most frequent migrants, i.e., 33,162 million individuals.

## Al. Stambolijski Reservoir

Al. Stambolijski reservoir was created in 1954 in the Rositse River (the Danube River basin), and it is located in the vicinity of the Balkan Mountains. The reservoir is of a river type, with steep rocky shores. The upper part of the reservoir has shallow water, with a muddy bottom and a lot of macrophytes.

### *Major Specifications*

Type	River-like
Water surface area	10.86 km <sup>2</sup>
Volume	0.222 km <sup>3</sup>
Length	19 km
Maximum width	2 km
Average width	0.6 km
Average depth	20.3 m
Maximum depth	46 m

Water surface area with up to 2 m depth	16 %
Average annual water flow	0.35 km <sup>3</sup>
Annual coefficient of water exchange	1.6

The major facilities include a concrete dam with the surface spillway and the deep (about 35 m deep) gatewell. After going through the turbine (Kaplan), the water enters the spillway of 5 m wide and up to 3 m deep. Some of the water goes to the Rositse river from the spillway.

Thirteen fish species have been recorded in the reservoir during our observations, specifically: Northern pike, chub, rudd, bleak, *Vimba vimba*, topmouth minnow, bitterling, carp, loach, Wels catfish, pikeperch, ruffe, and pumpkinseed sunfish.

There is no commercial fishing, but there is a lot of amateur fishing with hook tackle.

The fish downstream migration studies were performed from April through October 1984 and from April through June 1985. The fish were collected in the tailwaters spillway for identification of the species and concentration of the migrants, and in the headwaters for the studies of the distribution of young fish. The scope of the data is presented in Table 29.

Only two species have been registered as HPP migrants, i.e., pikeperch (82.1%) and ruffe (17.9%).

**Table 29 Scope of collected data**

Parameters	1983	1984	1985
Number of: Daily fish catching stations	8	24	6
Ichthyological samples	240	650	120
Fish caught	270	650	120
Number of: Daily fish catching stations	4	11	12
Ichthyological samples	140	390	300
Fish caught	2,500	12,460	2,900

**Table 30 Age of fish migrants, %**

Species	Larvae	0+	1+ and older	Total, specimen
Pikeperch	0.1	99.6	0.2	3,278
Ruffe	20.6	30.4	49.0	800
All species	3.8	87.2	9.0	4,478

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**Table 31 Average concentrations (no./1,000 m<sup>3</sup>) of fish migrants in 1984**

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pikeperch	0	0.04	1.00	50.0	0.10	0	0.001	0	0
Ruffe	0.15	0.80	0.30	3.00	0.20	0.03	0.30	0.07	0.01

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Mostly fry and fish 1+ migrated through the HPP (Table 30). For pikeperch, 30 – 55-mm-long fry predominated (99%). For ruffe, individuals in the first and second year of life predominated (93%), with about 32% of the fry of a length of 25 – 50 mm.

The fish downstream migration was the most intense in June (Table 31). On the average, for the entire period of studies, the concentration of pikeperch migrants was 5.68, and the concentration of ruffe was 0.54/1,000 m<sup>3</sup>.

**Table 32 Pikeperch and ruffe injuries and frequency of injuries**

Types of injuries	Frequency of occurrence, %
Expansion or rupture of the swim bladder	10
Hemorrhages in tissues or internal organs	92
Inversion of internal organs	37
Eye damage	40
Scratches and cuts	13

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In 1984, 23.5 million pikeperch and 0.6 million ruffe passed through the HPP turbine.

The fish injuries and losses have been observed continuously. Visual examination has made it possible to observe various mechanical and pressure-induced injuries (Table 32). The mortality of the migrants was 100%.

## Nurekskoe Reservoir

Nurekskoe reservoir was created in 1972 on the Vaksh River. It is located in the mountains of Tadjukistan. The reservoir is of a river type, and it has steep rocky shores.

### *Major Specifications*

Type	River-like
Water surface area	98 km <sup>2</sup>
Volume	10.5 km <sup>3</sup>
Length	70 km
Maximum width	6.5 km
Maximum depth	300 m
Average depth	107.1 m
Average annual water flow	34.2 km <sup>3</sup>
Annual coefficient of water exchange	3.3

The major HPP facilities include a concrete, 700-m-long dam, idle surface spillway in the dam, and HPP located on the shore. The HPP head is 275 m. The water is supplied to the HPP through the channels from the HPP gateway that is installed in the littoral zone 50 m deep. The HPP turbine flow rate is 155 m<sup>3</sup>/s, and there are six turbines at the HPP.

Twelve fish species have been recorded during the studies. The most common species are as follows: rainbow trout, Amudarya trout, *Hypophthalmichthys molitrix*, carp, snowtrout, and spirin. Beyond that, Transcaucasian barb and loach have been observed. There is no commercial fishing in the reservoir.

The fish downstream migration studies were performed in July 1986 – June 1987. The data on the downstream migration were collected in the tailwaters. In total, there were 12 daily stations (one station per month), and 144 fish samples taken, but no fish were caught, i.e., there was no downstream migration.

The fish distribution in the reservoir was studied by echo sounding in summer and in winter. The echo sounding has shown that both in summer and in winter, the fish primarily inhabit the surface water levels. No fish were detected in the vicinity of the gateway (50 m deep). Beyond that, there are more fish closer to the shores, and the greatest fish density in winter has been observed in the bays of the reservoir (Pavlov et al., 1992).



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