PŘÍRODOVĚDNÉ

PRÁCE

ÚSTAVŮ

ČESKOSLOVENSKÉ

AKADEMIE VĚD

V BRNĚ

ACTA SCIENTIARUM

NATURALIUM

ACADEMIAE

SCIENTIARUM

BOHEMOSLOVACAE

BRNO

ISSN 0032-8758

XXI • NOVA SERIES

1987

12

Dmitrij Sergejevič Pavlov — Vlastimil Baruš —
Viktor Konstantinovič Nezdolij — Josef Gajdůšek

DOWNSTREAM FISH MIGRATION FROM MOSTIŠTĚ AND VĚSTONICE RESERVOIRS

ACADEMIA • PRAHA

Přírodovědné práce ústavů Československé akademie věd v Brně

Acta scientiarum naturalium Academiae scientiarum bohemoslovacae — Brno

Abbreviation: Acta Sc. Nat. Brno

Přírodovědné práce ústavů Československé akademie věd v Brně (Acta scientiarum naturalium Academiae scientiarum bohemoslovacae — Brno) is a continuation of the periodicals *Práce Moravské přírodovědecké společnosti (Acta Societatis scientiarum naturalium moravicae)* I—XXVI, 1924—1954, and *Práce Brněnské základny Československé akademie věd (Acta Academiae scientiarum čechoslovenicae Basis brunensis)* XXVII—XXXIV, 1955—1962. Published by the Czechoslovak Academy of Sciences in the Publishing House ACADEMIA, Vodičkova 40, 112 29 Prague, Czechoslovakia.

Address of the Editor's Office (manuscripts, proofs, etc.): Institute of Systematical and Ecological Biology of the ČSAV, Květná 8, 603 65 Brno, Czechoslovakia.

Přírodovědné práce ústavů
Československé akademie věd
v Brně

Acta Sc. Nat. Brno, 21 (12): 1–64

Dmitrij Sergejevič Pavlov – Vlastimil Baruš – Viktor Konstantinovič Nezdolij – Josef Gajdůšek

DOWNSTREAM FISH MIGRATION FROM MOSTIŠTĚ AND VĚSTONICE RESERVOIRS

ACADEMIA
Nakladatelství Československé akademie věd
Praha 1987

Abstract

Downstream fish migration were studied in two Czechoslovakian reservoirs. The Mostiště reservoir is of a submontane type, the depth near the dam being about 30 m and the coefficient of water exchange about 5. The Věstonice reservoir is situated on a plain, the depth at the dam being some 3.2 m and the coefficient of water exchange 50.

In the deep reservoir the frequent migrants were those fish species inhabiting the pelagic and profundal-pelagic complex (perch, pike-perch, ruffe and eel). The highest migration occurred in the cool seasons of the year. The sharp decrease of hydrostatic pressure inflicted injuries or death of practically all migrants. In the shallow reservoir with a large discharge stream originating in the sublittoral zones the migration intensity was much higher in both fish larvae and older specimens. White bream, common bream, bleak, perch, *etc.*, presented the most frequent migrants. Mass migrations fell in spring and summer months.

Downstream fish migration showed diel changes. During spring and summer the migrants exhibited a twilight to nocturnal rhythm with one mode in night hours. In the autumn this pattern is less evident, the night activity being split into two modes, at twilight and at night.

The species composition differed in the reservoir and among the migrants. This phenomenon is explained by the horizontal and vertical distribution of fishes in the proximity of outlet currens. The fish's ability to overcome these currents grows with increasing fish size and declines with decreasing water temperature.

In general, the downstream fish migration from the deep reservoir cannot cause any substantial impoverishment of fish populations in the reservoir. On the contrary, in shallow reservoirs with a large water discharge this influence is considerable. To diminish the fish losses it is suggested to check the ecological measures, *i. e.*, to use outlets in different depths, and to install other devices, *i. e.*, fish screens.

Contents

Introduction

Fish migrations are usually related to or dependent upon the utilization of systems of water currents within the area of distribution of particular populations. The downstream migration of fishes presents an important period of their life cycle. The downstream migration manifests itself in mass movement of fishes and is characteristic not only of diadromous and semi-diadromous fishes, but also of a number of typical stream dwellers.

According to the character of movements it is possible to distinguish the following forms: (i) a passive drift downstream with the water current in a non-oriented position of fish with regard to the current; (ii) an active drift, the fish move active downstream; (iii) an active-passive drift, the fish are oriented by their heads against the current and are drifting downstream in spite of their (weak) resistence. The importance of these three forms of behaviour differs in particular species and changes during their ontogenesis. The passive migration is usually characteristic of prolarvae (sac fry), postlarvae (alevins) and young in the early stages of development, and occurs, to some extent, in most species. The active and active-passive migrations are characteristic of young and fishes of older age groups. The latter migrations occur rarely (Pavlov 1979).

The fishes migrate downstream with the current in all streams and rivers and from all inland reservoirs. The best knowledge of these migrations is available from streams in fry of families *Acipenseridae, Clupeidae, Salmonidae, Cyprinidae, Percidae, etc.* The main characteristics and manifestations were studied in the family of *Salmonidae, i. e.,* McDonald (1960), Horman & al. (1967), Harden Jones (1968), Bakštanskij (1970), *etc.*, in fishes of other systematic groups, *e. g.*, Pavlov (1979) and Pavlov & al. (1981).

The adaptive importance of downstream migration of fish fry lies in the dissemination and utilization of trophic parts within the distribution area. Downstream migration presents the first link of the migratory cycle of fishes which, to a great extent, determinates the range and the character of migrations in the following periods of their life as well as several other aspects of fish ecology.

The phenomenon of downstream fish migration from the reservoirs has been studied by Golovkov & Kožin (1939), Tichij & Viktorov (1940), Volodin (1958), Dr'agin (1953), Potechina (1956), Syrovatskij (1954), Mel'nikov (1956), Mokr'ak (1958), Nusenbaum (1961), Popova (1962), Ždanova (1963), Trofimova & Sosnov (1965), Šilov (1966), Batyčkov (1967), Čikova (1968), Raymond (1968), Rezanov (1969), Jereščenko (1971, 1972), Kuznecova (1966), Poddubnyj (1971), Šaronov (1972), Trefethen (1972), Nezdolij & Sazonov (1974, 1975), Nezdolij (1975, 1984, 1985), Verzin (1978), Gorodničij (1955, 1978), Orlov & al. (1976), Pavlov & al. (1980, 1981, 1984, 1985a, 1985b), Pavlov & Nezdolij (1981), *etc.* Nevertheless, special studies devoted to this problem are not adequate and papers based on diel observations are sporadic.

This phenomenon is sometimes denoted by other terms, "drift", "escape", *etc.* These terms emphasize an incidental and/or forced character of movement of fish. This is unjust. Any mass passive or active-passive movements of fish species with water current represents downstream migration regardless of whether these currents originate naturally or artificially. The movement of fishes with the water current from lakes and reservoirs is basically the same phenomenon. Therefore "drift" or "escape" of fishes through the dam, their passing through turbines, invading into water pump and in irrigation canals, are nothing other than migration of fishes downstream under changing conditions.

In this country a special investigation of this question was carried out only in the Lipno reservoir (Vostradovská & Vostradovský 1971, 1977). During six months of survey the authors registered the migration of eleven fish species; a mass occurrence showed the eel, perch, ruffe, carp and pike--perch. The authors emphasized the necessity and importance of research from the point of view of fishery practice.

During the investigations of reservoirs in the U.S.S.R. (Pavlov & al. 1981, 1984, 1985a, 1985b, Nezdolij 1984), it was ascertained that the downstream migration of fishes took place in all reservoirs studied. The intensity of migrations differed in accordance with the fish species, during ontogenesis, season of the year and in the course of the day. Moreover, the authors indicated a relation between the migration and the pattern of fish distribution in a sector of the reservoir near the dam.

In countries with developed hydrotechnical constructions this survey deals with practical, topical question. The importance lies in the fact that downstream fish migration substantially determines the composition of the ichtyofauna and the productivity of fishes in the reservoirs. Therefore a joint research project was worked out in partnership with scientists of the Institute of Systematical and Ecological Biology, Czechoslovak Academy of Sciences and the A. N. Severcov Institute of Evolutionary Animal Morphology and Ecology, U.S.S.R. Academy of Sciences. The year-round research was performed in two reservoirs situated in Southern Moravian Region. The main aim of this work was to clarify the peculiarities of downstream fish migrations in one deep reservoir (reservoir Mostiště) and in one flat reservoir (reservoir Věstonice) within 24-hour cycles. The reservoirs are situated on the Rivers Oslava and Dyje which belong to the drainage area of the Danube (Fig. 1). The project comprised the analyses of species and size structure of migrants, their migratory concentrations, seasonal and diel dynamics of migrations, examination of fish injuries and partly also the fish distribution in both reservoirs. Our attention was focused largely on fry, since this migration usually takes on a mass character and may have a profound impact on the formation of fish generations in reservoirs.

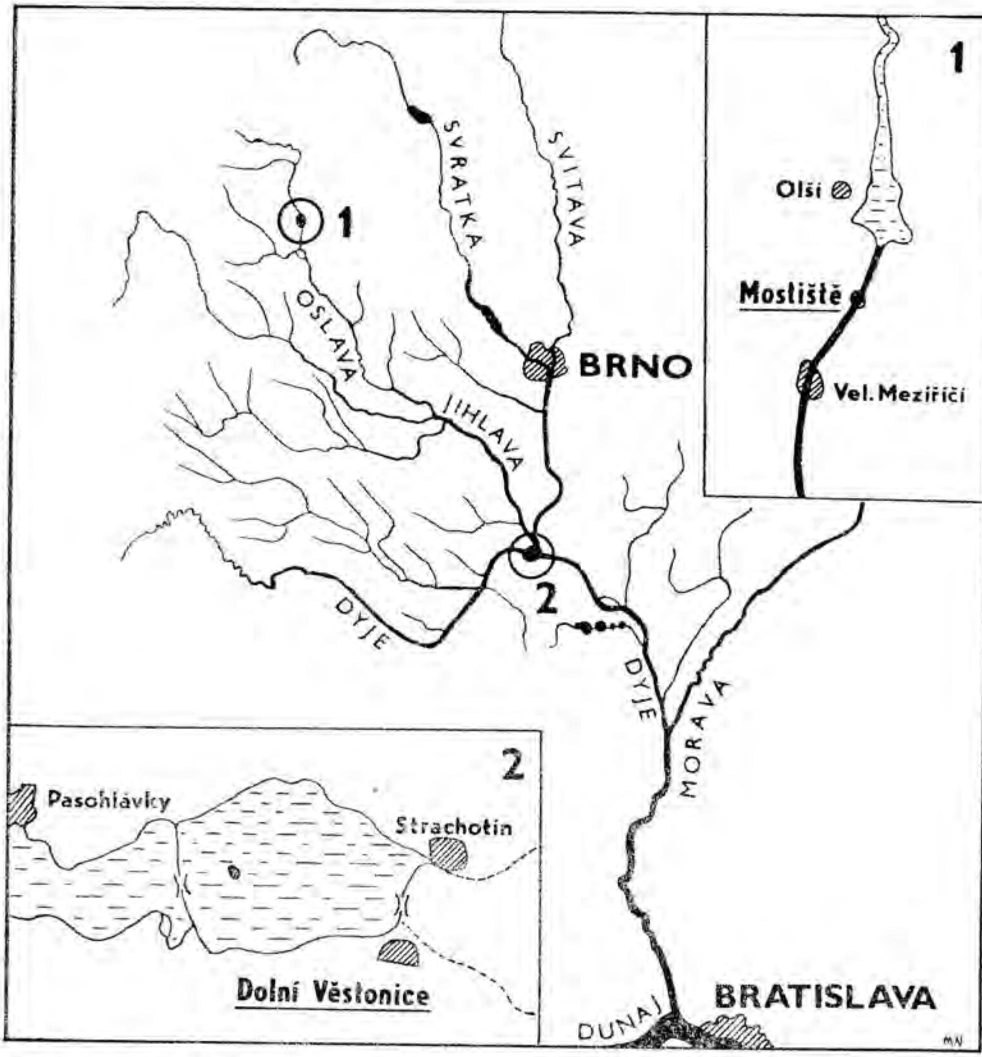

Fig. 1. A map showing the locations of the reservoirs studied.

The material has been partly published (B a r u š & al. 1984a, b, 1985a, b, and 1986). The present paper includes a complete review of results. The results published earlier on the concentration and numbers of migrants are accurately stated on the basis of supplemented measurements of water discharge.

The matter is divided according to the reservoirs studied: Mostiště reservoir (chapter three), Věstonice reservoir (chapter four) and within this framework according to two age groups, sac fry and larvae, and older age groups of fishes. This division follows from the peculiarities of migrations. In the former group it was a case of a passive migration, in the latter group it is often a case of active-passive or active migrations. Moreover, there is the problem of the methods of fish sampling. The survey of the fish material obtained and processed is given in chapters three and four according to the frequency of occurrence of the particular species. A comparative analysis of regularities of fish migrations from the two reservoirs is described in chapter five.

The implementation of the task described here would not be possible without the co-operative effort and assistance of a number of people. It is our pleasant duty to express our thanks to the technicians Mr V. Kotrbáček, Mr I. Brunner, Mr J. Kocián and Mrs Ing. L. D. Nezdolij. We feel indebted to Messrs J. Fňukal and A. Svoboda from the staff of the hydraulic water station at the Mostiště reservoir and to Mr J. Bartůněk, staff member of the waterworks in Mostiště reservoir, and to Ing. J. Ovesný of the waterwork of Věstonice for their extensive efforts and active co-operation.

Methods

The methods used were analogous to the procedure elaborated and described by Pavlov & al. (1981). The basic principle was to fish migrants in a water current running from the outflows by the passive mode of fishing. The active mode of fishing was adopted only when studying the distribution of fish fry in the part of the reservoir near the dam. Using other methods to study the downstream fish migrations, *i. e.*, trawl, seine, fishing with electricity, do not give the possibility of distinguishing migrants from local, sedentary fishes.

The main adaptations of these methods on local conditions are discussed below; the utilization of partial adaptations during our surveys is mentioned in the respective parts of the paper.

Fishing gears

The migrants were caught in non-standard conical nets made of different filter materials (Fig. 2). Ichthyoplankton was fished with a conical net (IKS) of capron linen No. 7 to 11; this net was used to fish sac fry and fish larvae. The conical net (KS) had two different mesh sizes, 4 and 7 mm bar measure. This net was applied for catching fry and older fish. The form and size of both types of nets determined some peculiarities of fish sampling (*cf.* Baruš & al. 1984a). IKS nets were set in water only during the period of the occurrence of ichthyoplankton, usually simultaneously with KS nets.

In the Mostiště reservoir we employed KS and IKS nets to fish in the outlet from the hydraulic water station (the surface of KS net being 2.78 m^2, the surface of IKS net fluctuating between 0.12 to 0.2 m^2). Another set of KS and IKS nets was used in two pipes of the water supply (the surface of KS net being 0.54 m^2, the surface of IKS net being 0.04 m^2).

In the Věstonice reservoir we used KS nets with a surface of 1 m^2 and IKS nets with a surface of 0.2 m^2. Fish were caught in three nets laid in the tail race near the opening of the first segment of the water gates from the right bank. The fishing was always carried out at the same water discharge of some 8 to 10 m^3/sec. Raising the water gate by 8 to 10 cm from the bottom resulted in a thin jet of water flow with a velocity of current exceeding 5 m/sec at the overflow lip.

The investigation of species and size structure in fry in the reservoir and fish distribution was implemented by means of active fishing gears, *i. e.*, long-handled dip net (the surface being 0.09 m^2) and the conical nets (KS,

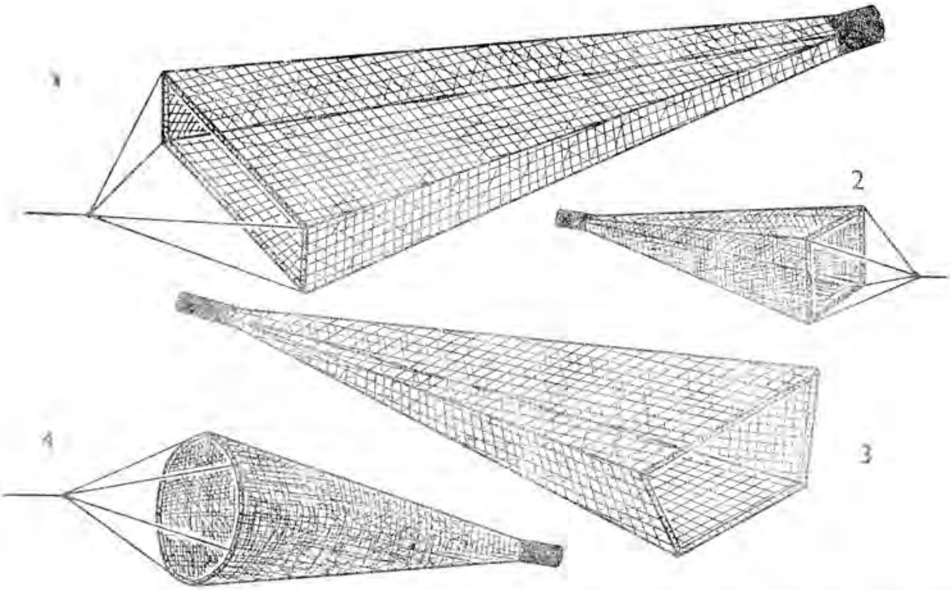

Fig. 2. Types of conical nets employed. Larger nets are conical nets (KS) to catch advanced fry and older fishes (1, 3). Smaller nets are ichthyoplankton conical nets (IKS) to catch sac fry and fish larvae (2, 4).

the surface being 2.2 m^2, and IKS, the surface being 0.5, 0.2 and 0.12 m^2). There were two modes of fishing: the vertical mode consisted in lifting the dip net from the bottom to the surface, the horizontal mode in trawling by means of a motor boat (Fig. 3). At all stations fishing with dip net was carried out with the same discharge of water, about 0.5 m^3.

When examining the vertical distribution of fishes, the conical net was raised with a velocity of 0.36 m/sec. Examining the distribution of fish in deep water, the conical net was raised by two halyards in turn. In such a way the net was always set at the level required.

In the case of the horizontal mode the velocity of trawling was 0.7 to 0.8 m/sec. and the duration of fishing was 3 to 15 min. Trawling was performed on a circuit of diameter 50 to 100 m. The horizon was determined by a hydrodynamic weight and by the length of halyards (e) for hauling the net. The depth of fishing (H) was computed according to the formula $H = \sin \alpha \cdot e$.

Fish sampling

The field work was carried out from October 24 1982 to November 25 1983. The fishing was run round-the-clock in different seasons of the year. The dynamics of downstream fish migrations was evaluated from samples taken each two hours. The seasonal dynamics was evaluated from 24-hour cycles performed usually twice a month. The exposition of nets when fishing for larvae was 10 to 30 min., for fry and adult fish 120 min. Fishing at the outlet of the reservoir and in the reservoir itself was carried out simultaneously.

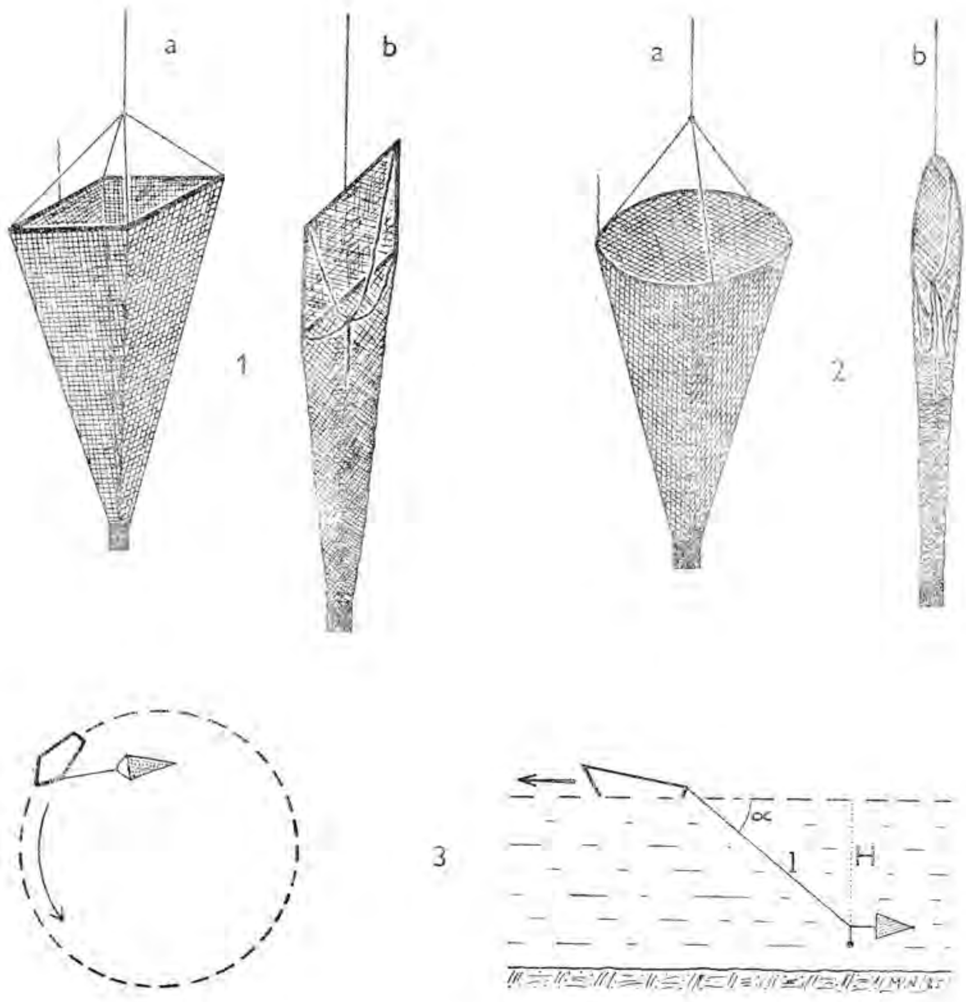

Fig. 3. Conical nets operated as lift nets (vertical mode of fishing) (1, 2). Trawling performed on a circuit (horizontal mode of fishing) (3).

Laboratory examination

The samples were sorted at the fishing place. The sac fry, fry and larvae were preserved in 4 % formalin solution. The species of the early fry were determined using the microscope MBS-9, according to the key by Koblickaja (1966, 1981). The standard length in larvae was measured from the beginning of the snout to the end of the notochord, in fry to the end of the scale cover. On examining the fry, we distinguished the following ontogenetic phases: embryonal (egg), prolarval, larvae and fry (Rass 1946, Kryžanovskij & al. 1953). In some instances we divided the larvae into early larvae and late larvae (Koblickaja 1966). The denomination of stages by letters is taken from papers by V a s n e c o v & al. (1957) and K o b l i c k a j a (1966).

The concentration of migrants was calculated from the formula:

$$K = \frac{1\,000 \,.\, N}{Q} = \frac{1\,000 \,.\, N}{V \,.\, S \,.\, t}$$

(K = number of fish, *i. e.*, number of individuals/1 000 m^3; N = number of fish in the volume of the sample, number of individuals; Q = volume of water filtrated for the sample, m^3; S = surface of the entry port, m^2; V = velocity of current in the net, m/sec; t = duration of fishing in sec.)

The velocity of water current measured at the entry to the net was made by a hydrodynamic trolling reel (GR-99). In some other instances it was computed from the hydrometric data obtained in the stations.

The fish material was processed according to the sequence of phases of the survey. We employed procedures of variation statistics by P l o c h i n s k i j (1970) and L a k i n (1977).

The status of fishes escaping from the reservoirs was examined visually. The examination related to the outer surface of fish bodies, internal organs immediately after catching and observation of their behaviour in aquaria, and results of further experiments (N e z d o l i j 1985).

Simultaneously with fish sampling several meteorological factors were registered (strength and direction of wind, cloudiness, precipitations; light intensity was measured with a luxmeter Ju-16). The water transparency was measured with Secchi disk. We also utilised data obtained from the hydrometeorological service of the waterworks in Velké Meziříčí and of the hydraulic water plant in Mostiště.

Downstream fish migration from the Mostiště reservoir

Region of investigations and material

The Mostiště reservoir is of submontane type. It is situated on the Oslava River at an altitude of 448.5 m. It was constructed during the years 1957 to 1961 and its main purpose is to retain rough drinking water. At the normal water level the reservoir has an acreage of 86 ha, the volume of water is about 10.4 million cubic m, the average water depth 12.1 m, the depth near the dam about 30 m, the coefficient of water exchange 5.0.

There are three outlets from the reservoir: through the tunnel to the turbine, through the pipe to the water treatment plant, and through the spill way. The tunnel to the turbine takes water at the water horizon of 24.0 to 29.2 m below the water surface and the water discharge may reach 17.5 cubic m per sec. (through the Kaplan turbine 1.5 cubic m per sec. and through the Johnson overflow 16 cubic m per sec.). The water intake by the waterworks, being possible from three different depths, 5, 10, and 16 m below the water surface, reaches a volume of 0.16 cubic m per sec. The spillway, being of the surface type, is 54 m wide and has a maximum capacity of 115 cubic m per sec. (Fig. 4). During the period of our survey the water was discharged through the turbine of the power station and through the pipe to the treatment plant.

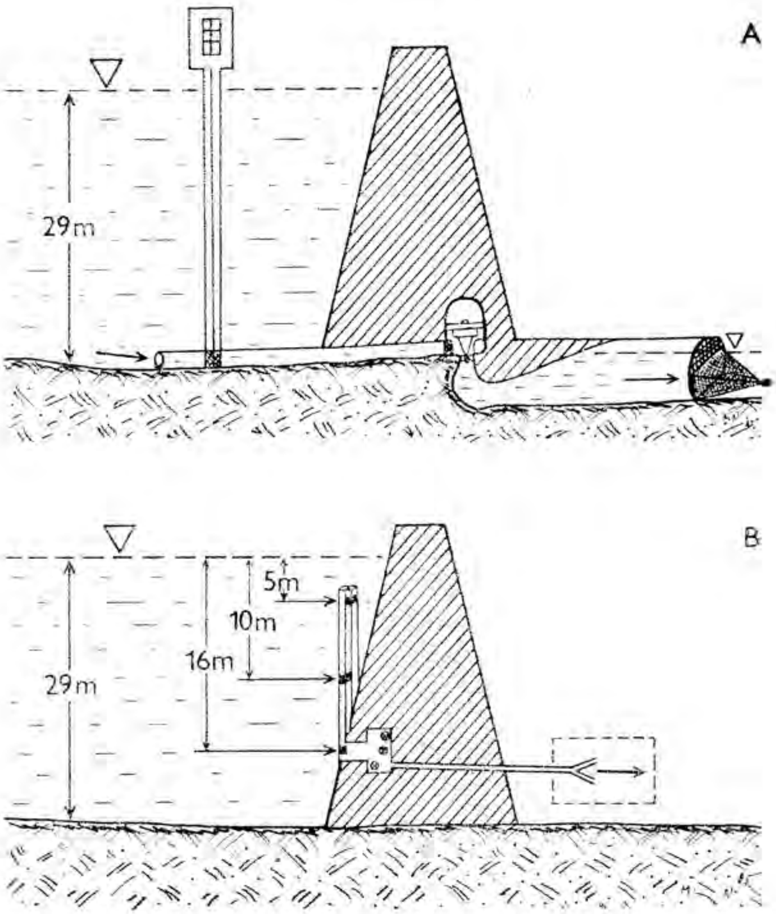

Fig. 4. Cross sections of the dam of the Mostiště reservoir. The outlet to the turbine of the hydraulic power station at the horizon of 24.0 to 29.2 m (A). Outlets to the waterworks; this is possible at three different depths (B).

The fishing was carried out in three sampling sites: in the outlet from the turbine, in the outlet supplying the water treatment plant (in two split parts of the pipe), and in the reservoir itself. In the first two fishing sites the fishing was implemented regularly in the course of the year and largely the whole volume of water was passed through the net. We employed conical nets (KS and IKS) and we feel that the methods used satisfactorily show the species, length and quantitative composition of the migrants (Tab. 1).

In the reservoir samplings were made irregularly in accordance to the season and time of day. The ichthyoplankton was caught only in May and June (three times repeated 24-hour cycle).

The survey of the fishes caught is given in Tab. 2. During the whole time of our research we captured 864 individuals of migrants in the turbine and in the pipe of the waterworks, and 4 116 individuals in the reservoir (Fig. 5).

Tab. 1. Parameters of the fishing nets employed (∅, opening diameter of the net)

Type of net	Abbrev.	Opening /m/	Surface of opening /m²/	Length of net /m/
Ichthyoplankton conical net	IKS	0.24 x 0.49	0.12	1.9
		0.40 x 0.50	0.20	2.2
		∅ 0.22	0.04	1.5
Conical net	KS	1.00 x [illegible]	1.00	9.0
		[illegible] x 2.14	2.78	4.1
		∅ 0.65	0.34	[illegible]
Dip net /Scoop net/	P	1.50 x 1.50	2.20	3.0
		∅ 0.80	0.50	1.5

Tab. 2. Data on the distribution and downstream fish migration from the Mostiště reservoir (G, inlet to the hydraulic water plant; V, inlet to the pipe of the water treatment plant; V. b., the reservoir; KS, conical net; IKS, conical net to catch ichthyoplankton; P, dip net). No. of fishings means fishing carried out round-the-clock

No. of diel fishings	1			2			3			4			5		
Date of fishing	24 Nov. to 1 Dec. 82			20 to 23 Dec.			17 to 20 Jan. 83			22 to 24 Febr.			22 to 24 March		
Locality	G	V	V.b.	G	V	V.b.	G	V	V.b.	G	V	V.b.	G	V	V.b.
Fishing gear	KS	KS	P	KS	KS	P	KS	KS	P	KS	KS	P	KS	KS	P
No. of samples	88	51	102	36	72	33	11	48	12	12	24	-	24	48	34
No. of fish	220	8	168	12	61	53	18	4	0	5	0	-	12	12	1

No. of diel fishings	6			7			8					9					10				
Date of fishing	25 to 28 Apr.			10 to 13 May			23 to 26 May					30 May to 2 June					20 to 23 June				
Locality	G	V	V.b.	G	V	V.b.	G		V.b.	V.b.⁺		G		V		V.b.	G		V		V.b.
Fishing gear	KS	KS	P	KS	KS	P	KS	IKS	KS	IKS	P	KS	IKS	KS	IKS	P	KS	IKS	KS	IKS	P
No. of samples	11	48	44	23	50	38	26	26	26	35	40	20	14	24	24	34	29	24	24	24	36
No. of fish	24	14	12	25	10	6	11	191	15	25	34	2	17	1	50	188	0	1	0	44	52

No. of diel fishings	11					12					13				14			15		
Date of fishing	11 to 14 July					25 to 28 July					1 to 2 Sept.				17 to 19 Oct.			24 to 25 Nov.		
Locality	G		V		V.b.	G		V		V.b.	G	V		V.b.	G	V	V.b.	G	V	V.b.
Fishing gear	KS	IKS	KS	IKS	P	KS	IKS	KS	IKS	P	KS	KS	IKS	P	KS	KS	P	KS	KS	P
No. of samples	24	24	12	12	37	24	24	12	12	36	12	12	12	30	24	48	28	12	24	-
No. of fish	6	0	0	10	22	13	0	30	0	19	16	0	0	230	6	1	8	0	0	-

Footnote: Besides these samplings we made 35 horizontal trawlings (IKS), which yielded 589 larvae; 18 vertical fishings (IKS) yielding 30 larvae; 6 fishings by dip net yielding 2 704 larvae

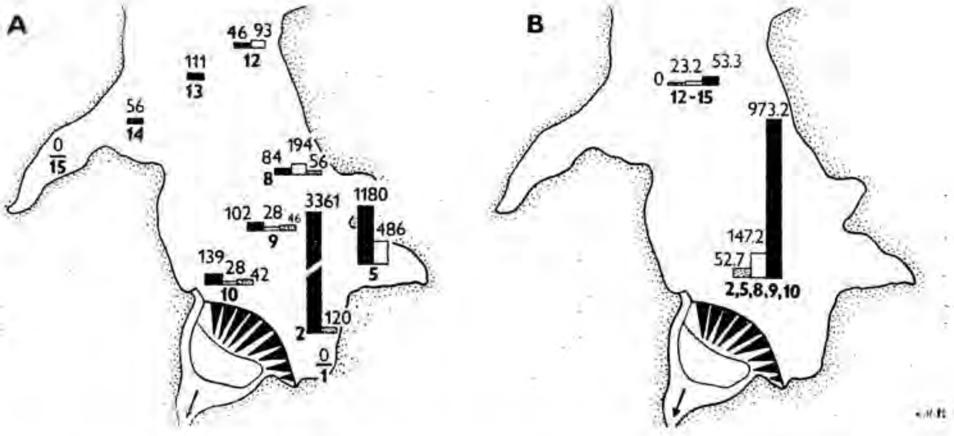

Fig. 5. Location of fishing stations in the Mostiště reservoir, in the pelagial and at the dam with catches (A) (*cf.* Tab. 5). Average catches of the two sectors (B). The sequence of species: perch, pike-perch and roach.

Composition of fish species in the reservoir and among the migrants

According to the results of Lusk (1978), Gajdůšek (1979) and Gajdůšek & Lusk (1984) the reservoir and the relevant reach of the Oslava river above the reservoir (within a distance of about 1 km) supported 26 species (Tab. 3). Out of them 15 species inhabited the reservoir, common bream, roach and perch being the most abundant.

Our catches comprised largely young age groups of fishes: sac fry, larvae, fry and yearlings; as regards adults we encountered the eel, perch (both stunted males) and ruffe. In the reservoir near the dam we ascertained 8 species (Tab. 4). Four of them, the roach, perch, common bream and pike-perch, occurred there in large quantities. Their proportion in the whole catch made up 99.9 per cent. Ruffe, bleak, dace and eel occurred only sporadically.

Seven species migrated from the reservoir downstream. The perch was among the species that made up the larger mass. Their proportion equalled to 85.5 per cent of the whole amount of 864 individuals. The proportion of the ruffe, eel and pike-perch was lower; 6.1, 5.6 and 2.3 per cent respectively. Common bream, roach and bleak were detected only rarely.

The species composition in the reservoir did not differ greatly from that of the migrants. According to our experience the low occurrence of the ruffe and eel in the reservoir was caused by our fishing gear. It were not adapted to catch fishes dwelling at the bottom. This opinion is based on the fact that they largely escaped through the gallery leading to the power station. The inlet of the gallery took water from the bottom zone. It is of interest to mention that the abundance of roach and common bream among the migrants was low, although the species were very common in the reservoir. The reason may lie in the peculiarities of fish distribution in the reservoir. This question will be discussed in the following section.

Tab. 3. **Distribution of fish species in the Mostiště reservoir. Abundance of species: +, sporadic; ++, intermediate; +++, abundant (according to G a j d ů š e k & L u s k 1984)**

	Fish species	Abundance in		
		reservoir	river	anglers' catches
1	Salmo trutta	-	++	+
2	Salmo gairdneri	-	+	+
3	Salvelinus fontinalis	-	+	+
4	Coregonus l. maraena	+	-	+
5	Thymallus thymallus	-	-	+
6	Esox lucius	++	++	++
7	Rutilus rutilus	+++	+++	++
8	Leuciscus leuciscus	-	+	+
9	Leuciscus cephalus	+	++	+
10	Scardinius erythrophthalmus	+	-	+
11	Aspius aspius	+	-	-
12	Tinca tinca	+	+	+
13	Chondrostoma nasus	-	++	+
14	Gobio gobio	+	++	+
15	Barbus barbus	-	++	+
16	Alburnus alburnus	++	++	+
17	Alburnoides bipunctatus	-	+	-
18	Abramis brama	+++	+++	++
19	Cyprinus carpio	++	+	+++
20	Noemacheilus barbatulus	-	+	-
21	Silurus glanis	-	+	+
22	Anguilla anguilla	++	++	++
23	Lota lota	-	+	+
24	Stizostedion lucioperca	++	-	++
25	Perca fluviatilis	+++	++	+++
26	Gymnocephalus cernua	+	+	-

Tab. 4. **Species composition and numbers of fishes caught in the outlets and in the reservoir. IKST, trawling with IKS, IKSP, vertical fishing with IKS; S, scoop net. For other acronyms see Tabs. 1 & 2**

Species	Outlet				Reservoir				Total catch
	Power station		Waterworks		IKST[1]	IKSP	P	S	
	KS	IKS	KS	IKS					
Leuciscus leuciscus	0	0	0	0	1	0	0	0	1
Rutilus rutilus	1	0	1	0	14	0	202	2538	2756
Alburnus alburnus	1	0	0	0	1	0	0	0	2
Abramis brama	0	1	0	0	1	2	65	136	205
Stizostedion lucioperca	1	0	0	15	60	4	[illegible]	0	84
Perca fluviatilis	269	208	152	110	511	24	528	30	1832
Gymnocephalus cernua	50	0	3	0	1	0	1	0	55
Anguilla anguilla	48	0	0	0	0	0	1	0	49

Footnote: 1) Including roach 55 and 97 mm, and common bream 145 mm in length

Fish distribution in the reservoir

The study of fish distribution in the reservoir presents a complex task. The imperfect methods and insufficient knowledge of this question are well known. Nevertheless, the knowledge of the ichthyofauna in the reservoir is extraordinarily important in order to comprehend the peculiarities of downstream fish migrations.

L a r v a e

The distribution of larvae in the pelagial was studied by the conical ichthyoplankton nets (IKS $= 0.12$ m^2) in ten sampling stations. Horizontal trawlings up to a depth of 9 m were carried out and fishing with dip nets from the bottom to the surface was also done, but less often. Another five stations situated in shallow water near the shore were fished with scoop nets. Sampling was also done in the period from 24 May to 2 June 1983. Fifty-nine samples comprised 3 323 individuals of fish.

In the pelagial catches the most abundant species were the perch, pike-perch and roach (Tab. 5); the bleak, ruffe and dace were encountered only sporadically.

The distribution of larvae in the pelagial near the dam was studied from the catches in the surface horizon. We found that the structure and concentrat-

Tab. 5. Distribution of fish larvae in pelagial and at the dam according to the catches obtained by trawling during 24 to 26 May 1983. X, means no fishing was done; O, means the fishing was unsuccessful. Localities see in *Fig.* 5

Locality	Day / Night	Concentration of fishes, ind./1 000 m^3					
		Perch 9.5 to 11.2 mm		Pike-perch 7.2 to 10.5 mm		Roach 6.9 to 7.8 mm	
		Surface	Depth	Surface	Depth	Surface	Depth
1	Day	0	0	0	0	0	0
	Night	X	X	X	X	X	X
[illegible]	Day	[illegible]	[illegible]	0	0	240	[illegible]
	Night	[illegible]	[illegible]	0	0	0	[illegible]
[illegible]	Day	[illegible]	[illegible]	[illegible]	X	0	X
	Night	0	[illegible]	[illegible]	[illegible]	0	0
[illegible]	Day	[illegible]	X	0	X	56	X
	Night	57	X	169	X	55	X
[illegible]	Day	[illegible]	1722	58	[illegible]	0	[illegible]
	Night	[illegible]	[illegible]	0	972	93	0
[illegible]	Day	[illegible]	X	56	X	0	X
	Night	[illegible]	X	0	X	[illegible]	X
[illegible]	Day	[illegible]	X	0	X	0	X
	Night	[illegible]	X	185	X	0	X
13	Day	[illegible]	X	0	X	0	X
	Night	[illegible]	X	0	X	0	X
14	Day	0	X	0	X	0	X
	Night	111	X	0	X	0	X
15	Day	0	X	0	X	0	X
	Night	0	X	0	X	0	X

ion of fish species differed (Fig. 5A). The number of samples was not adequate to judge the differences among the separate fishing sites. However, it is obvious that the fish concentration was substantially lower in stations remote from the waterworks (Loc. 12 to 15) than in stations in the neighbourhood of the dam (Loc. 2, 5, 8, 10). This is evident from Fig. 5B, which depicts the average results of the two zones. One of the arguments may be the direction of water currents toward the dam.

Fishing near the dam was performed in two main horizontal layers: 0 to 0.5 and 2 to 4.5 m (Fig. 6). It was ascertained that the roach was a stationary circadian in the surface layer and the pike-perch in the deeper layer. As to the perch we found a diel vertical migration. During the daylight hours the

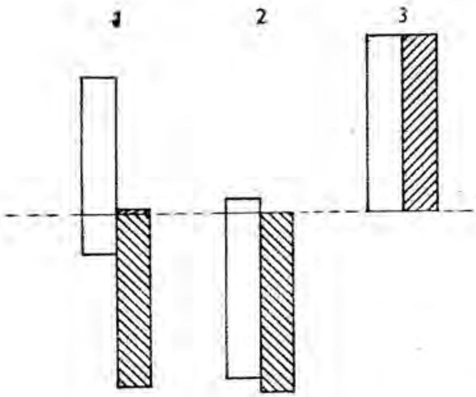

Fig. 6. Distribution of fish larvae. Left, perch; intermediate, pike-perch; right, roach. Open columns present daytime, shaded columns nighttime.

larvae largely occurred at the surface, at night in lower water layers.

The control trawling performed at night in three different horizons (0.2, 4.0 and 9.0 m) yielded the following relations of perch larvae: 0, 16 and 1 individuals respectively. Another control fishing carried out with the dip net in three horizons from the bottom to the surface confirmed a major occurrence of larvae in the upper horizon (Tab. 6). Supplementary fishing in two horizons

Tab. 6. Vertical distribution of fish larvae at the dam, Loc. 2. on 24 through 26 May 1983. Two samples were taken from each horizon

Horizon Depth /m/	t °C	Night		Day
		Perch 11 to 12 mm No. of fish	Pike-perch 8 to 10 mm No. of fish	Common bream 10 to 11 mm No. of fish
0 - 10	15.1	22	4	2
10 - 20	12.3	0	0	[illegible]
20 - 30	11.5	2	0	0

Footnote: Water temperature according to 31 May 1983

(5 m) of the same locality (No. 2) revealed that 77 per cent of perch larvae and 67 per cent of pike-perch larvae hung in the horizon of 0 to 5 m. In the lowest horizon the perch was rare.

During the period of our investigation of larvae distribution there was a vertical stratification of water temperature in the reservoir. In the upper horizon (0 to 5 m) preferred by fishes, the mean temperature of water was 16.3 °C, *i. e.* 2.3 °C higher than in the lower horizon (5 to 10 m).

Larvae of roach, common bream and perch were abundant in the littoral zone. In all five stations the roach was the most abundant species (Fig. 7).

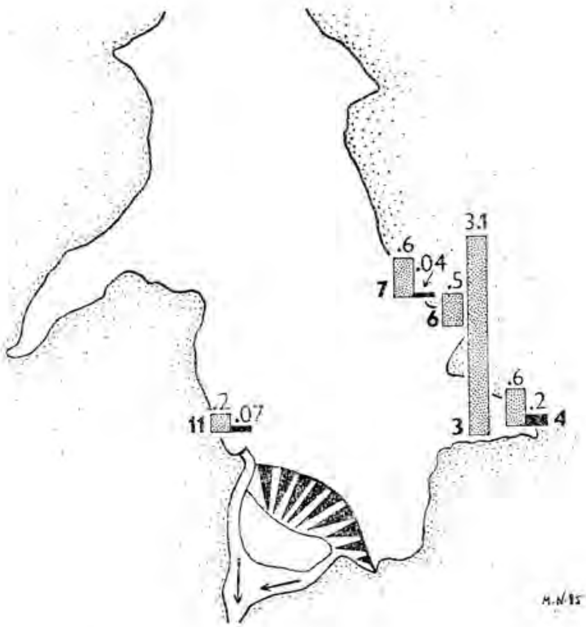

Fig. 7. Location of other five fishing stations in the Mostiště reservoir, littoral zone. The sequence of species: roach and common bream.

Its mean concentration reached a value of $1.0 \cdot 10^6$ ind./1 000 m^3. Common bream was captured at two stations ($4.8 \cdot 10^4$ ind./1 000 m^3), perch at one station ($1.4 \cdot 10^4$ ind./1 000 m^3).

Concluding our results on the fish larvae distribution in the sector of the reservoir at the dam, we state that the larvae occurred mainly in the littoral zone and in the upper horizon of the pelagial (0 to 5 m). In the latter place we ascertained an increased concentration. A contrasting distribution was found in the pike-perch, occurring in the pelagial zone, and in common bream occurring in the littoral zone. Perch and roach were abundant in both zones, with roach largely dwelling in the littoral zone and perch in the pelagial zone.

Fry and fish of older age groups

In order to study the occurrence of fishes of these different age groups, we carried out vertical fishings with a dip net from the bottom to the surface (Tab. 7). In the vicinity of the waterworks three stations were selected. The first one lay in the pelagial within reach of the hydrotechnical equipment for taking water to the power station (station 2, Fig. 5A). The fishing was done along the vertical line at the depth of 25 m. The fish concentration was influenced by the timetable of taking water from the bottom. Therefore part of fishing was done in two different horizons: 25 to 20 m and 20 to 0 m. The mean fish concentration at the depth of 25 m was also taken into account.

Tab. 7. Distribution of perch (ind. 1 000 m³) in Mostiště reservoir adjacent to the dam

Date	Mean length /mm/	Depth of fishing /m/			Horizons of fishing /m/	
		25	10	1.5 to 5	20 to 0	25 to 20
30 Nov. to 1 Dec.	55.2	22.6	11.1	504.4	2.8	88.8
20 to 23 Dec.	64.3	39.1	111.1	0	18.5	200.0
17 to 20 Jan.	-	-	-	0	-	-
22 to 24 March	57.0	0	5.5	0	0	0
25 to 28 Apr.	58.8	2.2	22.2	87.1	2.8	0
10 to 13 May	57.8	2.2	16.7	47.6	2.8	0
25 to 26 May	60.3	8.4	5.6	155.6	8.3	0
1 to 2 June	59.5	1.8	14.8	2872.0	0	0
20 to 23 June	58.5	0	0	844.4	0	0
12 to 14 July	44.2	0	0	313.7	0	0
25 to 28 July	33.5	0	0	44.4	0	0
1 to 2 Sept.	-	0	0	240.0	0	0
17 to 19 Sept.	153.0	0	0	11.1	0	0

The second station was also situated in the pelagial within the zone of the outlet to the waterworks. The fishing was carried out along the vertical line of 10 m. Since the three outlets were located at different depths and the water level fluctuated, the vertical line did not cover the horizons of the outlets taking water to the waterworks. For the same reason we were unable to make a comparison with the escape of fish through this efflux.

The third station was selected in the littoral sector (station 1, Fig. 5A) at the depth of 1.5 to 5 m. The vertical lines were near each other because of the rapidly increasing depth. For appraisal we thus considered to pooling the results of the fishings.

The data from the stations referred above and gathered together enabled us to characterize approximately the distribution of fishes in the zone at the dam. On the whole, we obtained **504** samples and the total catch amounted to 800 individual of fish. The perch and roach were most frequent, the common bream, pike-perch, ruffe and eel were less abundant (Tabs. 7 & 8).

Tab. 8. Distribution of separate species of fish (ind./1 000 m³) at the dam from catches in the long-handled dip net (+, not determined)

Species	Date of fishing	Mean length /mm/	Vertical lines of fishing /m/			Horizons /m/	
			25	10	1.5 to 5	20 to 0	25 to 20
Rutilus rutilus	30 Nov. to 1 Dec.	57.5	1.4	0	30.2	0	0
	25 to 26 May	64.0	2.0	0	0	0	0
	1 to 2 June	112.0	0	7.4	7.4	0	0
	20 to 23 June	64.0	0	0	27.8	0	0
	11 to 14 July	77.7	0	0	69.7	0	0
	25 to 28 July	45.3	0	0	33.4	0	0
	1 to 2 Sept.	+	0	0	1262.2	0	0
	17 to 19 Oct.	89.9	0	0	77.8	0	0
Abramis brama	30 Nov. to 1 Dec.	220.0	1.1	0	0	0	0
	1 to 2 June	117.0	0	0	24.6	0	0
	25 to 26 July	23.5	0	0	11.1	0	0
	1 to 2 Sept.	+	0	0	542.2	0	0
Stizostedion lucioperca	25 to 28 July	49.0	0	0	11.1	0	0
Gymnocephalus cernua	25 to 28 July	67.0	0	0	18.5	0	0
Anguilla anguilla	10 to 15 May	510.0	0	5.6	0	0	0

The distribution of perch in the zone at the dam was uneven during the year (Tab. 7). During the cold season from November 1982 to March 1983 perch occurred largely in the depths; their concentration at the bottom in separate seasons amounted to 200 ind./1 000 m³. Its concentration at the shore reached 504 ind./1 000 m³. This concentration was encountered only at the beginning of our survey.

With the coming of the warm season at the beginning of autumn, the perch largely occurred in the littoral zone; the maximum concentration reached 2 872 ind./1 000 m³. At the beginning of the warm season (the end of April to the beginning of June) its occurrence was also low in the profundal. At the same time, at a depth of 25 m the perch already disappeared from the zone at the bottom. In the other part of summer this species decreased in numbers at the bottom, though its concentration in the littoral zone remained high up to October.

Contrary to perch, the roach and common bream stayed in the littoral zone during the whole year (Tab. 8). In that zone the abundance of roach (= 1 262 ind./1 000 m³) and that of common bream (542 ind./1 000 m³) were highest. On the other hand these species were encountered in our catches from the bottom only sporadically. They were entirely missing in the bags taken from the horizons 20 to 0 and 25 do 20 m.

It may be concluded that in the profundal zone (horizon 20 to 25 m) it was the perch which largely inhabited these depths at the beginning of summer a small number of sac fry and larvae, during winter (November and

December) fry and individuals of older age groups. In the pelagial, first of all in its upper horizon (0 to 5 m), we detected a massive occurrence of larvae of perch, pike-perch and roach at the start of summer, whereas a sporadic occurrence of older specimens of perch was ascertained during the autumn and winter. Larvae of roach, common bream and perch were very abundant at the shore in May, from April to November the older age groups of perch, roach and common bream were common.

Migration of sac fry and larvae

Migration of these groups of fishes was studied during the period from 23 May to 2 September 1983. Within this period six samplings (24-hour cycle) of ichthyoplankton were carried out, 208 samples were obtained, consisting of 338 larvae belonging to three species: perch, pike-perch and common bream.

The mean concentration of sac fry and larvae during this period migrating through the power station was 4.29 ind./1 000 m^3, those migrating through the waterworks 4.51 ind./1 000 m^3. In both cases the perch showed a massive occurrence (99.9 per cent of the whole mean concentration through the power station and 92 per cent through the waterworks). Besides perch, common bream and pike-perch were also taken from the outlet of the power station and the waterworks (Tab. 9). In the following we shall discuss the migration of the particular species.

P e r c h

The sac fry and larvae of perch were found from the end of May to the mid-July (Fig. 8). Migration through the tunnel to the power station was ascertained in a short period of some ten days from the end of May to the beginning of June. Sac fry of perch, the developmental phases A and B (4.5 to 6.5 mm in length), made up 95 per cent of migrants. The other migrants were in the developmental phase C_1 to C_2 (7.1 to 7.2 mm in length). During the period of 23 to 26 May the concentration of fishes was the highest on the first station, 11.8 ind./1 000 m^3 (Tab. 9). The numerous fishings carried out on

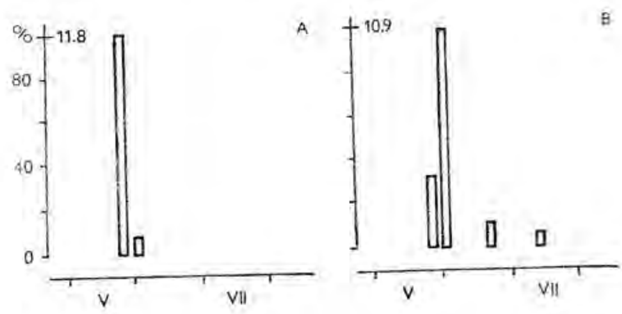

Fig. 8. Periodicity and numbers of sac fry and larvae of perch migrating downstream from the Mostiště reservoir. The numerals are numbers of fish/1 000 m^3.

Tab. 9. Species composition and concentration of fish larvae (ind./1 000 m^3) migrating from the reservoir in summer 1983

Species	Length range /mm/	Date of fishing					
		23 to 26 May	30 May to 2 June	20 to 23 June	11 to 14 July	25 to 28 July	1 to 2 Sept.
Power station							
Perca fluviatilis	4.5 - 7.2	11.8	1.01	0	0	0	-
Abramis brama	12.0	0	0	0.06	0	0	-
Waterworks							
Perca fluviatilis	6.0 - 17.8	3.7	10.9	1.19	0.82	0	0
Stizostedion lucioperca	5.9 - 11.1	0	0.87	0.67	0	0	0

Tab. 10. Dynamics of concentration of migrants (ind./1 000 m^3) of older age groups from Mostiště reservoir in 1982 to 1983. *K*, the mean value of concentration per year

Months	Nov.	Dec.	Jan.	Febr.	March	Apr.	May			June	July		Sept.	Oct.	Nov.	$\bar{K}$
Date of fishing	24	20	17	22	22	25	10	23	30	20	11	25	1	17	24	
Power station																
Perca fluviatilis	0.64	0.18	0.12	0.03	0.04	0.14	0.07	0.03	0	0	0	0.01	0	0	0	0.084
Anguilla anguilla	0.02	0	0	0	0	0.014	0.013	0.02	0.01	0	0.17	0.14	0.46	0	0	0.05
Gymnocephalus cernua	0.18	0.02	0	0.08	0	0.007	0.003	0.01	0	0	0	0	0	0.07	0	0.02
Others	0	0	0	0	0	0.007	0	0	0	0	0	0.011	0	0.014	0	0.002
Waterworks																
Perca fluviatilis	0.20	0.08	0.12	0	0.39	1.10	0.40	0.55	0.05	0	0	2.15	0	0	0	0.50
Gymnocephalus cernua	0	0	0	0	0	0	0	0	0	0	0	0.16	0	0.04	0	0.20
Rutilus rutilus	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0.002

24 and 25 May in the upper horizons at the dam and the littoral zone resulted in a practically total absence of the sac fry. In the horizon influenced by the uptake of water into the turbine we were able, for technical reasons, to conduct only one fishing. The absence of sac fry could be incidental.

The period of time in which the perch migrated through the waterworks was considerably longer than that through the turbine (some 50 days from the end May to mid-July). The mean length gradually increased from 6.0 to 17.8 mm. During the first fishing the water was taken to the waterworks from the lower inlet and, similarly as to that of the turbine the sac fry, some

92 per cent belonged to the phase A to B. During the second fishing, carried out on 30 May to 2 June, the water was taken from the higher horizon; of the sac fry captured some 67 per cent, belonged to the phase C_1 to D_2. These findings confirmed again that the sac fry of perch lived chiefly in the horizon at the bottom. Using the upper outlet (during the second fishing) led to an increasing concentration of migrating larvae from 3.7 to 10.9 ind./1 000 m^3 (Tab. 9), which corresponded to their main occurrence in the upper horizons at the dam. This concentration, however, was a hundred-fold lower than the concentration in the horizon adjoining the upper inlet (Fig. 5).

During the next fishings, when the lower inlet was in operation, the concentration of migrants gradually decreased and the length of fish increased. During the last fishing, from 11 to 14 July, a part of the fish reached the developmental phase of fry. Further investigations showed that the fry were absent. At the same time the fry began to populate the littoral zone of the reservoir, but their mean length decreased (Tab. 7).

It was found that the dynamic pattern of perch fry (within the 24-hour cycle) changed during ontogenesis. The sac fry (phases A to B) and early larvae (phases C_1 to D_1) migrated from the reservoir round-the-clock, but largely during the daylight hours (Fig. 9A). The postlarvae (phase D_2 to F) and advanced fry (G) migrated largely in twilight and at night (Fig. 9B). According to Pavlov (1979) and Pavlov & al. (1985a) this phenomenon is related to the decrease to loss of visual orientation in the water current.

The total number of perch migrants of the given age groups was computed from the volume of water passing through the power station and through the pipe supplying the waterworks, and the relation between the mean con-

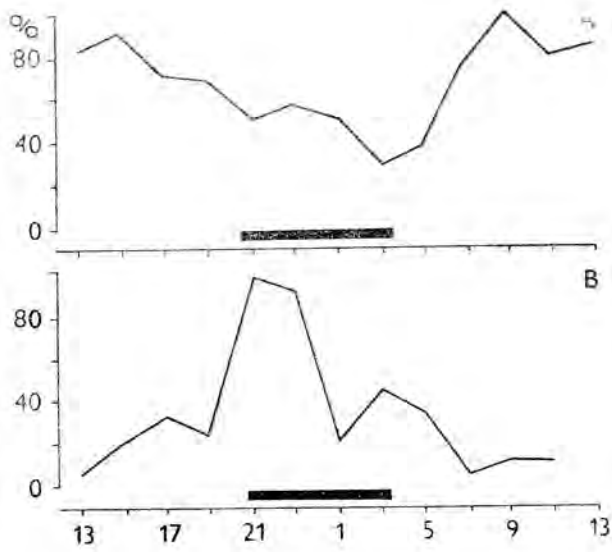

Fig. 9. Migrating pattern of perch fry. The sac fry and early larvae migrated round-the-clock, but largely during the daylight hours (A). Postlarvae and advanced fry migrated largely at twilight and at night (B).

centration of migrants. During the period May to June 26.5 thousand perch migrated through the turbine of the power station and during May and July three thousand perch through the pipe to the waterworks.

Pike-perch and other species

Individuals of pike-perch migrating as sac fry and larvae were found solely in the pipe of the waterworks. This was in accord with their vertical distribution in the reservoir at the dam (Fig. 6). The concentration of migrants reached 0.87 ind./1 000 m^3 and 0.67 ind./1 000 m^3 (Tab. 9). The migration of larvae exhibited a diel variation. Their total number during the period of drifting (June) amounted to 270 individuals.

Of other species we found one larva of common bream (l = 12 mm). This low frequency of common bream and a total absence of roach among the migrants contrasted with the high numbers of larvae of these species occurring in the water at the dam. Doubtless this phenomenon is related to the peculiarity of their distribution. Their occurrence was outside the zone influenced by the outlets, *i. e.*, in the littoral shallows or in the upper layers of the pelagial (Tabs. 5 & 8, Figs. 5 to 7).

Migration of fry and fishes of older age groups

The migration of fishes of these age groups was followed through the whole period of study. Altogether fifteen round-the-clock fishings were performed, resulting in 899 samples and 526 individuals of fishes belonging to six different species. The average concentration of migrants was 0.16 ind./1 000 m^3 and 0.70 ind./1 000 m^3 in the tunnel to the power station and in the pipes of the water treatment plant respectively. In these two locations the perch was the most abundant species, 52 and 71 per cent of the fishes entrapped. As regards the power station we encountered the eel, ruffe, pike-perch and roach (the species are arranged according to their abundance in the catch). As regards the water treatment plant, we found the ruffe and the roach (Tab. 10). In the following lines we are going to discuss the peculiarities of individual fish species.

Perch

As regards the migration of the perch in the given age groups we selected two periods: from 24 November 1982 to 2 June 1983 and from 20 June 1983 to 25 November 1983 (Fig. 10A, B). Whereas the former winter-spring period was characterized by regular downstream fish migration through the tunnel to the power station and through the pipes of the water treatment plant, the summer-autumn period was characterized by practically a total absence of this migration. These two periods were in accord with the period of perch occurrence in the deep layers of water at the dam (vertical lines 25 and 10 m) (Tab. 7). The perch inhabited the deep water layers up to the beginning of June; later on was absent. The only exception was the observation from 25 to 28 July 1983. During this period the perch migrated into the pipes of the waterworks. At the same time, however, the perch was not reported in the bags from the reservoir. The explanation may be that fishing was carried out above the horizon of the outlet to the waterworks (Fig. 10C). It is also possible that migration in that period was linked with an abrupt change of living condition of fishes in the reservoir.

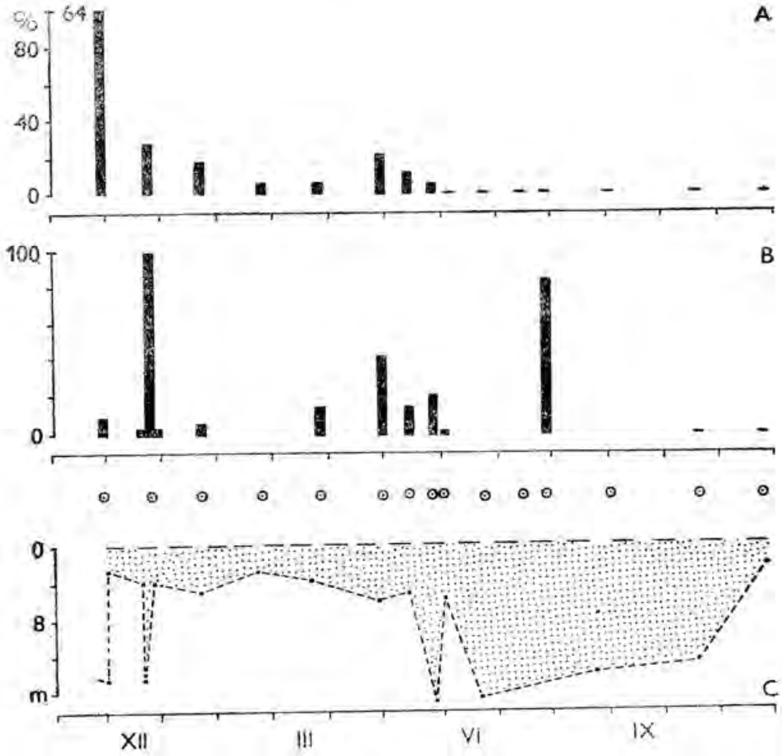

Fig. 10. Two apparently different stratifications of perch: from November 24 1982 to June 2 1983 perch migrated downstream more or less regularly, from June 20 to November 24 1983 perch were practically absent. Numbers are given in per cent of the whole catch (A). Concentration of migrants (B). The fishing was carried out above the horizon of the outlet to the waterworks (C).

The average length of drifting perch during the main period of migration (November to June) fluctuated within the range 52.0 to 59.6 mm. Only in July, after the beginning of the new growing season did the perch start to grow. On 24 to 27 July the mean length amounted to 64.1 mm. This increase reflects the process of fish growth in the reservoir. The mean legth of perch of the same age groups taken in the zone at the dam was, as a rule, a little higher than that of the migrants. *E. g.*, in December the values were $64.29 \pm \pm 0.72$ and 59.39 ± 0.72 in fish staying at the dam and in the migrants respectively. These differences were statistically significant.

The concentration of perch through the tunnel to the turbine during the main period of migration was the highest at the beginning of winter (November—December); later, towards summer, the concentration gradually decreased.

These findings are in accord with the fishing in the zone at the dam, the numbers of perch at the outlet to the turbine were highest at the same time.

The comparison of the concentration of perch migrants with that of perch living in the reservoir in the proximity of the outlet to the turbine shows that drifting from the reservoir affects only a negligible part of fish dwelling in the reservoir. During the two round-the-clock samplings (November-December 1982) the concentration of migrants was substantially (a thousandfold) lower.

Special experiments showed a relation between the concentration of migrants and the water discharge through the outlets. In two experiments conducted within a duration of an hour each the water discharge was increased in the tunnel of the turbine from 0.28 to 1.7 m^3/s. This water discharge resulted in a 4.3-fold raised concentration of perch (from 0.5 to 2.15 ind./m^3) compared with the density one hour before and one hour after the experiment.

Compared with the outlet to the turbine, the outlet to the waterworks differed in a higher variability of the concentration of migrants of perch. This was due to the fluctuation of water surface and due to the adequate horizon of fish distribution in respect of the outlet used (the upper, medial and lower outlet) (Fig. 10C).

The highest concentration of migrants was ascertained in the third decade of December, when the water was taken by the lower outlet. At the same time the highest concentration of perch was ascertained at the depth of 10 m in the zone at the dam (Tab. 7). A change from the lower outlet to the upper one caused a sudden decrease in fish density (Fig. 10B, C).

The impact of the stratum from which the water was taken to the waterworks and the intensity of fish escape from the reservoir was studied via the following experiment (Tab. 11). It was found that the maximum number of

Tab. 11. Number, mean length and mean concentration of perch caught in three stratified outlets to the waterworks from 24 Nov. to 1 Dec. and from 20 to 23 Dec. 1982

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]

migrants was in the lower water layers. This coincided with the data on the tendency of the distribution of perch in the reservoir during the season in question. From the end of December to mid-May only the upper opening was in operation. In the first half of that period the lowest concentration of fish was registered. In March and mainly during April the concentration of fish distincly increased consequently with the spring movements of perch (Tab. 7). With the water getting warmer and with the perch passing into the littoral zone during May, the migration became gradually lower (Fig. 10B), and later entirely ceased. During the following season from July to November 1983, the migration was observed only once, near the end of July.

On comparing the concentration of migrants escaping through the pipes of the waterworks with the concentration of fish in the reservoir at the dam, along the vertical line of 10 m. (Tab. 7) it turned out that the concentration of fish drifting through the waterworks was in all instances distinctly lower. This difference, however, was apparently smaller, since in contrast to the power station, we did not compare the concentration of fish in the horizon of the outlets, but in the total volume of water from the surface to the bottom.

It is necessary to note that, when we sampled in the two truncated branches of the pipe of the waterworks, the concentration of fish was usually higher in the branch with a smaller opening. *E. g.*, from 20 to 23 December 1982, *e. g.*, the concentration was 4.51 and 0.79 ind./1 000 m^3. In March and April a higher concentration of fish was observed in the smaller branch seven times out of the total number of ten. The fry were apparently divided irregularly in the pipe in the truncated section; this finding may be an attribute of the specification of the hydraulic structure of the water currents. The mechanism of this phenomenon requires a further survey, but it seems evident that, in such research, it is necessary to conduct samplings in all pipes.

As regards the 24-hour cycle, the migration intensity of perch in the age groups given differed during the year seasons. In summer and in winter (Fig. 11A, B) the late larvae and fry in the first phases of development showed a dusk-night rhythm. This pattern changed to a dusk-day rhythm in spring (Fig. 11C) with the maximum at seven and fifteen hours. This pattern corresponds with the increased activity of movements of the perch.

The whole number of migrants drifting from the reservoir per year with respect of the water discharge was estimated at 3.2 and 1.7 thousand individuals through the power station and the waterworks respectively. The highest number of fish migrating through the power station took place during the winter-spring period, through the waterworks during the spring-summer period.

Migration of eel, ruffe and other species

These species accounted for roughly 30 per cent of the total numbers of migrants of older age groups (older than 1 +).

The eel drifted exclusively through the turbine of the power station. Migration was ascertained only during the warm seasons of the year, from the end of April to the beginning of September (Fig. 12). The fish of relatively

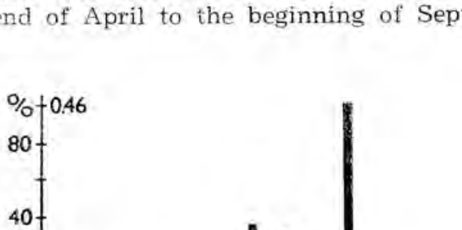

Fig. 12. Seasonal pattern of downstream migrations of eel (concentration = 0.26 ind. /1 000 m^3).

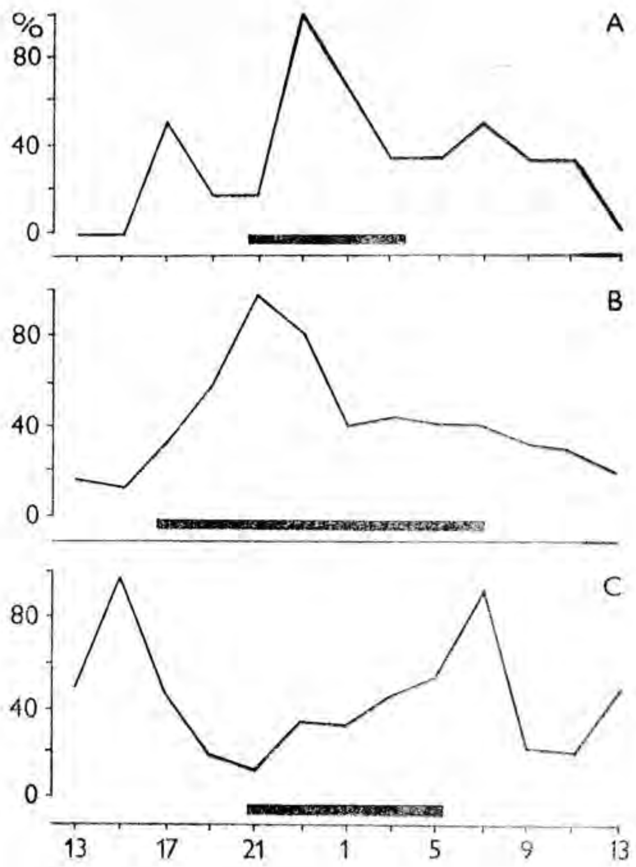

Fig. 11. Diel dynamics of downstream migration of advanced larvaeand fry of perch. A, summer migration; B, winter migration; C, spring migration.

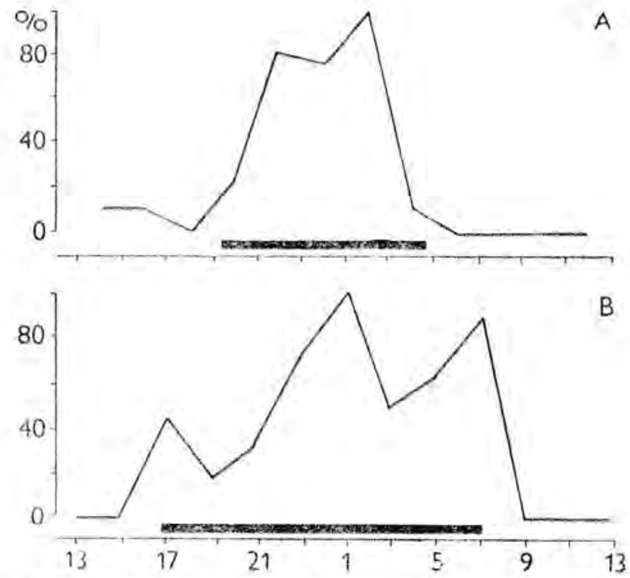

Fig. 13. Diel dynamics of downstream migration of eel (A) and ruffe (B).

large size migrated from April to June. Their mean length was 496 mm, the range fluctuating between 82 and 950 mm. The concentration of migrants was low, the average being 0.014 ind./1 000 m^3. Small eels migrated from July to September. Their mean length was 244 mm, the range varying between 110 and 550 mm. The concentration of migrants substantially increased, the mean being 0.26 ind./1 000 m^3. The highest concentration was ascertained in September (= 0.46 ind./1 000 m^3).

The dynamics were characterized by a night mode (Fig. 13A). As regards the whole number of migrants the eel was second after the perch; their number was 1 140 ind. per year.

The ruffe migrated downstream mainly through the turbine of the power station and largely during the cool season of the year, in October to February. The highest concentration amounted to 0.18 ind./1 000 m^3 (Tab. 10, November 1982). During the warm season (June to October) the ruffe was absent from the turbine of the power station, but it was found in the pipe of the waterworks in July. The mean length of ruffe migrants was 51 mm, the range being 37 to 99 mm. The migration of ruffe had in general a dusk-night rhythm (Fig. 13B). As to the number of individuals, the ruffe took third place among these migrants: 708 individuals drifting through the turbine and 77 individuals through the pipe of the waterworks during our survey.

As to the other fishes, the following species were sporadically captured: pike-perch (67 mm), roach (129 mm) and bleak (40 mm) drifting through the turbine and roach (61 mm) migrating through the pipes of the waterworks. The approximate total number in the volume of water was estimated about 150 individuals for the whole year.

Traumatic changes in migrants

According to the sources the fish have incurred mechanical injuries when passing through the turbine (Tichij & Viktorov 1940, Raben 1957, Schoeneman 1954, Volodin 1958, Čikova 1968, Šaronov 1972, Nezdolij & al. 1975, Pavlov & Nezdolij 1981, Morten 1985, *etc.*) through rapid decrease of hydrostatic pressure (Bishai 1961, Cramer & Oligher 1964, Faye & Scott 1965, Cvetkov & al. 1972), forming of caverns (Muir 1959) and hypersaturation (Smišek 1955, *etc.*). The influence of these factors was studied in detail in salmonids (Muir 1959, Cramer & Oligher 1964). The results of these papers made good use in designing projects observing the restriction and prevention of harmful effects of building and operation of hydraulic water plants (Geen 1975, Horst 1977, Swartzman & al. 1977).

During the whole period of our study we registered, among the fishes passing through the turbine, traumatized individuals. The visual examination and the pathological anatomical analysis of individuals of perch drifting from the reservoir through the Kaplan turbine disclosed a 100 per cent traumatization (Tab. 12). The main types of traumas were as follows: rupture of swim bladder, negative buoyancy and haemorrhage at the fin bases. A great number of fishes with burst swim bladders also displayed negative buoyancy and squeezed organs (stomach and eyes). This finding indicates that the state of the swim bladder is most decisive for the level of the injury.

The trauma of the swim bladder was usually caused by a sharp decline of the hydrostatic pressure during the fish's passage from the reservoir to the tail-race (the increase of pressure is of the value of 2.6 atm.). A high proportion of fish showing a barotrauma of the swim bladder was also reported among the fishes drifting downstream from other reservoirs (*e. g.*, Mitrofanov & Nezdolij 1974, Pavlov & Nezdolij 1981, Pavlov & al. 1981). The relatively high occurrence of mechanical injuries observed in Mostiště reservoir (up to 15 per cent), as compared with the data of the cited authors, may be explained by the construction of the tunnels, pipes and all other water conduits, by their small dimensions and particularly by their narrow clearances.

In order to differentiate the effect of hydrostatic pressure from other impacts, we devoted special attention to the state of physoclistic fishes — the perch. The fish were caught in the reservoir and quickly lifted from the depths

Tab. 12. The occurrence of the traumatization (%) of perch fry ($l = 57.4 \pm 1.32$ mm) during their migration through the Kaplan turbine (I) and lifted by scoop net in the head-race from a depth of 20 to 25 m (II) in the Mostiště reservoir, November to December 1982

Fish group	Normal status	Cases of traumatization								
		Swim bladder		Buoyancy		Haemorrhages			Squeezing out of organs	Mechanical damage
		Enlarged	Burst	Positive	Negative	In eyes	In fin bases	In internal organs		
I	0	10.0	65.0	10.0	50.0	20.0	35.0	5.0	10.0	15.0
II	6.5	19.6	80.4	45.6	47.8	21.7	32.2	10.9	54.4	0

Footnote: The estimation of traumatization is given following the frequency occurrence of several indices in all fishes analysed in groups (I, 20 specimens; II, 46 specimens)

of 20 to 25 m to the water surface. Examination of these fish revealed traumas similar to those described in drift migrants (Tab. 12). There were mainly pathological changes affecting the swim bladder. The only difference lay in the absence of mechanical injuries. The behaviour of perch lifted from the depths of 20 to 25 m differed from the behaviour of those caught in shallow water. The fish had clearly expressed positive buoyancy and widely spread gill covers, and lay on their side or with the belly turned up. Sometimes they attempted to dive into deeper water. They did not respond to visual and auditory stimuli and exhibited only weak reaction to tactile stimuli. Gradually, after one or two minutes, their eyes squeezed out "telescopic eyes" and exhibited injury to the swim bladder (*cf.* Baruš & al. 1984a). Analysis of these fish made after 13 hours showed that only four out of fifteen perch (= 26.7 %) survived. The eye protrusion disappeared. Seven individuals exhibited positive, eight individuals negative buoyancy. As the criterion of swimming ability we took the so-called factor of diving (Lowndes 1942).

The dissection of the latter group of perch showed that four fish had a conspicuously enlarged swim bladder. This was the reason for the compression of internal organs and haemorrhages. Three fish had their swim bladder burst and gas was accumulated in the belly cavity. The rupture of the swim bladder, open mouth and gill covers widely spread were characteristic feature of fish with negative buoyancy (B a r u š & al. 1984a). All indications of traumas mentioned above were also characteristic of fish drifting through the turbine. These findings revealed that traumas of fish were generated by abrupt decline in hydrostatic pressure.

Downstream fish migration from the Věstonice reservoir

Study area and material

The Věstonice reservoir, lying at 167 m a. s. l., has the lowland type of impoundments. It was built on the lower reaches of the Dyje River in 1980. The reservoir was built with the aim of retaining water for irrigation of agricultural land. At the water surface of 1 015 ha the reservoir retains a volume of 21 million cubic m; the depth at the dam is 3.2 m, the coefficient of water exchange being about 50. During our survey the water discharge varied between 8 and 115 m³/sec. The water is discharged by a bottom outlet consisting of six segmented water gates each 21 m long (Fig. 14).

The fishing was regularly carried out in the tail-water below the overflow lip and periodically in a sector of the reservoir at the dam. The passive fishing gears were employed in three stations; the typical station was that located below the lip. The dip net was used at two stations. The net taking the ichtyoplankton was used at four stations during the 24-hour cycle. A summary of the fishes caught is given in Tab. 13. During the whole survey we performed fourteen 24-hour cycles, obtained 934 samples and caught some 12.2 thousand fishes.

Tab. 13. Data on the distribution and downstream fish migration from the Věstonice reservoir. N. b., tail-water; V. B., the reservoir. For acronyms of fishing gears see Tab. 2

No. of diel fishings	1			2			3			4			5		
Date of fishing	2 to 3 Dec. 82			15 to 17 Dec.			13 to 14 Jan. 83			21 to 22 Febr.			21 to 22 March		
Locality	N.b.		V.b.	N.b.		V.b.	N.b.		V.b.	N.b.		V.b.	N.b.		V.b.
Fishing gear	KS	P	P	KS	P	P	KS	P	P	KS	P	P	KS	P	P
No. of samples	19	11	5	52	20	10	36	20	10	36	20	10	36	20	10
No. of fish	50	3	23	112	6	0	35	8	0	9	2	0	1104	41	0

No. of diel fishings	6			7			8					9				10		
Date of fishing	21 to 22 Apr.			5 to 6 May			19 to 20 May					30 May to 1 June				15 to 16 June		
Locality	N.b.		V.b.	N.b.		V.b.	N.b.			V.b.		N.b.			V.b.	N.b.		
Fishing gear	KS	P	P	KS	P	P	KS	IKS	P	P	IKS	KS	IKS	P	KS	KS	IKS	P
No. of samples	29	20	15	36	20	10	39	13	20	10	50	24	12	20	12	36	24	20
No. of fish	2747	70	31	2752	273	7	1406	1091	175	6	148	561	19	24	12	27	0	17

No. of diel fishings	11				12			13			14		
Date of fishing	6 to 7 July				18 to 19 Aug.			13 to 14 Sept.			22 to 23 Nov.		
Locality	N.b.			V.b.	N.b.		V.b.	N.b.		V.b.	N.b.		V.b.
Fishing gear	KS	IKS	P	P	KS	P	P	KS	P	P	KS	P	P
No. of samples	30	8	20	15	33	20	10	32	20	10	16	20	10
No. of fish	83+	0	16	5	22	19	0	9	6	2	277	29	83

Footnote: +, besides these samplings ten additional samples were taken with the dip net, yielding 127 larvae

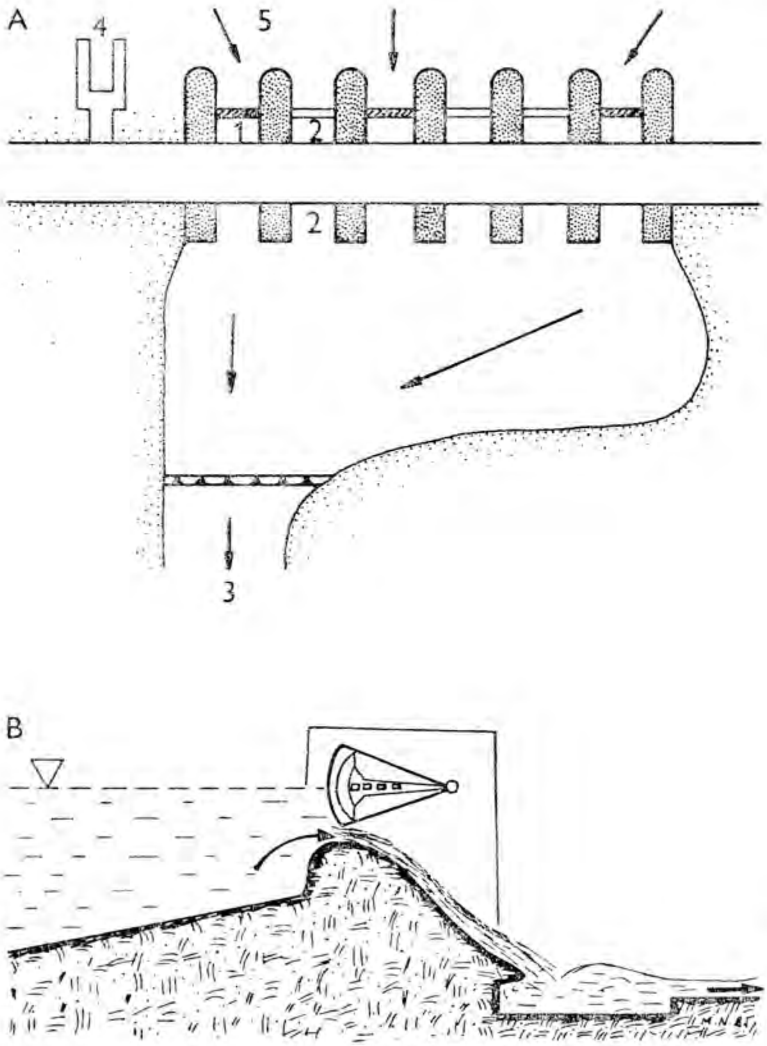

Fig. 14. Diagram of the watergate at the Věstonice reservoir with stations of fish samplings 1 to 5 (A). Location of the conical net near the lip (B).

Species composition of fishes in the reservoir and of the migrants

According to Lusk (1985) the reservoir housed forty species of fishes (Tab. 14). The dominant species are as follows: common bream, silver bream, roach, bleak and perch.

Tab. 14. Species distribution of fishes in the Věstonice reservoir and its tributaries, and in the Dyje River below the dam. Abundance of species: +, sporadic; ++, intermediate; +++, abundant (according to Lusk 1985)

	Fish species	Fish occurrence			
		Věstonice reservoir	Jihlava river	Svratka river	Dyje river below Věstonice
1	Salmo trutta	+	+	-	+
2	Salmo gairdneri	+	+	-	+
3	Coregonus peled	+	-	-	-
4	Thymallus thymallus	+	+	-	-
5	Esox lucius	+++	++	++	+++
6	Rutilus rutilus	+++	+++	+++	+++
7	Leuciscus leuciscus	+	+	-	+
8	Leuciscus cephalus	+	++	++	++
9	Leuciscus idus	++	+	+	++
10	Scardinius erythrophthalmus	+++	++	+	++
11	Ctenopharyngodon idella	++	+	-	+
12	Aspius aspius	+	+	+	+
13	Leucaspius delineatus	++	+	-	-
14	Tinca tinca	++	++	+	++
15	Chondrostoma nasus	+	++	+	++
16	Gobio gobio	+	+++	+++	++
17	Gobio albipinnatus	+	++	+	+
18	Pseudorasbora parva	+	-	-	-
19	Barbus barbus	+	++	+	++
20	Alburnus alburnus	++	++	+	++
21	Alburnoides bipunctatus	+	+	-	-
22	Blicca bjoerkna	+++	++	++	+++
23	Abramis brama	+++	+++	+++	+++
24	Abramis ballerus	+	+	+	++
25	Vimba vimba	+	+	-	+
26	Rhodeus sericeus	+	++	-	++
27	Carassius carassius	++	+	+	+
28	Carassius auratus	+	+	+	+
29	Cyprinus carpio	+++	++	+	++
30	Hypophthalmichthys molitrix	+	+	-	-
31	Aristichthys nobilis	+	+	-	-
32	Noemacheilus barbatulus	+	++	+	+
33	Cobitis taenia	-	+	-	+
34	Misgurnus fossilis	++	+	-	+
35	Silurus glanis	+	+	-	+
36	Anguilla anguilla	+	+	+	+
37	Lota lota	+	+	-	+
38	Perca fluviatilis	+++	++	+	++
39	Stizostedion lucioperca	++	++	+	++
40	Gymnocephalus cernua	++	+	-	+

Our catches carried out in the dam zone of the Věstonice reservoir included 24 species (Tab. 15). Of them, the abundant ones were: common bream, silver bream, bleak and perch. These fishes formed 82.3 per cent of the total number

Tab. 15. Species composition and numbers of fishes caught in different fishing gears in the reservoir and below the dam of Věstonice reservoir. For acronyms of fishing gears see Tabs. 2 & 4. KSR, conical net put in the tail-water, station No. 3, Fig. 14

Species	Spilling basin below the dam				Reservoir				Total
	Fishing gear								
	KS	IKS	P	KSR	P	KS	S	IKS	
Esox lucius	198	-	54	-	-	-	-	-	252
Leuciscus cephalus	4	-	-	-	-	-	-	-	4
Leuciscus idus	25	-	3	-	-	-	-	-	28
Leuciscus sp.	-	75	-	-	-	-	-	4	82
Rutilus rutilus	538	24	17	7	1	-	126	140	853
Scardinius erythrophthalmus	347	0	8	-	-	-	-	-	355
Leucaspius delineatus	3	0	-	-	-	-	-	-	3
Alburnus alburnus	864	2	33	26	11	-	-	-	936
Abramis brama	3431	0	246	1	6	2	-	-	3686
Abramis balerus	121	0	5	2	-	-	-	-	128
Blicca bjoerkna	2742	1	242	46	111	2	-	-	3144
Tinca tinca	21	0	11	-	-	-	-	-	32
Chondrostoma nasus	1	0	-	-	-	-	-	-	1
Gobio gobio	68	0	-	5	-	-	-	-	73
Barbus barbus	1	0	-	1	-	-	-	-	2
Carassius carassius	26	0	-	-	-	-	-	-	26
Cyprinus carpio	6	0	1	-	-	-	-	-	7
Misgurnus fossilis	22	0	-	-	-	-	-	-	22
Noemacheilus barbatulus	1	0	-	-	-	-	-	-	1
Anguilla anguilla	5	0	-	-	-	-	-	-	5
Lota lota	1	0	-	-	-	-	-	-	1
Stizostedion lucioperca	237^{+}	118	16	4	-	7^{++}	-	-	362
Perca fluviatilis	1100	845	39	11	28	1	1	4	2029
Gymnocephalus cernua	86	2	-	1	-	-	-	-	89

Footnote: +, inclusive 102 individuals of postlarvae in length range 23.4 to 35.7 mm; ++, postlarvae of 21 to 29 mm in length

of migrants. Common bream, silver bream and bleak were present in older age groups. Of the total number of perch 43 per cent were larvae. Common bream, silver bream and perch made up the bulk of all our catches. The same species were also abundant in the reservoir. Several other species, migrants and species living in the reservoir will be discussed separately.

Migration of sac fry and larvae

The study of migration of larvae is based on the catches in the conical ichthyoplankton nets in the period from 19 May to 7 July 1983. During this period the water level in the reservoir was low; the drop was some three metres. This situation was due to the necessary repair of side dams. Within this spell we carried out four round-the-clock investigations, took 57 samples and captured 1 070 larvae of seven different species. Perch and pike-perch were the most abundant fishes; they comprised 90 per cent of all specimens: *Leuciscus* sp. and roach were rare and bleak and silver bream occurred only sporadically.

During two days from 19 to 20 May 1983 we were able to catch a rich bag consisting of seven species of fishes. The whole concentration equalled 1 062 ind./1 000 m^3 (Tab. 16). During the next fishing we captured only the pike-

Tab. 16. Species composition and concentration of fish larvae (ind./1 000 m^3) drifting from the reservoir in May to June 1983

Species	Length range /mm/	Day		Night		Round-the-clock	
		19 to 20 May	30 May to 1 June	19 to 20 May	30 May to 1 June	19 to 20 May	30 May to 1 June
Perca fluviatilis	5.5 – 14.0	821.4	0	[illegible]	0	[illegible]	0
Lucioperca lucioperca	9.5 – 28.0	53.4	0.15	105.2	0.83	[illegible]	[illegible]
Leuciscus sp.	6.0 – [illegible]	59.8	0	16.9	0	78.8	0
Rutilus rutilus	7.0 – 10.0	34.2	0	3.2	0	24.2	0
Alburnus alburnus	6.0 – 8.0	2.6	0	0	0	2.0	0
Gymnocephalus cernua	7.0	0	0	8.4	0	2.0	0
Blicca bjoerkna	7.5	1.5	0	0	0	1.0	0

-perch. During the periods from 15 to 16 June and from 6 to 7 July the larvae were absent, but the ichthyoplankton net caught fishes of older age groups.

It may be concluded that the species composition of migrants (sac fry and larvae) differed from the species composition living in the reservoir. We want to point out that among the migrants we did not encounter those species presenting the mass abundance in the reservoir, *e. g.*, common bream, silver bream, roach and bleak. It is of interest that an analogous relation between the fishes living in the reservoir and migrants was ascertained in the Mušov reservoir situated immediatelly above the Věstonice reservoir. Roach fry were abundant in the littoral zone at the dam and lacking among the migrants (Tabs. 17 and 18). In the lines that follow our attention will be paid to the peculiarities of migrations of the particular species.

Tab. 17. Species composition and number of fish caught in the littoral zone of the reservoir at the dam (20 May 1983, daytime)

Species	Rutilus rutilus	Perca fluviatilis	Leuciscus sp.	Total
Length of fish /mm/	5.0 to 12.0	13.5	13.5	
Dip net	126	1	0	127
Trawling net /IKS 0.2/	140	4	4	148

Tab. 18. Species composition and number of fish caught in the littoral zone of the Mušov reservoir at the dam and in the outlet (20 May 1983)

Species	Rutilus rutilus	Leuciscus sp.	Blicca bjoerkna	Lucioperca lucioperca	Perca fluviatilis	Total
Length /mm/	6.0 to 9.5	10.0	8.0 to 9.5	12.0 to 13.0	12.0	
Reservoir Dip net	115	0	0	0	0	115
Outlet /IKS 0.2/	0	1	5	2	1	9

P e r c h

The perch were very abundant among species, comprising 79 per cent of the total amount of larvae. The mean concentration during the 24-hour cycle (19 to 20 May) amounted to 853.5 ind./1 000 m^3 (Tab. 16). Among the perch migrants we found sac fry, early and advanced larvae (phases B to E). Their length fluctuated between 5.5 and 14.0 mm, the average being 10.8 $\pm$ 0.06 mm. The occurrence of sac fry was only rare. Most of the larvae measured 9.5 to 12.0 mm.

The fry migrated from the reservoir round-the-clock, but largely at the dusk and at night from 20.00 to 6.00 hours (Fig. 15A). The peak migration fell on the morning and evening hours; the least migration was observed during the light hours. The fish migrating at night were somewhat bigger than those migrating in the daytime, but the differences were not significant. The total number of migrating perch of the given age (sac fry and larvae) was equal some 22.1 million individuals (from 19 May to 1 June).

P i k e - p e r c h a n d o t h e r s p e c i e s

This group formed 20 per cent of the total number of migrants; the pike--perch comprised 11.0, *Leuciscus* sp. 7.3, roach 2.2, ruffe, bleak and silver bream 0.5 per cent each. Among the migrants of pike-perch we found larvae 9.5 to 29.0 mm in length (phases C_2 to F). Their mean length was 12.0 and 23.4 mm, the concentration being 100.0 and 0.39 ind./m^3 at the first and second fishings respectively (Tab. 16).

The 24-hour cycle of pike-perch migrants showed a twilight to night pattern. The highest number of migrants was ascertained in the evening and at the beginning of night. A slightly increased migration activity was also ascertained in the morning (Fig. 15, B, C). The first fishing (phases C_2 to E) was reminiscent of the 24-hour cycle of migration dynamics of perch. In the second fishing the migrants of pike-perch had already reached the developmental

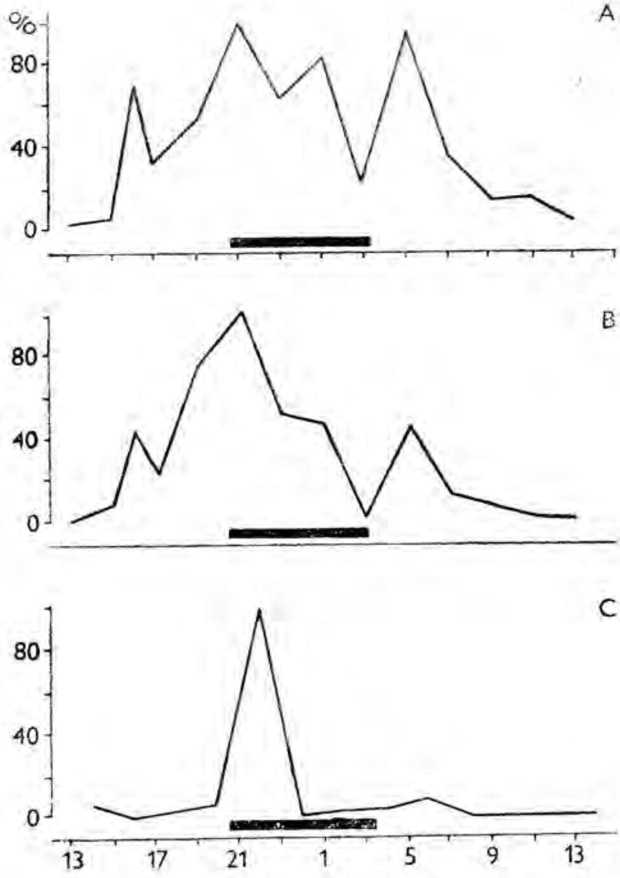

Fig. 15. Diel dynamics of downstream migration of perch larvae (A). Migration of pike-perch larvae, stages C_2 to E (B). Migration of pike-perch larvae, stages E to F (C).

phases E to F and exhibited a twilight to night activity; their migration dynamics were already considerably different.

The migrants of the other species were encountered only during the first fishing by means of an ichthyoplankton net (Tab. 16). Of the fishes *Leuciscus* sp. was caught in lengths 6.0 to 11.0 mm, the average being 9.3 mm, roach in lengths 7.0 to 10.0 mm, the average being 8.8 mm. The total number of migrants of the fishes mentioned above in this age group amounted to 5.4 million individuals (out of them about 2.6 million larvae of pike-perch) between 19 May and 1 June.

Migration of fry and older age groups

The migration of fishes of this group was followed through the whole period of our research. Altogether, 14 diel samplings were carried out, 464 samples taken and 9 848 individuals caught belonging to 23 species. The mean concentration of migrants amounted to 7.24 ind./1 000 m^3 during the whole spell. The silver bream, common bream, roach and rudd were most numerous species, their proportion made up 18.7 per cent, the next species, the pike, pike-perch, blue bream and ruffe, 3.6 per cent. The other species formed only 1.3 per cent of the mean annual concentration (Tab. 19). The remainder of the species were

Tab. 19. Average concentration of fish species per 24 hours (ind./1 000 m^3) of older age groups caught in conical net set in tail-water of Věstonice reservoir in 1982 to 1983. *K*, average concentration per year

Date	Dec.		Jan.	Febr.	March	Apr.	May			June	July	Aug.	Sept.	Nov.	K
	2	15	13	21	21	21	5	19	30	15	6	18	13	22	
B. bjoerkna	0	0.007	0.006	0.013	0.64	4.07	4.20	17.60	0.81	0.11	4,48	0	0.04	0.1	2.29
A. brama	0.15	0.04	0.03	0.06	1.46	5.28	7.20	9.45	0.19	0.05	2.65	0	0.04	0.04	1.98
Al. alburnus	0.05	0.08	0.03	0	0.43	0.26	0.36	13.70	0.10	0.02	2.54	0.11	0.03	0.04	1.27
P. fluviatilis	0.03	0.07	0.04	0.026	1.13	2.12	0.82	2.40	0.68	0.05	0.18	0	0	0.47	0.57
R. rutilus	0.05	0	0.026	0	0.34	0.73	0.14	2.30	0.19	0.03	2.15	0.10	0	0.1	0.44
S. erythrophthalmus	0	0	0	0	0.025	1.13	0.04	3.30	0.12	0	0.16	0	0	0	0.34
E. lucius	0.01	0.04	0.02	0.006	0.30	0.24	0.30	0.14	0	0	0	0.03	0.01	0	0.08
S. lucioperca	0.37	0.134	0.05	0	0.087	0.017	0.005	0	0	0	0.27	0.01	0.08	0.12	0.08
A. ballerus	0.01	0	0.006	0	0.14	0.18	0.20	0.32	0.004	0	0	0	0.01	0.01	0.06
G. cernua	0	0.004	0	0	0.02	0.04	0.32	0.18	0.012	0.04	0	0	0	0	0.04
Others	0	0.04	0.018	0.006	0.045	0.576	0.21	0.176	0.008	0	0	0.02	0.035	0.08	0.087

as follows: gudgeon, mud-loach, crucian carp, tench, carp, ell, chub, sunbleak, barb, nase, stone-loach and burbot.

Below the overflow lip at the dam of Věstonice reservoir there were zones of whirling; a number of fishes always stayed in this swiftly circulating water. Obviously, in these zones shoals were formed by the migrants drifting from the reservoir, but also by fishes living below the dam in the Dyje River. Fishing with dip nets resulted in catching 12 species; these fish belonged mainly to older age groups, including a great number of adults (Tab. 15). The common bream and silver bream were most abundant (73 per cent), the same two species were ascertained in the reservoir and among the migrants. The representatives of the rheophilous fauna (*i. e.*, chub, barb, nase, gudgeon, stone-loach) were encountered rarely. The total number of species caught in all types of fishing gears used below the dam amounted to 24.

The water is discharged by a bottom outlet consisting of six segmented water gates each 21 m long. Raising the water gate some 8 to 10 cm off the bottom resulted in a thin jet of water flow with the velocity of current exceeding 5 m per sec. at the overflow lip. When we set the nets close to the lip, they were soon damaged by the strong current. In order to save the nets we eventually placed them at a distance of 1 to 6 m downstream (behind the boundary of the contact of the current with the surface in the spilling basin). In doing this, we were not able to prevent, to a certain extent, the water from the sides of the net (eddy zones) entering the net and, with this water fishes from the tail-race also appeared in the net (despite the fact that, prior to each 24-hour sampling, we raised the water gate for some 5 to 15 min. and discharged an amount of water downstream in order to wash out the fishes from the whirling zone and also from the reach of the river). In order to remove doubts regarding the method of fish sampling, we made a trial and set the net on the lip. In spite of serious damage to the net webbing, we caught, after three hours of daytime fishing, only one pike and some remains of fish bodies, and stones.

Repeated trials of the same type were performed during the period 30 May to 1 June, 1983. During this period the water level in the reservoir dropped and the water depth decreased from 3.2 to some 0.5 to 0.8 m. In this case the gear could be installed directly in the water current flowing from the reservoir some 30 to 50 m ahead of the outlet of the first segment. During 24-hours we carried out twelve fishings and caught three species: silver bream (90 to 192 mm in length), common bream (120 to 285 mm) and perch (102 mm) (Tab. 15, fishing gear KS). The computed total concentration of fishes caught was 0.067 ind./1 000 m^3. Thus we were able to deduce that some 200 individuals of fishes migrated downstream per 24 hours. The virtual concentration and the total number of fishes were obviously much higher because the water velocity in the fishing place was only 0.5 m/sec., thus two or three times lower than the critical rate of fishes of the given length category (*cf.* Pavlov 1979). We are not therefore able to compare these results with results obtained from the tail water; in the tail water the water velocity was substantially and constantly higher than the critical water rates. It is interesting to note that the downstream fish migrations were also manifested at a certain distance some 250 m downstream in the river bed (station No. 3, Fig. 14). During round-the-clock fishing, from 22 to 23 November 1983, we caught 104 individuals which belonged to ten species (Tab. 15, KSR).

Our experimental fishing indicates that there were also migrations of older age groups of fish from the reservoir. However, it was not possible precisely determine the percentages of fish which swam into the net from the reservoir. Thus our data on the concentration and number of migrants of older age groups were approximate and require further precision. In the following lines we shall discuss the regularities of migration of those fish species that occurred most often.

Silver bream

Silver bream was the most frequent species, its proportion equalled 31.6 per cent. The mean concentration of migrants reached 2.29 ind./1 000 m^3. The migration took place practically through the whole research, but largely in April to May and in July (Fig. 16A). The highest concentration was ascertained in mid-May, 17.6 ind./1 000 m^{-3} (Tab. 19). At the same time, the silver bream gathered in great numbers in the tail water (Fig. 16B). The catch of silver

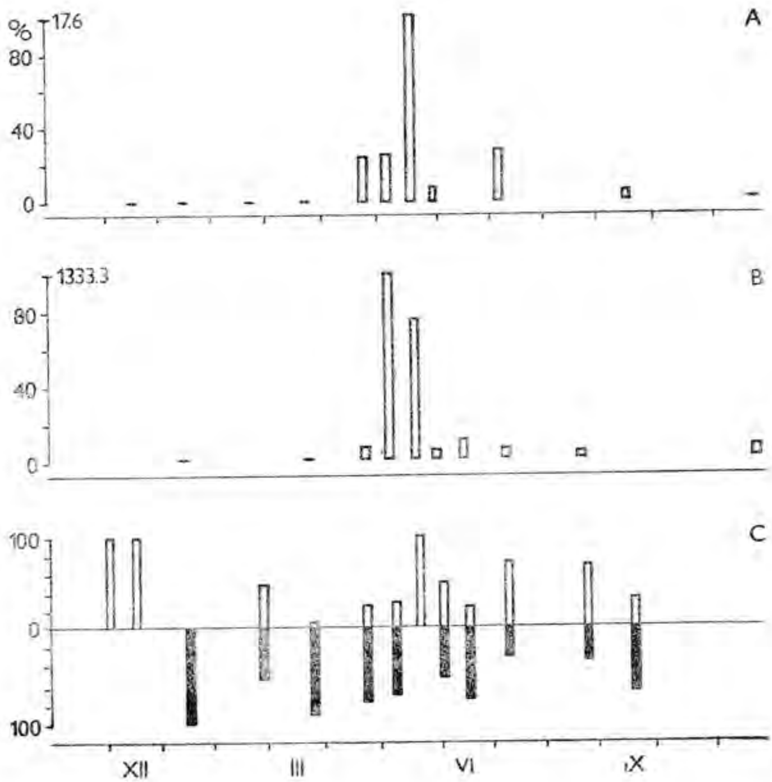

Fig. 16. Patterns of downstream migration and catches in tail water of advanced larvae and fry of silver bream. Migration of fish in per cent (A). Catches in dip net in tail water (B). Migration dynamics in daytime and nighttime (C).

bream in dip nets during the spring formed 85.9 per cent of the total annual bag. The length of the migrants fluctuated between 33 and 290 mm, the average varying from 84 to 122 mm. Bigger fish occurred largely during spring, smaller fish during summer.

The dynamics of migrations during the 24-hours cycles of silver bream differ with relation to the daytime and night. The relationship indicated a sinuosity, the day and night maxima altering twice (Fig. 16C). The length of the light and dark periods is given in Fig. 17. As evident in Fig. 18A at the

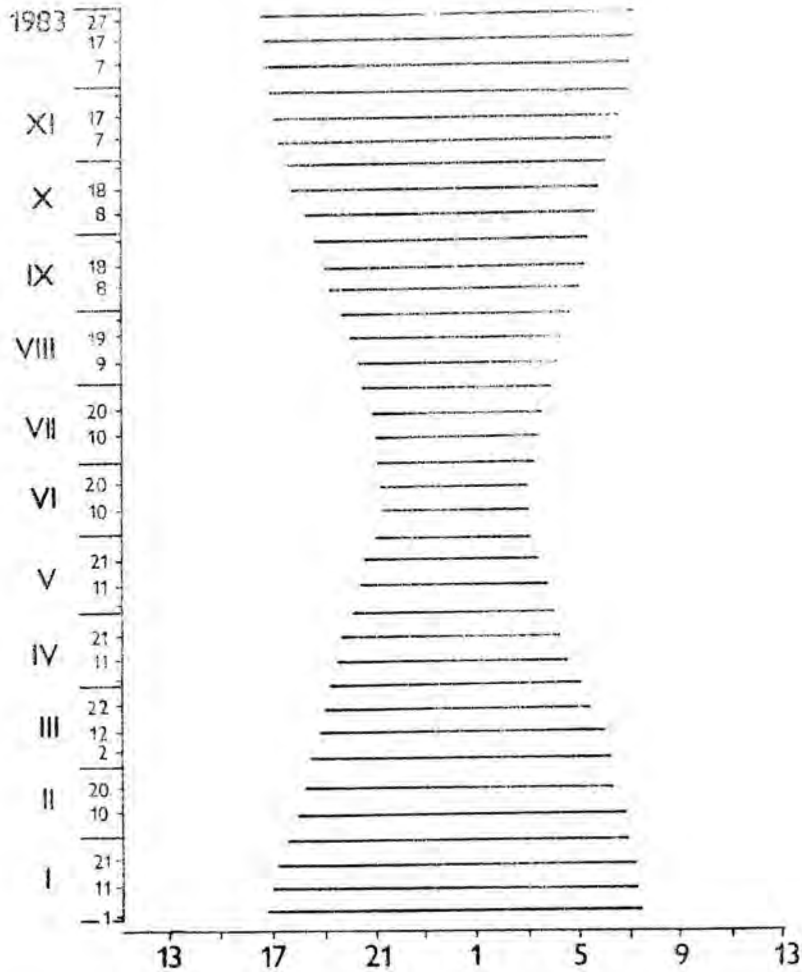

Fig. 17. Diagram of light and dark parts of day through the year.

station with the highest number of fish caught (= 499) the maximum fell on 23.00 hr. At other stations the maximum fell on 21.00, 22.00, 23.00 and 1.00 hours. In summer the dynamics of migration largely exhibited a day character. The maximum was observed at 16.00 or 20.00 hrs. (Fig. 18B).

Common bream

Common bream belonged also to frequent migrants; its proportion of the total catch reached as much as 27.3 per cent. The mean annual concentration

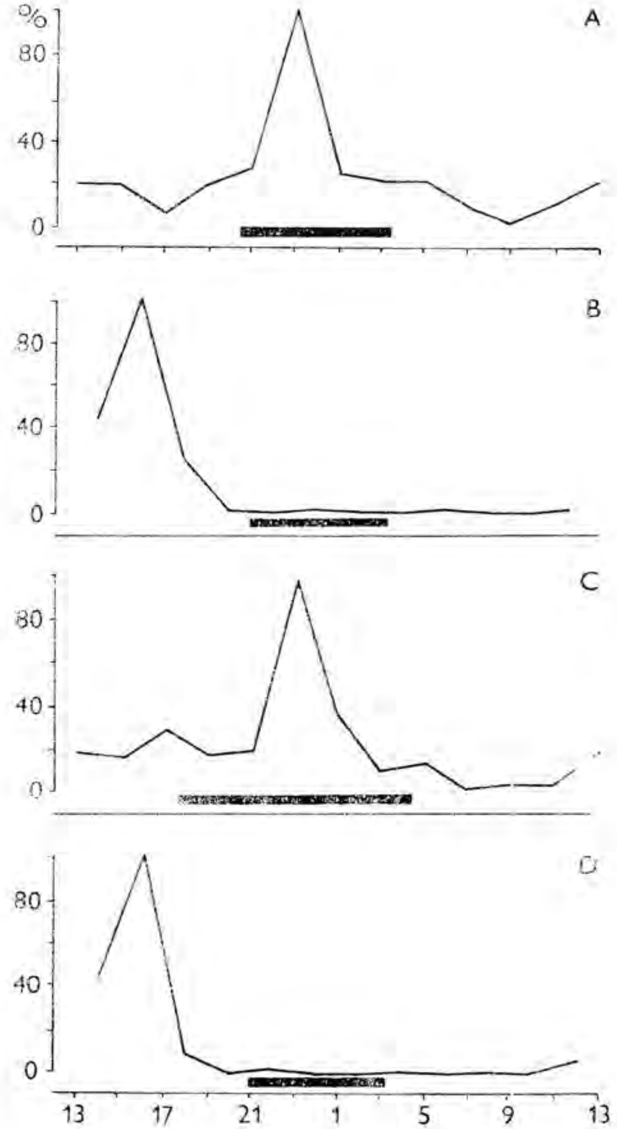

Fig. 18. Diagram of diel dynamics in silver bream (A, B) and common bream (C, D).

was 1.93 ind. 1 000 m^{-3}; (Tab. 19). With the exception of August migration took place through the whole period of research. The migration had three peaks, the first in April and May, the second in March, the third in July (Fig.19).

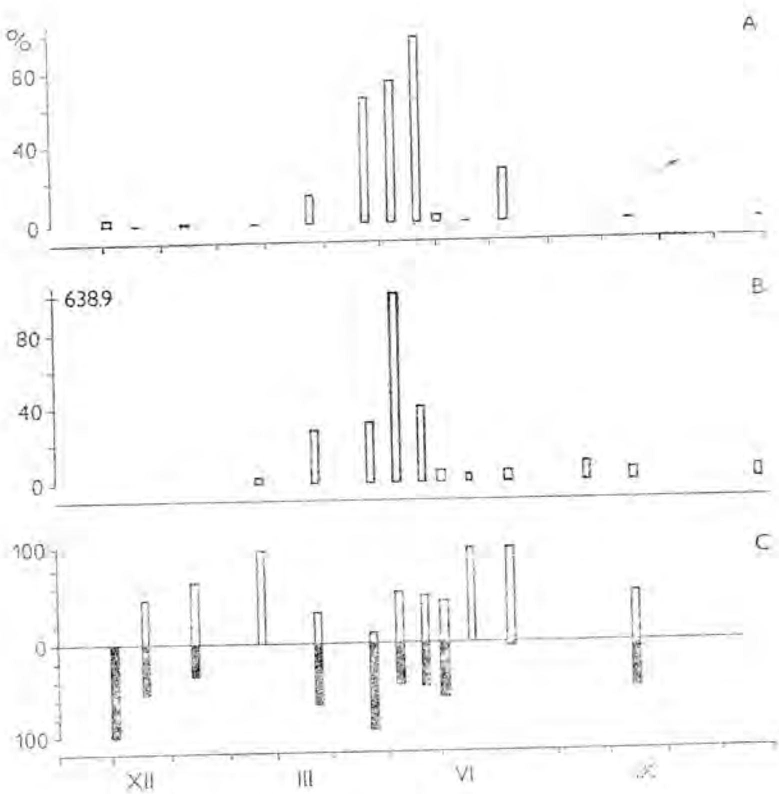

Fig. 19. Patterns of downstream migration and catches in tail water of advanced fry of common bream. Migration of fish in per cent (A). Catches in dip net in tail-water (B). Migration dynamics in daytime and in nighttime (C).

The highest migration was recorded in mid-May, 9.45 ind./1 000 m^3. The length of common bream ranged between 47 and 290 mm, the mean lengths at the separate stations varied between 86 and 228 mm. The big fish migrated in winter ($l = 192.5$ mm) and in spring ($l = 177.9$ mm), the small fish ($l = 95.3$ mm) in summer.

The aggregation of fish in the tail water was observed, similarly as in silver bream, in spring; the catches in dip nets reached 80.9 per cent of the whole annual bag. The relations to the light- and dark-time within 24-hour cycles were well manifested during the year. The course, however, was slightly different (*cf.* Fig. 19B). During the massive occurrence of migrants the maximum intensity fell in the specific parts of the day. In spring it was at 15.00, 20.00, 23.00 hours, in summer at 16.00 and 22.00 hours. Different patterns of the time cycles are depicted in Fig. 18C, D.

Bleak

The frequency of occurrence of the bleak was fairly high (17.5 %), its mean annual concentration amounting to 1.27 ind./1 000 m^3. The migration of bleak was recorded through the whole year, except February. The most intensive migration took place in spring, in mid-May, 13.7 ind./1 000 m^3 (Tab. 19). Another small mode was observed at the beginning of July, 2.54 ind./1 000 m^3. The size of caught fish fluctuated between 30 and 161 mm, the mean values at the separate stations varied between 50 to 131 mm. The biggest mean length

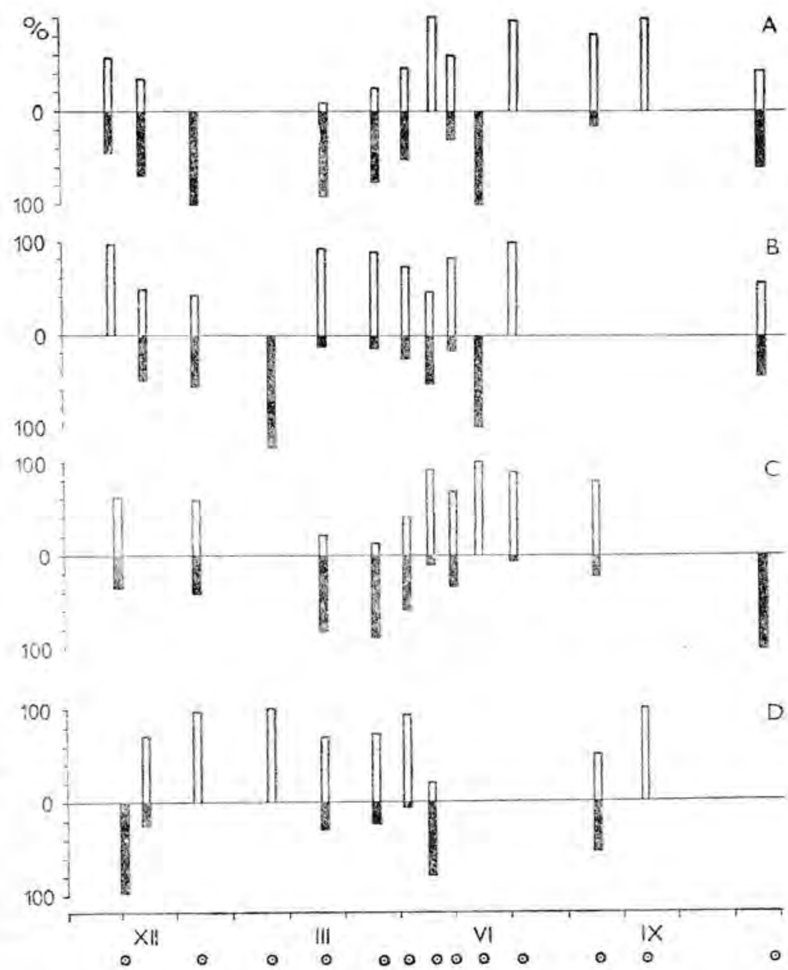

Fig. 20. Patterns of downstream fish migration through the year 1983. Bleak (A), perch (B), roach (C) and rudd (D).

was ascertained in spring (= 121.5 mm), the smallest mean length was registered in winter (= 69.7 mm) and in summer (= 99.0 mm). Unlike to silver bream and common bream, the period of forming great aggregations of bleak in the tail-water in the autumn (= 86.8 per cent of the total catch) was not in accord with the period of intensive migration of the bleak. The rhythm of 24-hour dynamics of migration had, similarly as the two species mentioned above, a sinuous character (Fig. 20A). During the massive migration, the 24--hour cycle, the bleak exhibited daytime maximums at 13.00, 14.00, 16.00, 17.00 hours and nocturnal maximums at 21.00, 22.00, 23.00 hours. Separate examples of this rhythm are shown in Fig. 21A, B.

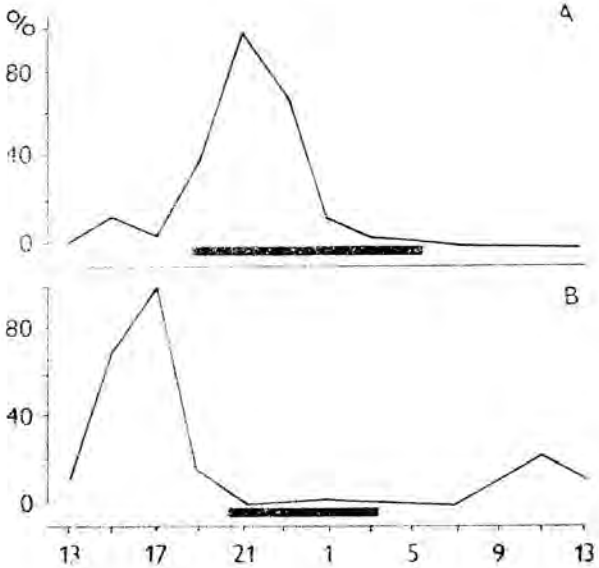

Fig. 21. Diel dynamics of bleak. Spring dynamics (A). Summer dynamics (B).

Perch, roach, rudd and other species

The proportions of perch, roach and rudd were as follows: 7.9, 6.1 and 4.7 per cent of the total number of migrants respectively. The mean annual concentration of these species equalled 0.57, 0.44 and 0.34 ind./1 000 m^3. The percentage of each of the other 17 species varied between 0.004 and 1.1 per cent, the mean annual concentration varying between 0.0003 and 0.08 ind./1 000 m^3 (Tab. 19). Most of the fish species migrated in the spring months. However, two species also migrated in summer, roach in July, pike-perch in November, December and in July. Burbot, nase, barb, sunbleak and chub occurred only sporadically.

The analysis of length and age structure of this group of migrants affirmed that all these species were of the age 1 and older, inclusive adults. The pike--perch was an exception, this species was represented in part by fry. The pike were the biggest fish species among the migrants (the mean length equalled 539 mm), the roach were smallest fish (the mean eqalled 62.3 mm). In perch, roach, rudd and the other species bigger mean lengths were observed in spring, smallest mean lengths in summer. In the same season of the year as the downstream fish migration, the aggregations of most fish species of this group were observed in the tail-water, except the ide and tench.

During the highest migration activity the 24-hour cycles exhibited a different course. The daytime maxima were ascertained mainly in perch, roach, rudd, pike and blue bream, the night maxima in pike-perch and gudgeon. Similarly as in the species migrating in shoals, the sinuous periodicity also existed in this group of fishes; the relation to the daytime a nighttime migration during the year is also conserved (Fig. 20B, C, D).

Comparative analysis of downstream fish migration from deep and shallow reservoirs

The result of our research is the finding of an intense downstream fish migration from both reservoirs. This chapter contents a comparative analysis of the regularities controlling the migrations from the deep reservoir of Mostiště and from the shallow reservoir of Věstonice. The peculiarities of the fish migrations from the reservoirs of different type were discussed by Pavlov & al. (1985b) in twenty-two reservoirs situated in the European part of the U.S.S.R. The results of this huge undertaking gave a definitive basis to assess our material. Moreover, the fish migration analysis relates to the following parameters: species, size and age composition of migrants, their numbers, seasonal and round-the-clock dynamics.

Species composition of migrants

Of the twenty-six species living in the Mostiště reservoir we ascertained seven species migrating through the turbine of the power station and four species migrating through the water treatment plant. Of the forty species inhabiting the Věstonice reservoir twenty-four were found to migrate downstream. Our analyses showed that the index of species unity was 0.27 in Mostiště reservoir and 0.60 in Věstonice reservoir (the index of species unity is the ratio between the number of migrating fish species and the number of fish species occurring in the reservoir). In the Mostiště reservoir the highest index of species unity was ascertained in summer and spring (in the outlet from the turbine in summer and spring, and in the outlet of the water treatment plant in summer), in the Věstonice reservoir the highest index of species unity was found in spring. The lowest indices were ascertained in the Mostiště reservoir in winter (the outlet from the turbine in winter, and in the outlet of the water treatment plant in spring), in Věstonice reservoir in the autumn. The highest index of species unity was found in the Věstonice reservoir. These findings are in accord with the results of the previous investigations (Pavlov & al. 1985b).

All seven species of migrants encountered in the Mostiště reservoir were also present in the Věstonice reservoir. In the deep reservoir the most numerous was the perch, in the shallow reservoir the silver bream, common bream and bleak. The eel, ruffe and pike-perch were common in the former reservoir, perch, roach and rudd in the latter reservoir. All mentioned species except the eel and rudd were found as abundant or common inhabitants in similar reservoirs (Pavlov & al. 1985a, b). It is necessary to note that the eel and rudd were present in reservoirs in the U.S.S.R. relatively scanty.

There are different opinions on reasons why a number of fish species are absent among the migrants. The frequent argument is the distribution of fish species in the reservoirs, the distance between the different location of fish shoals, mainly from the zone influenced by the outlets. This is valid in rheophilous species, which live in the upper layers of the reservoirs, and rivers and tributaries joining the reservoirs (brown trout, brook trout, grayling, dace, chub, nase, gudgeon, asp, stone-loach, *etc.*). Next, there are peculiarities of vertical and horizontal distribution of fishes in the reservoir near the dam in the proximity of the outlet current. The last aspect is very important in throwing light upon the downstream migration of separate fish species. The fact is that we did not find several fish species which were known to be abundant in the Mostiště reservoir (roach and common bream). The absence may be explained by their preference for littoral zones with a depth up to 5 m. Thus they occur outside the zones of the influence of the outlet currents. Similar examples may be introduced in the same reservoir with the larvae of pike-perch, roach and common bream. In the both reservoir studied this phenomenon also holds for the roach. This circumstance may clear up the findings by Vostradovská & Vostradovský (1971, 1977) who recorded a very low number of fish species migrating downstreams. This concerned fish species abundant in the reservoir (roach, common bream and pike).

Size and age structure of migrants

In both reservoirs studied we ascertained among the migrants fishes of different lengths and different age groups: larvae, fry, yearlings and other age groups up to adults. In the Mostiště reservoir larvae formed 39.1 and in the Věstonice reservoir 9.8 per cent of the total number of migrants.

In the Mostiště reservoir among fishes of the older age groups the biggest fish was an eel measuring 950 mm in length (the rest of the eel ranged from 25 to 55 cm in length). In the Věstonice reservoir the biggest fish caught was a pike measuring 825 mm (the rest of the pike fluctuated between 409 and 539 mm). The second biggest fish was a pike-perch (= 530 mm), the usual range being 400 to 439 mm.

The perch was the most numerous species in the Mostiště reservoir. Their average length during the seasons of the year varied between 54.6 and 62.0 mm, and 55.2 and 64.2 mm in the outlets of the power station and the water treatment plant respectively. The perch in the Věstonice reservoir during the seasons of the year averaged from 79.5 to 97.3 mm in length. The maximum length of perch migrants drifting from the Mostiště reservoir was 13.0 mm. In the reservoir itself we repeatedly caught much bigger individuals of this species.

It is necessary to stress that maximum length of migrants from the Věstonice reservoir was higher than the maximum length ascertained by Pavlov & al. (1985b) during a survey of twenty-two reservoirs situated in the European part of the U.S.S.R. In those reservoirs the biggest fish measured 250 mm;

in most cases, the variation fluctuated about 120 mm. Our results, however, fully agreed with the lengths of migrants from other reservoirs, for example Kapčagajskoje reservoir (Nezdolij 1974), Rybinskoje and Ivankovskoje reservoirs (Poddubnyj 1971), Karakumskoje reservoir (Rezanov 1969) and Čardarinskoje reservoir (Jereščenko 1971, 1972).

According to our experience, fish migrants from shallow reservoirs were bigger than those from deep reservoirs. These findings seem not to be determined by the depth of the reservoir or by the peculiarities of the fish distribution, but rather by the construction of the outlet equipment and by the water discharge through the outlet. If we divide the outlets from the two reservoirs studied according to water discharge, the first place takes the Věstonice reservoir followed by the power station and the water treatment plant, both being installed in the Mostiště reservoir. With the decreased water discharge and velocity of currents the mean lengths of migrants become smaller.

During the cool seasons (autumn, winter and spring) the mean length of migrants of the majority of species, as evidenced by our numerous material from the Věstonice reservoir, was bigger than in summer (Tab. 21). These findings and results by Pavlov & al. (1984, 1985a, b) point to a relationship between fish migration and their swimming abilities. The ability to overcome the water currents grows with increasing fish size and declines with decreasing water temperature during the cool seasons. Thus the maximum mean lengths in a number of fish species were found in spring. This findings correlates with the increasing locomotory activity of fishes at rather low water temperature and, consequently, decreasing swimming ability. Besides this the ability of fishes to overcome water currents during spawning and immediately after spawning (in the phase of sexual ripeness V and VI to II) abruptly decreases, with no regard to the advancing water temperature (Pavlov 1979). The higher the swimming velocity under the given circumstances the greater the fish's ability to overcome the outlet currents from the reservoir and to escape from the zone of their direct operation.

The tendency of different fishes to migrate downstream is to a great extent also determined by their age structure. Fish species which reach the sexual maturity at a greater body length (pike-perch, common bream, silver bream, blue bream, *etc.*), migrated, according to our findings, largely before reaching sexual maturity (except the pike). Fish species which reach sexual maturity at a lower length (bleak, roach, perch, ruffe, gudgeon, mud-loach, *etc.*) were often presented by mature individuals.

Although we caught a great number of migrants in older age groups, we did not find larvae and fry of several fish species. This relates, *e. g.*, to ruffe in the Mostiště reservoir, common bream, rudd, pike and blue bream in the Věstonice reservoir. In our opinion, this phenomenon in the former reservoir was occasioned by the distribution of fishes, in the latter reservoir the larvae and fry of those species were lacking at the dam.

Concentration of migrants

The mean concentration of larvae during the period of their migration through the power station of the Mostiště reservoir was 4.3 ind., through the water treatment plant 4.5 ind., and in the Věstonice reservoir 530.9 ind./1 000 m^3; thus the migration in the shallow reservoir was many times higher. The mean concentration of migrants of older age groups was also markedly higher; the concentration of these fishes per year comprised 7.25 ind. in the Věstonice reservoir, 0.16 ind. in the power station and 0.51 ind./1 000 m^3 in the water treatment plant of the Mostiště reservoir. The concentration of migrants of the individual species is shown in Tabs. 20 & 21. The mean values of these indices

Tab. 20. Average concentration of migrants (K = ind./1 000 m^3) and average fish lengths (in mm) of older age groups caught in conical nets in tail-water of the Mostiště reservoir during different year seasons of 1982 to 1983

Year season	Winter		Spring		Summer		Autumn	
	K	Length	K	Length	K	Length	K	Length
Power station								
Perca fluviatilis	0.24	54.6	0.07	56.6	0.002	62.0	0	-
Anguilla anguilla	0.002	550.0	0.01	515.6	0.08	272.2	0.15	249.6
Gymnocephalus cernua	0.07	58.3	0.01	66.0	0	-	0.02	47.0
Other species	0	-	0.002	129.0	0.003	40.0	0.005	67.0
Waterworks								
Perca fluviatilis	0.10	58.7	0.61	55.2	0.55	64.2	0	-
Gymnocephalus cernua	0	-	0	-	0.04	79.5	0.01	43.0
Rutilus rutilus	0.01	61.0	0	-	0	-	0	-

Tab. 21. Average concentration of migrants (K = ind./1 000 m^3), their average fish lengths **(in mm) caught in conical nets, and average number of fish (%) caught in dip net in tail-water of Věstonice reservoir during the different seasons of 1982 to 1983**

Yeer season	Winter			Spring			Summer			Autumn		
	K	Length	N	K	Length	N	K	Length	N	K	Length	N
Fish species												
Blicca bjoerkna	0.007	93.4	0.4	6.63	112.1	85.9	1.35	86.7	9.2	0.07	106.9	4.5
Abramis brama	0.072	192.5	0.7	6.09	177.9	80.9	0.72	95.3	8.1	0.04	115.1	10.3
Alburnus alburnus	0.04	69.7	0.9	3.69	121.5	7.9	0.59	99.0	4.4	0.035	114.3	86.8
Perca fluviatilis	0.042	57.8	6.2	1.62	97.3	40.9	0.23	79.5	7.6	0.24	83.9	43.3
Rutilus rutilus	0.02	74.9	0	0.88	113.2	70.5	0.62	62.3	29.5	0.05	74.6	0
Scardinius erythrophthalmus	0	-	0	1.12	127.7	100	0.07	81.7	0	0	-	0
Esox lucius	0.02	400.1	7.8	0.24	462.6	51.2	0.008	492.5	20.2	0.005	539.0	20.8
Stizostedion lucioperca	0.19	400.4	14.2	0.027	439.0	57.1	0.07	-	28.6	0.10	-	0
Abramis ballerus	0.004	199.6	0	0.21	212.8	79.9	0.001	263.0	20.1	0.01	222.3	0
Gymnocephalus cernua	0.001	109.0	0	0.14	118.7	0	0.013	120.8	0	0	-	0
Other species	0.016	-	20.8	0.25	-	58.4	0.007	-	20.8	0.058	-	0

per 24 hours and those per year were higher in the Věstonice reservoir. The highest mean concentration for 24 hours was ascertained in larvae of perch (= 853.5 ind./1 000 m^3).

The high concentration of fish migrants from the shallow reservoir attests on the one hand great fish productivity and high numbers of fishes inhabiting the reservoir, on the other hand, however, a high water discharge flowing through the watergate. The concentration of migrants is largely determined by the concentration of fishes living in the horizon of the outlet and the peculiarities of fish distribution in the reservoir. The fish material perfectly documents the importance and effect of vertical distribution of fishes in the reservoir and horizon of water uptake on the concentration of migrants. For example, from the comparison of the mean concentration of perch migrating through the power station and through the water treatment plant it follows that, during the cool seasons of the year with fish staying in deep water, the concentration of migrants was higher in the outlet of the power station in the deepest situated outlet opening. During spring and summer, with the perch moving into upper horizons and littoral parts of the reservoir, the highest concentration of migrants was ascertained in the highest situated outlet of the water treatment plant. A clear picture emerges from our experiment aimed at selecting stratified outlets taking the water to the water treament plant. During November and December the ratio of concentration of perch migrants was 1 : 3 : 22 from the depths of 5, 10 and 16 m respectively. A contrary relationship was found, taking the same horizons of outlets during May and June, in perch larvae. It is noteworthy that the concentration of migrants was many times lower than that of fish in the reservoir and the zone adjacent to the outlets. From this it follows that several fish are able to escape from the zone of influence of water currents near the outlets.

Without doubt, the total number of migrants increases with increased water

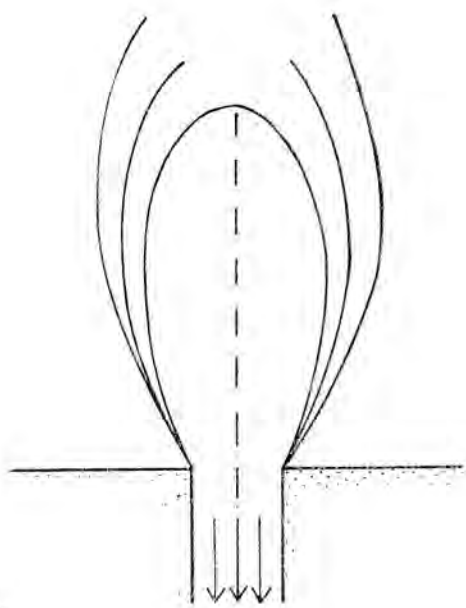

Fig. 22. Scheme of the zones with different velocities of water currents.

discharge through the outlets. This is due to extending the zones under the influence of outlet currents. Still, however, it is not clear, whether the concentration of fishes also increases. Special experiments were conducted with the aim of changing the water discharge through the outlet to the water treatment plant. In the course of a short-term experiment of one hour duration we increased the water discharge sixfold; this resulted in an increased number of migrants by 4.3 times. The increased water discharge extended the zone with critical velocities of currents (Fig. 22). The range of this increased concentration of migrants depends on concrete hydraulic conditions within the zone of outlets, on the peculiarities in behaviour, distribution and swimming velocities of fish. The effect of water discharge or the volume of influence on water currents may have a character other than merely the influence on the concentration of fish. It is assumed that this increased fish concentration may have only short duration until the majority of fish from the zone is driven by the current through the outlet. The frequent and intense changes of water discharge through the outlet (pulsation), may result in a greater number of fish being carried by the water (according to the opinion of Pavlov & al. 1984 mainly from profundal and sublittoral). Unfortunately, we were not able to justify these findings by conducting long-term experiments.

24-hour dynamics of fish migration

The intensity of fish downstream migration exhibited diel changes. Except for early larvae, the fish downstream migration materializes largely at dusk and at night both in running and standing waters (from reservoirs and lakes) (Pavlov 1979, Pavlov & al. 1981, 1984, 1985a, b, Baruš & al. 1984a, b, 1985a, b, c). This is connected with the decreased visual orientation of fish in the water currents and also with the subsequent rapid decline in their swimming ability (Pavlov 1979). With the changes in the duration of light and dark periods of the day, during the seasons of the year, the duration of fish migrations over 24 hours also changes. The migration of fishes was thoroughly studied in the Ivankovskoje reservoir in the U.S.S.R. (Pavlov & al. 1984). It was shown that during the summer the fishes had a conspicuous twilight to nocturnal rhythm, with one mode in night hours. In the autumn this rhythm was less evident: the night activity split into two modes, at twilight and at night. The migration ceased only during the brightest hours of the day. In winter there is an intensive tendency to prolong the migration and the escape is in progress round-the-clock. The number of modes increases at twilight and by night. In spring the period of migration becomes shorter and the intensity of migration approaches the summer pattern. An exception from this scheme was found in the bleak in spring and in perch in spring and autumn.

In the present paper the study of 24-hour dynamics of migration of the advanced larvae and fish of older age groups in the Mostiště reservoir practically confirms the twilight to nocturnal rhythm in separate fish species. The only exception, similarly as in the Ivankovskoje reservoir, was the perch behaviour in spring. In our opinion this may correlate with the increased locomotory activity of this species in the daytime during the spawning period (before or during spawning). Unfortunately, our material of older fish from the Věstonice reservoir was not suitable for analysis, as we did not know the relative number of fishes migrating from the lower layers. It is probable that the aggregation of fishes in that zone was not identical during the seasons. In a number of cases we ascertained an increased number of migrants in the evening, when the locomotory and feeding activities were also higher (M a n - t e j f e l & al. 1965, Č e r n ý 1973, 1975a, 1975b, *etc.*). The fish larvae, because of their low swimming ability, were not able to overcome even a slight current; they run round-the-clock. With increasing age and ability of active movement, the evening and nocturnal migrations were markedly shown in the perch and pike-perch in both reservoirs. In the Mostiště reservoir this rhythm was linked with the vertical migrations.

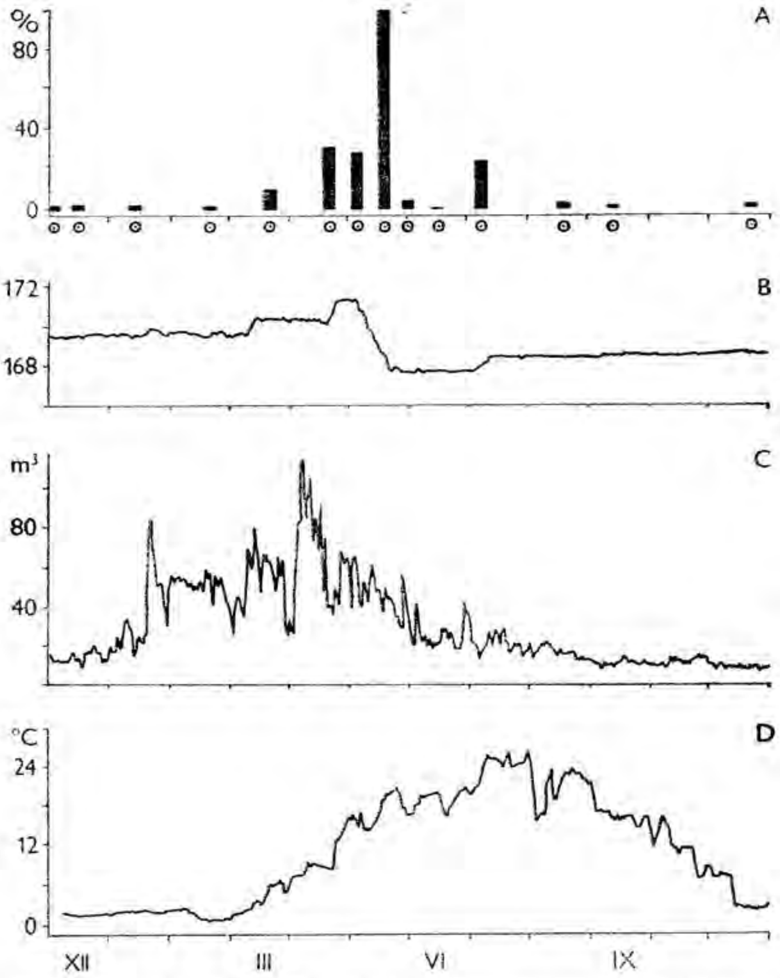

Fig. 23. Fluctuations of basic factors in the Věstonice reservoir during the year. From the top to the bottom: Summary of the intensity of downstream migration of fishes of older age groups (A). Water level in the reservoir (B). Water discharge from the reservoir (C). Water temperature (D).

Seasonal dynamics of intensity of fish migration

During our study we found that the downstream fish migration was in progress practically the whole year round. The migration changed with the season of the year (*cf.* Tabs. 20 & 21). Migration was observed in both reservoirs in summer, from the end of May till the first decade of July. The migration from the Věstonice reservoir began a week sooner than that from the Mostiště reservoir. In both reservoirs the migration started as soon as the temperature of the surface water reached 15 to 17 °C. The different intensities of downstream fish migrations of older fish according to the dates of fishing with the curves of the basic factors of the environment (water level, temperature and water discharge during the year) are given in Figs. 23 to 25. From

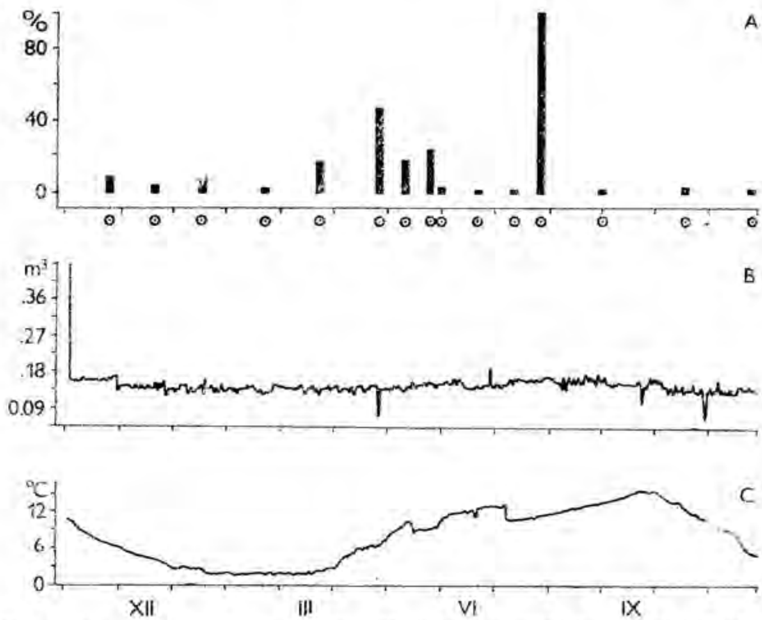

Fig. 24. Fluctuation of basic factors in the Mostiště reservoir (in the outlet of the hydraulic power station) during the year. Summary of the intensity of downstream migration of fishes of older age groups (A). Water discharge (B). Water temperature (C).

the appraisal of those data it follows that the seasonal dynamics' of downstream fish migration is analogous in the two reservoirs. In both cases the main period of migration fell in March to May. This migration run was obviously connected with the increased locomotory activity due to extending of the light hours of the day and to warming of the water in the reservoir during the spawning season, but also the abrupt decline of the fish's ability to overcome the currents immediately after spawning. In the Věstonice reservoir we experienced a rapid rise in fish migrants due to an extreme decline in water level. Any abrupt decrease of water surface, as is generally known, represents a stress to fishes and stimulates migration from the endangered zone.

The period of the second increase of migration intensity through the water treatment plant and through the Věstonice reservoir was in July. The strongest run was observed through the water treatment plant of the Mostiště reservoir; this phenomenon was obviously correlated with radical changes of abiotic conditions for fish life in the reservoir. The extraordinary character of that migration period confirmed a higher variety of migrants and fishes taken from the dam zone. This variety, usually not exceeding one or two fish species, consisted of four to five species. We therefore assumed that the causes of that migration run were common to all fish species.

Two migration runs were also recorded in the outlet channel of the water

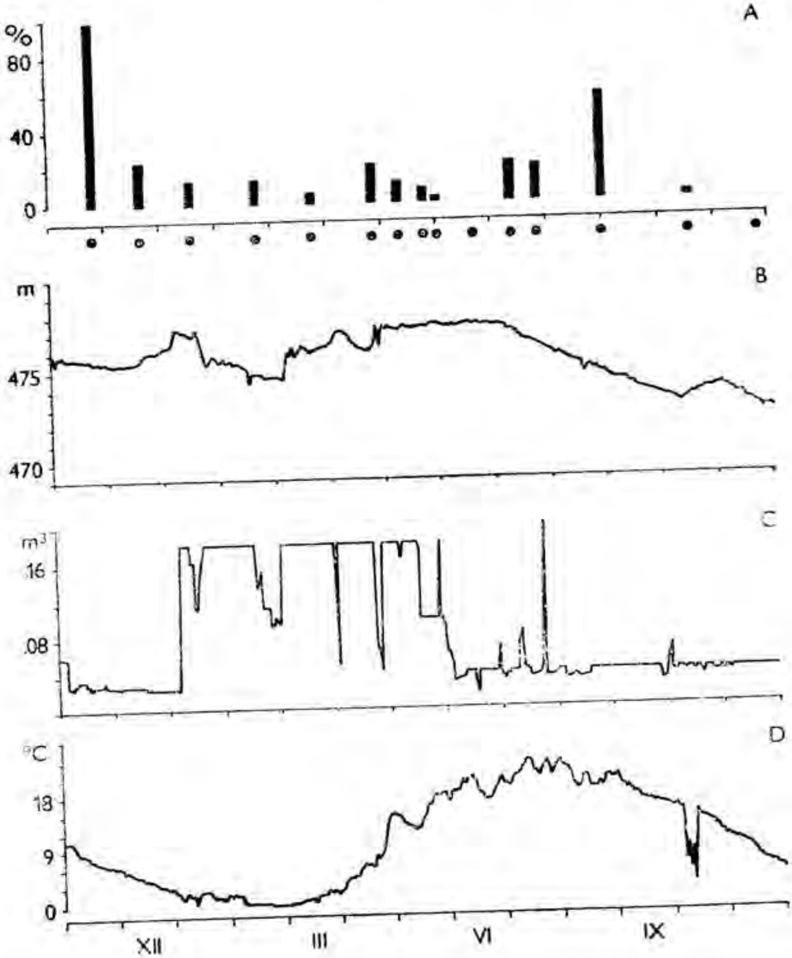

Fig. 25. Fluctuation of basic factors in the Mostiště reservoir (in the pipe to the water treatment plant) during the year. See Fig. 23.

treatment plant of the Mostiště reservoir. There, however, the stronger migration intensity occurred during the cool period of the year, in November to February. Those findings, in our opinion, may be connected with the fact that the fish stayed in the lower strata of the reservoir, and due to the low water temperature had a decreased ability to stand the water current. Besides this, a slightly increased concentration of migrants was recorded towards the end of summer (September); in that period we encountered a higher migration of the eel.

Ecological conditions of the discharge currents and its importance for downstream fish migration

The above material and its analysis shows that downstream fish migration from the reservoirs investigated is conditioned by many factors: the species, size and age composition of the fish inhabiting the reservoir, their density, the peculiarities of their distribution, the season of the year, illumination, water level and water temperature in the reservoir, water passage through the waterworks, *etc.* Of the different factors which are not given here in their entirety the main and most important regularities of downstream fish migration must be chosen.

Pavlov (1982) proved theoretically and verified using extensive material (Pavlov & al. 1985) that the influence of many factors is determined by the conditions of the discharge currents and the morphology of the bottom of the reservoir. The reservoirs investigated by Pavlov (1982) were divided into four groups:

1. deep lakes with water discharge from the littoral and sublittoral zones,
2. regulated lakes and reservoirs with water discharged from the sublittoral and littoral zones,
3. reservoirs with water discharged from the profundal zone,
4. shallow (littoral) reservoirs, the littoral representing their ecological zone.

Downstream fish migration from these reservoirs was found to differ in the species, size and age composition of the migrants, their quantity and even the diel dynamics. If this classification based on the ecological zones of the reservoirs is used, then the Věstonice reservoir will represent an intermediate type between group two and four, and the Mostiště reservoir will belong to group three if water is discharged through the hydro-electric power station. If water is discharged through the waterworks (with variable horizon of water intake) the Mostiště reservoir does not belong to any of the above groups, but forms an independent group with water discharged from the profundal zone.

Thus the ecological conditions of water discharge from the reservoirs investigated differ, which determines the different specific character of downstream fish migration. These differences concern such migration parameters as *e.g.* the specific composition, the size and age composition, the concentration of the migrants, *etc.* This is especially apparent if the seasonal dynamics of the migration of fish belonging to higher age groups are investigated The results of two-factor, non-orthogonal dispersion analysis (Lakin 1977) of the seasonal dynamics of downstream fish migration (Tab. 22) have shown that the total concentration of migrants depends on the ecological conditions of water discharge, the season of the year and the combination of these factors.

Tab. 22. Impact of outlet currents (Factor A) and year season (Factor B) on the total concentration of migrants of older age groups (*F*, Fisher variance ratio; n^2, power of factor in per cent; mn^2, error of n^2; Fn^2, Fisher variance ratio for n^2; *K*, average concentration (ind./1 000 m^3)

Concentration of migrants /ind./1 000 m^3/

A \ B	Spring	Summer	Autumn	Winter	K
	Seasons of the year				
Věstonice res.	11.36+/	3.78	0.60	0.37	4.03
Power station Mostiště res.	0.09	0.08	0.15	0.31	0.16
Water plant Mostiště res.	0.63	0.05	0.04	0.08	0.20
X	4.03	1.30	0.27	0.26	-

Result of analysis of variance

Factor	F	n^2 /%/	mn^2 /%/	Fn^2	F tab. P = 0.05
A	8.67	22.5	6.2	3.63	3.4
B	4.16	16.2	10.1	1.61	3.0
AB	3.71	28.9	17.1	1.69	2.5

Footnote: +, the avertage concentration for 24-hours ascertained on May 19 1983 (49,6 ind. 1 000 m^3) was omitted because of the extreme migration resulting from the abrupt decrease in the water level.

Tab. 23. Impact of outlet currents (Factor A) and year season (Factor B) on the total concentration of perch migrants of older age groups. *K* = average concentration of fish per year. For other acronyms see Tab. 22

Concentration of migrants /ind./1 000 m^3/

A \ B	Spring	Summer	Autumn	Winter	K
	Seasons of the year				
Věstonice res.	1.62	0.23	0.24	0.04	0.53
Power station Mostiště res.	0.07	0.0025	0	0.24	0.08
Water plant Mostiště res.	0.63	0.05	0.04	0.067	0.20
X	0.77	0.094	0.093	0.116	-

Result of analysis of variance

Factor	F	n^2 /%/	mn^2 /%/	Fn^2	F tab. P = 0.05
A	7.93	14.4	6.6	2.20	3.4
B	12.25	33.4	7.7	4.34	3.0
AB	5.25	28.6	16.5	1.74	2.5

Thus the total concentration of the migrants differs significantly in the individual seasons of the year, the mean annual concentration differs in migration through different water-intakes and the seasonal dynamics of the concentration differ even in the different water-intake pipes. Of the two factors a greater influence is shown by the conditions of water discharge, the force of their influence being 22.5 ± 6.2 per cent (the characteristic is significant).

A similar analysis was also carried out at the species level. The perch, which belongs to the main species in all the reservoirs studied (Tab. 23),

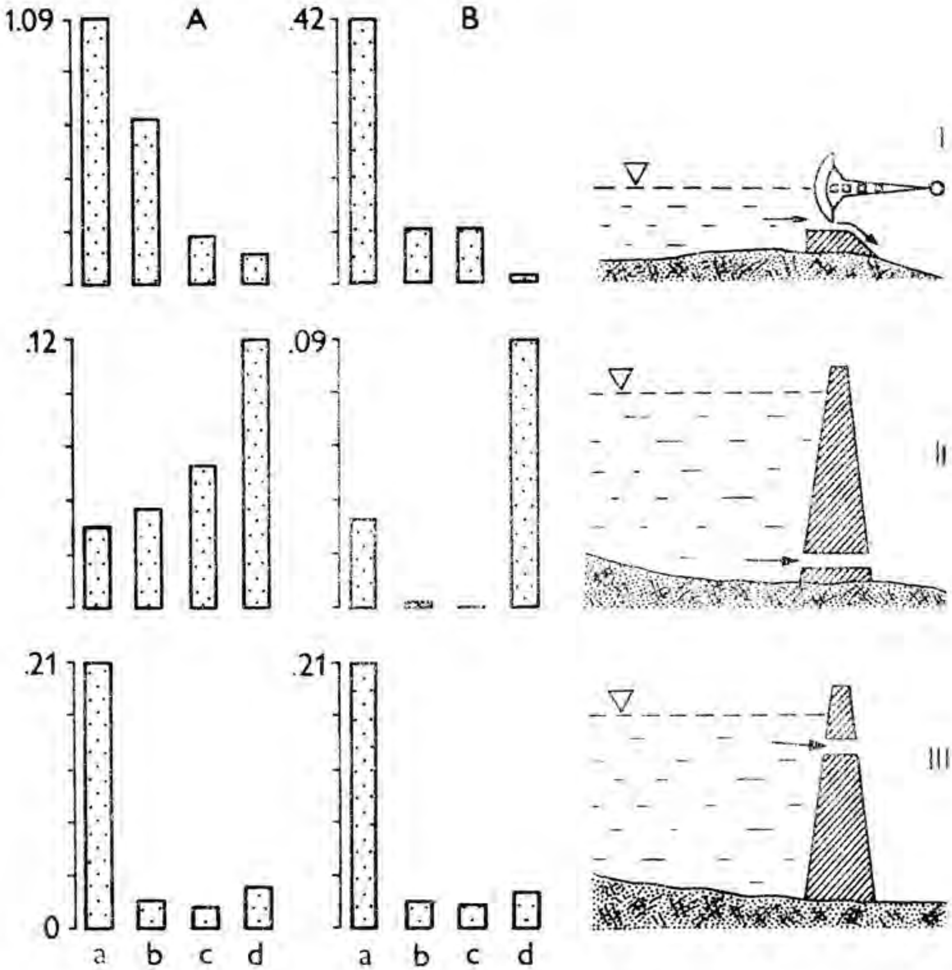

Fig. 26. Impact of the type of water discharge on the seasonal dynamics of fish migrants. From the top to the bottom: Water outlet over the lip (I), Water outlet at the bottom (II). Water outlet from the upper horizon (III). All migrants (A). Perch only (B). Seasons of the year: spring (a), summer (b), autumn (c), winter (d).

served as indicative species. Each individual factor and their combination were found to have a significant influence on the concentration of perch migrants. Fig. 26 illustrates the influence of water discharge on the seasonal dynamics of downstream fish migration. Greatest differences can be found between the Věstonice reservoir and the Mostiště power station, where seasonal dynamics have a contrary character. The downstream fish migration is determined by the specificity of fish distribution, the locomotoric and orientation abilities of the fish, and also by the hydraulic conditions which occur in the zones influenced by the inlet to the water treatment plant. The mutual influence of these factors will be dealt with in greater detail.

The Věstonice reservoir is shallow, its maximum depth at the dam zone is 5 m, the mean total depth measured in our survey was 2.5 m (1.5 to 3.2 m). The reservoir has no profundal zone. The Mostiště reservoir is deep; its depth at the dam zone is 30 m, the mean annual depth was 9.8 m (8.1 to 12.1 m). In this reservoir the profundal zone covers the greatest part of the dam zone.

As far as the influence of the discharge currents is concerned, in the Věstonice reservoir the greatest influence was exhibited by the lower layers of the sublittoral zone, in the hydro-electric power station of the Mostiště reservoir by the lower layers of the profundal zone and in the Mostiště waterworks by the layer of the profundal zone. As mostly the upper outlet of the water treatment plant was in operation, the whole analysis is based on the relevant material. The water layer lying above it varied throughout the year between 1.6 and 5.1 m, the mean value being 4.0 m. Thus in this case the ecological layer of water intake was formed by the upper layers of the pelagic zone above the profundal zone.

In all the three cases investigated abrupt longitudinal and transversal gradients of water velocity occur before the outlet of the waterworks. This results in the fact that the fish suddenly get into current zones which are faster than those critical for them. This is assisted by the absence of visual orientation points, such as water vegetation which, in other reservoirs with water discharged from the littoral zone, gives the fish a chance for timely response to higher flow velocity. The greatest influence on the fish inhabiting the reservoir is doubtless shown by the conditions of water discharge through the Věstonice reservoir. This is given by the large water discharge, ranging from 8 to 115 m^3/sec. (0.22 to 17.5 m^3/sec. in the Mostiště hydro-electric power station, 0.045 to 0.16 m^3/sec. in the Mostiště waterworks), intensive water exchange — up to 50 volumes yearly (only 5 in the Mostiště reservoir) and the small depth of the Věstonice reservoir; in May to June this influence was strengthened by a marked decrease in the water level.

The ecological conditions of water discharge from the Věstonice reservoir determine the wider species composition and the greater species unity with the fish inhabiting the reservoir. The coefficient of species unity was 0.60, whereas in the Mostiště power station it was 0.27 and in the Mostiště waterworks (with the smallest influence zone of the outlet) it was only 0.15. The highest coefficient of species unity was accompanied in the Věstonice reservoir by the largest size of the migrants.

In all the three outlets the perch took first place. In the Věstonice reservoir its maximum mean diel concentration was 853.5 individuals 1 000 m^3, in Mostiště reservoir it was distinctly smaller: 72 times in the hydro-electric power station and 78 times in the waterworks. In the Věstonice and Mostiště reservoirs it was followed in frequency by the larvae of pike-perch. They were not found, however, in the Mostiště hydro-electric power station, as the discharge currents did not include the upper layers of the pelagic zone inhabited by them.

Fish larvae from the littoral zone (largely *Cyprinidae*, roach, common bream and others) found in great concentrations (up to 3 million individuals/1 000 m^3) actually did not occur among the migrants in the two outlets of the Mostiště reservoir; in the Věstonice reservoir they formed only 10 per cent of the total number of migrants. Thus in the first two cases the discharge currents seem to have no influence, in the last case their influence is small.

In the Věstonice reservoir fish belonging to higher age groups included mainly white bream, common bream and bleak. These species inhabit the sublittoral zone and probably represent the most frequent species in the reservoir. In the Mostiště reservoir in the tunnel to the power station the most frequent species were perch, eel and ruffe, *i. e.* those species which inhabit considerable depths in the bottom water layers of the reservoir; in the Mostiště waterworks this concerned only perch, which occurred in the pelagic zone for the largest part of the period under study.

The mean concentrations of the migrants and water discharge in the individual months of the year were used for the calculation of the total quantity of fish migrating from the reservoirs studied within a year (November 1982 to November 1983). In the Mostiště reservoir the total number of larvae was some 30 thousand individuals (26.5 thousand individuals in the hydro-electric power station, 3.3 thousand individuals in the waterworks); in the Věstonice reservoir it was 100 million individuals. In the Mostiště reservoir the total number of fish belonging to higher age groups equalled 7 thousand individuals (5.2 thousand individuals in the hydro-electric power station, 1.8 thousand individuals in the waterworks), in the Věstonice reservoir it was 8 million individuals. The last value, however, is only approximate, due to what has been said above. Thus the influence of the ecological conditions of water discharge from a shallow reservoir on the frequency of fish is much greater than in a deep reservoir, as was already ascertained in Lake Nero in the U.S.S.R. by Pavlov & al. (1985).

Under the existing conditions of the cascade on the Dyje river, of which the third, lower reservoir is not finished yet, losses of fish production can be prevented. It is, however, necessary to check the ecological conditions of water discharge from the reservoir and implement measures for fish protection to prevent mass downstream migration. This would make it possible to maintain fish production on the reservoir and also in the two higher-situated reservoirs (Mušov and Věstonice). In the last case this would be assisted by the fact that injury to the fish migrating downstream is slight. As for actual measures (cf. Pavlov & Pachorukov 1973), we may suggest the use of outlets with variable depth of water intake together with more costly nets and electric screens for fish protection.

Conclusion and summary

The authors found mass downstream fish migration from the two reservoirs studied. In different reservoirs this phenomenon plays different roles even in the life of one and the same species. In the deep Mostiště reservoir with a small water discharge, the cur-

rents originating in the profundal zone, the migration intensity is small both in larvae and in fish belonging to higher age groups. The most frequent migrants are the representatives of the pelagic and the profundal-pelagic complex (perch, pike-perch, ruffe, eel). Their highest concentration occurred in the cold seasons of the year, *i. e.* in autumn and in winter. Injury and kill affected practically all the migrants, mainly due to the sharp decrease in hydrostatic pressure.

In the shallow Věstonice reservoir, with large passage of the discharge stream originating in the sublittoral zone, the migration intensity is much higher in larvae and in fish belonging to higher age groups. The main species occurring among the migrants were the representatives of the sublittoral zone, *i. e.* of the main zone of the reservoir investigated (white bream, common bream, bleak, perch and others). Migrants belonging to higher age groups are usually larger than those from a deep reservoir, and the number of adults occurring among them increases. The highest concentration was ascertained in spring and in summer. Injury and kill affected only individual fish after their passage through the dam.

The connection of the zones of influence of the outlets in the zones inhabited by fish, and the ecological conditions of discharged water in general, determine the main characteristic of downstream fish migration from the reservoirs: the species, size and age composition of the migrants, their concentration and the seasonal dynamics of the process.

At the existing volume of the discharged currents the downstream fish migration from the deep reservoir (Mostiště), cannot have any substantial effect on the frequency of fish population. This cannot be said of the shallow reservoir (Věstonice); with a large volume of the discharge currents this influence is considerable.

In shallow reservoirs this negative influence on fish production can be diminished by checking the ecological conditions of the discharge currents (especially by using outlets with variable depth of water intake) and by using devices for fish protection.

Резюме

На обоих исследованных водохранилищах наблюдалась массовая покатная миграция рыб. Это явление занимает различное место в жизни даже у одного и того же вида на различных водоемах.

В глубоководном водохранилище с небольшим расходом стоковых течений, берущих начало из профундальной зоны, интенсивность миграции невысока, как у личинок, так и у рыб старших возрастных групп. Основными мигрантами являются представители пелагического и профундально-пелагического комплекса (окунь, судак, ерш, угорь). Наибольшие их концентрации имеют место в холодное время года — зимой и осенью. Наблюдается травматизация и гибель практически всех покатников, главным образом, за счет резкого перепада гидростатического давления.

В мелководном водохранилище с большим расходом стокового течения, берущего начало, в основном, из сублиторальной зоны, интенсивность миграции многократно выше, как у личинок, так, видимо, и у рыб старших возрастных групп. Ведущими видами среди мигрантов являются представители сублиторальной зоны, т.е. основной зоны данного водоема (густера, лещ, уклея, окунь и другие). Покатники старших возрастных групп, как правило, крупнее, чем на глубоководном водоеме, при этом среди них отмечается большое количество половозрелых рыб. Наибольшие концентрации имеют место весной и летом. Травматизация и гибель после прохождения плотины наблюдается только у отдельных рыб.

Таким образом, сочетание зон влияния водозаборов с зонами обитания рыб и в целом экологические условия изъятия стока определяют основные параметры покатной миграции из водоемов: видовой и размерно-возрастной состав покатников, их концентрацию и сезонную динамику интенсивности этого процесса.

Покатные миграции из глубоководного водохранилища, при имевшем место объеме стоковых течений, не могут оказывать существенного влияния на численность популяций рыб. Этого нельзя сказать о мелководном водохранилище с большим объемом стоковых течений, где такое влияние значительно.

Снижение этого влияния на рыбопродуктивность мельководных водохранилищ возможно за счет управления экологическими условиями изъятия стока (в частности применение оголовков с переменной глубиной) и использования рыбозащитных устройств.

Literature

BAKŠTANSKIJ, E. L., 1970: Skat molodi gorbuši i kety i pričina jego zaderžki v rekach Kol'skogo poluostrova [Downstream migration of fry of ping salmon and keta, and the reasons of stoppage in rivers of Kola Peninsula]. *Tr. VNIRO, 74: 129—143* (in Russian).

BARUŠ, V., GAJDŮŠEK, J., PAVLOV, D. S., NEZDOLIJ, V. K., 1984a: Downstream fish migration from two Czechoslovakian reservoirs in winter conditions. *Folia Zool. Brno, 33(2): 167—181.*

BARUŠ, V., GAJDŮŠEK, J., PAVLOV, D. S., NEZDOLIJ, V. K., 1984b: Zimní migrace ryb s proudem vody z nádrže Mostiště [Downstream migrations of fish from the Mostiště in winter conditions]. *Sb. Migrace ryb v tekoucích vodách a údolních nádržích, Vodňany, pp. 28—36* (in Czech).

BARUŠ, V., GAJDŮŠEK, J., PAVLOV, D. S., NEZDOLIJ, V. K., 1985a: Downstream fish migration from two Czechoslovakian reservoirs in spring conditions. *Folia Zool. Brno, 34(1): 79—87.*

BARUŠ, V., GAJDŮŠEK, J., PAVLOV, D. S., NEZDOLIJ, V. K., 1986: Downstream fish migration from the Mostiště and Věstonice reservoirs (ČSSR) in the spring--summer period. *Folia Zool. Brno, 35(1): 79—93.*

BARUŠ, V., PAVLOV, D. S., NEZDOLIJ, V. K., GAJDŮŠEK, J., 1985b: Downstream fish migration from the Mostiště and Věstonice reservoirs (ČSSR). *Topical problems of ichthyology 2. (Transaction of the Czechoslovak-Soviet ichthyological cooperation). Brno, pp. 7—18.*

BATYČKOV, G. A., 1967: Skat molodi osetra iz Volgogradskogo vodochranilišča v 1960—1964 gg. [Downstream migration of sturgeon from Volgogradskoje reservoir in 1960 to 1964]. *Tr. Volg. otd. GosNIORCH, 3: 247—258* (in Russian).

BISHAI, H. M., 1961: The effect of pressure on the survival and distribution of larval and young fish. *J. Conseil perman. internat. explorat. mer, 26(3): 292 to 311.*

CRAMER, F. & OLIGHER, R., 1964: Passing fish through hydraulic turbines. *Trans. Am. Fish. Soc., 93: 243—259.*

CVETKOV, V. I., PAVLOV, D. S., NEZDOLIJ, V. K., 1972: Letal'nyje perepady davlenij dl'a molodi nekotorych presnovodnych ryb [Lethal thresholds of pressure decline in fry of some freshwater fishes]. *Vopr. Ichtiol., 12: 344—356* (in Russian).

ČERNÝ, K., 1973: Pohybová aktivita plůdku některých druhů ryb v přirozených podmínkách Kličavské údolní nádrže [Swimming activity of fry of several fish species under natural conditions of Kličava reservoir]. *Acta Mus. Reginae--hradecensis, S. A., Sci. Nat., 14: 105 to 120* (in Czech).

ČERNÝ, K., 1975a: Vývoj plotice obecné, tloušťe a perlína s ekologickými poznámkami o raných vývojových stadiích plotice a okouna [Development of roach, chub and rudd with ecological remarks on early stages of roach and perch]. *Ph. D. Thesis, pp. 373* (in Czech).

ČERNÝ, K., 1975b: Ještě k biologii a lovu okounů [More about biology and capture of perch]. *Rybářství, 11: 245* (in Czech).

ČIKOVA, V. M., 1968: Vidovoj i vozrastnoj sostav ryb v nižnem b'efe Volžskoj GES im. V. I. Lenina [Species and age structure in tailwater of Volžskoj GES im. Lenina]. *Tr. In-ta biol. vnutren. vod, AN SSSR, 16(19): 135—140* (in Russian).

DR'AGIN, P. A., 1953: O vozrastnoj strukture popul'acij u ryb [On age structure of fish populations]. *Zool. Ž., 32: 88—92* (in Russian).

FAYE, R. E. & SCOTT, M., 1965: Effects of pressure on survival of six species of fish. *Trans. Am. Fish. Soc., 94(1): 88 to 91.*

GAJDŮŠEK, J., 1979: Bionomie cejna velkého Abramis brama (Linnaeus, 1758) [Bionomics of the bream, Abramis brama (Linnaeus, 1758)]. *Ph. D. Thesis, pp. 285* (in Czech).

GAJDŮŠEK, J. & LUSK, S., 1984: Ichtyofauna údolní nádrže Mostiště na řece Oslavě [Ichthyofauna of the valley reservoir Mostiště on the Oslava river]. *Vertebrat. Zprávy, 1984: 95—106* (in Czech).

GEEN, G. H., 1975: Ecological consequences of the proposed Moran Dam on the Frase River. *J. Fish. Res. Board Can., 32(1): 122—135.*

GOLOVKOV, R. & KOŽIN, N., 1939: Rybochod na reke Tulome [Fishway in Tulome River]. *Rybn. Choz'aj., 6: 40—44* (in Russian).

GORODNIČIJ, A. E., 1955: Nekotoryje čerty biologiji molodi osetrovych ryb reki Dona v uslovijach zaregulirovanija stoka [Sketch on biology of juveniles of sturgeons in Don River in conditions of regulated run-off]. *Zool. Ž., 6: 1326—1337* (in Russian).

GORODNIČIJ, A. E., 1976: Dannyje po biologićeskomu obosnovaniju mer zaščity ryb ot popadanija v vodozabornyje sooruženija [Data on biological reasoning of measures of fish protection from washing through the water-intake constructions]. In: Biol. osn. primenenija rybozaščitnych i rybopropusknych sooruženij. *Moskva, Nauka, pp. 58—64* (in Russian).

HARDEN JONES F. R., 1968: Fish migrations. *London, Arnold, pp. 325.*

HORMAN, W. L., HEARD, W. R., DRUCKER, R., 1967: Migratory behaviour of sockey salmon fry and smolts. *J. Fish. Res. Board Can., 24(10): 2069—2099.*

HORST, T. J., 1977: Effects of power station on mortality of fish population stability in relationship to life history strategy. *Proc. Conf. Assessing Eff. Power. New York, pp. 297—310.*

JEREŠČENKO, V. I., 1971: O vynose ryby z Čardar'inskogo vodochranilišča [About fish washing from Čardar'inskoje reservoir]. *Biol. osn. primenenija rybopropustnych i rybozaščitnych sooruženij, Moskva, Nauka, pp. 20—23* (in Russian).

JEREŠČENKO, V. I., 1972: Sazan Čardar'inskogo vodochranilišča i puti uveličenija ego stada [Wildcarp Čardar'inskoje reservoir and ways of increasing of its stock]. In: Ryb. resur. vod Kazachstana i ich ispol'zovanija. *Alma-Ata, 7: 24 to 37* (in Russian).

KOBLICKAJA, A. F., 1966: Izučenije neresta presnovodnych ryb [Study of spawning of freshwater fishes]. *Moskva, Piščevaja prom-st', pp. 110* (in Russian).

KOBLICKAJA, A. F., 1981: Opredelitel' molodi presnovodnych ryb [Key to freshwater juvenile fishes]. *Izd-vo Legkaja i piščevaja prom., Moskva, pp. 208* (in Russian).

KRYŽANOVSKIJ, S. G., DISLER, N. N., SMIRNOVA, E. N., 1953: Ekologo-morfologičeskije zakonomernosti okun'evych ryb (Percoidea) [Ecological and morphological regularities in perch fishes (Percoidea)]. *Tr. In-ta morfol. životnych AN SSSR, 10: 3—139* (in Russian).

KUZNECOVA, I. A., 1966: Skat i pitanije snetka Osmerus eperlanus e. morpha spirinchus Raijas v r. Volge [Downstream migration of smelt Osmerus eperlanus e. morpha spirinchus Raijas in Volga River]. *Vopr. Ichtiol., 6: 744—749* (in Russian).

LAKIN, G. F., 1977: Biometrija [Biometrics]. *Izdat. Vysš. škola, pp. 344* (in Russian).

LOWNDES, A. C., 1942: The displacement method of weighing living aquatic organisms. *J. Mar. Biol. Ass. U. K., 25: 555—574.*

LUSK, S., 1978: The ichthyofauna of the Oslava River. *Folia Zool. Brno, 27(2): 165—176.*

LUSK, S., 1985: Rybí společenstva v zájmové oblasti VD Nové Mlýny a jejich obhospodařování [Fish communities in the region of water works of Nové Mlýny and their management]. In: Buček, S. & Pelikán, J. (eds.): Geologické aspekty vodohospodářských úprav na jižní Moravě. *Geografický ústav ČSAV + Ústav pro výzkum obratlovců ČSAV, Brno, pp. 132—153.*

LYNWOOD, B., 1974: Bends in fish. *Comp. Biochem. and Physiol., A-49(2): 311—321.*

MANTEJFEL', B. O., GIRSA, I. J., LEŠČOVA, T. S., PAVLOV, D. S., 1965: Vlijanije izmen'ajuščejs'a osveščennosti na obrazovanije i raspadenije staj u ryb [Influence of changing illumination on forming and disintegration of fish shoals]. *Moskva, Nauka, pp. 82—99* (in Russian).

McDONALD, J., 1960: The behaviour of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. *J. Fish. Res. Board Can., 17(5): 655—676.*

MEL'NIKOV, G. B., 1956: O podlednom skate ryb na Dnepre i v ozere Lenina [Downstream migration of fishes in Dnepr River and Lake Lenin under ice]. Pro pidl'odove skočuvanija ryb na Dnipri ta v ozeri Lenina. *Dopovedi AN URSR, 3: 291 to 294* (in Ukrainian).

MITROFANOV, V. P. & NEZDOLIJ, V. K., 1974: Vlijanije zaregulirovanija stoka reki Ili na migraciju ryb [Influence of regulated run-off on fish migration in Ili River]. *Mat. prof. — prepodavatel'skoj konferenciji KazGU, Alma-Ata, pp. 89 to 190* (in Russian).

MOKR'AK, G. S., 1958: Nabl'udenija nad propuskom ryby v Ciml'anskom rybopod'emnike [Observations of escapement of fishes in Ciml'anskoje fish nursery]. *Nauč.-tech. b'ul. VNIORCH, 6—7: 13—18* (in Russian).

MONTEN, J. F., 1985: Fish and turbines. *Vattenfall, pp. 111.*

MUIR, J. F., 1959: Passage of young fish through turbines. *J. Power Div. Proc. Amer. Soc. Civil Engrs., 85(1): 23—46.*

NEZDOLIJ, V. K., 1984: Pokatnaja migracija molodi ryb r. Ili v načal'nyj period zaregulirovanija stoka [Downstream migrations of juvenile fishes of the River Ili during the initial period of regulated run-off]. *Voprosy Ichtiol., 24: 212—224* (in Russian).

NEZDOLIJ, V. K., 1985: Skat ryb čerez turbiny Kapčagajskoj GES i mechanizmy travmirovanija [Downstream fish migration through the turbines of Kapčagajskoje GES and mechanism of traumatization]. In: Pokatnaja migracija ryb. *Moskva, IEMEŽ, pp. 44—59.*

NEZDOLIJ, V. K., MITROFANOV, V. M., DUCHRAVEC, G. M., GEREŠČENKO, A. M., 1975: Raspredelenije molodi promyslovych i sornych ryb v Kapčagajskom vodochranilišče [Distribution of juvenile commercial and nuisance fishes in Kapčagajskoje reservoir]. In: Biologičeskije nauki. *Alma-Ata KazGU, 9: 128—134* (in Russian).

NEZDOLIJ, V. K. & SAZONOV, Ju. G., 1974: Vozdejstvije rezkich perepadov gidrostatičeskogo davlenija na molod' nekatorych vidov ryb [Influence of abrupt decline of hydrostatic pressure on fry of some fish species]. *Mat. prof.-prepodavatel'skoj konferenciji KazGU, Alma--Ata, pp. 186—187* (in Russian).

NEZDOLIJ, V. K., SAZONOV, Ju. G., DUBROVSKIJ, A. S., 1975: Otrycatel'noje vlijanije propuskov Kapčagajskoj GES na rybnyje zapasy Ili [Negative influence of escapement in Kapčagajskoje GES on the fish stocks of Ili River]. *Rybnoje Choz'aj.: 30—33* (in Russian).

NUSENBAUM, L. M., 1961: O povedeniji ryb v priplotinnych učastkach v sv'azi s ustrojstvom rybozaščitnych i rybopropusknych sooruženij [On the behaviour and downstream migration of juveniles of fishes in the reaches near the dam in connection with protective constructions]. In: Tr. sovešč. ichtiol. komissii po razvedke ryb. *Moskva, Izv-vo AN SSSR, 10: 235-238* (in Russian).

ORLOV, A. B., NEZDOLIJ, V. K., VEREM'EV, V. M., 1976: Raspredelenije i skat molodi sudaka a byčka amurskogo v verchnem a nižnem b'efach [Distribution and downstream migration of juveniles of pike-perch and Amur goby upstream and downstream Kapčagajskoje reservoir]. In: Biol. osn. rybn. ch-va respubl. Sr. Azii i Kazachstana. *Dušanbe, pp. 330—332* (in Russian).

PAVLOV, D. S., 1979: Biologičeskije osnovy upravlenija povedenijem ryb v potoke vody [Biological bases controlling fish behaviour in a water-flow]. *Moskva, Nauka, pp. 319* (in Russian).

PAVLOV, D. S., 1982: Migracii ryb v sv'azi s problemoj upravlenija jich čislennost'ju [Fish migrations in connection with the steering their numbers]. *Tez. Konf. po dinamike čislennosti. Moskva, pp. 247—249* (in Russian).

PAVLOV, D. S., KOGAN, A. V., NEZDOLIJ, V. K., ČERNOUSOV, A. N., FOMIN, V. K., 1980: Pokatnaja migracija molodi ryb iz Verchnevolžskogo vodochranilišča [Downstream migration of fish from Verchnevolžskoje reservoir]. *Raspredelenije i ekologičeskije sposoby zaščity molodi ryb. IEMEŽ AN SSSR, pp. 5—29* (in Russian).

PAVLOV, D. S., KOSTIN, V. V., NEZDOLIJ, V. K., GORŠKOV, N. I., LOBANKOV, V. Ju., 1985 b: Pokatnaja migracija ryb iz vodojemov s zamedlenym vodoobmenov [Downstream migration of fish from reservoirs with slow water exchange]. *IEMEŽ, p. 136* (in Russian).

PAVLOV, D. S., KOSTIN, V. V., NEZDOLIJ, V. K., LOCHMATIKOV, A. I., BOLDYREV, A. M., OL'CHOVSKAJA, G. I., 1984: Pokatnaja migracija molodi ryb iz Ivan'kovskogo vodochranilišča [Downstream migration of juvenile fishes from the Ivankovskoje reservoir]. In: Povedenije i raspredelenije molodi ryb. *IEMEŽ, pp. 5—47* (in Russian).

PAVLOV, D. S. & NEZDOLIJ, V. K., 1981: O travmirovanii molodi ryb pri skate čerez nizkonapornyje plotiny (Ivan'kovskoje, Ugličskoje, Rybinskoje vodochranilišča) [Traumatization of fish fry during their migration through low-pressure dams (Ivan'kovskoje, Ugličskoje and Rybinskoje reservoirs)]. *Inf. B'ull. IBVV AN SSSR, 50: 29—37* (in Russian).

PAVLOV, D. S., NEZDOLIJ, V. K., CHODOR'EVSKAJA, R. P., OSTROVSKIJ, M. P., POPOVA, I. K., 1981: Pokatnaja migracija molodi ryb v rekach Volga i Ili [Downstream migration of fish fry in Volga and Ili rivers]. *Moskva, Nauka, 320 pp.* (in Russian).

PAVLOV, D. S., OL'CHOVSKAJA, G. I., MOSIEVSKIJ, A. A., ARBUZENKO, V. A., 1985a: Raspredelenije molodi ryb v verchnej priplotinnoj zone a jejo migracija čerez Ugličskij gidrouzel [Distribution of juvenile fishes in upper zones at the dam and their migration through Ugličskij hydro-center]. In: Pokatnaja migracija ryb. *IEMEŽ, pp. 60—86* (in Russian).

PAVLOV, D. S. & PACHORUKOV, A. M., 1973: Biologičeskije osnovy zaščity ryb ot popadanija v vodozabornyje sooruženija [Biological bases of fish protection from passage in water-intake constructions]. *Moskva, Piščepromizdat, pp. 208* (in Russian).

PLOCHINSKIJ, N. A., 1970: Biometrija [Biometrics]. *Moskva, Iz-vo MGU, pp. 367* (in Russian).

PODDUBNYJ, A. G., 1971: Ekologičeskaja topografija popul'acij ryb v vodochraniliščach [Ecological topography of fish po-

pulations in reservoirs]. *Leningrad, Nauka, pp. 309* (in Russian).
POPOVA, M. S., 1962: Sbros molodi i vzroslych ryb iz Sengilejevskogo vodochranilišča [Escapement of juvenile and mature fishes from the Sengilejevskoje reservoir]. *Tr. Stavropol'skogo sel'skoch. inst., 33: 89—93* (in Russian).
POTECHINA, E. V., 1956: Vozmožnost' ispol'zovanija vodochranilišča nizov'ev Dona dl'a vosproizvodstva poluprochodnych ryb [Possibility of utilization of reservoirs lying in lower Don River for production of semi-diadromous fishes]. *Rybnoje Choz'aj., 11: 23* (in Russian).
RABEN, K., 1957: Über Turbinen und ihre schädliche Wirkung auf Fische. *Z. Fischerei, 6 (1—2): 171—182.*
RASS, T. S., 1946: Stupeni ontogeneza kostistych ryb (Teleostei) [Stages of ontogenesis of bony fishes (Teleostei)]. *Zool. Ž., 25: 137—148* (in Russian).
RAYMOND, H., 1968: Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake River. *Trans. Am. Fish. Soc., 97(4): 356—359.*
REZANOV, D. P., 1969: K ekologii osnovnych promyslovych ryb Kajrak-Kumskogo vodochranilišča [To the ecology of main commercial fishes of Kajrak-Kumskoje reservoir]. *Dušanbe, pp. 238—245* (in Russian).
SCHOENEMAN, D. S. & JUNGE, O., 1954: Investigation of mortalities of downstream migrant salmon at two dams on the Elwha River. *Washington State Department of Fisheries, Res. Bull., 3, pp. 51.*
SMIŠEK, J., 1955: Vliv vody přesycené plyny na vývoj pstružího materiálu [The influence of water hypersaturated with gas on the development of trout]. *Čs. Rybářství, 1955 (7): 100—101* (in Czech).
SWARTZMAN, J. & al. 1977: Comparison of simulation models used in assessing the effects of power-plant-induced mortality on fish population. *Proc. Conf. Assessing Eff. Power plant-induced mortality of fish. popul. Gallinburg, Tenn. New York, pp. 333—361.*
SYROVATSKIJ, I. Ja., 1954: O pričine gibeli segoletkov sudaka v Ciml'anskom vodochranilišče i celesoobraznost' zaryblenija vodochranilišča poluprochodnymi rybami [On the reason of mortality of yearlings of pike-perch in Ciml'anskoje reservoir and the purpose of planting semi-anadromous fishes]. *Tezisy dokladov na III. ekologičeskoj konferencii, Kijevskij universitet č. 2, pp. 126—128* (in Russian).
ŠARONOV, A. B., 1972: Proniknovenije severnych i južnych form ryb v Kujbyševskoje vodochranilišče [Penetration of northern and southern forms of fishes into Kujbyševskoje reservoir]. *Tr. Tatar. otd. VNIORCH, 12: 178—179* (in Russian).
ŠILOV, V. I., 1966: Razmnoženije osetrovych v verchnem b'efe Volgogradskoj GES [Reproduction of sturgeons in the Volgogradskoje reservoir]. *Voprosy Ichtiol. 4: 663—671* (in Russian).
TICHIJ, M. M. & VIKTOROV, P. V., 1940: Zapasy ryb i gidrostrojitel'stvo (Fish stocks and hydroconstructions]. *Moskva, Piščepromizdat, pp. 200* (in Russian).
TREFETHEN, P., 1972: Man's impact on the Columbia River. In: River ecology and man. *Academic Press, Inc. New York, London, pp. 77—98.*
TROFIMOVA, L. M. & SOSNOV, O. I., 1965: K voprosu o predotvraščenii sbrosa kormovych organismov i ryb iz malych vodochranilišč (Stavropol') [To the question of prevention of escapement of feeding organisms and fishes from small reservoirs (Stavropol)]. *Vses. gidrobiol. ob-vo Voprosy gidrobiol., Moskva, Nauka pp. 419—420* (in Russian).
VASNECOV, V. V., JEREMEJEVA, E. F., LANGE, N. O., 1957: Etapy razvitija promyslovych poluprochodnych ryb Volgi i Dona — lešča, sazana, vobly, tarani i sudaka [Stages of evolution of commercial semi-anadromous fishes of rivers Volga and Don — common bream, wild carp, roach and pike-perch]. *Tr. In-ta morfol. životnych AN SSSR, 16: pp. 314.*
VERZIN, JU. N., 1978: Vynos molodi ryb v Generalovskuju orositel'nyju sistemu iz Ciml'anskogo vodochranilišča [Fish juveniles drifting in Generalovskoje irrigation system from Ciml' anskoje reservoir]. In: Biol. osnovy primenenija rybozaščitnych i rybopropusknych sooruženij. *Moskva, pp. 89—93* (in Russian).
VOLODIN, V. M., 1958: O vynose ryb čerez plotinu Rybinskoj GES [On fish washing through the dam of Rybinskoje GES]. *B'ul. IBVV, 2: 63* (in Russian).
VOSTRADOVSKÁ, M. & VOSTRADOVSKÝ, J., 1971: K úniku ryb turbinami a hrází údolní nádrže Lipno [On the escape of fish through the turbines and dam of the Lipno dam lake]. *Bull. VÚRH Vodňany, 3: 24—28* (in Czech, with a summary in English).
VOSTRADOVSKÁ, M. & VOSTRADOVSKÝ, J., 1977: Stavby na tocích a rybářské zájmy [Constructions on running waters and fishery interests]. *VTEI, 7—8 262—266* (in Czech).
ŽDANOVA, N. N., 1963: O skate molodi sudaka r. Don [On downstream migration of pike-perch from Don River]. *Rybn. choz'aj., 6: 28—29* (in Russian).