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Drift of juveniles after riverine spawning of fishes from the Římov reservoir, Czech Republic

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Abstract

Downstream drift of fish eggs and larval and juvenile fish was investigated in close relation to upstream spawning runs of the reservoir parent stock during two seasons in the tributary of the Římov Reservoir (Malše River, South Bohemia, Czech Republic). Five drift nets were set across the river at weekly intervals from the end of April to mid June. Drift of fish eggs was bimodal with the highest peak in early May (massive cyprinid spawning). A distinct evidence of riverine spawning by some of the reservoir fish species like asp (*Aspius aspius*) and roach (*Rutilus rutilus*) has been shown. The asp was the prevailing drifting species at the beginning of May, the roach on the remaining sampling dates. In mid May bullhead (*Cottus gobio*) also contributed significantly to the drifting fish. On the other hand, absence of otherwise very abundant species in the migrating parent stock like bream (*Abramis brama*) and bleak (*Alburnus alburnus*), suggests differences in preferences for the spawning area, even within the short river/reservoir ecotone. Apparent tendency for drifting during night time was reported in bullhead. In other fish species no differences were found between the day/night numbers of drifting individuals. Diurnal changes in spatial distribution of drifting eggs across the river profile suggested slight tendency for spawning closer to the right riverbank during night time, where lowest flow velocities were reported.

Key words: egg and larval drift, 0+ fish, spawning, migration, river, reservoir.

1. Introduction

Reservoir fish reproduce either in the reservoirs or migrate to rivers to spawn (Ilyina *et al.* 1978; Duncan, Kubečka 1995). Although there is a vast amount of publications on the downstream drift of juveniles from reservoir (Vostradovská, Vostradovský 1971; Pavlov *et al.* 1981, 1984, 1985a, 1985b, 1987; Nezdoliy 1984; Baruš *et al.* 1985, 1986), the drift of early stages from the upstream riverine habitats has received much less attention (Teraguchi 1962; Lindsey, Northcote 1963; Geen *et al.* 1966).

To estimate the importance of tributary for the functioning and management of a reservoir fish stock, an intensive study was undertaken in the Římov Reservoir (Southern Bohemia, Czech republic) from 2000 to 2003 (Hladík, Kubečka 2003). The aim of the study was to provide a detailed understanding of fish migration events

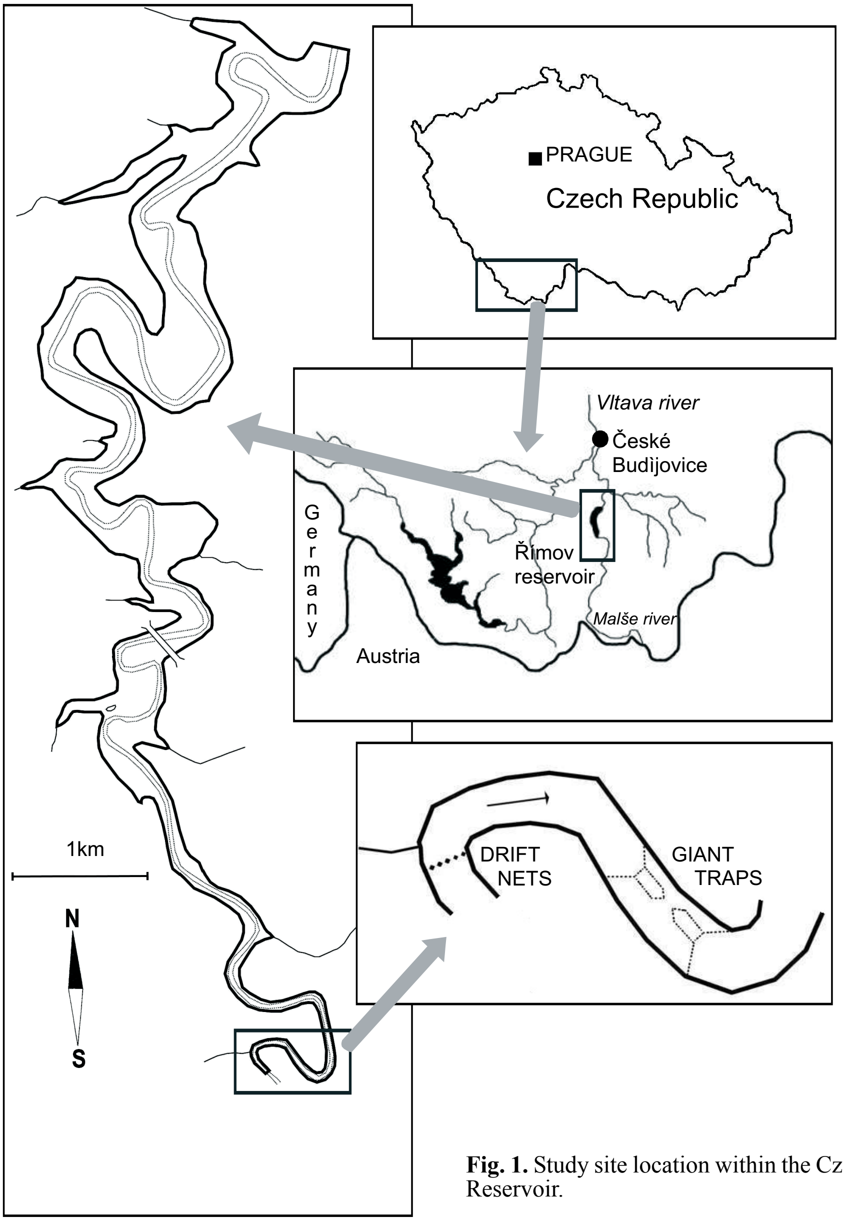

Fig. 1. Study site location within the Czech Republic and the Římov Reservoir.

between the main river inflow and the reservoir. Already in the first year of the project the authors found that more than 10% of the fish biomass in the reservoir migrated through the tributary zone and that the most important period was the spring spawning run of the parent stock.

In close relation to that finding, the downstream drift of fish eggs, larvae and juveniles was monitored with aims to 1) especially, find evidence for the spawning success of the reservoir parent stock migrating upstream, and therewith also 2) to obtain detailed information on the species composition of the drifting fish giving insight into anticipated spatial differences in spawning locations of different fish species, and 3) to get information on the differences of the spatial (across the river profile) and temporal (diel) course of the downstream migration.

2. Materials and methods

Study site

The Římov Reservoir is a steep sided drinking water supply reservoir located on the Malše River (Vltava River system Fig. 1). The reservoir is 12 km long, mean area 210 ha, average depth 16 m and average retention time 90 days. The Malše River is the only large water inflow into the

Table I. Environmental characteristics of the sampling location in the Malše River in 2002, showing the depth of the water column and the average flow velocity at specific drift nets, and the average water temperature; R - net closest to right river bank, M - net in the middle of the river, L - net closest to left river bank (for details see Fig. 2).

date	water depth [cm]					day/night average flow velocity [m s^{-1}]					average temperature [°C]	average DO concent. [mg dm^{-3}]
	R	MR	M	ML	L	R	MR	M	ML	L		
24 Apr	46	65	85	75	60	0.43 / 0.5	0.46 / 0.54	0.61 / 0.56	0.49 / 0.54	0.32 / 0.61	9.7	12
2 May	16.5	32	40	46	35.5	0.46 / 0.57	0.83 / 1.9	0.46 / 1.19	0.63 / 1.63	0.97 / 1.81	14.3	9.7
9 May	21	34	34	39	22	0.28 / –	0.42 / –	0.42 / –	0.64 / –	0.63 / –	15.3	8.3
15 May	30	41	41	45	36	0.28 / 0.35	0.45 / 1.55	0.45 / 1.25	0.48 / 1.47	0.42 / 1.97	13	9.2
22 May	10	24	32	33	16	0.12 / 0.58	0.25 / 0.58	0.56 / 0.77	0.62 / 0.73	0.52 / 0.82	16.6	7.7
29 May	24	27	32	32	27	–	–	–	–	–	12.5	–
5 Jun	28	50	32	45	42	0.17 / 0.32	0.25 / 0.57	0.29 / 0.63	0.27 / 0.58	0.22 / 0.69	17	7.5

reservoir with a catchment area of 465 km^2 and an average discharge of 4.1 m^3 s^{-1}. The study was conducted about 500 m upstream from the point where the cooler river water submerges below the warmer reservoir epilimnion during summer thermal stratification (plunging point). The width of the river at the sampling location was 12 m with maximum depth not exceeding 1 m. The drift nets were located on the lowermost end of grayling zone before impounded water to the reservoir. The river bed consisted of cobbles and gravel in the mainstream and sand close to the right riverbank. Significant parts of the bottom were overgrown by *Batrachium* sp. For further environmental details see Table I. The sampling site represented a typical stretch of the river.

Sampling design and regime

A circular drift net was used for preliminary sampling in 2001. The length of the net was 3 m with a mesh size of 1x1 mm. The diameter of the entrance opening was 1 m. The net was positioned over deeper water (>1.5 m) so that the upper part of the frame of the net touched the water surface. Sampling dates were May 4, 5, 21, 22, 23, 24, 27, 28, 29, 30, 31 and June 1, 3, 4, 6, 7 and 8. The net was set into operation for period of 12 h (mostly over night). Because clogging was not prevented, these results should be considered as qualitative only.

In 2002 five passive drift nets were set evenly across the river on each sampling date. The conical nets were 2 m long with a mesh size of 1x1 mm. The entrance opening was rectangular, 1.5 m high and 0.5 m wide (Fig. 2). The shorter side was equipped with two spikes that were driven into the bottom in order to keep the frame stable. In the upper part, the frames of the nets were fastened to a rope stretched over the river and weighted to prevent movement. The drift nets were emptied from their downstream ends. The nets sampled the whole water column.

Samples were collected at weekly intervals during the main upstream migration of the parent stock; the actual sampling dates were April 24, May 2, 9, 15, 22, 29 and June 5. Sampling started in late afternoon and continued at 3 h intervals from dusk to dawn and at 6 (or 8) h intervals during daytime. Actual sampling times were usually 18.00, 21.00, 00.00, 03.00, 06.00, 10.00 (or 12.00) and so covered the 24 h period. A period of 30 min ensured adequate sampling before the net was clogged by drifting debris. All nets were sampled simultaneously.

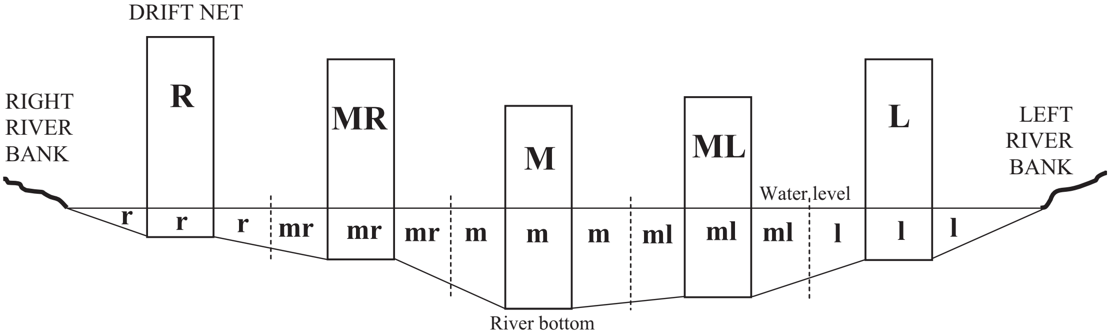

Fig. 2. Schematic view of the position of five drift nets (R - net closest to right river bank, MR, M - net in the middle of the river, ML, L - net closest to left river bank) across the river profile and the visualization of the way of transformation of the catches of individual nets to the whole river profile. Net covered areas and neighbouring areas where the same drift rate was assumed are marked by small letters (r, mr, m, ml or l).

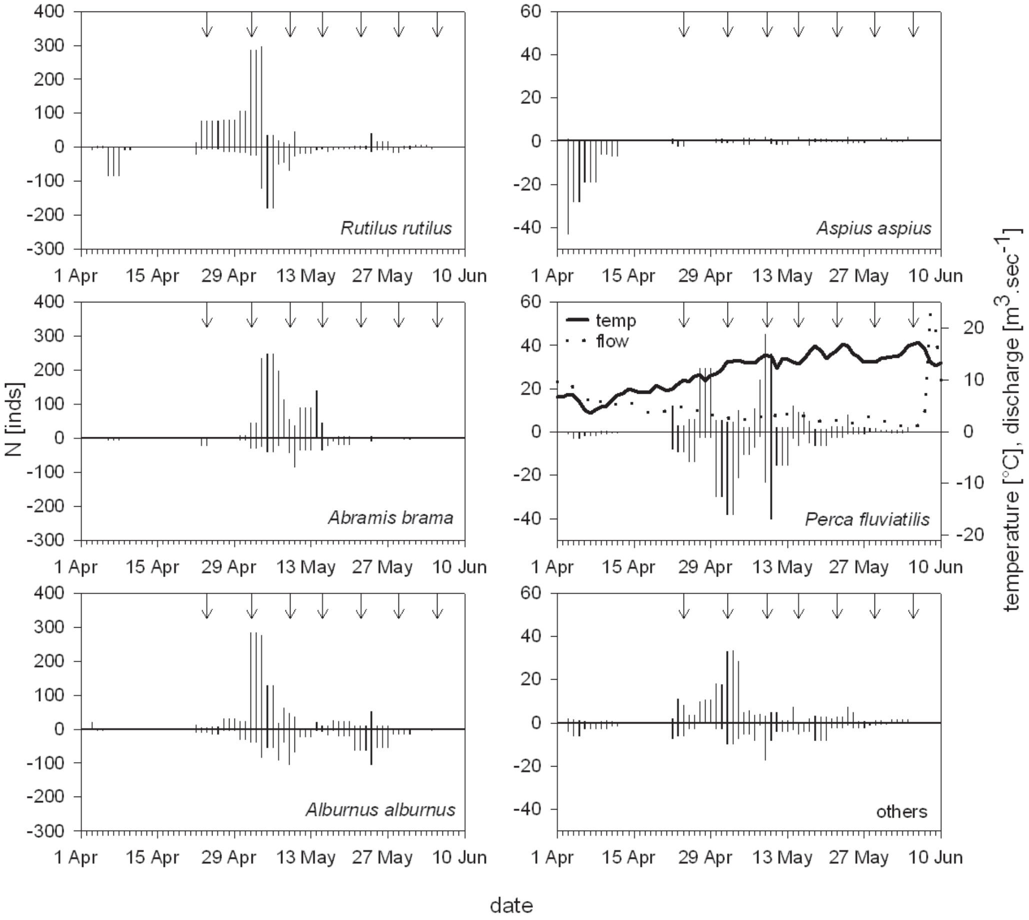

Fig. 3. Temporal variation in the abundance of upstream (positive values) and downstream (negative values) migrating parent stock of the most important fish species in 2002. Upper arrows indicate the dates when drift samples were taken. For further details on parent fish stock migrations see Hladík, Kubečka (2003).

Environmental data and sample processing

A mechanical velocity meter was used for measuring water current in the middle of the water column in front of all the drift nets twice during the day and once during the night on each sampling date. Temperature and dissolved oxygen data were recorded by an automatic probe device YSI 5560 at 1 min intervals on all sampling dates. Temporal variations in temperature and water velocity values (Fig. 3) were obtained from the nearest Hydrometeorological Station of the Czech Hydrometeorological Institute located eight km upstream on the Malše River. Before each sampling trial light intensity was measured using a portable light meter BEHA UNITEST 93408. Night time was defined as a period when light intensity was <1 lx. The most important environmental data are summarized in Table I.

After each sampling the collected material was examined on a white photographic tray. Fish eggs were counted and fish older than 0+ and >30 mm standard length (SL) were identified and measured immediately. Fish larvae were preserved in 4% formaldehyde for further laboratory analyses. In the laboratory, the fishes were identified using Koblickaya (1981), Pinder (2001) and Spindler (1988), and SL (from tip of the snout to the end of the notochord) was measured to the nearest 0.1 mm.

Data transformation and statistical analysis

For general comparisons, data were transformed to the whole river profile area, i.e. the drift rate of the net R was also extrapolated to neighbouring areas r and so on for MR, M, ML and L (Fig. 2). On each sampling event the river profile area was approximated to a regular geometrical shape that was obtained on the basis of distances between nets and from nets to riverbank, and water depths at each drift net. This transformation was not used when comparing the drift variation across the river profile.

Table II. Temporal variation in the drift rate of fish eggs and larval and juvenile fish on different sampling dates in 2001. Although the data are presented as numbers of individuals.day^{-1} meter^{-2} of the net, notice the rather qualitative character of the data, due to long sampling time and probable net clogging (see Materials and methods).

date	drift rate [inds day^{-1} m^{-2} (of the net)]									
	eggs	*Aspius aspius*	*Rutilus rutilus*	*Abramis bjoerkna*	*Leuciscus leuciscus*	*Leuciscus cephalus*	*Perca fluviatilis*	*Cottus gobio*	*Salmo trutta*	*Σ*
4 May	586.0									586.0
5 May	203.8									203.8
21 May					5.1			10.2		15.3
22 May									2.6	2.6
23 May		3.2	1.6	3.2						8.0
24 May		2.8	2.8	2.8						8.4
27 May			0.9							0.9
28 May							12.7			12.7
29 May			2.8				61.2			64.0
30 May			109.7				81.5	22.3		213.5
31 May			52.2			3.3	108.3	3.8		167.6
3 Jun			76.4	2.6			56.1			135.1
6 Jun							2.4			2.4
7 Jun			2.2				33.5			35.7

In the temporal domain the data were extrapolated to 24 h period by the following equation:

Daily catch = $\Sigma (C_i\ T / 0.5)$

where C_i is the catch of all five nets from the 30 min sampling period i, and T the time in hours between two subsequent sampling periods. For diel comparisons the data were transformed only to 1 h periods. For these comparisons also, the daytime was defined, with respect to season and light intensity measurements, as the period from 04.00 to 22.00 hours and the night time vice versa.

Diel (day/night) differences in numbers of drifting eggs and fish on different dates were tested using two-sample F-test for variances.

3. Results

During the preliminary sampling in 2001, only drifting eggs were reported on the first two sampling dates at the beginning of May (Table II). The bulk of the eggs drifted attached to pieces of vegetation (mainly *Batrachium* sp.), but free eggs were reported also (<20% of the sample). Fish larvae were caught firstly on May 21, but up to the end of May only very low numbers were observed, not exceeding ten per sample (Table III). Higher drift rates were reported at the end of May and at the beginning of June (Table II), estimated up to 213.5 individual fish larvae and juveniles.day^{-1} m^{-2} of the net on May 30 when the drift rate was the highest over the studied period. During the drift peak, the sample was nearly exclusively composed of roach (Rutilus rutilus) and perch (*Perca fluviatilis*). From other fish species asp (*Aspius aspius*), silver bream (*Abramis bjoerkna*) and bullhead (*Cottus gobio*) were caught in numbers >2 individuals over the whole studied period (Table III).

In 2002, >31704 drifting eggs day^{-1} m^{-2} occurred at the beginning of May (Fig. 4). Thereafter, the numbers of drifting eggs dropped to zero in mid May and then a second maximum of 2015 eggs day^{-1} m^{-2} was observed at the end of May. As in 2001, most eggs were attached to parts of

Table III. Average standard length and numbers of fish caught on different sampling dates in 2001.

date	mean standard length [mm] ± standard error, (n)							
	Aspius aspius	*Rutilus rutilus*	*Abramis bjoerkna*	*Leuciscus leuciscus*	*Leuciscus cephalus*	*Perca fluviatilis*	*Cottus gobio*	*Salmo trutta*
21 May				7.8 ± 0.18 (2)			9.1 ± 0.11 (4)	
22 May								24 (1)
23 May	9.5 ± 0.35 (2)	11 (1)	8.3 ± 0.53 (2)					
24 May	10 (1)	11 (1)	12 (1)					
27 May		13 (1)						
28 May						20.3 ± 0.40 (6)		
29 May		14 (1)				20.0 ± 0.39 (22)		
30 May		11.8 ± 0.44 (13)				19.8 ± 0.45 (12)	10.3 ± 0.18 (2)	
31 May		13.8 ± 0.22 (12)			14 (1)	20.6 ± 0.29 (27)	12 (1)	
3 Jun		12.9 ± 0.37 (18)	13 (1)			20.4 ± 0.5 (18)		
6 Jun						20.5 (1)		
7 Jun		13 (1)				20.6 ± 0.24 (13)		

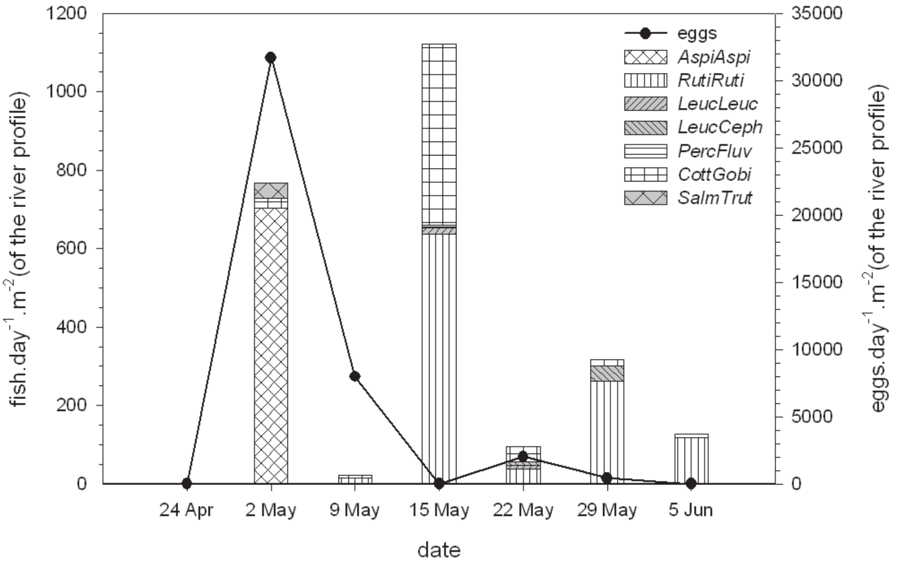

Fig. 4. Temporal variation in the drift rate of fish eggs and larval and juvenile fish on different sampling dates in 2002.

Batrachium sp. Drifting fish larvae occurred first with the massive egg drift at the beginning of May. Except for one brown trout (*Salmo trutta*), the sample was composed of asp. In mid May, drifting fish larvae reached a maximum of >1122 inds day^{-1} m^{-2}. The drifting fish community was composed nearly exclusively by roach (56.9%) and bullhead (41.3%). On the next sampling date the numbers of drifting larvae were much lower. Higher numbers (317 and 128 inds day^{-1} m^{-2}) occurred again at the end of May and start of June.

Over the period studied in 2002, mean SL of the roach increased from 4.9 to 9.8 mm, but increased rather less in bullhead from 7.8 to 9.8 mm (Table IV). The highest increase occurred in perch, from 7.3 to 19.2 mm (Table IV), similar to the situation in 2001 (Table III).

There were significant differences between day and night in numbers of drifting fish in 2002 in bullhead (F=0.018, p=0.0002) and perch (F=72.8, p=0.001). For bullhead this was most evident on May 15, when numbers of drifting larvae were 7.25 times higher during the night than the day (Fig. 5). On the other hand in perch, numbers of drifting juveniles were higher during daytime on June 5 (Fig. 5 and 6). Differences in diel variation in drifting larvae of asp and roach were insignificant (F=0.43, p=0.19 and F=0.92, p=0.46 respectively). There were no distinct trends in spatial diel variation in numbers of eggs and fish, but there was a slight shift of the egg catches to the right river bank at night (Fig. 6).

The bycatch of fish older than 0+ was rather low in 2001, when only three stone moroko (*Pseudorasbora parva*, 30-43 mm SL) and one sneep (*Chondrostoma nasus*, 54 mm SL) were caught, but was higher in 2002 comprising ruffe (*Gymnocephalus cernuus*, 50-70 mm SL, n=12), roach (42-150 mm SL, n=5), gudgeon (*Gobio gobio*, 24 and 29 mm SL), brown trout (90 mm SL), bullhead (70 mm SL) and chub (*Leuciscus cephalus*, 40 mm SL).

4. Discussion

In both years there was evidence of successful spawning in the river by some of the reservoir fish. The drift succession pattern was very similar in both seasons. At the beginning of May the sample was composed primarily of asp larvae, that

Table IV. Average standard length and numbers of fish caught on different sampling dates in 2002.

date	mean standard length [mm] ± standard error, (n)						
	Aspius aspius	*Rutilus rutilus*	*Leuciscus leuciscus*	*Leuciscus cephalus*	*Perca fluviatilis*	*Cottus gobio*	*Salmo trutta*
2 May	7.3 ± 0.05 (40)						19 (1)
9 May		4.9 ± 0.62 (2)				8 ± 0.71 (2)	
15 May		6.3 ± 0.07 (97)	9.3 ± 0.18 (2)		7.3 (1)	7.8 ± 0.04 (73)	
22 May		7.5 ± 0.2 (4)	8.8 (1)	12.5 (1)		8.8 ± 0.41 (5)	
29 May		8.4 ± 0.24 (7)		13.1 (1)		9.8 ± 0.18 (2)	
5 Jun		9.8 ± 0.18 (15)			19.2 ± 0.63 (13)		

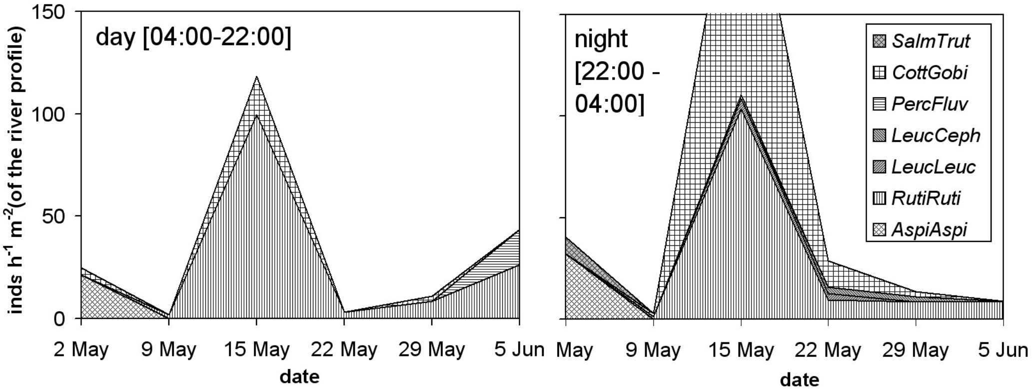

Fig. 5. Diel variation in the abundance of drifting fish larvae and juveniles on different sampling dates in 2002.

were replaced later on mainly by roach and bullhead, followed by a characteristic appearance of perch at the end of May and beginning of June. This succession pattern reflects to some extent the temporal variation in the upstream parent stock spawning runs observed by Hladík, Kubečka (2003, Fig. 3). Both the most important drifting cyprinid species in our study either tend to spawn in streams adjacent to reservoirs as was found for asp (Oliva *et al.* 1968; Vostradovský 1974), or are one of the most abundant species drifting in rivers as was found for roach (Peňáz *et al.* 1992; Pavlov 1994; Jurajda 1998), suggesting that these behaviours may be important links in their life history also in reservoirs.

On the other hand the absence of larvae of bream (*Abramis brama*) and bleak (*Alburnus alburnus*) otherwise very abundant among the migrating adult fish (Fig. 3), suggests differences in preferences of the parent fish for the spawning area even in the short tributary habitat. The most probable explanation, is the restriction of the spawning habitat, at least for bream, to the area just between the giant traps and drift nets (400 m long, Fig. 1), particularly confirmed by the observations in 2003 (Hladík unpubl.). The absence of drifting bleak larvae remains unexplained, although short upstream migration and subsequent downstream drift seems to be a regular part of bleak life history, especially in rivers

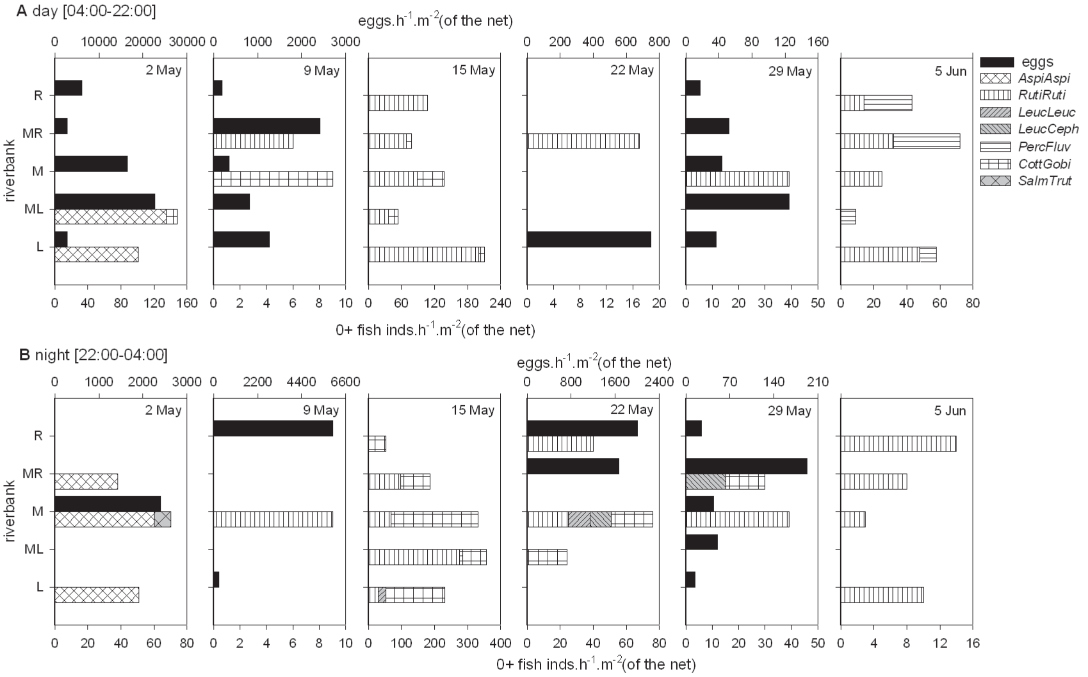

Fig. 6. Diel and spatial (across the river profile) variation in numbers of drifting eggs and larval and juvenile fish on different sampling dates in 2002; R - net closest to right river bank, M - net in the middle of the river, L - net closest to left river bank (for details see Fig. 2).

(Jurajda *et al.* 1998). In Rybinskoye Reservoir (Russia), juvenile fish of the same species spend up to 2-3 years in the tributary before downstream migration to the reservoir (Ilyina *et al.* 1978), but with respect to the grayling character of the Malše River such behaviour seems unlikely in the present case.

One of the exclusively riverine species that contributed significantly to the drifting fish abundance was bullhead. Its maximal contribution per sampling date was 10.5% and 41.3% in 2001 and 2002 respectively (Table II, Fig. 1). The difference between the two seasons is probably the consequence of different sampling method used. The ring net, sampling just below the water surface in 2001, rather underestimated the abundance of the bottom living bullhead. From this point of view the whole water column sampling used in 2002 revealed more realistic results giving the bullhead a significant place in the drifting fish community. Very high proportions of drifting larvae of sculpins (*Cottus aleuticus* and *C. asper*) have been reported also by White, Harvey (2003). The sculpins outnumbered other fish taxa in the coastal rivers Smith and Van Dunzen, Northern California, reaching 63% and 90% of the fish drift community respectively.

In 2002 attention was paid to diel and spatial course of the drift. Although most of the drift studies (Peňáz *et al.* 1992; Jurajda 1998; Carter, Reader 2000; Copp *et al.* 2002; Reichard *et al.* 2002; White, Harvey 2003) reported significant increase in the abundance of drifting fish during night hours, the present study found diel change only in bullhead (Fig. 5). In other fish species, except perch that migrated during daytime, no statistical differences were found between daytime and night time catches. The general absence of diel variation in the drift catches in the present study is interesting not only because it has been largely reported by other authors, but especially because the present flow velocities were about twice as high during night hours, than during daytime due to evening hydro power station operation further upstream. Similar absence of diel variation of drifting fish larvae was observed by Robinson *et al.* (1998) in the fast flowing Little Colorado River, Arizona.

A similar unclear pattern has been observed in the diel course of drifting fish eggs. The drift rate was more then twenty times higher during the daytime on May 2, when the maximum was reported (32 000 eggs day^{-1} m^{-2}), but was about two and five times higher during night hours on May 9 and 22, when lower values of about 8000 and 2000 eggs day^{-1} m^{-2} were observed (Figs. 4 and 6). More than 80% of the drifting eggs were attached to pieces of vegetation. These could have been loosened either by the massive spawning activity of adult fish or by the higher flow velocity. Although less apparent, the night time egg catches were situated at or closer to the lower flows near the right river bank. This spatial change suggests that, although during daytime spawning occurred in the deepest, safest, middle part of the river, during night hours the fish spawned rather closer to the river bank with low velocity as suggested by the spatial pattern of the egg catches. The spatial variation in drift rates of fish larvae across the river profile revealed rather no diurnal differences, with highest drift rates in the deepest middle part of the river, with the exception on June 5 when higher rates were reported at the river banks. By contrast, higher nearshore drift rates were observed by Robinson *et al.* (1998) and Reichard (2002). Reichard (2002) has also reported that spatial differences were correlated with the developmental stage (i.e. also length) in bream, with larvae migrating close to river banks and juveniles in the mid-channel.

In the present study, all of the drifting cyprinids and bullheads were in the developmental stage of free embryo to intermediate larva (Pinder 2001). On the other hand 0+ perch and brown trout were caught at the young juvenile stage. Moreover the perch mean SL was about twice the mean roach SL on the same sampling date (Table IV). The same length difference was observed in 2001 (Table III). The perch of this length are not present in the reservoir at this time (Matěna pers. com.), therefore it is suggested that they most probably come from fishponds further upstream, where temperature conditions were especially suitable for such fast growth.

Although the numbers of drifting eggs and fish larvae can be assessed as rather high, knowledge of survival rates to recruitment is necessary to proper evaluation of the impact of tributary or river upstream spawning to reservoir fish populations. For the inactive fish eggs and freshly hatched larvae, survival may be rather poor due to rapid change of environmental conditions.

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