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The effect of water level fluctuation on tributary spawning migration of reservoir fish

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Abstract

The Rímov Reservoir (Czech Republic) was chosen as a model object to study the importance of the tributary zone (Malše River) for the fish populations of the reservoir. The migrating fish were captured by two specially constructed large fykenets during four seasons 2000 - 2003. One trap was sampling upstream- and the second one was sampling downstream- migrants. The spring spawning migration of cyprinids was found as the most important event of every season and the number of migrating individuals of individual fish species corresponded to the total abundance in the reservoir and to affinity of individual fish species to the spawning in the tributary area of the reservoir. During first three seasons, the water level had a similar pattern with maximum level in the beginning of spring and flooded terrestrial vegetation was available for phytophilic fish to spawn along the shoreline of whole reservoir. In 2003, the water level was maintained down by at least 2 m and no plant-spawning substratum was available in the reservoir and therefore a much stronger upstream spawning run of the phytophilic fish to the tributary area was expected. Increased numbers of migrating individuals were found only for white bream (*Blicca bjoerkna*) and to a small extent bream (*Abramis brama*). Roach (*Rutilus rutilus*) and bleak (*Alburnus alburnus*) tributary run seems to be proportional to the number of adult fish in the reservoir. None of the above factors determined the strength of run of perch (*Perca fluviatilis*), chub (*Leuciscus cephalus*) and roach x bream hybrid. Most reservoir fish (bream, bleak and roach) used rocky shores with small stones for alternative spawning in the reservoir, perch spawned on old tree stumps. Timing sequence of the main tributary spawning run is determined by the temperature. Absence of submerged plants played no role in timing. During four years, up to 43% of adult bream stock of the reservoir, 30% adult bleak, 15% roach, 22% roach x bream hybrid and 4% perch used tributary for spawning during the main spawning run.

Key words: freshwater fish spawning migration, tributary, reservoir, water level fluctuation.

1. Introduction

An increasing number of investigations have focused upon migration of non-salmonid fish in fresh-water ecosystems in last two decades (Northcote 1984; Lucas, Baras 2001) and fish migration in the fresh water ecosystems can be classified as either reproductive, feeding and refuge migrations (Lucas, Baras 2001). The roach *Rutilus rutilus* (L.) (L´Abée-Lund Vollestad 1985) bream *Abramis brama* (L.) (Prignon *et al.* 1998;Molls 1999, Grift *et al.* 2001) white bream *Blicca bjoerkna* (L.) (Prignon *et al.* 1998; Lelek, Libosvárský 1960) have all been shown to undergo significant spawning migrations. A significant number of studies have looked at the fish migration in still-water ecosystems (Vostradovský 1968; Vostradovská 1974; Holčík 1970) and also on the fish migration between the lacustrine and fluvial ecosystems (L´Abée-Lund, Vollestad 1985; Lilja *et al.* 2003).

In artificial reservoirs, originally riverine fish fauna encounter extensive lacustrine habitats (Fernando, Holčík 1981) and increased fluctuations of water level (Draštík *et al.*2004 this issue). The extreme water level fluctuations in the energy-exploited reservoirs can potentially disable the natural reproduction of fish species dependant on the spawning in the shallow littoral areas (Peňáz *et al.* 1996).

The patterns of fish migrations between the Rímov Reservoir and its main tributary during three seasons (2000-2002) under relatively high spring water level were established by Hladík and Kubečka, 2003 and the fish inhabiting the reservoir were divided into three groups:

1. obligatory tributary spawners (asp *Aspius aspius* (L.), chub *Leuciscus cephalus* (L.), bleak *Alburnus alburnus* (L.) and white bream,
2. generalists (spawning in both the reservoir and the tributary, the most abundant species like roach, bream, bream (*Abramis brama*) x roach (*Rutilus rutilus*) hybrid (hybrid), pike *Esox lucius* L and perch *Perca fluviatilis* (L.)),
3. fish never using tributary for the spawning (carp *Cyprinus carpio* L., pikeperch *Stizostedion lucioperca* (L.), catfish *Silurus glanis* L. and eel *Anquilla anguilla* (L.)).

The terrestrial vegetation grows in the shores of the reservoir during the summer and autumnal drawdown of the water level (Duncan, Kubečka 1995), and it is flooded during the spring spawning period. Phytophylic and phyto-lithophylic (Balon 1975) fish belonging to generalist category had extensive opportunity to spawn in the main body of the reservoir. During all sampling seasons, it was observed that under the conditions of flooded terrestrial vegetation generalist species highly preferred the phytophylic spawning on the plants and avoid lithophylic spawning on stones and gravel as described by (Holčík, Hruška 1965). In the season 2003, the water level was maintained at an unusually low level due to reconstruction of the dam devices. No flooded terrestrial vegetation was available to the fish and it was expected that most generalist fish might attempt to find the plant spawning substrata in the tributary and than the upstream run would increase significantly. In Rybinskoye Reservoir, the high upstream runs of bream, pikeperch, roach, white bream, pike and bleak were observed during seasons with shortage of spawning substratum caused by the low water level and erosion (Ilyina *et al.* 1978). The aim of study undertaken during 2003 was to find whether the upstream spawning run would be influenced by changes in spawning conditions in the Rimov Reservoir and its tributary.

2. Material and methods

Description of study site

The Rímov Reservoir was built in 1978 at the Malše River 20 km south of České Budějovice, Czech Republic (dam coordinates: 48°51´00´´N, 14°29´29´´E). It is about 12 km long and it is a deep valley water supply reservoir with a mean area of 210 ha, average depth of 16 m and average storage time of about 90 days. The Malše River is a small river with an average discharge of 4.1 m^3 s^{-1} and it is the only significant inlet of the Rímov Reservoir.

The development of the fish stock in the reservoir has been studied regularly since filling of the reservoir by the method of night shore seining (Kubečka, Böhm 1991; Seďa, Kubečka 1997).

The fish stock of the reservoir was relatively stable during last decade and it was dominated by cyprinids (bream 30-50%, roach 30-50%, bleak 5-10%, asp 3-5%) and the proportion of other fish was low (perch 3-4%, pikeperch 1-2%, ruffe *Gymnocephalus cernuus* (L.) 1-2%) (Annual reports of the Hydrobiological Institute, http://www.hbu.cas.cz).

Because of the size and function of traps, the experimental site was located at the point where the depth of impounded water on the former riverbed was 3 m at most (for detailed description see Hladík, Kubečka 2003). In the seasons 2000 - 2002, the sampling area was located in the upper part of the reservoir (48°48´04´´N, 14°29´51´´E) and in the season 2003, the sampling area was located about 1 km downstream due to lower water level in the reservoir.

Methods

The inshore areas of the reservoir had been sampled at night by seine nets 50-150 m long, 4 m deep with the mesh size of 10 mm (Kubečka, Böhm 1991; Seďa, Kubečka 1997). The area swept varied between 3-5 hectares during seasons 2000 - 2002. In the season 2003, the sampling area was lower (1 ha) due to reduction of the littoral parts of the reservoir caused by lower water level in the reservoir.

Since the season 1999, the fish stock of the reservoir was additionally sampled by gillnetting (Vašek *et al.* 2004). A similar arrangement of the Nordic survey standard multi-mesh gillnets was used in all parts of the reservoir. The open water habitats were sampled by epipelagic (in the depth of 0-3 m), mesopelagic (5-9 m) and bathypelagic (5 m above the bottom) multi-mesh gillnets. In the benthic habitats, individual sets of benthic multi-mesh gillnets 1.5 m high were installed above the bottom gradually in different depths (2-3 m; 4-5 m; 7-9 m; 11-13 m; 15-17 m) parallel to the shoreline. Gillnets were installed about two hours before the sunset and were taken out about two hours after sunrise next morning to sample two periods of the high fish activity, the total area of installed gillnets every season reached approximately 15 000 m^2.

The data recorded by epipelagic and littoral gillnets installed in the depth of 0-5 m were used for the estimation of the composition of the fish stock in the reservoir because deeper parts of the reservoir are avoided by fish during summer temperature stratification (Vašek *et al.* 2004). The reservoir was split into three pelagic and four littoral areas ($i \ldots n$) whose area proportion of the total reservoir area (APi) was established by gravimetric planimetry. For every fish species ($j \ldots k$), the weighted proportion (WPj) of species j on the total fish stock was established from the formula:

$$WP_j = \frac{\sum_{i=1}^{n} CPUE_{ij} * AP_i}{\sum_{j=1}^{k}\sum_{i=1}^{n} CPUE_{ij} * AP_I}$$

where $CPUE$ is catch per unit of effort per 1000 m^2 of gillnet-nights. For whole reservoir, the weighted $CPUE$ ($WCPUE$) was calculated using the relationship:

$$WCPUE = \frac{\sum_{i=1}^{n} CPUE_I * AP_i}{\sum_{i=1}^{n} AP_i}$$

Weighted $CPUE$ of the species j ($WCPUEj$) was then calculated by the formula:

$$WCPUE_j = WCPUE * WP_j$$

Because the pelagic areas (>150 ha) exceed the inshore (about 50 ha) in the Rimov Reservoir, *WCPUEj* characterised the fish composition and the fish density mainly in the offshore pelagic habitats while the results from the night shore seining apply mostly to the inshore littoral areas. Bream population in the reservoir was furthermore sampled during spawning in suitable littoral parts around of the reservoir by electro-fishing and by daytime seining.

The fish migrating into the tributary zone of the reservoir were sampled by two independent specially constructed giant traps or fyke-nets (for detailed description and drawing see (Hladík *et al.* 2002). The downstream-located trap sampled migrants travelling upstream (the wings and entering funnel facing to the reservoir) and an upstream-located trap sampled migrants travelling downstream (wings and entering funnel facing to the river). All captured fish were identified, measured, marked by fin clipping and by fluorescent elastomer tags (Northwest Marine Technology) and released over one hundred meters beyond the traps in the direction they were originally swimming.

In the seasons 2000 and 2001, the fish migration was studied approximately from the end of March to the middle of July, in the season 2002, the sampling was finished in the middle of June. In the season 2003, the trap operation was running only from April 27th till May 16th and it was focused on the period with the high fish spawning activity which rarely exceed 10 days (Pivnička, Švátora 2001). The "tributary run" (TR) was defined as the total number of fish recorded during upstream and downstream migration in the tributary during first 15 days after beginning of peak cyprinids spawning runs (period 3 and the first part of period 4 according to Hladík, Kubečka 2003, see Fig. 1) except recaptured fish (Fig. 2, Table I, Table II). Proportional tributary run (PTR) was introduced for the comparison of TR with the pool of adult fish available in the reservoir.

$$PTR = \frac{TR}{N}$$

Where N was the total pool of adult fish of a given species calculated by multiplying of species abundance estimated by night shore seining (N ha^{-1}, Table I) by the total area of the reservoir at the time of summer night shore seining census. The total fish activity (TA) was defined as the total number of fish (upstream and downstream migrants altogether including recaptured fish) recorded in the tributary during first 15 days after beginning of peak cyprinids spawning runs (Fig. 3).

The study deals with the spawning migration of fish and therefore only mature individuals of bream, roach, hybrid and white bream were considered. A marginal minimum body length of adult fish using tributary for spawning was established during spawning season (Table II) and this value increased by growth was next used for the determining of adult individuals during summer

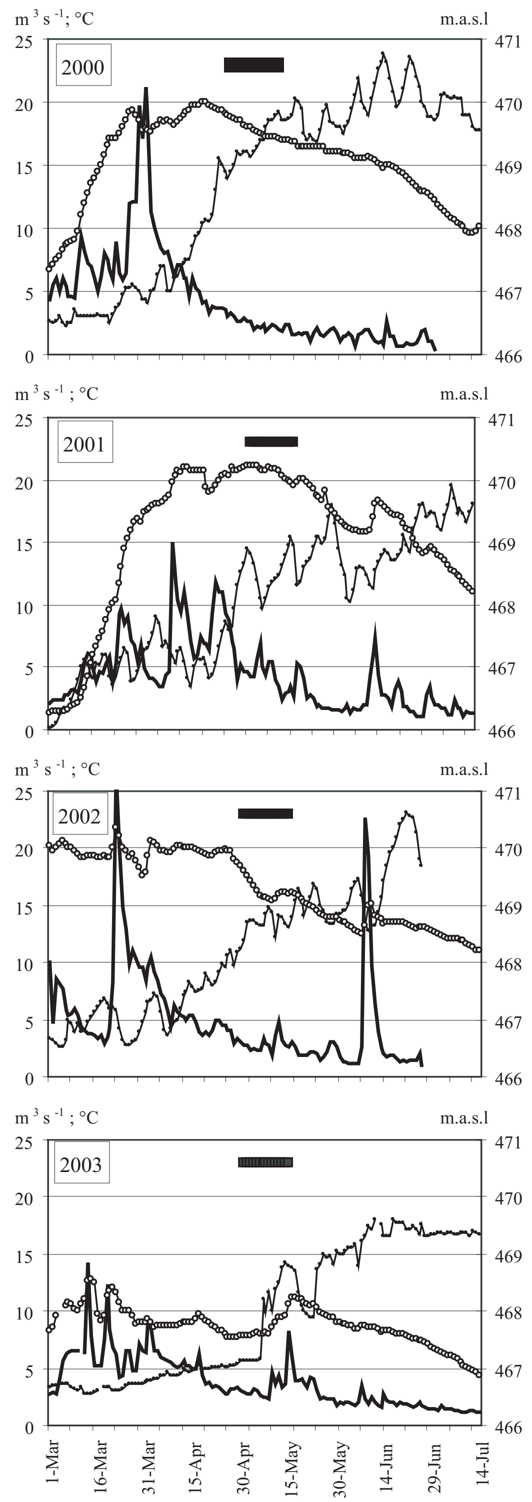

Fig. 1. The course of the water level in the Rímov Reservoir (altitude above see level, right y-axis, white dots), average daily water temperature in the Malse River (°C, left y-axis, black dots) and average daily flow in the Malše River (m^3 s^{-1}, left y-axis, solid line) during individual sampling seasons. Thick straight lines on the top of each plot mark the period of *TR* (see text).

samplings. High mortality of bleak was observed after the spawning and *TR* was thus compared with the abundance and gillnets *WCPUE* of corresponding year classes in the previous years. The size structure of perch was similar in the tributary and in the main body of the reservoir and as already 1+ old mature individuals were recorded, only 0+ fish were not considered.

The water level, water flow and water temperature data were supplied by Vltava River Authority (Povodi Vltavy) and Dr. J. Hejzlar, HBI ASCR, České Budějovice.

3. Results and Discussion

The annual pattern of the water level in the Rímov Reservoir was similar during seasons 2000 - 2002 (the period from March 1st to July 15th shows Fig. 1). The reservoir was regularly filled during spring snow melting and rainfall periods and the water level reached the maximal level over 470 m a.s.l. during March or April. Next the water level gradually decreased and this trend was broken only by periods with high rainfall represented by high flow in the river (Fig. 1). The annual difference between low winter level and maximal water level in spring was of the order of range 2-4 meters and uncovered littoral areas were every season vegetated by terrestrial and wetland macrophytes. In the spring 2003, the water level was artificially maintained at a low level due to reconstruction of the dam devices and the water level decreased further due to poor rainfall during spring and summer. The vegetated part of the shore was situated above the water surface for whole season and no spawning substratum was available for phytophylic fish. Water temperatures during the spawning period are given in Fig. 1. The total number of fish recorded in the tributary zone during *TR* is shown in Fig. 2. It is possible to note that some species showed a year-on year increase in migration size (bream, hybrid and white bream), other species showed a fluctuating *TR* (roach, perch and chub) whilst the bleak showed continually decreasing *TR*.

The TR of bream continually increased through all four sampling seasons and it can be even observed on the values of *PTR* (Table II). Early 2000 and 2001 *TR* values may be underestimated because the bream spawning during these seasons was slightly delayed and significant number of bream migrated to the tributary in the later phase (phase 4 according to Hladík, Kubečka 2003). *TR* in 2002 may have been supported by the decline of the water level during the bream spawning (Fig. 1) although flooded plants were available during whole period of the main bream spawning in 2002 (plants grow down to approximately 468.8 m a.s.l.). *PTR* of 43.2% recorded in 2003 may indi-

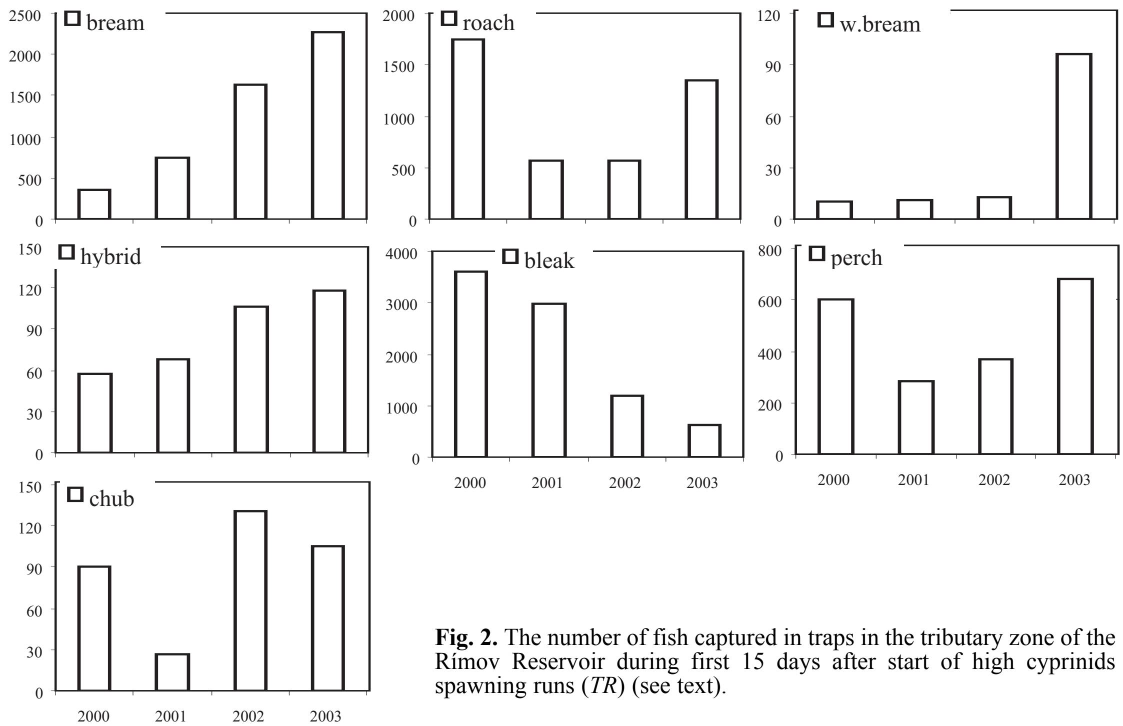

Fig. 2. The number of fish captured in traps in the tributary zone of the Římov Reservoir during first 15 days after start of high cyprinids spawning runs (*TR*) (see text).

cate the increased affinity of adult bream to the tributary when no plants were available in the reservoir. However, we should be aware that in 2003, the littoral estimate of adult bream was rather low while *WCPUE* suggest that the offshore density was relatively high (see also negative correlation between bream *WCPUE* and estimates, Table I). A significant part of the bream population might have been neglected by shore seining, which would led to overestimate of *PTR* in 2003. *PTR* values (Table II) do not confirm increasing *TR* of the hybrid between bream and roach, absence of plants did not stimulate the migration of this ecospecies.

White bream *TR* recorded in 2003 was eight-

Table I. The comparison of the inshore fish abundance estimated by night shore seining (N ha^{-1}), gillnets WCPUEj (N 1000m^{-2}) and the total number of migrated fish in the tributary zone during first 15 days after start of high spawning runs of cyprinids (TR, see text).

species	value	season				correlation coefficient r		
		2000	2001	2002	2003	gillnets x seining	tributary x seining	tributary x gillnets
bream	abundance	80.1	41.9	47.1	32.4	0. 5310	- 0. 7806	-0. 6742
	WCPUE	3.5	4.0	2.3	10.8	*- 0. 9873*	*0. 5628*	*0. 6869*
	TR	350	743	1627	2265			
roach	abundance	57.8	160.7	53.8	464.7	0. 9956**	0. 2059	0. 1772
	WCPUE	4.7	23.9	7.3	78.0	**0. 9996***	*0. 9667*	*0. 9745*
	TR	1739	570	574	1348			
hybrid	abundance	6.1	4.4	2.6	6.1	0. 3285	- 0. 2156	0. 6148
	WCPUE	1.4	3.8	2.4	5.4	*0. 9992**	*0. 2142*	*0. 2516*
	TR	57	68	106	118			
bleak	abundance	56	121	70	14	0. 2518	0. 5263	0. 9158
	WCPUE	76.4	79.5	59.4	36.3	*0. 9999**	*0. 9497*	*0. 9449*
	TR	3610	2977	1195	635			
perch	abundance	34.7	34.9	23.9	9.1	- 0. 4732	0. 6214	- 0. 1072
	WCPUE	34.7	34.9	23.9	9.1	*- 0. 8894*	*- 0. 9715*	*0. 9724*
	TR	604	284	369	682			

Italic - represents data without season 2000.
*p<0.05. **p<0.01.

Table II. The proportion of individuals migrating through the tributary zone on the total fish stock of the reservoir (%) estimated by night shore seining (*PTR* of individual species in individual years). Only adult fish executing tributary run of the size exceeding the marginal length (mm) are considered (ignoring juveniles).

species	2000	2001	2002	2003	average	SD	marginal length
bream	2.3	9.8	19.2	43.2	18.6	15.41	250
roach	15.5	2.0	5.9	1.8	6.3	5.57	230
bleak	30.5	11.7	8.1	22.3	18.1	8.81	150
hybrid	4.8	8.6	22.4	11.8	11.9	6.55	170
perch	3.4	2.9	4.2	2.2	3.2	0.72	150

times higher than in previous seasons and yet no individuals of this species relatively rare in the reservoir were captured during the summer night seining census. This suggests that *TR* of this phytophylic species was stimulated by unavailability of plants in the reservoir.

The lower number of recorded chub (riverine fish species wintering in the reservoir and migrating to the river to spawn and to prey) in 2001 (Table I) was probably caused by higher permeability of traps (Hladík *et al.* 2002) during periods with high flow in the river (Fig. 1). The upstream migration of chub, which should be rather considered as the reversal of refuge migration (Lucas, Baras 2001), was probably relatively even during all sampling seasons and it was not influenced by low water level in the reservoir.

Table I attempts to compare the numbers of fish in the reservoir (densities estimated by the shore seining and mainly open water gillnet *WCPUE*) with *TR*. It is interesting that the estimates by the shore seining show low correlation with gillnet *WCPUE* for all fish except roach. Comparison of all seasons suggests that there is no correlation between inshore and offshore fish. However if 2000 data are removed, the correlation between the abundance becomes significant for roach, bleak and hybrid, while bream and perch shows negative correlation. The reasons why 2000 data show different inshore/offshore pattern are difficult to judge and the disproportion shows the complexity of the problem of holistic understanding of the fish stock of the reservoir. Only if 2000 data are excluded, the roach and bleak *TR* show some positive correlation with the pool of fish estimated in the reservoir by the two approaches. That population dynamics plays important role in forming of the pool of fish *TR* is evident in the case of bleak, whose numbers in the reservoir declined steadily concurrent with decreasing *TR*. Similar patterns were found for roach, the increase of *TR* in 2003 related to the increased abundance of mature roach in the whole reservoir caused by maturation of the strong 1998 year class.

The relative expression of *TR* as a fraction of the total fish stock estimate (*PTR*, Table II) could indicate by correcting for the influence of fish stock whether the season 2003 *TR* differed from previous years. Most species do not show clear trend of increasing *PTR*. The only exception is the bream, whose *PTR* more than doubled between 2002 and 2003. The table shows the varying importance of the tributary zone for different fish species in individual years, the highest proportions of adult fish using tributary zone during the main spawning run were found with bream and bleak, the lowest affinity was found with the perch.

Another significant event could have influenced the 2003 results. In the August 2002, the extensive flood affected the Římov Reservoir. Approximately three reservoir volumes flowed through the reservoir during two weeks, however fish stock estimates before and after the flood has shown that the native fish stock of the reservoir was not influenced too highly by the flooding (Kubečka *et al.* 2004). The fish community was mainly affected by fish flushed to the reservoir from the Malše River (dace *Leuciscus leuciscus* (L.) trout *Salmo trutta*, L.) and from ponds located in the river basin of the Malše River (carp *Cyprinus carpio* (L.), Prussian carp *Carrasius ´gibelio´* (L.)). No indication of fish loss due to the washing downstream was recorded. *TR* of above 'exotic' was recorded, but the bulk of native fish remained the same. Immigrated native species could influence *TR* but not *PTR* and *TA*. The course of high cyprinid spawning runs showed that the tributary activity (*TA*) was similar in seasons 2000, 2002 and 2003 under the increasing water temperature caused by warm weather (Fig. 3). Roach, bleak and chub started massive migration practically simultaneously, migration occurred in several subsequent waves with fluctuating number of migrating fish. High spawning activity decreased after approximately 10 days. Bream began spawning migration a few days later and its spawning activity prolonged to next periods (Hladík, Kubečka 2003). In the season 2001, the course of fish spawning activity was quite different. All fish species migrated simultaneously and their activity dropped after two days from the maximal number to the nearly

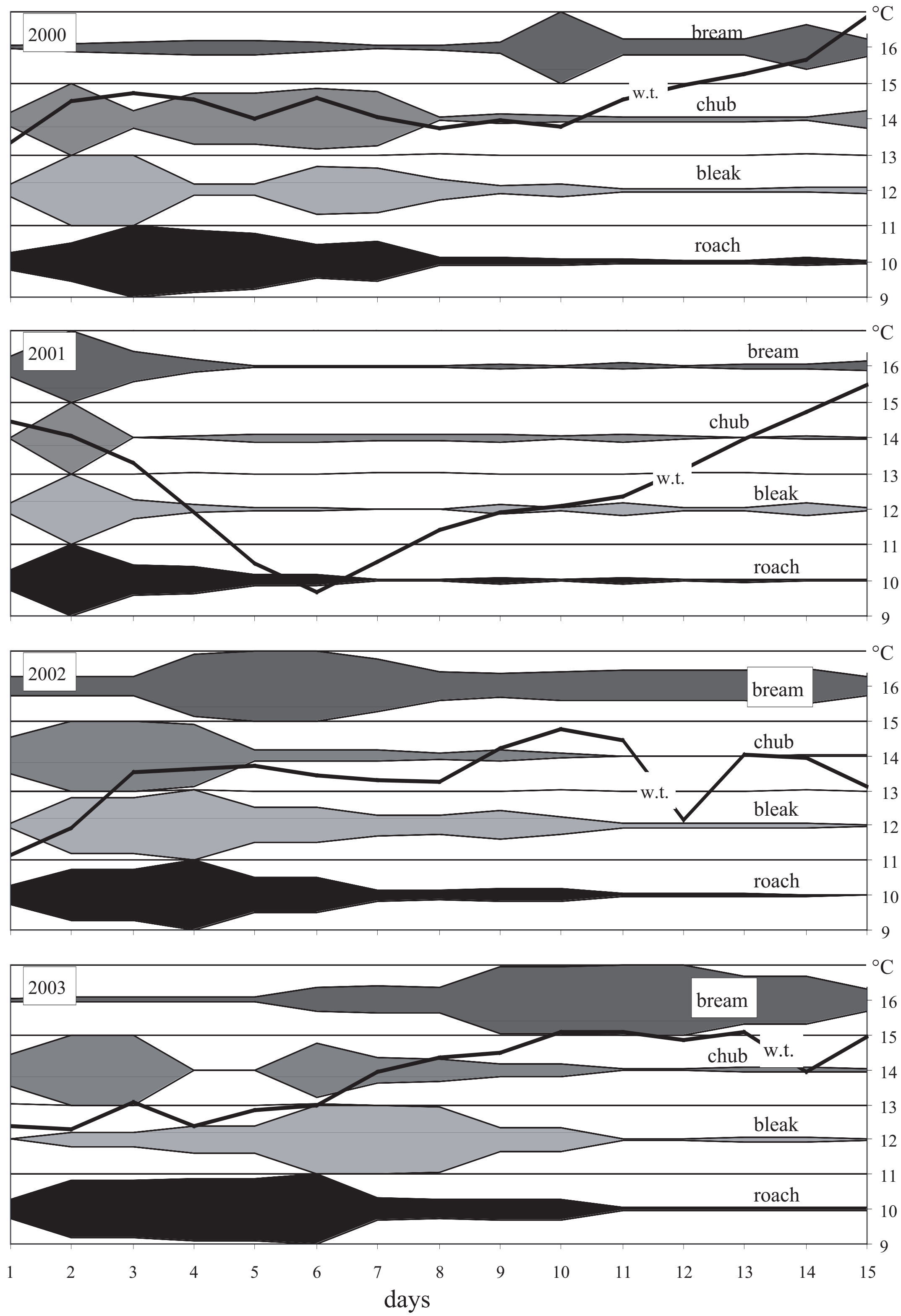

Fig. 3. Detailed analysis of the total migration activity of four main cyprinid species during first fifteen days (x-axis) after start of massive cyprinids spawning runs (*TA* - see text). Maximum overall daily catch of every species fills the whole space between separating horizontal lines and the thickness of the shaded area shows every daily catch proportionally to maximum catch. The right y-axis and the solid line show the water temperature.

zero as a consequence of a cold weather period. A significant number of multiple-spawning bream and bleak migrated to the tributary later (Hladík, Kubečka 2003). The development of the water temperature was found as the main factor affecting the course of *TA*, while the low water level and absence of phytophylic spawning substratum does not seem to influence the spawning succession.

In the season 2003, the visual observation and electro-fishing in the littoral areas of the reservoir during the cyprinid spawning period proved intensive spawning activity of bream on stony shores in a similar way as reported by Holčík and Hruška (1965). This substratum is not the preferred one but it is evident that most bream decided to stay in their home range instead of undertaking the migration to the tributary. For the first time in the history of fish stock monitoring in Rimov Reservoir, the occasional spawning of bleak (tributary spawning specialist according to Hladik, Kubecka 2003) in stony shores in the reservoir was observed. The uncovered stony shores in the littoral areas of the reservoir probably offered suitable spawning substratum for this phyto-litophilic fish and part of the adult population preferred spawning in the reservoir to the migration to the tributary. The hypothesis of significant increase of tributary run during low water level conditions with potential consequences for commercial fishing was rejected.

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