

Ontogenetic changes in the bathypelagic distribution of European perch fry *Perca fluviatilis* monitored by hydroacoustic methods

Martin ČECH¹ & Jan KUBEČKA

Hydrobiological Institute, Academy of Sciences of the Czech Republic, Na sádkách 7, CZ-37005 České Budějovice, Czech Republic and Faculty of Biological Sciences, University of South Bohemia, Branišovská 31, CZ-37005 České Budějovice, Czech Republic; e-mail: carcharhinusleucas@yahoo.com

Abstract: The behaviour of bathypelagic perch fry (BPF) was monitored during 21 May, 24 June, 8 August and 5 September 1996 along the longitudinal profile of Římov reservoir (Czech Republic), using acoustic methods (SIMRAD EY 500 echosounder, elliptical split-beam transducer, Sonar5 postprocessing software). In May, the BPF layer comprised a mass of solitary perch larvae at an abundance of over 31,000 ind. ha⁻¹. In contrast, in June, the BPF layer consisted almost exclusively of shoaling individuals. The abundance of BPF increased up to 166,000 ind. ha⁻¹. Similarly, in August, fish in shoals prevailed in the BPF layer but the abundance dropped to less than 3,000 ind. ha⁻¹. In September, the BPF layer consisted of both individuals and small groups of fish. At this time the abundance of BPF slightly increased to almost 5,000 ind. ha⁻¹. Individual parameters describing the BPF layer, depth of the main layer, abundance of BPF in the main layer and thickness of the whole layer, differed significantly among months. The negligible abundance of potential predators below the thermocline, both in June and in August (exclusively adult perch), suggests that the BPF shoals were more likely to be created as a result of a social need rather than as a defense against predators. During similar surveys carried out prior to (25 April, 5 May, 7 May, 12 May, 15 May) and after this period (3 October, 7 November, 2 December), the BPF layer was not recorded.

Key words: *Perca fluviatilis*, bathypelagic perch fry layer, echosounder, shoals, Sonar5, Římov reservoir, Czech Republic.

Introduction

It is widely accepted that perch larvae migrate from near-shore spawning sites into the pelagic area soon after hatching (WHITESIDE et al., 1985; POST & MCQUEEN, 1988; TREASURER, 1988; WANG & ECKMANN, 1994) where, owing to their transparency (WARD & ROBINSON, 1974; COLES, 1981), they are probably less vulnerable to predation (FABER, 1967). Perch fry are reported to stay in the pelagic zone for a month, or longer, and after metamorphosis, when pigmented juveniles are more susceptible to predation in the offshore habitat, they return to the littoral area (WARD & ROBINSON, 1974; COLES, 1981; WHITESIDE et al., 1985; TREASURER, 1988). However, several studies (HAMLEY et al., 1983; PERRONE et al., 1983; MATĚNA, 1995a) have suggested that it cannot be completely excluded that after this period some part of the young-of-the-year (YOY) perch population remained pelagic and effectively escaped the sampling gear. Despite the facts that perch fry seem to be positively phototactic (DISLER & SMIRNOV, 1977; CRAIG, 1987) and prefer higher temperatures (ROSS et al., 1977), soon after their shift into the pelagic two different distribution maxima could be established. In addition to the surface-confined or epipelagic perch fry (EPF) distribution re-

ported by many authors (e.g., COLES, 1981; WHITESIDE et al., 1985; POST & MCQUEEN, 1988; TREASURER, 1988; WANG & ECKMANN, 1994; MATĚNA, 1995a; URHO, 1996), at least in some lakes and deep stratified reservoirs, deep water – bathypelagic, or even benthic, perch fry distributions were also recorded (e.g., WARD & ROBINSON, 1974; PERRONE et al., 1983; KUBEČKA & SLAD, 1990). Recently, ČECH et al. (2005) gave evidence of sympatric EPF and BPF communities occurring simultaneously in the Slapy reservoir during May and June. The EPF spent the whole 24 hours in the upper 4 meters of the water column (i.e. above the thermocline) whereas the BPF performed diel vertical migrations with an amplitude exceeding 10 m, being in the epilimnion during the night and migrating into the cold hypolimnetic layers during the day. At this time the BPF community was present as a several meters thick scattering layer, which could be followed by the echosounder. The contribution of the bathypelagic part of the population to the total numbers of pelagic perch fry decreased in Slapy reservoir from 28.1% in May to 4.7% in June. However, in this reservoir, and similarly in Lake Ros (JACHNER, 1991), the overall abundance of pelagic perch fry reached its maximum in June.

Since the behaviour and relationship between EPF and BPF community is widely described in ČECH et al.

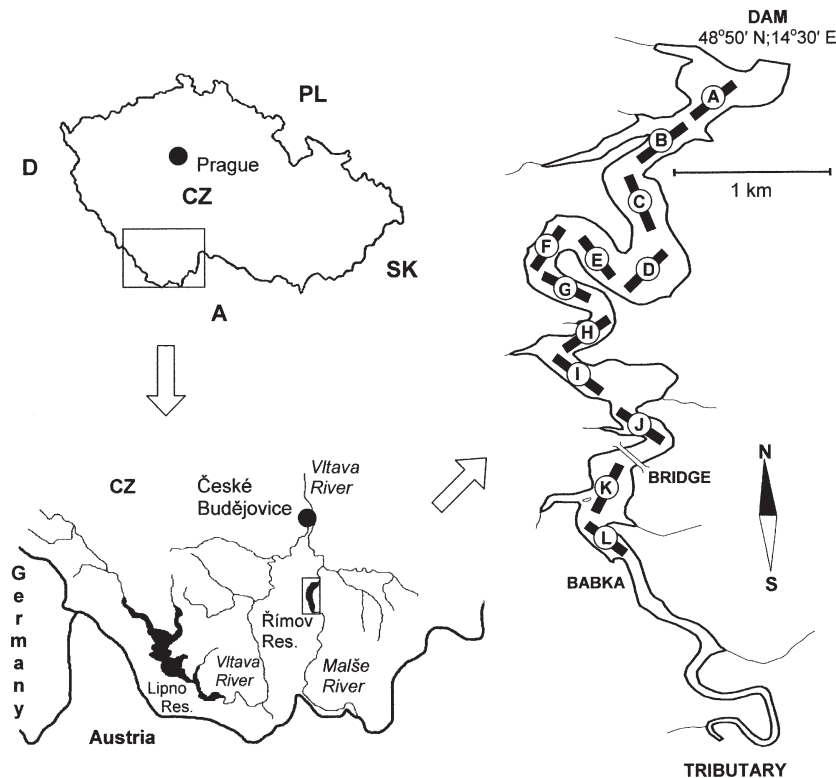


Fig. 1. A map of Římov reservoir and its location in the Czech Republic. The relative positions of 12 sampling transects are shown.

(2005), the present study is focused exclusively on the bathypelagic layer of European perch fry, *Perca fluviatilis* L., 1758, monitored in Římov reservoir using hydroacoustic methods. The main objective is to describe ontogeny of the BPF layer, including changes in abundance, shoaling activity, depth distribution and presence on the longitudinal profile of the reservoir.

Study area

The study was carried out in the canyon-shaped meso- to eutrophic Římov reservoir, Czech Republic (48°50' N, 14°30' E, 170 km south of Prague) created by damming the Malše River, which is the main reservoir tributary (Fig. 1). The reservoir has an area of 210 ha, a volume of $33 \times 10^6 \text{ m}^3$ and maximum depth of 45 m. The average water retention time varies from 80 to 180 days (SEDA & KUBEČKA, 1997).

Previous large-scale studies of pelagic YOY fish assemblages carried out in 1985 and 1991–1994 using a Clarke-Bumpus sampler, conical ichthyoplankton net and a push net, found perch to be the dominant species in the Římov reservoir, comprising 73.6–99.9% of the total fish population (KUBEČKA & SLAD, 1990; MATĚNA, 1995a, b; MACHÁČEK & MATĚNA, 1997; WANZENBÖCK et al., 1997). The pelagic abundance of the other two percid species to form a bathypelagic scattering layer, zander *Sander lucio-perca* (L., 1758) and ruffe *Gymnocephalus cernuus* (L., 1758) (ČECH et al., 2005) was much lower ($\ll 15\%$ all the time) than that of perch (KUBEČKA & SLAD, 1990; MATĚNA, 1995a; WANZENBÖCK et al., 1997). During daytime, no other organisms (like *Chaoborus* sp.) of the acoustic target strength (TS in dB; for definition see MACLENNAN & SIMMONDS, 1992) similar to perch fry are known from the open water of Římov reservoir (SEDA, unpubl. data). For

the purpose of this study, therefore, it was assumed that all small size signals on the echogram were related almost exclusively to perch.

Material and methods

Acoustic data were collected in four sampling surveys during midday on 21 May, 24 June, 8 August and 5 September 1996 along the longitudinal profile of Římov reservoir. Twelve transects (“A” – “L”), each 350 m in length, were defined (Fig. 1). Stratification variables (temperature in °C, dissolved oxygen concentration in mg L^{-1}) were measured with a calibrated WTW OXI 196 probe in transects “A”, “F”, “J” and “L”. From transect “L” to the inflow the insufficient depth of the reservoir profile (depth < 10 m) prevented further monitoring of the BPF layer.

The investigation was carried out using a SIMRAD EY 500 split-beam scientific echosounder, working with a frequency of 120 KHz. The pulse repetition rate was 10 pings s^{-1} , the pulse duration was 0.1 ms (frequency bandwidth 12 KHz). The transducer used (SIMRAD ES120-4) had an elliptical beam pattern with nominal beam angles of $9.1 \times 4.3^\circ$. The transducer, beaming vertically, was held by a remotely controlled aluminium plate on the frame constructed in front of the Dory 13 research vessel. Acoustic data were stored on the hard disk of the notebook computer for later analysis. The whole sonar system was calibrated with a standard calibration tungsten carbide sphere of 36 mm diameter (FOOTE et al., 1987). To detect all BPF, including the smallest perch larvae, the threshold for the primary noise filtering of the acoustic record during fieldwork was set to a minimal TS of -70 dB (ČECH et al., 2005).

The acoustic data were analyzed using the automatic tracking facilities of the post-processing software Sonar5 (BALK & LINDEM, 2004). The water column was divided

Table 1. Tracking parameters: min. track length (minimum numbers of detections to track a fish – hits in beam); max. ping gap (maximum numbers of missing pings per track); gating range (maximum range between detections); min. and max. TS threshold (minimum and maximum threshold in between which BPF were supposed according to previous studies; see below). Total length (mm) of BPF in parenthesis calculated using TS/L_T conversion according to FROUZOVÁ & KUBEČKA (2004).

Parameters	21 May	24 June	8 August	5 September
Layer (m)	4–17	4–17	4–17	4–17
Min. track length (ping)	4	4	4	4
Max. ping gap (ping)	2	2	1	1
Gating range (m)	0.07	0.07	0.07	0.07
Min. TS threshold (dB)	–70 (6.2) [†]	–68 (7.7) [†]	–60 (18.6) [‡]	–58 (23.3) [‡]
Max. TS threshold (dB)	–57 (26.0) [†]	–50 (56.4) [†]	–48 (70.4) [‡]	–46 (87.8) [‡]
No. of tracked fish (all fish)	6257	1655	349	303

Key: [†] Direct ichthyoplankton catches of larvae and juvenile perch in May and June from Římov reservoir (MATĚNA, 1995a, b; MACHÁČEK & MATĚNA, 1997; WANZENBÖCK et al., 1997) and Slapy reservoir (ČECH et al., 2005). [‡] Direct trawling catches of YOY perch in August and September from Římov reservoir (VÁŠEK et al., in press) and Lipno reservoir (JŮZA & KUBEČKA, unpubl. data).

into 1m-thick layers down to a depth of 17 m below the water surface. Below this depth no fry were observed. The uppermost 4 m of the water column were excluded from acoustic analysis due to the near field of the transducer (3.75 m). For each of the other thirteen 1 m thick layers, the abundance of BPF was then calculated for each transect separately. This was done in a classical way using echointegration, and by scaling the echointegrated energy with the average backscattering cross section σ_{bs} (MACLENNAN & SIMMONDS, 1992). The area backscattering coefficient s_a for the layers 4–17 m was used as a measure of the water column acoustic biomass, while the volume backscattering coefficients s_v were used to characterize acoustic biomass in individual layers (MACLENNAN et al., 2002). The BPF layer was defined as all the one-meter thick layers where s_v exceeds 5% of s_a . The backscattering cross sections were derived from tracking individual fish (Tab. 1). In June, August and September most BPF were present in shoals where the estimation of σ_{bs} was possible only for the individuals outside the shoals. Some individual transects did not contain sufficient numbers of single targets to be tracked as fish (“tracked fish” includes all detections of the same fish in subsequent acoustic pings during beam passage). In order to provide sufficient numbers of tracked fish, fish tracks from all transects were pooled into one “fish basket” (database of tracked fish in Sonar5; BALK & LINDEM, 2004) and s_v from individual transects was scaled by the average σ_{bs} from all transects. In this way, reasonable numbers of tracked fish were achieved (Tab. 1). For the indication of aggregating behaviour, the proportion of the acoustic biomass of multiple (overlapping, shoaling) targets in the total s_a was calculated:

$$\text{Aggregation index} = \frac{(s_a - s_{a,\text{single}})}{s_a} \times 100$$

where $s_{a,\text{single}}$ is the area backscattering coefficient of single targets in a particular transect. An aggregation index of 100% means that no single targets were present. All sizing of acoustically detected fry and setting of the size thresholds (see below) was done using perch fry TS/L_T regressions for their dorsal aspect (FROUZOVÁ & KUBEČKA, 2004).

In order to examine whether the depth of the BPF changed from month to month, the depth of the main layer was defined as the 1 m thick layer of the water column with the highest s_v .

For every BPF shoal, its physical dimensions were measured according to ČECH et al. (2005): 1 – the length of a fry shoal was calculated from the number of acoustic emissions produced per second (system ping rate) and the time of the shoal record and the actual speed of the research vessel; 2 – the height of the shoal was calculated from the uppermost and lowermost shoal margins.

For acoustic studies of fish fry, it is necessary to set both minimum TS threshold (conventional noise threshold used in most other studies) and also maximum TS threshold. Layers with BPF were quite clean and it was possible to set the noise thresholds low enough to detect all BPF which could be expected at one time, considering previous results of direct ichthyoplankton catches of larvae and juvenile perch in May and June (MATĚNA, 1995a, b; MACHÁČEK & MATĚNA, 1997; WANZENBÖCK et al., 1997; ČECH et al., 2005) and trawling catches of YOY perch in August and September (VÁŠEK et al., in press; JŮZA & KUBEČKA, unpubl. data). The same references were used for setting of the maximum TS threshold in order to exclude infrequently occurring larger fish (Tab. 1). Targets bigger than the maximum TS threshold for the appropriate month were manually erased from the analysis, using the erase function of Sonar5 (BALK & LINDEM, 2004). The remaining configuration of the automatic tracking facility is given in Table 1.

The data were analyzed using ANOVA, linear regression and Mann-Whitney U -test.

Results

The BPF layer was observed during all four acoustic surveys carried out during 21 May, 24 June, 8 August, 5 September along the longitudinal profile of Římov reservoir. In contrast, this BPF layer was not observed during either of the similar surveys carried out prior to (25 April, 5 May, 7 May, 12 May, 15 May) and after this period (3 October, 7 November, 2 December). In May and in September the BPF layer was clearly apparent only from the dam to the bridge (transects “A” – “J”) while in June and August the layer was also recorded up to transect “L” (Fig. 2). Table 2 gives the mean, S.D., and minimum and maximum values of the parameters describing the BPF layer in individual months.

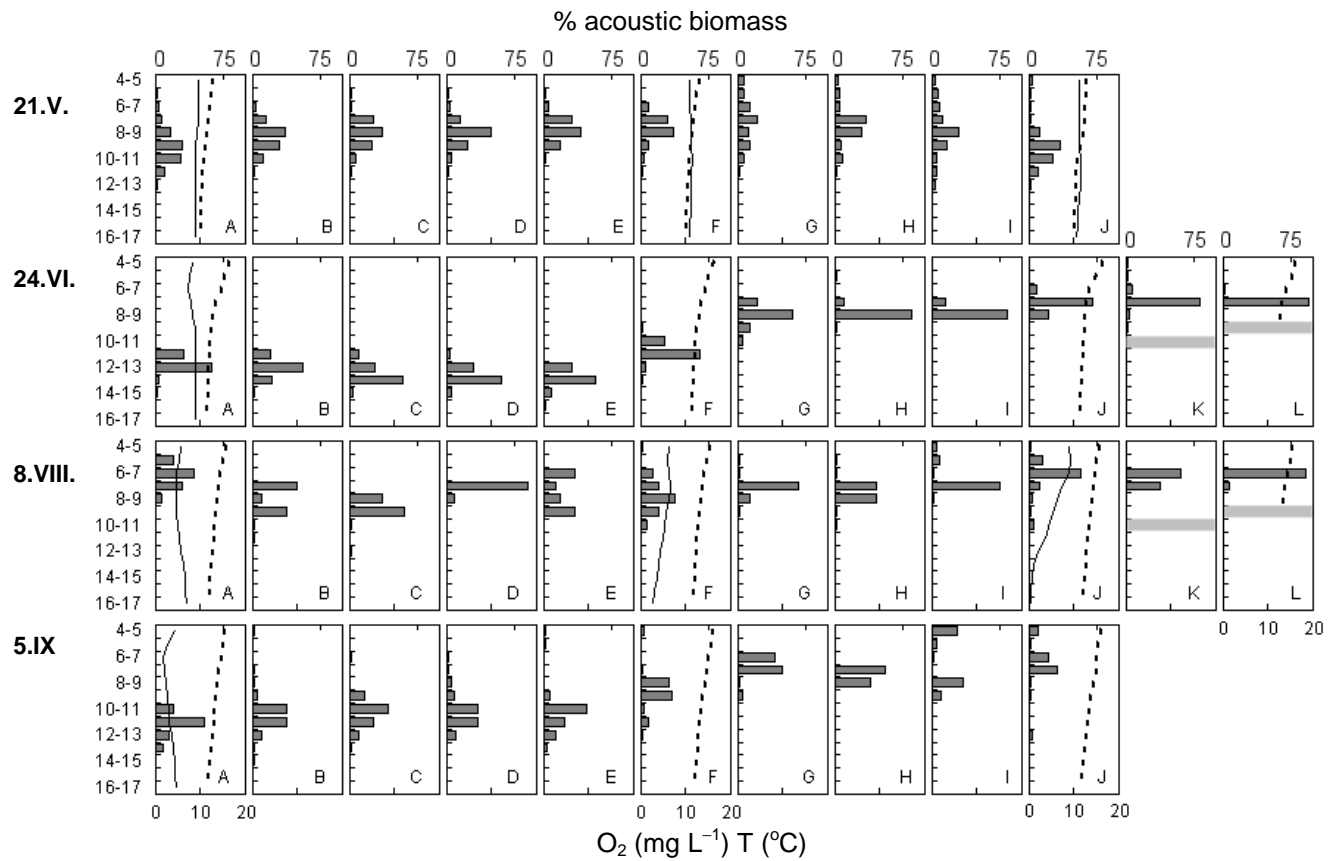


Fig. 2. Position of BPF layer in the longitudinal profile of Římov reservoir on 21 May (21.V.), 24 June (24.VI.), 8 August (8.VIII.) and 5 September (5.IX.) 1996 expressed as the percentage of acoustic biomass calculated from the ratio between s_v in each meter layer and the total s_a of the acoustically sampled water column (depth range 4–17 m). Temperature (dashed line) and, in some cases, dissolved oxygen (solid line) are given in transects “A”, “F”, “J” and “L”. Depth (m) is on the Y-axis. Grey zones in transect “K” and “L” indicate bottom position. Note the thermocline is outside the range of the Y-axis, in most cases around a depth of 4 m.

Table 2. Mean, SD, maximum and minimum values for individual parameters describing BPF layer in Římov reservoir in May, June, August and September 1996 (10 transects “A” – “J”, see Fig. 1).

Parameters	21 May	24 June	8 August	5 September
	21 May	24 June	8 August	5 September
Average depth of main layer (m)				
Mean \pm SD	8.6 \pm 0.9	11.0 \pm 2.5	7.6 \pm 1.0	9.4 \pm 1.8
Min. – Max.	7.5 – 10.5	7.5 – 13.5	6.5 – 9.5	6.5 – 11.5
s_v of main layer ($m^2 m^{-3}$)				
Mean \pm SD	2.4E-07 \pm 2.2E-07	2.4E-05 \pm 3.6E-05	8.4E-07 \pm 1.0E-06	1.1E-06 \pm 1.6E-06
Min. – Max.	6.0E-08 – 7.4E-07	1.9E-06 – 1.1E-04	1.5E-07 – 3.3E-06	2.5E-07 – 5.6E-06
Abundance of main layer (ind. m^{-3})				
Mean \pm SD	1.3 \pm 1.2	11.5 \pm 16.1	0.2 \pm 0.2	0.3 \pm 0.7
Min. – Max.	0.3 – 4.1	1.8 – 52.1	0.03 – 0.6	0.04 – 2.3
% of multiple targets in the whole BPF layer (Aggregation index)				
Mean \pm SD	45.7 \pm 14.7	97.1 \pm 2.9	75.4 \pm 24.1	67.6 \pm 25.0
Min. – Max.	24.1 – 68.4	90.5 – 99.5	36.9 – 98.3	13.9 – 99.7
Thickness of whole BPF layer (m)				
Mean \pm SD	4.5 \pm 1.3	2.6 \pm 0.7	3.1 \pm 1.1	3.2 \pm 1.1
Min. – Max.	3 – 7	2 – 4	2 – 5	2 – 5
BPF abundance (ind. ha^{-1})				
Mean \pm SD	31140 \pm 22309	165447 \pm 229031	2951 \pm 2359	4850 \pm 8427
Min. – Max.	8322 – 72893	28990 – 764611	433 – 6906	994 – 28616

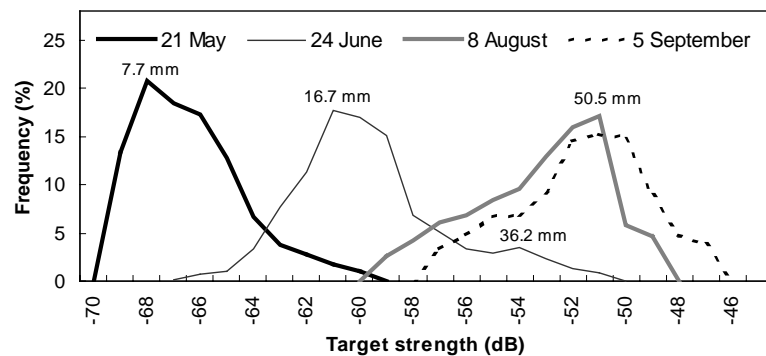


Fig. 3. Frequency distribution of target strength of bathypelagic perch fry in Řimov reservoir in May, June, August and September 1996. Corresponding lengths estimated using TS/L_T conversion according to FROUZOVA & KUBEČKA (2004).

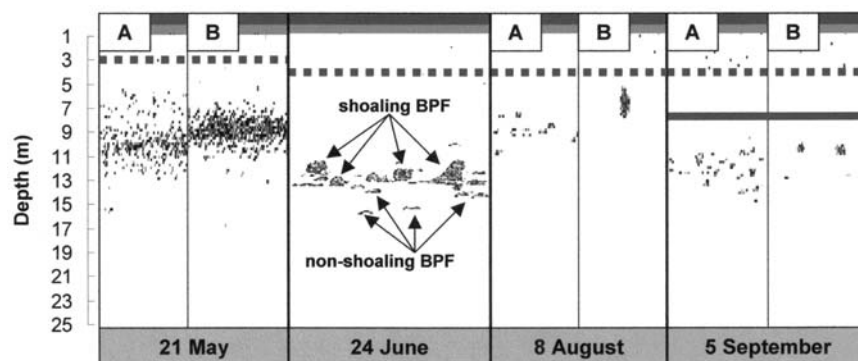


Fig. 4. Sequence of raw 20 LogR TVG echograms illustrating ontogenetic changes of the BPF layer in Řimov reservoir in May, June, August and September 1996 (transect "A"). The dotted line shows the position of the thermocline, the solid line in September indicates the layer with depleted oxygen ($< 2 \text{ mg O}_2 \text{ L}^{-1}$). Note the position of individual fish (A) each month deeper in the water column, in contrast to the position (B) of dense fish aggregations (May), shoals (August) and compact groups of several fish individuals (September), each month shallower in the water column. In June, the BPF layer was a relatively dense mixture of individual fish and shoals respectively, but the different positions of both in the water column are also apparent.

In May, the layer was composed of a mass of perch larvae whose size peaked at -68 dB (7.7 mm; Fig. 3). The BPF were distributed as solitary targets with no apparent shoaling activity. However, in some areas the scattering layer became very dense and the aggregation index increased. At least, in the lacustrine part of the reservoir (transects "A" – "G", Fig. 1, 20 sub-transects reaching 100 m each to reveal the small scale patchiness) the denser the aggregation index, the higher the main layer in the water column (regression analysis; $F_{1,18} = 37.51$, $P < 0.00001$; Fig. 4). At this time the abundance of all BPF was greater than $31,000 \text{ ind. ha}^{-1}$.

In June, the BPF layer was composed almost exclusively of shoaling individuals (aggregation index $\gg 90\%$) of a bimodal size distribution peaking at -61 dB (16.7 mm, stronger peak) and -54 dB (36.2 mm, weaker peak; Fig. 3). Consistent with the findings of ČECH et al. (2005) the shoals of BPF appeared to be higher in the water column than the non-shoaling individuals (Fig. 4). The lengths of the observed BPF shoals ($n = 183$) ranged from 1.8 to 22.3 m with an average shoal length of 4.6 m. Their distribution was highly asymmetric, with only a few shoals $> 9 \text{ m}$ in length (Fig. 5A). The height of the BPF shoals ranged from 0.52 to 3.01 m, with an average of 1.10 m (Fig. 5B). The abundance

of BPF was nearly $166,000 \text{ ind. ha}^{-1}$ (10 transects "A" – "J" which contained BPF every month).

Similarly, in August, the BPF layer was created mainly by shoaling individuals. The peak of the TS distribution was at -51 dB (50.5 mm; Fig. 3). The numbers of fish in the shoals were still very high (aggregation index exceeding 75%; Fig. 4) compared to the non-shoaling fish. The length of bathypelagic perch shoals ($n = 21$) ranged from 1.4 to 3.7 m with an average length of 2.4 m (Fig. 5A); the height of the shoals ranged from 0.4 to 2.42 m with an average of 1.0 m (Fig. 5B). The average length of the BPF shoals, in individual transects ("A" – "L"), was much greater in June than in August (Mann-Whitney U -test; $Z_{1,22} = 3.98$, $P < 0.0001$) whereas the average heights of the shoals did not differ in June and August (Mann-Whitney U -test; $Z_{1,22} = 1.55$, $P = 0.12$). In August, the abundance of BPF dropped to less than $3,000 \text{ ind. ha}^{-1}$ (again only transects "A" – "J").

In September, both individual fish and in groups of several fish the sizes peaked again at -51 dB (50.5 mm; Fig. 3) in the BPF layer (Fig. 4). At this time the abundance of BPF increased slightly to almost $5,000 \text{ ind. ha}^{-1}$.

Among the other parameters describing the BPF layer in individual months three, depth of main layer of

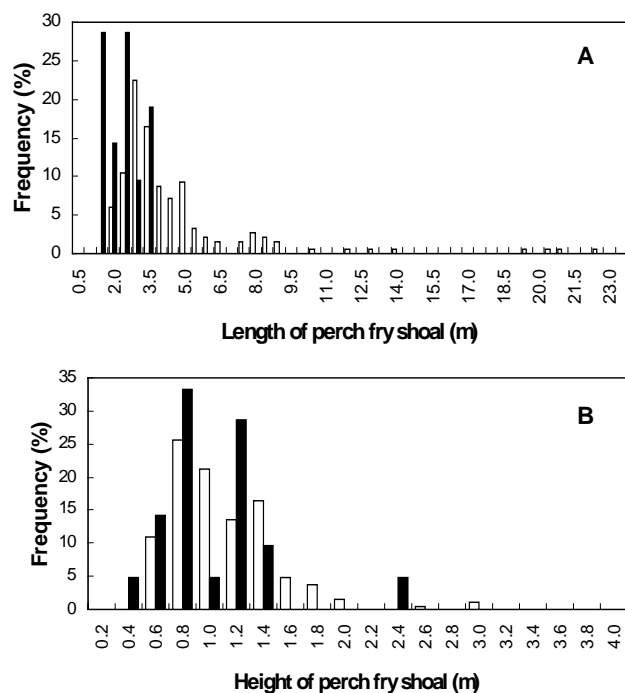


Fig. 5. Frequency distribution of length (A) and height (B) of the bathypelagic perch fry shoals in Rimov reservoir in June (white bars) and August (black bars) 1996.

BPF, abundance of BPF in the main layer and thickness of the whole BPF layer, all of clear biological significance, were tested across their ranges from the dam to the bridge (ten transects, "A" – "J"). The depth of the main layer of BPF differed significantly among months (ANOVA; $F_{3,36} = 7.49$, $P < 0.001$), being greatest in June (mean 11 m). On the other hand, in August, the main layer was at its shallowest in the water column (mean 7.6 m). In September, the whole BPF layer seems to be confined by oxygen depletion around the depth of 7 m ($< 2 \text{ mg O}_2 \text{ L}^{-1}$; Figs 2, 4). Also the abundance of BPF in the main layer differed significantly among months (ANOVA; $F_{3,36} = 4.57$, $P < 0.01$), being greatest in June (mean 11.5 ind. m^{-3}) and lowest both in August and in September (mean 0.2 ind. m^{-3} and 0.3 ind. m^{-3} , respectively). Similarly, the thickness of the whole BPF layer differed significantly among months (ANOVA; $F_{3,36} = 5.71$, $P < 0.01$), being greatest in May (mean 4.5 m) and lowest in June (mean 2.6 m).

Discussion

In May the BPF layer was observed only from the dam to the bridge (i.e. in the lower lacustrine part of the reservoir) while a month later the layer was also observed up to transect "L" (i.e. entering the upper riverine part of the reservoir). However, at this time some echograms in shallower parts of the reservoir suggest that the layer of BPF continually changes into "benthic" fry where there is insufficient depth (i.e. the BPF layer touches the bottom until it vanishes). Similar ben-

thic perch fry maintaining contact with the bottom have been reported e.g. from Lake Michigan (PERRONE et al., 1983), Lake Constance (IMBROCK et al., 1996), or Lipno reservoir (ČECH & KUBEČKA, unpubl. data). The reason for the absence of a BPF layer in the upper third of the reservoir in May could be delayed hatching induced by colder water coming in from the Mašše River and generally less appropriate temperature conditions in this part of the reservoir, or a local flood in mid-May which hit the upper part of the reservoir (RŮŽIČKA et al., 2002) and might have destroyed the egg strands. The mass of water might also have swept the newly hatched perch larvae into the lower part of the reservoir due to their low swimming ability (HAMLEY et al., 1983).

Surprisingly, the abundance of BPF increased dramatically from May to June, being half an order higher ($31,000 \text{ ind. ha}^{-1}$ and $166,000 \text{ ind. ha}^{-1}$, respectively). This colonization pattern of the bathypelagic zone was completely opposite to that described by ČECH et al. (2005) from Slapy reservoir where the density of BPF decreased between May and June. However, as in Slapy reservoir also, and similarly in Lake Ros (JACHNER, 1991), the overall pelagic abundance of perch fry (including EPF) had its maximum in June instead of May. The reason for relatively low numbers of BPF in May could be prolonged spawning so that the hatching period results in conditions where some of the egg strands might still have been unhatched during sampling (HAMLEY et al., 1983). The possibility that the May sampling did not catch the maximum of perch larvae in the pelagic habitat could be confirmed by both the size of the tracked BPF, which corresponds well with the usual length of perch larvae soon after hatching, and the ensuing migration from littoral to the open water (WHITESIDE et al., 1985; TREASURER, 1988; WANG & ECKMANN, 1994; MATĚNA, 1995a, b; URHO, 1996) and also by bimodal size distribution of BPF in following month. The other evidence for this assumption could be that the BPF layer in June was newly observed in the upper part of the reservoir, indicating delayed hatching for reasons such as those mentioned above. Although addition of the reservoir perch fry community by larvae hatched from eggs spawned later in the Mašše River, which had drifted downstream, could also not be completely excluded (PERRONE et al., 1983) the results of PETERKA et al. (2004) working with drift traps in the Mašše River tributary did not support this possibility.

The strong decline of BPF abundance observed in August ($< 3000 \text{ ind. ha}^{-1}$) could be explained by three different reasons (i) a previous overall shift of perch fry from the pelagic habitat into the littoral area after metamorphosis, connected with fin development and newly acquired barred color pattern appropriate to survival in shallow waters (WARD & ROBINSON, 1974; COLES, 1981; WHITESIDE et al., 1985; TREASURER, 1988; WANG & ECKMANN, 1994), (ii) due to a shift

of BPF from the bathypelagic to an epipelagic habitat induced by the zooplankton decline below the thermocline (KRATOCHVÍL et al., in press), which density in Římov reservoir is, however, generally very low during the season in hypolimnion compared to epilimnion (MACHÁČEK & SEĎA, 2003) or (iii) due to a mortality generated mainly by predatory fish where cannibalism seems to play the crucial role (e.g., BOGDANOV, 1959). Most likely, in August the abundance of BPF is a result of a combination of several of the above causes while the daily mortality calculated only from the June maximum up to August (KUBEČKA, 1991) results in a theoretical abundance of approximately 25,000 ind. ha⁻¹.

The proximate cause of the moderate increase of BPF abundance in September (ca. 5000 ind. ha⁻¹) may be the gradual return of littoral (COLES, 1981; WANG & ECKMANN, 1994) or epipelagic, or both, parts of the YOY perch community into the bathypelagic habitat, in connection with overwintering (ECKMANN & IMBROCK, 1996; IMBROCK et al., 1996). In Římov reservoir this event was accompanied by the BPF layer vanishing from the upper, shallower part of the reservoir and followed by termination of bathypelagic behaviour in October.

EKLÖV & PERSSON (1995) have experimentally shown that, in the absence of reasonable refuges, juvenile perch have a low capacity to avoid predation, being quickly eliminated from the pelagic zone. Consequently, the dwelling of BPF in a cold hypolimnion could be an important mechanism of predator avoidance (LEVY, 1990). Moreover, their shoaling behaviour could also serve to reduce predation (for review see e.g., MOYLE & CECH, 2003). Confirming this is the fact that, in June and August the majority of the BPF in Římov reservoir were present in shoals. In contrast, no shoaling behaviour was observed in May. At this time the transparency of perch larvae (WARD & ROBINSON, 1974; COLES, 1981; WANG & ECKMANN, 1994) is supposed to be sufficient adaptation for life in the pelagic zone of lakes and reservoirs, since they are thus invisible to predators (FABER, 1967). However, in their classical study, THETMEYER & KILS (1995) have demonstrated that transparent organisms may also be highly visible and detectable by predators, due to light absorbance by opaque parts of the body or light scattered in the tissues, and ČECH & KUBEČKA (2002) have suggested that the sinusoidal cyclic swimming of fish may be a mechanism effectively eliminating the advantage gained by transparent prey. There is some evidence that the onset of shoaling is likely to be mediated by the development of the lateral line system (CAHN et al., 1968). This ontogenetic threshold occurs in larval perch at around a length of 14 mm (DISLER & SMIRNOV, 1977). Therefore, the inability to form shoals in late May appears to be more due to poor development of the perch larvae, which at this time had a unimodal size of 7.7 mm, than blind belief in transparency. The clear absence of shoaling behaviour in May agrees with the observations

of ČECH et al. (2005) from Slapy reservoir (BPF average L_T 11.9 mm). In contrast, the ontogenetic threshold for the onset of shoaling at 14 mm length fits well with late June observation where the BPF layer in Římov reservoir consisted almost exclusively of shoaling individuals with a bimodal size distribution peaking at 16.7 mm and 36.2 mm. Shoaling behaviour by some of the BPF (average L_T 14.6 mm, i.e. close to the ontogenetic threshold) in mid-June was also reported from Slapy reservoir (ČECH et al., 2005).

In Římov reservoir, during the summer period, adult perch are clearly the only predatory fish present below the thermocline, comprising almost 50% of gill-net catches (VAŠEK et al., 2004) which supports the assumption that shoals serve as a protection against inter-cohort cannibalism (WANG & ECKMANN, 1994). However, acoustic estimates of abundance of this predator, calculated for individual transects ("A" – "L") for fish > 100 mm (> -44 dB according to TS/L_T regressions for adult perch dorsal aspect; FROUZOVÁ et al., 2005) were generally very low, being 76 ind. ha⁻¹ in June and only 26 ind. ha⁻¹ in August. Moreover, the densities of fish > 100 mm estimated in Římov reservoir by gillnets are always very low below the thermocline (VAŠEK et al., 2004). This low density of predators may suggest that BPF shoals are unlikely to be created as an effective defense against predators but more likely as the start of a social need (MORGAN, 1988). Despite the fact that the average length of BPF shoals is definitely abundance dependent, the average height of shoals seems to be constant at about 1 m in both months. This is not far from the average height of BPF shoals observed by ČECH et al. (2005) in Slapy reservoir, while IMBROCK et al. (1996) reported from Lake Constance the mean height of perch (age 0+ to 4+) shoals to be between 2 and 4 m.

This study has focused on ontogenetic changes of the BPF layer in the conditions of Římov reservoir which confirm the conclusions of NOBLE (1970) from Oneida Lake and WANG & ECKMANN (1994) from Lake Constance, that at least a fraction of the 0+ perch community remains pelagic until August, or even until September as in this study. Strong evidence for this, apart from the acoustic observations, has also been obtained directly from trawl catches carried out on Římov and Lipno reservoirs in mid-August and early September (VAŠEK et al., in press; JŮZA & KUBEČKA, unpubl. data). It appears that, despite the fact that the littoral region of many canyon-shaped Czech reservoirs is favored by fry (DUNCAN & KUBEČKA, 1995; MATĚNA, 1995b), the littoral comprises a negligible part of the total reservoir volume and definitely has a highly limited carrying capacity. On that account, it seems reasonable that part of the perch fry community should utilize the pelagic zone of these reservoirs for a longer period. The colonization of bathypelagic habitat, however, can be also ascribed to the apparent marine origin of perciform fishes (HOLČÍK, 1998).

Acknowledgements

The authors thank Z. PRACHAŘ for help in data collection, M. BURGIS for careful reading and correcting the English and R. ECKMANN and two anonymous referees for helpful comments to the manuscript. The study was supported by the Grant Agency of the Czech Academy of Sciences (projects No. A 6017201 and Z 6017912) and Grant Agency of the Czech Republic (project No. 206/06/1371).

References

- BALK, H. & LINDEM, T. 2004. Sonar4 and Sonar5-Pro post processing systems (operation manual). University of Oslo, Norway, 339 pp.
- BOGDANOV, G.A. 1959. Pitaniye nekotorykh vidov ryb Ustkamenskogo vodokhranilishcha. Sb. Rab. Ichtiol. Hidrobiol. AN KazSSR **2**: 234–244.
- CAHN, P.H., SHAW, E. & ATZ, J.W. 1968. Lateral line maturation related to development of schooling in the atherinid fish, *Menidia*. Bull. Marine Sci. **18**: 660–670.
- COLES, T.F. 1981. The distribution of perch, *Perca fluviatilis* L. throughout their first year of life in Llyn Tegid, North Wales. J. Fish Biol. **18**: 15–30.
- CRAIG, J.F. 1987. The biology of perch and related fish. Croom Helm Ltd., Kent, 333 pp.
- ČECH, M., KRATOCHVÍL, M., KUBEČKA, J., DRASTÍK, V. & MATĚNA, J. 2005. Diel vertical migrations of bathypelagic perch fry. J. Fish Biol. **66**: 685–702.
- ČECH, M. & KUBEČKA, J. 2002. Sinusoidal cycling swimming pattern of reservoir fishes. J. Fish Biol. **61**: 456–471.
- DISLER, N.N. & SMIRNOV, S.A. 1977. Sensory organs of the lateral-line canal system in two percids and their importance in behavior. J. Fish. Res. Board Can. **34**: 1492–1503.
- DUNCAN, A. & KUBEČKA, J. 1995. Land/water ecotone effects in reservoirs on the fish fauna. Hydrobiologia **303**: 11–30.
- ECKMANN, R. & IMBROCK, F. 1996. Distribution and diel vertical migration of Eurasian perch (*Perca fluviatilis* L.) during winter. Ann. Zool. Fenn. **33**: 679–686.
- EKLÖV, P. & PERSSON, L. 1995. Species-specific antipredator capacities and prey refuges: interactions between piscivorous perch (*Perca fluviatilis*) and juvenile perch and roach (*Rutilus rutilus*). Behav. Ecol. Sociobiol. **37**: 169–178.
- FABER, D.J. 1967. Limnetic larval fish in northern Wisconsin Lakes. J. Fish. Res. Board Can. **24**: 927–937.
- FOOTE, K.G., KNUTSEN, H., VESTNES, G., MACLENNAN, D.N. & SIMMONDS, E.J. 1987. Calibration of acoustic instruments for fish density estimation. Cooperative Research Report, International Council for the Exploration of the Sea **144**: 1–70.
- FROUZOVÁ, J. & KUBEČKA, J. 2004. Changes of acoustic target strength during juvenile perch development. Fish. Res. **66**: 355–361.
- FROUZOVÁ, J., KUBEČKA, J., BALK, H. & FROUZ, J. 2005. Target strength of some European fish species and its dependence on fish body parameters. Fish. Res. **75** (1–3): 86–96.
- HAMLEY, J.M., HOWLEY, T.P. & PUNHANI, A.L. 1983. Estimating larval fish abundance from plankton net catches in Long Point Bay, Lake Erie, in 1971–78. J. Great Lakes Res. **9**: 452–467.
- HOLČÍK, J. 1998. Lacustrine fishes and the trophic efficiency of lakes: prelude to the problem. Ital. J. Zool. **65**: 411–414.
- IMBROCK, F., APPENZELLER, A. & ECKMANN, R. 1996. Diel and seasonal distribution of perch in Lake Constance: a hydroacoustic study and in situ observations. J. Fish Biol. **49**: 1–13.
- JACHNER, A. 1991. Food and habitat partitioning among juveniles of three fish species in the pelagial of a mesotrophic lake. Hydrobiologia **226**: 81–89.
- KRATOCHVÍL, M., PETERKA, J., KUBEČKA, J., MATĚNA, J., VANÍČKOVÁ, I., ČECH, M. & SEDA, J. 2006. Feeding behaviour of larvae and juveniles of perch (*Perca fluviatilis*) performing diurnal vertical migrations in a deep canyon-shaped reservoir. J. Fish. Biol. (in press).
- KUBEČKA, J. 1991. A case of an extremely low share of the 0-age group on the total biomass, production and ration of the perch (*Perca fluviatilis*) population. Acta Soc. Zool. Bohemoslov. **55**: 114–119.
- KUBEČKA, J. & SLAD, P. 1990. Ichthyoplankton nádrže Římov [Ichthyoplankton of the Římov reservoir], pp. 109–113. In: KUBEČKA, J. (ed.) Ichthyofauna řeky Malše a nádrže Římov (Ichthyofauna of the Malše River and the Římov reservoir), České Budějovice, Museum of South Bohemia.
- LEVY, D.A. 1990. Sensory mechanism and selective advantage for diel vertical migration in juvenile sockeye salmon, *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. **47**: 1796–1802.
- MACHÁČEK, J. & MATĚNA, J. 1997. Diurnal feeding pattern of age-0 perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) in a steep-side reservoir. Arch. Hydrobiol. Spec. Issues Adv., Limnol. **49**: 59–70.
- MACHÁČEK, J. & SEDA, J. 2003. Vertikální distribuce perlooček rodu *Daphnia* v nádrži Římov a její změny v průběhu sezóny [The vertical distribution of *Daphnia* species and its seasonal changes in Římov reservoir]. Acta Fac. Ecol., Zvolen **10**: 91–94.
- MACLENNAN, D.N., FERNANDES, P.G. & DALEN, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES J. Mar. Sci. **59**: 365–369.
- MACLENNAN, D.N. & SIMMONDS, E.J. 1992. Fisheries Acoustics. Chapman & Hall, London, 325 pp.
- MATĚNA, J. 1995a. Ichthyoplankton and 0+ pelagic fish in the Římov Reservoir (Southern Bohemia). Folia Zool. **44**: 31–43.
- MATĚNA, J. 1995b. The role of ecotones as feeding grounds for fish fry in a Bohemian water supply reservoir. Hydrobiologia **303**: 31–38.
- MORGAN, M.J. 1988. The effect of hunger, shoal size and the presence of a predator on shoal cohesiveness in bluntnose minnows, *Pimephales notatus* Rafinesque. J. Fish Biol. **32**: 963–971.
- MOYLE, P.B. & CECH, J.J. Jr. 2003. Fishes, an introduction to ichthyology. Prentice Hall, London, 744 pp.
- NOBLE, R.L. 1970. Evaluation of the Miller high speed sampler for sampling yellow perch and walleye fry. J. Fish. Res. Board Can. **27**: 1033–1044.
- PERRONE, M. Jr., SCHNEEBERGER, P.J. & JUDE, D.J. 1983. Distribution of larval yellow perch (*Perca flavescens*) in nearshore waters of southeastern Lake Michigan. J. Great Lakes Res. **9**: 517–522.
- POST, J.R. & MCQUEEN, D.J. 1988. Ontogenetic changes in the distribution of larval and juvenile yellow perch (*Perca flavescens*): a response to prey or predator? Can. J. Fish. Aquat. Sci. **45**: 1820–1826.
- PETERKA, J., VAŠEK, M., KUBEČKA, J., HLADÍK, M. & HOHAUSOVÁ, E. 2004. Drift of juveniles after riverine spawning of fishes from the Římov reservoir, Czech Republic. Ecohydrology and Hydrobiology **4**: 459–468.
- ROSS, J., POWLES, P.M. & BERRILL, M. 1977. Thermal selection and related behavior in larval yellow perch (*Perca flavescens*). Can. Field-Nat. **91**: 406–410.
- RŮŽICKA, M., HEJZLAR, J., MIKESOVÁ, P. & COLE, T.M. 2002. 2-D water quality modeling of a drinking water reservoir. J. Hydrology and Hydromechanics **50**: 258–272.
- SEDA, J. & KUBEČKA, J. 1997. Long-term biomanipulation of Římov Reservoir (Czech Republic). Hydrobiologia **345**: 95–108.
- THETMEYER, H. & KILS, U. 1995. To see and not to be seen: the visibility of predator and prey with respect to feeding behaviour. Mar. Ecol. Prog. Ser. **126**: 1–8.
- TREASURER, J.W. 1988. The distribution and growth of lacustrine 0+ perch, *Perca fluviatilis*. Environ. Biol. Fish. **21**: 37–44.

- URHO, L. 1996. Habitat shifts of perch larvae as survival strategy. *Ann. Zool. Fenn.* **33**: 329–340.
- VÁSEK, M., KUBEČKA, J., MATĚNA, J. & SEDA, J. 2006. Distribution and diet of 0+ fish within a canyon-shaped reservoir in late summer. *Int. Rev. Hydrobiol.* (in press).
- VÁSEK, M., KUBEČKA, J., PETERKA, J., ČECH, M., DRASTÍK, V., HLADÍK, M., PRCHALOVÁ, M. & FROUZOVÁ, J. 2004. Longitudinal and vertical spatial gradients in the distribution of fish within a canyon-shaped reservoir. *Int. Rev. Hydrobiol.* **89**: 352–362.
- WANG, N. & ECKMANN, R. 1994. Distribution of perch (*Perca fluviatilis* L.) during their first year of life in Lake Constance. *Hydrobiologia* **277**: 135–143.
- WANZENBÖCK, J., MATĚNA, J. & KUBEČKA, J. 1997. Comparison of two methods to quantify pelagic early life stages of fish. *Arch. Hydrobiol. Spec. Issues Adv. Limnol.* **49**: 117–124.
- WARD, F.J. & ROBINSON, G.G.C. 1974. A review of research on the limnology of West Blue Lake, Manitoba. *J. Fish. Res. Board Can.* **31**: 977–1005.
- WHITESIDE, M.C., SWINDOLL, C.M. & DOOLITTLE, W.L. 1985. Factors affecting the early life history of yellow perch, *Perca flavescens*. *Environ. Biol. Fish.* **12**: 47–56.

Received May 11, 2005
Accepted December 13, 2005

Biologia, Bratislava, **61**/2: 219–220, 2006

FAUNISTICAL NOTES

First record of *Cimex pipistrelli* (Cimicidae) in Slovakia

Ján KRIŠTOFÍK¹ & Peter KAŇUCH²

¹*Institute of Zoology, Slovak Academy of Sciences, Dúbravská cesta 9, SK-84506 Bratislava, Slovakia; e-mail: jan.kristofik@savba.sk*

²*Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, SK-96053 Zvolen, Slovakia; e-mail: kanuch@savzv.sk*

The family Cimicidae includes obligatorily somatic ectoparasitic forms of bugs which parasitize on warm-blooded vertebrates. The taxonomic position of the *Cimex* genus in the Palaearctic region has not been clarified and especially the data on the species group *Cimex pipistrelli* Jenyns, 1839 are chaotic. Already POVOLNÝ (1957) was of the opinion that the species *Cimex dissimilis* Horváth, 1910, *C. stadleri* Horváth, 1955 and *C. singeri* China, 1938 are synonyms of *C. pipistrelli* and are distributed in Great Britain, France, Belgium, the Netherlands, Hungary, Switzerland, Czechoslovakia, Poland, Russia, Byelorussia and Ukraine. USINGER (1966), in his monograph, distinguished seven bug species from the Palearctic region parasitizing on bats, viz. *C. pipistrelli* (Great Britain), *C. dissimilis* (Hungary, Germany), *C. stadleri* (Germany, Czechoslovakia), *C. cavernicola* Usinger, 1966 (Turkmenia), *C. japonicus* Usinger, 1966 (Japan), *C. flavifuscus* Wendt, 1939 (East China) and *C. burmanus* Usinger, 1966 (Burma). However, USINGER (1966) himself noted that this species group was less investigated than the Nearctic congeners from the group of *C. pilosellus* Horváth, 1910. In PÉRICART'S (1972) opinion there were not more species in West Europe than two, namely *C. pipistrelli* and *C. dissimilis* (= *C. stadleri*). The typical species *C. pipistrelli* occurs in the Netherlands. The bugs from the bats from Sweden, European part of the former USSR, Kazakhstan and C Asia represent, according to PÉRICART (1972), transitional forms between both W European species. Incorrectly, he gave the occurrence of *C. dissimilis* from Slovakia, as the site – surroundings of Brno – lays in S Moravia (Czech Republic). Later PÉRICART (1996) also mentioned the occurrence of *C. pipistrelli*

from England, Ireland and Germany and with a question mark, from Sweden. According to KERZHNER (1989), the differences between species presented in the identification key and in the comparing text were partly contradictory and contained more discrepancies in the species descriptions. KERZHNER (1989) compared a material of bugs from the Zoological Institute in Sankt Petersburg and stated that all characters used by USINGER (1966) were highly variable and due to it they did not allow a reliable identification. KERZHNER supposed that all bugs from the Palaearctic region were to be considered as *C. pipistrelli* until more detailed investigation would be done. On the base of present knowledge, MORKEL (1999) included three species (*C. dissimilis*, *C. stadleri*, *C. pipistrelli*) into the group of *C. pipistrelli*. MELBE (1999) published a simultaneous finding of *C. dissimilis* and *C. pipistrelli* from one site in Germany. The occurrence of two individuals of *C. pipistrelli* from *Nyctalus leisleri* (Kuhl, 1817) was published by WALTER (2004). However, some specimens of *C. dissimilis* examined by him had a long pubescence, while others had a short pubescence.

The bug *C. pipistrelli* is a typical ectoparasite of bats. In Europe it was recorded first of all on the bats *Nyctalus leisleri*, *N. noctula* (Schreber, 1774) and *Pipistrellus pipistrellus* (Schreber, 1774). Our findings are the first records of the occurrence of *C. pipistrelli* in Slovakia.

Material examined: S-C Slovakia, Ipeľská kotlina basin, Kirt' village (48°06' N, 19°29' E, 151 m a.s.l), an old park established in a hardwood floodplain forests (150 years old), collected from *Nyctalus noctula* harp-trapped from roots in tree-hollows (mostly in poplars and ashes), 1 ♀ –