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The influence of the trawl mouth opening size and net colour on catch efficiency during sampling of early fish stages

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ABSTRACT

The efficiency of different sized (0.5 m × 2 m, 1 m × 2 m, 2 m × 2 m, 4 m × 2 m) and coloured (black, white) ichthyoplankton trawl nets and the densities of fry between day and night were investigated in the surface stratum of the Římov Reservoir (Czech Republic) during two surveys in mid-May and early June 2007. In mid-May, perch (*Perca fluviatilis*) was the most abundant fry species in the open water, whereas cyprinids (*Cyprinidae*) dominated 2 weeks later. Minor fry species in the trawl catches were pikeperch (*Sander lucioperca*) and ruffe (*Gymnocephalus cernua*) in both surveys. The comparison of fry densities during day and night revealed significantly higher day densities for the dominant perch and cyprinids, whereas for pikeperch and ruffe significantly higher densities were observed during the night. No significant differences in efficiency and body lengths of the fry sampled were found for any taxa when black and white trawl nets were compared. Comparison of the efficiencies of different sized trawl nets revealed different patterns for the dominant perch and cyprinids during both day and night. For perch, the lowest efficiency was observed for the smallest trawl, whereas the greatest efficiency was observed for the largest trawl net. The efficiencies were significantly different between trawls during day and night only for perch. For cyprinids, the efficiencies of different sized trawl nets were insignificantly different during both day and night. For pikeperch and ruffe similar trends in efficiency of different sized trawl nets were revealed. The lowest efficiency was reached with the smallest trawl but during the day a significant decline in efficiency of the largest trawl was also observed. Our results indicate that for sampling perch fry during both day and night and for sampling ruffe and pikeperch fry, especially during the day, a trawl net with a 1 m^2 mouth is not sufficiently efficient. The density of these fry species is significantly under estimated with such small nets. The fry body lengths sampled by different sized trawl nets did not differ significantly.

1. Introduction

Year-class strength of fish is generally considered to be established during the first year of life, through spawning success and survival of the resulting progeny (Nelson et al., 1968) and can be determined early in the year during the larval and early juvenile stages (Mooij, 1996; Anderson et al., 1998). The abundance and size structure of the early young-of-the-year (YOY) fish have been intensively studied in the open water areas of lakes and reservoirs, because the pelagic phase of their early life history has been described in many studies, especially for European perch (*Perca fluviatilis*) (Coles, 1981; Treasurer, 1988; Urho, 1996) and its close relative the North-American yellow perch (*Perca flavescens*) (Whiteside et al., 1985; Post and McQueen, 1988). Other numerous percid species in European reservoirs are pikeperch (*Sander lucioperca*) and ruffe (*Gymnocephalus cernua*), which have also been described as having an obligatory pelagic phase during early ontogeny (Matěna, 1995; Čech et al., 2007). In contrast to the percids, cyprinids, which dominate in most European reservoirs, usually migrate into the pelagic zone later, after spending more time at their spawning grounds in the littoral area (Matěna, 1995).

The accurate sampling of larval and juvenile fish is an important measure in fisheries ecology (Wanzenböck et al., 1997; Tischler et al., 2000). The usual methods used in ichthyoplankton studies consist of various types of nets, which are either towed behind the boat (Cada and Loar, 1982; Anderson et al., 1998; Čech et al., 2005; Kratochvíl et al., 2008) or fixed on the sides or forward end of the boat (Frankiewicz et al., 1996, 1997; Quist et al., 2004). Because of the selectivity of these types of nets (Treasurer, 1978), both the esti-

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mated densities and size distributions determined by the different methods vary (Wanzenböck et al., 1997; Tischler et al., 2000).

A common feature of all these ecological studies, which have focused on larval and juvenile fish sampling, is the relatively small mouth opening of the sampling tools used. Just the size of the mouth opening of trawl or push nets may significantly affect their efficiency (Treasurer, 1978; Jůza and Kubečka, 2007; Itaya et al., 2007) and the size of the mouth opening also significantly influences the sizes of fish captured (Mous et al., 2002). Another typical characteristic of most studies describing ichthyoplankton densities in lakes and reservoirs is the absence of information about the net colour. In some studies, dark entrances to the main cylinders of the nets (Scharf et al., 2009) or transparent samplers (Noble, 1970) were used, but generally, the potential influence of the net colour on its efficiency has been overlooked.

The main aim of this study was to investigate the efficiency and size selectivity of ichthyoplankton trawl nets with different sizes of mouth opening and different net colours for dominant species of early YOY fish. We were specifically interested in differences in the densities and size distribution between the different mouth openings of the trawl nets and colours of the trawl nets.

2. Materials and methods

2.1. Study area

The experiments were carried out in the canyon-shaped Římov Reservoir (Fig. 1a), a narrow, deep, man-made lake in South Bohemia, Czech Republic (48°50′N, 14°30′E, 170 km south of Prague, Fig. 1b). Its surface area is 210 ha, volume 33.10×10^6 m^3, length 12 km, maximum depth 45 m and the maximum surface elevation is 471 m a.s.l. The Reservoir was built in 1978 on the Malše River and serves as the drinking water storage for the South Bohemian region. The trophic status of the reservoir can be characterized as moderately eutrophic to eutrophic, with both phosphorus and chlorophyll-*a* concentrations decreasing downstream (Sed'a and Devetter, 2000). The average water retention time varies from 80 to 180 days (Sed'a and Kubečka, 1997). The ichthyofauna of 1+ and older fish is dominated by cyprinids – common bream (*Abramis brama*), roach (*Rutilus rutilus*) and bleak (*Alburnus alburnus*) contributed more than 60% of the total fish abundance in nighttime shore seining catches in 2006 (Říha et al., 2009) and the same three species comprised more than 90% of the total nighttime offshore abundance of 0+ fish in fry trawl catches in late summer of 2006 (Jůza et al., 2009).

2.2. Sampling and statistical analysis

The ichthyoplankton trawling in the Římov Reservoir was conducted in two sampling surveys (experiment I and II), during 16–17 May and 31 May–1 June 2007. All the ichthyoplankton trawl nets used were fixed frame, with a rectangular mouth opening, rectangular mesh size of 1 mm × 1.35 mm, with the collecting bucket at the end (Fig. 1c). The trawl nets had a weight (one or two depending on the size of the trawl) attached to the lower part of the frame and a polystyrene floater attached permanently to the upper rim, so that only the surface water stratum was sampled (Fig. 1c). These ichthyoplankton trawl nets were equipped with 4 bridles and were towed 50 m behind the boat, usually for 5 min, at a velocity of 0.8–1 m s^{-1} (Čech et al., 2005). In the majority of cases (see below), the research vessel Ota Oliva (64 hp diesel engine, Kubečka et al., 2003) was used as a trawler. The trajectory of the tow was slightly curved, so that the net did not sample the area directly disturbed by the boat. The length of each haul was estimated using a flow meter (General Oceanics, USA), which was fixed to the rim of the trawl frame (Fig. 1c). During all trawl tows the echosounder (Simrad EK 60 with circular split-beam transducer operating on frequency 120 kHz) fixed to the front part of the research vessel (Fig. 1c) was

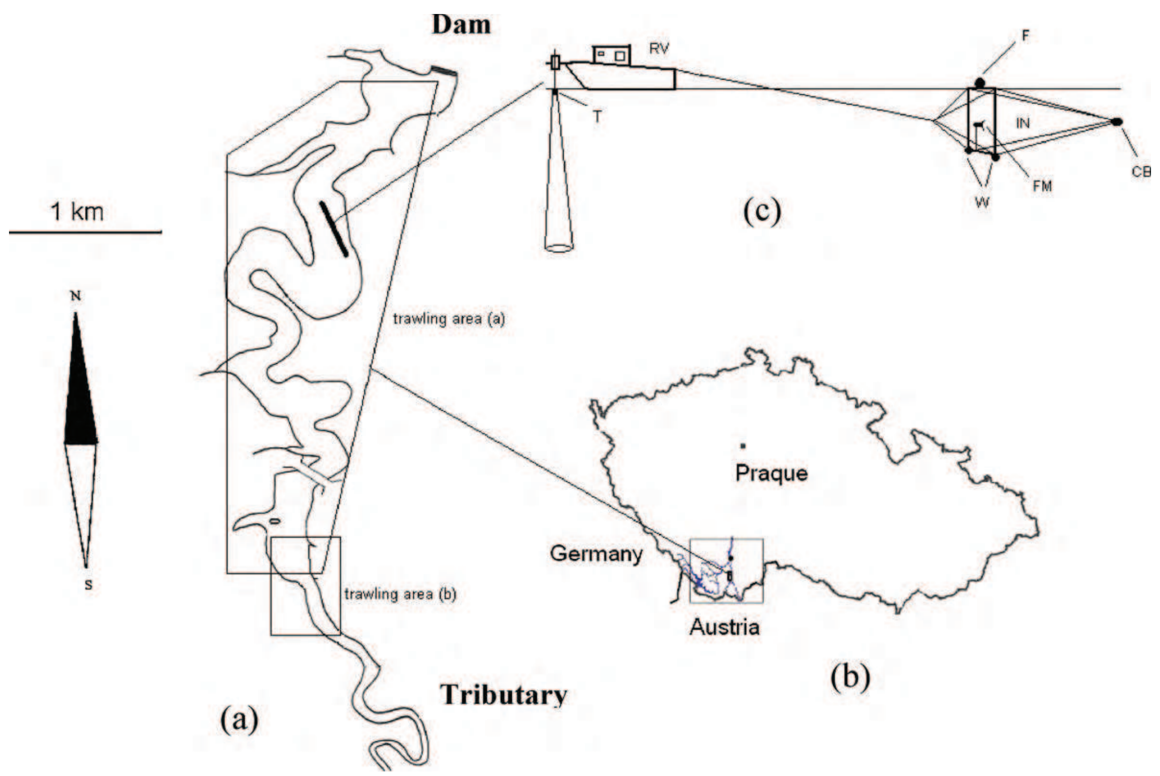

Fig. 1. (a) A map of Římov Reservoir and (b) its location in the Czech Republic. (c) Diagram showing the sampling operation: T, transducer; RV, research vessel; W, weights; F, floater; FM, flow meter; IN, ichthyoplankton net; CB, collecting bucket.

used to check the water depth and vertical distribution of fish larvae in the water column. Light intensity on the water surface was determined with a lux meter MDLX during each trawl haul.

2.2.1. Experiment I: comparison of the efficiency of different coloured nets

The experiment comparing the efficiency of different coloured nets was conducted during the earlier sampling period (16–17 May, 2007). Two identical trawl nets, with a 2 m × 2 m square mouth opening but different coloured netting (black or white) were used. Both nets were towed, during the day, in the surface stratum along the whole length of the reservoir. During the day on May 16, 24 tows were made along most of the reservoir length (trawling area (a) – Fig. 1a). During the day on May 17, 8 tows in the upper reservoir area (trawling area (b) – Fig. 1a) were added in order to obtain data from the whole longitudinal profile, where the depth was sufficient for safe trawling with a 2 m deep net. We always did 4 tows with the net of one colour, then we changed the net and made 4 tows with the net of the second colour along tracks 50–200 m apart in order to be sure that we did not sample the area fished previously. The time-lag between the tows with different coloured nets in the same locality was never greater than 90 min and the order of nets colour used was random. The weather conditions were similar during the whole experiment.

2.2.2. Experiment II: comparison of the efficiency of different sized nets

During the later sampling period (31 May–1 June 2007), the experiment comparing the efficiency of different sized trawl nets was conducted. All the trawl nets used were black and had the same mouth height (2 m) but different widths (0.5, 1, 2, and 4 m). Trawls were towed in the surface water stratum again, so the top 2 m were sampled (Fig. 1c).

During the daylight hours on May 31, 45 tows with 3 nets (0.5 m × 2 m, 1 m × 2 m, 2 m × 2 m – 15 tows with each net) were carried out along most of the length of the reservoir (trawling area (a) – Fig. 1a). To obtain as much as possible reliable data, all 3 smaller trawls were towed in parallel at the same time and location. The two smallest trawl nets (0.5 m × 2 m and 1 m × 2 m) were simultaneously towed by the research vessel Ota Oliva, while the third net (2 m × 2 m) was towed by a flat-bottomed boat powered by a 25 hp outboard engine. Because it was not technically possible to tow the largest (4 m × 2 m) trawl in parallel with the others, it was towed during the next day (1st June) in exactly the same localities as the other 3 trawls were towed the day before (again 15 tows with the 4 m × 2 m net). There was similar sunny, windless weather during both days of sampling.

During the night hours from 31st May to 1st June, 3 nets (0.5 m × 2 m, 1 m × 2 m, 2 m × 2 m) were towed in the trawling area (a) (Fig. 1a) of the reservoir. The design of this experiment was similar to the design used during the day, so all three nets were towed in parallel, for exactly the same time in the same locality. As during the day, 15 tows were done with each trawl net (45 tows altogether) but the largest (4 m × 2 m) trawl net was not used during the night. The light intensity was well below 1 lx without a full moon.

According to the tow length (L, m), which was obtained through the use of a flow meter, the water volume sampled (V_W, m^3) was calculated as:

$$V_W = L \times S$$

where S is the area of the mouth of the trawl (1, 2, 4 or 8 m^2) and the efficiency of each trawl was expressed as catch per 100 m^3 of filtered water during both experiments. The samples obtained were immediately preserved in 4% formalin. In the laboratory, all percids captured were identified to species and all cyprinids were identified as the family *Cyprinidae*. Using a binocular microscope, the fish were measured to the nearest 0.5 mm for standard length. From catches with a large amount of fish the samples of 200 fish of each taxa were taken for measurement, while from less numerous catches all fish were measured. Densities recorded for different sized and coloured nets, and between day and night for different species, were compared ($\alpha = 0.05$) with one-way analysis of variance (Zar, 1984) with locality and trawl net size (trawl net colour, diurnal period) as independent variables and fish density as the dependent variable. If the catch data lacked a normal distribution, they were log-transformed (log 10) to approximate the normal distribution. The comparison of densities reached by different pairs of trawl nets was made using the post hoc Tukey's HSD test. For comparisons of body lengths sampled by different sized and coloured trawl nets, and between day and night, one-way analysis of variance was used with trawl net size (net colour, day period) as the independent variable and body length as the dependent variable.

3. Results

3.1. Species composition and fry densities during both experiments and during day and night

During both experiments a total of 81,235 YOY fish were captured by the ichthyoplankton trawls in 137 tows. The pelagic fry community was composed of epipelagic fry only, the bathypelagic fry were missing in 2007 (no scattering targets were observed by the echosounder). The highest density was observed during experiment I in mid-May (181 ind 100 m^{-3}). The densities recorded during experiment II, at the turn of May and June, were lower, both during the day (52 ind 100 m^{-3}) and during the night (25 ind 100 m^{-3}). Species composition also differed strongly between both experiments: during daylight sampling in mid-May, perch (*P. fluviatilis*) was the most abundant species in the open water area of the reservoir, whereas cyprinids strongly dominated during day and night in the second experiment, 2 weeks later (Fig. 2). The majority of these cyprinids were fry of common bream (*A. brama*). The catch of pikeperch (*S. lucioperca*) and ruffe (*G. cernua*) combinated was never higher than 18% of the total catch during both experiments (Fig. 2).

During the experiment II the day densities of perch and cyprinids (data from the 0.5 m × 2 m; 1 m × 2 m and 2 m × 2 m trawl

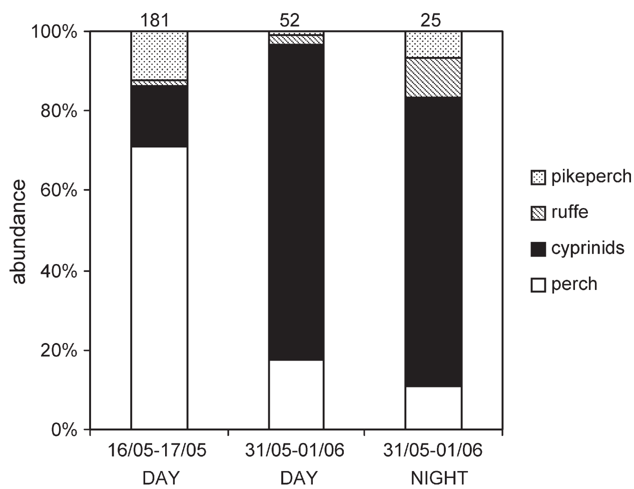

Fig. 2. Composition of the fry assemblage in the pelagic area of Římov Reservoir in three periods sampled in 2007 (16–17 May – Day; 31 May–1 June – Day; 31 May–1 June – Night) estimated by ichthyoplankton trawling. Numbers above each column show mean density of fry (ind 100 m^{-3}) from all trawl hauls on the appropriate date and diurnal period.

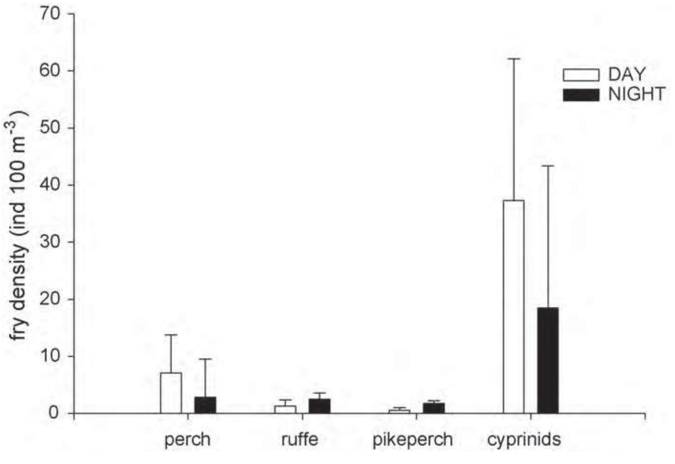

Fig. 3. Comparison of densities of different fish species reached during the day on 31 May and at night on 31 May–1 June (mean of 0.5 m × 2 m, 1 m × 2 m and 2 m × 2 m trawl nets + S.D.). The 4 m × 2 m trawl net was not included in this comparison, because it was used during the day only.

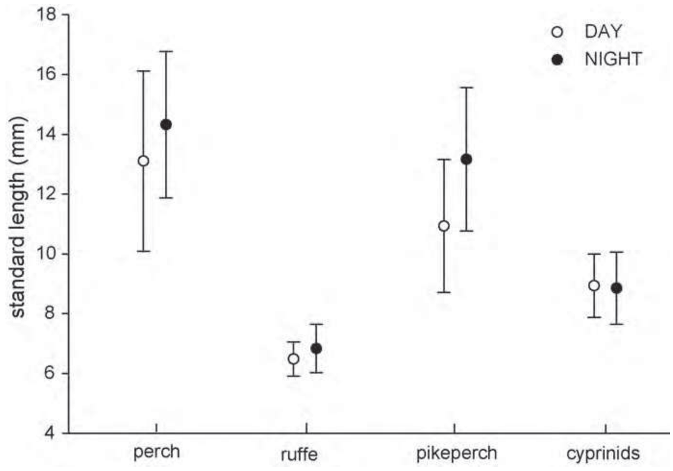

Fig. 4. Comparison of standard lengths of different fish species caught during the day on 31 May and during the night of 31 May–1 June (mean of 0.5 m × 2 m, 1 m × 2 m and 2 m × 2 m trawl nets ± S.D.). The 4 m × 2 m trawl net was not included in this comparison, because it was used only during the day.

nets pooled together) were significantly higher compared to the nighttime densities (Fig. 3; ANOVA (of log-transformed data); perch: $p < 0.001$; cyprinids: $p < 0.001$). For pikeperch and ruffe the results were the opposite – significantly higher densities were observed at night compared to during the day (Fig. 3; ANOVA (of log-transformed data); pikeperch: $p < 0.001$; ruffe: $p < 0.001$). Significantly larger fry of perch, pikeperch and ruffe were captured during the night (Fig. 4; ANOVA; perch: $p = 0.005$; pikeperch: $p < 0.001$; ruffe: $p = 0.002$). For cyprinids only, larger fish were captured during the day but the difference was not significant (Fig. 4; ANOVA; cyprinids: $p = 0.79$). These results were consistent for all the nets that were used for both day and night sampling (0.5 m × 2 m, 1 m × 2 m, 2 m × 2 m).

3.2. *Comparison of densities and length distributions reached by different coloured nets*

We did not find statistically significant differences in fry density for any fish species taken by trawl nets of different colour (Table 1). For pikeperch, ruffe and cyprinids the densities obtained by black and white trawl nets were practically the same. For perch, an enhanced efficiency was observed for the white trawl nets: the density reached by the white net trawls was 1.4 times higher than the density reached by the black trawl nets, but this difference was, again, not statistically significant.

Comparisons of body lengths of different fish species revealed no significant differences for any taxa between the black and white trawl nets (Table 1).

3.3. *Comparison of densities and length distributions obtained by different sized trawl nets during the day*

The comparison of densities obtained by different sized trawl nets during the day revealed significant differences for perch, pikeperch and ruffe, when all the trawls were evaluated together (ANOVA (of log-transformed data for perch); perch: $p < 0.001$; pikeperch: $p < 0.001$; ruffe: $p < 0.001$). For cyprinids, however, we did not find any significant differences between the trawl nets ($p = 0.33$). For perch, pikeperch and ruffe, the lowest density was obtained with the smallest (0.5 m × 2 m) net. However for perch only the highest density was obtained with the largest (4 m × 2 m) net (Fig. 5). For pikeperch and ruffe the densities increased from the 0.5 m × 2 m net to the 2 m × 2 m net, but for both species, the density obtained with the 4 m × 2 m net was markedly lower (Fig. 5). For perch, the significant differences in the densities measured were not found between 1 m × 2 m *vs.* 2 m × 2 m and 2 m × 2 m *vs.* 4 m × 2 m (Table 2). Densities obtained with the smallest (0.5 m × 2 m) net were significantly lower than densities obtained with all the other nets for perch. For ruffe and pikeperch, the reduced density obtained with the 4 m × 2 m net resulted in there being no significant differences between this biggest trawl net and the two smallest nets (0.5 m × 2 m and 1 m × 2 m). For cyprinids we did not find significant differences in density between any of the trawl nets used.

Comparisons of body lengths of different fish species revealed no statistically significant differences between the trawl nets for any taxa (Table 3).

Table 1
Comparison of densities (ind 100 m^{-3}) and body lengths (mm; mean ± 0.95S.D.) of different YOY fish taxa in trawls of different net colour with *p*-levels of significance obtained by comparing different coloured nets.

Net colour	Perch	Cyprinids	Pikeperch	Ruffe	All species
Black – density	107.5 ± 73.9	28.3 ± 38.9	22.6 ± 21.3	2.3 ± 1.9	160.7 ± 88.9
White – density	153.7 ± 104.9	27.1 ± 43.2	23.3 ± 14.6	2.2 ± 1.9	206.3 ± 97.5
p-Level	0.16	0.91	0.60	0.79	0.22
Black – length	10.49 ± 1.56	9.24 ± 1.07	9.98 ± 1.52	6.95 ± 0.89	
White – length	10.99 ± 1.47	9.63 ± 0.81	10.21 ± 1.45	6.91 ± 0.83	
p-Level	0.47	0.36	0.73	0.91	

The results for all YOY fish pooled together are in the last column. Density data were log-transformed to approximate the normal distribution.

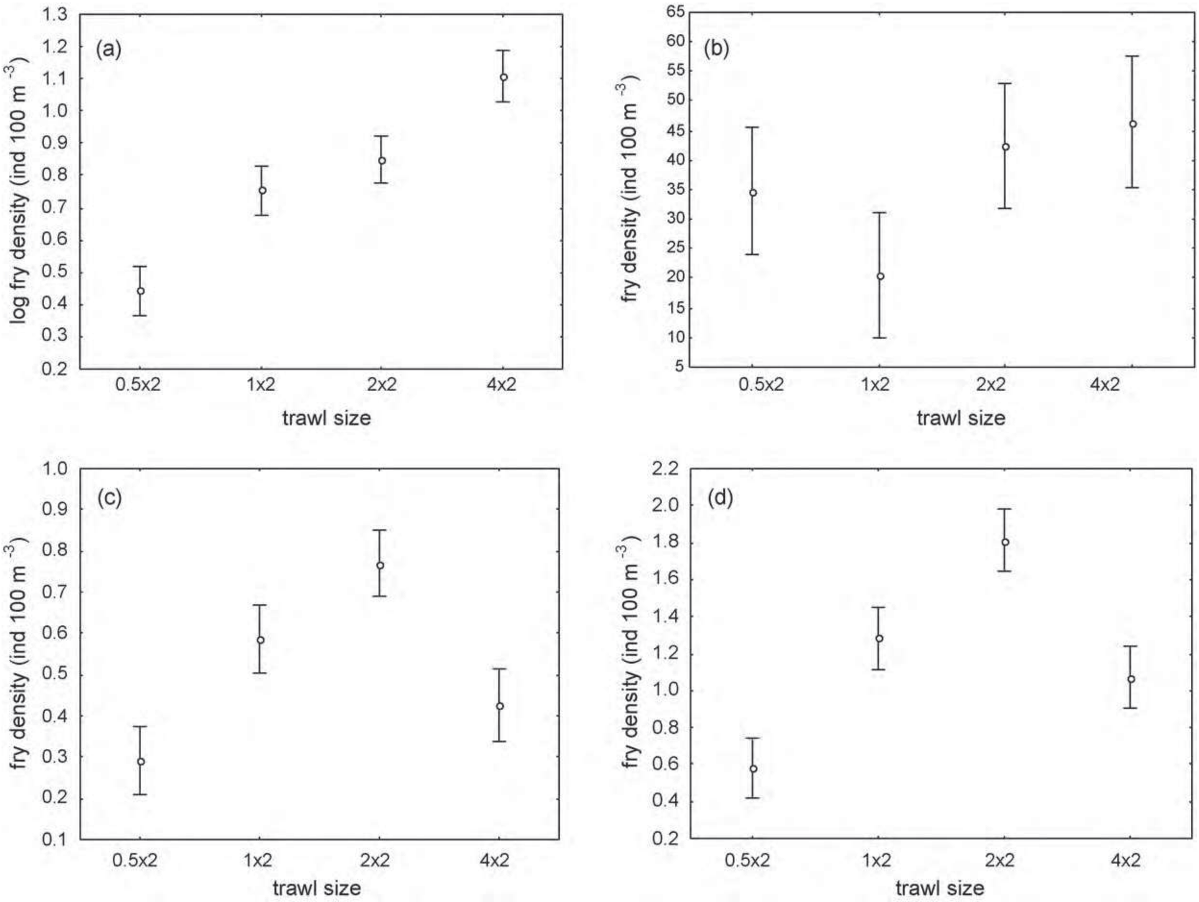

Fig. 5. Comparisons of fry densities estimated from different sized trawl nets during the day for (a) perch, (b) cyprinids, (c) pikeperch and (d) ruffe. Vertical bars denote ± standard errors. Density data for perch are presented in logarithmic form to approximate the normal distribution. The 4 m × 2 m trawl net data were not obtained in the same day.

Table 2
Comparison of *p*-levels of significance of between trawl nets densities (log-transformed for perch) of the day catches for different fish taxa. Bold lettering indicates significant differences.

Perch	0.5 × 2	2 × 2	4 × 2	Cyprinids	0.5 × 2	2 × 2	4 × 2
1 × 2	**0.02**	0.81	**0.02**	1 × 2	0.77	0.46	0.29
2 × 2	**0.002**			2 × 2	0.95		
4 × 2	**0.0002**	0.14		4 × 2	0.84	0.99	
Pikeperch	**0.5 × 2**	**2 × 2**	**4 × 2**	**Ruffe**	**0.5 × 2**	**2 × 2**	**4 × 2**
1 × 2	0.07	0.4	0.27	1 × 2	**0.02**	0.1	0.70
2 × 2	**0.0009**			2 × 2	**0.0002**		
4 × 2	0.89	**0.007**		4 × 2	0.20	**0.007**	

3.4. Comparison of densities and length distributions obtained by different sized trawl nets during the night

The comparison of densities obtained using different sized trawl nets during the night revealed significant differences for perch and ruffe when all the trawls were evaluated together (ANOVA (of log-transformed data); perch: $p < 0.001$; ruffe: $p < 0.001$). The densities of cyprinids and pikeperch were not significantly different between the trawl nets used (ANOVA (of log-transformed data); cyprinids: $p = 0.05$; pikeperch: $p = 0.06$). For all the species the lowest den-

Table 3
Comparison of body lengths (mm) of different YOY fish taxa in trawl nets with different mouth sizes (mean ± 0.95S.D.) from day catches with *p*-levels of significance obtained by comparing four trawls with different mouth openings.

Size of trawl net	Perch	Cyprinids	Pikeperch	Ruffe
0.5 × 2	11.80 ± 2.38	9.01 ± 1.08	11.08 ± 2.34	6.68 ± 0.59
1 × 2	13.98 ± 2.99	8.99 ± 1.03	11.19 ± 2.17	6.51 ± 0.60
2 × 2	12.87 ± 3.27	8.81 ± 1.16	10.87 ± 2.36	6.46 ± 0.57
4 × 2	13.30 ± 3.07	9.10 ± 1.28	11.42 ± 3.82	6.66 ± 0.69
p-Level	0.41	0.94	0.93	0.84

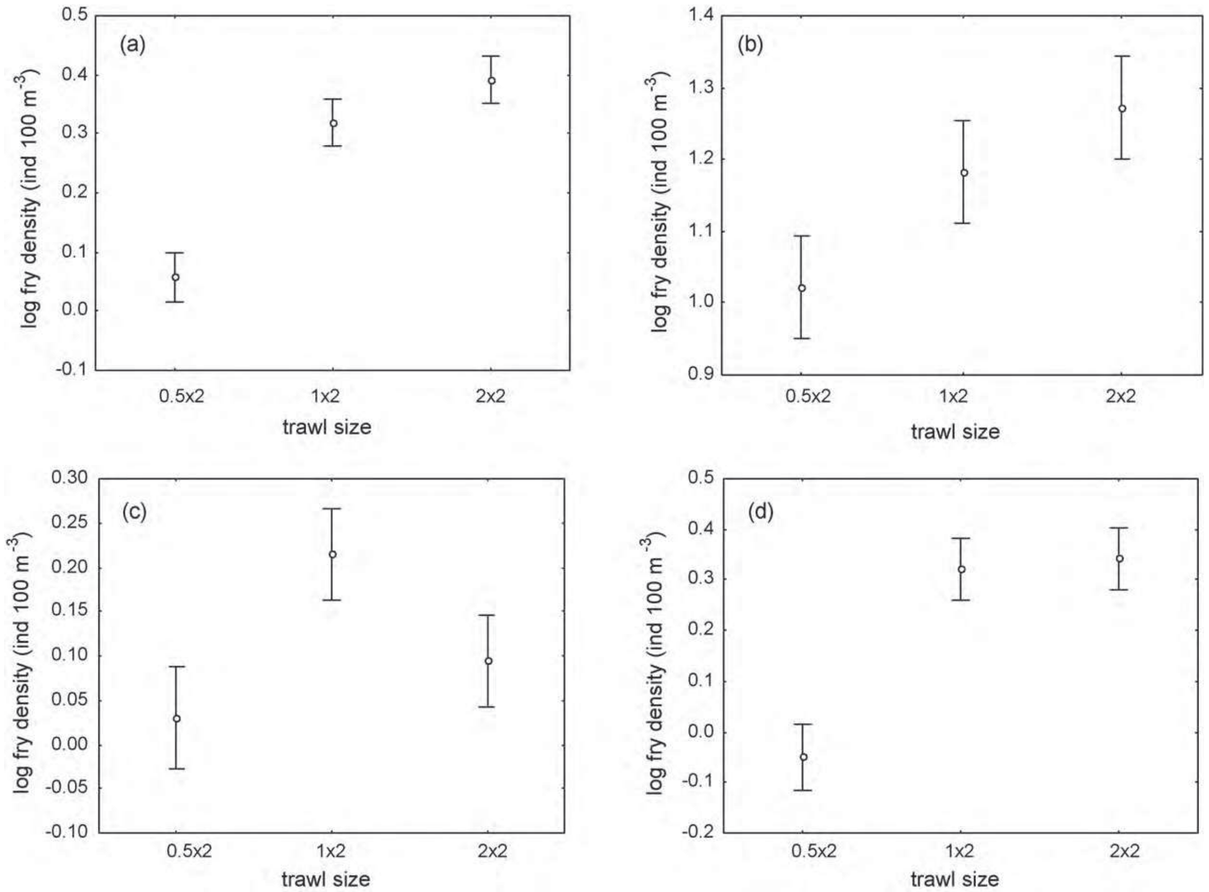

Fig. 6. Comparisons of fry densities estimated from different sized trawl nets during the night for (a) perch, (b) cyprinids, (c) pikeperch and (d) ruffe. Vertical bars denote ± standard errors. Fry density data is in logarithmic form.

Table 4
Comparison of *p*-levels of significance between trawl nets densities (log-transformed) of the night catches for different fish taxa. Bold lettering indicates significant differences.

Perch	0.5 × 2	1 × 2	Cyprinids	0.5 × 2	1 × 2	Pikeperch	0.5 × 2	1 × 2	Ruffe	0.5 × 2	1 × 2
1 × 2	**0.0009**		1 × 2	0.25		1 × 2	0.12		1 × 2	**0.003**	
2 × 2	**0.0001**	0.42	2 × 2	**0.04**	0.42	2 × 2	0.90	0.23	2 × 2	**0.002**	0.97

Table 5
Comparison of body lengths (mm) of different YOY fish taxa in trawl nets with different mouth sizes (mean ± 0.95S.D.) from night catches, with *p*-levels of significance obtained by comparing three trawls with different mouth openings.

Size of trawl net	Perch	Cyprinids	Pikeperch	Ruffe
0.5 × 2	13.96 ± 2.72	8.86 ± 1.25	13.84 ± 2.76	6.93 ± 0.76
1 × 2	14.24 ± 2.54	8.88 ± 1.14	13.63 ± 2.55	7.02 ± 0.92
2 × 2	14.52 ± 2.60	8.87 ± 1.21	13.02 ± 2.37	6.76 ± 0.78
p-Level	0.89	0.99	0.77	0.77

sity was observed in the smallest 0.5 m × 2 m trawl net (Fig. 6). The density determined with the smallest, 0.5 m × 2 m, trawl net was significantly lower than the densities estimated with both the other, bigger nets for perch and ruffe (Table 4). For cyprinids, the significant difference was found between the smallest (0.5 m × 2 m) and largest (2 m × 2 m) nets. For pikeperch there was no significant difference between any of the trawl nets used (Table 4). We did not find significant differences in density, of any species of fry, between the 1 m × 2 m and 2 m × 2 m trawl nets when they were used at night.

The comparison of body lengths of different fry taxa again revealed no statistically significant differences between the trawl nets (Table 5).

4. Discussion

4.1. Comparisons of fry density and species composition between both experiments and between day and night

The present study clearly showed differences both in species composition and the fry densities observed in mid-May, and 2 weeks later in early June. During the day in Římov Reservoir in mid-May, perch dominated the trawl catches in the open water area, whereas cyprinids dominated 2 weeks later. Mid-May has been described as the period with the highest density of perch fry in the open water area of this Reservoir in previous years (Matěna, 1995) and in early spring perch is also the most abundant species in other European lakes and reservoirs (Wanzenböck et al., 1997; Tischler et al., 2000; Čech et al., 2005; Scharf et al., 2009). The dominance of perch in May in the open water is not surprising, because soon after hatching the perch larvae migrate from the littoral into pelagic habitat, and before they return to littoral areas after metamorphosis, the fry stay in the epilimnion for a month or even longer (Ward and Robinson, 1974; Coles, 1981; Treasurer, 1988). In contrast to perch, cyprinids migrate into the pelagic zone later, after they have spent some time at the spawning grounds (Rheinberger et al., 1987; Matěna, 1995). The different times of movements to and from the open water could be a reason for the reverse proportions of perch and cyprinids recorded in mid-May and early June in the open water area of Římov Reservoir. During the second experiment some of the perch could be back in the littoral area, whereas the cyprinid pelagic phase had started.

Fry density reached during the day in mid-May was more than 3 times higher than during the day in the second trawling survey, 2 weeks later. There are several explanations for this decline: First, fry migration to the inshore area (see above). Second, the larval period is considered to be critical in the life history of many fish species (Quist et al., 2004) with predation and starvation as the major causes of mortality (Urpanen et al., 2005). Natural mortality could therefore be the main reason for the density decline. Third, body length of the fry could explain the decline. The mean body length of the perch fry was 2.3 mm longer at the beginning of June than in mid-May. The ability of a fish to escape the fishing gear is strongly dependent on its size (Nelson et al., 1968; Godø et al., 1990; MacLennan, 1992) therefore it is probable that, especially perch fry, which dominated in mid-May during the day and whose body length was larger in comparison with the relatively small cyprinids fry, were able to avoid the trawl net 2 weeks later. Finally, a possible change of vertical distribution could be another reason. During both trawling surveys, we only sampled the upper epipelagic fry in the surface (comp. Čech et al., 2005) although bathypelagic fry were absent in 2007.

Comparing densities of different taxa between day and night during the second trawling survey separated out two groups of fish fry. The dominant perch and cyprinids were significantly more abundant during the day while, in contrast, densities of the minority pikeperch and ruffe were significantly higher during the night in the surface water stratum (0–2 m). Most studies describing the open water densities of larvae and early juveniles have revealed higher densities during the night (North and Murray, 1992; Wanzenböck et al., 1997; Guest et al., 2003; Čech et al., 2005). The main reasons for the higher night densities are usually attributed to higher avoidance of sampling tools during the day (Noble, 1970; North and Murray, 1992) or diurnal horizontal or vertical migrations of the fish larvae (Wanzenböck et al., 1997; Čech et al., 2005). During our study the echosounder did not reveal any scattering layer of bathypelagic perch fry during our experiments in the daytime so all the pelagic fry were present in the epilimnion. The more detailed focus on distribution patterns described in Čech et al. (2005) revealed differences in perch fry distribution within the epilimnion during day and night. During the daytime in May, most perch fry were present in the upper epilimnion just below the water surface, whereas during the nighttime the majority of perch fry inhabited the deeper epilimnion close above the thermocline (2.5–4.5 m depth). During our experiment we sampled the surface water stratum only (0–2 m) and this fact, in combination with the diurnal distribution of perch fry within the epilimnion, could be a reason for higher densities of perch fry observed during daytime.

Comparisons of body length of different fry species between day and night revealed significantly larger fry captured during the night for perch, pikeperch and ruffe. For cyprinids we did not find any significant difference in body length between day and night. The catches of larger fry of perch and pikeperch during the night were probably due to the combination of greater swimming capacity of larger fish (Nelson et al., 1968; Godø et al., 1990) and stronger avoidance reactions of these fish during the day (North and Murray, 1992; Guest et al., 2003) and, possibly, vertical migration.

4.2. Comparison of efficiency of different coloured trawl nets

Noble (1970) points out that fry avoidance of nets is, at least in part, a response to a visual stimulus and that the catches of a transparent Miller sampler were significantly greater than the catches of a standard (dark) Miller sampler. We hypothesized that during the daytime, in the surface water stratum, the netting colour could influence trawl efficiency. In our experiment we compared the efficiency of black and white ichthyoplankton trawl nets. We assumed that, in a reservoir with usually relatively low water transparency, a black net would be less contrasting and therefore more effective. However, we were not able to demonstrate any significant differences in fry densities caught by different coloured nets so it could be concluded that trawl nets of both colours were equally efficient, and that it is not important which colour of trawl netting is used for estimates of early fry density. For the dominant perch, the differences in efficiency of black and white trawl nets were not significant, but slightly enhanced fry density was recorded for the white net. Our experiment took place during the clear-water phase (Devetter and Sed'a, 2005) with relatively high water transparency (5 m Secchi depth near the dam, 1.6 m Secchi depth in the uppermost part) and during two sunny days (illumination 50,000–100,000 lx). Trawling in the surface water stratum, in water with relatively high transparency, and during high light conditions, could result in greater contrast of the black net in the surrounding water and, contrary to our expectations, the white trawl net was slightly more effective for catching fry.

4.3. Comparison of densities and length distributions reached by different sized trawls

For actively escaping fry, catch per 100 m^3 should be higher for the trawl net with a larger mouth opening (Treasurer, 1978; Viljanen and Holopainen, 1982; Mous et al., 2002) because these fry are able to more easily escape net with a smaller mouth opening, whereas in cases of minimal avoidance capability the catch of different sized trawl nets is similar (Jůza and Kubečka, 2007). The size of the trawl nets's mouth can also influence the size of fish caught (Mous et al., 2002), because larger fish have greater swimming capability (Godø et al., 1990) and are able to escape the opening of a trawl net with a small mouth. In many studies, different types of ichthyoplankton nets and samplers have been used for catching fish larvae and to estimate the abundance of early juveniles (Cada and Loar, 1982; Mooij, 1996; Quist et al., 2004; Urpanen et al., 2005; Scharf et al., 2009), but a common feature of most of these studies is the relatively small mouth opening of the sampling tools (usually less than 1 m^2).

The results indicate that a 0.5 m × 2 m trawl net (1 m^2 mouth opening) is too small and significantly underestimates the density of perch and ruffe fry during the night. Mooij (1996) compared the efficiency of 20 cm, 40 cm and 80 cm diameter hoopnets for capturing fish larvae in Tjeukemeer. Similar to our results, the catch with a 20 cm diameter hoopnet was significantly lower than with the 40 and 80 cm nets, whereas the difference between the 40 and 80 cm nets was not significant. However, the efficiency was not significantly different between our trawl nets for cyprinids and pikeperch at night. These results indicate, that in contrast to perch and ruffe, the smallest net was efficient enough in capturing cyprinids and pikeperch. During the day, significant differences in estimated density were observed for perch, pikeperch and ruffe but, for the dominant cyprinids, the differences were again not significant. The most obvious pattern was evident for perch because the highest estimated density was obtained with the biggest (4 m × 2 m) trawl net and significantly lower estimated density was obtained between the smallest (0.5 m × 2 m) and all remaining trawl nets. For pikeperch and ruffe the efficiency increased from the 0.5 m × 2 m net to the 1 m × 2 m and to the 2 m × 2 m trawl net (towed simultaneously), but we observed a steep decline in the efficiency of the 4 m × 2 m trawl net for these two fry species. Probable reason could be the different times of the trawling, because the 4 m × 2 m trawl net was towed on the day following the other three trawls. These results indicate the necessity of parallel trawling with all the nets in exactly the same place over the same time period in such a studies, as was mentioned by Jůza and Kubečka (2007).

Our results clearly showed differences in efficiency of different sized trawl nets for capturing the dominant perch and cyprinids. For cyprinids we did not find any significant differences between the efficiencies of different sized trawl nets both during day and night. The sampling of small early cyprinid fry seems to be quantitative without significant avoidance reactions to an ichthyoplankton trawl. The same results, with minimal avoidance reactions, were evident for fry during the night in late summer, when cyprinids formed the majority of the catch (Jůza and Kubečka, 2007). For perch we have shown clear evidence that trawl nets with larger mouths are more effective than trawl nets with a small mouth, both during the day and night. Density estimates of perch, or of their close relative yellow perch, have been the main objective of many studies (Viljanen and Holopainen, 1982; Urho, 1996; Anderson et al., 1998; Čech et al., 2005, 2007; Scharf et al., 2009) and, according to our results, trawl nets or bongo nets with relatively small mouth openings (often less than 1 m^2) are not efficient enough. Perch densities obtained using these small nets are significantly underestimated. Itaya et al. (2007) reported differences in avoidance behaviour of different species and this effect was caused by the different ranges of each species' body lengths. Because cyprinid fry were smaller in comparison to perch fry it is likely that small cyprinid fry were not able to avoid the approaching net. Nevertheless, this explanation is not supported by the avoidance behaviour of the other two species. The fry of ruffe were the smallest but we have shown clear avoidance of the net both during day and night. Pikeperch fry were only a little bit smaller than the perch fry but, nevertheless, their avoidance of the net was not significant during the night. According to these results it seems that body size is not the main cause of the different avoidance behaviours of perch and cyprinids.

Comparison of fry densities using different sized trawl nets has revealed avoidance behaviour of the young fry of perch and ruffe during both day and night, and for pikeperch during the day, but these results were not supported by the fry length distributions in different trawls. We expected, that in cases of such avoidance reactions, the between-trawl differences in body lengths sampled would be different, with the smallest fry captured by the smallest trawl net and the largest fry captured by the biggest trawl net. Nevertheless, we did not find any significant differences in body lengths between different trawl nets and no clear pattern in enlargement of body length in larger trawl nets. These results suggest that early fry are probably too small to be segregated according to body length in different sized trawl nets and that the avoidance capabilities of such small fish are similar. The length range of such small fry is narrow and probably has no influence on swimming ability. According to our results, the mouth size of the ichthyoplankton trawl net significantly influences the observed fry density of some species, nevertheless the hypothesis connected with larger fry being caught in nets with larger mouth openings, in case of avoidance reactions, was not proved.

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