Fisheries Research 102 (2010) 291–296

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Fish activity as determined by gillnet catch: A comparison of two reservoirs of different turbidity

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ARTICLE INFO

Article history:
Received 20 October 2009
Received in revised form
21 December 2009
Accepted 22 December 2009

Keywords:
Diel pattern
Soak time
CPUE

ABSTRACT

Fish activity was monitored analyzing the catches of gillnets exposed for short time intervals at night. Experiments were done in two Central European reservoirs with different turbidity and fish density. Cyprinids dominated in both reservoirs. The aims of the study were to describe and model a pattern of fish activity in general and on species and age group levels, and in turbid and clear water. Fish activity showed two distinct peaks around sunset and sunrise and was low during night. This pattern was the same in clear and turbid reservoirs, as well as for all species and age groups tested. This study established some justifications and standards for gillnet sampling: (i) it is possible to compare overnight gillnet catches between different lowland European species and waterbodies, as the pattern of fish activity is general; (ii) gillnets should be set 2–3 h before sunset and lifted 2–3 h after sunrise to cover activity peaks, thus getting reliable and comparable results; (iii) depicting gillnet catches per average hour of exposition produces biased and incomparable results.

1. Introduction

Fish activity plays major role in the efficiency of passive fishing gear like gillnets and varies during the diel cycle. In order to explain diel activity, fish biologists have described fish species to be diurnal, nocturnal or crepuscular according to the period of the day in which they exhibit the highest activity (Helfman, 1993). The pattern of diel activity may change with season (Prchalová et al., 2006), turbidity (Reichard et al., 2001), predation pressure (Pettersson et al., 2001), age of the fish (Järvalt et al., 2005), breeding (Helfman, 1993), food availability or intraspecific competition (Reebs, 2002).

It is crucial to be aware of the diel activity pattern for reliable interpretations of gillnet catches. It is recommended to set gillnets as long a time as possible to ensure that the activity peaks of each fish species are sampled, while also ensuring they do not degrade and are protected from predators while being caught (CEN, 2005). To fulfill this requirement, gillnets should be and traditionally are set overnight. The catch per unit of effort (CPUE) is then expressed as catch per night. In cases of shortened or prolonged soak time, the CPUE should be expressed as catch per one hour of exposition (CEN, 2005). But how do we know that we cover the activity peaks of all target species and what catch per average hour of exposition actually reveals?

In order to answer these questions, we carried out a simple experiment with gillnets exposed for short periods of time from sunset to sunrise in two reservoirs. Both reservoirs have a stable fish community dominated by cyprinids (Prchalová et al., 2009a,b). The Římov Reservoir is deep and relatively clear while the Nové Mlýny I is shallow and turbid. Our aims and assumptions were:

i. To describe and model a general pattern of fish activity. We expected lower catches during the night and higher catches at dusk and dawn, as indicated by previous studies (Olin and Malinen, 2003; Olin et al., 2004; Vašek et al., 2009). We wanted to use the created model of fish activity for the definition of effective soak times and recommendations for gillnet sampling.
ii. To describe the pattern of fish activity for species caught. We assumed that the pattern would be different for diurnal and nocturnal species. Among the common European species, roach *Rutilus rutilus* (L.) (Hautala, 2008) and perch *Perca fluviatilis* L. (Zamora and Moreno-Amich, 2002) have been described as diurnal species while pikeperch *Sander lucioperca* (L.) (Brabrand and Faafeng, 1993) and ruffe *Gymnocephalus cernuus* (L.) (Ylönen et al., 2007) as nocturnal species.
iii. To describe the pattern of fish activity for young-of-the-year (YOY) and older fish. We hypothesized that the fish activity of YOY and older fish would be uniform, as it is driven by the twilight migrations between day and night habitats (Vašek et al., 2009).

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doi:10.1016/j.fishres.2009.12.011

iv. To describe the pattern of fish activity in turbid and clear water. We supposed together with others (Jacobsen et al., 2004; Andersen et al., 2008; Hazelton and Grossman, 2009) that fish would be more active under turbid conditions. Identification of prey in the turbid water is more difficult and increased activity can compensate for this situation (see Andersen et al., 2008).

2. Materials and methods

2.1. Study areas

Experiments were carried out in two reservoirs located in the Czech Republic, Central Europe. The Římov Reservoir is a deep canyon-shaped reservoir with a surface area 210 ha and maximum and average depths of 45 and 16 m, respectively. The trophic status is classified as eutrophy (Vašek et al., 2008). The fish community is represented mainly by cyprinids (family Cyprinidae), with roach *Rutilus rutilus* (L.), common bream *Abramis brama* (L.) and bleak *Alburnus alburnus* (L.) being the most abundant species. For details on reservoir characteristics and the residing fish community see Prchalová et al. (2009a). The fish biomass at the location of the experiment in the upper part of the reservoir was 201 kg ha^{-1} (horizontal hydroacoustic survey in August 2004; Draštík et al., 2008).

The Nové Mlýny I Reservoir is a shallow pond-like reservoir with a surface area of 528 ha and maximum and average depths of 4.3 and 1.8 m, respectively. The trophic status is classified as hypertrophy (Žáková et al., 2006). The fish community is represented mainly by cyprinids, with white bream *Blicca bjoerkna* (L.), roach *R. rutilus* (L.), bleak *A. alburnus* (L.) and common bream *A. brama* (L.) being the most abundant species (Prchalová et al., 2009b). The fish biomass in the location of the experiment in the upper part of the reservoir was 538 kg ha^{-1} (horizontal hydroacoustic survey in September 2008; Prchalová et al., 2009b).

2.2. Gillnetting and data analyses

Benthic, bottom mounted gillnets were used for the experiments. Gillnets were made according to the European standard EN 14 757 (CEN, 2005), i.e. with 12 mesh sizes in the range of 5–55 mm, knot to knot, each mesh size in panels 2.5 m long and 1.5 m high (Pokorny-site, Brloh, Czech Republic).

In the Římov Reservoir, the experiment was performed at a location close to the tributary (48°48′52″N and 14°28′50″ E), where the highest abundances of fish were found (Prchalová et al., 2009a; the maximum depth at the site was 9 m). Three anchored gillnets were exposed to a 1.6 m depth in the littoral zone from 19:00, 9 August 2008, to 7:00 the next day. Gillnets were cleared every hour during the exposition. It resulted in 36 individual samples. Sunset was at 20:37 and sunrise at 5:47.[1] The intensity of visible light was measured above the water surface in lx using the MDLX lux meter. The transparency measured as the Secchi depth was 100 cm (this reservoir is called clear in the text). The surface water temperature was 23 °C and the concentration of surface dissolved oxygen was 11.3 mg l^{-1}.

In the Nové Mlýny I Reservoir, the experiment was performed at a location close to the tributary, approximately 50 m from the shore (48°53′45″N and 16°32′33″E). Three gillnets were exposed to a 1.6 m depth from 16:00, 16 September 2008, to 9:30 the next day. Gillnets were replaced by new ones every half an hour during periods of high catches, i.e. from 16:30 to 20:30 in the evening and from 6:30 to 9:30 in the morning. During periods of lower catches, gillnets were anchored and cleared every hour. It resulted in 72 individual samples. Sunset was at 18:57 and sunrise at 6:35.[1] The intensity of visible light was measured as described previously. The transparency measured as the Secchi depth was 35 cm (this reservoir is herein called turbid). The surface temperature was 13 °C and the concentration of surface dissolved oxygen was 8.8 mg l^{-1}.

We did our best in order to bias the fish activity and our results by the study design in a minimal possible way. We tried to replace the survey gillnets as quickly and silently as it was possible to do not disturb fish more that it was inevitable.

All fish were identified to species. Standard lengths were measured with 5 mm accuracy in case of older fish. YOY fish were measured with 1 mm accuracy. Size ranges of YOY and age 1+ fish were defined according to a size-frequency distribution with the help of scale reading. The age groups of 1+ fish in white bream and bleak were used in analyses instead of YOY fish because of the absence of YOY of these species in catches at the Nové Mlýny I Reservoir. Small fish are highly underestimated in gillnet sampling (Prchalová et al., 2009c), thus we tested them only in cases where their numbers were high.

Catches per time intervals of the experiments are referred as 'fish activity' or 'activity' in the text.

The differences among catches in particular time intervals were tested using factorial ANOVA and Tukey HSD tests in STATISTICA (StatSoft). The nonparametric correlations were calculated using the Spearman correlation coefficients in STATISTICA (StatSoft). The models and figures were created using Mathematica software (Wolfram Research).

The catches in individual time periods were found to be independent on each other. This was proved by positive or zero correlation coefficients between following catch residuals. If the catches were dependent, the correlation would be negative—when the value was higher than the mean, i.e. the residual was positive, the value and the residual of the following catch should be negative and vice versa. However, this was not valid for our data sets. Thus, the ANOVA for independent samples was used.

3. Results

A distinct pattern of fish activity was found. In both reservoirs, the activity had evening and morning peaks with night plateau between peaks (Fig. 1). The average catches during the night plateau were similar in both reservoirs (Římov: 0.885 fish gillnet^{-1} 0.5 h^{-1}, SD 0.814; Nové Mlýny I: 0.970 fish gillnet^{-1} 0.5 h^{-1}, SD 0.749). The peak catches were around 13.2-fold (SD 8.7) and 13.8-fold (SD 6.2) higher than the average plateau catches in the Římov and Nové Mlýny I reservoirs, respectively. The heights of the evening and morning peaks were comparable in each reservoir.

The patterns of gillnet activity were similar in both reservoirs for all species and also for YOY and older fish, corresponding to the general activity pattern (Tables 1–4, Fig. 2). In the Římov Reservoir, all species and age groups tested were positively correlated with each other (Table 3). The exception was bleak, which was positively correlated only with the sum of all species. The reason was that bleak did not reach peak values during the evening peak of general fish activity and thus its activity pattern was not significant (Table 1). In the Nové Mlýny I Reservoir, all species and age groups tested were positively correlated (Table 4). The exceptions were YOY bream and age 1+ bleak, which were not positively correlated with other species. However, they were positively correlated with the sum of YOY fish and their older conspecific fish.

The activity pattern of the peaks and the night plateau was modeled separately by two independent mathematical models. The peaks were fitted using a quadratic model

$$y = a * x^2 + b * x + c \quad (1)$$

[1] Sunsets and sunrises were calculated using the spectral calculator at http://www.spectralcalc.com/solar_calculator/solar_position.php.

Table 1
Total catches of three gillnets in each time interval at the Římov Reservoir. Hours refer to the end of gillnet expositions. Values are related to all age groups excluding the row YOY and the column Sum YOY referring to the number of YOY fish. Superscripts show the level of significance of ANOVA tests for the comparison of time intervals.

Hours	Ruffe *Gymnocephalus cernuus*	Bleak *Alburnus alburnus*	Roach *Rutilus rutilus*	Bream *Abramis brama*	Perch *Perca fluviatilis*	Hybrid *Rutilus* × *Abramis*	Pikeperch *Sander lucioperca*	Gudgeon *Gobio gobio*	Sum	Sum YOY
20:00	7	6	8	1	6	0	0	0	28	10
21:00	68*	1	21*	16*	5	2	0	0	113*	36*
22:00	3	2	1	2	0	0	0	0	8	1
23:00	1	1	2	1	0	0	0	0	5	2
24:00	4	2	2	1	0	0	1	0	10	4
1:00	2	0	1	0	0	0	0	0	3	2
2:00	1	0	2	0	0	0	0	0	3	3
3:00	2	0	3	1	0	0	0	0	6	5
4:00	1	3	0	0	0	1	0	0	5	1
5:00	1	2	1	0	0	0	0	0	4	0
6:00	52*	25	21*	4	11*	1	1	0	115*	34*
7:00	3	28	0	1	2	0	0	1	35	4
Sum	145*	70^{NS}	62*	27*	24*	4	2	1	335*	
YOY	85*	0	7	0	9	0	1	0		102*

*$p < 0.05$, NS: not significant.

Table 2
Total catches of three gillnets in each time interval at the Nové Mlýny I Reservoir. Hours refer to the end of gillnet expositions. Values are related to all age groups excluding the row YOY and the column Sum YOY referring to the number of YOY or 1+ fish (the case of white bream and bleak indicated with ^{f}). Superscript shows the level of significance of ANOVA tests for the comparison of time intervals.

Hours	W. bream *Blicca bjoerkna*	Bream *Abr. brama*	Bleak *Alb. alburnus*	Pikeperch *San. lucioperca*	Roach *Rut. rutilus*	Carp *Cyrpinus carpio*	Ruffe *Gym. cernuus*	Perch *Perca fluviatilis*	Hybrid *Rut.* × *Abr.*	Asp *Aspius aspius*	Barbel *Barbus barbus*	Sum	Sum YOY
16:30	19	12	17*	5	14*	1	1	0	1	0	1	71*	17
17:30	45*	6	11	13*	11*	2	1	1	1	1	0	92*	15
18:30	77*	34*	7	4	2	5	1	2	0	0	0	132*	16
19:30	10	4	0	1	0	0	0	0	0	0	0	15	0
20:30	0	2	0	1	0	0	0	0	0	0	0	3	3
21:30	1	0	0	2	0	0	0	0	0	0	0	3	1
22:30	0	7	0	1	0	0	0	0	0	0	0	8	5
23:30	0	7	0	1	0	0	0	0	0	0	0	8	5
0:30	0	1	2	0	0	0	0	0	0	0	0	3	3
1:30	0	4	5	0	0	0	0	0	0	0	0	9	7
2:30	0	5	4	0	0	0	0	0	0	0	0	9	5
3:30	1	1	4	1	0	0	0	0	0	0	0	7	5
4:30	1	3	1	2	0	0	0	0	0	0	0	7	3
5:30	1	2	1	0	0	1	0	0	0	0	0	5	1
6:30	0	9	0	6	0	0	0	0	0	0	0	15	6
7:30	85*	27*	7	8	1	1	0	0	0	0	0	129*	16
8:30	106*	28*	21*	8	1	3	2	2	0	0	0	171*	29*
9:30	17	4	8	1	5	0	3	1	0	0	0	39	14
Sum	363*	156*	88*	54*	34*	13	8	6	2	1	1	726*	
YOY	44^{f*}	39^{NS}	33^{f*}	29*	3	0	3	0	0	0	0		151*

*$p < 0.05$, NS: not significant.

where x was time, y represented activity and a, b and c were parameters. Parameters were significant for both peaks and in both reservoirs (Table 5). Addition of another (cubic) term was not successful as it was insignificant. a parameters were similar between the evening and morning peaks, demonstrating the equal curvature of these two time-points.

The night plateaus were fitted using a linear model

$$y = m * x + n \quad (2)$$

Table 3
Spearman correlation coefficients of relationships between individual species caught during the experiment at the Římov Reservoir. Bold values are significant. The row Sum and column Sum YOY refer to the total number of fish of all age groups and to the total number of YOY fish, respectively.

	Bleak	Roach	Bream	Perch	Sum	YOY ruffe	SumYOY
Ruffe	**0.096***	**0.550***	**0.622***	**0.769***	**0.828***	**0.939***	**0.894***
Bleak		0.192	0.126	0.135	**0.450***	−0.012	0.041
Roach			**0.319***	**0.443***	**0.652***	**0.481***	**0.624***
Bream				**0.585***	**0.577***	**0.577***	**0.548***
Perch					**0.728***	**0.793***	**0.779***
Sum						**0.755***	**0.791***
YOY ruffe							**0.939***

*$p < 0.05$.

Table 4
Spearman correlation coefficients of relationships between individual species caught during the experiment at the Nové Mlýny I Reservoir. Bold values are significant. The row Sum and column Sum YOY refer to the total number of fish of all age groups and to the total number of YOY or 1+ fish (the case of white bream and bleak), respectively.

	Bream	Bleak	Pikeperch	Roach	Sum	YOY w. bream	YOY bream	YOY bleak	YOY pikeperch	Sum YOY
White bream	**0.531***	**0.680***	**0.549***	**0.590***	**0.835***	**0.734***	−0.050	0.170	**0.485***	**0.594***
Bream		**0.456***	**0.340***	**0.369***	**0.789***	**0.418***	**0.514***	0.051	**0.306***	**0.671***
Bleak			**0.343***	**0.625***	**0.740***	**0.700***	−0.023	**0.576***	**0.358***	**0.776***
Pikeperch				**0.310***	**0.573***	**0.496***	0.011	−0.088	**0.716***	**0.433***
Roach					**0.563***	**0.656***	−0.037	0.229	**0.394***	**0.535***
Sum						**0.672***	0.142	**0.292***	**0.464***	**0.782***
YOY w. bream							−0.062	0.107	**0.513***	**0.705***
YOY bream								−0.132	−0.075	**0.348***
YOY bleak									−0.193	**0.365***
YOY pikeperch										**0.542***

*$p < 0.05$.

where x was time, y represented activity and m and n were parameters. Parameters were insignificant in both reservoirs (Table 5). Thus it was better to use the average plateau catch (n) to describe plateau activity.

Intersections of peak models with the average plateau catch defined the duration of the peaks and plateaus: In the Římov Reservoir, the peaks lasted approximately 2 h, in the evening from 19:30 to 21:30 and in the morning from 4:30 to 6:30. The night plateau was 7 h long. In the Nové Mlýny I Reservoir, the evening peak lasted approximately 2 h and 40 min (16:15–18:55) and the morning peak was about 3 h and 5 min long (6:10–9:15). The night plateau was 11 h and 15 min long.

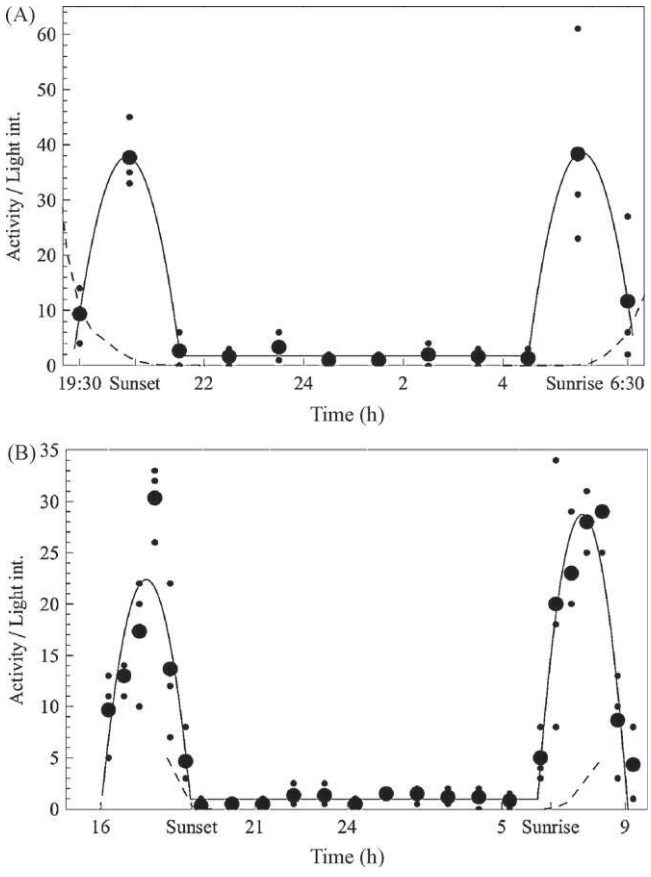

Fig. 1. Raw data on fish activity in the Římov (a; activity in fish gillnet^{-1} 1 h^{-1}) and Nové Mlýny I reservoirs (b; activity in fish gillnet^{-1} 0.5 h^{-1}). Larger circles are average values. Dashed lines represent light intensity in lx/100. Sunsets (Římov: 20:37, Nové Mlýny I: 18:57) and sunrises (Římov: 5:47, Nové Mlýny I: 6:35) are displayed in the X axis.

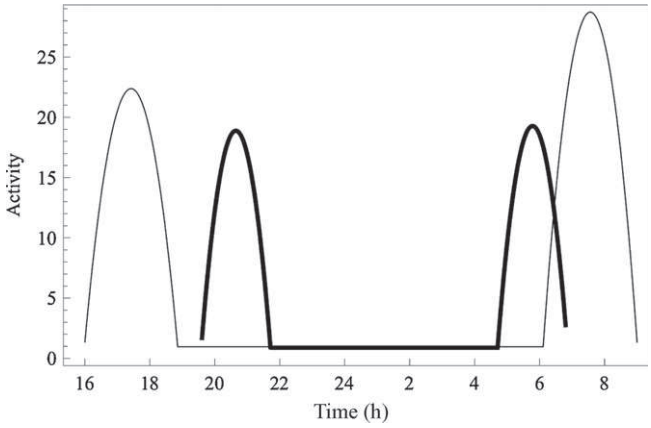

Fig. 2. The pattern of fish activity (fish gillnet^{-1} 0.5 h^{-1}) in the Římov (thick line) and Nové Mlýny I reservoirs (thin line).

When plotted against light intensity, sunset and sunrise (Fig. 1), the evening peak started 1 h and 5 min before sunset and lasted 55 min after it and the morning peak started 1 h and 20 min before sunrise and lasted 40 min after it in the Římov Reservoir. In the Nové Mlýny I Reservoir, the evening peak occurred completely before sunset and the morning peak started 20 min before sunrise and lasted 2 h and 50 min after it.

Table 5
Parameter statistics of the evening (parameters a–c with the number postfix 1) and morning (parameters a–c with the number postfix 2) peak models and the plateau models (m and n).

Parameter	Estimate	Standard error	t statistic	p Value	R^2
Římov					
a1	−31.667	3.559	−8.898	<0.001	0.932
b1	376.667	42.758	8.809	<0.001	
c1	−1082.330	126.366	−8.565	<0.001	
m	−0.114	0.230	−0.497	0.626	0.565
n	2.978	2.446	1.217	0.241	
a2	−31.833	9.866	−3.227	0.018	0.652
b2	960.167	296.028	3.244	0.018	
c2	−7201.670	2214.870	−3.252	0.017	
Nové Mlýny I					
a1	−10.405	2.520	−4.128	<0.001	0.533
b1	56.655	13.984	4.051	0.001	
c1	−54.750	18.020	−3.038	0.008	
m	0.070	0.040	1.7435	0.091	0.670
n	0.308	0.401	0.768	0.448	
a2	−13.191	2.681	−4.921	<0.001	0.638
b2	444.757	89.819	4.952	<0.001	
c2	−3720.370	750.818	−4.955	<0.001	

4. Discussion

This study revealed a consistent pattern of fish activity with peaks around sunset and sunrise and with very low catches during night. This pattern was similar in both reservoirs as well as in all species and age categories of fish. The gillnet determined fish activity was described using a combination of a simple model for peak activity and an empirically determined constant for low night activity.

To our best knowledge, fish activity has never been described in such detail as in this study. Vašek et al. (2009) described fish activity observed in 2 h intervals within a 46 h cycle. Olin and Malinen (2003) and Järvalt et al. (2005) compared catches of gillnets exposed for 4 h during a 24 h cycle. The same design was used by Olin et al. (2004), who further analyzed catches of gillnets exposed for 1 h, but only during four evening hours.

High fish activity at dusk and dawn and low activity at night corresponded well to active telemetric (Jacobsen et al., 2002, 2004; Zamora and Moreno-Amich, 2002; Hautala, 2008) and hydroacoustic (Lilja et al., 2003) studies, as well as to passive trapping (Baade and Fredrich, 1998) and gillnetting (Olin and Malinen, 2003; Olin et al., 2004; Vašek et al., 2009) studies on common European fish.

The pattern of fish activity was similar in clear and turbid reservoirs. The differences were in peak timing with respect to sunset and sunrise, and in peak duration. In the clear Římov Reservoir, the peaks occurred at sunset and sunrise. However, the highest activity in the turbid Nové Mlýny I Reservoir occurred before sunset and after sunrise, respectively. These differences were most likely caused by earlier decrease and later increase of light intensity in turbid water at sunset and sunrise, respectively. Activity peaks lasted longer in the turbid reservoir, which could be explained by the higher general activity of fish in a turbid environment (Andersen et al., 2008; Hazelton and Grossman, 2009). Also, it could be connected to a shift in diel activity pattern in varying water temperatures, as observed by Hautala (2008). During the experiments, the water temperature at the turbid reservoir was about 10 °C lower than that in the clear reservoir. Hautala detected higher dusk and dawn activity of roach during a time period with a water temperature of 10 °C in comparison with 20 °C (Hautala, 2008).

The fish biomass was 2.7-fold higher in the turbid reservoir in comparison to the clear one (Draštík et al., 2008; Prchalová et al., 2009b), which was reflected by the observed higher gillnet catches during peaks in the turbid reservoir (Fig. 2). However, fish activity at night was equal in both reservoirs (Fig. 2). This indicated that gillnets catch almost nothing during zero light intensity, irrespective of the fish density.

In all tested species and age categories (e.g., roach, bream, white bream, bleak, ruffe, perch, pikeperch, and YOY bream, YOY pikeperch, YOY ruffe, and age 1+ white bream and age 1+ bleak), the catches were higher during the evening and morning peaks of activity than during night. In view of fish activity, the nocturnal activities of ruffe and pikeperch were not proved. Experiments of Ylönen et al. (2007) with ruffe showed that this species was active during the night only in the absence of predator fish. When predator odor was present, ruffe decreased night activity considerably. Potential ruffe predators were present in both of the studied reservoirs, which could explain the very low night activity of ruffe in our study.

Positive correlations were found between activity patterns of YOY and older fish. This demonstrated that both age groups activated during the same periods overnight which corresponded to the twilight migrations between day and night habitats (Vašek et al., 2009). The exceptions from this pattern were YOY bream and age 1+ bleak in the Nové Mlýny I Reservoir. In the case of YOY bream, it was caused by insignificant differences in its overnight catches most probably due to low number of caught individuals. Age 1+ bleak showed significant differences between overnight catches, however, none of the night plateau values were significantly higher than the peak values. Higher number of observations would be needed to prove potential differences in activity level of young bream and bleak in the Nové Mlýny I Reservoir.

The observed pattern of activity could be biased by sampling design. In particular, low night catches could be caused by overfishing at the given locations followed by immigration of fish during the morning peak of activity. However, if gillnets caught all fish at the locations during the night, the activity pattern should demonstrate much slower decrease towards low night catches than it was observed (Fig. 1). Further, densities of fish at both locations reached thousands of fish per hectare (Draštík et al., 2008; Prchalová et al., 2009) and it was unlikely that catches of 164 and 335 fish (from the beginning of the experiment till midnight) in the Římov and Nové Mlýny I reservoirs, respectively, could deplete all potential gillnet catch. Finally, the successive catches were found to be independent thus representing separate samples of fish communities.

5. Conclusions

Important recommendations for gillnet samplings were established in this study. Based on this study and the earlier findings (Olin and Malinen, 2003; Olin et al., 2004; Järvalt et al., 2005; Vašek et al., 2009) it could be concluded that the overnight pattern of catching fish in gillnets is uniform for water bodies of different turbidity and fish density, as well as for different species and age categories. This universality simplifies the interpretation of gillnet results. The overnight soak time should always include all evening and morning peaks of fish activity, i.e. to set gillnets 2–3 h before sunset and lift them 2–3 h after sunrise. If the soak time is shortened in a manner so that a portion of or the whole peak is missed, the results will not be representative. Thus expressing the CPUE from shortened soak time per hour of exposition is incomparable.

Acknowledgements

The authors would like to thank Jája Svobodová, Jiří Blondák Jan, Martin Jankovský, Zdeněk Prachař, Lukáš Vejřík and Jan Zima for their help with field work. We also thank Hassan Hashimi for English language corrections and an anonymous referee for valuable comments. This study was supported by the CZ 0091 grant from Iceland, Liechtenstein and Norway through the EEA Financial Mechanism and the Norwegian Financial Mechanism.

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