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Overestimation of percid fishes (Percidae) in gillnet sampling

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Abstract

Overestimation of the number of percid fishes taken by gillnets was studied in eight reservoirs in the Netherlands and the Czech Republic during 1998–2006. Overestimation was defined as a higher proportion of percids (percids/(percids + cyprinids)) in gillnets than in the reference community (catches by seines on the same beach and night as the gillnet catches). In total, 97 pairs of catches were compared and overestimation was found in more than 80% of cases. The overestimation ranged from a few percent to more than 1,000%, being dependent on the proportion of percids in the fish community. Overestimation was highest in reservoirs with the lowest proportions of percids. Overestimation was proved for perch *Perca fluviatilis*, but not for pikeperch *Sander lucioperca* and ruffe *Gymnocephalus cernuus*. A correction factor was developed, for the proportion of perch in the gillnet catches, using an empirical cubic function. Analysis of the direct mechanisms by which fish were enmeshed in the gillnets showed that most fish were wedged, one quarter were gilled and only 1.5% were tangled. Percid species were relatively more frequently tangled and gilled than cyprinids but not to an extent that can completely explain the total overestimation. Furthermore, the overestimation was not caused by a higher probability of perch being retained in the gillnet, as was evident from an experiment with retaining perch and roach *Rutilus rutilus* in the gillnet. Overestimation of perch is most likely caused by a higher probability of them encountering the gillnet, in comparison with cyprinids, which is related to their greater activity during dusk and dawn.

Keywords: Gillnet; Seine; Percidae; Cyprinidae; Species selectivity; Perch

1. Introduction

Gillnets are typical passive gear, widely used by scientists for fish community estimates, but the passive nature of the gear is often associated with selectivity problems. Gillnets are only able to capture individual fish which are actively moving (Finstad et al., 2000) and this represents the first step in gillnet selectivity. When some part of a community or a particular species swims in a different way, or does not swim at all, estimates derived from gillnet sampling must be biased in comparison with the real composition of the whole community (Kurkilahti, 1999). For example, pike *Esox lucius* are usually inadequately included in gillnet catches due to their ambush behaviour (Holmgren, 1999). The next step in the selection process is the direct contact of a fish with the net and then retention of the fish in the net until the observers arrive. These steps could be expressed by the probability equation (Hamley, 1975):

$$P_{\mathrm{CAPTURE}} = P_{\mathrm{ENCOUNTER}} P_{\mathrm{CONTACT}} P_{\mathrm{RETAIN}} \quad (1)$$

Probability of encounter depends on the fish activity (Rudstam et al., 1984; Olin and Malinen, 2003), which is affected by water temperature (Linløkken and Haugen, 2006) and biotic interactions (Borgström, 1992; Bean and Winfield, 1995). Probabilities of contact and retention are related to net characteristics and to the means by which a fish is enmeshed in the net. Generally, three basic types of capture are considered

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(according to Baranov; Hamley, 1975): (i) wedged—when the fish is held tightly by the mesh around the body; most fish are caught in this way (Yokota et al., 2001); (ii) gilled—when the fish is prevented from backing out of the net by the mesh caught behind the gillcover; (iii) tangled—when the fish is held in the net by teeth, opercular spines, maxillaries, or other projections, without necessarily penetrating the mesh. In this respect, the morphology of the fish body is very important (McCombie and Berst, 1969; Pet et al., 1995; Reis and Pawson, 1999) and gillnets tend to be more efficient in capturing fishes adorned with external projections, teeth, etc. (Lagler, 1978). Eels *Anguilla* sp. are very rarely caught in gillnets (Hammar and Filipsson, 1985; Degerman et al., 1988; Rossier, 1997; Holmgren, 1999; Vetemaa et al., 2006); thanks to their smooth body morphology and motoric abilities. Tangling particularly has a very close association with the properties of the fish body, which may differ among families (McCombie and Berst, 1969; Reis and Pawson, 1999). For example, common European percid species (family Percidae), such as perch *Perca fluviatilis*, pikeperch *Sander lucioperca* and ruffe *Gymnocephalus cernuus*, possess structured body surfaces and have a relatively firm body structure (Kipling, 1963; Hamley and Regier, 1973). It has been reported that the selectivity curve of perch is positively skewed due to fish tangled by their spines and/or by their operculum (Jensen, 1986). Hamley and Regier (1973) described how, for walleye *Sander vitreum* (a congeneric species of pikeperch), a very spiny species, tangling can be as important a means of capture as wedging. A bimodal length frequency distribution derived from gillnet catches owing to tangling, has been described for Atlantic cod *Gadus morhua* (Hovgärd, 1996a,b; Hovgärd et al., 1999; Holst et al., 2002), for sole *Solea solea* (Madsen et al., 1999), for flathead mullet *Mugil cephalus* (Gray et al., 2005), a toothy species, *Glossobogius giuris* (Pet et al., 1995) and for dusky flathead *Platycephalus fuscus*, a species with a body characterised by prominent morphological discontinuities (large teeth, opercular spines, maxillaries; Broadhurst et al., 2003). These circumstances may result in a higher probability of percid species being caught and retained in gillnets compared with smooth-bodied fish such as cyprinids (Cyprinidae) or salmonids (Salmonidae) and further bias the species composition.

The main goals of this study were (i) to find out if there is a bias in the species composition derived from the gillnet catches, (ii) to describe the causes of potential bias in detail and (iii) to suggest a possible correction of the species composition data. For the first goal, we compared the fish species composition derived from gillnet catches with catches of a reference gear—beach seine. Both types of catches were made on the same night and on the same beach in order to minimize differences in their spatial distribution (Vašek et al., 2004). Regarding the second purpose of the study, we examined the ways that fish were captured in the gillnets in order to describe the catch mechanisms in detail and, in addition, we compared the retention probabilities of different families by conducting a simple experiment, observing the ratio of retained perch and roach *Rutilus rutilus* in our gillnets. Finally, we tried to find the best correction curve by means of least squares curve fitting.

2. Materials and methods

2.1. Study areas

Field work was carried out in reservoirs located in the Czech Republic and in the Netherlands.

The Římov, Želivka and Žlutice Reservoirs are canyon-shaped water supply reservoirs located on the Malše River (South Bohemia; 210 ha, impounded in 1978), on the Želivka River (Central Bohemia; 1432 ha, 1971) and on the Střela River (West Bohemia; 150 ha, 1968), respectively. The Nýrsko Reservoir (West Bohemia; 147 ha) is a rather wide water supply reservoir built on the Úhlava River in 1969. The residual open-cast mining pit Chabařovice (North Bohemia) is still filling, and its area reached 180 ha in the year 2006.

Dutch water-supply bankside reservoirs (Biesbosch area—Southeast Netherlands; De Gijster, 312 ha, 1982; Honderd en Dertig, 219 ha, 1974; Petrusplaat, 106 ha, 1974) create a cascade on the source river Meuse (Kubečka et al., 1998). Water in all these reservoirs is artificially mixed using strong aeration (Ketelaars et al., 1998). In contrast to the Czech reservoirs, which have natural shores and bottom, the Dutch ones are basin-shaped and all built from concrete. All three Dutch reservoirs are similar in terms of species composition (Kubečka et al., 1998; Prchalová et al., 2006) as well as in reservoir morphology (Ketelaars et al., 1998) so their results were combined.

2.2. Gillnet sampling

The Nordic type of multi-mesh, benthic gillnets (Appelberg et al., 1995) were used for the study (Pokorný-sítě, Brloh, Czech Republic). These gillnets consisted of 2.5 m long and 1.5 m high blocks of different mesh sizes that were sewn together to cover the full depth. Sixteen mesh sizes were used. Twelve mesh sizes (5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43 and 55 mm, knot-to-knot) were as given by European standard EN 14757 (2005) and there were also four larger mesh sizes: 70 and 90 mm (thread diameter 0.25 mm) and multifilament 110 and 135 mm (4 and 6 mm × 0.15 mm, respectively). The gillnets were anchored at a depth of 2–3 m of the littoral area for approximately 12 h overnight.

2.3. Beach seining

Night hauls with a 50 m long and 4 m high beach seine with a mesh size of 10 mm, were performed as described by Kubečka and Bohm (1991) on the same beach and during the same night as the gillnet sampling, and as close to the gillnets as possible without disturbing the fish. Generally, the distance between the seining and gillnetting sites was more than 50 m. The beach seine net was set at a depth of no more then 4 m and then hauled towards the shore. Seining is an active sampling method and, in principle, should capture all species equally well (Parsley et al., 1989). We ignored local exploitation of fishes by the gillnets before these fishes could be caught by the seine and vice versa.

The beach seine and gillnet sampling was carried out in August and September each year during the period 1998–2006.

2.4. Analysis of the capture mechanism

The ways in which fish were enmeshed were observed in 2003 and 2004 in the Římov and Želivka Reservoirs while the fish were being taken out of the nets. The fish were divided into four groups: wedged, gilled, tangled and other (usually fishes that fell out of the net before being classified into the previous categories). Differences between percids and cyprinids in their probability of being caught by different mechanisms of enmeshing were tested using χ^2-test in Statistica 7.1.

2.5. The retention experiment

Roach and perch were selected for the retention experiment, since they are the most abundant species from the families Cyprinidae and Percidae in the Římov and Želivka Reservoirs (Vašek et al., 2004). The experiment was carried out during 11–13 April 2005 in the Římov Reservoir and during 16–18 August 2005 in the Želivka Reservoir. Fishes for the experiment were taken from the beach seine catches conducted the day before the experiment and were stored together in a floating cage. The fish were divided into four size categories (<120, 120–140, 141–170 and >170 mm of standard length) relevant for the mesh sizes (16, 19.5, 24 and 29 mm, respectively) used for the experiment (benthic gillnet; each panel 25 m long and 1.5 m high; twine diameters as given by European standard EN 14757 (2005); installation depth 1.7 m close to the shore). Mesh size/fish size categorization was determined according to the gillnet catch database, of every mesh size, of the Institute of Hydrobiology. In total, 112 roach and 132 perch were marked by fin clipping. Every fish of a particular size category was manually placed just in front of the net of the relevant mesh size and released. Most of the fish immediately penetrated the net and were captured; only a small number of fish swam away without being caught in the net (21 roach and 22 perch). This enmeshing was carried out just before dusk and the net was lifted after dawn the next day.

In describing results of the retention experiment, we used four terms (Table 2): marked fishes were fishes that were fin-clipped; enmeshed fishes were fishes that were enmeshed in the net after releasing; escaped fishes determined fishes that escaped during the net exposure; retained fishes were those caught in the gillnet till the net lifting.

Differences in numbers of perch and roach retained were tested using the *t*-test for independent samples in Statistica 7.1.

2.6. Data analysis

Fishes smaller than 80 mm (∼0 + fishes) in gillnet and seine catches were removed from the data sets due to the different minimum mesh sizes in the gillnets (5 mm) and the beach seine (10 mm). The ratio of the number of percids to the sum of percids and cyprinids was the subject of the statistical analysis. In addition to the sum of all percid species, catches of individual species (perch, ruffe and pikeperch) were tested. A paired *t*-test for dependent samples was used to compare 97 pairs of catch ratios from gillnets and seines using Statistica 7.1. In the *t*-test for the sum of all percid species, pairs with gillnet and/or beach seine catches of less than 20 fishes were excluded. For example, seine catches in the Chabařovice pit in 2006 were very low due to reduced inshore migration under the full moon (Gaudreau and Boisclair, 2000; Horký et al., 2006). In the *t*-tests for individual species, pairs with zero gillnet and/or beach seine catches of given species were also excluded. Prior to the *t*-tests, the data were transformed using arcsin transformation (arcsin(square root of the value)). Species from other families, also included in the catches in insignificant amounts (Salmonidae, Esocidae, Coregonidae, Anguillidae, Osmeridae and Gasterosteidae), were omitted. A correction curve was fitted on unweighted data using least-square Marquardt–Levenberg fitting algorithm (Marquardt, 1963) implemented in SigmaPlot 2000 for Windows 6.10. Size distributions of roach and perch were compared using Mann–Whitney *U*-test in Statistica 7.1.

3. Results

Percid (perch, ruffe and pikeperch) and cyprinid species (roach, bream *Abramis brama* and rudd *Scardinius erythrophthalmus*) were the most important species in the reservoirs sampled and represented over 80% of the catches (Fig. 1). Only in the Želivka Reservoir did bleak *Alburnus alburnus* (Cyprinidae) comprise an important part of the community—27% of abundance in the seine catches. The following results on overestimation are based on 17,197 fishes from gillnet catches and 26,205 fishes from beach seines.

In total, 97 pairs of samples from gillnets and seines were analysed—81 pairs from the Czech reservoirs (Římov: 42; Želivka: 16; Žlutice: 7; Nýrsko: 8; Chabařovice: 8) and 16 pairs from the Dutch reservoirs (Fig. 2). Overestimation, i.e. a higher proportion of percids in gillnets than in seines was found in 74% of cases in the Římov Reservoir, 94% in the Želivka Reservoir, 86% in the Žlutice Reservoir, 75% in the Nýrsko Reservoir, 100% in the Chabařovice pit and in 75% of the Dutch samples. The overestimation of percid species in gillnets was verified by the significant results of the paired *t*-test (*t*-value 6.571, d.f. 96, $p < 0.001$).

Overestimation of percid species varied between the reservoirs sampled, being related to the proportion of percid species, especially perch, in the fish community (Fig. 3). Overestimation was lowest in the Dutch reservoirs (77% on average) where the share of percids was 61%, and highest in the reservoirs Žlutice (906%), Želivka (631%) and Chabařovice (541%) where the proportions of percid species were 9, 7 and 6%, respectively. The Římov and Nýrsko Reservoirs, with similar proportions of percids (18 and 21%, respectively), had overestimations of 219 and 192%, respectively.

Perch, pikeperch and ruffe were also tested separately for overestimation (Fig. 2). The proportions of perch were found to be significantly higher in gillnets than in seines (*t*-value 10.486, d.f. 88, $p < 0.001$) but the proportions of pikeperch were not significantly higher in the gillnets (*t*-value 1.628, d.f. 52, $p > 0.05$).

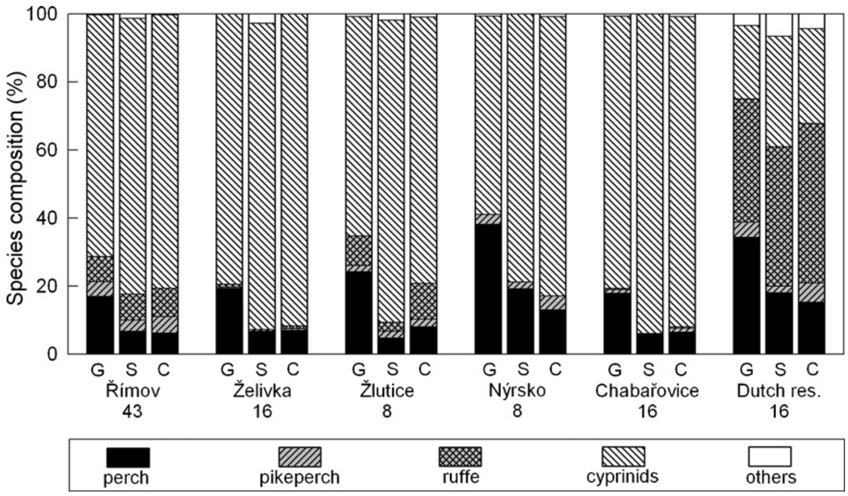

Fig. 1. Average species compositions in gillnet (G) and seine catches (S) in Dutch and Czech reservoirs. Column C corresponds to average species composition of gillnet catches corrected for overestimation of perch. Numbers below the name of each reservoir report to numbers of pair gillnet–seine observations that were carried out.

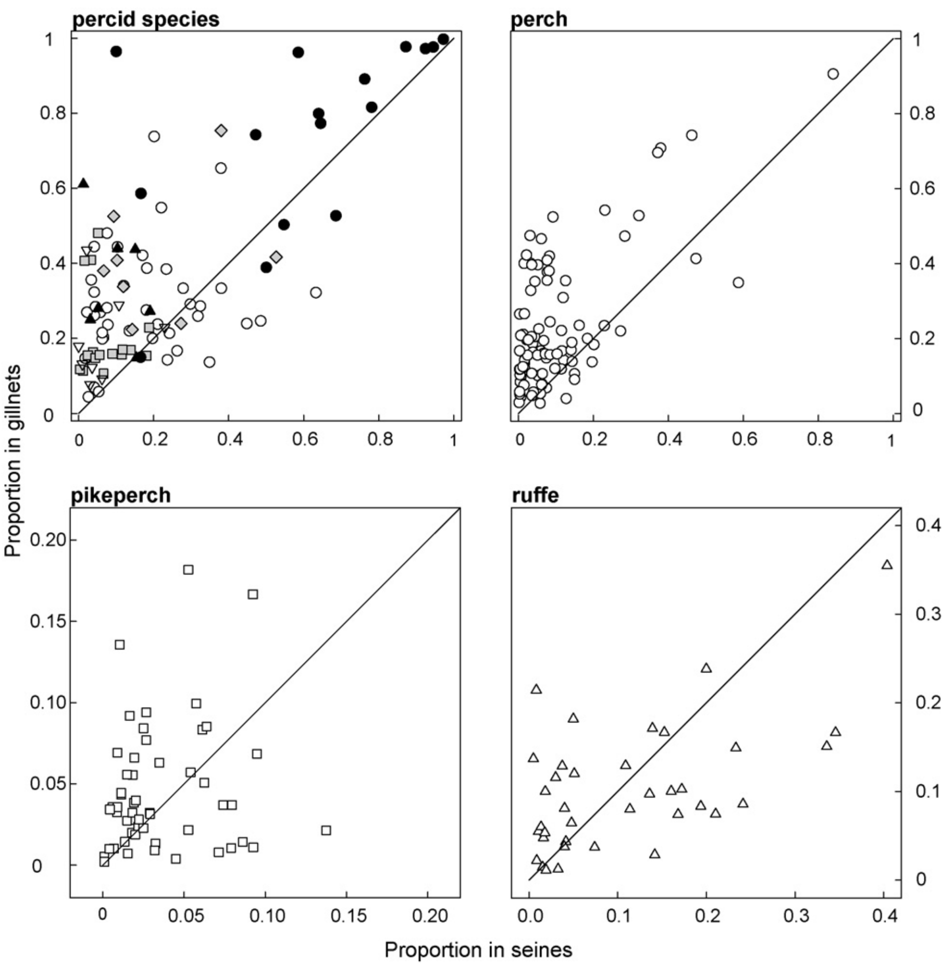

Fig. 2. Scatter plots of the proportions of percid species (perch, pikeperch and ruffe) in seine catches vs. gillnet catches. The diagonal line represents equal proportions in seine and in gillnets. In the first figure with all percid species, the open circles represent data from the Římov Reservoir; shaded squares, Želivka; black triangles, Žlutice; shaded diamonds, Nýrsko; open triangles, Chabařovice; black circles, Dutch reservoirs.

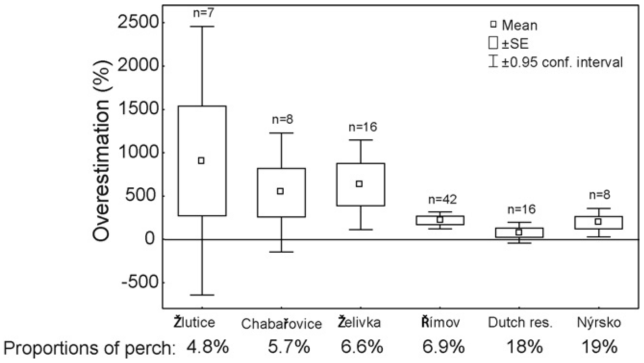

Fig. 3. Overestimation of percid species calculated as [100 × (proportion of percids/proportion of percids and cyprinids)$_{gillnets}$/(proportion of percids/proportion of percids and cyprinids)$_{seine}$] − 100. *n* above the plots refers to the number of observations. The reservoirs are shown in ascending order of the share of perch in the reference fish community (the row with %).

Proportions of ruffe were insignificantly slightly lower in the gillnets (t-value −0.654, d.f. 48, $p > 0.05$).

To correct the bias caused by overestimation, we developed a simple model for adjusting the proportion of perch in gillnets

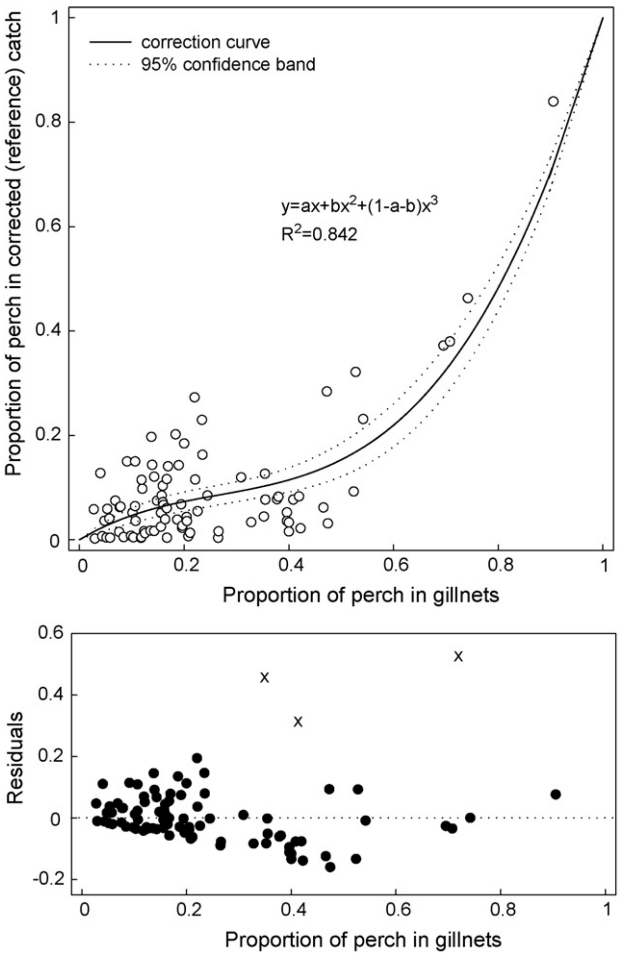

Fig. 4. Correction curve with 95% confidence limits for overestimation of perch in gillnets together with model residuals. Data represented by × marks were excluded from the model as outliers.

according to the cubic curve (Fig. 4):

$$y = ax + bx^2 + (1 - a - b)x^3, \quad R^2\ 0.842 \tag{2}$$

where x is the proportion of perch in gillnets, y is the corrected proportion, and a and b are the fitted constants 0.604 and −1.587, respectively. Data entered the correction as proportions (range from 0 to 1), not percentages. The proportion of perch should be corrected and then the composition of other species should be adjusted. After applying the correction to our data, the proportion of perch in gillnets and seines corresponded satisfactorily (Fig. 1). The best concordance was reached in Římov, Želivka and Chabařovice Reservoirs. At the Žlutice Reservoir, the perch were still slightly overestimated due to the fact that this reservoir exhibited the highest, and also the most varied, overestimation. On the other hand, the corrected proportion of perch was slightly underestimated in the Dutch reservoirs and in the Nýrsko Reservoir. These water bodies had the highest proportions of perch, where the cubic function went through only a few samples and thus the fit was weaker.

In total, 2205 fishes were analysed in order to observe the direct mechanisms of their enmeshing in the net. Most fishes (64%) were wedged, 24% were gilled and only 1.5% were tangled, while 10% of the fishes fell out of the net before being analysed (Table 1). A significant difference was found between percids and cyprinids in their probability of being caught by different mechanisms of enmeshing (χ^2-value 115.6, d.f. 5, $p < 0.001$). Percids were more often tangled and gilled than cyprinids (Fig. 5). Among the percid species, pikeperch was most frequently tangled.

During the retention experiment, 110 perch and 91 roach were enmeshed. Most of the enmeshed fishes were retained in the gillnet. The proportion of retained perch was lower than the proportion of retained roach: on average, 69 and 83%, respectively (Table 2), and this difference was significant (χ^2-value 9.87, d.f. 1, $p < 0.05$). The proportions of retained fishes were not equal across the size categories in both perch and roach. Most retained perch belonged to the size categories >170 and 141–170 mm. The highest proportions of retained roach were found in size categories 120–140 and 141–170 mm.

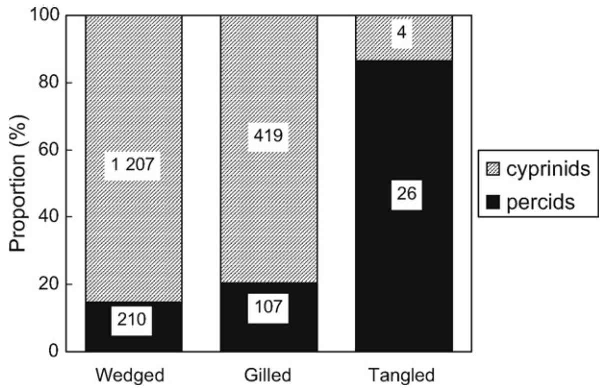

Fig. 5. Proportions (%) of percid and cyprinid species that were wedged, gilled and tangled in the gillnets. Numbers of fishes analysed are in boxes for relevant plots.

Table 1
Proportions (%) of the given species that were wedged, gilled, tangled and caught in other ways in the gillnet catches from the Římov and Želivka Reservoirs

Species	Scientific name	Wedged	Gilled	Tangled	Others	Sum
Percidae						
Perch	*Perca fluviatilis* L.	50	26	4	20	270
Ruffe	*Gymnocephalus cernuus* (L.)	57	28	8	7	113
Pikeperch	*Sander lucioperca* (L.)	43	22	30	4	23
Cyprinidae						
Roach	*Rutilus rutilus* (L.)	71	20	0	9	693
Bleak	*Alburnus alburnus* (L.)	61	30	0	10	680
Bream	*Abramis brama* (L.)	75	16	0	8	344
Asp	*Aspius aspius* (L.)	47	29	0	24	34
Hybrid	*Abramis* × *Rutilus*	57	39	0	4	23
Carp	*Cyprinus carpio* L.	94	0	0	6	17
Rudd	*Scardinius erythrophthalmus* (L.)	33	33	0	33	3
Gudgeon	*Gobio gobio* (L.)	50	0	0	50	2
Chub	*Squalius cephalus* (L.)	0	100	0	0	1
Pike	*Esox lucius* L. (Esocidae)	0	0	100	0	2
Sum		1417	526	32	230	2205

Columns sum give total numbers of fishes analysed.

Table 2
Results of the retention experiments with numbers of perch and roach marked, enmeshed, escaped and retained in each size category

Species	Size category (mm)				Sum	%
	<120 16[a]	120–140 19.5[a]	141–170 24[a]	>170 29[a]		
Perch						
Marked	34	30	19	49	132	
Enmeshed	27	24	17	42	110	100
Escaped/%	10/37	14/58	3/18	5/12	32	31
Retained/%	17/63	10/42	14/82	37/88	78	69
Roach						
Marked	19	44	37	12	112	
Enmeshed	19	40	23	9	91	100
Escaped/%	6/32	0/0	1/4	3/33	10	17
Retained/%	13/68	40/100	22/96	6/67	81	83

The column % gives average shares.
[a] Mesh size in mm.

4. Discussion

Comparison of 97 pairs of catches from gillnets and seines showed that overestimation of percids in gillnets does occur. Of three common European percid species—perch, pikeperch and ruffe, perch were primarily responsible for the overestimation. The observed proportions of pikeperch and ruffe were unbiased. Additional analyses and experiments revealed that mechanisms of capture and probability of retention in the gillnet cannot account for the full extent of the overestimation.

In this study, we compared active beach seines with passive gillnets. Such comparison may bring certain difficulties in interpreting results. However, we consider beach seining over fine and flat substrate as the most representative gear for sampling fish communities on shallow beaches. Research done by Říha et al. (personal communication, 2007) showed that 50 m long beach seine nets had negligible species selectivity. Further, the net of this length caught approximately 90% of abundance of the most important species (roach, perch, bream, bleak and ruffe) in the fished area. With this background, the results of comparison of gillnet and beach seines are reliable.

To the best of our knowledge, the reliability of proportions of perch in gillnet catches has not been discussed in scientific publications so far. The only hint is in the paper by Linløkken and Haugen (2006), where they compared Nordic multi-mesh gillnets with single-mesh series of gillnets against the background of a mark–recapture experiment in three Norwegian lakes. The proportion of perch:roach was, on average, 0.39 when using mark–recapture population estimates, 0.55 in the single-mesh series and 1.37 in the Nordic gillnets. The authors hypothesized that the greater catchability of perch may be due to different habitat use (perch dwell in certain sites in the littoral and roach are more pelagic than perch) and, consequently, roach is likely to encounter the gillnet in a more random fashion, hence avoiding the guidance effect of gillnets more frequently than perch. However, this hypothesis has an assumption that, in contrast to our study, gillnets are set perpendicular to the shore.

We found differences in the mechanisms of percid and cyprinid species becoming enmeshed in the gillnet. Only a limited number of studies have been dedicated to direct observations of enmeshing mechanisms (Hovgärd, 1996b), especially in coarse fishes. Hamley (1980) pointed out that perch are easily tangled and roach are usually only wedged or gilled. Our percids were more frequently gilled and tangled than cyprinids, but still the majority of all species were wedged, which is in accordance with the results of other studies (Winters and Wheeler, 1990; Henderson and Wong, 1991; Mattson, 1994; Santos et al., 1995; Hansen et al., 1997; Reis and Pawson, 1999; Yokota et al., 2001; Grant et al., 2004). Due to the low number of percids that were tangled, and the similar proportions of percids and cyprinids that were gilled, it could be concluded that the mechanism of enmeshing cannot importantly bias the gillnet catches towards a higher proportion of percid species in the reservoirs studied. However, we assume that in fish communities with a higher proportion of pikeperch, the bias caused by tangling of this species in gillnets could be considerable. Hamley and Regier (1973) concluded that for congeneric walleye tangling could be as important as wedging. On the other hand, Grant et al. (2004) found out that only 8 of 35 retained walleye were tangled and most of retained walleye were wedged.

Results from the retention experiment showed that the probability of retaining perch in gillnets was lower than that for roach. Consequently, differences in body structure between these two species most likely did not affect the probability of being retained in the gillnet. Probability of retention has been studied rarely so far, in spite of the fact that this topic is worthy of scientists' attention. For example, Grant et al. (2004) demonstrated, using an underwater camera, the very interesting fact that walleye had a relatively high ability of escaping from the gillnet after being temporarily wedged or tangled—29 of 147 walleye that contacted the gillnets escaped by that means and only 35 walleye were retained (46 fish swam through the net and 37 fish were never enmeshed in the net).

On the basis of these results, we hypothesized that overestimation of perch in gillnets would be most likely due to different probabilities between species of encountering the gear. As passive gear, gillnets depend to a very large extent on, and perhaps provide a measure of, the activity of fishes (Hammar and Filipsson, 1985; Sechin et al., 1991). Neuman et al. (1996) used gillnet catches as a direct measure of fish activity. The activity rate is, in other words, the probability of encountering the net. Activity, within the same time period, may differ among species and also among size classes. In European lentic waters, common percid and cyprinid species were found to be most active during the same time of day, with peaks of activity at dusk and dawn during a shift from daytime to night-time habitats (e.g. Kubečka, 1993; Vašek et al., 2000; Horppila et al., 2000; Olin et al., 2004). For example, average swimming speed increases markedly in perch at dusk and dawn (Zamora and Moreno-Amich, 2002). Helfman (1979) described this phase of faster activity as a flux, when swimming speed increased from 0.8 to 8.7 m min^{-1} in congeneric yellow perch *Perca flavescens* and the fish swam with fewer turns and stops. Similarly, the dusk and dawn activity also increases in roach and bream (Borcherding et al., 2002; Lilja et al., 2003; Jacobsen et al., 2004). Jacobsen et al. (2004) described the movement of roach as higher during dusk and dawn (>50 and >75 m h^{-1}, in clear and turbid lakes, respectively, August measurement) than during the daytime and, especially, during the night.

Rudstam et al. (1984) considered that the probability of encounter is directly proportional to the distance travelled by a fish during the sampling period. Anderson (1998) pointed out that the direct proportionality assumption would be appropriate only when swimming is strongly directional and individuals change direction infrequently, which could be applicable to pelagic species like *Coregonus* sp., which was used by Rudstam et al. (1984). In a situation when the fish change direction frequently or have a limited home range, Anderson (1998) recommended application of a random walk or diffusion model to describe encounter rates as a function of swimming speed and turning frequency. Distance travelled or number of encounters, in other words, increases with the fish swimming speed, which

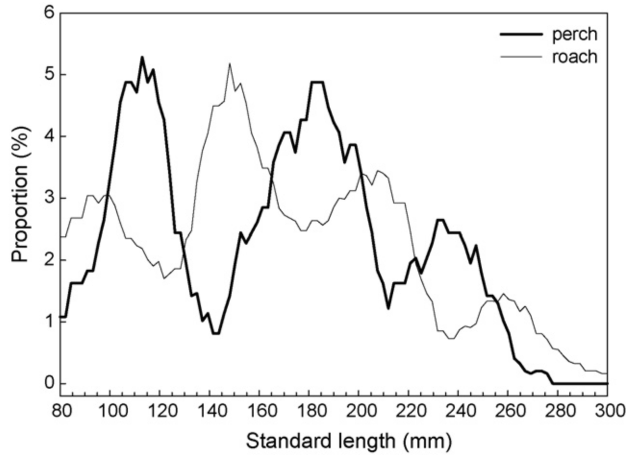

Fig. 6. Size distributions of perch and roach in gillnet catches in the Římov Reservoir in the years 2005 and 2006.

is dependent on the fish size (Rudstam et al., 1984; Anderson, 1998; Jepsen et al., 1999; Čech and Kubečka, 2002; Jacobsen et al., 2002; Porch et al., 2002). Thus, the overestimation could be evoked by different sizes of compared species. In this study, the size distributions of sampled perch and roach were comparable (Fig. 6; e.g. Římov 2005 and 2006—Mann–Whitney *U*-test, *U*-value 37 906, d.f.$_{perch}$ 122, d.f.$_{roach}$ 617, $p > 0.05$), so the overestimation of perch cannot be explained by a higher probability of encountering the gear due to a higher proportion of larger fish in the perch population than in the population of roach.

We conclude that, in the case of perch, a higher probability of encounter would be caused by higher activity rates and different behaviour during dusk and dawn in comparison with cyprinids. For example, according to underwater camera observations in the pelagic zone of the Římov and the Nýrsko Reservoirs, perch moved faster than roach (Čech et al., 2007) and as Hamley (1980), Finstad et al. (2000) and Pivnička (1987) discussed, stronger swimmers may penetrate into the gillnet more actively and effectively. Also Bean and Winfield (1995) and Winfield (1986) have shown that roach and rudd, but not perch, showed reduced swimming speeds in more structured environments and in the presence of pike as a predator. Similarly, Finstad et al. (2000) and Finstad and Berg (2004) concluded that the bimodal size distribution of Arctic char *Salvelinus alpinus* may be affected by different probabilities of encounter—cryptic antipredator behaviour of smaller fish reduced the swimming distance in the presence of conspecific cannibals which, on the other hand, may have increased the probability of encounter due to an active predacious feeding strategy. Further, the behaviour reactions when a fish encounters the gillnet may differ between perch and other species. So a simultaneous, comprehensive telemetry study of behaviour and activity of given species would be most helpful for unravelling the possible differences in encounter probability.

In this study we have shown that gillnets are species selective, even within the spectrum of commonly catchable species. Regarding its proportion in the community, perch is widely overestimated, most probably due to different activity and behaviour between perch and other species during dusk and dawn, which affects the probability of them encountering the gillnet. We have described the overestimation of perch by a cubic curve and thus provided a simple method for correcting the proportion of perch taken by gillnets. With this correction, we believe that gillnets themselves can provide a true picture of the species composition of a sampled fish community.

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