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Comparison of gillnet and trawl in diurnal fish community sampling

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Abstract

The fish community in a shallow, eutrophic lake basin in southern Finland was sampled diurnally with gillnets and trawl. The differences in species number, relative abundances and length distributions were considered. The fish density estimations differed notably depending on the gear and diurnal period. The most abundant species in the trawl catch, smelt, was almost totally missing from the gillnet catch. The proportions of perch, roach, white bream and asp were higher in the gillnet catch. Gillnets regularly underestimated the proportion of small (<10 cm) individuals in size distributions. The trawl probably underestimated the density of piscivores. In the two gears, diurnal changes, in both fish catch and species distribution, were considerable. Both trawl and gillnets are needed to get more reliable figure of fish communities in shallow eutrophic lakes.

Introduction

To successfully manage fisheries or lake environment, one needs to know the properties of the whole fish assemblage: species number, abundance and size distributions. To attain this, representative and reliable fish community samples are needed. However, none of the existing sampling methods give non-biased estimates of true values (e.g. Bagenal, 1979). Gillnets, widely used in fish monitoring, are passive and selective (Hamley, 1975; Backiel & Welcomme, 1980; Kurkilahti, 1999). The probability of a fish to encounter and retain in a net increases with swimming distance and speed, and discontinuities of body outline (e.g. spines). The size distribution estimates are skewed because small individuals move less and when encounter the net are caught less effectively due to slower speed and lower flexibility of small mesh sizes. A trawl, as an active gear, should be less selective producing more reliable estimates of species abundance and length distributions. However, the trawl is not useful in small, shallow or rough-bottom waters (Backiel & Welcomme, 1980). In addition, trawl catchability can be relatively low for large individuals (Bethke et al., 1999; Hjellvik et al., 2001), which may avoid the trawl but not gillnets (Richardson, 1956).

Further to gear problems, a fish community is under continuous spatial change even in the short run. Number of species have diurnal vertical or horizontal migrations due to feeding or predation avoidance (Bohl, 1980; Helfman, 1981). Fish activity changes diurnally (Helfman, 1981) and affects the encounter probability in passive gears.

Given the shortcomings of gears and the dynamic nature of fish assemblages, reliable results are attained only by standardising gears and fishing time, and by combining different methods. Studies including simultaneous diurnal fish sampling with different gears help us to understand when it is profitable to use a certain method, and how the methods can supplement each other. Such studies are, however, rare, as stated by Peltonen et al. (1999) and Pierce et al. (2001).

The aim of our study is to compare fish community data collected at different time of day with two gears: gillnets and the trawl. We will consider the differences in species number, relative abundances, and length distributions. We hypothesise that due to the passiveness of gillnets (1) the proportion of small individuals and species will be smaller in gillnets compared to the trawl, (2) the relative catch of spiny and actively swimming predators like perch and pikeperch will be higher in gillnets, and (3) the changes in diurnal activity will cause an ‘extra’ variation in gillnet catch not existing in the trawl catch.

Materials and methods

Study area was a basin (area 2.6 km^2, maximum depth 4.5 m) of eutrophic Lake Hiidenvesi (see Nurminen et al., 2003) in southern Finland (60°22′N, 24°12′E). Fish were sampled during 1 and 2 August 2001. During the study, water temperature was ca. 20 °C and Secchi depth 0.4 m. Weather was partly cloudy, including gusty NW wind and few showers. Sun raised at 05:00 and set at 21:55 h.

NORDIC multimesh gillnets (Kurkilahti et al., 1998) with 12 mesh sizes (5–55 mm, from knot to knot) and total size of 1.5×30 m were used. The trawl was a small pelagic pair-trawl with the theoretical opening of 1.5×5 m, and the cod-end of 3-mm mesh size. Gillnetting was conducted in four different depth zones: at surface or on bottom of 1.5–3 m or 3–4.5 m depth (Fig. 1). The trawl was towed with an average towing speed of 1.34 m s^{-1} in two depth layers: at the depth of 0–1.5 m from 1.5 m depth contour to another (layer area 175 ha), and at the depth of 3–4.5 m from 3 m depth contour to another (layer area 44 ha). The length of transects ranged from 500 to 800 m, and the total trawled area was 11.8 ha. Sampling was done in 4-h periods: 20–24, 00–04, 04–08, 08–12, 12–16 and 16–20 h. Gillnet sites and trawl transects were randomly selected. The gillnet sites were changed after each period, but the trawl transects were maintained. Total fishing effort was 72 gillnets and 19 trawl hauls (12 gillnets and three to four hauls per each 4-h period). The number of gillnets in a given depth zone was adjusted to the volume of the zone.

The catch of every gillnet and at least 30 kg subsample of every trawl haul was assorted to species, and then counted and weighed. All or at least 50 individuals of each species in one gillnet or haul were measured (total length, 1 mm accuracy). Bream (*Abramis brama*), white bream (*A. bjoerkna*) and blue bream (*A. ballerus*) smaller than 5.0 cm were treated as a one group, <5 cm *Abramis* sp., due to difficulties in assorting the battered trawl catch.

The trawl data were transformed to number ha^{-1} and kg ha^{-1} estimates. From every haul, fish catch per hectare was counted by dividing the catch by the hauled area [trawl width (5 m)×hauled length (500–800 m)]. Average catch per hectare in a given depth layer was calculated as the weighted mean with transects’ lengths as weights. To get the catch per hectare for the total study area, the catch per hectare of both depth layers was summed up after weighting with layer area.

Percentage values for each species were calculated from the transformed trawl data and from the total gillnet catch. As only few <5 cm fish were caught from gillnets, species’ shares in the catches excluding smelt (*Osmerus eperlanus*) and <5 cm *Abramis* sp. (altogether 96.5% of the total catch of <5 cm fish), were counted for both gears. From the latter data, differences between the gears were tested with non-parametric sign test having 12 observations (the percentages in trawl and gillnet catches of each depth layer in every period).

Before calculating mean NPUEs (number net^{-1} 4 h^{-1}) and BPUEs (g net^{-1} 4 h^{-1}), the gillnet data were $\ln(x+1)$-transformed due to positive skewness. Differences between time-periods in total NPUE and NPUEs of species were analysed with ANOVA, including the variables period and depth zone. These effects were not tested in the trawl catch due to the small number of replicates. The relation between the gillnet NPUE and the trawl number catch was tested with linear regression, and the diurnal concordance in the number catches of the gears with correlation analysis.

In both gears, relative length distributions (percentage value of the total n ha^{-1} or total NPUE) were calculated for the total catch and for the catch of bleak, which was the most abundant species when <5 cm fish were excluded. Before testing the between-gear differences, the >5 cm fish were divided into 5-cm length classes, and then analysed like the data of species’ shares.

Results

Total catches, number of species, and species distribution

The total catch was 690 kg and 52 540 individuals in the trawl, and 136 kg and 5996 individuals in gillnets. Altogether 14 species were caught; 13 by the trawl and 12 by gillnets (Table 1). Vendace (*Coregonus albula*) and eel (*Anguilla anguilla*) were not caught by gill-

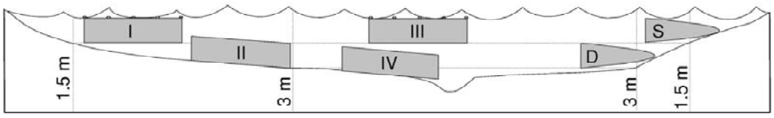

Figure 1. Sampling procedure. Depth contour of 1.5 and 3 m are shown. I – surface nets in 1.5–3 m depth zone ($n = 25$); II – bottom nets in 1.5–3 m depth zone ($n = 23$); III – surface nets in 3–4.5 m depth zone ($n = 11$); and IV – bottom nets in 3–4.5 m depth zone ($n = 13$). S – shallow hauls ($n = 13$) from 1.5 m depth contour to another; and D – deep hauls ($n = 6$) from 3 m depth contour to another.

Table 1. Trawl and gillnet catches and percentage shares of each species. BPUE and NPUE = g or n net^{-1} 4 h^{-1}. Weight$_2$ % and Number$_2$ % are percentage values without smelt and <5 cm *Abramis* sp. Species are listed in descending order of trawl weight catch

	Trawl	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl	Gillnet
	(kg ha^{-1})	BPUE	(n ha^{-1})	NPUE	Weight %		Number %		Weight$_2$ %		Number$_2$ %	
Blue bream	42.4	591	207	2.8	59.1	31.2	3.6	3.4	59.9	31.2	7.3	3.4
Bream	18.3	147	466	4.3	25.5	7.8	8.2	5.1	25.8	7.8	16.4	5.2
Bleak	6.3	493	1731	51.2	8.8	26.0	30.5	61.5	9.0	26.0	60.9	62.0
Pikeperch	1.7	169	376	2.8	2.4	8.9	6.6	3.4	2.4	8.9	13.2	3.4
White bream	1.1	235	47	13.9	1.5	12.4	0.8	16.7	1.5	12.4	1.6	16.9
Smelt	0.7	<1	1966	<0.1	0.9	<0.1	34.6	<0.1	–	–	–	–
Pike	0.4	9	1	<0.1	0.5	0.5	<0.1	<0.1	0.5	0.5	<0.1	<0.1
Abramis sp.	0.3	<1	872	0.7	0.4	<0.1	15.3	0.8	–	–	–	–
Asp	0.2	79	<1	0.2	0.3	4.2	<0.1	0.3	0.3	4.2	<0.1	0.3
Roach	0.1	105	4	3.2	0.2	5.5	0.1	3.9	0.2	5.5	0.1	3.9
Perch	0.1	54	4	3.0	0.2	2.8	0.1	3.6	0.2	2.8	0.1	3.6
Eel	0.1	–	<1	–	0.1	–	<0.1	–	0.1	–	<0.1	–
Ruffe	<0.1	10	8	1.1	0.1	0.5	0.1	1.3	0.1	0.5	0.3	1.3
Vendace	<0.1	–	<1	–	<0.1	–	<0.1	–	<0.1	–	<0.1	–
Rudd	–	2	–	<0.1	–	0.1	–	<0.1	–	0.1	–	<0.1
Total	71.6	1895	5682	83.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

nets, and rudd (*Scardinius erythrophthalmus*) was not caught by the trawl.

The species' distributions between the gears deviated clearly. In the trawl catch, the most abundant species by weight were blue bream, bream and bleak (*Alburnus alburnus*), but in the gillnet catch, they were blue bream, bleak and white bream (Table 1). Compared to the trawl, gillnets had smaller proportions of bream and blue bream (P values: 0.006 and 0.038, respectively) and higher proportions of ruffe (*Gymnocephalus cernuus*), roach (*Rutilus rutilus*), bleak, white bream and asp (*Aspius aspius*) (P values: 0.038, 0.040, 0.000, 0.000 and 0.070, respectively).

The differences in species' distributions were greater in the number catches than in the weight catches (Table 1). Smelt was the most numerous fish in the trawl catch, but only two individuals retained in gillnets. Also, small *Abramis* sp. were only sporadically caught from gillnets. When excluding smelt and <5 cm *Abramis* sp., gillnets had smaller proportions of pikeperch (*Sander lucioperca*), bream and blue bream (P values: 0.006, 0.006 and 0.038, respectively), and greater shares of ruffe, roach, bleak, white bream and asp (P values: 0.006, 0.040, 0.012, 0.000 and 0.070, respectively).

Effect of diurnal period on total number catch and the catches of species

The trawl estimate of fish density increased from the start, reached a peak at 04–08 period and decreased steadily towards the end of the sampling (Fig. 2A). Also, the gillnet catches changed periodically (ANOVA, $P = 0.006$), however, not similarly to the trawl. The clearest difference was during the darkest hours (00–04 h) when the trawl catch increased but the gillnet catch decreased. In this period, the trawl catch consisted mainly of smelt and <5 cm *Abramis* sp. (Fig. 3), and with these species omitted, the gillnet NPUE followed better the trawl estimate (Fig. 2A).

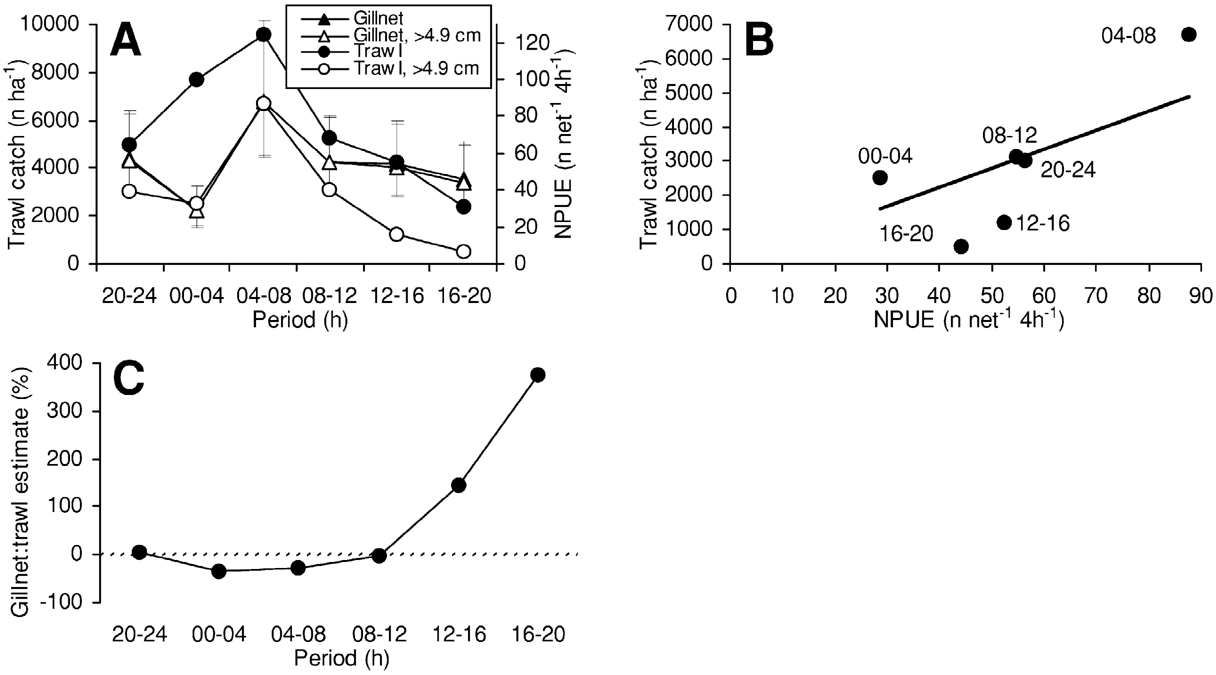

Figure 2. (A) Diurnal total catches by trawl and gillnet. >4.9 cm – catch excluding smelt and <5 cm *Abramis* sp. 95% confidence limits are shown in gillnet catches; (B) relation between gillnet NPUE and the trawl number catch (both excluding smelt and <5 cm *Abramis* sp.): $y = 55.972x$ ($r^2 = 0.529$, $F = 5.620$, $P = 0.077$). Numbers above the dots refer to sampling periods; (C) diurnal deviation (%) between the gillnet density index (from above equation) and trawl density estimate.

The gillnet NPUE predicted ca. 50% of the variation in the >5 cm fish density estimations by trawl (Fig. 2B). Clearest deviations between the gillnet density index (from the regression model in Fig. 2B) and the trawl density estimate were in the periods 12–16 and 16–20 h, when the gillnet index was high (Fig. 2C), mainly due to the big catch of bleak (Fig. 3).

The gillnet NPUEs of pikeperch, white bream, bream and blue bream varied significantly between the time periods (ANOVA, P values: 0.003, 0.073, 0.000, and 0.000, respectively). The catch development of bleak, white bream, bream and blue bream correlated significantly in the gears ($r^2 = 0.482$, 0.812, 0.840 and 0.625, respectively). The peak catch of these species was in the 04–08 period (Fig. 3). Diurnal trends in the pikeperch catch were different between the gears: the trawl catch was highest in 00–04 and 04–08 periods and the gillnet catch in 20–24 and 16–20 h periods. The diurnal trawl catch of ruffe had a clear peak in the 00–04 period. The ruffe NPUE did not vary significantly, though the NPUE in the daytime (08:00–20:00) seemed to be lower. The trawl catch of <5 cm *Abramis* sp. had two peaks in 00–04 and 12–16 periods, but the gillnet catch did not vary diurnally. The trawl catch of smelt was highest in the night time (00:00–08:00).

Length distributions

Of the total trawl number catch, <5.0 cm individuals comprised 51%. The corresponding value in the gillnet catch was only 1% (Fig. 4A). With the size class <5.0 cm excluded, the overall length distribution of the two gears still differed: gillnets had lower proportion of the length class 5.0–9.9 cm ($P = 0.038$) but higher share of the length class 10.0–14.9 cm ($P = 0.000$). In the bleak size distribution (Fig. 4B), gillnets had lower proportion of the small size class (<10.0 cm) and higher share of the large size class (>9.9 cm) compared to the trawl ($P = 0.032$ in both cases). However, the peaks in the length distribution were approximately on the same locations.

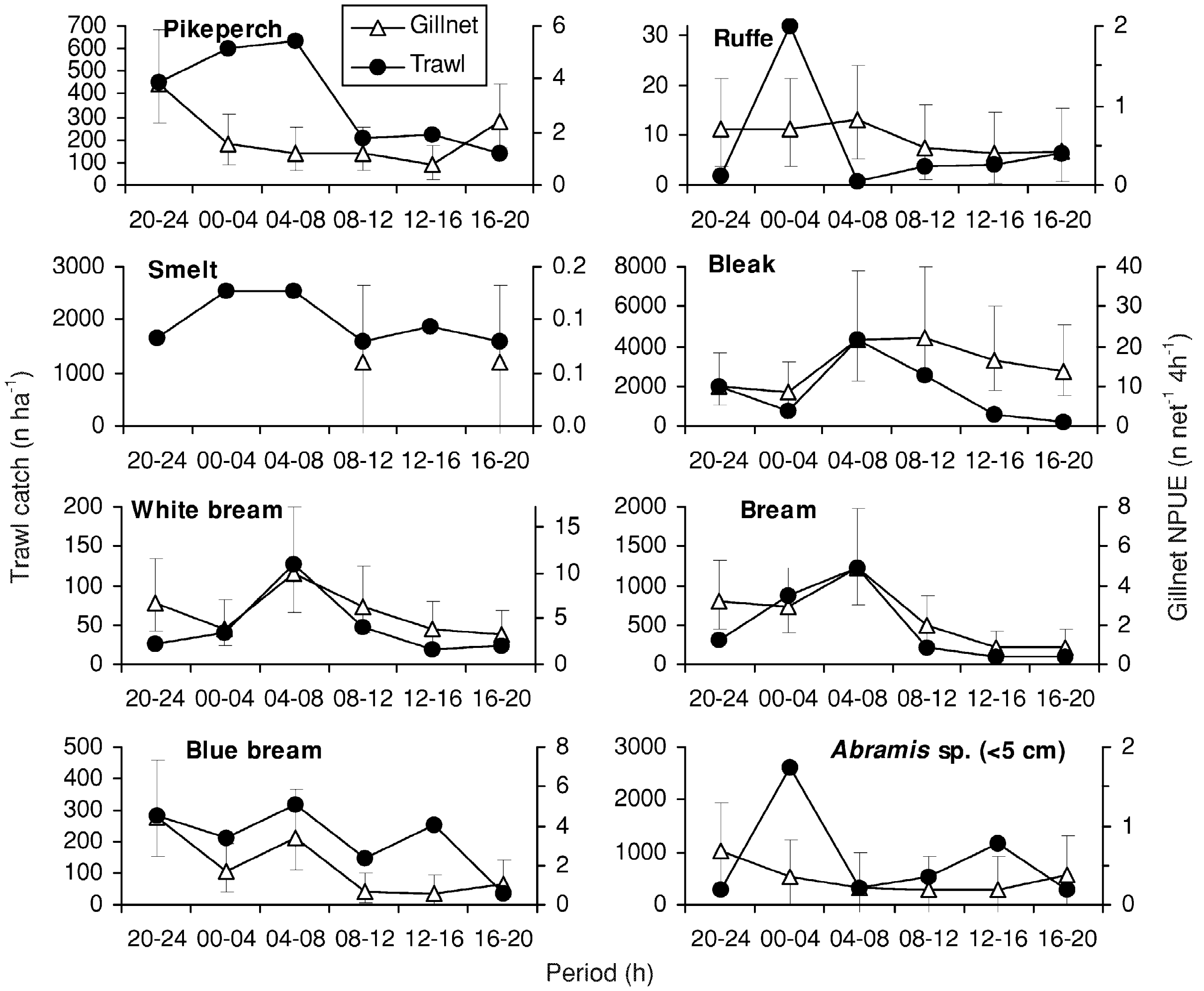

Figure 3. Diurnal catch of most abundant species by trawl (n ha^{-1}) and gillnet (n net^{-1} 4 h^{-1}). 95% confidence limits are shown in gillnet catches.

Discussion

As assumed, the estimates of fish density, species composition and size distributions can differ notably depending on the sampling method and time. In this study, we found that (1) the most abundant species in the trawl catch, smelt, was almost totally missing from the gillnet catch. In the catch of >5.0 cm fish, the trawl had higher proportions of bream and blue bream, and lower proportions of other fishes compared to gillnets, (2) in the size distributions, gillnets generally gave lower estimates of the proportion of small (<10.0 cm) individuals, (3) the diurnal changes in the density estimates were considerable in both gears. In the daytime, the trawl density estimate was much lower than the gillnet density index suggested.

The main reason for the between-gear differences was likely the gillnet selectivity over fish size and activity. The catchability of <5.0 cm fish in Nordic gillnets appeared to be very low. The main difference in the total size distribution was due to the fact that the smelt size (mean 4.2 cm) was so small that they swam through the smallest 5-mm mesh panels of the gillnets. Peltonen et al. (1999) also found gillnets not suitable for smelt stock monitoring. Correspondingly, the relatively low number share of pikeperch in gillnets may be due to the small mean size (5.8 cm) of the pikeperch stock on the basis of the trawl catch. As smelt and <5 cm *Abramis* sp. excluded, the shares of asp and perch, an active predator and a spiny fish (Döner et al., 2003), were still higher in gillnets. This could be due to the high possibility for the former to encounter a net and for the latter to retain after encountering (Hamley, 1975). The relatively small weight catch of bream and blue bream in gillnets could be due to low catchability for large specimens as the biggest mesh size was only 55 mm (Psuty & Borowski, 1997). It should be pointed out, that the comparison of proportions is problematic because the share of a given species is dependent, not only on the catch of the species, also on the catch of other species.

Secondly, the trawl efficiency may have been relatively low in the beginning and at the end of the transects. After the start of towing from the 1.5 or 3 m depth contour, the catching efficiency of the trawl could have been low due to the delay in reaching the optimum catching performance (Backiel & Welcomme, 1980). The low catchability near the 1.5 m depth contour could be one reason for the small proportions of some species in the trawl catch. The gillnet number catch of perch, white bream and roach was mainly (96, 91 and 96%, respectively) caught from the shallow areas (1.5–3 m).

Thirdly, some fish may have avoided or escaped from the trawl. Only four asp were caught by the trawl and 16 by gillnets. Four large perch (>19.9 cm) were caught by gillnets but none by the trawl. Corresponding values for pikeperch (>19.9 cm) were 57 individuals in gillnets and 52 in the trawl. Given the nine times higher total number catch of the trawl, it seems not likely that high activity or spiny body form (see above) of these species would be the only reasons for the higher numbers in gillnets. It may be that the trawl had underestimated the density of these piscivores. Bethke et al. (1999) and Hjellvik et al. (2001) also found that large individuals may avoid a trawl. However, for bream and blue bream, the other 'big fishes' of the present study, the trawl catch of >19.9 cm length classes was several times higher than the gillnet catch. The trawl avoidance of these species may have been ineffective due to slower movement or weaker vision.

Fourthly, in the deepest areas, the trawl moved slightly above the bottom, and some fish oriented in this environment may have avoided it. This could be one reason for the relatively low proportion of ruffe in the trawl catch.

The diurnal variability in the catches of both gears could have been induced by several possible reasons. The fish assemblage in the study area possibly changed due to the horizontal migrations from the littoral area to deeper areas. According to Bohl (1980), juvenile cyprinids migrate from littoral area to open water at the night time because of lower predation risk from visual predators. This was also indicated in our study, as the trawl catches of small *Abramis* sp. were highest during the darkest hours. Some fishes have diurnal vertical migrations, staying on the bottom by day and feeding above the bottom in the night time. Considering that the trawl moved slightly above the bottom, it seems that the trawl efficiency for ruffe was highest in the 00–04 period causing the peak catch. In addition, light-related changes in gear catchability may affect the catches because both gears are easier to avoid in good light conditions (Hamley, 1975; Buijse et al., 1992). This could be one reason for the lower trawl catch during the daytime. However, the turbidity in the study lake was high, reducing the possibility of visual avoidance.

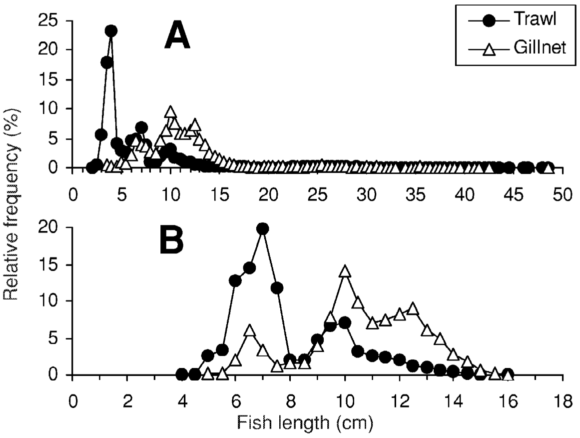

Figure 4. Total (A) and bleak (B) length distribution in the trawl and gillnet catch.

On the basis of our results, the reliability of gillnet NPUE as an index of fish density depends on the structure of fish community. When sampling fish communities consisting largely of species like smelt and/or small individuals, gillnets produce unreliable density indexes. In our study, however, when smelt and <5 cm *Abramis* sp. were excluded, the gillnet NPUE followed quite well the trawl fish density estimate. Other factors affecting the gillnet NPUE include fish activity, visual avoidance, and the duration of sampling. In this study, the high gillnet density index compared to the trawl estimates in the daytime, is likely due to high fish activity. Visual avoidance will more likely skew the results in clear water (Hamley, 1975; Hansson & Rudstam, 1995). The long duration of gillnetting may also decrease the value of gillnet NPUE as a density index (Minns & Hurley, 1988). In the present study, the turbid water and short gillnetting time probably prevented a notable decrease in gillnet catchability.

It should be considered that the trawl density estimate might have been biased by several factors. The catch of the earlier hauls could have affected the catch of the later hauls. However, the total trawl catch, 52 540 fish, was small compared to the estimated total fish number in the study area (5682 ind. $\mathrm{ha}^{-1} \times 260$ ha=1 477 320). If the trawl catch had decreased the overall fish density, it should have decreased the gillnet catch as well, which was not the case. Instead, the high gillnet catch refers to high fish activity. Thus, as every trawl transect had 4 h for filling before the next haul, the effect of the earlier hauls to the later hauls should be small. Finally, the width of the trawl opening when towing is only approximately 5 m, and some fish may escape after entering the opening. The significance of the latter factor is difficult to evaluate.

As a conclusion, neither a trawl nor gillnets alone are sufficient to get an extensive sample of a fish community in a lake like Hiidenvesi. To get information of juvenile fish in deeper areas one needs to use a trawl; to get samples of piscivores or when sampling in shallow areas it pays to use gillnets. The catchability of the Nordic multimesh gillnet is very low for smelt and <5 cm size fish, and this should be noted when using the Nordic nets in standard fish surveys.

Acknowledgements

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