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Electrofishing versus gillnet sampling for the assessment of fish assemblages in large rivers

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With 4 figures and 4 tables

Abstract: During three consecutive years, two fishing techniques were used to sample fish assemblages in a large river (River Meuse, Belgium). In order to sample both pelagic and benthic species, electrofishing was used along the river banks while gillnet leadlines were placed on the bottom of the main channel. Electrofishing sampled more species (up to 22 species) but principally small individuals (young of the year or small-size species), while gillnet sampled fewer species (up to 16 species), but larger individuals. Capture variability of species richness was lower with electrofishing (CV = 16.6 %). However, gillnet sampled some species (e. g., *Abramis brama*) better than electrofishing. In order to evaluate the influence of fishing gear on the proportion of species belonging to the different ecological guilds, values of some biological parameters (number of native species, number of tolerant species, etc.) were calculated on the electrofishing and gillnet data. Gillnets caught principally tolerant individuals (i. e. fish belonging to species that are classified as tolerant to water, habitat and chemical degradation) (88 %), but fewer "indicator species" (i. e. species that are indicators of good ecological quality). Such differences in guilds collected by the different gears indicate that consistent methods are needed to make assessments.

Key words: electrofishing, gillnet, fish assemblage, fish community, large river.

Introduction

River systems throughout the world have been disturbed by a wide variety of human activities. Large rivers in particular have been subjected to dramatic physical alterations. These alterations have reduced habitat heterogeneity within the river channel, ultimately reducing the diversity and abundance of ri-

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verine fish assemblages (Welcomme 1995, Madejczyk et al. 1997). The open nature of large river ecosystems, their diversity of physical habitat types, the differences in fish behaviour and environmental conditions (often extremely variable) contribute to inaccuracies in quantitative sampling of large river fish assemblages (Penczak & Jakubowski 1990). Indeed, the structure and species interactions of large river fish assemblages are generally less known than those from lakes or small and medium size rivers. Sampling methodologies in large riverine systems are less well developed than those used in other freshwater aquatic systems. Among the large choice of existing gears, each collecting method is likely to have some bias on selectivity for different taxa or size ranges (Harvey & Cowx 1996, Rulifson 1991, Growns et al. 1996, Pusey et al. 1998), morphology and behaviour (e. g., solitary or schooling species). Moreover, no single type of gear was found suitable for quantitative sampling in all large river habitats (Casselman et al. 1990), and the use of several gear types broadened the information obtained (Rulifson 1991). Moreover, the combination of several techniques allows the sampling of both pelagic and benthic species present in the river. Both gillnetting and electrofishing techniques have their own advantages and constraints in large rivers.

Gillnetting methods are generally not suitable for fast-flowing waters, where there are obstructions in the river, or where extensive weed growth occurs. Although gillnets are widely used as a research tool to sample fish populations, they are very selective (Hamley 1975) and tend to underestimate species displaying reduced external projections or hard structures, those exhibiting a more sedentary life-style, and the smallest individuals of a given species (Rulifson 1991). To reduce this effect of size selectivity, it is strongly recommended to use experimental gillnets with panels of varying mesh size.

Several authors consider electrofishing the most adequate method for describing assemblage structure (Zalewski & Cowx 1989, Casselman et al. 1990, Persat & Copp 1990, Growns et al. 1996, Simon & Sanders 1999). Electrofishing may be applied successfully in small streams and rivers but in large rivers a disproportionately large amount of effort is required to make small catches of fish. Moreover, electrofishing is not without bias either. Galvanotaxic and galvanonarcotic responses vary among species and size classes within species (Pusey et al. 1998), and electrofishing efficiency varies with physical or chemical characteristics of streams (e. g. conductivity, temperature, stream depth and width) or swimming behaviour of species within an electric field (Casselman et al. 1990). Some studies have shown that relatively high proportions of sampled fish sustain skeletal injuries, reduced fertility, physiological and behavioural disturbances. However, the incidence and severity of electrofishing damage is partly related to the type of equipment chosen and the waveform produced, and compared to other methods, electrofishing constitutes the least harmful and selective, and the most cost-effective method.

Based on these statements, several authors (Casselman et al. 1990, Simon & Sanders 1999) suggested a combination of gears involving at least electrofishing, to better assess fish assemblages in large rivers. While some authors underline this as an absolute necessity, few have actually used different sampling techniques (Bramblett & Fausch 1991, Osborne & Wiley 1992, MacLeod et al. 1995, Hay et al. 1996, Angermeier et al. 2000, Gammon & Simon 2000, McCormick et al. 2001).

The River Meuse is the largest river of Belgium. However, apart from the study of Philippart et al. (1988), the structure of its fish assemblages has been poorly investigated. The implementation of the recent Water Framework Directive published by the Council of the European Communities (2000/60/EC) requires the regular fish monitoring, including large rivers for which the question of sampling representativeness is still open. Indeed, except for the paper of Growns et al. (1996), who compared fish assemblages sampled with electric fishing versus gillnetting in Australian rivers and, Vaux et al. (2000) who compared in lakes, to our knowledge, no study has previously been devoted to this important issue. Moreover, despite the large set of literature dealing with comparisons among fish sampling methods, most of the available studies focused on species-specific or species richness comparisons. Although biological characteristics of fish assemblages are central in fish-based index calculations, functional metrics have remained poorly examined.

The objective of this study was to determine and compare, in the River Meuse, the effectiveness of electrofishing and gillnet sampling. Comparisons were made not only in terms of species richness, relative abundance, and size class, but also on different functional parameters currently used in fish-based indices (e.g. Angermeier & Karr 1986) and based on fish guild classifications. As a result, both ecological and management implications of the two fishing techniques were investigated.

Study area

The River Meuse rises in eastern France and flows through Belgium and The Netherlands, where it meets the lower Rhine, forming the Dutch Delta, which opens into the North Sea. The river's total length is 925 km and its catchment area is 36 011 km^2, 40.7 % of which lies in Belgium (Descy 1987). The Belgian stretch of the Meuse once had a slope of 0.23 ‰. During the last 150 years, the river has become increasingly canalised (Philippart et al. 1988). Fifteen navigation dams are located on the River Meuse within Belgium. As a consequence, the River Meuse, which was classified as a barbel zone in Huet's (1949) zonation study, now displays the main characteristics of a bream zone (slow flowing, width of 100 m). The mean annual water temperature is about 16 °C, ranging seasonally from 3–4 °C in January to 25–26 °C in August (Micha & Pilette 1988).

This study was carried out at the Heer and Hastiere reaches, located at 478 and 488 km from the spring, respectively. The mean river channel is 3.5 m deep (5 m in the centre and 1.5 m along the banks) and 100 m wide. The reach is weakly affected by anthropogenic influences, in contrast to sections downstream of the confluence with the highly polluted River Sambre, located 100 km below the sampling areas.

Materials and methods

Fish sampling

From April to September in 1998 to 2000, 36 samples (18 by boat electrofishing and 18 by bottom gillnetting) were taken from the River Meuse, 8, 16 and 12 in 1998, 1999 and 2000, respectively. Electrofishing was carried out in an upstream direction along the banks with a generator set consisting of a 3 KW alternator delivering a continuous current (300–400 V at 5–6 A); the cathode floated at the rear of the boat. Only one hand-held electrode, two dipnetters and one boat driver were used. Twelve habitats of 50 m length representative of the reach diversity were sampled. Gillnetting was performed with a set of 7 gillnets of different mesh sizes, (length: 50 m, height: 2 m, mesh size: 10 to 70 mm and yarn size: 0.14 to 0.25 mm). Gillnets were fished with leadlines on the bottom of the main channel for two hours. To exclude temporal variability, both techniques were used at the same dates and in the same river stretches. Sampling occurred in daylight from 09.00 to 14.00. Immediately after sampling, large and medium size specimens were identified, individually measured (to the nearest mm), weighed (to the nearest g) and macroscopically observed to assess health status. When the catch was large (more than 200 individuals of a particular species), the whole catch of those species was weighed. A sub-sample was taken and counted; and thereby the number of fish was calculated.

Data analysis

As the catch data from two sampling methods were not directly comparable in terms of number of individuals, comparisons were based on species richness and relative abundance and biomass.

Monte-Carlo simulation models were used to examine the relationships between species richness and number of samples. These simulations generated 1000 collections of n randomly combined samples. One thousand values of richness were computed. Mean value and standard deviation for these 1000 collections were computed for each value of n. A linear regression analysis was used to model the relationships between expected richness (S) and number of samples (Gleason 1922):

$$S = a + b \ln n$$

T-tests determined whether regression coefficients (a and b) varied among sampling methods.

Results

Species richness and composition

A total of 23 species were caught in the River Meuse from 1998 to 2000 (Table 1). Twenty two species were collected by electrofishing, but only 16 were caught by gillnet, 15 of which were common to both fishing gears. The mean number of fish species caught by electrofishing (mean ± SD = 12.6 ± 2.1 species) was significantly greater (t test, $P < 0.001$) than that collected by gillnet (8.2 ± 2.6 species). Differences of species richness between electrofishing and gillnets were mainly due to species representing about 5 % of the total abundance of sampled fish (Fig. 1a).

Table 1. Species list, code and guilds (habitat, reproductive and trophic) of 23 species caught during the study. Bent: benthivores; Herb: herbivores; Insv: insectivores/invertivores; Omni: omnivores; Pisc: piscivores; Lith: lithophils; Phli: phytolithophils; Phyt: phytophils; Poly: polyphils (non-specialist); Psam: psammophils; Ostr: ostracophils; Lib: limnophilic benthic; Liw: limnophilic mid or surface water; Rhb: rheophilic benthic; Rhw: rheophilic mid or surface water, Tol/Intol: Tolerance on habitat (expert judgment) and water quality.

Species	English name	Trophic guild	Reproductive guild	Habitat guild	Tol/ Intol
Abramis brama	Bream	Omni	Phli	Lib	Tol
Alburnus alburnus	Bleak	Insv	Phli	Liw	Tol
Alburnus bipunctatus	Stream bleak	Insv	Lith	Rhw	Intol
Anguilla anguilla	Eel	Omni	?	Lib	Tol
Barbatula barbatula	Stone loach	Insv	Lith	Rhb	Intol
Barbus barbus	Barbel	Omni	Lith	Rhb	Tol
Blicca bjoerkma	Siver bream	Omni	Phli	Liw	Tol
Chondrostoma nasus	Nase	Omni/Herb	Lith	Rhb	Intol
Cottus gobio	Bullhead	Insv/Bent	Lith	Rhb	Intol
Cyprinus carpio	Carp	Omni/Bent	Phyt	Lib	Tol
Esox lucius	Pike	Pisc	Phyt	Liw	Intol
Gobio gobio	Gudgeon	Insv/Bent	Psam	Rhb	Tol
Gymnocephalus cernuus	Ruffe	Omni	Lith	Lib	Tol
Leuciscus cephalus	Chub	Omni	Lith	Rhw	Intol
Leuciscus leuciscus	Dace	Omni	Lith	Rhw	Intol
Leuciscus idus	Ide	Omni	Phli	Rhw	Intol
Perca fluviatilis	Perch	Insv/Pisc	Phli	Liw	Tol
Phoxinus phoxinus	Minnow	Omni	Lith	Rhw	Intol
Rhodeus sericeus	Bitterling	Insv/Herb	Ostr	Liw	Tol
Rutilus rutilus	Roach	Omni	Phli	Liw	Tol
Salmo trutta fario	Trout	Insv/Pisc	Lith	Rhw	Intol
Scardinius erythrophtalmus	Rudd	Omni	Phyt	Liw	Intol
Sander lucioperca	Pikeperch	Pisc	Poly	Liw	Tol
Tinca tinca	Tench	Omni	Phyt	Lib	Tol

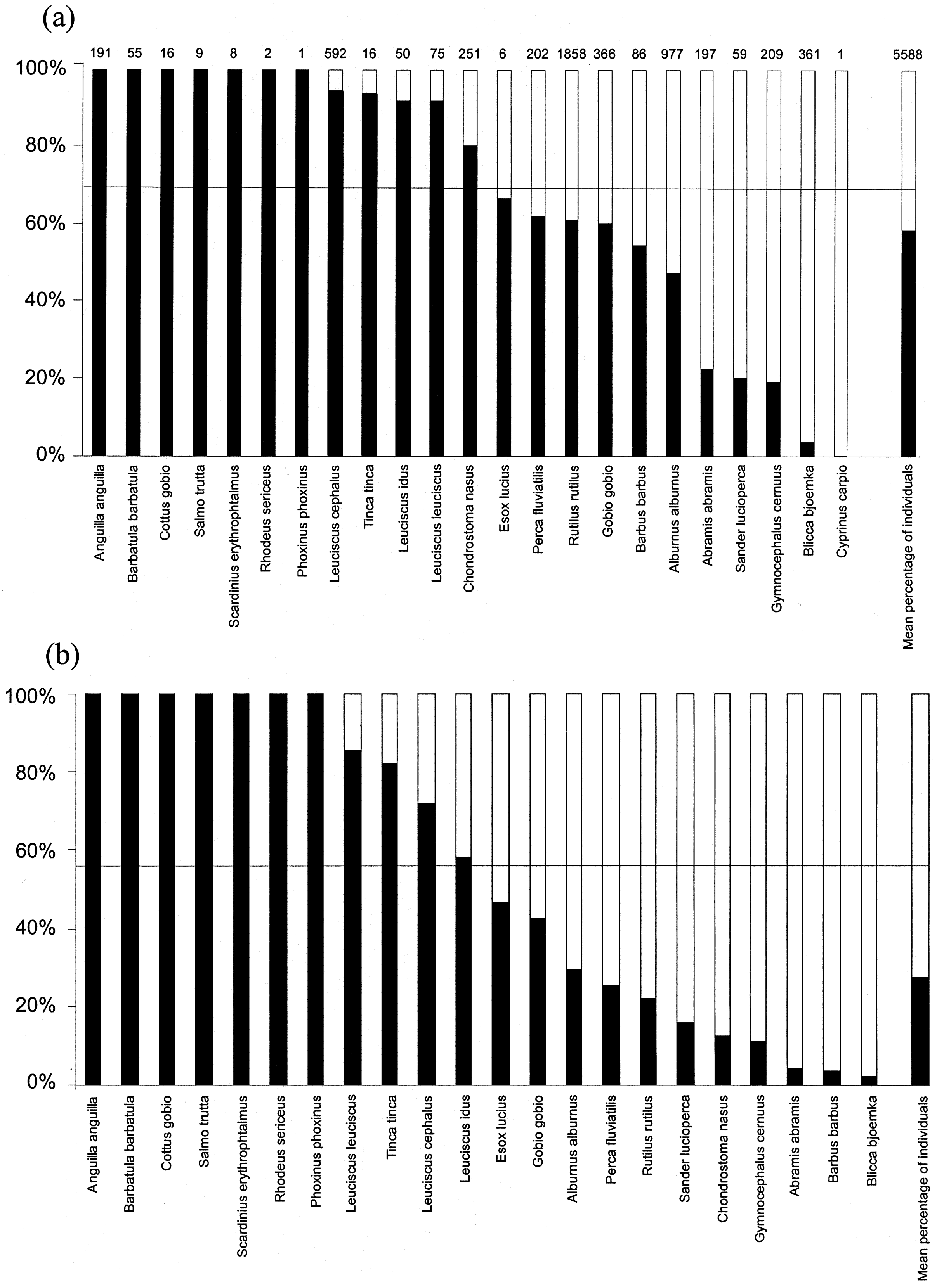

Fig. 1. Contribution of the different techniques to the total catch (black by electricity, open by gillnet) of (**a**) abundance and (**b**) biomass (except for *Cyprinus carpio*) of fishes caught in the River Meuse. The horizontal lines represent the mean percentage by species.

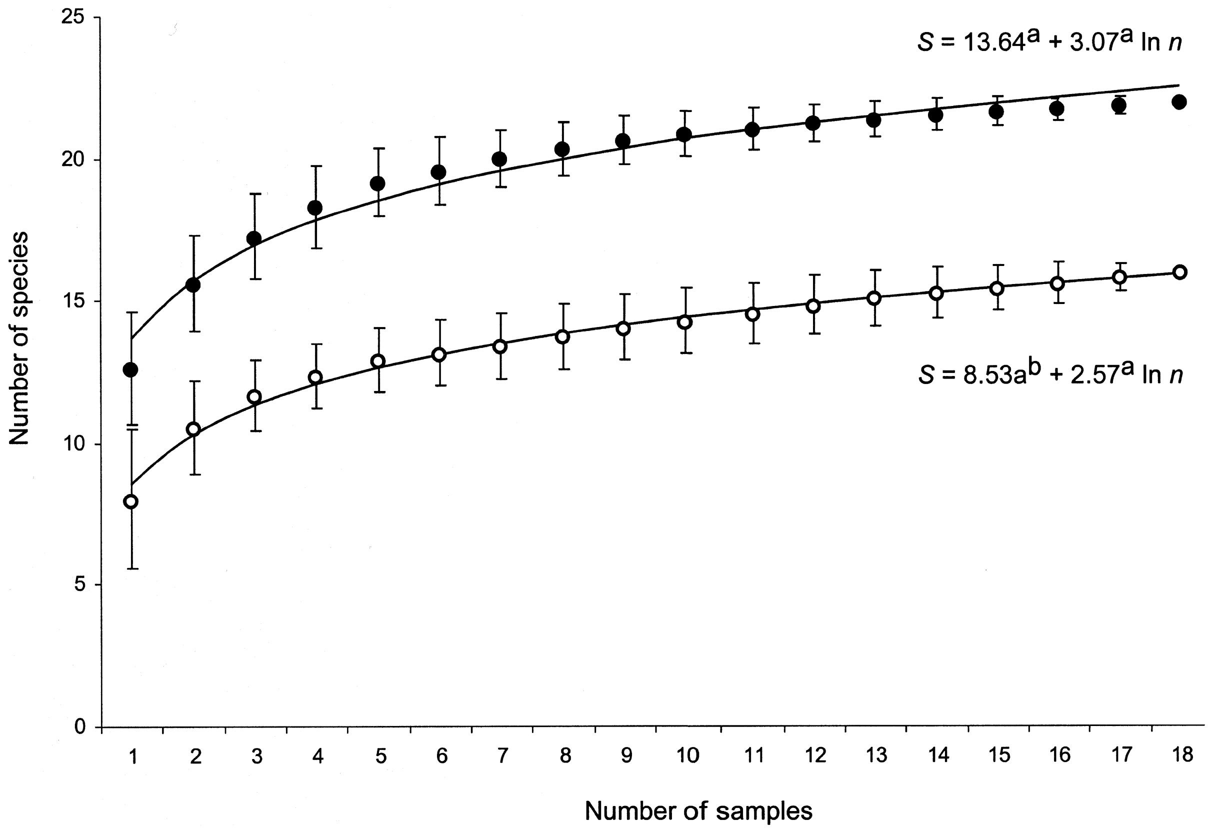

Fig. 2. Relation between species richness (S) and the number of samples (n) for electrofishing (●) and gillnet sampling (○). Each point is the observed number of species (mean value from 1000 Monte Carlo simulations). Vertical line indicates 95 % confidence intervals. The curve is the expectation from a modelled linear regression equation. Regression parameters among fishing techniques with a common letter are not significantly different at $P = 0.05$ (t-tests).

Monte Carlo simulations showed that the relationship between fish species richness and number of samples could be described by a linear regression model expressing richness as a function of the logarithm of the sample number (Fig. 2). Both constant and slope significantly differed ($P < 0.001$ and $P = 0.002$, respectively) and were significantly higher with electrofishing than with gillnet sampling.

Abundance and biomass

Among the 15 species common to both techniques, 13 were abundant (number of individuals caught with the two techniques was > 50) in one or both sampling methods and represented 99.9 % of abundance and 99.8 % of biomass for fish captured by gillnet, and 90.8 % of abundance and 78.8 % of biomass for fish captured by electrofishing. The two other species (tench Tinca tinca and pike Esox lucius) were present in much smaller proportions, regardless of sampling methods (Fig. 1 a).

More individuals were caught by electrofishing than by gillnets (Fig. 1 a), but the total biomass caught by gillnets was higher than that by electrofishing (Fig. 1 b), indicating that the mean individual body weight of fish caught by electrofishing was lower than that of fish caught by gillnets. There was a highly significant influence of sampling technique on the respective abundance of each species (χ^2, $P < 0.001$). Eel *Anguilla anguilla*, stone loach *Barbatula barbatula*, chub *Leuciscus cephalus*, ide *Leuciscus idus* and dace *Leuciscus leuciscus* were mainly caught by electrofishing, while common bream *Abramis brama*, pikeperch *Sander lucioperca*, ruffe *Gymnocephalus cernuus* and silver bream *Blicca bjoerkna* were the most abundant catches in the gillnets.

Temporal variability

Species richness variability between dates was relatively low, with a coefficient of variation of 16.6 % and 32.7 % for electrofishing and gillnets, respectively. In terms of capture frequency (Table 2), only 4 species, (roach *Rutilus rutilus*, bleak *Alburnus alburnus*, silver bream and bream) were frequently caught by gillnet (occurrence > 75 %), whereas 9 species (roach, chub, perch

Table 2. Catch frequency of species with electricity and gillnet samples.

Species	Electricity (%)	Gillnet (%)
Barbel	61.1	61.1
Bitterling	5.6	0
Bleak	88.9	88.9
Bream	44.4	77.8
Bullhead	55.6	0
Carp	0	5.6
Chub	100	55.6
Dace	88.9	5.6
Eel	94.4	0
Gudgeon	94.4	44.4
Ide	55.6	11.1
Minnow	5.6	0
Nase	94.4	55.6
Perch	94.4	72.2
Pike	16.7	11.1
Roach	100	100
Rudd	16.7	0.0
Ruffe	33.3	55.6
Pikeperch	50.0	66.7
Silver bream	16.7	83.3
Stone loach	77.8	0
Tench	38.9	5.6
Trout	22.2	0

Perca fluviatilis, nase *Chondrostoma nasus*, gudgeon *Gobio gobio*, eel, bleak, dace and stone loach) were frequently captured by electrofishing. Conversely, species like carp *Cyprinus carpio*, minnow *Phoxinus phoxinus*, bitterling *Rhodeus sericeus*, rudd *Scardinius erythrophthalmus*, pike and trout *Salmo trutta* were scarce with both sample techniques (occurrence < 25 %). Some species like roach, bleak and barbel *Barbus barbus* displayed the same capture frequency in both techniques (100 %, 100 % and 61.1 %, respectively).

At the abundance level, for some species like roach, bream and silver bream, temporal variability of catches (i. e. variation in the number of fish caught at different sampling dates) was lower with gillnet sampling (CV = 111.1, 95.6 and 138.2 %, respectively) than with electrofishing (CV = 180.7, 210.1 and 303.4 %, respectively). On the other hand, temporal variability of perch, chub, dace and ide catches with electrofishing (CV = 48.5, 79.2, 101.3 and 216.1 %, respectively) was lower than with gillnets (CV = 115.0, 159.7, 424.3 and 329.4 %, respectively).

Body size

The fishing method affected size distributions of fish caught. Nearshore electrofishing captured principally small individuals while bottom gillnets caught fish significantly larger (t-test, P < 0.001), suggesting that gillnets are size selective, and more efficient to capture large individuals. Indeed, the majority of fish caught by electrofishing (72.4 %) were smaller than 120 mm, while no fish captured by gillnet were smaller than 80 mm (Fig. 3). Within species, some like, chub, nase and bream displayed a slight overlap, while other species did

Table 3. Mean (± standard deviation) body size (mm) of the main species caught by electricity and gillnet. (t-test; NS: non significant).

Species	Electricity	Gillnet	P
Barbel	87.8±71.8	482.5±114.6	< 0.0001
Bleak	87.3±22.6	116.8±14.2	< 0.0001
Bream	107.6±85.5	327.2±105.4	< 0.0001
Chub	157.7±104.2	396.7±56.2	< 0.0001
Dace	94.4±30.8	129.2±15.7	0.008
Gudgeon	95.7±23.2	123.3±16.0	< 0.0001
Ide	118.2±21.1	143.0±17.1	0.03
Nase	104.5±55.2	403.0±73.3	< 0.0001
Perch	136.0±50.4	238.1±70.8	< 0.0001
Roach	97.0±42.8	182.6±48.6	< 0.0001
Ruffe	87.6±17.8	111.9±16.0	< 0.0001
Pikeperch	161.6±169.6	284.4±95.6	0.03
Silver Bream	216.7±92.8	238.8±51.4	NS

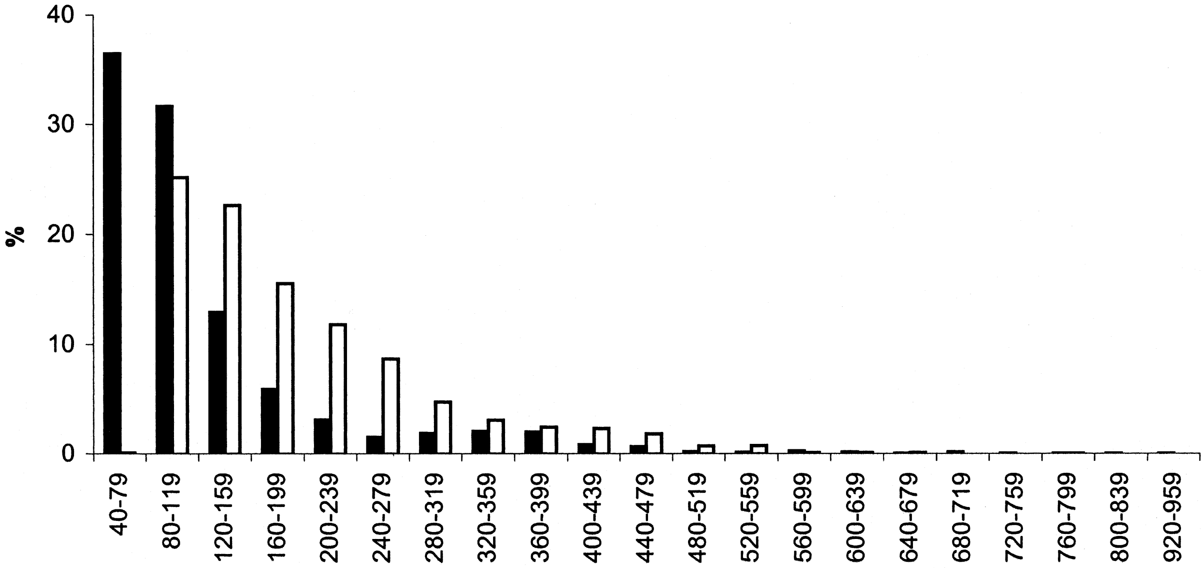

Fig. 3. Size class distribution (mm) of fish (all species combined) caught by electricity (black box) and gillnet (open box).

not (Fig. 4). However, except for silver bream, the size of fish caught were significantly larger by gillnet (t-test, $P < 0.001$) than by electrofishing (Table 3).

Ecological guilds

In order to evaluate the influence of fishing gear on the proportions of species belonging to different ecological guilds, values of selected biological indicators were calculated on electrofishing and gillnet data (Table 4). Species considered as intolerant, rheophilic, benthic, lithophilic, omnivorous and invertivorous (see Table 1) were principally caught by electrofishing in term of species number (t-test, $P < 0.0001$). In percentage of individuals, species considered as intolerant, rheophilic and lithophilic, were significantly more frequent in electrofishing sampling. In contrast, percentage of tolerant individuals caught by gillnet was higher than by electrofishing but no significant difference was observed for number of tolerant species. No significant difference was observed for percentage of benthic individuals.

Discussion

Among the studies comparing the methods used in fish biology and fisheries, very few reports exist on electrofishing versus gillnet samplings (Growns et al. 1996, Vaux et al. 2000). Comparison of active (electrofishing) and passive (gillnet) sampling techniques is not easy, since many variables are concerned, such as the selectivity of the sampling gear, the intensity of the fishing effort, the physical and chemical characteristics of the river (depth, width, current velocity, water temperature, turbidity, conductivity, etc.). All these variables will

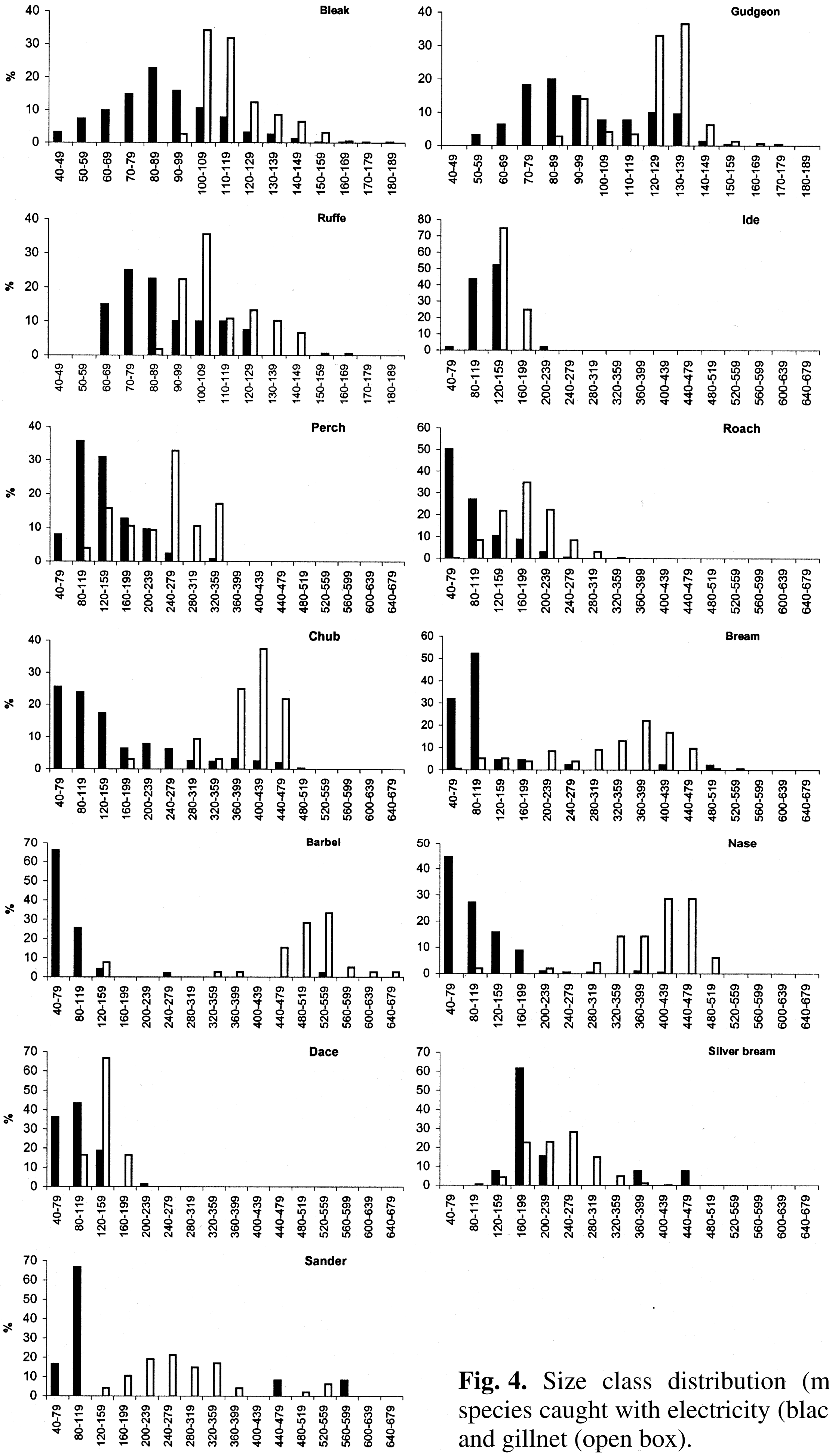

Fig. 4. Size class distribution (mm) of species caught with electricity (black box) and gillnet (open box).

Table 4. Mean values of fish metrics for both techniques (t-test, NS: Non significant t-test).

Guilds	Metrics	Electricity	Gillnet	P
Abundance	Number of total species	12.6	8.0	<0.0001
	Number of native species	12.1	7.3	<0.0001
	Number of introduced species	0.5	0.7	NS
Tolerance	Number of intolerant species	5.2	2.0	<0.0001
	% of intolerant individuals	36.1	12.0	0.001
	Number of tolerant species	7.4	6.0	NS
	% of tolerant individuals	63.9	88.0	0.001
Habitat	Number of rheophilic species	6.6	2.3	<0.0001
	% of rheophilic individuals	46.1	18.2	0.0002
	Number of benthic species	6.0	2.5	<0.0001
	% of benthic individuals	28.8	27.6	NS
Reproduction	Number of lithophilic species	5.4	2.3	<0.0001
	% of lithophilic individuals	36.3	15.1	0.004
Feeding	Number of Piscivorous species	1.6	1.5	NS
	% of Piscivorous individuals	12.6	17.0	NS
	Number of omnivorous species	7.7	4.6	<0.0001
	% of omnivorous individuals	61.0	57.2	NS
	Number of invertivorous species	3.3	1.9	<0.0001

influence the results of capture and, consequently, the estimated efficiency of each fishing method differently. However, as emphasised by Rulifson (1991) and Simon & Sanders (1999), the use of multiple sampling gears is needed to ensure that most species and size classes are sampled, and, as a corollary, to assess the fish assemblage as completely as possible. The present study confirmed the statements of previous authors (Zalewski & Cowx 1989, Casselman et al. 1990, Persat & Copp 1990, Growns et al. 1996, Simon & Sanders 1999, Vaux et al. 2000), as the species richness captured by electrofishing sampling was significantly greater than that captured by gillnet sampling (mean = 12.6 ± 2.1 and max = 22 species versus mean = 8.0 ± 2.6 and max = 16 species for electrofishing and gillnet, respectively). Cumulative species curves performed for both sampling techniques confirmed that gillnet selectivity was higher (species richness was lower). After 9 samplings, electrofishing captured 21 species (representing more than 90 % of the total number of species caught in this study) and twice that effort was necessary to obtain only one additional species. With gillnets, 14 species were captured after 9 samples and two additional species were captured when the effort was doubled. However, the total number of species captured in this study (23) was lower than that cited by Philippart et al. (1988) (30), using complementary data from fish passes, fish kills, and sport fishing catches. Compared to the study of Phi-

LIPPART et al. (1988), missing species are rainbow trout *Oncorhynchus mykiss,* grayling *Thymallus thymallus,* sea trout *Salmo trutta trutta,* burbot *Lota lota,* Crucian carp *Carassius carassius,* Channel catfish *Ameiurus nebulosus* and three-spined stickleback *Gasterosteus aculeatus*. The first three species are considered rare to very rare for which the River Meuse is not considered as suitable habitat. In evaluations of raft electrofishing effort in large Oregon, USA, rivers, CAO et al. (2001) concluded that an average sampling distance 286 times the mean wetted channel width (cw) was needed to obtain all species, while 161 cw was needed for 90 % of true species richness. HUGHES et al. (2002), with an expanded Oregon data set, concluded that collecting all fish species in a reach required an average electrofishing distance of 300 cw, but that foregoing 1–3 rare species required an average of only 100 cw.

It is worth noting that the additional species collected by electrofishing were in part the smaller ones, such as the stone loach, the bitterling and the minnow, as previously reported by GROWNS et al. (1996). Ecological habits of stone loach and minnow, which are usually considered as benthic species in shallow rivers, account for their absence in gillnet samples, which were settled in the deepest part of the river. The selectivity of gillnet arrays used in our study also explains the absence of those species in our gillnet samples. Indeed, the average size of small fish species (bleak, gudgeon and ruffe) caught by the smallest mesh size (10 mm) were generally larger than the adult size reported in the literature for the three species only captured by electrofishing, i. e. 100–120 mm for loach, 80–90 mm for minnow and 50–70 mm for bitterling (KESTEMONT 2001, PERRIN 2001, PERSAT 2001, OLIVIER & CARREL 2001). Moreover, large species were either morphologically never caught by gillnet (such as eel) or rarely present in the bream zone (such as trout). Carp was rarely caught, and only by gillnet, although this species is common in the River Meuse. The location of sampling sites and/or the technical specifications of our fishing gears were probably responsible for the low capture of this species.

Bream is one of the most characteristic species of the River Meuse (bream zone). Its higher abundance in gillnet samples is explained by its preference for lentic (deep and slow flowing) mid-channel habitats and its gregarious be haviour, as was the case for silver bream and ruffe (PHILIPPART & VRANKEN 1983).

Regarding capture variability, electrofishing provided a more constant species richness (CV between dates = 16.6 %) while gillnet captures were more variable (CV = 32.7 %). This could probably be explained by the active mode of fishing with electrofishing, while gillnet efficiency is largely dependent on fish movements, which are themselves influenced by environmental conditions. Chub, dace and ide were more evenly and abundantly caught by electrofishing and bream and silver bream by gillnet.

The main difference between fish caught by electrofishing and gillnet was related to the size class distribution of most species. Except for silver bream, the mean length of fish caught by gillnet was greater than that caught by electrofishing. In lotic systems, young-of-the-year live along the banks, where current velocity is low and shelter abundant. During development, the size and swimming performance of fish increase and they can use other types of habitat or other river reaches (TANS 2000). As young fish grow, they become more susceptible to capture by passive gear while remaining susceptible to active gear (RULIFSON 1991). Moreover, our electrofishing was limited to a single anode, and multiple anode arrays are more effective for large rivers (CEN 2002). In addition to its size selectivity, gillnet sampling is a passive technique dependent on fish activity. In this respect it has been demonstrated by HANSSON & RUDSTAM (1995) that fish activity is dependent on the stage of development, the young individuals being less active than the older ones in the main channel, thus reducing their probability of capture. The smallest size-class (40–79 mm) was never caught by gillnet and hence gillnet catches tend to underestimate the smallest individuals of the assemblage (RULIFSON 1991). As mentioned by VAN DENSEN (1987), the body girth of the fish caught most efficiently is roughly proportional to the mesh perimeter.

To our knowledge, no other authors have compared explicitly the results of electrofishing and gillnet sampling in terms of values of biological guilds, such as those used in fish-based indices like the Index of Biotic Integrity (IBI). Very few authors have used gillnet sampling for the calculation of such indices (SIMON & SANDERS 1999, BRAMBLETT & FAUSCH 1991, SCHULZ et al. 1999, HAY et al. 1996 and HUGUENY et al. 1996). Except for HUGUENY et al. (1996), they used it as a second technique, to complement electrofishing, without distinguishing results from each technique. According to the results of our study, we expect that the total number of species, the species number and percentage of individuals of rheophilic, lithophilic and intolerant species (which positively affect IBI scores) would be significantly higher in electrofishing samples. Conversely, the number of tolerant species (which negatively affect IBI scores) was not significantly different between gillnet and electrofishing (6.0 and 7.4, respectively), but the percentage of tolerant individuals was significantly higher in gillnet samples (88 % versus 63.9 % for electrofishing). As mentioned by HUGUENY et al. (1996), it is possible that species significantly influencing an IBI metric are inadequately sampled by gillnet, and consequently affect IBI score. The number of benthic species was significantly higher in electrofishing samples but no difference was observed in term of percentage of individuals. This is in contradiction with the study of CASSELMAN et al. (1990) who showed no differences between gears. However our difference could be related to the higher species richness observed by electrofishing.

Eel and stone loach, two species of importance for IBI calculation, were never caught by gillnet, while they were frequently caught by electrofishing.

Even if the abundance of eel and stone loach was low, their occurrence was high (94 and 78 % of the electrofishing operations, respectively).

Conclusion

Except for the larger sizes of some large species, the use of gillnets did not improve the fishing results in terms of fish species richness and abundance. In large rivers electrofishing remains the most effective single method to qualitatively describe fish assemblages. However, electrofishing is not sufficient for a quantitative estimation of entire fish assemblages. The combination of electrofishing and another method is thus essential. To this end, gillnets can add valuable information on the largest individuals and species for which adult stages are almost never found along the banks (bream, silver bream and nase).

Although we are not recommending a sampling protocol for large river assessment, our study increases knowledge of fish assemblages in these ecosystems and highlights the influence of sampling techniques on biological indicators currently used in fish-based assessment methods.

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