FISHERIES RESEARCH 151: pp. 12-19. (2014) --DOI: 10.1016/j.fishres.2013.12.004

Application of an electrified benthic frame trawl for sampling fish in a very large European river (the Danube River) – Is offshore monitoring necessary?

Z. Szalóky[a], Á.I. György[a], B. Tóth[b], A. Sevcsik[b], A. Specziár[c], B. Csányi[a], J. Szekeres[a], T. Erős[c,*]

[a] *Danube Research Institute, MTA Centre for Ecological Research, Jávorka Sándor u. 14., H-2131 Göd, Hungary*

[b] *Danube-Ipoly National Park Directorate, Költő u. 21, H-1121, Budapest, Hungary*

[c] *Balaton Limnological Institute, MTA Centre for Ecological Research, Klebelsberg Kuno u. 3., H-8237 Tihany, Hungary*

*Corresponding author:
Tibor ERŐS
Balaton Limnological Institute, MTA Centre for Ecological Research
Klebelsberg K. u. 3., H-8237 Tihany, Hungary
Tel.: +36 87 448 244
Fax.: +36 87 448 006
E-mail address: eros.tibor@okologia.mta.hu

Abstract

The organization of fish assemblages in offshore, deep channel habitats is poorly known in very large rivers compared with shoreline, littoral areas. We report on the parameters and testing of an electrified benthic frame trawl (EBFT), developed for monitoring the distribution and abundance of benthic fishes in the Danube River, Hungary. We also compare the results of the benthic main channel survey with a shoreline electrofishing (SE) data set. Altogether 33 species were collected offshore during the 175 trawling paths (500 m long each). Both sample based and individual based rarefaction showed that night time SE detected significantly more species with increasing sampling effort than day time trawling of offshore areas. However, offshore surveys detected sterlet *Acipenser ruthenus*, which could not be detected by SE, even using extreme high sampling effort. Offshore trawling also proved the common occurrence and high abundance of the strictly protected endemic Danube streber *Zingel streber* in the river, which proved to be extremely rare in SE catches. The EBFT caught larger/older individuals of many species than SE, and indicated diverse size/age structure for many species offshore. Our survey revealed that offshore areas are intensively used by a variety of species, which occur relatively evenly, but with variable abundance in the Danube River. We suggest that even a relatively small (i.e. 2 m wide 1 m high) EBFT can be a very useful device for monitoring offshore fish assemblages in very large rivers and provide important data for bioassessment and conservation purposes.

Keywords: trawling, large rivers, shoreline electrofishing, sampling, fish assemblages

1. Introduction

Sampling the biota in the main channel of large rivers presents a continuing challenge for freshwater ecologists. While our knowledge of the organization of shoreline fish assemblages and their representative sampling are increasing (e.g. Jurajda et al., 2001; Erős et al., 2008), information about the composition and spatial and temporal distribution of fishes in deep channel habitats is still relatively sporadic (Dettmers et al., 2001). Inferences about how main channel habitats contribute to the bioassessment of large rivers compared with shoreline monitoring data should also be more precisely developed (de Leeuw et al., 2007; Flotemersch et al., 2011). The highway analogy, a postulate of the flood pulse concept (Junk et al., 1989), which states that the main channel of large alluvial rivers is used by fishes mainly as a route for gaining access to floodplain habitats, has been proved to be oversimplified, because main channels were shown to maintain diverse fish assemblages with several species spending most of their life-time offshore (Galat and Zweimüller, 2001; Wolter and Bischoff, 2001; Stewart et al., 2002). However, detailed quantitative studies are restricted to only a very few large rivers even in the relatively well studied temperate large river systems of Europe and North-America (see e.g. Wolter and Freyhof, 2004; Gutreuter et al., 2009; Ridenour et al., 2009). It would be thus important to develop deep channel fish monitoring methods in a variety of biogeographical and ecoregions for providing data for both basic research and the conservation management of riverine fish species.

With its 2872 km length, the Danube River is the second longest river in Europe. Although the river is the cradle of Europe's most diverse fish fauna (Reyjol et al., 2007), the large scale organization of its fish assemblages is relatively poorly known, compared with other central and especially western European large rivers. The monitoring of its fish assemblages is mainly based on shoreline electrofishing methods (Hirzinger et al., 2003; Erős, 2007). For example, the second Joint Danube Survey (JDS2), organized by the International Comission for the Protection of the Danube River (ICPDR) in 2007, provided the first data about the longitudinal distribution of fish assemblages along the river with a standardized methodology (http://www.icpdr.org/jds/). However, the electrofishing based surveys were restricted to inshore areas, and consequently did not provide information on main channel fish assemblages. Further, although national monitoring programs intend to address the deepwater main channel species in some countries (e.g. long line sampling in Austria) a really effective and routinely used methodology for sampling main channel species, to our knowledge, has not been developed yet. Such an easily applicable monitoring methodology would be essential for example to provide complementary information about the occurrence and abundance of conservationally important species.

Many small, benthic species are important for conservation purpose (Labonne et al., 2003; Ridenour et al., 2009), yet they are especially difficult to collect with conventional fishing gears (e.g. trammel nets, gillnets) used to sample deep habitats in slow flowing large rivers (Murphy and Willis, 1996; Herzog et al., 2005; Freedman et al., 2009). Additionally, entangling nets and hook and line (i.e. long line) sampling can injure these small fish seriously. Note that we by no means refer to boatable (raftable), but rather shallow (i.e. less than 2 m deep) rivers which are usually sampled with electrofishing from boats or with boom mounted electrofishing ships (see e.g. Hughes et al., 2002). Monitoring the populations of benthic species with the more intensively used hydroacustic methods is still problematic, since their exact identification still present difficulties for researchers, especially in case of species from the same genus. Naturally, the combination of hydroacustic surveys with a suitable fishing gear can be fruitful, because the latter can help to collect fish for identification. For this purpose, trawling is the most preferred fish sampling method of the main channel trough (Dettmers et al., 2001; Wolter and Bischoff, 2001; De Leeuw, 2007;

Doyle et al., 2008). Recently, different trawling gears has been developed and their efficiency tested for the more effective sampling of benthic species in very large rivers (Herzog et al., 2005; Freedman et al., 2009; Ridenour et al., 2009; 2011).

In this study, we report on the application of an electrified benthic frame trawl (EBFT), developed for monitoring the distribution and abundance of benthic fishes in the Danube River. Specifically, we show the parameters of the EBFT device and provide the first detailed data on sampling effort species richness relationships, abundance, and size structure of the most common benthic species in the offshore, deep channel habitats of this very large river. We also compare the results of our benthic main channel survey with an extensive shoreline electrofishing (SE) data set. Based on these comparisons we evaluate the applicability of main channel benthic surveys for the study of fish assemblages in a very large river for bioassessment and conservation purposes.

2. Material and methods

2.1. Study area

The Danube has a drainage area of approximately 796,250 km^2. River regulation, namely the construction of hydroelectric schemes, especially in the Upper Danube (i.e. in Germany and Austria), and channelization have profoundly modified the physical structure of the Danube throughout its course. The Hungary section, referred to as the 'Middle Danube', runs for 417 km and has a mean annual discharge of 2000 m^3 s^{-1}. The main channel has a substratum dominated by gravel and sand, a mean depth of 4 m and a mean velocity of 0.6 m s^{-1}. The banks are relatively natural (except the section lying within Budapest), interrupted with embanked rip-rap shorelines of ~ 100-1000 m long sections.

2.2. Data collection

To construct the sampling device (EBFT) to be effective in catching small sized benthic species we combined the design of conventional trawl nets and framed sledge nets, the latter used to sample fish fry in deep habitats (Fig. 1). This consisted of a 3.4 cm diameter stainless steel frame (2 m long × 1 m high) to which a drift net was attached. The drift net was 5 m long and consisted of a 5 mm-stretch inner mesh bag and an 8 mm-stretch outer mesh bag. A buoy was attached to the codend with a rope to indicate the position of the net while fishing. We used weighted metal wheels to help keeping the device close to the bottom and also keeping the frame 6 cm above the bottom to prevent the filling of the net with the substrate material. We electrified the frame with a 40 m long electrode cable which was connected to a Hans-Grassl EL65 IIGI electrofishing device operated with a VANGUARD HP21 14.9 KW generator. A 6 m long copper cathode cable was hanged freely and pulled approx. 2 m before the electrified frame (Fig. 1). Preliminary catching experiments, (specifically with and without electricity, different positions of cathode cables, different net mesh sizes and frame sizes) showed that this construction yielded the most acceptable compromise between catching rates and sampling from boat with a four person crew (see Szalóky et al., 2011). In this crew, 2 people handled the framed net, one handled the electrofishing device and one operated the boat. Fishing (hereafter trawling) was conducted with a 6.3 m long boat powered by a 50 horsepower outboard Mercury four stroke engine.

When starting trawling, the EBFT operators lowered the frame to the bottom while the boat was slowly moving downstream with the flow. Trawling route was started to be measured by a GPS only after EBFT reached the bottom, which could be easily felt while holding the central rope (Fig. 1) and right after electroshocking started. The direct current (approx. 350 V, 33 A) was given for 5-8 s with 3-5 s breaks between the operations to minimize fright bias and injury of fish. The applied trawling speed was slightly higher than the current velocity of the river (approx. 60 cm s^{-1}). Each haul had a length of 500 m. Trawling was carried out during daytime. This study contains data of the samples collected in April 2011 - September 2011 period.

We collected altogether 175 samples, 500 m long each, along a ~ 350 km stretch of the 417 km Hungarian Danube River section (Fig 2). We used a stratified design to select segments in order to get a representative coverage of the whole main channel area (excluding the section where the capital, Budapest can be found). In each of these segments several, but a minimum of 3 transects were selected randomly, perpendicular to the bank. Along each transect, across the width of the main channel, we generally distributed 5-6 trawl paths, excluding the littoral, less than 2 m deep shoreline zone. These paths were approximately equispaced and centred over the approximate place of the main channel centreline (Gutreuter et al., 2009). Note that the number of trawl paths along the transects varied depending on the river width. Sometimes the trawl was stopped due to interruption by large rocks or logs. The trawl paths were then grouped into five classes depending on their offshore position, starting conventionally from the right side of the river. As such, the offshore classes 1 and 2 situated on the right side of the centreline, and had a mean (±SD) distance of 74 (±35) and 123 (±52) m from the right side of the river, respectively. Class 3 situated approximately at the centreline with a mean distance of 255 (±65) and 229 (±66) m from the right and left side of the river, respectively. Classes 4 and 5 situated on the left from the centreline and had a mean distance of 112 (±27) and 57 (±19) m from the left side of the river, respectively. The mean depths (±SD) for Classes 1, 2, 3, 4, and 5 were 3.7 (±2.4), 4.6 (±1.9), 4.4 (±1.3), 4.4 (±1.6) and 3.9 (±2.1) m, respectively. Fish were identified and measured to the nearest mm standard lengths (*L*) and then released back to the river.

Besides evaluating main channel fish data, we compared EBFT data with SE monitoring data collected between 2005 and 2011Although the SE and EBFT data were only partly overlapping they are comparable at such a large spatial scale since yearly or seasonal changes were relatively small compared with the effect of the mesohabitat type and spatial position of the sampling sites in the SE data (Erős et al., 2008; Erős et al unpublished data). Briefly, the SE data set contains electrofishing data of altogether 207, 500 m long stretches in the frame of which approximately 48,000 individuals were caught (Table 1). The stretches were fished from a boat using either a 7.5 KW or a 13 KW generator powered machine (Hans-Grassl Gmbh EL64 II GI, DC, 7.5 KW, and EL65 II GI, DC, 13KW). Note that preliminary evaluations did not show significant differences in species richness and fish relative abundance distributions between the two machines (Erős et al., unpublished data). Fish were caught with one hand held anode (2.5 m long pole with a ring anode of 40 cm diameter and a net mesh size of 6 mm) while slowly moving downstream with the boat as per Wolter and Freyhof (2004). The cathode, a 5 m long copper cable, was floated at the rear of the boat. We used night time sampling because former surveys of the Danube (Erős et al., 2008) and other systems (Wolter and Freyhof, 2004) justified that it is more efficient than daytime sampling of shoreline fish assemblages.

2.3. Statistical analysis

We used both sample based and individual based rarefaction analyses to examine changes in the number of species with increasing sampling effort (Gotelli and Colwell, 2001; Erős et al., 2008; Flotemersch et al., 2011). The analyses were conducted to compare the differences in the number of species between 1) the SE and the EBFT collections, and 2) the different offshore distance classes of the EBFT collections (1-5 classes).

We used the nonparametric Kruskall-Wallis ANOVA to test whether total median CPUE data (i.e. median of the total number of individuals captured per a 500 m long sampling transect) differ among the five offshore classes. To test for significant differences in assemblage structure among the offshore classes, we used ADONIS in Vegan package of R (R Development Core Team, 2013), which is the more robust version of nonparametric permutational analysis of variance (PerMANOVA) method developed by Anderson (2001). The analysis was run using 999 permutations of the raw catch per unit effort (CPUE) data of fishes (i.e. number of individuals captured per a 500 m long sampling transect) and the Bray-Curtis measure.

Between gear (i.e. SE vs. EBFT) differences in the $\log_{10}(x+1)$ transformed CPUE data of the benthic species were tested with two-sample t-test. Standard length distributions of fish in cumulated samples were compared between the SE and the EBFT with the nonparametric Kolmogorov-Smirnov test, and median fish sizes were tested for significant differences with the Mann-Whitney U-test.

Note, that the effectiveness and efficiency of the two sampling gears (i.e. boat electrofishing vs trawling) cannot be directly compared, since the two gears sampled two different habitats during different time of the day. In fact the two gears cannot be used in the same habitat, because it is clear that boat electrofishing is ineffective in deep offshore areas, whereas the use of the EBFT is very laborious and can be even dangerous in shallow shoreline areas, especially during the night. Therefore, it is important to emphasize that the purpose of “between gear comparisons” was to evaluate the complementary information EBFT can provide to SE about the fish assemblages of a very large river.

3. Results

We collected 33 species and 8112 specimens with the EBFT during the 175 trawling paths. In 4 trawlings we did not catch any fish due to sampling error (i.e. the gear was snagged on logs). These tows were excluded from further analyses. The mean number of species per 500 m long sampling reach was 5.1 ± 2.1 (mean ± SD), which is significantly lower ($P<0.05$) than the number of species estimated for shoreline electrofishing (SE), where 14.7 ± 2.1 species was caught for the same sample unit length (Fig. 3a). Both sample based and individual based rarefaction showed higher increase in the estimated number of species with increasing sampling effort in case of SE compared with offshore sampling with the EBFT (Fig. 3a,b). However, offshore sampling detected sterlet *Acipenser ruthenus* L., which could not be detected by SE, even using extreme high sampling effort.

Sample based rarefaction curves indicated relatively large differences between the EBFT based samples differing in their offshore position (Fig 4a). Samples which situated in the centreline of the river (i.e. class 3 samples) tended to have the lowest number of species at any sample size. However, the differences between the different offshore sample classes were not really supported by the individual based rarefaction (Fig. 4b). The number of species varied only between 17 and 19 among the five offshore classes at a standardized number of individuals collected (i.e. 678 individuals, the total number of individuals collected in offshore class 4).

Both relative abundance and frequency of occurrence data of fishes differed between the EBFT and the SE samples (Table 1). As expected, benthic species dominated in the catches of the EBFT, while surface oriented, water column and benthic species were all important assemblage constituting species in the SE catches. Of these, the silver bream *Blicca bjoerkna* (L.), the bleak *Alburnus alburnus* (L.), the white-finned gudgeon *Romanogobio albipinnatus* (Lukasch), the schraetzer *Gymnocephalus schraetser* (L.), the bighead goby *Ponticola* *kessleri* (Günther) and the round goby *Neogobius melanostomus* (Pallas) were the most abundant species using both monitoring methods. However, the EBFT indicated the commonness of some benthic species in the river, which information would have remained hidden using only shoreline surveys (SE). The most striking difference was the common occurrence and relatively high abundance of *Zingel* species, and especially Danube streber *Zingel streber* (Siebold) offshore. Mean CPUE of the benthic species showed that Danube streber was the only species which had significantly higher abundance in the main channel than in the shoreline catches (Fig. 5). Total CPUE data of EBFT catches varied between 2 and 1761 ind 500 m^{-1}, and showed weakly significant differences between the five offshore classes (Kruskall-Wallis ANOVA, H=10.07, p=0.039). Similarly, the ADONIS analysis also indicated significant differences in assemblage structure between the offshore classes (pseudo-F=1.62, p=0.015). However, the variance explained was extremely low (R^2=0.038), which showed that distance from shore cannot explain differences in fish assemblage structure (i.e. raw CPUE data) and that probably the high sample size influenced the result of the significance test. This latter result was further confirmed by two-dimensional solution of non-metric multidimensional scaling analysis (NMDS), which yielded almost completely overlapping assemblages among the five offshore classes in the ordination plane (results are not shown for brevity).

Median values of standard length data of the abundant species (i.e. >1% relative abundance in the total catch of any method) showed significant differences for most fishes between the EBFT and SE samples (Table 2, Mann-Whitney U-tests). In general larger specimens of many cyprinids (e.g. barbel *Barbus barbus* (L.), common bream *Abramis brama* (L.), common nase *Chondrostoma nasus* (L.) and vimba *Vimba vimba* (L.)) were relatively more abundant in the EBFT than in the SE samples (Fig. 6., see Table 2 for Kolmogorov-Smirnov tests).

4. Discussion

The EBFT proved to be very effective in detecting both benthic and water column species in offshore areas of the Danube River in habitats which are unavailable for conventional boat electrofishing methods. All known benthic species from the last ten years of fish faunistic surveys (Harka and Sallai, 2004; Erős et al., 2008) were collected with the one year study using EBFT, with the exception of some rare benthic species, which prefer shallow, slow flowing habitats (e.g. the spined loach *Cobitis elongatoides* Bacescu and Mayer) or species which appear extremely rarely in the Hungarian section of the river (e.g. Danube sturgeon *Acipenser gueldenstaedtii* Brandt and Ratzeburg). Although sample based rarefaction analyses indicated differences between the EBFT samples differing in their shoreline distance position (i.e. offshore classes 1-5), these differences were not supported by individual based rarefaction. These results thus indicate that simple passive sampling effects (i.e. the number of individuals caught) can explain the differences found in the number of species between the samples of the offshore classes (Gotelli and Colwell, 2001). Our large scale spatial survey thus revealed that offshore areas are intensively used by a variety of species which are distributed relatively homogenously in the river, at least regarding their occurrence, because their abundance can vary largely at the mesoscale (i.e. between 500 m long sampling stretches). These results on the River Danube, therefore, complement studies from other large rivers (e.g. Dettmers et al., 2001; Wolter and Bischoff, 2001), and support the view that main channel offshore areas provide important habitats for riverine fish assemblages which should be more intensively considered by habitat managers .

Although it is difficult to make direct comparisons, because of methodological differences, density data of fishes were comparable with or even higher than the values found for offshore fish assemblages in other large European rivers. For example, Wolter and Freyhof (2004) estimated density values (i.e. mean CPUE per 1200 m^{-2}, see Table IV daytime data) ranging between 0.01 and 3.7 individuals for the 6 most common species using a 12 m wide and 1.8 m high bottom otter trawl from a ship in the River Oder in Germany. For comparison, our mean CPUE values ranged between 0.3 and 24.2 individuals obtained by fishing 500 m long stretches with the 2 m wide and only 1 m high net (i.e. roughly 1000 m^{-2}, but lower water column depth) for the 12 most common benthic species. Note that although the frame was electrified, we do not believe that these data would largely overestimate actual density values, because the electrofishing rather helped to catch dormant or hidden fish. However, this methodological question remains to be tested in the future by fishing with sonar combined devices (see Jůza et al., 2013). Consequently, our study proves the broad applicability of the EBFT in monitoring benthic fishes in the Danube, but how density (i.e. CPUE) data would change using larger ships or bigger devices remains the topic of further research (see Jůza et al., 2010). In fact it is likely that larger trawls could be more effective in catching large specimens of many benthic and water column species in very large rivers, but care should be taken because increasing mesh size of the net may yield the underestimation of the abundance of small benthic species. Nevertheless, due to its relatively easy handling we propose that a two metre wide EBFT can be a reasonable compromise in the monitoring of offshore areas in large rivers, when logistic constraints or other reasons (e.g. manoeuvring, width and depth of the river, stopping of the net) may hinder the routine and wide scale application of large trawls and fishing ships.

Night-time sampling of the shoreline using boat electrofishing was highly more effective in detecting species than offshore bottom trawling. Further, SE proved the occurrence of all fishes detected by the EBFT, with the exception of sterlet, which is a strictly deep channel trough species. However, the EBFT provided essential information on the occurrence and abundance data of some benthic species in the river, which would have been highly underestimated using only SE. Most importantly, we revealed the commonness and relatively high abundance of strictly protected *Zingel* species with the EBFT. Therefore, the EBFT should be an essential device for monitoring spatial and temporal changes in the abundance of these species of high conservation concern. In this respect, monitoring the stock of small bodied benthic species is critically important. Consequently, we believe that night time SE can be a very efficient cost effective method for monitoring fish assemblages for assessing environmental health, if only a single device can be applied for logistical difficulties reasons. However, the sampling of offshore habitats is required for monitoring the status of some species of high conservation concern (i.e. NATURA 2000 species, like zingel *Zingel zingel* (L.) and Danube streber). To emphasize the importance of the previous finding note that the JDS2 survey could not even prove the occurrence of Danube streber in the Hungarian Danube river section (Wiesner et al., 2007).

An important methodological question is whether time of the day could influence our comparisons between SE and EBFT catches. Several studies proved that night time electrofishing of shoreline areas is more effective than day time sampling, because most fishes are usually more active at night and many species move from offshore to inshore areas at night (Wolter and Freyhof, 2004; Erős et al., 2008). Therefore, it is likely that for example the shape of the species accumulation curves (Fig. 3) would differ less between the SE and EBFT data set if we used day time SE data. Similarly, some differences in the catches of day time and night time trawlings also exist due to movement of fish from offshore to inshore areas at night (Wolter and Freyhof, 2004), although our preliminary studies could not prove this finding due to large variability in CPUE data between hauls (unpublished data). These differences however, did not influence the main findings of this study about the practical use of offshore trawling in the monitoring of large river fishes for complementing shoreline data sets. Additionally, nigh time trawling can be especially dangerous in the navigation channel of ships, and therefore only day time sampling is recommended for security reasons and for not disturbing the traffic of ships in very large rivers.

Larger specimens of many species were generally caught offshore, which suggests that older age classes prefer these areas to shoreline areas as habitats. Therefore, to provide more detailed information on the size structure of riverine fish assemblages offshore monitoring would be essential. It is also clear, that shoreline areas present only a small fraction of large river habitats. For example, in the River Danube shoreline areas which can be effectively monitored with electrofishing comprise only a maximum of 10 or 20 m wide zone of the 300-500 m wide channel. Therefore, although doubtlessly highly important for the diversity of fish assemblages, sampling the shoreline exclusively provide a biased picture of the composition and structure of the fish assemblages in this very large river. Consequently, we recommend the monitoring of offshore areas for a better understanding of fish assemblage composition and dynamics in the Danube and in other large rivers.

Acknowledgements

This study is part of the doctoral (PhD) thesis of Zoltán Szalóky under the supervision of Tibor Erős. The work of Tibor Erős was supported by the Bolyai János Scholarship of the Hungarian Academy of Sciences and the OTKA K104279 research grant. We thank Clayton Ridenour for pre-reviewing the ms and Péter Sály for drawing Fig. 1.

References

Anderson, M.J., 2001. A new method for non-parametric multivariate analysis of variance. Austr. Ecol. 26, 32–46.

De Leeuw, J.J., Buijse, A.D., Haidvogl, G., Lapinska, M., Noble, R., Repecka, R., Virbickas, T., Wisniewolski, W., Wolter, C., 2007. Challenges in developing fish-based ecological assessment methods for large floodplain rivers. Fish. Manage. Ecol. 14, 483-494.

Dettmers, J.M., Gutreuter, S., Wahl, D.H., Soluk, D.A., 2001. Patterns in abundance of fishes of the main channel of the upper Mississippi river system. Can. J. Fish. Aquat. Sci. 58, 933-942.

Doyle, W., Paukert, C., Starostka, A., Hill, T., 2008. A comparison of four types of sampling gear used to collect shovelnose sturgeon in the Lower Missouri River. J. Appl. Ichthyol. 24, 637-642.

Erős, T., 2007. Partitioning the diversity of riverine fish: the roles of habitat types and non-native species. Freshw. Biol. 52, 1400-1415.

Erős, T., Tóth, B., Sevcsik, A., Schmera, D., 2008. Comparison of fish assemblage diversity in natural and artificial rip-rap habitats in the littoral zone of a large river (River Danube, Hungary). Int. Rev. Hydrobiol. 93, 88-105.

Flotemersch, J.E., Stribling, J.B., Hughes, R.M., Reynolds, L., Paul, M.J., Wolter, C, 2011. Site length for biological assessment of boatable rivers. River Res. Appl. 27, 520-535.

Freedman, J.A., Stecko, T.D., Lorson, B.D., Stauffer, J.R., 2009. Development and efficacy of an electrified benthic trawl for sampling large-river fish assemblages. N. Am. J. Fish. Manage. 29, 1001-1005.

Galat, D.L., Zweimüller, I. 2001. Conserving large-river fishes: is the highway analogy an appropriate paradigm? J. N. Am. Benthol. Soc. 20, 266-279.

Gotelli, N.J., Colwell, R.K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4, 379-391.

Gutreuter, S., Vallazza, J.M., Knights, B.C., 2009. Lateral distribution of fishes in the main-channel trough of a large floodplain river: Implications for restoration. River Res. Appl. 26, 619-635.

Harka, Á., Sallai, Z., 2004. The fish fauna of Hungary. NIMFEA, Szarvas. (in Hungarian)

Herzog, D.P., Barko, V.A., Scheibe, J.S., Hrabik, R.A., Ostendorf, D.E. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large-river systems. N. Am. J. Fish. Manage. 25, 594-603.

Hirzinger, V., Keckeis, H., Nemeschkal, H.L., Schiemer, F., 2003. The importance of inshore areas for adult fish distribution along a free-flowing section of the Danube, Austria. River Res. Appl. 20, 137-149.

Hughes, R.M., Kaufman, P.R., Herlihy, A.T., Intelman, S.S., Corbett, S.C., Arbogast, M.C., Hjort, R.C., 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. N. Am. J. Fish. Manage. 22, 1229-1240.

Junk, W.J., Bayley, P.B., Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems, in: Dodge, D.P. (Ed.), Proceedings of the International Large River Sysmposium (LARS). Can. Spec. Publ. Fish. Aquat. Sci.106, pp. 110-127.

Jurajda, P., Reichard, M., Hohausová, E. Černý J. 2001. Comparison of 0+ fish communities between regulated-channelized and flooplain stretches of the River Morava. Arch. Hydrobiol., Suppl. Large Rivers 12, 187-202.

Jůza, T., Čech, M., Kubečka, J., Vašek, M., Peterka, J., Matěna, J., 2010. The influence of the trawl mouth opening size and net colour on catch efficiency during sampling of early fish stages. Fish. Res. 105, 125-133.

Jůza, T., Rakowitz, G., Draštík, V., Blabolil, P., Herzig, A., Kratochvíl, M., Muška, M., Říha, M., Sajdlová, Z., Kubečka, J. 2013. Avoidance reactions of fish in the trawl mouth opening in a shallow and turbid lake at night. Fish. Res. 147, 154-160.

Labonne, J., Allouche, S., Gaudin, P., 2003. Use of a generalized linear model to test habitat preferences: the example of *Zingel asper*, an endemic percid of the River Rhone. Freshw. Biol. 48, 687-697.

Murphy, B.R., Willis, D.W. (Eds.), 1996. Fisheries techniques, 2nd ed.. American Fisheries Society, Bethesda, Maryland.

R Development Core Team, 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Reyjol, Y., Hugueny, B., Pont, D., Bianco, P.G., Beier, U., Caiola, N., Casals, F., Cowx, I., Economou, A., Ferreira, T., Haidvogl, G., Noble, R., De Sostoa, A., Vigneron, T., Virbickas, T., 2007. Patterns in species richness and endemism of European freshwater fish. Global Ecol. and Biogeog., 16, 65-75.

Ridenour, C.J., Doyle, W.J., Hill, T.D., 2011. Habitats of age-0 sturgeon in the Lower Missouri River. Trans. Am. Fish. Soc. 140, 1351-1358.

Ridenour, C.J., Starostka, A.B., Doyle, W.J., Hill, T.D., 2009. Habitat used by Macrohybsis chubs associated with channel modifying structures in a large regulated river: implications for river modifications. River Res. Appl. 25, 472-485.

Stewart, D.J., Ibarra, M., Barriga-Salazar, R., 2002. Comparison of deep-river and adjacent sandy-beach fish assemblages in the Napo River Basin, eastern Ecuador. Copeia 2002, 333-343.

Szalóky, Z., György, Á.I., Csányi, B., Tóth, B., Sevcsik, A., Szekeres, J., Erős, T., 2011. Development and testing of an electrified benthic trawl for monitoring benthic fish assemblages in the River Danube. Pisces Hungarici 5: 37-42. In Hungarian with a summary in English.

Wiesner, C., Schotzko, N., Cerny, J., Guti, G., Davideanu, G., Jepsen, N., 2007. Technical report with results from the fish sampling and analyses from the Joint Danube Survey 2007. International Commission for the Protection of the Danube River, Vienna. 73pp.

Wolter, C., Bischoff, A., 2001. Seasonal changes of fish diversity in the main channel of the large lowland river Oder. Reg. Rivers. Res. Manage. 17, 595-608.

Wolter, C., Freyhof, J., 2004. Diel distribution patterns of fishes in a temperate large lowland river. J. Fish Biol. 64, 632-642.

Table 1

The species composition, relative abundance (A%) and frequency of occurrence (FrO%) of fishes collected by shoreline electrofishing (SE) and by trawling with the electrified benthic framed net (EBFT) in the River Danube, Hungary.

	SE		EBFT	
Species name	A%	FrO%	A%	FrO%
Abramis brama (L.)	0.84	42.51	0.97	16.00
Acipenser ruthenus L.	-	-	0.02	1.14
Alburnus alburnus (L.)	29.80	98.55	4.25	36.00
Anguilla anguilla (L.)	0.01	0.48	-	-
Aspius aspius (L.)	1.94	78.26	0.04	1.14
Babka gymnotrachelus (Kessler)	0.69	41.06	0.53	8.57
Ballerus ballerus (L.)	0.04	4.35	0.02	1.14
Ballerus sapa (Pallas)	0.52	34.30	0.57	13.71
Barbus barbus (L.)	0.59	35.75	1.64	37.14
Blicca bjoerkna (L.)	14.36	91.79	9.27	49.71
Carassius gibelio (Bloch)	0.28	28.50	0.01	0.57
Chondrostoma nasus (L.)	2.46	55.56	0.12	4.57
Cobitis elongatoides (Bacescu and Mayer	0.00	0.48	-	-
Ctenopharyngodon idella (Valenciennes)	0.00	0.48	-	-
Cyprinus carpio L.	0.26	16.91	0.01	0.57
Esox lucius L.	0.17	17.39	-	-
Eudontomyzon mariae (Berg)	0.01	2.90	-	-

Gasterosteus aculeatus L.	0.00	0.48	-	-
Gymnocephalus baloni Holcík and Hensel	0.47	26.57	0.63	2.86
Gymnocephalus cernua (L.)	0.21	10.14	0.05	1.71
Gymnocephalus schraetser (L.)	4.08	72.46	4.83	36.00
Hypophthalmichthys molitrix (Valenciennes)	0.00	0.48	-	-
Lepomis gibbosus (L.)	0.02	2.90	-	-
Leuciscus idus (L.)	2.46	75.36	0.64	16.00
Leuciscus leuciscus (L.)	0.03	4.35	-	-
Lota lota (L.)	2.77	43.96	0.01	0.57
Neogobius fluviatilis (Pallas)	0.91	46.86	0.23	6.86
Neogobius melanostomus (Pallas)	18.32	84.54	52.18	52.00
Pelecus cultratus (L.)	0.07	14.49	0.02	1.14
Perca fluviatilis L.	0.69	21.74	0.02	1.14
Ponticola kessleri (Günther)	3.01	82.13	1.06	14.86
Proterorhinus marmoratus (Pallas)	0.11	10.63	0.02	1.14
Pseudorasbora parva (Temminck and Schlegel)	0.00	0.97	-	-
Rhodeus sericeus (Pallas)	0.03	0.97	-	-
Romanogobio albipinnatus (Lukasch)	6.63	73.43	8.12	75.43
Rutilus rutilus (L.)	1.46	56.04	0.02	1.14
Rutilus virgo (Heckel)	0.35	29.47	0.21	8.00
Sabanejewia aurata (De Filippi)	0.11	5.80	0.11	2.29
Sander lucioperca (L.)	3.27	79.23	0.43	14.86
Sander volgensis (Gmelin)	0.43	40.58	0.04	1.14
Scardinius erythrophthalmus (L.)	0.01	2.42	-	-

Silurus glanis L.	0.08	11.11	0.05	1.71
Squalius cephalus (L.)	1.11	42.51	-	-
Vimba vimba (L.)	1.10	42.03	0.30	6.86
Zingel streber (Siebold)	0.06	6.76	11.81	74.29
Zingel zingel (L.)	0.27	28.50	1.73	25.14
Number of species	45		33	
Number of individuals	47731		8112	
Number of samples	207		171	

Table 2

Standard length (mm) data of the most common benthic species collected by shoreline electrofishing (SE) and trawling with the electrified benthic framed net (EBFT) in the River Danube, Hungary. Differences in the distribution and median values of data between the sampling gears were examined with non-parametric Kolmogorov-Smirnov test and Mann-Whitney *U* test, respectively.

	SE				EBFT				Kolmogorov-Smirnov test	Mann-Whitney *U* test
	Median	Min.	Max.	*N*	Median	Min.	Max.	*N*	*p*	*p*
Abramis brama	78	21	440	242	325	100	509	78	<0.001	<0.001
Barbus barbus	71	35	600	105	360	40	610	127	<0.001	<0.001
Blicca bjoerkna	85	33	280	2005	91	35	330	642	<0.001	<0.001
Chondrostoma nasus	110	45	450	416	273	107	420	10	<0.05	<0.001
Gymnocephalus schraetser	70	11	220	1162	75	40	170	387	<0.001	<0.001
Lota lota	230	28	480	605	240	240	240	1	-	-
Neogobius melanostomus	62	18	165	1470	40	15	125	1957	<0.001	<0.001
Ponticola kessleri	70	30	165	385	72	45	115	85	<0.001	ns

Romanogobio albipinnatus	71	18	150	1388	64	18	125	617	<0.001	<0.001
Vimba vimba	85	32	185	323	181	80	380	23	<0.001	<0.001
Zingel streber	54	45	95	15	66	29	175	932	<0.01	<0.05
Zingel zingel	81	60	350	68	84	45	275	133	ns	ns

Legends to figures

Fig. 1. Schematic picture and parameters of the electrified benthic framed trawl (EBFT) developed to sample fish in the offshore areas of the Danube River, Hungary.

Fig. 2. The spatial distribution of samples along the 350 km long section of the Danube River . Distances (m, mean±SD) of five classes of electrified benthic framed trawl (EBFT) samples from the right and left (in parentheses) river banks are indicated. Shoreline electrofishing (SE) samples were taken at mainly 2-5 m distances off the shore. Solid and open circles represent SE and EBFT samples, respectively.

Fig. 3. Estimated number of species (±95% CI.) as a function of (a) number of samples and (b) number of individuals collected with shoreline electrofishing (SE) and the electrified benthic framed trawl (EBFT) in the Danube River, Hungary.

Fig. 4. Estimated number of species (±95% CI) as a function of (a) number of samples and (b) number of individuals collected with the electrified benthic framed trawl (EBFT) in five classes of samples differing in their offshore position in the Danube River, Hungary (Fig. 2).

Fig. 5. Mean (±SD) catch per unit effort data (CPUE, ind 500 m^{-1}) of the benthic species in the EBFT collections in the Danube River, Hungary. The symbol * indicates significant differences at $p<0.05$ level.

Fig. 6. Length frequency distribution of the most common benthic species collected with shoreline electrofishing (SE) and the electrified benthic framed trawl (EBFT). See Table 2 for sample numbers.